Invited Paper:

EFFECTIVE MONITORING FOR ADAPTIVE WILDLIFE MANAGEMENT: LESSONS FROM THE GALÁPAGOS ISLANDS

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Abstract: Successful monitoring underpins effective wildlife management insofar as monitoring serves to track the response of wildlife resources to management and to identify whether management should be continued or changed. Here we provide both general guidelines and specific examples for the design and implementation of effective monitoring programs for adaptive wildlife management based, in part, on lessons we have learned in the Galápagos Islands, where development of a comprehensive monitoring program for its wildlife is underway. To be effective, wildlife monitoring programs should (1) be framed by well-articulated objectives that are closely linked to management goals; (2) measure a subset of informative indicators with sampling methods that permit unbiased and statistically powerful results while minimizing costs and logistical problems; (3) ensure program continuity despite the vagaries of change in personnel, technology, and program objectives; and (4) quickly make accessible appropriately analyzed information to a wide audience, particularly policymakers. Only through such an integrated process can the adaptive "loop" in wildlife management be closed and management practices and policies evolve in a manner ultimately beneficial to wildlife, both in Galápagos and elsewhere.

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Successful monitoring underpins effective wildlife management. Monitoring permits evaluation of management efficiency for harvested, endangered, or indicator species, documentation of compliance with regulatory requirements, and detection of incipient change in wildlife populations and habitats. Although many managers consider monitoring simply as the measurement of temporal changes in wildlife indicators (Goldsmith 1991), monitoring is most useful if explicitly linked to the objectives of resource management. In particular, defining monitoring as the collection and analysis of repeated observations or measurements to evaluate changes in condition and progress toward meeting a management objective (Elzinga et al. 1998) promotes a problem-oriented approach to monitoring and greatly enhances its rigor, effectiveness, and utility. Such a definition also recognizes the key role of monitoring in the "adaptive management" process (Holling 1978, Ringold et al. 1996), in which monitoring serves to track the response of a resource to management and to direct future management activities as well as changes to objectives.

Despite the intuitive appeal of the adaptive management concept, there are startlingly few examples in wildlife management in which the adaptive management "loop" has been completed. Monitoring is a complex and quantitative undertaking that often fails to guide management efforts for several reasons. Sampling may be inadequate to generate reliable, precise, and defensible estimates of changes in resources upon which management decisions can be confidently based. Baseline conditions also may be unknown, and indicators often are monitored that do not directly address management issues at hand. Objectives are typically not explicitly formulated in a manner that promotes measuring their success; therefore, altering activities and future objectives in response to the "success" of past management action can be difficult (Ringold et al. 1996). Monitoring also involves much more than the simple collection of data. Monitoring information is wasted if it is not analyzed correctly, archived well, reported timely, or communicated appropriately to policymakers.

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Here we describe an ongoing attempt to integrate monitoring and wildlife management in a region where the stakes are extremely high: the Galápagos Islands (Galápagos) of Ecuador. This archipelago is unique among oceanic islands of the 20th century. Unlike other inhabited groups of islands that have experienced many extirpations, at least 96% of the original species diversity of the Galápagos remains intact. The Galápagos have escaped from the usual pattern of extirpations seen on, for example, Hawaii, New Zealand, and the Caribbean Islands, primarily because the history of human activity has been relatively short and the numbers of inhabitants small. Unfortunately, that situation is changing rapidly. Human population growth is approximately 6% annually (Anonymous 1999*a*). New alien species are introduced every year, and many populations of Galápagos organisms common 20 years ago are now rare. While problems caused by past human activity remain, it is obvious that new threats to the biological diversity of the Galápagos will appear. Meeting these threats effectively depends upon quick and decisive management responses prompted by a reliable monitoring system.

Our purpose here is to provide both general guidelines and specific examples for the design and implementation of effective monitoring programs for adaptive wildlife management based, in part, on lessons we have learned in the Galápagos, where development of a comprehensive monitoring program for its wildlife is underway. Our target audience is practicing wildlife managers, who perform the bulk of wildlife monitoring activities around the world. We propose that some of the lessons learned so far in Galápagos can be usefully applied to better manage and conserve wildlife resources there and elsewhere.

