Breeding Season Population Census Techniques for Seabirds and Colonial Waterbirds throughout North America

Introduction

For a continent-wide monitoring program to succeed, it is essential that methods be developed and agreed upon that are consistent and comparable. This manual is the first step towards standardizing monitoring methods. Standardized methods also need to be developed for montoring populations outside of the breeding season and for monitoring habitats at multiple geographic and temporal scales.

This manual synthesizes information from existing monitoring programs and the literature on colonial waterbird surveys for determining population trends from breeding season surveys, examines the weaknesses and strengths of each technique, the habitats and species best suited for specific techniques, and wherever possible, describes approaches for estimating detection probabilities associated with each method. It should be noted up front, that the methods proposed by this manual are for developing standardized reliable, comparable indices of population size to establish trend information, but will not result in robust estimates of total population numbers. While this manual addresses only breeding season methodologies, there is a recognized need for information on methodologies for counting colonial waterbirds outside of the breeding season. Therefore, we have included a few methods in Appendix this manual addresses only those breeding season methodologies. A separate manual will

For the purposes of this manual, colonial waterbirds are defined as those birds represented by the families listed in Table One. Definitions of terms used throughout this document are found in Appendix A.

Table 1. List of avian families included in the North American Colonial Waterbird Monitoring Manual

Family	Species
Diomedeidae	albatrosses
Procellariidae	shearwaters and petrels
Hydrobatidae	storm-petrels
Phaethontidae	tropicbirds
Sulidae	boobies and gannets
Pelicanidae	pelicans
Phalacrocoracidae	cormorants
Anhingidae	darters
Fregatidae	frigatebirds
Ardeidae	herons, select bitterns, and allies
Threskiornithidae	ibises, spoonbills
Ciconiidae	storks
Phoenicopteridae	flamingos
Laridae	skuas, gulls, terns, and skimmers
Alcidae	auks, murres, and puffins

Purpose

The purpose of this manual is to provide managers and biologists with the tools necessary to develop standardized data collection methods for monitoring colonial waterbirds throughout North America. We hope that by providing a list of standardized methodologies, better coordination can be accomplished amongst agencies and individuals monitoring colonial waterbirds throughout Mexico, Meso-America, Canada, the Caribbean Nations, and the United States. Our ability to manage and conserve many of these species is presently hampered by a lack of reliable information on the status and trends of their populations, information that can only be obtained through the use of standardized data collection techniques. As habitats become increasingly pressured by multiple uses, it has become critical to be able to make informed management decisions, and this will require a coordinated data collection effort at the local, regional, and continental scales.

Question: Why do we need to be concerned with counting colonial waterbirds using standardized methods?

Answer: To make informed management decisions about colonial waterbird populations, we must understand the status and trends of their populations at various geographic scales. If site-specific data are collected using different methodologies and without quantifying the error associated with each method, the result is colony-specific information that cannot contribute to the determination of population trends at larger geographic scales.

Question: Do I need to conduct an Inventory?

The first step is to determine whether you need to conduct an inventory or are ready to design a monitoring program. Do you know the distribution, locations, species composition, and approximate sizes of the colonial waterbird breeding colonies within the area of interest? Is there a breeding atlas, report, or other data sources available delineating colonies within the area of interest, which has been completed within the past 10 years?

Answer:

NO	Yes
You must first conduct an **inventory** to determine the distribution of colonies within your area of interest. Once an inventory is completed, you can design a monitoring program using this inventory data.	You can begin to design your monitoring program. The first step, is to answer many questions to establish the goals and objectives of the program (see Design considerations, below).

Conducting Inventories

The main purpose of an inventory is to find all of the waterbird colonies within the area of interest. Complete inventories can be conducted within a single breeding season for small geographic areas, such as a wildlife refuge or national park. Large regional inventories, for a state or province for example, may require several years to locate the majority of colonies, and it is likely that some small colonies may be overlooked. Hence, maintaining a current atlas of known and historic colony sites is an important component of any colonial waterbird monitoring program.

Inventorying a large area may require utilization of more than one resource. The method chosen will be dependent on the resources available, the degree of habitat heterogeneity within the area to be surveyed, and the biological characteristics of the species to be sampled. Aerial surveys may be adequate for large conspicuous species. However, most inventories require locating colonies on the ground, using boats to survey along waterways and other aquatic habitats that are inaccessible from roads. Timing of the inventories will be based on the breeding chronology of these species in the area, and should occur during the peak of breeding activities to better establish the absence of species from colonies. Colonies of Great Blue Herons and other species building large conspicuous nests could be inventoried during the non-breeding season. Nocturnal burrowing species are especially difficult to inventory, and will likely require nighttime surveys specific for them. Nocturnal mist-netting combined with the use of tape play-backs during one or a few nights may be an efficient method for determining the species composition of nocturnal species at multi-species colonies without causing undue disturbance to the nesting birds. You may want to take advantage of volunteers to conduct an inventory (see below).

Opportunities for Conducting Inventories:

Use of Volunteer Birding Groups – Often local birding groups have considerable knowledge of the status and locations of breeding waterbird colonies in their area. This information is frequently useful to help determine where the inventories should be conducted. Individuals within these groups can be organized to survey specific areas and report on the presence or absence of colonies, the species present, and approximate numbers of nesting pairs. This local knowledge can be very important in developing an understanding of the locations of the colony sites within your area of interest.

Establishing a Monitoring Program: Establishing Goals and Objectives The key to setting up a successful population monitoring program is first determine the purpose of your survey. Why are you interested in establishing changes in the abundance of a population? Are you going to use the data to determine the status and/or trends of populations? At what scale are you trying to determine status or trends: A park or Refuge, state, or, region? What is your qualitative goal? Do you want to be able to detect a 2% change in numbers per year? Do you want to be able to detect a 50% decline over 20 years? Are you going to use the data to make habitat management decisions or is it going to be used to measure species' responses to specific management actions? When designing a new monitoring program, or improving an existing program, we recommend answering the following questions before selecting specific survey methodologies.

(1) **At what scale do you want to detect population trends?** Do you wish to develop trend estimates for an individual colony? for a group of colonies at a local level (i.e., a refuge or park)?, or are you developing a state/provincial or regional monitoring program? If the methods outlined in this manual are followed, then surveys of individual colonies can contribute to monitoring efforts at larger geographic scales. But the geographic scale and objectives of the monitoring program will greatly influence the answers to the questions below.

Trends at individual colonies may not be very informative for some species. For example, nomadic species such as White and White-faced ibis exhibit limited site fidelity and large numbers of breeding pairs frequently move from one colony to another between years in response to changing habitat conditions. These annual movments will likely obscure trends at individual colonies, and only regional surveys will likely provide reliable population estimates for these species. Species that occupy ephemeral habitats, such as as interior populations of Least Terns nesting on sandbars in large rivers, also exhibit limited site fidelity and would be most appropriately monitored at larger regional geographic scales.

(2) **What is an appropriate time scale for detecting population trends?** Many of these species are long-lived, frequently with life spans of 10-25+ years under normal circumstances, so that population changes may be evident over a period of decades rather than years. Any species could experience dramatic declines over a fairly short time interval, however, and periodic monitoring

surveys at wide intervals would likely be insufficient to detect these changes. Additionally, given the annual variability in numbers of breeding pairs at many colonies and the imprecision associated with some of the survey methods, a minimum of 10-15 surveys will likely be needed in order to establish population trends for most species with a reasonable degree of certainty.

While desired levels of precision and power to detect trends strongly influence the sampling regime, resource limitations often dictate the level of survey effort. Annual surveys would be best, but realistic goals should be established based on available resources. For species with relatively short life spans, nomadic species, and others that exhibit considerable annual variability in numbers of breeding pairs at their colonies, annual surveys are preferred. For long-lived species with high rates of site fidelity to their breeding colonies, surveys every 2-3 years would be sufficient under most circumstances.

(3) **What magnitude of change should be detected by a monitoring program?** In general, detecting smaller rates of population change or trends over shorter periods of time requires greater survey effort, both in terms of frequency of surveys and improving the accuracy and precision of the annual counts of individuals. A traditional goal is to be able to detect a 25% rate of change over a 20-year period. This goal may be achievable for many species, assuming that the resources are available to conduct the necessary surveys. However, it may not be a realistic goal for species exhibiting considerably annual variability in the counts of breeding adults at colonies. Power analyses may provide insight into the levels of surveys effort needed to meet various potential goals, but the resources available frequently dictate the levels of survey effort , and in effect, the magnitude of change that can be detected by a monitoring program.

(4) **What level of Type I statistical error is acceptable?** How often should a false claim of a significant trend be accepted? The scientific literature normally uses a maximum value of 5% as an acceptable level of Type I error. The 5% level is frequently used as an indication of statistical

significance by existing monitoring programs, although a 10% level has also been used as a strong indication that a trend is occurring. Keep in mind that it is better for the species to receive "unnecessary attention" than to be declining over a period of years and ignored simply because the trend estimates barely exceeded a 5% level of statistical significance.

(5) **What level of power to detect trends is appropriate?** In other words, what proportion of the time should a monitoring program detect a trend if one really exists. Because the purpose of a monitoring program is to detect population trends, 80% is normally the minimum acceptable level of power for most monitoring programs. Levels of 90% or even 100% would be preferable, but may require greater levels of survey effort than can be achieved with the available resources.

Establishing a Monitoring Program: Design Considerations

Even when monitoring programs are carefully designed and data are collected using standard methods, they will never be able to detect every individual of a species. Hence, the estimates of population size derived from the methods described in this manual should be viewed as indices of abundance rather than counts of the total population. Resource limitations usually limit the number of surveys that can be conducted during a year, requiring sampling a representative selection of colonies in an area rather than attempting to survey every colony. These surveys may be conducted over a period of weeks or possibly months, so that colonies are visited during different portions of the breeding cycle. Additionally, since many colonies host large numbers of breeding pairs, accurately counting every individual may not be possible. All of these factors contribute to inaccuracies in the counts of individuals obtained during surveys of colonial waterbirds, producing three general sources of potential error in the indices of population size obtained from the surveys: (1) spatial variability, (2) temporal variability, and (3) detectability.

Spatial variability results from sampling animal abundance over space in an uncontrolled environment. A number of factors contribute to this source of error. Habitat heterogeneity is evident in most landscapes, and very few species are equally numerous in all available habitat types. Additionally, our ability to detect species will likely vary from one habitat to another. Unless detection probabilities are incorporated into the survey methodology, one cannot simply assume that differences in counts obtained from two different habitats are solely due to different population sizes in each habitat. Birds are highly mobile and may move into and out of the sample area while we are counting. Many species are also very adept at remaining hidden from view. Hence, an unknown proportion of the entire population will be detected during these surveys, and this proportion may vary from one habitat to another across a species' range.

For surveys conducted over large geographic scales where every colony cannot be visited annually, the sampling design should stratify by habitat type and possibly other characteristics of the landscape that are believed to influence the distribution of the nesting waterbirds. In this way, all important landscape features are incorporated into the sample design and the selection of colonies will be representative of the distribution of breeding sites across the landscape. At small geographic scales, every colony can be visited each year and these problems are avoided. However, all colonial waterbird surveys should address habitat-specific differences in detectability by incorporating estimates of detection probabilities into their survey methodology. These approaches will not eliminate every source of spatial variability, but will reduce this source of error in all surveys and produce more robust indices for use in estimating population change. The second source of potential error is temporal variability. Previous studies have demonstrated that for many species, the numbers of individuals present in a colony will vary markedly with the stage of the breeding cycle. Even at the same stage of nesting, counts can vary with the time of day, weather conditions, and possibly other factors. There is also a temporal component to the seasonal movements of adults. For terns and some other species, failed breeders may move to another colony and initiate a second nesting attempt during the breeding season and could be counted more than once if surveys are conducted over a long period of time.

Many previous regional surveys of breeding colonial waterbirds have failed to control for these factors, and temporal variability associated with the surveys may have obscured the population trends for some species. These surveys should be conducted during the same stage of the nesting cycle in order to produce comparable data between sites. Hence, the timing of annual surveys should coincide with the same stage of nesting each year. The nesting cycle may be very predictable in some habitats and geographic areas, but in others, there could be up to a several week difference between years in the timing of nesting activities. Decisions on the timing of surveys should be based on actual observations of nesting behavior and not solely on calendar date. This factor complicates surveys conducted over large geographic areas, since these surveys will require greater numbers of participants to survey the colonies within a relatively short time period.

Standardizing for time of day and weather conditions is more important for some methods, especially flight line counts, counts of alcids in attendance at colonies, or similar approaches based on observations of birds near the colony sites. Recommendations on the most appropriate times and weather conditions for conducting these surveys are detailed in the description of the methods below, but may frequently require knowledge of local activity patterns in order to reduce this source of error to acceptable levels. Avoiding adverse weather is also important an important consideration to reduce exposure of eggs or chicks to inclement conditions if the adults are flushed from their nests during the survey.

The third source of variability is caused by differing abilities to detect animals between surveys. As discussed above, differences in detection probabilities can vary between habitats. The knowledge and skill of the observers are also important factors influencing detection probabilities. Even when training is provided before the surveys are conducted, different observers may vary significantly in their ability to estimate the sizes of large flocks, identify individuals of similar species, and locate nests. Observer skill levels may improve (or decline) over time, and establishing detection probabilities will distinguish between actual population changes and changes in counts resulting from changes in skill levels. Because more than one observer will be involved in collecting data for all long-term monitoring programs for colonial waterbirds, determining observer-specific and colony-specific detection probabilities is critical for producing comparable data.

Many previous large scale surveys have employed single observers to survey every colony in order to avoid problems with differing detection probabilities between observers. However, this sampling scheme would likely increase the temporal variability associated with these counts, since the colonies would be visited during different stages of the nesting cycle. Experience with other monitoring programs, especially waterfowl surveys, indicate that if we select sample sites using robust protocol, standardize the timing of the surveys during the nesting cycle, and estimate detection probabilities for each survey, our data will have higher precision and be better to determine changes in abundance over space and time. Additionally, use of standardized survey methodologies will help control these sources of variability, and to compare data sets at different spatial scales. This manual suggests actions to reduce variability and offers suggestions for measuring detection probabilities wherever possible.

Parameters and Scale

Previous surveys of nesting colonial waterbirds have reported their results using several parameters: occupied nests, numbers of breeding adults present (not distinguishing between pairs and single birds present during the survey), and numbers of adults present (not distinguishing between breeders and non-breeders). These parameters are not directly comparable, which greatly complicates any attempts to develop estimates of population trends at larger geographic scales. To avoid these problems, the specific parameter to be measured during colonial waterbird surveys are specifically mentioned below. Some parameters may be species specific, while others will be used for groups of taxa.

Whenever possible, the total number of nests should be counted, especially for studies conducted at local scales involving a small number of colonies or at all colonies hosting small numbers of breeding pairs. .

While the total number of nests, even if counted during the peak of the season, underestimates the total nesting effort for the year by missing early failed egg laying attempts and late nesters, this parameter provides a more reliable estimate of the total nesting effort for the year than the total number of adults. Unless no other options exist, counts of the total number of birds should be avoided because this number includes both breeders and non-breeders. The proportion of non-breeders to breeders in attendance at colonies varies daily, hourly, seasonally, and between years, making comparisons of these counts problematical. However, some species, such as the cliff-nesting alcids, do not build nests and require that all birds be counted.

Three factors influence the decision on whether or not to conduct a complete nest count: colony size and accessibility, the resources available to conduct the surveys each year, and if the surveys can be completed with an acceptable level of disturbance to the nesting adults. Survey methodology should be consistent between years. If sufficient resources may not be available each year to conduct complete counts, then a sampling approach should be used.

For surveys of larger geographic areas, resource limitations will likely preclude attempting to survey every colony each year. The first step is to design a survey design that selects colonies representative of the landscape and will allow for making inferences about the population within the entire area of interest.

Before a sampling scheme can be designed, an inventory of the total area of interest must be conducted. As indicated above, information collected during an inventory includes colony locations and size , and wherever possible, species composition and an approximate number of nests. This inventory will provide the framework from choosing the sampling sites. To select sites, we recommend two methods: (1) simple random sampling or (2) stratified random sampling. The use of each is dependant on the degree of habitat homogeneity within the area of interest.

Question: Are the habitats in the area of interest homogeneous?

Yes	No
If the area of interest is homogeneous in character, a Simple Random Sampling approach is the recommended approach to use to select your survey sites: Simple Random Sampling consists of selecting a group of sample sites in such a way that each sampling site has the same chance of being selected. One method of selecting sites is to overlay a grid onto a map of the area of interest, number the each square in the grid, and use a table of random numbers or a random number generator to choose squares or colonies within grid squares to survey.	If your area is not homogeneous, it is best to use a stratified random sampling approach. In this approach, the area of interest is first divided into groups or strata, as defined by common variables. For example, in a coastal state, colonial waterbirds are far more likely to be found along the coastal counties, as opposed to inland counties. You might divide the state into coastal and interior strata, and then take simple random samples from each stratum.

Stratification by colony size may also be necessary, especially in situations where there are large numbers of small colonies and only a few large colonies for a species as may typify Great Blue Heron colonies in inland areas.

Preparatory Work (From Bibby et al. 2000)

Before conducting these surveys, two factors need to be recorded :

(1) You should provide a description of the study area. Aerial photographs can be used as a base-map to mark locations of colonies, or a GPS can be used to record locations and then geographic coordinates entered into a mapping program, such as ARC-VIEW.

