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Incorporating precision, accuracy and alternative sampling designs into a continental monitoring program for colonial waterbirds

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A comprehensive monitoring program for colonial waterbirds in North America has never existed. At smaller geographic scales, many states and provinces conduct surveys of colonial waterbird populations. Periodic regional surveys are conducted at varying times during the breeding season using a variety of survey methods, which complicates attempts to estimate population trends for most species. The US Geological Survey Patuxent Wildlife Research Center has recently started to coordinate colonial waterbird monitoring efforts throughout North America. A centralized database has been developed with an Internet-based data entry and retrieval page. The extent of existing colonial waterbird surveys has been defined, allowing gaps in coverage to be identified and basic inventories completed where desirable. To enable analyses of comparable data at regional or larger geographic scales, sampling populations through statistically sound sampling designs should supersede obtaining counts at every colony. Standardized breeding season survey techniques have been agreed upon and documented in a monitoring manual. Each survey in the manual has associated with it recommendations for bias estimation, and includes specific instructions on measuring detectability. The methods proposed in the manual are for developing reliable, comparable indices of population size to establish trend information at multiple spatial and temporal scales, but they will not result in robust estimates of total population numbers.

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1. Introduction

Colonial waterbirds have been the subjects of extensive scientific studies and have received considerable popular attention for many decades. The millinery trade and other exploitation produced marked population declines of many colonial-nesting birds during the nineteenth century, and initiated the first organized efforts in North American bird conservation at the turn of the twentieth century (Bent 1926). Although the conservation of these species remains an important environmental issue today (Bartle 1991, Brothers 1991, Kushlan 1992, Luthin 1987), it is now realized that the very existence of waterbirds at the boundaries of terrestrial and aquatic ecosystems allows them to serve as important bioindicators of environmental change (Cairns 1987, Custer & Osborn

1977, Kushlan 1993). Hence, knowledge of population trends provides useful information about the effectiveness of conservation activities for these species and the overall health of our ecosystems.

Measuring population change for most colonial waterbirds poses considerable challenges. Their colonies frequently are located in relatively inaccessible locations that preclude access to many nesting pairs, and the number of breeding adults can be enormous, thus preventing accurate counts of individuals. Nesting habitats, nest site preferences, and breeding behavior vary considerably among species and even among populations of a species, and multiple methods are required to survey their populations effectively (Bibby *et al.* 2000, Nettleship 1976, Walsh *et al*. 1995). Crevice-nesting and burrowing species are difficult to survey by any technique (Gaston *et al*. 1988, Savard & Smith 1985), and a better understanding of their population trends will occur only with the development of improved survey methods. Potentially, population surveys measure several parameters including numbers of active nests, numbers of pairs, or the total numbers of adults present at a colony (including both breeding pairs and non-breeders), producing population estimates that may not be directly comparable.

These potential problems have not discouraged the regular surveys of colonial waterbird populations. The status of individual colonies are routinely monitored for scientific and conservation purposes, while periodic organized efforts are undertaken to estimate population sizes at national and regional geographic scales (Lloyd *et al*. 1993, Sowls *et al*. 1978, Spendelow & Patton 1988). The failure to include estimates of the accuracy and precision associated with the counts complicates comparisons of population change between surveys, resulting in uncertainty concerning the actual extent of population change that occurred over time (Burnham 1981, Johnson 1995, Nichols *et al*. 2000).

In North America, most population surveys of colonial waterbirds have been undertaken at the scale of individual states, provinces or regions (e.g. Erwin 1979, Nesbitt *et al*. 1982, New York Department of Environmental Conservation 1998, Scharf 1998, Scharf & Shugart 1998, Sowls *et al*. 1978). However, the development of a conservation plan for waterbirds has renewed interest in creating a coordinated effort for monitoring the colonial-nesting species at various geographic scales in order to provide population information relevant to the management of these species (Steering Committee 2000). This paper discusses the issues associated with the creation of a coordinated colonial waterbird monitoring program for North America and the need to incorporate measures of accuracy and precision into the survey methodologies to improve the robustness of population estimates for these species.

2. Existing Field Methods

2.1. Sampling Design

The traditional approach for most colonial waterbird monitoring efforts is to obtain population estimates from every colony within the geographic area of interest (Erwin 1979, Scharf 1998, Scharf & Shugart 1998, Shuford & Ryan 2000, Texas Colonial Waterbird Society 1982). This approach reflects the temporal and

geographic shifts in colony locations and the changes in species composition and population sizes that normally occur over time, and the belief that comparable data are most likely to be obtained only by surveying every known breeding location.