WHY MONITOR?

The goal of monitoring is generally to develop a scientifically defensible estimation of the status and trends in wildlife resources and to determine whether management practices are sustaining those resources or should be changed. In the Galápagos, the first step in meeting threats to its wildlife is recognizing them. While this step sounds simple, it is not. There are 127 islands in the Galápagos, which support 24 species of introduced vertebrates, nearly 500 species of introduced plants, and a currently unknown number of introduced invertebrates (Snell et al. 1996). Approximately 60,000 tourists visit each year, and there are some 16,000 to 20,000 local inhabitants. More than 1,100 airline flights provide over 180,000 roundtrip fares, while 5 cargo ships bring some 55,000 tons of materials to the islands each year. Within the archipelago, 100 vessels move between 5 ports, 50 visitor sites, and uncounted fishing areas, covering nearly 3 million nautical miles a year (Anonymous 1999*a*). Obviously, this is a tremendous amount of human activity that can potentially affect the 115 indigenous terrestrial vertebrates. Tracking all of these species on all of the islands is impossible. Hence, successfully identifying new threats and new occurrences of old threats, as well as evaluation of whether efforts to mitigate these threats are successful, will depend upon a system of monitoring that is effective, economical, and sustainable over the foreseeable future.

DEFINING OBJECTIVES

Monitoring provides the information for making appropriate management decisions. To be successful, monitoring must be done to satisfy particular, well-articulated objectives (Ringold et al. 1996). The objectives specifically describe some desired state of an appropriate indicator that management is intended to meet, and these objectives then drive what ought to be measured and where and how often measurement should occur. Nevertheless, many management programs initiate monitoring activities without first defining what they hope to accomplish by doing so.

In the Galápagos, the general goal established to guide its wildlife monitoring program is the preservation of biological diversity of the archipelago in its natural state. Two secondary and supporting goals have been subsequently defined: (1) changes in wildlife resources must be evaluated, and (2) management must respond appropriately to those changes. Evaluating alterations in wildlife resources involves detection of changes and identification of the causes of those changes. Responses to detected changes may be of 4 types that depend upon their cause as well as temporal nature. Purely natural changes are part of a natural state and are only observed. Anthropogenic changes, those influenced directly or indirectly by human activity, initiate active responses. Past anthropogenic changes require restoration, current anthropogenic changes require mitigation, and