(2) You need to provide a description of the breeding colony. A colony is defined as a single location supporting breeding birds located close enough in distance to interact socially (Gochfield 1980). For each colony, record colony name (including previous/historic names), location (descriptive and geographic reference), land ownership, detailed description of the site, including geology and vegetation, access instructions, including landowner name and address, GPS coordinates delineating the boundary (if possible), history of counts, difficulties encountered while counting, and any other notes. If the colony is expanding or shrinking in size, or is located on unstable habitats that may shift in response to storms or

other conditions (such as sand/gravel bars in a river), then the GPS coordinates should be provided every time the colony is surveyed.

The amount of information will depend upon the size and complexity of the colony site. If transects are needed, their locations should be indicated (possibly accompanied by GPS coordinates) in the colony description. If a survey requires viewing the colony from multiple sites or through the use of multiple methods (i.e. aerial survey combined with a ground count), then each viewing should be described including recording obvious landmarks.

Timing of Counts/Breeding Phenology

Specific recommendations are provided with each method described below. In general, the most effective time to count nests is during the mid- to late incubation stage of nesting, recognizing that even if we count at the peak of the nesting season, we underestimate the total number of nests attempted over the entire breeding season.

Disturbance

The effects of observer disturbance on the breeding success of colonial waterbirds remains a controversial topic. Carney and Sydeman (1999) summarized the available literature on the topic, although some of their conclusions were challenged by Nisbet (2000). While disturbance is a potential problem at every colony, each species may react differently depending upon the source and proximity of the disturbance and the birds' ability to acclimate to it.

A number of factors contribute to defining acceptable levels of disturbance at a colony, including status as a listed species of management concern, proximity of potential predators that will prey upon the eggs or chicks if the adults leave the nests, harsh weather conditions that will lead to the deaths of chicks or developing embryos in relatively short periods of time, and the behavioral traits of the species. In general, acceptable levels of disturbance should cause the individual adults to leave their nests for fewer than 10 minutes. In large colonies where only a portion of the adults will leave their nests due to the presence of observers, the surveys should still be completed with 2 hours.

Data Storage

A centralized location for storing information on colonial waterbirds is key to their conservation. Centralized databases support analyses of long-term trends of waterbirds and document population status and shifts in distribution and habitat use; this information helps (1) document the present and future problems facing colonial waterbirds and, (2) better defines the management actions necessary to support their long-term conservation. The Pacific Seabird Group pioneered a database for archiving records on Pacific seabird surveys and is housed at US Geological Survey's Alaska Science Center. This database will, in the near future, be accessible over the Internet.

Based on the experience of the Pacific Seabird Group, US Geological Survey Patuxent Wildlife Research Center has developed a centralized colonial waterbird database as part the National Bird Population Data Center. This database is one of a number of databases managed at Patuxent, and integrates information on the status, trends, and biogeography of waterbirds across regions, provinces, and states. This colonial waterbird database has been developed to archive data on colonial waterbirds throughout their ranges, regardless of survey locality, and will facilitate a coordinated response to conserve these birds throughout their ranges; furthermore, because the colonial waterbird database at Patuxent is part of the National Bird Population Data Center, it will aid in integrating all-bird conservation. The database is accessible over the Internet for both data submission and retrieval and will, in the near future, be linked to the Pacific Seabird Database at the Alaska Science Center.

Annual estimates for Pacific seabird surveys should be sent to the "Pacific Seabird Monitoring Database", a database maintained by the Pacific Seabird Group (Form attached in Appendix E). The centralized database housed at Patuxent Wildlife Research Center will archive long-term data on seabirds and colonial waterbirds for the remainder of the continent. This centralized database will store both raw and analyzed data and provide a convenient vehicle for data submission and dissemination through the Internet. Data may be submitted and retrieved via the World Wide Web by accessing the following URL…. A standardized data form has been developed and is attached as Appendix C.

Choosing a Survey Method

We have divided this portion of the manual into methods pertaining to species groups based on nesting behavior and nesting habitats, listing the recommended standardized methods for each group. Detailed protocols for conducting each method are provided, as well as a discussion of the advantages and disadvantages associated with each method.

Note: Species in bold text are those for which the recommended protocol were developed. However, these survey methods may be applied to all of the species within the respective group.

Cliff (Ledge) Nesting Species

Northern Fulmar, Northern Gannet, **Brandt's Cormorant, Double-crested Cormorant**, Great Cormorant, Red-faced Cormorant, Pelagic Cormorant, Herring Gull, Thayer's Gull, Iceland Gull, Glaucous-winged Gull, **Black-legged Kittiwake, Red-legged Kittiwake**, **Common Murre**, Thick-billed Murre, Razorbill [Note: The survey methods outlined in this section were specifically designed for species in bold, but may be applied to other cliff-nesting species]

There are numerous techniques available to count cliff nesting species. The preferred method will be dependent on resources available, total area to cover, colony sizes, colony accessibility, safety considerations, and program objectives.

Timing of Surveys:

Surveys should coincide with peak nest numbers, which for most cliff nesters, occurs during the mid-incubation to early nest-rearing stage of the breeding cycle. The timing of counts is best determined by the bird's biology at each individual colony (Rothery et al. 1988). For example, in California, one survey per colony per year in late May or early June has been sufficient to obtain a peak or near peak count of nests of Common Murres, Brandt's Cormorants, and Double-crested Cormorants. Keep in mind that peak or near peak counts actually under-represent the total number of nests over the entire breeding season as they fail to include nest failures prior to the survey and/or egg laying that occurs after counts are conducted, and that species will peak at different times.

Data Recording:

It is vital to record the year, month, date and breeding phenology (nest courtship/building, egg laying, incubation, hatching/chick-rearing, fledging) for interpretation of the counts and to allow comparisons over time and space.

Aerial Photograph (either fixed-wing or helicopter)

Objective: Population Indices for Detecting Trends

The following protocol were designed to count Murres and Cormorants, but can be applied to other cliff-nesting species. The protocol are from Carter et. al (1996).

Purpose: Population Trend Indices with an ability to detect ≤ 20% change in the numbers of birds present at colonies (power = 90% at 0.1 level of significance). (OVER WHAT TIME PERIOD? Year to year?)

Target Population: Total number of viewable/photogaphable bird and nests within a colony from the air. Using aerial photography to count birds allows a large proportion of the colonies to be surveyed. The extent of your surveys will be dependent on available resources and safety considerations.

Survey Design:

Step One – Flying the colonies

Small aircraft should be used to photograph colonies using standard techniques; in California, twin engine Partanavia aircraft have been utilized to increase the safety of over-water flights but single-engine

Cessna's have been flown as well (Carter et al. 1996). When determining the altitude from which to photograph colonies, keep in mind that a minimum altitude of 500 feet is required by the Federal Office of Aircraft Services (OAS)/USGS-BRD/USFWS flight rules for those federal employees. You must also consider whether there are marine mammals present at colonies. If marine mammals are present, permits must be applied for through the National Oceanic and Atmospheric Administration.

It is ideal to have three persons (in addition to the pilot) in the plane to perform various tasks. This will allow two persons to shoot the photographs while a third records the data associated with each colony and pass flown. Most often, a number of passes over the colony will be required to obtain photographs of the entire colony. The altitude of the aircraft should be between 122 - 274 meters, where possible. Two researchers should shoot photographs using 35 mm cameras with rapid shutter speeds (1/500 or 1/1000 seconds), telephoto lenses (300mm telephoto lenses have been reported in the literature, (Carter et al. 1996)). Cameras should be fitted with autowinders to allow quick enough succession of photographs. In addition to photographs taken as passes are made over the colony, it is important that the entire colony is photographed from the front of the aircraft, using a 50 mm lense (or thereabouts). This will provide you with an overview of the colony which will be important when you begin to piece together individual photographs of individual passes and will allow you to determine whether the entire is covered by the passes.

Data Recording: For each survey and colony, the data recorder records aircraft, pilot, observers, date, time, altitude, photo roll numbers, frame numbers, and general notes in the flight log. When several passes are necessary to obtain complete coverage of a colony, the data recorder will describe each pass separately. For example, during a second pass taken from the south to the north of a colony, 12 exposures are taken, numbering from 12 to 24; the data recorder will note in the flight log, the roll number, pass, and frames used during the pass.

During the flight, as rolls of film are completed and new film is loaded into a camera, the data recorder marks exposed film cartridges with a specific roll number corresponding to notes taken in the flight log. Each roll will be developed using an individual mailer marked with the roll number. Once developed, each slide is again labeled with the colony name, photographer, date, and roll number.

Disturbance: Aircraft can disturb birds, leading to increased nesting failure or colony abandonment. Care should be taken to note agitated behaviors. In some cases, ground observers in radio contact with aircraft personnel might be required during initial surveys. Signs of agitation might include head bobbing and birds being flushed off the nests. If agitated behaviors are noted, increase the altitude of the aircraft and note whether the behavior disappears. If agitation continues to be a problem, surveys of that colony should be discontinued.

Step Two: Counting Aerial Photographs

Once developed, those slides providing the clearest image of individual birds and nests should be chosen for counting. Count areas may be marked using landmarks or colony outlines. Once a full set has been pieced together, the slides should be projected onto a white wall or large pieces of white paper.

Parameter: Total number of nests and birds within a colony*:* One or two observers intensively search the projected images for birds and nests. Each bird and nest is marked by a felt tip marker, using different colors and symbols for birds and nests (and, in some cases, "sites" and empty nests) of all species present, including nesting and roosting birds. Where nest material is not visible, nests may be inferred from incubation posture of attending adults. For those species that do not build nests (such as Common Murres), you must count all birds. Often these species nest in close proximity to one another, making it difficult to distinguish between incubation posture and other postures or behaviors. Sometimes it is difficult to distinguish between species in a mixed-species colony. Usually, species will nest within the same region of a colony in "species groups" and birds counted within these regions can be assumed to be a species. However, when species cannot be discerned in mixed colonies, these birds should be counted and identified as unidentified species. Unidentified species are not included in colony totals but can be considered when assessing changes in colonies over time.

Sample Size: The sample size is a complete count of all birds in all passes for a colony.

Distinguishing between species:

There are multiple factors that can be used to distinguish between species. Differences in species behaviors, nesting phenology, nest materials and types, and known historical use of specific nesting areas can be used to delineate between species. For example, cormorant species can be distinguished using throat color, nesting habitats, nest materials and types, breeding phenology, and known historical use of specific nesting areas. In California, Brandts Cormorants build nests from seaweed or other vegetation, and Double-crested Cormorants often use large sticks. This detail may show up on quality photographs. Often breeding phenology can be used within regions, with one species nesting earlier than another.

Advantages: One advantage of using aerial photographs is that counts over a large area can be completed during a short period of time, allowing counts during the same or similar nesting stage. Another advantage is that often, aerial photographs are less disruptive to the colony and result in the adults spending less time off the nest. Finally, aerial photographs can be more economical than direct counts.

Disadvantages: Aerial photographs may not provide as precise information as direct counts. It is difficult to distinguish between species at some sites, nests are hidden by ledges, and, as mentioned above, it is difficult, or in the case of the Common Murre, impossible to distinguish between breeders and nonbreeders.

Measuring detectability – As touched on by the introduction, variability in detection amongst observers and amongst sites leads to problematical comparisons between data sets. To control for this, detectability should be measured once, for each observer at each site.

To get at detectability: (**ask harry to insert the protocol he and mike parker are using**)

- If possible, use photos that have every nest visible and have different observers count the number of nests. By measuring the difference in the number of nests counted by multiple observers, use a curve to get at detection.
- Two observers count photos and switch—mark individual nests by projecting the photo onto a wall
- Could also scan photos into photoshop and put into color—then create different layers. This could be used to archive data.

Counts from Land (From Bryd, FWS…)

The following protocol were developed for Common Murres and Kittiwakes in Alaska, but can be applied to other cliff-nesting species. The nest is defined as any structure to which vegetation has been added that year.

Purpose: Population Indices for Detecting Trends. The standard goal is to detect ≤ 20% changes in the numbers of birds present at monitoring plots (power = 90% at 0.1 level of significance).

Target Population: **Viewable population from land**. To get at population trend indices, we don't need to target the whole population at breeding colonies. Instead, the "viewable" population, defined as the portion of breeding birds that can be seen from land, is used as the target population for trend monitoring.

Survey Design: For many seabird colonies, it is too expensive to conduct replicate counts of large colonies. Therefore, index plots consistently measured over time may provide a reasonable basis for assessing trends. A sample plot is defined as a segment of cliff-nesting habitat which; (1) may be viewed from the same location repeatedly, (2) has readily identifiable boundaries by any person conducting the survey, and (3) contains fewer than 300 birds. It is not necessary to attempt to randomly select plots from a colony, but, where the viewable portion of a colony allows the option, plots should be selected systematically for thorough geographic coverage. On small colonies, it may be desirable to count the entire viewable population, but at large colonies, as little as 10% of the viewable population might be included in the survey. Cliff sections, viewable from above or below on a beach are good candidates for plots. Continuous coverage is fine, but the cliffs should be subdivided to create segments supporting fewer than 300 birds. It is ideal to have 20-30 plots per monitoring site; if you have a small number of plots, the loss of any one plot over the course of your monitoring reeks havoc on the statistical effectiveness of a long-term monitoring scheme. Observation points must be carefully marked to allow year-to-year repeatability of counts from the same location. The most reliable method is to physically mark the location and record the GPS coordinates. For boat counts, GPS coordinates should be recorded for observation points.

Parameter: Due to variability in attendance of ledge-nesting seabirds at cliffs, the average number of birds present during the "count" period on the index plots is the parameter of interest for population trend monitoring. Day to day changes in counts at plots is one of the most important sources of variation in counts. This is influenced by daily changes in attendance at plots. Components of variation include hourly differences and daily differences within a given year, but the daily differences are much greater than hourly differences as long as counts are conducted during the middle portion of the day.

Sample Size: A complete count of birds on all plots is one sample. Multiple counts on the same day likely are not independent and thus should not be considered as additional samples. It is better to count again on a different day. To attain the objective of detecting between-year differences as small as 20%, 5-10 replicate samples (complete counts of all plots) are needed. The exact number of replicates needed depends on the variability among count days which may vary among sites and years.

Data Collection

To minimize variability and standardize counts the following protocols should be followed:

1. Make counts during the mid-incubation to early chick-rearing stage of the reproductive cycle.
2. Make all counts between 11:00 - 1800 hours (if conditions necessitate counting outside these periods it may be worth doing, but variability likely will increase. Note: This may change regionally!

3. Complete 5 - 10 separate counts (replicate samples) of birds on all plots during the periods listed above. Ideally, complete counts of all plots on a single day, however, if that is not possible, complete one replicate within as short a period as possible, and finish it before starting a second. An exceptoin may be where most (e.g. 90%) of the plots or birds have been counted, but fog persistantly precludes finishing the replicate. In such cases missing values may be estimated, and it would be wise to start a second replicate.
4. At each plot, record the number of birds and the number of nests for cormorants and kittiwakes (a nest is defined as a structure to which vegetation has been added in the current year). Count birds and nests at least twice at each visit to insure that counts are within 5% of each other (generally the only reason for more divergent counts is observer error). Note that this standard is more precise than that suggested for the Relative Abundance Procedure above. Record the average of clustered counts for all plots on each count date or dates on appropriate forms. Gaston et al. (1983) determined that there was little improvement to increased observation hours above two hours per day at a site.
5. Don't conduct counts when winds are severe, during fog, or during heavy rain.

Advantages: The advantage is that such data as these are useful in ecosystem monitoring. In fact, monitoring for population trends in seabirds is becoming an objective of conservation biologists concerned with marine ecosystems worldwide. Seabirds are seen as relatively inexpensive indicators of change in this complex ecosystem. In Alaska, ledge-nesting seabirds have been identified as important indicators. As such, trends will be used to track the response of target populations to natural and man-caused events. These data will be used with information gathered on other components of the ecosystem (e.g., forage fish, marine mammals, oceanography) to try to understand processes, an integral part of ecosystem management.

Disadvantages: A disadvantage of this type of monitoring is that it is labor intensive and therefore costly.

Data Analysis and Reporting

Data Analysis: A completed data set for each year would be composed of daily counts of each plot, and daily totals for the system of plots. It is important to keep track of counts for each plot in case one or more plots or observation points are lost in the future, making it necessary to use a smaller subset for multi-year comparisons.

Measuring Detectability: A double-observer approach can be used to develop detection probabilities for this method. During the first count at each plot, one observer is designated as the "primary" observer, who verbally describes the specific portion of the plot where they are counting and the number of individuals of each species that are present. At the same time, the second observer counts individuals at the same portion of the plot, and independently records individuals that are observed and missed by the "primary" observer. This process is followed throughout the entire count. The observers switch roles during the second count at each plot. By recording both the individuals that are detected by both observers and those missed by each observer, detection probabilities can be calculated for both observers.

INSERT FIGURES FROM BIRD CENSUS TECHNIQUES HERE (asking permission to use)

Burrow Nesting Species

Bermuda Petrel, Manx Shearwater, Black-vented Shearwater, Fork-tailed Storm-Petrel, Leach's Storm-Petrel, Ashy Storm-Petrel, Black Storm-Petrel, Ancient Murrelet, Cassin's Auklet, Rhinoceros Auklet, Atlantic Puffin, Horned Puffin, Tufted Puffin

Definition of burrow – Any hole in the ground.