At larger geographic scales, this approach requires considerable coordination and expenditure of resources in order to be implemented in the field, not only for the population surveys but also for colony inventories required to locate newly created colonies and colony sites that may have shifted following previous surveys. This need for substantial resources to implement regional colonial waterbird surveys usually allows these surveys to occur only at intervals of 5-10 years or longer, eliminating the chance of detecting short-term changes in most populations and the ability to implement appropriate conservation and management activities in the event of rapid short-term population declines (Fig. 1).

2.2. Survey Methods

During these population surveys, survey methods tend to be standardized in an attempt to reduce variability in the estimates of population size. The assumption is that with the use of standardized methods, changes in counts between surveys reflect actual changes in population size and not changes in the proportion of the populations that were actually detected by the method. Many factors can influence the detection probabilities associated with a survey technique (Jolly & Dickson 1983, Nichols *et al*. 2000), and unless detection probabilities are explicitly measured during the surveys, the changes in counts between surveys may reflect changes in population size, detection probabilities, or some unknown combination of both.

Standardization of survey methods also implies that a single technique is equally appropriate for all nesting habitats and locations occupied by a species. This assumption may be true for some species with specific breeding habitat requirements. However, widely distributed species frequently occupy a variety of nesting habitats, and a single survey technique may have different detection probabilities in each habitat. Hence, temporal shifts in colony locations may be accompanied by changes in detection probabilities and confound analyses of population change between colonial waterbird surveys.

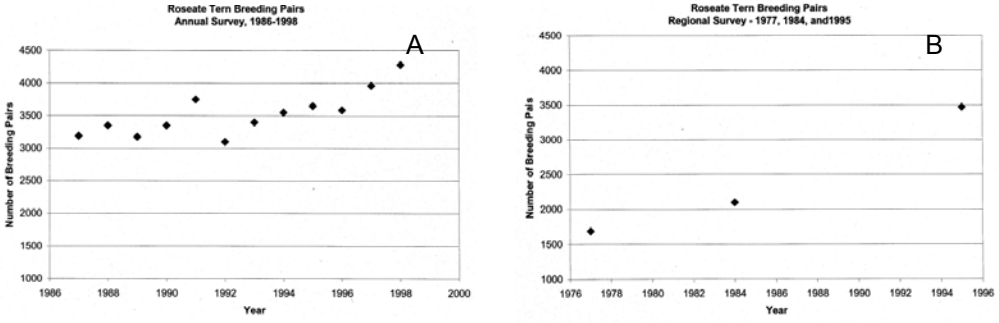

Fig. 1. A comparison of the difference in interpretation of Roseate Tern *Sterna dougallii* data collected (a) annually, and collected (b) every 5-10 years. Data collected annually shows fluctuations in numbers of breeding pairs each year, whereas data collected by regional surveys conducted every 5-10 years may be interpreted as increasing numbers of breeding pairs.

Observer variability is well known to influence counts obtained during bird population surveys (Erwin 1982, Prater 1979, Verner 1985). In order to reduce this variability, it is customary to use either a single observer or a small number of observers to conduct colonial waterbird surveys. These observers receive training in survey methodology and in the estimation of large concentrations of birds. While standardization improves the consistency of data collect within each survey, temporal changes in observers and comparisons among observers surveying over large geographic areas can still result in substantial variability in population estimates obtained during colonial waterbird surveys (Gibbs *et al*. 1988).

2.3. Survey Timing

When colonial waterbirds are surveyed over large geographic areas, the use of a small number of observers necessitates conducting surveys throughout the breeding season. Attendance rates are known to vary with the stage of breeding chronology (Hatch & Hatch 1989, Jones 1992, Piatt *et al*. 1990, Rothery *et al*. 1988), and changes in attendance rates can be confounded with population change at a colony. Nest failure may result in intercolony movements of adults during a nesting season (Massey & Atwood 1981), and these movements could result in the double counting of adults within a single survey period. All of these factors contribute to increased variability in the estimates of population size obtained during these surveys, and reduces the benefits obtained by standardizing observers.

3. Proposed Monitoring Program

Implementing a colonial waterbird monitoring program across North America poses considerable challenges. Limited resources will preclude any attempt to obtain population estimates at every colony, and sampling populations of most species will be a necessity. Even sampling colonies will require a large number of observers to conduct such surveys over North America. Multiple methods will likely be employed to survey most species. Estimation of detection probabilities associated with each observer-method combination is essential to produce comparable population estimates over time. Taking these factors into consideration, the proposed North American colonial waterbird monitoring program is outlined below.

3.1. Inventory

Inventories conducted at the scale of states and provinces will provide information on the current species composition, size, and distribution of waterbird colonies. Information obtained from these inventories will be used to develop an appropriate sampling framework for the widely distributed species. These inventories will be updated periodically to permit adjustments in the sampling design to accommodate temporal changes in distribution and abundance for each species.