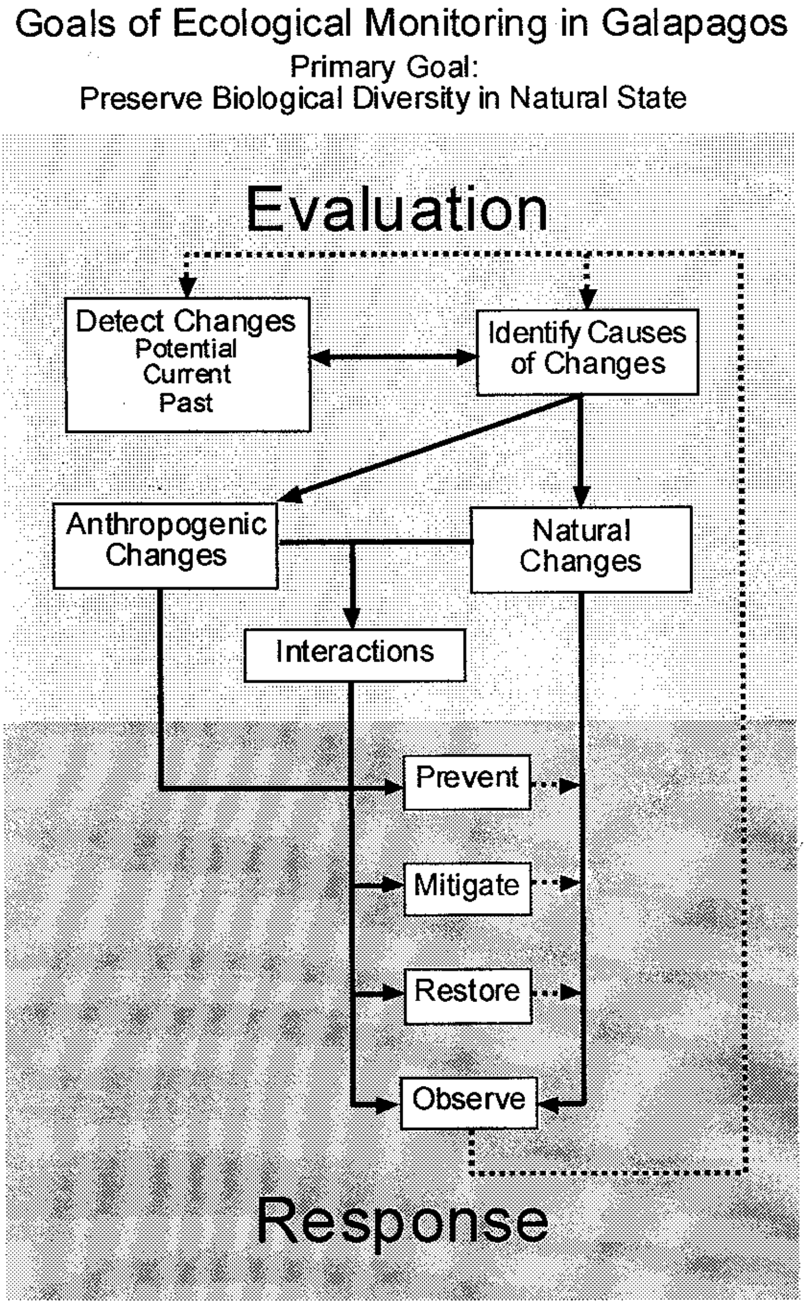

Fig. 1. Relation among goals for conservation activities for the Galápagos Islands. Solid lines and arrows indicate primary interactions, and dotted lines are secondary. The monitoring program is primarily an evaluation activity, and the subsequent management activities are responsive.

potential anthropogenic changes require prevention. The interaction between these goals and actions via monitoring is depicted in Figure 1.

Before the monitoring program can evaluate change in Galápagos, baseline conditions of the wildlife resources must be established. Effectively, the baseline is the biological condition of the Galápagos prior to discovery by Europeans in 1535. Four factors contribute to efficiently establishing the baseline for vertebrate wildlife. First, vertebrates include some of the most conspicuous organisms of the Galápagos. Second, remains of at least 65–70% of the vertebrate species occur in the nonmineralized fossil deposits commonly found in lava tubes, making them the most effective indicators of prehistoric patterns (e.g., Steadman 1981). Third, much of the early research activity within the Galápagos dealt with vertebrates, and the historic record of their early distribution is substantial. Fourth, a broad literature also exists covering the island biogeography of vertebrates in general, which supports hypotheses about distributions in the few cases where data are lacking.

The current situation can be described as deviations from the baseline. While not a simple task, it is possible to measure the complete species richness of all vertebrates on all islands within the Galápagos. The maximum number of vertebrate taxa known to inhabit an island within the Galápagos is 62, while the average for the 10 larger islands is 41. The vast majority of these taxa are diurnally active, and only a few of those are secretive. These same characteristics of Galápagos vertebrates also facilitate monitoring for future change. While information used to establish the baseline and current situation for vertebrates will be drawn from the complete archipelago, formal monitoring can address a subset of the islands.

However, simply detecting change is inadequate. To devise appropriate management responses it is necessary to evaluate the causes of observed alterations as frequently as possible. The vast ecological literature about vertebrates can provide a basis for hypotheses about causes of changes observed within the Galápagos fauna. Confirming or rejecting specific hypotheses can be the result of informative research involving manipulative experiments in the most significant cases, and correlative analyses of monitoring data in others. Declines in the abundance of dark-rumped petrels (*Pterodroma phaeopygia*) within Galapagos provide an example. Controlled experiments on 2 islands identified introduced black rats (*Rattus rattus*) as the cause of reproductive failure (Cruz and Cruz 1987). On other islands, correlations of reproductive failure and the presence of black rats suggest a similar cause. However, conclusions based upon correlations can be misleading. Recent assumptions about the causes of slow recovery from population declines by Galapagos penguins (*Spheniscus mendiculus*) were based on correlations with the presence of black rats, but ongoing research suggests the situation is far more complicated (Boersma 1998).