There are a few factors which must be considered before beginning to design your monitoring program for burrow nesters.

(1) Timing – The timing of the surveys must be considered. Observing burrows is much easier before vegetation becomes rank, but evidence of occupancy (see below) is not as prevalent as later checks. Most species of burrow-nesting seabirds are prone to abandon nests if disturbed early in incubation, but then tolerate disturbance much better after mid-incubation. Ideally, burrows should be counted in plots as early

as possible, but not until incubation is well underway (for those species where observers will reach into nest chambers, and then rechecked after chicks hatch).

(2) Species Identification – Many burrow-nester colonies contain more than one species; the most diverse containing 5-6 species. Where index plots are subjectively placed, an effort should be made to minimize diversity, especially of species similar in size. When transects are used, multiple species often cannot be avoided. In such cases, it will be necessary to assign burrows to species groups based on entrance sizes. The following divisions are suggested:

Tunnel Width	*Species*
< 10 cm	storm-petrels
10 to 12 cm	Ancient Murrelet, Cassin's auklet
12 cm to 15	rhinoceros auklet
> 15 cm	puffins

(3) Occupancy – Many burrows have tunnels so long that observers cannot reach the nest chamber with their arm, or they are curved which also may restrict access. Furthermore, it is frequently impossible to see the nest chamber from a burrow entrance with a bright light. Typically, excavating entry ports to tunnels will not be used for routine monitoring. Remote camera set ups are probably the best tools, particularly for puffin and Rhinoceros Auklet burrows, to determine the contents of burrows quickly. Nevertheless, for storm-petrels, Ancient Murrelets, and Cassin's Auklets reaching into each burrow is the recommended method. Indirect evidence of occupancy should be used for puffins and Rhinoceros Auklets when cameras are not available, and Cassin's auklets when burrows are too deep to reach the chambers. Indirect evidence of an occupied burrow would be the presence of droppings, feathers, or egg fragments near the burrow entrance.

(4) Placement of transects – We need to consider the influence annual monitoring has on vegetation succession at colony sites. Choosing random plots along transect lines instead of going back to the same burrows each year will have less influence on the vegetation and should be considered.

It is important to note that accuracy and precision are both problems for methods developed to count burrow nesters and methods will be improved as studies are completed to determine the best methods for counting burrow nesters. We need to better understand the relationship between the number of burrows and the number of birds, and how much error is associated with these numbers. In the meantime, the following protocols are recommended for estimating population trends using population indices.

Ground Counts (Whole Colony)

Purpose – Population Estimation (entire colony) or Population Indices for Detecting Trends (Index Plots) with an ability to detect ≤ 20% change in the numbers of birds present at colonies (power = 90% at 0.1 level of significance).

Target Population – Number of burrow entrances either in an entire colony or in a series of index plots. Burrow-nesting seabirds are hidden from view at their nest sites and colony attendance is either highly variable among days and hours (Tufted Puffin) or it occurs only at night (other species). As a result, it is not feasible to monitor population trends by counting birds. Instead, the target population is the number of burrow entrances either in an entire colony or in a series of index plots.

Survey Design – It is seldom possible for observers to get to all burrows on an island without technical climbing gear, because burrow-nesters often use steep slopes or bluff edges. Therefore, the sampling "universe" would usually be the portion of the colony that is accessible to observers.

Survey Unit: Strip Transects – If the objective is to estimate entire colony populations (at least the accessible portion), strip transects are the preferred sample plot. The width of the transects would depend upon the species involved. For example storm-petrels may occur at such high densities that 2 m wide transects would be ideal, whereas wider transects may be appropriate for tufted puffins where burrow densities are lower. Transects would vary in length depending upon the "depth" of the colony in a particular spot.

Sample Size: To estimate overall population size, in relatively small colonies, select enough transects to sample approximately 10% of the area occupied by burrow nesters. The proportion could be as low as 5% in larger colonies, but in any case at least 20 transects should be sampled.

Parameters: Two parameters are of interest: 1) The number of burrow entrances in the colony, and 2) the proportion of burrows that are occupied. A burrow is considered occupied if an egg or a chick is present. This statistic will vary among plots. It is essential to record the units being used.

Data Collection – Whether the objective calls for estimating the total population in the colony, the approach is to record the number of burrow entrances in each transect or plot. For the purpose of this procedure, a burrow entrance is defined as a hole at least 10 cm long apparently dug by a bird (no burrowing mammals are present at most locations where burrow-nesting birds would be monitored).

For transects, a systematic sampling design should be employed. As indicated above, 5%-10% of the colony should be sampled. The steps are as follows:

1. Delineate the extent of the colony.
2. Select the transect width that is appropriate.
3. Select the interval between transects based on the percent sample desired (e.g., select every kth strip to sample 10% of the colony area).
4. Randomly select a start point.
5. Lay out each transect with a compass and tape measure.
6. Mark ends of transects with permanent stakes.
7. Count burrow entrances in each transect.
8. Record occupancy in a subsample of burrows (e.g., every kth transect)
9. Record information on a standardized data reporting form (See Appendix C).

Advantages: The advantage is that such data are useful for assessing absolute impacts from local perturbations.

Disadvantages: A disadvantage of estimating overall populations is that it is labor intensive and therefore costly. Furthermore, it is probably not necessary for monitoring trends.

Data Analysis – For estimating the entire colony population, systematic sampling estimators would be used to calculate the mean density of burrows per transect. The mean and variance would be used to estimate the total number of burrows in the colony. In a similar way, the mean occupancy rate would be calculated. It is important to keep track of counts for each transect, so that investigators will be able to determine whether future changes are restricted to certain portions of the colony. Inter-year comparisons would be made by analysis of variance techniques and long-term trends would be characterized using regression.

Ground Counts (Index Plots)

Purpose – Population Indices for detecting trends, with an ability to detect ≤ 20% change in the numbers of birds present at colonies (power = 90% at 0.1 level of significance) between years.

Target Population – Number of burrow entrances in a series of index plots. Burrow-nesting seabirds are hidden from view at their nest sites and colony attendance is either highly variable among days and hours (Tufted Puffin) or it occurs only at night (other species). As a result, it is not feasible to monitor population trends by counting birds. Instead, the target population is the number of burrow entrances in a series of index plots.

Survey Design – It is seldom possible for observers to get to all burrows on an island without technical climbing gear, because burrow-nesters often use steep slopes or bluff edges. Therefore, the sampling "universe" would usually be the portion of the colony that is accessible to observers.

Circular Plots: If the objective is to monitor trends, but not necessarily to estimate the overall population size, a series of permanent circular plots would be appropriate. Circular plots are easier to mark (one stake) and layout (a line of fixed diameter) than transects or other quadrates. Nevertheless, the configuration of a colony (e.g., a narrow coastal strip) may lend itself better to quadrates than circular plots in some cases. Like the transects referred to above, the diameter of the plots would be based on the species. Plots should be located subjectively to include areas of high, moderate and low density because the object is to be sure that both increases and declines are noted (i.e., choosing just high density plots could result in not seeing increases which are showing up in less saturated areas). For trend monitoring, at least 10 plots should be monitored in small colonies, and up to 20 plots are needed in large colonies. Plots should be photographed and mapped in such way to facilitate relocation. GPS coordinates for the center point also should be recorded. Center stakes need to be tall enough to be seen at a distance even when vegetation is tall and they should be of a material that will last (plastic, iron).

Important Considerations when setting up plots: Long-term population trend monitoring depends on standardizing as much as possible. It is critical to mark plots in such a way that they can be resurveyed in an identical manner. GPS coordinates could be used to get observers into the vicinity, but permanent obvious plot markers are essential. For circular plots or quadrates, locations should be selected within density strata to insure that areas with high, medium, and low density are included. Once colonies are delineated and crude abundance codes have been assigned to general areas, plots could subjectively located. The steps are as follows:

1. Delineate the extent of the colony.
2. Assign density codes to different parts of the colony.
3. Select an appropriate plot size and shape.
4. Select sample size (see above).
5. Locate and permanently mark plots.
6. Count burrow entrances and record occupancy rate in each plot.
7. Record information on a standardized data reporting form.

Parameters*:* Two parameters are of interest: 1) The number of burrow entrances in the index plots, and 2) the proportion of burrows that are occupied in the index plots. The purpose of trend monitoring is to detect changes in burrow-nester populations, and burrow-entrances are only an indication of all possible nest sites. Occupancy rate must be estimated to relate burrows to birds. A burrow is considered occupied if an egg or a chick is present. This statistic will vary among plots. It is essential to record the units being used.

Advantages: Index plots to determine population indices likely provide the most cost- effective approach for monitoring burrow nesting species and do not require the same level of effort as methods to estimate total population . Monitoring for population trends in seabirds is becoming an objective of conservation biologists concerned with marine ecosystems worldwide. Seabirds are seen as relatively inexpensive indicators of change in this complex ecosystem. It is unlikely that "presence or absence" or "relative abundance" data will provide the kind of information most useful in the ecosystem approach to conservation. In Alaska, burrow-nesting seabirds have been identified as important indicators (U.S. Fish and Wildlife Service 1992). As such, trends will be used to track the response of target populations to natural and man-caused events. These data will be used with information gathered on other components of the ecosystem (e.g., forage fish, plankton, marine mammals, oceanography) to try to understand processes, an integral part of ecosystem management.

Measuring Detectability

A double-observer approach can be used to determine detection probabilities. The first observer would walk the transect line or completely cover the study plot, marking each nest with an object such as a colored washer. If multiple species are present at a site, different colors should be used for the burrows of each species. Different colors should also be used to distinguish between occupied and unoccupied burrows. After the first observer has finished their survey, a second observer independently marks each burrow using a different set of colored washers. This process could be repeated by additional observers if necessary. After the surveys are completed, an additional person (or possibly more if the burrows are difficult to find in the terrain) would visit the transect/plot and indicate how many burrows were located by each observer, and how many were missed (or mis-classified) by one of the observers, and these data can be used to calculate detection probabilities.

Data Analysis

For index plots, the total number of burrows in all plots would be summed for the annual statistic. In addition, the mean occupancy rate would be calculated. Inter-year comparison would be made with non-parametric paired sample tests (probably the non-parametric Friedmann test for $n \geq 3$). Long-term trends would be characterized using regression.

Radar (TO BE ADDED)

Crevice Nesting Species

Audubon's Shearwater, Least Storm-Petrel, White-tailed Tropicbird, Red-billed Tropicbird, Red-tailed Tropicbird, Dovkie, Xantus's Murrelet, Craveri's Murrelet, Parakeet Auklet, Least Auklet, Whiskered Auklet, Crested Auklet, Black Guillemot, Pigeon Guillemot

Ground Counts
Purpose: Population Trend Indices

The purpose of trend monitoring is to detect changes in crevice-nester populations, but the minimum detectable difference of 20% desired for ledge-nesters and burrow-nesters may be more difficult to obtain for crevice-nesters due to the high variability in colony attendance for most species. More research is needed to improve ways of partitioning this variability, before accurate predictions can be made about the minimum detectable differences with a given sample size. Standard techniques for monitoring population trends of most species of crevice-nesting seabirds have not yet been developed. Nevertheless, approaches have been suggested for pigeon guillemots (Drent 1965, Ainley and Boekelheide 1990, Sanger and Cody 1993, Vermeer et al. 1993) and crested and least auklets (Bedard 1969, Byrd et al. 1983, Roby and Brink 1986, Piatt et al. 1990). Techniques for Crested and Least Auklets could be applied to Horned Puffins, but no techniques are suggested here for Parakeet Auklets or Whiskered Auklets.

Target Population: Average number of birds counted at index plots during a standard period. The target population is the average number of birds counted at index plots during a standard period (selected based on the peak or least variable portion of the diurnal attendance pattern) on a sample of days during the incubation and/or chick-rearing period. Crevice-nesting seabirds are hidden from view at their nest sites, and colony attendance patterns vary among species. Some species like Pigeon Guillemots congregate on the sea near colonies whereas other species like Least and Crested Auklets and Horned Puffins congregate on the surface of talus slopes. These congregations provide an opportunity to count birds, but there are a number of variables to consider in interpreting counts. For example, what proportion of the entire population is visible to the observers, and what proportion of the visible birds are breeders versus non-breeders?

Survey Design

Pigeon Guillemot - ***Survey Unit*** - Pigeon guillemots tend to nest in small coastal colonies, so the sample unit would be a count of all birds associated with a colony or small island on a particular day.

Parameters - The main parameter of interest is the average number of birds present at a colony during the sampling period (i.e., incubation and chick-rearing period) in a given year.

Sample Size - Counts should be made on 4-6 mornings each year.

Crested and Least Auklets and Horned Puffin: ***Survey Unit*** -These species often congregate in large colonies, and it is frequently impossible to count all birds associated with colonies. An appropriate sample unit would be a series of 10 m x 10 m plots on which birds are counted (during a standard period of time) on one day. The number of plots should vary based on the size of the colony, but a normal range would be 10-20 plots. Plots should be located subjectively to include areas of high, moderate and low density because the object is to be sure that both increases and declines are noted (i.e., choosing just high density plots could result in not seeing increases which are showing up in less saturated areas). This process can be facilitated by conducting an initial day-long survey at new sites to roughly map (on Polaroid photographs or sketches) the extent of the area used by birds and to locate potential sites for plots in areas with various densities. Plots and observation points should be clearly marked to remove confusion about boundaries. Ideally, up to 5 plots could be viewed from a single observation point. Plots also should be photographed and mapped in such way to facilitate relocation. GPS coordinates for the center point also should be recorded. Permanent stakes need to be used to mark plot locations. The objective is to count the number of birds present on the same plots among years.

Parameters **-** Because diurnal patterns of attendance include steep peaks (Byrd et al. 1983), some sort of index has to be used to characterize the abundance of birds using the colony. If birds on the surface of colonies are counted at set intervals (e.g., 15 min) throughout a daily peak, which may last up to 5 hours, the highest 10 counts could be averaged to provide an estimate for a particular plot on a particular day. The mean of *n* daily averages could be used for an annual point estimate for each plot.

Sample Size**--**Counts of sample units should be conducted on at least 4-6 days each year.

Data Collection

Pigeon Guillemot **-** On at least 4 different mornings (between dawn and 1000 h) during the incubation period (local knowledge needed to know timing of nesting events, but generally June to mid-July in Alaska), count guillemots within about 100 m of shore at selected colonies. Usually counts would be made on fairly calm days from a small boat or from land. Typically, most islands or island groups have a number of small guillemot colonies. If colony locations have not previously been delineated, an initial inventory should be conducted. If surveys are of entire island coastlines, subdivisions no larger than 1 km should be delineated for the purpose of recording data.

Auklets and Puffins **-** On at least 4 different days during the incubation period (usually mid-June to early July in most locations in Alaska) auklets and/or horned puffins present on the surface of the plots should be counted at 15-minute intervals (± 3 minutes) throughout the morning/early afternoon activity peak (varies among locations but is usually about 5 h long). The purpose of the 15 minute interval is to ensure counts are taken with some measure of periodicity. Gulls or foxes may cause flyoffs and counts could be delayed a few minutes to allow birds time to settle down again.

Advantages and Disadvantages

Population index data are more expensive to obtain than presence/absence and relative abundance data, but they are needed to track trends. Monitoring for population trends in seabirds is becoming an objective of conservation biologists concerned with marine ecosystems worldwide. Seabirds are seen as relatively inexpensive indicators of change in this complex ecosystem. It is unlikely that "presence or absence" or "relative abundance" data will provide the kind of information needed to understand ecosystem processes.

In Alaska, crevice-nesting seabirds have been identified as important indicators. As such, trends will be used to track the response of target populations to natural and man-caused events. These data will be used with information gathered on other components of the ecosystem (e.g., forage fish, plankton, marine mammals, oceanography) to try to understand processes, an integral part of ecosystem management.

Data Analysis

***Pigeon guillemot* -** The annual means for individual colonies could be compared with one-way analysis of variance. For series of colonies on a particular island or in an island group where a number of islands were surveyed in the same years, inter-year comparisons would be made with paired sample tests (probably the non-parametric Friedmann test for years ≥ 3). Long-term trends (e.g., years ≥ 5) would be characterized using regression.

***Auklets and puffins* -** The index values (e.g., average of top 10 counts on each count day) for each plot would be arranged in a repeated measures design for inter-year comparisons (as for guillemots above). Paired sample tests would be used to test for differences. Plot counts would have to be combined in some manner (e.g., index values could be summed over all plots for each year) to use regression methods to test for long-term trends.

Measuring Detectability

Pigeon Guillemots – The difficulty with this method is that the individuals are active during the survey period, and an unknown number of individuals may be below the surface of the water at any time. A double-observer could be used, with a "primary" and "secondary" observer scanning the water and counting birds simultaneously. The "primary" observer would verbally identify the locations of each individual they are counting (including birds that may be underwater at the time of the "maximum" count). The "secondary" observer would try to locate individuals missed by the "primary" observer, as well as birds that may be double counted by that observer. The observer roles can be switched on alternate days. By recording numbers of individuals seen by both observers and missed by one of the observers, detection probabilities can be estimated. This method may require additional refinement when attempted in the field.

Auklets and puffins – A double-observer approach identical to that described for cliff-nesting birds can be used for these species.