3.2. Sampling Design

For species with small, locally distributed breeding populations, every colony will be surveyed in order to develop population estimates. Examples include populations

of Elegant Terns *Sterna elegans* in southern California and Sooty Terns *S. fuscata* and Brown Noddies *Anous stolidus*) on the Dry Tortugas of Florida as well as endangered or threatened species such as Roseate Tern *S. dougallii*.

Most species are more widely distributed and a sample of their colony sites will be regularly monitored to estimate changes in population size. For some species, the appropriate sampling scheme will be developed based upon their patterns of distribution and abundance across their entire ranges. This approach is appropriate for nomadic species such as White-faced Ibis *Plegadis chihi* and White Ibis *Eudocimus albus* and for species with regional distribution patterns such as Wood Storks *Mycteria americana* in the southeastern United States and Ashy Storm-Petrel *Oceanodroma homochroa*, Xantus' Murrelets *Synthliboramphus hypoleucus* and other species found only along portions of the Pacific Coast. For the most widely distributed species, appropriate regional sampling schemes will be developed and range-wide population estimates produced through the summation of regional estimates. Dual-frame sampling, which accommodates for the bias of known nest sites (Haines & Pollock 1998), will be one sampling design considered and tested for its efficacy in sampling colonial waterbirds.

3.3. Method Development

Survey techniques remain poorly developed or nonexistent for some groups of species such as crevice-nesting alcids and nocturnal birds. A high priority is the development of appropriate survey methods with their associated detection probabilities for these taxa. Use of new technologies, such as high-frequency surveillance radar (Burger 1997) and modifications to existing methods will be encouraged as long as these methods allow for the determination of detection probabilities. New and improved survey techniques will be incorporated into the monitoring efforts once their reliability has been established, assuming that the necessary resources are available to support their use.

A handbook of recommended methods is under development for this monitoring program (Steinkamp & Peterjohn 2000), recognizing that several methods may be needed in order to monitor adequately all populations of a species. Approaches for determining detection probabilities are described for each method in order to produce estimates of precision for every population. Methods lacking sufficient levels of accuracy or the inability to estimate detection probabilities have been excluded from this handbook.

Instead of recommending a single method for surveying each species, multiple methods are described for use in various habitats and generally follow well-established techniques for surveys of colonial waterbird populations (Bibby *et al*. 2000, Nettleship 1976, Walsh *et al*. 1995). The advantages and disadvantages of each method are discussed thus allowing the user to decide which technique is most appropriate (given the available resources) to survey specific colonies. Determination of detection probabilities is a critical component of these methods, for it allows for the comparison of results between colonies within a region and between years at each location.

This handbook also provides recom-

mendations on sampling within colonies as an alternative to attempting a complete count of breeding adults or nests. For any colony, the long-term availability of resources influences such a decision; the handbook recommends the consistent use of one approach or the other.

While several techniques for sampling within a colony have been developed (Anker-Nilssen & Rostad 1993, Bibby *et al*. 2000, Nettleship 1976), their suitability for detecting changes in population levels requires additional study. Population change within most colonies does not tend to be a series of random events, but is normally most evident at the periphery of colonies while preferred nest sites in the center of colonies tend to be consistently occupied. Hence, a simple random placement of sample plots within a colony may not accurately represent the population changes occurring over time (Walsh *et al*. 1995). Accessibility also influences the placement of sample plots; topography may determine the placement of plots at cliffs or other inaccessible locations.

3.4. Survey Timing

Because sampling allows fewer colonies to be regularly monitored, the surveys can be more concentrated at the most appropriate stage of the breeding chronology, so that the colony attendance of each species is represented accurately (Byrd *et al*. 1983, Hatch & Hatch 1988, 1989, Jones 1992), the intent being to conduct surveys at the same nesting stage each year. The survey timing will vary from locality to locality as a reflection of geographic differences in breeding chronologies, and may also have to vary annually at any colony to reflect between-year differences in the timing of breeding activities. For Least Terns *Sterna antillarum* and other species whose breeding adults frequently move between colonies during a breeding season, survey timing will have to be coordinated at a regional level to avoid the potential for multiple counts of adults.

3.5. Demographic and Habitat Monitoring

Population indices provide the resource manager with only one piece of necessary information. To make scientifically informed decisions on population and habitat management, managers must have demographic information on populations, including survival measures, and site-specific habitat information. This monitoring program proposes to identify reference sites within regions where demographic information will be collected. Site selection will be dependent on regional sampling designs and priority species. A standardized habitat collection protocol will be developed and implemented at colony sites.

3.6. Observers

This monitoring program will require the cooperation of numerous professional biologists and volunteer birdwatchers. Observer training in survey methodologies and estimation of large numbers of birds is essential to reduce some of the variability associated with the implementation of a continental monitoring program (Bibby *et al*. 2000, Erwin 1982). The determination of observer-based detection probabilities will also improve the comparability of data collected during these surveys.

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