QUANTIFYING TARGETS

To ultimately be successful, wildlife management and monitoring have to be coupled closely enough to permit articulation of specific objectives for evaluation at the site- or regional-level. To be most useful, objectives should be realistic and measurable and include these components (Elzinga et al. 1998): (1) what will be monitored, (2) the geographical area where it will be monitored, (3) the specific metric of the indicator that will be measured, (4) the expected response of the indicators to management (to increase, decrease, or remain stable), (5) the magnitude of change expected, and (6) the time frame during which the response to management is expected to be manifested. An example of an acceptable objective is as follows: decrease the mean density of species A at site B before 2001 to *n*/ha. This is an example of a target or threshold objective (Elzinga et al. 1998). Alternatively, monitoring objectives may be more appropriately framed in terms of changes or trends (e.g., decrease the frequency of occurrence of species A at site B by 50% from 1999 to 2001).

Use of the framework of Elzinga et al. (1998) to articulate objectives has the further benefit of permitting monitoring results to be evaluated on a statistical basis. This approach permits managers to gauge the relative certainty surrounding conclusions about the effectiveness of management actions and provides managers a sense of how confident they can be in defending management prescriptions to skeptical groups (Murphy and Noon 1991). To do so, however, requires that managers be familiar with the concept of statistical errors and to further specify more components to monitoring objectives, that is, levels of α and β.

Owing to the vagaries of sampling, when tests of trends or differences in monitoring data are made, 2 types of errors can be made. First, one can conclude falsely that a difference or trend occurred when it in fact did not, which is a Type I error, or α. Alternatively, one may falsely conclude that a difference or trend did not occur when it in fact did, which is a Type II error, or β. A related concept is statistical power, which is the probability of detecting a difference if a difference exists. This concept is critical in a monitoring context because the key problem managers face in detecting trends or changes is that sources of "noise" in the indicator measured can obscure the "signal" associated with ongoing changes in it. The probability that a monitoring program will detect a change in the indicator when the change is occurring, despite the "noise" in the data, represents its statistical power.

Standard wildlife literature generally sets the α-level to 0.05 and the β level at 0.2. However, it may be more appropriate in a monitoring context to relax the α-level requirement to 0.1 or even 0.2 if a manager is willing to have a monitoring program that at times "cries wolf," claiming that a change has occurred when it really has not (Kendall et al. 1992, Gibbs et al. 1998). The likelihood of turning in a few false claims of changes is a reasonable tradeoff for missing important changes. Because a primary function of many monitoring programs is to warn of impending changes in wildlife resources, it is generally preferable to spend extra effort investigating a few false reports of change than to have waited for definitive results of change, at which point a resource has collapsed or exploded and one has fewer management options. Ultimately, those making quantitative evaluation of monitoring data in Galápagos and elsewhere must become comfortable making rational decisions about appropriate levels of statistical errors to tolerate for a given monitoring context. Alternatively, trend objectives described in terms of confidence intervals for measured attributes rather than as hypotheses to be tested may sometimes be more useful because biological significance and statistical significance are not always equivalent (Dixon et al. 1998, Johnson 1999).

WHAT TO MONITOR

Given the natural complexity of wildlife populations and the habitats they inhabit as well as the severe constraints on resources available for monitoring, a key challenge in designing a monitoring program is to successfully perform triage on all possible indicators to select those for measurement that best reflect the status and dynamics of the system under management. This step is among the most difficult in developing a monitoring program (Noss et al. 1997:191). It is notable that despite vast amounts of research there is still little consensus on which classes of indicators are best to measure (Karr 1987, Vora 1997).