Special Considerations

Long-term population trend monitoring depends on standardizing as much as possible. It is critical to mark plots in such a way that they can be resurveyed in an identical manner. GPS coordinates could be used to get observers into the vicinity, but permanent obvious plot markers are essential.

Tree and Shrub Nesting Species

Red-footed Booby, Brown Pelican, Neotropic Cormorant, Double-crested Cormorant, Great Cormorant, Anhinga, Magnificent Frigatebird, Rufescent Tiger-heron, Bare-throated Tiger-heron, Great Blue Heron, Cocoi Heron, Great Egret, Snowy Egret, Little Blue Heron, Tricolored Heron, Reddish Egret, Cattle Egret, Green Heron, Striated Heron, Agami Heron, Capped Heron, Black-crowned Night Heron, Yellow-crowned Night Heron, Boat-billed Heron, White Ibis, Glossy Ibis, White-faced Ibis, Roseate Spoonbill, American Wood Stork, Snail Kite, Bonaparte's Gull, Mew Gull, Brown Noddy, Marbled Murrelet

COLONIES IN TREES AND LARGE SHRUBS

Ground Surveys

Counts conducted from the ground tend to provide the most reliable estimates of numbers of breeding individuals. The preferred method is to conduct strip transects through the colony, a method that also readily allows for a determination of the precision associated with the counts. This method is not appropriate under all circumstances, however. Strip transects may create an unacceptable level of disturbance to the nesting birds in some colonies, because the presence of people within the colony for a long period of time may produce excessive predation or abandonment of the nests. When disturbance to the nesting birds must be minimized, a nest count during the non-breeding season provides an alternative approach for estimating population size for single-species colonies or mixed colonies where the nests of each species can be readily identified. For mixed colonies supporting species whose nests cannot be readily identified after the birds have left the colony, a perimeter count during the breeding season combined with a nest count during the non-breeding season is the preferred approach for establishing population size. For colony sites with dense vegetation that hides most nests from the perimeter and are impenetrable on the ground, such as those located on small mangrove islands, flight-line counts provide the only method for developing an index to population size. Flight-line counts only provide an index to population size and are not directly comparable to the estimates of total population size derived from the other methods, so their use should be avoided under most circumstances. Aerial surveys should be strongly considered as an alternative to flight-line counts for these colonies if they are composed of light-colored species.

Purpose: Population Trend Estimation, with an ability to detect ≤ 20% changes in the numbers of birds within colonies, along transects, or visible from the perimeter (Power = 90% at 0.1 level of significance).

Target Population: The breeding population of each species present in the colony.

Timing of Counts: Counts should be conducted during the same stage of the breeding cycle. For example, if you are counting White Ibis in the Great Basin, it is best to conduct your surveys during the incubation period. During incubation, it is assumed that one of the parents will remain at the nest (Earnst et al. 1998). During the chick-rearing period, both parents may be away from or at the nest and making it difficult to determine the number of breeding pairs. The nesting stage during which to conduct counts should be determined based on the nesting habitat and the species.

Parameter - The number of active nests for each species present in the colony.

Survey Design

Strip Transects - When considering strip transects of colonies, the first decision is whether to attempt counting every nest within the colony or to sample only a portion of the colony and extrapolate from this sample to an estimate of the total population. Under most circumstances, complete counts should be conducted in colonies totaling 100 or fewer pairs. Complete counts are also preferred for colonies in the range of 100-500 nests, assuming that sufficient personnel are available to conduct the survey with relatively minimal disturbance to the birds, preferably spending less than one hour in the colony and disturbing birds from individual nests for less than 10 minutes. For colonies in the range of 500-1,000 nests, complete counts should be conducted only when available personnel can complete the census within one hour; otherwise, the colony should be sampled. Sampling is the preferred approach for most colonies in excess of 1,000 nests, although some sites may permit complete nest counts of very large colonies if sufficient personnel are available to conduct the surveys without causing unacceptable levels of disturbance.

Strip Transects/Complete nest counts - The objective of these surveys is to accurately count every nest in the colony without double-counting individual nests. Simply walking a single unmarked transect and counting every nest may be an appropriate method for many small colonies composed of 50 or fewer pairs. Such simple survey methods may also be employed for larger colonies under exceptional circumstances, such as colonies located along narrow riparian corridors. But if all nests are not visible from a single transect, then the more complicated process of marked transect lines must be used.

Complete nest counts necessitate that transects are established at intervals allowing every nest to be viewed from one line. The transect lines should be created during the non-breeding season to minimize disturbance to the nesting birds, preferably in late summer or early autumn when the nest visibility is similar to the conditions during the breeding season. Transects established during winter may prove to be inadequate when the habitats are fully vegetated. These transects should be marked with plastic flagging or some other fairly permanent marker at intervals that will easily allow the surveyor to follow each line through the habitat. The same transects should be used annually, although new lines may have to be established as colony size increases or shifts location, or if the vegetation density changes over time. The outer-most transect lines should always be located beyond the current perimeter of the colony.

Transect width will vary with the density of the vegetation; transects may be only 2-5 m wide in dense habitats, but widths of 30-60+ m are possible in open woodlands. Transect width can vary within a colony, especially when the vegetation density is heterogeneous, and should be dictated by the observer’s ability to see the next transect line in order to accurately determine the boundaries of the strip being surveyed. Transect length is dictated by colony size, and should always provide a complete cross-section of the colony. Transect length may expand or contract to reflect changes in colony size.

Whether an observer chooses to count nests within both strips bordering a transect line or only one of the strips will depend upon factors such as the vegetation height and density, nest density, species composition, and the need to minimize disturbance to the nesting birds. When multiple observers are conducting the survey, the decision on how to count along each transect line should be made before entering the colony. For nests located in trees or shrubs that extend over the transect boundary, the nests should be counted only when the base of the supporting tree/shrub is located within the strip, regardless of the actual position of the nest.

Strip Transects/Sample Sites - These procedures require knowledge of the size of the entire colony in order to develop an appropriate sampling scheme. This information can be obtained from aerial photographs or from the ground, and should be updated each time the colony is surveyed. Standard colonial waterbird surveys use either 20% or 40% coverage as the basis for extrapolating the entire colony size; 40% is preferred under most circumstances, because this coverage will normally produce more accurate estimates of total population size. In extremely large colonies or habitats that are very difficult to traverse, then 20% coverage is adequate.

Transects used to achieve a 40% sample of a colony should be chosen at random from the entire set of possible transects. As long as the colony size and location remains constant, the same transects can be surveyed for more than one year. However, the random selection process should be repeated whenever the colony size and distribution of nests changes. For multi-species colonies that are partially or entirely segregated by species, a random sample approach stratified by species distribution should be used to ensure that all species are adequately surveyed (i.e. each species receives 40% coverage). Establishing transects, determining transect width, and conducting the surveys should follow the methods described in the Complete Nest Counts section.

Measuring Detectability – A double observer approach can be used to estimate detection probabilities. The first observer walks the transect line, and uses plastic tape to mark every shrub/tree that supports an active nest. Each shrub/tree is individually identified by the tape, and the number of nests for each species is counted. Once the first observer is finished, a second observer independently repeats this process. After the second observer is finished, a third observer would walk the transect and note how many shrubs/trees were found by both observers and how many were missed by both.

For large colonies, this process does not have to be followed for every transect. Depending upon the number of nests detected along each transect, following this procedure for 5-10 transects should be sufficient to establish detection probabilities. For small colonies ($\leq$5 transects), this procedure should be followed for every transect.

Nest counts during the non-breeding season - (May be useful for Double-crested Cormorants in the Great Lakes region and Great Blue Herons in the Northeast)

Nest counts conducted during the non-breeding season are more problematical to accurately translate into numbers of breeding pairs, because it is impossible to positively establish whether a nest was actually used during the previous nesting season. These surveys can only count the total number of nests, and assume that the changes in these counts reflect actual changes in numbers of breeding pairs.

In Florida, colonies may be continuously used for most months of the year. The composition of the breeding populations will vary seasonally, so that species breeding in late spring and summer may not be the same as those breeding in late winter. A single nest may be used by two or more species during the course of a single year. These colonies will have to be surveyed on multiple dates during the breeding season in order to accurately assess the changing composition of the breeding communities, and nest counts during the non-breeding season should not be attempted.

Nest surveys during the non-breeding season should follow the methods described in the Complete Nest Counts section. Since disturbance to birds is normally not a factor, these surveys should attempt to count every nest when possible. All nests located in bushes and trees should be counted, even those that may not be habitable by birds in the future. Nests that have fallen to the ground should also be counted, and then broken up to avoid counting them again in future years.

Multi-species colonies pose additional challenges, since nests will have to be identified by species when they are counted. In some colonies, nest identification is straightforward because each species' nests are readily segregated by height, size, and type of supporting vegetation. In a Great Blue Heron/Black-crowned Night-Heron colony, for example, the Great Blue Heron nests are located near the canopies of tall trees while the Night-Herons are found much lower in the understory, and nest identification is fairly easy. In many mixed colonies, however, it will not be possible to identify every nest to species. Nests of large herons can be distinguished from the smaller species, and nest placement and structure may distinguish some of the smaller species. But Little Blue Herons, Snowy Egrets, and Cattle Egrets build similar nests in similar locations, and positively identifying them will not be possible under most circumstances during the non-breeding season. For colonies where all nests cannot be positively identified during the non-breeding season, surveys must also be conducted during the breeding season to accurately establish the number of breeding pairs for each species.

Measuring Detectability The double-observer method described for the transects can be used for counts during the nonbreeding season.

***Perimeter Counts* –** Perimeter counts can be conducted by boat or by locating fixed points around the perimeter of a colony and conducting counts from these pre-determined stations. Several potential problems complicate the use of perimeter counts. Under most circumstances, some nests within a colony will not be visible during perimeter counts. The proportion of undetected nests will vary from colony to colony depending upon vegetation structure and density, nest location, and other factors, so that developing a correction factor to compensate for these undetected nests has to be done on a colony by colony basis. Normally, a complete nest count (using transects or aerial photographs when appropriate) is performed in addition to the perimeter count, and provides the basis for establishing the proportion of nests that are undetected from the perimeter. Another problem is that some nests may be counted from more than one location along the perimeter. In many instances, determining whether or not a nest has been previously counted is not possible, so that double-counting is a potential source of error in these estimates of population size. For these reasons, use of perimeter counts is recommended for colonies when accurate nest counts are possible only during the non-breeding season and the nests of some species cannot be distinguished during these surveys. Perimeter counts provide an index to the size of the breeding populations for each species that can then be combined with the nest counts to provide a more reasonable estimate of total population size. Perimeter counts are also recommended for small colonies (<50) nests of Great Blue Herons or other species that build conspicuous nests and return to the colonies before the nests are concealed by vegetation, especially in areas where access to the colony is difficult.

The number and location of survey points will vary from colony to colony depending upon vegetation structure and density, colony size and shape, types of species breeding in the colony, and possibly other factors. The points should be located at sufficient intervals around the colony to allow for counting the maximum number of nests while minimizing the risk of double-counting nests.

Initially, the survey locations should be established during the non-breeding season when nests are most visible. The points should be located from positions that allow birds to be counted without disturbing them from the colony. These points should also provide views of unique "landmarks" within a colony that can be used to establish which nests to count from each point. The number of nests visible from each point should be counted. The total number of nests visible from the perimeter can then be compared with a nest count from within the colony taken at the same time to determine the proportion of nests that are visible from outside of the colony. Enough points should be established to count at least 50 percent of the nests within the colony, and coverage of 75 percent or greater is preferable. The survey points should be marked and used during each survey, except when there are changes in colony size, nest location, and/or vegetation structure which may require periodic adjustments in the locations of the perimeter survey locations in order to count a comparable proportion of the breeding population of each species present in the colony.

Measuring Detectability

A double-observer approach can probably be used to determine detection probabilities from perimeter counts, although the specific method requires additional development. Basically, a "primary" observer would verbally count the nests for each species that are visible from each survey point. The “secondary” observer would independently conduct counts and record nests that were missed by the primary observer. For large colonies where there are many survey points, the observers can trade roles between points in order to obtain detection probabilities for each observer.

Flight-Line Counts **–** This method would be used only for colonies that cannot be surveyed from the ground, have a large proportion of the nests that are not visible from the perimeter, and the colony supports populations of dark-colored species that would be poorly sampled by aerial surveys. This method can also be used if disturbance to the colony by other methods is significant and must be avoided. Flight-line counts provide an index of population size at a colony, but tend to under-estimate the numbers of breeding adults at a colony. Many factors influence the relationship between this index and the actual number of breeding pairs that are present, including the stage of the nesting cycle, species-specific patterns in feeding rates, time of day, and tidal stage. The importance of these factors normally varies from colony to colony. Hence, standardization may allow for comparison of totals between years at a colony but does not permit comparisons among colonies.

Survey locations for flight-line counts are established at a position that allows for unobstructed views of birds flying between the colony and their foraging habitats. A single observer or multiple observers may conduct these counts if birds are returning to the colony from all directions. The flight directions are generally non-random, and if a single observer is conducting the count, the location should be selected to detect the greatest number of birds entering or leaving the colony. Multiple observers should establish points at sites that will not duplicate counts of individual birds. Reference points in two different directions should be identified from each survey point, and only birds crossing the line between the observer and these reference points should be counted. Individual birds flying to and from the colony should be counted separately. Counts are conducted for 3 hours, preferably during the incubation stage of nesting to reduce the variability associated with repeated visits to feed a brood of hungry young. If tidal feeding is important, then these counts should be made at low or ebbing tides. These counts should be conducted during the morning hours (0800-1200) in most areas.

Parameter The number of adults observed flying to/from the colony is used as an index to the overall population size.

Advantages This method provides an index to abundance at sites that cannot be sampled by other methods.

Disadvantages The relationship between the number of birds counted during these surveys and the total number present in the colony is unknown, and may vary from colony to colony. Timing of these surveys is critical for obtaining reasonable counts, and must be based on the local biology and patterns of movements for the species. All birds are assumed to be breeders, but the proportion of non-breeders in the population is unknown.

Measuring Detectability

A double observer approach can be used to determine detection probabilities. The “primary” observer would verbally identify and count all individuals as they fly to/from the colony. The “secondary” observer would try to find individuals/flocks that are missed by the “primary” observer, as well as check the identification and counts of birds reported by the primary observer. Since these counts are frequently taken over a several hour period, the observers should change roles half-way through the survey period in order to obtain detection probabilities for both observers.

Aerial Surveys

Purpose: To estimate population numbers and to determine population trends at ≤ 20% between years (Power = 90% at 0.1 level of significance). (For colonies with <100 nests). At larger colonies, the ability to detect population trends may vary from site to site depending upon the species composition, numbers of individuals present, and the visibility of the colony from the air.

Advantages: While ground surveys may provide the most accurate counts of nesting adults, these techniques may be uneconomical for large-scale monitoring programs, logistic constraints may prevent access to some colonies or restrict the number of colonies that may be surveyed during a single breeding season, and are somewhat disruptive of the breeding birds since they frequently require entering the colony. Since a number of colonies can be visited during a single flight, the cost-effectiveness of these surveys can be fairly high despite the relatively high cost of using aircraft. For these reasons, aircraft have been regularly used to survey colonial waterbird colonies.

Disadvantages: Some species are poorly detected by aerial surveys, especially dark-colored species and those that nest under the canopy or within the vegetation. Visibility of all individuals may be an issue in some habitats, primarily where the vegetation is relatively dense. Because of these visibility problems, ground counts must be periodically conducted concurrently with the aerial surveys in order to document the proportion of individuals that are missed from the air.

Parameter: Number of nesting pairs in a colony

Survey Design: The main problem with aerial surveys is unequal visibility of species from the air. White birds tend to be very visible since they are normally viewed against a dark background. Dark-colored birds are frequently significantly under-counted by these surveys. Vegetation density is another factor influencing the visibility of birds on aerial surveys, especially species that nest under the tree canopy.

For these reasons, aerial surveys provide biased estimates of population sizes for many species. To correct for the species that are under-counted by aerial surveys, they should be supplemented by counts conducted on the ground. These ground counts should be made very close to the date of the aerial surveys, and use an appropriate ground survey method described above. Totals obtained from the ground surveys can then be used to develop appropriate visibility correction factors for species that are under-sampled by the aerial surveys, so that appropriate adjustments can be made during years when only aerial surveys can be conducted at a colony.

Both fixed-wing aircraft and helicopters have been used for aerial surveys. Disturbance from both types of aircraft tend to be minor and of short duration. A study comparing the levels of disturbance associated with each type of aircraft indicated that helicopters caused the same or less disturbance than fixed-wing aircraft for most of the species (Kushlan 1979). Because of their slower speeds and better visibility from inside the aircraft, helicopters tend to provide more accurate counts for most species.

These surveys will normally consist of two passes over a colony, one at an altitude of 100-200 m above the colony and a second pass at 60-80 m altitude. At least ten minutes should separate the two passes. During both passes, the aircraft should circle the colony three to five times during a 2-3 minute period until a satisfactory count has been completed. A single pass may be sufficient under some circumstances, such as for nest counts during the non-breeding season.

Observer variability is one of the main sources of imprecision in aerial surveys. Estimating large concentrations of birds is always difficult and observers conducting aerial surveys should receive training in estimation before conducting the surveys. Detecting and identifying species from the air also requires some training prior to the surveys. Because of the issues associated with observer variability, the use of methods to determine detection probabilities for each observer is essential for all aerial surveys.

Aerial photographic surveys are not likely to produce precise estimate in most circumstances because of the problems with unequal visibility from the air. A possible exception would be for colonies composed of large white species (Great Egrets, Wood Storks) that have widely spaced nests in the tree canopy. Any attempt at an aerial photographic survey should be combined with ground counts to determine the precision of the aerial population estimates.

Measuring Detectibility - A double observer approach similar to those used in waterfowl surveys would provide estimates of detection probabilities for these surveys. Both observers will need training in the estimation of flock size, and should be tested to ensure that their abilities are comparable. One observer would be the “primary” observer, verbally identifying and counting all of the birds that they see. The "secondary" observer would note all birds that were missed by the "primary" observer. The observers can switch their roles between colonies, in order to obtain detection probability estimates for both observers.

Marbled Murrelet (From Marbled Murrelet Effectiveness Monitoring Plan for the Northwest Forest Plan)

Monitoring Marbled Murrelets at sea has been determined to be the best available technique available, at present, for estimating population status and trends. These birds are easiest to detect at sea and occur in the highest numbers within one mile of the shoreline. Surveys can be conducted by boat or air and there is opportunity to collect some demographic information, as juvenile plumages are discernable from adults. At sea counts allow estimates of total population size or density and estimates of productivity as measured by the ratio of juvenile birds to after hatch-year birds. Becker (1997) recommends focusing on detecting trends in densities rather than population size.

The Marbled Murrelet Effectiveness Monitoring Plan for the Northwest Forest Plan (1999) calls for standardizing marine survey protocol after completion of studies to resolve the key logistical and statistical problems facing marine surveyors. Until standardized protocol are developed, for specific at-sea survey techniques see the pelagic surveys section.

Ground Nesting Species

Laysan Albatross, Black-footed Albatross, Masked Booby, Blue-footed Booby, Brown Booby, American White Pelican, Brown Pelican, Double-crested Cormorant, Glossy Ibis, White-faced Ibis, Greater Flamingo, American Oystercatcher, Pomarine Jaeger, Parasitic Jaeger, Long-tailed Jaeger, Laughing Gull, Black-headed Gull, Heerman's Gull, Mew Gull, Ring-billed Gull, California Gull, Herring Gull, Western Gull, Glaucous Gull, Great Black-backed Gull, Sabine's Gull, Ross's Gull, Ivory Gull, Gull-billed Tern, Caspian Tern, Royal Tern, Elegant Tern, Sandwich Tern, Roseate Tern, Common Tern, Arctic Tern, Forster's Tern, Least Tern, Aleutian Tern, Bridled Tern, Sooty Tern, Kittlitz's Murrelet

Purpose:

To estimate population numbers and to determine population trends at ≤ 20% between years (Power = 90% at 0.1 level of significance).

Target Population: Number of occupied nests within the area of interest.

Ground-nesting Gulls, Terns

Selection of the survey technique should be based on colony accessibility and nest visibility. The preferred method is a direct nest (ground) count, which is possible only for accessible colonies where all nests can be readily observed. Where nests are located in dense vegetation and are difficult to locate, or in very large colonies where a total nest count is not feasible, a sampling procedure is recommended for the nest counts. Counts of adults or total individuals should be avoided unless no other options exist, since these counts include both breeding and non-breeding individuals. The proportion of non-breeders to breeders may vary hourly, daily, seasonally, and between years, so that comparisons of these counts is problematical under most circumstances. Additionally, counts of flying birds tend to be inaccurate and do not allow for the determination of detection probabilities.

Protocols for Gulls. Surveyors should count or develop an estimate of the number of occupied nest sites at each colony. Defining an occupied nest site varies from species to species, depending upon the complexity of the nest that is normally constructed. For some species, it may be necessary to distinguish between the more elaborate nests built by breeding adults from the less well-built structures constructed by non-breeding individuals. For all species, an occupied nest site should be more than a simple scrape, but should include a defined built-up edge. The presence of fecal matter may be helpful to distinguish between occupied nests and sites that were abandoned prior to incubation.

Nest counts should be conducted during the mid- to late incubation period for gulls. Most nesting pairs should be present at this time, except possibly some adults that failed early during the incubation period and did not attempt to re-nest. These counts should be made between 0900 and 1600 since colony attendance is most stable during these hours. Heavy rain, fog, and high winds should be avoided. Caution should also be exercised on very hot days, since lengthy exposure to direct sunlight and high temperatures may kill the developing embryos. Under these conditions, the adults should be kept off their eggs for only the minimum amount of time needed to count nests, ideally for 20 minutes or less, and the surveys should be conducted during the relatively cooler morning hours. This time period may be extended in large colonies if the disturbance is local and birds in adjacent areas remain on their nests. However, small newly established colonies tend to be very prone to desertion after disturbance and great caution should be exercised when surveying these colonies.

Protocols for Terns. For terns, an occupied nest site is usually defined as adults that are sitting tight and apparently incubating eggs or brooding chicks. Most colonies of breeding terns are very difficult to count with an acceptable degree of precision. In addition to the problems associated with counting large numbers of birds, the numbers of terns at colonies vary throughout the breeding season. Unsuccessful pairs may shift to another colony for a second nesting attempt, hence, numbers may decrease at unsuccessful colonies during the season and increase at sites where success rates are relatively high. In bad years, some colonies might be suddenly abandoned and large numbers of birds may not attempt to breed. A complete count of every pair that attempts to breed at a colony will not be possible under most circumstances, and the number of nesting pairs counted during a single survey will probably under-represent the total population for a breeding season.

Some species of terns have a fairly well defined peak of egg laying early in the breeding season, followed by one or more smaller peaks. Renesting attempts and young birds nesting for the first time account for the latter peaks. For these species, surveys should be conducted shortly after the main peak of laying so that the most synchronized group of breeding terns are counted.

Other species of terns may have a fairly prolonged laying peak, or may not have any clearly defined laying peak. For these species, the surveys should be conducted during the middle of the main egg laying period, noting the stage of the breeding phenology that exists on the survey date. Future surveys of these sites should be timed to coincide with a similar stage of the breeding phenology so that nest counts are comparable from year to year.

Complete Nest Counts. If good vantage points are available, all nests are readily visible, and the colony contains fewer than approximately 200 pairs, then complete nest counts can be made from the perimeter. One or more survey points should be established as needed to count all nests within the colony, but necessary caution should be used to avoid double counting of nests. If more than one survey point is needed, then clear landmarks should be used to define the nests that are counted from each point. The same survey points should be used in subsequent surveys, unless the colony location shifts or its visibility changes and new points are needed to obtain a complete count of nests.

If perimeter counts are not suitable for counting every nest, then a systematic ground survey should be conducted. These surveys are possible only at accessible sites. The entire colony is surveyed and each nest marked with spray paint or by some other means to avoid omission or double counts.

The decision to conduct systematic ground surveys or to use a sampling method will depend upon the colony size, accessibility of the colony site, ability to find nests within the vegetation, and the number of people available to conduct the survey without causing unacceptable levels of disturbance to the nesting birds. Under most circumstances, systematic surveys should be attempted for colonies with fewer than approximately 200-300 pairs. If accessibility is not an issue and sufficient personnel are available to conduct the surveys, then colonies of 500-1,000+ pairs can be surveyed by these methods.

Parameter: Total number of nests within the colony

Sampling colonies. For large colonies, generally those in excess of 1,000 pairs, and for colonies where the nests are hidden in vegetation and more difficult to locate, complete nest counts are not feasible without causing unacceptable levels of disturbance to the nesting birds. In these situations, a sampling methodology should be used to develop an estimate of the population size. The sampling procedures require developing nest density estimates in a portion of the colony, and using these densities to extrapolate to the total number of nesting pairs at the site.

In order to develop these estimates, the total area occupied by the colony must be established. For colonies of relatively conspicuous species in open habitats, aerial photographs may be adequate for establishing colony size. For less conspicuous species or where the nests are hidden by vegetation, the colony location will have to be mapped on the ground. This process should be repeated every time the colony is surveyed to develop more reasonable estimates of population change over time.

The number of sampling units (transects or quadrats) will depend upon the colony size, relative ease of locating nests, and the availability of personnel to conduct the survey. Ideally, 20% to 40% of the total colony area should be sampled to develop an estimate of population size, assuming that sufficient personnel are present to conduct the survey without causing unacceptable levels of disturbance to the nesting birds. A minimum of 10% coverage should be achieved under most circumstances, except for huge colonies (tens of thousands of nesting pairs over a large area) or sites where the nests are very difficult to locate and only a small number of units can be adequately sampled within the appropriate period of time. In these situations, only 5% coverage may be realistic.

For colonies that are rapidly increasing or decreasing in size, or that frequently move between years, permanent sampling locations are not practical; the selection of sampling locations will have to be made before each survey. Where colony sites are stable between years, permanent sampling locations can be used. Since between-year population changes are more likely to be reflected by changing densities at the periphery of the colony rather than at the preferred nesting sites within the center of the colony, stratifying sampling sites by their location within the colony may be important for more accurately detecting population changes.

The accuracy of the population estimates will reflect the proportion of the colony sampled by these methods. As the area sampled increases, these estimates will generally become more accurate. A consistent level of coverage between years is helpful to produce comparable estimates of population sizes over time. The need to achieve consistent levels of coverage, and the personnel needed to reach these levels, should be factored into the choice of an appropriate amount of coverage for each colony when they are initially surveyed.

Parameter: Total number of occupied nests per colony.

Transects. Transects are normally preferred in fairly open and uniform habitats where the nests are relatively visible. If the vegetation is relatively dense and nests are not easily found, the quadrat method would be preferred under most circumstances. If habitats are heterogeneous at a colony, then both methods may be employed.

Once a colony has been mapped, transects need to be defined in order to obtain a representative sample of the population. Transects should be placed at 5m intervals. If possible, they should be permanently marked at both ends of the line and possibly at regular intervals if they are extremely long. Marking the lines with colored string may facilitate following the transects through the colony. The subset of transects chosen for the survey should be randomly selected from all possible transects crossing the colony. As the colony size varies over the years, the number of transects that are sampled should be correspondingly adjusted to maintain a consistent level of coverage. The number of occupied nests sites within 1m on either side of each transect are counted and marked to avoid double counting. Once the area of the colony and transects are known, then the number of breeding pairs can be estimated.

Quadrats. Choice of quadrat size will reflect the nest density and vegetation density at the colony. The standard size is 10m x 10m, but a 20m x 20m may be employed where large species (e.g. Great Black-backed Gulls) are prevalent or the nests are widely spaced. Smaller quadrats may be used where nests are tightly packed or where the vegetation is fairly dense and the nests are located with some degree of difficulty.

Quadrat location should be selected at random, although stratification by sub-areas within the colony may be necessary to ensure that the sites are representative of the entire colony. These locations can be points placed at equal distances along randomly selected transect lines, or they can be sites randomly chosen within the colony to include both nests along the periphery and preferred sites in the center.

Measuring Detectability

For the complete nest count, transect, and quadrat methods, a double observer approach can be used to determine detection probabilities. For all methods, a single observer would conduct the survey method and mark the nests using a colored washer or some other inconspicuous object. Once this count was completed, a second observer would independently conduct the same survey and mark each nest with a different object. At the completion of the second survey, a third observer would record how many nests were found by both individuals and the number found by only one observer.

For the transect and quadrat methods, detection probabilities do not necessarily have to be calculated for each plot or transect. Instead, this method would be employed at only enough transects/plots to establish the detection probabilities for each observer involved in the survey.

Flush Counts. This method should be used only where colonies are inaccessible or where nest counts can be accomplished only with unacceptable levels of disturbance. Flush counts can be completed relatively quickly without entering the colony, but some inaccuracy is inevitable in counts of flying birds and determining the degree of error is difficult to establish in the field. Detection probabilities also cannot be determined for counts obtained with this method.

In this method, a flying bird constitutes the counting unit. A group of observers approach the colony and startle the adults by using a loud horn or some other noise for terns or by waiving their arms for gulls. The adults are counted while they are flying. Estimates of population size should be made within the first minute that all of the birds flush; as the birds fly around the colony for longer periods of time or as the adults return to their nests, the counts become less accurate. These counts should be conducted between the mid-incubation and early nestling stage of the breeding phenology to count the peak numbers of birds at a colony.

Flush counts are most appropriate for small colonies (fewer than 200 pairs) occupied by single species or where the multiple species can be easily identified by sight. In colonies hosting species that are difficult to distinguish in the field, such as Arctic and Common Terns, accurate estimates of population sizes for each species may not be possible. Given the inaccuracies associated with counts of flying birds, multiple observers should produce estimates for each species at a colony. These counts can be averaged to provide a reasonable estimate of total population size (Prater 1979). A minimum of five observers should conduct the flush counts, and each observer should receive training on the estimation of numbers of birds prior to the surveys.

Bullock and Gomersall (1981) developed a nest-attendance index to relate the true numbers of nesting pairs with the estimates derived from flush counts. Comparing counts of “apparently occupied nest sites” with flush counts from a small number of tern colonies in the Scottish islands every five days over the breeding season at 2-hourly intervals between 0800 and 2200 derived this index. At these colonies, they calculated that three flying birds were the equivalent of two breeding pairs. The applicability of this index to other locations and species is uncertain, and similar nest-attendance indices should be developed for colonies where flush counts are the only acceptable methods for population estimation.

Parameter: Total number of adults present in the colony. This number includes both breeders and an unknown proportion of nonbreeders. While counts of individual birds may be possible at small colonies, the precision of estimates at large colonies is uncertain. At large colonies, only major changes (probably >25%) in abundance will be evident from year to year.

Measuring Detectability

At very small colonies where individual birds can be counted, perhaps a double observer approach can be developed to produce estimates of detection probability. Field testing of a method is necessary, and given the difficulty of attempting to count any flock of birds milling around a colony site, even these detection probabilities should be viewed as approximate. At large colonies, determining detection probabilities is not possible for this method.

Cliff-nesting Gulls

These habitats tend to be inaccessible so that surveys are conducted from vantage points providing good visibility of the colony, either from land or boats. As a result of the physical structure of most cliffs, all nests will seldom be visible from the available series of vantage points. Exceptions are likely to be relatively small colonies, such as those found on small islands that can be circumnavigated by boats or occupy small cliffs. Complete nest counts are feasible only for those cliffs where every nest can be observed and have relatively small numbers of nesting pairs that can be accurately counted given the available resources and personnel.

Colonies at most cliffs will have to be surveyed by sampling representative portions of the nesting population.

The survey methods used for cliff-nesting gull colonies are the same as those described for nesting kittiwakes in the cliff-nesting species section (see page). Surveyors should count or develop an estimate of the number of occupied nest sites at each colony. Unlike breeding kittiwakes that construct well-defined nests, most gull nests are composed of a relatively loose association of materials with conspicuous amounts of whitewash. However, regularly used loafing sites are also characterized by considerable whitewash, and observers should be careful to distinguish between nests and loafing sites.

Parameter: Estimate the number of occupied nest sites at each colony.

Tree-nesting Gulls

Bonaparte's Gulls and occasionally Mew Gulls are the only North American gulls that nest in trees. Their breeding biology has been poorly described in the literature. Bonaparte's Gulls do not apparently nest in well-defined colonies and may be rather nomadic during the breeding season. Mew Gulls nest as solitary individuals and in colonies, with the colonies tending to be located on the ground. No methodology for monitoring tree-nesting gulls has been proposed to date. Until specific methods are developed, surveyors can use the same survey methods as are described for tree-nesting herons (see page).

Marsh-Nesting Species

Black-crowned Night Heron, Black Skimmer, Black Tern, Cattle Egret, California Gull, Common Tern, Double-crested Cormorant, Eared Grebe, Forster's Tern, Franklin's Gull, Gull-billed Tern, Glossy Ibis, Great Egret, Green Heron, Great Blue Heron, Herring Gull, Laughing Gull, Lesser Black-backed Gull, Little Blue Heron, Least Tern, Little Gull, Magnificent Frigatebird, Neotropic Cormorant, Ring-billed Gull, Roseate Spoonbill, Snowy Egret, Tricolored Heron, Western Grebe, White-faced Ibis, White Ibis

In general, methods for monitoring the populations of colonial-nesting birds in wetland habitats remain poorly developed. Access to the colonies in these habitats is frequently difficult, and many monitoring methods proposed for terrestrial habitats become inappropriate in wetlands. All methods used to monitor wetland-nesting species should respect the relative fragility of these habitats and the vegetation at the colony sites; disturbance to the vegetation should be avoided as much as possible to minimize the possibility of nest failure and/or colony abandonment in response to the monitoring activities. Disturbance to the nesting adults should be kept within the guidelines outlined previously. Since observer movement through the colonies generally requires greater periods of time in wetlands than in uplands, minimizing disturbance of the breeding pairs becomes a critical factor in the selection of potential monitoring methods for these species. These factors, combined with the difficulty of locating nests, contribute to the relative imprecision associated with the existing methods used to monitor colonial-nesting species in these habitats.

The following section summarizes the strengths and weaknesses of the methods that have been used to monitor populations of colonial-nesting birds in wetlands. In some cases, alternative methods are suggested, although these approaches certainly require testing and verification in the field before they should be applied across a large geographic area. Methodological development is a critical need before meaningful population monitoring programs can be initiated for most of these species, and must include creating approaches for determining the detection probabilities associated with these methods.