A useful indicator to monitor is some attribute reflective of environmental conditions that extends beyond its own measurement (Noss et al. 1997). From a scientific perspective, such indicators should have known statistical properties and should provide early warning of change (as opposed to a lagged response). Valuable indicators are also those that directly indicate a cause of change rather than simply the existence of change (e.g., measuring fecundity and survival rather than simple measurement of total numbers; DeSante 1991). Similarly, indicators should provide continuous assessment over a wide range of stress (that is, not "bottom out" or "level off" at certain thresholds and thereby lose their ability to indicate change). Last, indicators that represent broad changes in the resources of concern are useful. Good candidates are umbrella species (those species whose habitat hosts many other, associated species) or keystone species (those species whose strong interactive effects with other species generate effects that are large relative to the keystone species' abundance). Another possibility includes synthetic indices, such as Karr's (1987) indicators of biotic integrity, which are aggregated from a set of individual metrics and therefore may reflect the emergent properties of a population or habitat.

Other, more practical considerations also dictate which indicators are most useful (Noss et al. 1997:192). Indicators must be cost-effective to measure and be accurately and precisely estimated by all personnel involved in the monitoring. Indicators that can be easily interpreted and explained and require low impact to measure (that is, can be nondestructively sampled) also are useful. Politically appealing indicators (e.g., may be endemic, alien, harvested, or have protected status) also are expedient because they can help to sustain external interest and support for monitoring although they may not be the most scientifically relevant. Finally, the indicator measured also must be logically linked to the original monitoring goals. It is surprisingly common for indicators to be monitored that cannot logically address program objectives.

In the Galápagos, monitoring activities concentrate on a subset of species and localities. These subsets are chosen based on several criteria. First, species chosen are representative of their communities in that they interact with a variety of species and respond to a variety of environmental components (abiotic and biotic factors), including some that reflect and some that resist abiotic or biotic fluctuations, some with great and some with low susceptibility to anthropogenic alterations, some with long life-spans and some with short life-spans, which provides different response times to environmental change. For example, adult Galápagos tortoises (*Geochelone nigra*) are extremely resistant to short-term environmental fluctuations, while lava lizards (*Tropidurus* spp.) can quickly respond in detectable ways to the presence of introduced predators (Stone et al. 1994). Second, species chosen are easily monitored, meaning they are easily detected in the environment with minimal sampling effort, they are abundant enough to obtain adequate samples, they are easily captured or measured if individual measurements are required, and they are harmless when being handled and measured by researchers. In many instances, for example, up to 100 tortoises or lava lizards can be captured and sampled in a single day. Third, preference is given to those species with baseline data available, either from Galápagos or other island systems. This approach requires collaboration with a variety of current and past projects of basic research to capitalize on information spanning as much as 20 or more years; for example, finches (Grant and Grant 1995), iguanas (Snell et al. 1984, Wikelski et al. 1997), seabirds (Anderson and Hodum 1993), and Galápagos tortoises (Fritts 1984). Fourth, they contribute greatly to Galápagos' unique component of global biological diversity, (i.e., most significant are endemic species that inhabit only a single island, whereas least significant are nonendemic native species that inhabit all islands). In this case the native Galápagos rodents are a good example (Patton and Hafner 1983). Last, in the case of exotic species, good candidates are species that exhibit significant threats to indigenous organisms or have large potential for dispersal are targeted. Within the vertebrates these include goats, pigs, cats, and rats. Another useful description of the process of identifying monitoring indicators is described by Davis (1989).

SAMPLING INTENSITY

Surveys to detect changes in wildlife resources must have adequate effort to obtain precise enough population or density estimates to have a reasonable chance to detect an important change (Thompson et al. 1998). Surveys with less effort waste time and money because they have little chance of providing useful information. In some circumstances, it is possible to oversample such that monitoring effort is expended in excess of what is needed. Whatever the case, the most effective way to change statistical power is to change the number and frequency at which the chosen indicator is sampled (Steele et al. 1984, Fairweather 1991, Kendall et al. 1992).

Some increases in power can also be obtained by reducing the variability among sampling units through changes in methodology, although the opportunity to do so often is limited by the requirement to use standardized methods that increase comparability across monitoring studies. Other less obvious but often equally important factors to be considered include α levels and desired effect sizes (magnitudes and direction of change sought for detection), which are set by researchers (Kendall et al. 1992, Hayes and Steidl 1997, Thomas 1997). Increasing α and effect size tends to increase power. Understanding how these factors interact with the inherent sampling variation of abundance indices can provide insights into the design of statistically powerful yet labor-efficient monitoring programs (e.g., Gerrodette 1987, Peterman and Bradford 1987, Fairweather 1991, Taylor and Gerrodette 1993, Steidl et al. 1997).