HERONS, IBIS

The species that are most frequently found nesting in wetland habitats are Great Egrets, Snowy Egrets, Black-crowned Night-Herons, and White-faced Ibis. These colonies most frequently occur in the western half of North America, especially on the Great Plains and Great Basin regions where suitable nesting trees are relatively scarce. Four survey methods have been used to develop estimates of breeding populations: direct nest counts, flight-line counts, helicopter surveys that serve as a "flush count", and surveys from fixed-wing aircraft.

Direct Nest Counts.

Purpose: Population Trend Estimation, with an ability to detect ≤ 20% changes in the numbers of birds within colonies, along transects, or visible from the perimeter (Power = 90% at 0.1 level of significance).

Parameter: All active nests within the colony.

This method consists of an observer or group of observers traversing a colony on foot or by boat to locate and count the nests of all breeding pairs. This method has generally been used in relatively small colonies (<100 nesting pairs) that do not require transects, especially where the colonies are located in discrete patches of vegetation and can be fairly easily located within the wetland. The habitats must allow for access by boat or on foot so that the nests can be counted without causing excessive disturbance to the adults and young.

The advantage of this method is that it counts the number of nesting pairs, providing estimates that are comparable to those obtained from the recommended methods for colonies located in upland habitats. The precision of this method is uncertain and may vary from wetland to wetland; hence, determining detection probabilities should be incorporated into these surveys.

Use of this method will likely be restricted to relatively small colonies, in order to keep disturbance of the nesting adults within acceptable levels and since establishing transects may not be possible in most wetland habitats. Whether this method is appropriate in all habitat types remains to be determined, especially in wetlands where the vegetation is dense and finding nests may become more difficult; determining detection probabilities by habitat type will likely indicate those wetlands that are most appropriate for the use of this method.

For larger colonies, one possible approach would be to conduct direct nest counts in quadrats and use the density estimates from these quadrats to develop estimates of total population size. Quadrat size requires additional investigation, and may vary depending upon the species present and vegetation characteristics. This approach might provide a reasonable alternative to flight-line counts or aerial surveys for species that may not be well sampled by those methods.

Measuring Detectability: Methods for determining detection probabilities still need to be developed and tested in the field. If transects are created, then methods employed in other transect surveys may also work in wetlands. If habitats are systematically searched for nests, then a double-observer method might work in areas with fairly discrete patches of habitats. The first observer could try to locate as many nests as possible in the colony, marking each nest with plastic flagging or some other marker. The second observer would independently locate nests, recording how many had been found by the previous observer and the number of nests found only by the second observer. These data could be used to estimate detection probabilities.

Flight-line Counts.

Purpose: Given the uncertain relationship between the flight-line counts and the total number of nesting pairs in a colony, the ability of this method to detect population trends is uncertain and may vary from colony to colony. Large changes should be evident, but changes in the range of 20% per year may not be detectable at most sites.

Parameter: The number of adults observed flying to/from the colony is used as an index to the overall population size. This parameter may include both breeding adults and nonbreeders, and the proportion of nonbreeders may vary between surveys.

This method has been described previously, and its appropriateness for marsh-nesting species requires additional study. As in colonies located in other habitats, the primary problem is the relationship between the numbers of individuals counted by this method with the actual number of pairs nesting in the colony. This method only provides an index of population size, so comparison with estimates of total population size become problematical.

At wetland colonies, flight-line counts have generally been conducted "shortly after sunrise" during the incubation period. Its appropriateness may vary from species to species depending upon the amount of synchrony in their nesting behavior. For example, large colonies of White-faced Ibis are composed of highly synchronized sub-colonies that are spatially discrete; one sub-colony may be incubating while another is feeding young in the nest so that the movement patterns of adults may vary from one sub-colony to another. Hence, timing of the count with respect to the breeding chronology each year becomes important if between-year comparisons of population size are needed.

Use of this method to monitor marsh-nesting species requires verification at colonies where population estimates have been determined by other methods. Determining the most appropriate time of day and period of the nesting chronology for each species is necessary for developing indices that are comparable between years.

Measuring Detectability:

A double observer approach can be used to determine detection probabilities. The “primary” observer would verbally identify and count all individuals as they fly to/from the colony. The “secondary” observer would try to find individuals/flocks that are missed by the “primary” observer, as well as check the identification and counts of birds reported by the primary observer. Since these counts are frequently taken over a several hour period, the observers should change roles half-way through the survey period in order to obtain detection probabilities for both observers.

Surveys by Fixed-Wing Aircraft.

Purpose: To estimate population numbers and to determine population trends at ≤ 20% between years (Power = 90% at 0.1 level of significance). This level of precision would apply only to light-colored species that are readily visible from the air, and probably for smaller colonies were counts of individual birds are possible.

Parameter: The total number of adult birds present in the colony and visible from the air, either counted from aerial photographs or by observers in the plane, How this number relates to the total number of nesting pairs is uncertain, because the counts may include both breeders and nonbreeders.

This method has been described previously and is most appropriate for nesting egrets and other light-colored species. It will likely underestimate numbers for dark-colored species. This method needs to be combined with ground counts in order to determine appropriate correction factors for individuals not visible from the air.

These surveys have generally involved estimating numbers of visible birds from the aircraft. Use of aerial photography warrants additional study. Aerial photographs would eliminate the observer-related biases associated with estimating large numbers of birds from the air. Ground counts would still be necessary for developing appropriate visibility correction factors, but this approach may improve the accuracy of estimates obtained from these aircraft.

Measuring Detectability: Methods used to estimate detection probabilities for other taxa from aerial surveys should be used for marsh-nesting birds.

Flush-Counts by Helicopter.

Purpose: The precision of this method tends to be poor, especially at large colonies where only very approximate estimates of total populations are possible. At large colonies, between-year differences of an order of magnitude should be detectable, but smaller changes may not be evident. At small colonies where individual birds can be readily counted, the precision will be better but may still be less than the standard goal for other survey methods.

Parameter: Total number of adults flushed by the helicopter from the colony. How this number relates to the total number of nesting pairs is uncertain, because the counts may include both breeders and nonbreeders. The proportion of birds that do not flush is also unknown, and could vary between surveys.

This method has been used for dark-colored species, especially White-faced Ibis that are poorly represented on surveys by fixed-wing aircraft. In this method, a helicopter is used to flush the birds from the colony and the numbers of individuals in flight are estimated. Large numbers of birds cannot be accurately counted in flight as they mill around the colony, so this method provides only a rough estimate of total population size; determining relatively minor year-to-year changes is not possible in many instances, especially for common species. Observer-related biases associated with these counts may be substantial, and comparing estimates between two different observers may not be possible.

Measuring Detectability:

For small colonies where individual birds can be readily counted, a double-observer approach might be developed to produce an estimate of detection probabilities. Since flushed birds may quickly re-settle on their nests or fly away from the colony, a double-observer method may be difficult to develop, For large colonies where total population size can only be estimated, no method for determining detection probabilities is possible. Because of the difficulty in obtaining precise counts of breeding population size and an inability to determine detection probabilities under most circumstances, this method should be used only when no other options are available.

GULLS

In North America, two species of gulls are obligate wetland nesters: Franklin's Gull that is widely distributed across the northern Great Plains and Little Gull which has a very small breeding population on this continent. Ross' Gull also nests at the edge of arctic wetlands, but is a peripheral breeder in North America. Other species may occasionally nest in wetlands, but these infrequent events do not warrant specific discussion here.

Franklin's Gull.

Purpose: The standard goal is to detect ≤ 20% changes in the numbers of birds present at monitoring plots (power = 90% at 0.1 level of significance).

Parameter: To develop estimates of the numbers of nesting pairs at each colony. Nest counts are needed to avoid counting nonbreeders.

Franklin's Gulls breed in large colonies at permanent wetland sites, always nesting over water on mats of vegetation, muskrat houses, floating debris, and similar structure. They prefer areas with low vegetation densities and where there are patches of open water of varying size. Their nests are generally 0.5-4.5 m apart, and their nesting behavior tends to be highly synchronous.

Since their colonies normally number in the hundreds or thousands of pairs, they are normally fairly easy to locate. Developing accurate estimates of numbers of nesting pairs can be difficult at the larger colonies, and no specific monitoring methods have been proposed. Aerial photography of the colonies during the early to mid-incubation period (generally during the last half of May or early June) might be the most promising method for monitoring this species. The adults nest in relatively sparsely vegetated habitats, and the adult birds should be visible from photographs taken at low altitudes during that time of the year. Concurrent ground counts taken at small colonies or portions of large colonies would be needed to develop a correction factor for birds that are not visible from the air.

Direct nest counts may be possible at smaller colonies (<100-200 pairs), although considerable care will be needed to accurately count the nests across a relatively featureless habitat. A quadrat method may also be possible at some larger colonies, although given the relatively broad spacing of the nests, these quadrats would have to be fairly large (at least 20 X 20m) in order to contain enough nests for developing a reasonable estimate of total population size. This approach may be feasible at locations that are consistently occupied by nesting colonies. But colony sites tend to change frequently in response to fluctuating water levels, hence, establishing quadrats may be difficult at most colonies.

Measuring Detectability:

Until methods are better defined to adequately survey the breeding population, developing methods for estimating detection probabilities is not possible. If aerial photography proves to be a useful survey method , then methods described previously for estimating detection probabilities for other taxa from aerial photos should also apply to Franklin's Gulls. For direct nest counts, a double-observer approach will have to be developed.

Little Gull. The known breeding population of Little Gulls in North America is very small, probably totaling no more than 100-200 pairs. Discovering their breeding locations on this continent is much more of a challenge than counting the numbers of breeding adults at a site, and will likely remain the greatest challenge for the foreseeable future. Little Gulls tend to nest in the more open and wetter portions of wetlands, frequently at the edges of dense stands of emergent vegetation, on floating dead vegetation, muskrat houses, floating debris, and one small rocky islets within marshes. They may occur in small segregated colonies or among other nesting gulls and terns. If Little Gulls are believed to be nesting at a wetland, they only approach is to systematically cover all suitable habitats in the marsh in order to find their nesting locations.

TERNS

In North America, two species of terns are obligate wetland nesters: Forster's Tern and Black Tern. These species tend to nest in small colonies, usually totaling fewer than 50 pairs. Both species regularly nest as isolated pairs or small groups of 5 or fewer pairs. Direct nest counts are the most appropriate method for estimating population size, but the most important challenge is actually finding all of the nesting locations that may be scattered within a large wetland. Their nest site preferences are described below, and these habitats at potential breeding sites should be systematically searched (normally by boat) in order to locate all nesting pairs. The defensive behavior of the adults is frequently a good indicator that an observer is near a nest site. These surveys should be conducted during the incubation stage of nesting, since some adults may abandon their breeding sites if their nesting attempts fail during incubation. The timing of the surveys should be consistent from year to year to produce comparable results. Counts of foraging adults should not be used as an index of breeding population size, since both species will forage at wetlands away from their nesting locations.

Forster's Tern. This species only nest in "large" marshes, preferring those is excess of 100 acres in extent with permanent open water. Forster's Terns regularly occupy freshwater and tidal wetlands. Their nests are usually located at the edge of large open pools, frequently on muskrat houses, mats of vegetation, and other sites that are well above normal water levels. They tend to be more social than Black Terns, and as many as five pairs may nest on a single muskrat house.

Black Tern. Black Terns prefer large freshwater wetlands where 25-75% of the surface is covered with vegetation and water depths are generally 0.5-1.5m. They frequently nest as isolated pairs, although clusters of fewer than 50 nests may be found within a relatively small area. The response of the adults to the presence of the observer is a good indication if more than one pair is present at a site. Their nests are usually located on floating mats of dead vegetation barely above water level, normally within 2m of a large expanse of open water. Some nests are hidden within small patches of emergent vegetation, while others are on floating mats that are completely exposed.

Other terns will occasionally nest in various wetland habitats, generally in small numbers that are monitored using direct nest counts. Common Terns may form fairly large colonies in some wetland habitats, and the methods previously discussed for that species will likely prove to be most appropriate for monitoring their colonies in wetlands.

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Appendix A

Survey methodologies conducted outside of the breeding season

PELAGIC SURVEYS

For some pelagic species, the population cannot be counted at the breeding colonies, or information on species needs outside of the breeding colonies is desired. For these birds, counts at sea can be conducted by air or boat. While open ocean surveys are beyond the scope of most cooperating land and water managers, in some cases, they are the only method available to allow managers to gain insight into seabird population status and trends. Additionally, managers are beginning to recognize the importance of changes in ocean habitats, whether caused by shifting ocean regimes, or commercial and/or recreational fisheries activities on marine and coastal ecosystems. In the past decade, it has become increasingly important to use pelagic surveys to track ocean habitat use by species whose populations appear to be declining, such as the Black-capped and Bermuda Petrels, but also for tracking concentrations of species, such as shearwaters.

There are a number of problems associated with detecting seabirds in the open water. Tasker et al. (1984) divided detection problems into five interrelated categories: size, color, behavior, weather, and observer ability. Each of these factors, by themselves or in some combination, can result in significant bias and variability in counts. For example, larger birds are easier to see than smaller birds at some set distance; a storm petrel, whose wing span is one-fifth that of sulid is much harder to detect. A dark colored bird such as a murre, in a dark sea or a kittiwake against a light sky, have less chance of detection than a light colored bird against a dark sea. The behavior of particular species can make them easier or more difficult to detect; procellariformes, who spend more time flying or moving through an observer's plane of view will be easier to detect than an auk, who spends portions of the time diving or stationary on the surface of the water. Additionally, flocking birds are easier to detect than species who are solitary most of the time.

It has been documented that the presence of the ocean vessel can influence species' behavior and bias its detectability (Bailey and Bourne 1972). Some species, such as Northern Fulmars, albatrosses, and Tufted Puffins, are attracted to ocean vessels while storm petrels and other species avoid ships. Weather may influence an observer's ability to detect birds; winds generating waves may obscure birds sitting on the water from the view of an observer. Sun, glare, and fog may limit may limit visibility. Weather may also affect bird behaviors; during calm conditions, birds may sit on the water instead of flying, decreasing their chances of detection. All of these factors, either singly, or in combination, lead to variability in counts and makes it difficult to interpret whether changes in numbers are the result of bias or true population change.

Perhaps one of the most important biases influencing counts of birds from ships is caused by birds flying through the total area surveyed. A count of all birds passing through a count zone within a count period will overestimate the total number of birds within that zone at any one moment by incorporating flux. Counting flux overestimates actual bird density. To account for this, coefficients of detection should be established for each observer per species. Correction factors derived from these coefficients of detection can be applied to the data.

Transect methods were developed to minimize many of the biases and variables discussed above. Transects reduce the area of sea examined at any one time so that a substantial proportion of the birds within the transect are detectable. However, most band-transect methods don't address the bias associated with flux, the movement of birds through a transect during a count period. Ideally, the observer should make an instantaneous count of all birds within the transect band. Tasker et al. (1984) has suggested that an instantaneous count is impossible to accomplish, especially at higher ship speeds. However, van Franeker (1996) reported on a snapshot method used for counting seabirds in the southern ocean. We recommend the snapshot method, below.

As with colony surveys, the pelagic survey design will depend on the objectives of the monitoring program; if quantitative results are desired, the program must attempt to control for unwanted systematic Standardization of methodologies must be adopted if data from different surveys are to be comparable.

Boat Surveys

Purpose – Population Indices for Detecting Trends, with an ability to detect ≤ 20 % change in the numbers of birds represented by open water transects.

Parameter – Continuous counts of all stationary birds (swimming, sitting on ice, or actively feeding) within the transect limits and (2) snap-shot counts of all flying birds within the transect limits.

Survey Design: Birds should be observed from an observation post aboard the vessel which give the greatest angle of clear view and permits the additional use of sound to detect less conspicuous birds. Ten minute blocks have been the standard count period over the past decade for many pelagic surveys. Count periods longer than this will make it difficult to record changing conditions with bird numbers. Birds within a 150 meter transect on one side of the ship should be counted in 10 minute blocks of time. Although many surveys have used a 300 meter transect, previous work has reported difficulties in detecting small, inconspicuous birds at distances of greater than 150 meters (Briggs et al. 1985; van Franeker 1994). A range finder can be used to determine this distance. Detection of birds should be done with an unaided eye; binoculars (10 x 40 suggested) should be used for species confirmation and for aging or looking at plumage. Counts should be made: (1) continuously of all stationary birds (swimming, sitting on ice, or actively feeding) within the transect limits and (2) in a snap-shot fashion for all flying birds within the transect limits. The speed of the ship determines the forward limit of the snapshot area within a range of 150 meters. Longer or shorter forward distances are avoided by adapting the frequency of the snapshot counts. Birds following and circling the ship should be omitted from both snapshot and continuous counts. If birds arrive and then follow the ship, they should be included in the count only if their first sighting falls within a normal snapshot or continuous count of the transect area.

Data recording

Ship Information: Information on the ship's position, course and speed, and the starting time of observation should be recorded. Also recorded should be the height of the "eye" above the water and viewing arc. Environmental factors must be recorded such as wind speed and direction, cloud cover, barometric pressure and tendency, precipitation type and intensity, visibility, sea state, swell height and direction, air temperature, and an assessment of the sun's effect on the observation areas, based on the strength of the sun and its direction relative to the direction of viewing. Observation notes should be repeated at least every 100 minutes, with major changes noted as they occur.