Although statistical power is central to every monitoring effort, it is rarely assessed (Gibbs et al. 1998). This has occurred, in part, because until recently there have been few tools available to animal ecologists that permit assessment of statistical power for trends or changes (Thomas 1997). Recently, a conceptually straightforward, Monte Carlo approach based on linear regression analysis has been devised (Gibbs et al. 1998) that permits evaluating the tradeoffs between sampling effort, logistical constraints, and power to detect changes. The simulation software ("monitor.exe") has been adapted for general use on DOS-based microcomputers and is available via the internet at "http://www.im.nbs.gov."

Power to detect changes is inversely related to the magnitude of indicator variability, and monitoring programs must be designed around the component of index variability that cannot be controlled (Gerrodette 1987, Link et al. 1994). Without pilot studies, however, researchers often have no notion of indicator variability.

Lacking estimates of this critical parameter hinders design of statistically powerful monitoring programs. Wildlife managers typically measure numbers of individuals in populations as a monitoring indicator, and a ready source of data on the variability of population indices can be found in published time series of population counts.

A recent survey of 512 published count series of local animal populations analyzed for 24 separate taxonomic and ecological groups (Gibbs et al. 1998) indicated that only a few groups had low variability indices (coefficient of variation [CV] <25%) and included large mammals, grasses and sedges, and herbs. A larger number had intermediate variability indices (CVs = 25–50%) and included turtles, terrestrial salamanders, large birds, lizards, salmonid fishes, and caddisflies. Most groups had indices with CVs between 50–100% and included snakes, dragonflies, small-bodied birds, beetles, small mammals, spiders, medium-sized mammals, non-salmonid fishes, pond-breeding salamanders, moths, frogs and toads, and bats. Only butterflies and flies had average indices with CVs >100%.

Estimates of index variability were incorporated into a power analysis (Gibbs et al. 1998) to generate sampling recommendations for wildlife managers for designing effective programs for monitoring local populations. Assuming levels of $\alpha = 0.1$ and power > 0.8, a general power analysis predicted that infrequent monitoring (e.g., once or twice per year) on a relatively small number of sites or plots ($\leq$10) would reliably detect strong population trends (that is, a 50% change over 10 yr) in most animal groups. Even for highly variable groups, frequent monitoring (3–5 times/yr) of a relatively small number of plots ($\leq$30) would permit detection of a trend of this magnitude. More intensive monitoring is needed, however, to detect slighter trends of 25% and 10%, but nevertheless is still at a logistically feasible level ($\leq$100 plots) for wildlife managers to undertake for most groups. Sampling recommendations using other combinations of α, β, effect size, and time frame have been developed and are available over the Internet at "http://www.im.nbs.gov/powcase/powcase.html."

These recommendations can be useful in the initial stages of planning a monitoring program. Once underway, however, local monitoring data should be analyzed to measure indicator variability and re-estimate required sampling intensity to detect the threshold changes identified. Detailed case studies of the application of power analysis to improve wildlife monitoring are available in Steele et al. (1984) for birds and small mammals, Kendall et al. (1992) for bears, Taylor and Gerrodette (1993) for owls and marine mammals, Gibbs and Melvin (1997) for waterbirds, Beier and Cunningham (1996) for large cats, Zielinkski and Stauffer (1996) for mustelids, Van Strien et al. (1997) for butterflies, and Mac Nally (1997) for forest songbirds.

OBTAINING REPRESENTATIVE SAMPLES

Balancing sampling needs and logistical constraints in the design of monitoring programs can be extremely problematic, in part because conventional random sampling schemes recommended for acquiring representative samples of wildlife indicators are often unworkable in practice (Gillison and Brewer 1985). For example, sites near roadsides, trails, or landings, and those on public lands, are generally easier to access by survey personnel than are randomly selected sites. Also, monitoring sites that occur in clusters minimize unproductive time traveling among survey sites. Time is generally at a premium in monitoring efforts not only because of the costs of supporting survey personnel but also because the survey "window" each day or season for many wildlife species is brief (e.g., Gibbs and Melvin 1997).