Species Information: For each bird observation record species, number of individuals present, activity, plumage and age of bird where possible, approximation of bird's flight direction, and notes on other distinguishing characteristics, such as whether a bird was oiled.

Target Population – number of birds on the sea in a continuous count and a snapshot of the birds flying within a defined band transect.

Analysis - Densities may be calculated as the sum of stationary plus snapshot birds per surface area.

Beached Bird Surveys (To be added)

Systematic Reconnaissance Flights (To be added)

Other Methodologies to be added….

Appendix B: Colonial breeding waterbird species of North America grouped by nesting substrate. Breeding status based on A.O.U.'s Checklist of North American Birds, 7th Edition. Only most common nesting substrates have been listed, with few species allotted more than one nesting substrate type. Nest substrate types: cl=cliff, bu= burrow, rc=rock crevice, gr=ground, fv=floating vegetation, lv=low vegetation, tr=tree, sh=shrub.

Burrow or Rock Crevice Nesters	Nest Code	Cliff Nesters	Nest Code	Ground, Floating Veg, or Low Veg Nesters	Nest Code	Tree or Shrub Nesters	Nest Code
Bermuda Petrel	bu	Northern Fulmar	cl	Eared Grebe	fv	Red-footed Booby	sh
Manx Shearwater	bu	Northern Gannet	cl	Western Grebe	fv	Brown Pelican	sh/tr
Black-vented Shearwater	bu	Brandt's Cormorant	cl	Clark's Grebe	fv	Neotropic Cormorant	tr
Audubon's Shearwater	rc	Double-crested Cormorant	cl	Laysan Albatross	gr	Double-crested Cormorant	tr
Fork-tailed Storm-Petrel	bu	Great Cormorant	cl	Black-footed Albatross	gr	Great Cormorant	tr
Leach's Storm-Petrel	bu	Red-faced Cormorant	cl	Masked Booby	gr	Anhinga	sh/tr
Ashy Storm-Petrel	bu	Pelagic Cormorant	cl	Blue-footed Booby	gr	Magnificent Frigatebird	sh
Black Storm-Petrel	bu	Herring Gull	cl	Brown Booby	gr	Rufescent Tiger-Heron	tr
Least Storm-Petrel	rc	Thayer's Gull	cl	American White Pelican	gr	Bare-throated Tiger-Heron	tr
White-tailed Tropicbird	rc	Iceland Gull	cl	Brown Pelican	gr	Great Blue Heron	tr
Red-billed Tropicbird	rc	Glaucous-winged Gull	cl	Double-crested Cormorant	gr	Cocoi Heron	tr
Red-tailed Tropicbird	rc	Black-legged Kittiwake	cl	Pinnated Bittern	lv	Great Egret	tr
Dovekie	rc	Red-legged Kittiwake	cl	American Bittern	lv	Snowy Egret	tr
Xantus's Murrelet	rc	Common Murre	cl	Least Bittern	lv	Little Blue Heron	tr
Craveri's Murrelet	rc	Thick-billed Murre	cl	Glossy Ibis	gr	Tricolored Heron	tr
Ancient Murrelet	bu	Razorbill	cl	White-faced Ibis	gr	Reddish Egret	tr
Cassin's Auklet	bu			Greater Flamingo	gr	Cattle Egret	tr
Parakeet Auklet	rc			Common Eider	gr	Green Heron	tr
Least Auklet	rc			Snail Kite	lv	Striated Heron	tr
Whiskered Auklet	rc			American Oystercatcher	gr	Agami Heron	tr
Crested Auklet	rc			Pomarine Jaeger	gr	Capped Heron	tr
Rhinoceros Auklet	bu			Parasitic Jaeger	gr	Black-crowned Night-Heron	tr
Atlantic Puffin	bu			Long-tailed Jaeger	gr	Yellow-crowned Night-Heron	tr
Horned Puffin	bu			Laughing Gull	gr	Boat-billed Heron	tr
Tufted Puffin	bu			Franklin's Gull	fv	White Ibis	tr
Black Guillemot	rc			Little Gull	fv	Glossy Ibis	sh
Pigeon Guillemot	rc			Black-headed Gull	gr	White-faced Ibis	sh
				Bonaparte's Gull	gr	Green Ibis	tr
				Heermann's Gull	gr	Roseate Spoonbill	sh/tr

Burrow or Rock Crevice Nesters	Nest Code	Cliff Nesters	Nest Code	Ground, Floating Veg, or Low Veg Nesters	Nest Code	Tree or Shrub Nesters	Nest Code
				Mew Gull	gr	Jabiru	tr
				Ring-billed Gull	gr	American Wood Stork	tr
				California Gull	gr	Snail Kite	sh/tr
				Herring Gull	gr	Bonaparte's Gull	tr
				Western Gull	gr	Mew Gull	tr
				Glaucous Gull	gr	Brown Noddy	sh
				Great Black-Backed Gull	gr	Marbled Murrelet	tr
				Sabine's Gull	Gr		
				Ross's Gull	Gr		
				Ivory Gull	gr		
				Gull-billed Tern	gr		
				Caspian Tern	gr		
				Royal Tern	gr		
				Elegant Tern	gr		
				Sandwich Tern	gr		
				Roseate Tern	gr		
				Common Tern	gr		
				Arctic Tern	Gr		
				Forster's Tern	Gr		
				Least Tern	Gr		
				Aleutian Tern	Gr		
				Bridled Tern	Gr		
				Sooty Tern	Gr		
				Black Tern	Fv		
				Black Skimmer	Gr		
				Kittlitz's Murrelet	Gr		

APPENDIX C. COLONIAL WATERBIRD FIELD FORM

GENERAL INSTRUCTIONS: Thank you for your contribution to the North American colonial waterbird database. Please fill in as many fields as possible. This data form is set up to aid in standardization of survey information and will be used as a platform for data entry into the centralized colonial waterbird database housed at USGS Patuxent Wildlife Research Center. Electronic access for data entry and retrieval is at: URL>>>>>

COLONY VISIT INFORMATION

Date Started (mm/dd/yy): ____________________ Date Completed (mm/dd/yy): ____________________

Time started (military): ______________________ Length of visit ____ . ____ hours

Observers:

Observer Name	Organization	Phone Number	Email Address

COLONY LOCATION INFORMATION

Colony name:

Colony ID numbers and Source:

Latitude: Longitude: ☐ Decimal Degrees ☐ Degrees/Min/Sec

UTM Coordinates: E N

Method (GPS, Topo Map, etc): Datum: ☐ WGS84 ☐ NAD27 ☐ NAD83 ☐ Other

Nearest Town: ______________________ County: ______________________ State/Province/Territory: _______________

Nearest Water: ______________________

COLONY HABITAT INFORMATION

Landmass Type:
- ☐ Barrier island
- ☐ Non-barrier island
- ☐ Mainland
- ☐ Unknown
- ☐ Other________________

Nest Habitat:
- ☐ Beach
- ☐ Marsh
- ☐ Cliff/crevice
- ☐ Raft
- ☐ Jetty/pier/dock/breakwater
- ☐ Rooftop
- ☐ Unknown
- ☐ Other_______________

Salinity:
- ☐ Brackish
- ☐ Fresh
- ☐ Salt
- ☐ Upland
- ☐ Unknown
- ☐ Other:________

Waterbody Type:
- ☐ Bay
- ☐ Coastal Water
- ☐ Estuary
- ☐ Impoundment
- ☐ Lake
- ☐ Pond
- ☐ River
- ☐ Unknown
- ☐ Other:__________

Nesting Substrate:
- ☐ Trees
- ☐ Shrub (2-7m)
- ☐ Shrub (2m or less)
- ☐ Herbacious (non-grass)
- ☐ Grass
- ☐ Sand
- ☐ Cobble/shell
- ☐ Rock crevices/
- ☐ Rock face
- ☐ Dirt

SURVEY DESIGN INFORMATION (Please fill in any of the following fields that are applicable to your survey):

Dispersion Measure:
- ☐ Standard Error
- ☐ Standard deviation
- ☐ 95% confidence limits
- ☐ 90% confidence limits
- ☐ Unknown/Other:

Calculation Method:
- ☐ Normal, Simple Random Sampling
- ☐ Ratio Estimator
- ☐ Weighted Estimator
- ☐ Multiple-stage Sampling

Dispersion Value:
- ☐ Exact binomial confidence limits
- ☐ Normal approximation for binomial
- ☐ Exact binomial standard deviation
- ☐ Unknown/Other:

Sampling Replication:
- ☐ Single Count/Estimate ☐ Multiple within-season count/estimate
- ☐ Unknown/Unassigned/Other:

Estimate Type:
- ☐ Exact Count ☐ Index Plots
- ☐ Adjusted Count ☐ Unknown
- ☐ Estimate ☐ Other:

COLONIAL WATERBIRD SURVEY

Using the codes from the provided chart, please identify the survey type, parameter, and unit descriptor for each species count that you report below:

Species	Census Tech.	Survey Type	Parameter	Units	Survey Value	Comment

Census Technique:				
	(A) Aerial Plane	**(C)** Land - within colony	**(E)** Aerial photograph	**(G)** Flightline
	(B) Boat	**(D)** Land - distant from colony	**(F)** Aerial helicopter	**(H)** Unknown/Other

(CODE) SURVEY TYPE	(CODE) PARAMETER	(CODE) UNITS
(A) Population	**(1)** Total Population	**(a)** Total number of birds
		(b) Unknown
	(2) Breeding Population	**(a)** Number of adults
		(b) Number of burrows
		(c) Number of burrows with at least indirect evidence of occupancy
		(d) Number of burrows with >= 1 adult
		(e) Number of burrows with >= 1 egg, chick, and/or adult
		(f) Number of nesting pairs
		(g) Number of active nests
		(h) Number of total nests
	(3) Population Index	**(a)** Number of adults
		(b) Number of burrows
		(c) Number of burrows with at least indirect evidence of occupancy
		(d) Number of burrows with >= 1 adult
		(e) Number of burrows with >= 1 egg, chick, and/or adult
		(f) Number of nesting pairs
		(g) Number of active nests
		(h) Number of total nests
(B) Productivity	**(4)** Total number of chicks	chicks (no code required)
	(5) Total number of eggs	eggs (no code required)
	(6) Total number of fledged young	fledged young (no code required)
	(7) Total number of nesting pairs	nesting pairs (no code required)
	(8) Total number of nests	nests (no code required)
	(9) Total number of nests with 1 or more chicks	nests (no code required)
	(10) Total number of nests with 1 or more eggs	nests (no code required)
	(11) Total number of nests with fledged young	nests (no code required)
	(12) Other	please describe in comments field
(C) Reproductive Chronology	**(13)** Arrival on colony	date (no code required)
	(14) First egg observed	date (no code required)
	(15) First laying date	date (no code required)
	(16) Mean laying date	date (no code required)
	(17) Median laying date	date (no code required)
	(18) Peak laying date	date (no code required)
	(19) First hatching date	date (no code required)
	(20) Mean hatching date	date (no code required)
	(21) Median hatching date	date (no code required)
	(22) Last hatching date	date (no code required)
	(23) First fledging date	date (no code required)
	(24) Median fledging date	date (no code required)
	(25) Last fledging date	date (no code required)
	(26) Departure of last fledge	date (no code required)
	(27) Departure of last adults	date (no code required)
	(28) Other	please describe in comments field

Appendix D

Definitions:

The following are definitions used throughout this document:

POPULATION – a measure of the total population. For the purposes of this manual, population is defined as the total number of birds within the entire area of interest.
POPULATION INDEX – an index of the total population useful for establishing population trends.
SURVEY – a general term for any type of inventory and monitoring procedure.
INVENTORY – a term applied to methods determining presence, relative abundance, and/or distribution of species.
MONITORING – a term applied to methods determining population trends or measuring health of populations over space and time.
ACCURACY – a measure of the nearness of the data you collect to the actual value of the variable being measured.
PRECISION – is a measure of the variability within your data or the closeness to each other of repeated measurements of the same quantity. Variability results from many factors, including observer differences, collecting data during different nesting stages, collecting data during different times of day, changes in weather conditions from year to year or site to site, etc…
BIAS – A systematic error associated with the methodology which results in consistently over or under-counting the variable of interest, in our case, number of breeding pairs or number of nests. For example, one might end up including nonbreeders in a count of nesting pairs, including non-targeted pair members, or end up missing targeted pairs; all would lead to consistently over- or under-counting.
PARAMETER – Describes or characterizes a population.
DETECTABILITY – a measure of the ability of an observer to detect the individuals within a sample. Detectability will vary by observer and by site or sample.

Appendix E

Survey Form for Pacific Seabird Database (TO BE ADDED)

Appendix F CWB Censusing Methods/Errors Literature Matrix

	Citation Number, Taxa, Location	**Error**	**Method Notes**
Ground Nest Count	2. hrgg, lbbg, United Kingdom	Avg. % nests missed: 16.9±3.3(SE) Range: 5.0-27.3% 2758 and 3651, original and actual, respectively	9 plots Initial count (mark nests), then 2nd count
	3. gulls, Massachusetts	Range 4-22% error Estimate: Lincoln's Index (mark/recapt) $X_t/N_m = N_t/N_{m1}$ X_t=total # nests, N_m=# nests marked in 1st search, N_t=total nests found in 2nd search, N_{m1}=total nests of 2nd search that are marked	8 plots; 0.06-0.73 ha plots Initial count (mark nests), then 2nd count
	9. hrgg, New England	5% error	duplicate ground count
	18. gtbh, South Carolina	Only ground counts produced consistent results under variety of conditions. Post-nest ground counts, aerial est. and all transect tech. had acceptable level of precision (+ or – 20% for large colonies (>320 nests).	Compared ground counts to aerial count/estimate, point count, perimeter count, 20% 2m transect, 40% 4 m transect, 20% 4m transect, and post-nesting ground count; completed other techniques w/in 12 days of ground count.
	20. statistical models	Best method is total ground count. If completeness of count cannot be assumed, map objects from both ground and air.	Danger in applying correction factors determined for one study under specific conditions to another study.
	8. greg, sneg, trhe, bche, Gulf Coast	Time intensive—only useful for small colonies that observer can see whole nesting group at once	Estimated number of lete adults flushed from colonies as walked along beach
	22,gulls, cormorants, skuas, gbbg, kittiwakes,	"5% margin of error between direct counts and replicates	errors attributed to overlooking nests and poor counting
	22., hrgg, gbbg, dcco, ME	"5% for gulls, and dcco	aerial estimates and aerial photos by 2 obs. from altitude of 150m. At completion of aerial census, ground crew approaced by boat and completed independent estimates (4-6 crew) by circling colony. Then grnd count completed systematic search marking searched areas.
	24., Razorbill and Guillemot, Handa Is., Sutherland	Census counts should be made during nestling stage; 46% error for Razorbill, 26% for Guillemot (difference from mean)	warden "visited the cliffs daily for 18-20 days during April-July

Ground Estimate	22., hrgg, gbbg, dcco, ME	"71 % for gulls, and 82% dcco	aerial estimates and aerial photos by 2 obs. from altitude of 150m. At completion of aerial census, ground crew approaced by boat and completed independent estimates (4-6 crew) by circling colony. Then grnd count completed systematic search marking searched areas.
	27.,common murres, thick-billed murres, AK	wind speed and direction effected daily counts; large plots (>300 birds appear to be disadvantageous (higher variability);	
	25., thick-billed murre, N.W.T.	differences due to observers is small; observations beyond 2 hrs give little more benefit; accuracy of estimates is higher with high hatching success; 3 hrs obs. for plot of 80 prs gives "5%	Five study plots; at 2 plots, daily obs. fixed and same observers; at one plot recorded independently and compared results at second plot
Post-Nesting Ground Count	18. gtbh, South Carolina	Accuracy was low in this study but Gibbs et. al. (1988) found close correspondence with midseason ground counts	Compared ground counts to aerial count/estimate, point count, perimeter count, 20% 2m transect, 40% 4 m transect, 20% 4m transect, and post-nesting ground count; completed other techniques w/in 12 days of ground count.
Aerial Count Helicopter	4. wading birds, Everglades NP, Florida	10-16% error for white or dark birds in tree canopy (greg, sneg, whib, anhi, dcco) -inaccurate for small dark birds nesting under the tree canopy (trhe, lbhe) -disturbance to nesting birds # fixed wing surveys	2 colonies (n nests=150 and 1363) 3 tests (2nd colony surveyed 2 times)
	5. mainly wading birds, Atl. Coast	helicopter surveys more efficient than ground; also more accurate than fixed-wing aircraft	mainly synopsis of existing literature
	9. hrgg, New England	19 – 31% error	
	23., blsk, cote, LI, NY	"5% error from one-time census for blsk; 0.92 multiplicative conversion factor for cote gives error of "-12 to +18%	
Aerial Count / Estimates Fixed-Wing Aircraft	4. wading birds, Everglades NP, Florida	32-100% error for white or dark birds in tree canopy (greg, sneg, whib, anhi, dcco) -inaccurate for small dark birds nesting under the tree canopy (trhe, lbhe)	2 colonies (n nests=150 and 1363) 3 tests (2nd colony surveyed 2 times)