Purely random sampling schemes often also produce unacceptably low encounter rates with the organisms being monitored, which may in turn constrain power to detect trends in their populations. This could be overcome by stratifying sampling according to habitat types frequented by the species being monitored (e.g., Rutherford and Hayes 1976). However, information on habitat distributions in an area from which a random sampling scheme might be developed may not be available to researchers. Furthermore, a prior knowledge of habitat associations of most species often is not available as a basis for stratifying a random sampling scheme. Adaptive cluster sampling (e.g., Thompson et al. 1992, Smith et al. 1995) does provide the opportunity to accurately estimate parameters for rare species with clumped distributions without having the prior knowledge of their spatial distribution needed to stratify a random sample, but this approach has not been widely used. Whatever sampling method is used, however, managers must recognize that many monitoring programs simultaneously track multiple species; hence, a single, optimal sampling strategy simply may not be identifiable.

These difficulties in implementing random sampling schemes would imply that nonrandom site selection schemes are the only practical way to organize monitoring programs. However, samples obtained haphazardly, by convenience, or by best judgement can be severely flawed and seriously mislead managers (Thompson et al. 1998). For example, managers initiating a survey program are often drawn to sites with abundant populations where counts are initiated under the rationale that visiting low density or unoccupied sites will be unproductive. If the populations or habitats under study undergo natural cycles, however, then initial counts may be made at cycle peaks. As time progresses, populations at the sites selected will then tend, on average, to decline. Hence, the resulting pattern of decline observed in counts is an artifact of site selection procedures and does not reflect any population trend.

Despite these complexities, some generalizations about sampling can be made. Owing to environmental heterogeneity, indicators often vary more among monitoring sites than within monitoring sites over time. For this reason, permanent plots (as opposed to plots that shift annually) are a valuable way to control for among-site variability and strengthen the statistical power of a monitoring program. Gaining detailed knowledge of the habitat associations of the species being monitored, as well as the distribution of those habitats in a region, also can provide useful guidance on how to lay out a representative system of sampling sites that is also logistically feasible to monitor. Specifically, managers would do well to identify species–habitat associations and generate habitat maps prior to initiating surveys so that the explicit tradeoffs between alternative sampling schemes, logistical costs, and sampling bias can be evaluated. If bias can be estimated during a pilot study by comparing randomly versus purposely selected sites, then correction factors can potentially be applied later and correct for the bias (Anganuzzi and Buckland 1993). A coarse-filter approach to habitat monitoring (cf. Noss et al. 1997) also can provide a first approximation to changes in wildlife populations where intensive, large-scale population surveys are not feasible.

In the Galápagos, information for monitoring current patterns comes from a combination of systematic and opportunistic sampling activity. Systematic monitoring activity involves repeated sampling at determined intervals within specified areas. Opportunistic monitoring activity is designed to take advantage of other activities within the archipelago that can provide significant information about current patterns of wildlife diversity. The Galápagos covers thousands of square kilometers, and restricting the monitoring program to systematic activity would either make the program incredibly costly or inadequate. The main factor to be established for opportunistic sampling is the quality of the data. Examples of specific sampling include point counts to quantify avian diversity, transects for most species of reptiles, and capture per unit effort to assess population- and individual-level parameters for specific species of terrestrial birds, reptiles, and mammals. These activities are carried out by resident scientists and park personnel. Opportunistic sampling is carried out in collaboration with visiting researchers, tour companies, and other local agencies. Variables sampled in this manner are less precise and often focus on simple presence or absence of particular organisms or phenonema. Such opportunistic sampling has proven particularly useful in estimating the phenology of breeding in, for example, colonies of seabirds and distributional shifts in marine mammals and reptiles (see also Davis 1989).

DATA MANAGEMENT, QUALITY CONTROL, AND REPORTING

Successful monitoring involves much more than simple data collection (Stafford 1993). Even modest monitoring efforts can generate substantial amounts of information to proof, digitize, analyze, and interpret (Elzinga et al. 1998). In reality, time and resources devoted to data entry, management, and analysis typically equals or exceeds that involved in field collection of data. Therefore, remote as they may seem, issues of data management are best dealt with early in the planning of a monitoring program. Streamlining and troubleshooting data collection are therefore 2 key themes to focus upon early in developing a monitoring program.

Even after a dataset is compiled, issues of reporting, sharing, and archiving data also are critical. Unlike many areas of wildlife science in which data are rarely examined following publication, the value of monitoring data increases substantially as it ages. Consider if we all had decades-old, comprehensive baseline surveys against which we could compare current conditions. While few have this luxury, properly organizing and archiving today's monitoring data can permit that opportunity for future wildlife biologists.

Generally speaking, integration of diverse monitoring program components, successful data management, and timely report generation are facilitated by designating a single person as responsible for overseeing a monitoring program (MacDonald 1994). That said, personnel turnover is a frequent obstacle to monitoring, whether it occurs among data collectors or data managers. For this reason, explicit documentation of sampling protocols must be made so that new personnel can repeat measurements exactly. Proven and standardized methods should be implemented that are not susceptible to the vagaries of technology change or changing observer ability (Ringold et al. 1996). Use of such protocols also increases the comparability of monitoring data among different sites and programs and thereby generates a valuable spatial component as well as true replication on a large scale.

Timely reporting of monitoring data to a wide audience increases interest for a program and creates a constituency in support of the program. This is most easily accomplished through production of well-crafted annual reports (MacDonald 1994, Elzinga et al. 1998). Widely available computer databases now have reached sufficient sophistication to permit direct generation of annual summaries of monitoring data with minimal analysis. Periodic review by experts from both within and outside a program greatly enhances the program's credibility. It also is important to recognize from the start that priorities and goals for a monitoring system will change as data are accumulated and new perspectives emerge; thus, periodic revision of monitoring design should be encouraged (Ringold et al. 1996).

These issues are particularly relevant in the Galápagos, where the complexity of the wildlife resource and of conservation politics is great. Simply accounting for presence or absence of species among the islands would require cataloging >3,500 species across 127 islands: 441,000 possible interactions. Hence, to draw quick and useful conclusions from the data, it must be extremely well organized and verified. To this end, there are 3 components within the primary activity of information management: (1) establish adaptable Geographical Information System (GIS), database, and museum collection interactions; (2) train and equip collaborators for spatial and temporal data recording; and (3) establish an interactive system to verify data. The backbone of the program's information management is an interacting GIS and database system. To ensure that these systems maintain their value into the future, they are designed for effective export and exchange of data so that they will not be dependent upon any single software package. Data management in Galápagos also attempts to circumvent inefficiencies traditionally associated with recording tremendous numbers of observations to paper and moving the data to an electronic format for analysis with computers. This program integrates the use of small, inexpensive Global Positioning System receivers as data loggers to avoid the delays associated with manually recorded data.

The final component of the monitoring program for the Galápagos is communication. The conservation of the biological diversity of the archipelago is mandated by a special law for the Galápagos (Anonymous 1999*b*). This legislation combines a series of amendments to the Constitution of Ecuador that provide a broad framework for immigration control, quarantine, the control and eradication of alien species, and the sustainable use of natural resources within the Galápagos. The special law also identifies numerous agencies with various responsibilities for the conservation of natural resources and provides for considerable input from the public via participatory processes. An effective communication strategy is necessary to ensure that the results of the monitoring program reach the broadest number of individuals involved in management processes.

The communication strategy for the Galápagos monitoring program consists of 3 levels. Direct networking of computers, regular meetings, and joint development of annual operating plans comprise the first level and ensure frequent communication between the Charles Darwin Research Station and the Galápagos National Park Service, the 2 agencies most directly involved with wildlife management. The second level is carried out by the departments of environmental education of the Park Service and the Research Station. Those programs combine information centers within the local communities with regular reports via local news media (television, radio, printed media) to reach the broadest array of individuals and agencies. The third level is more formal and consists of the roles played by the Charles Darwin Research Station and the Galápagos National Park Service in the long-term planning processes for the Galápagos. Both agencies are represented in the various commissions and working groups that formulate and evaluate conservation and development policy and activities within the archipelago.

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