	8. wading birds (greg, sneg, trhe, bcnh), N. Gulf of Mexico	greg-4times > than actual, 15times<actual sneg-error: -8.7±92.0 (SD) trhe-error:79.1±25.1 (SD) bcnh-error:-84.4±14.7 (SD)	greg-33colonies, avg col size=511 nests sneg-6colonies, avg col size=1992 nests trhe-8colonies, avg col size=3192 nests bcnh-7colonies, avg col size=573nests
	14. wading birds, FL ('white birds' =greg, whib, sneg, caeg; 'dark birds' = lbhe, trhe, gtbh, bcnh, glib)	Aerial estimates for white wading birds were about 80±18% and 73.5±13.7% of totals (derived from combined aerial and ground counts) for nests and colonies, respectively. Aerial estimates for dark birds were about 17.0±21.8% and 15.0±14.3% of totals for nests and colonies, respectively. The error for these estimates were attributed to inability to detect colonies, as well as underestimation of nests at known colonies.	East-west transects spaced 2.6 km apart were flown, 244m (alt), 185 kph; adult counts converted to nest counts based on nesting chronology (preincubation: 2 adults = 1 nest, incubation: 1 adult = 1 nest). Ground counts conducted by airboat, and on foot if necessary.
	18. gtbh, South Carolina	-1% error, SD=66; 95% CI for predicting colony size indicated that all tech, were imprecise for colonies <320 nests.	Compared ground counts to aerial count/estimate, point count, perimeter count, 20% 2m transect, 40% 4 m transect, 20% 4m transect, and post-nesting ground count; completed other techniques w/in 12 days of ground ct.
	15. wost, FL	Range of proportional differences was –73.3-206.1%; 150 nests gave a 95% fiducial interval of 59-634 nests for corresponding ground count; aerial surveys underest. # wost in colonies with high proportion of other white birds; canopy cover no effect on aerial	< 50 nests, all nests accessible for ground count, ground cts were 25 m transects, marked nests—aerial in 2 phases, earlier in south FL.
	18. wading birds	25% error with SD = 56;moderately accurate; require a 58% change in nesting to detect difference between annual nest estimate	Compared ground counts to aerial count/estimate, point count, perimeter count, 20% 2m transect, 40% 4 m transect, 20% 4m transect, and post-nesting ground count; completed other techniques w/in 12 days of ground ct
	8. greg, sneg, trhe, bcnh	trhe and bcnh grossly underestimated (79% and 84% avg error, respectively); greg and sneg 4-8% visual error est.; estimated only 10% of trhe from air (missed 90%); concluded that the wide variation in percent error of visual estimates precluded generation of correction factors.	Used small fixed-wing at 200m altitude and 160 km/hr; averaged the estimates of two observers

	19. gtbh, Maine coast	Aerial estimates averaged 87% of ground counts; mean difference betw. grnd counts and aerial est. was 13.2 nests (±25.07 SD).	Four independent observers from fixed-wing aircraft on Jun 20, 1983.
	20. cliff-nesting Osprey, Midriff Islands	Used Peterson Estimator. The proportional SE between ground count and aerial counts was 4% (high precision); 51 nests from air, 63 from ground (population estimate using Peterson Estimator N=78.24); Estimated aerial visibility rate of 65%.	Both observers in the plane take independent estimates. Peterson Estimator could never be used for moving objects but may work for nests. If both observers have same vantage point, will have negative bias on estimate of population.
	22.,blsk	"5% under ideal conditions; "19 percent under some conditions, "67% with human error	
	22., gulls	"50% when compared to aerial photos	
	22., hrgg, gbbg, dcco, ME	" 140% (gulls), "56% (dcco)	aerial estimates and aerial photos by 2 obs. from altitude of 150m. At completion of aerial census, ground crew approaced by boat and completed independent estimates (4-6 crew) by circling colony. Then grnd count completed systematic search marking searched areas
	21., waterfowl decoys, Mississippi Alluvial Valley	Reducing transect width lessed the effect of changes in use of habitat. Transect width of 100m had a predicted ratio of visibility rate between 0.87 and 1.16; visibility rate was highest for intermediate densities (0.4 or 0.76 decoys/ha).	Used decoys to measure visibility under different conditions.
	26., hrgg, gbbg, Kent Island NB, Canada to LI, NY	On average, estimated 0.8 of the counted gulls (comparing visual estimate to grnd count); consistently underestimated (up to 50%)	Conducted aerial estimates, aerial photos and ground counts of gulls.
Aerial Photography	1. pelicans, ND	1368:1355 aer.photo:actual 1%	
	8. greg, rote, sate, blsk, Gulf Coast	For greg, aerial photography was most reliable est. in fresh water marsh and brackish marsh;	
	9. hrgg, New England	26 – 35% error	
	10. waterfowl from photos	-effects of observer experience had no sig. effect on accuracy of estimates; inexperienced obs. underestimated more consistently than experienced -with training, 8 of 9 observers were within 10% of actual number.	9 observers, 10 photographs, each of 5 consecutive days 3 levels of observer experience: inexperienced, past experience, recent experience. Reinforced counts in one scenario and did not in a second.

	11,12. Murres, seabirds, Canada	correction factors for accessible island-top nesters: count birds on photo, and/or field count adults, then flush adults and count eggs in a defined area. (can take up to 6 weeks for 1 observer to complete)	
	13. gannets, Canada	<20% error	600m, b&w 7X10 or 9X13" photos
	18. gtbh, South Carolina	Neither precise nor accurate and will not reliably detect fluctuations in popln size	Compared ground counts to aerial count/estimate, point count, perimeter count, 20% 2m transect, 40% 4 m transect, 20% 4m transect, and post-nesting ground count; completed other techniques w/in 12 days of ground count.
	19. gtbh, Maine Coast	Mean difference between ground counts and aerial photo counts was 16.7 nests (±22.27 SD)	Aerial photos taken of colony sites with hand-held 35 mm camera using color transparency film.
	22., gannetts, cormorants, gulls, blk legged kittiwakes, sate, rote, murres, Adelie penguins, coei	"20% error-ring-billed gulls (23,000); "26-35% error for hrrg and gbbg; -2-30% below ground estimates for kittiwakes and guillemots	less direct disturbance to colonies,
	22., hrgg, gbbg, dcco, ME	"33% (gulls) " 12% (dcco)	aerial estimates and aerial photos by 2 obs. from altitude of 150m. At completion of aerial census, ground crew approaced by boat and completed independent estimates (4-6 crew) by circling colony. Then grnd count completed systematic search marking searched areas
	26., hrgg, gbbg, Kent Island NB, Canada to LI, NY	" 10% and " 15% for two years;conclude that counts of gulls on aerial photos plus grnd counts of gulls is reliable method for monit. population.	Conducted aerial estimates, aerial photos and ground counts of gulls.
Belt Transects	8. herons, Gulf Coast, USA	95% confidence limits: n=16,880, CI=2,672 (16% of n.e.), mangrove n=14,938, CI=3,090 (21%), mangr. n=14,279, CI=1,809 (13%), mangr. n=12,666, CI=1,337 (11%), mangr. n=3,240, CI=810 (25%), willow	10% of total area sampled
	8. LAGU, FOTE, Gulf Coast	95% confidence limits: LAGU n=17,326, CI=2326 (13% of n.e.) FOTE CI within 25% of nest estimate	10% of total area sampled vegetation: *Spartina*
	3. gulls and herons, RI, MA	3-142% error (5 samples were under 11%; one each at 26% and 54% error)	6 gull colonies, 3 heron colonies 10-20% of plot sampled

	18. gtbh, South Carolina	40% transect technique was most accurate and precise of methods tested (95% CI indicated single year fluctuation of 22 % to detect real change in nesting numbers (13% error) BUT was time consuming; 20% transect (2m) for colonies > 550 nests was similar to 40% transect.	Transects were laid out perpendicular to the long axis of the colony with transects (2m or 4 m) chosen at random within each section. Nests recorded within 1 m of transect line (2 m) or within 4 meters (4m).
Point-Centered Quarter	3. gulls and herons, RI, MA	3-400% error performs poorly when nest distribution is clumped	6 gull colonies, 3 heron colonies 8-15 points sampled
Flight Line Count	6. caeg, trhe, sneg, lbhe; FL, (VA,NC)	-high error rates at the colony level (200%) -regional, population predictions were within 10% error -high hour to hour variability (#40%, trhe)	13 colonies -# birds entering/leaving the colony in a 3-hr time pd., observed by 2-3 people surrounding the colony -nest counts performed by total counts or belt transects (12-20% samples)
	20. statistical model	Future research should look at combining Peterson Model with Flight Line transects.	The detection function is defined as the probability of sighting an animal located at a perpendicular distance from a line transect flown. Assumes all animals present on line are seen and prob. of sighting an animal decreases with distance from the line.
At-Sea line Transect Surveys	28., Marbled Murrelets	Density estimates from line transects sig. greater than estimates from strip transects of 100 and 200m and had higher stat. power to detect tends; 83% sighted on 400, 14% on 900m and 85-100% detected on 400 m on 7 of 9 days; suggest shift from estimating popln for large geog. area to changes in popl density within limited areas;	

"Net Movement"	7. leau, crau, whau, Alaska	-more accurate estimate than Bedard's (1969) method of counting adults on surface in the a.m.; although it was more time - intensive, and results could be difficult to interpret depending on nesting stage of colony
		-most activity (depart/arrive) occurred f/ . 1000-1400 and 2200-2330 during the chick feeding stage (slight variation for other stages)
		-suggested that this method be used during the incubation stage (1 adult=1nest); this method may be particularly tricky to use the colony as a whole transitions from incubating to chick-feeding
			5 randomly sel., 10x10-m plots
			4 daylight counts: pre-laying, early incuabation, late incubation, chick-feeding
			
			# of each spp present on rock surface (every 15 minutes)
			# of birds arriving/departing (15-min periods, every 30 min)
			
			Net Movement= (B-E) + (A-D)
			A= # birds arriving during ct pd.
			B= # birds present at beg. of ct.
			D= # birds departing during ct.
			E= # birds present at end of ct.

Boat Count	16. brpe, FL, used age classes for popln trend analys.	No comparison but concluded could count adults and number of nests at peak and then once/month from June-Sept. count % age of adults in population	Weekly boat surveys between 1000 and 1500 of all mangrove islands from Jan '71-July '76; birds classified as adult, subad, and imm based on plumage
Perimeter Counts	18. gtbh, South Carolina	Concluded that point and perimeter counts were imprecise with 76% and 40% error, respectively.	Compared ground counts to aerial count/estimate, point count, perimeter count, 20% 2m transect, 40% 4 m transect, 20% 4m transect, and post-nesting ground count; completed other techniques w/in 12 days of ground count.
Point Counts	18. gtbh, South Carolina	Concluded that point and perimeter counts were imprecise with 76% and 40% error, respectively.	Compared ground counts to aerial count/estimate, point count, perimeter count, 20% 2m transect, 40% 4 m transect, 20% 4m transect, and post-nesting ground count; completed other techniques w/in 12 days of ground count.
Radio Telemetry	17. trhe, FL	Concluded visual estimate by transects through colonies underestimates nestling survival.	Attached radio transmitters to young and color-banded young.

Literature Citations included in CWB Censusing Methods / Errors Matrix

id	Authors	Year	Journal	Vol.	Title
1	Sidle, J.G. and E.L. Ferguson	1982	Prairie Naturalist	14:13-26	White pelicans populations at Chase Lake, North Dakota, evaluated by aerial photography
2	Ferns, P.N. and G.P. Mudge	1981	Bird Study	28:244-246	Accuracy of nest counts at a mixed colony of herring and lesser black-backed gulls
3	Erwin, R.M.	1980	Trans. Linnaean Soc. New York	9:77-86	Censusing waterbird colonies: Some sampling experiments
4	Kushlan, J.A.	1979	J. Wildl. Manage.	43:756-760	Effects of helicopter censuses on wading bird colonies
5	Erwin, R.M.	1980	Atlantic Naturalist	33:19-22	Censusing colonial waterbirds: Problems and progress
6	Erwin, R.M.	1981	Colonial Waterbirds	4:91-95	Censusing waterbird colonies: An update on "flight line" count method
7	Byrd, G.V., R.H. Day, and E.P. Knudtson	1983	Condor	85:274-280	Patterns of colony attendence and censusing of auklets at Buldir Island, Alaska
8	Portnoy, J.W.	1980	Trans. Linnaean Soc. New York	9:127-134	Censusing methods for gulf coast waterbirds
9	Kadlec, J.A. and W.H. Drury	1968	Ecology	49:644-676	Structure of the New England herring gull population
10	Erwin, R.M.	1982	J. Field Ornithol.	53:159-167.1	Observer variablility in estimating numbers: An experiment
11	Nettleship, D.N.	1980	Can. Wildl. Serv.	Occ. Pap. 43	Census methods for murres, *Uria* species: A unified approach
12	Nettleship, D.N.	1976	Can. Wildl. Serv.	Occ. Pap. 25	Census techniques for seabirds of arctic and eastern Canada
13	Nettleship, D.N.	1975	Can. Field Naturalist	89:125-133	A recent decline of gannets, *Morus bassanus*, on Bonaventure Island, Quebec
14	Frederick, P.C, T. Towles, R.J. Sawicki, and G.T. Bancroft	1996	Condor	98:837-841	Comparison of aerial and ground techniques for discovery and census of wading bird (Ciconiiformes) nesting colonies
15	Rodgers, J.A., S.B. Linda, and S. A Nesbitt	1995	J. Wildl. Manage.	59(4):656-666	Comparing aerial estimates with ground counts of nests in wood stork colonies
16	Schreiber, R.W. and E.A. Schreiber	1983	J. Wildl. Manage.	47(1):105-111	Use of age-classes in monitoring population stability of brown pelicans
17	Frederick, P.C., M.G. Spalding, and G.V.N. Powell	1993	J. Wildl. Manage.	57(1):34-41	Evaluating methods to measure nestling survival in tricolored herons
18	Dodd, M.G., and T.M. Murphy	1995	J. Wildl. Manage.	59(4):667-673	Accuracy and precison of techniques for counting great blue heron nests

19	Gibbs, J.P., S. Woodward, M.L. Hunter, and A.E. Hutchinson	1988	J. Field Ornithol	59(2):130-134	Comparison of techinques for censusing great blue heron nests
20	Pollock, K.H., and W.L. Kendall	1987	J. Wildl. Manage.	51(2):502-509	Visibility bias in aerial surveys: A review of estimation procedures
21	Smith, D.R., K.J. Reinecke, M.J. Conroy, M.W. Brown, and J.R. Nassar	1995	J. Wildl. Manage.	59(3):515-527	Factors affecting visibility rate of waterfowl surveys in the Mississippi Alluvial Valley
22	Hutchinson, Alan E.	1979	Proc. Colonial Waterbird Group	Vol 3:235-244	Estimating numbers of colonial nesting seabirds: A comparison of techniques
23	Buckley, P.A. M.Gochfeld, and F.G. Buckley				Efficacy and timing of helicopter censuses of black skimmers and common terns on Long Island, NY: A preliminary analysis
24	Lloyd, Clare	1975	Brit. Birds	68:507-513	Timing and freqency of census counts of cliff-nesting auks
25	Gaston, A.J., D.G. Noble, and M.A. Purdy	1983	J. Field Ornithology	54(3):275-282	Monitoring breeding biology parameters for Murres *Uria* spp.:Levels of accuracy and sources of bias
26	Kadlec, J.A., and W.H. Drury	1968	J.Wildlife Manage.	32(2):287-293	Aerial estimation of the size of gull breeding colonies
27	Hatch, S.A., and M.A. Hatch	1989	J. Wildlife Manage.	53(2):483-493	Attendance patterns of Murres at breeding sites: implications for monitoring
28	Becker, B.H., S.R. Beissinger, and H.R. Carter	1997	The Condor	99:743-755	At-sea density monitoring of marbled murrelet in central california: methodological considerations.

Literature not in matrix

Buckley, and F.G. Buckley	1979	Proc. Colonial Waterbird Group	Vol 3:1-15	What constitutes a waterbird colony? Reflections from the Northeastern U.S.
Boyd, W.S., and J.R. Jehl Jr.	1998	Col. Waterbirds	21(2):236-241	Estimating the abundance of eared grebes on mono lake, California, by aerial photography
Jones, Ian L.	1992	The Condor	94:93-100	Colony attendance of least auklets at St. Paul Island, AK: Implications for population monitoring
Hatch, S.A., and M.A. Hatch	1988	The Condor	90:613-620	Colony attendance and population monitoring of black-legged kittiwakes on the Semidi Islands, Alaska

Piatt, J.F., B.D. Roberts, and S.A. Hatch	1990	The Condor	92:97-106	Colony attendance and population monitoring of least and crested auklets on St. Lawrence Island, Alaska
Rothery, P., S. Wanless, and M.P. Harris	1988	J. of Animal Ecology	57:1-19	Analysis of counts from monitoring guillemots in Britain and Ireland
Caugley, G., and J. Goddard	1972	J. Wildl. Manage.	36(1):135-140	Improving the estimates from innacurate censuses
Routledge, R.D.	1981	J. Wildl. Manage.	45(4):997-1000	The unreliability of population estimates from repeated, incomplete aerial surveys
Magnusson, W.E., and G.J. Caughley	1978	J. Wildl. Manage.	42(1):174-176	A Double-survey estimate of population size from incomplete ground counts
Samuel, M.D. and K.H. Pollock	1981	J. Wildl. Manage.	45(4):993-997	Correction of visibility bias in aerial surveys where animals occur in groups