U.S. Tropical Pacific Seabird Surveying Guide
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Cover photos by E. VanderWerf: Clockwise from top left - Black-footed Albatross, Hawaiian Petrel, White Tern, and Red-tailed Tropicbird.

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List of abbreviations used in the text:

BCC - Bird of Conservation Concern
CNMI - Commonwealth of the Northern Mariana Islands
MIC - Mean Incubation Count
NWHI - Northwestern Hawaiian Islands
PRC - Pacific Rim Conservation
PSP - Pacific Seabird Program
US - United States of America
USFWS - U.S. Fish and Wildlife Service
USTP - U.S. Tropical Pacific

EXECUTIVE SUMMARY

The islands in the U.S. Tropical Pacific (USTP) contain some of the largest tropical seabird colonies in the world and are of global importance to multiple seabird species, some of which are only found within this region. Tens of millions of individual birds representing more than 31 species breed in this region, and many more forage in its waters. Some of these seabird populations have been monitored for many years, but in some cases the methods used have varied over time or among sites, and for some species little is known about their population size, trends, or distribution. These information gaps have been caused by difficulty in accessing the remote locations where some species nest, lack of practical and effective monitoring methods, and lack of consistent methods or training, or ability to obtain such information.

Results of long-term monitoring efforts have shown that seabirds can be used as indicators of local and large-scale change in the marine environment. Seabird populations are known to be dramatically impacted by human activities including fisheries, oil extraction and transportation, wind energy projects, persistent organic pollutants, commercial harvest, introductions of invasive species, disturbance, and the presences of non-native predators. Scientific information about current distribution and abundance of seabird species is needed for a variety of reasons ranging from resource and public-use management to assessing the impacts of threats and effectiveness of conservation actions. During a time of global decline for approximately 70% of seabird populations as well as shifting ranges, comprehensive and consistent assessments of the abundance and distribution of seabirds in the USTP is needed, particularly for species that are rarely surveyed.

The purpose of this guide is to provide guidance for those who are planning or already implementing seabird monitoring in the USTP. Specifically, this guide discusses a variety of methods that are useful for monitoring different attributes of seabird biology and is intended to help the reader choose a method that is best suited to survey objectives, available resources, and capacity. This guide also discusses aspects of tropical seabird natural history and their breeding sites that can complicate monitoring, and how to account for these factors to improve performance.

The main attributes of interest for surveying identified in a recent poll of seabird biologists throughout the USTP were the following: 1) population size and trend; 2) distribution; 3) effects of threats and management; and 4) breeding biology (e.g., nesting success, recruitment). As a result, the survey methods presented in this guide are grouped by the attribute(s) that they address. It assumes that readers do not have previous seabird monitoring experience so techniques are applicable for beginners and experts. It also describes scenarios where monitoring can only be conducted during limited time periods (rapid assessments) as well as situations where long term, regular access is possible. It recognizes the varying needs and backgrounds of those conducting surveys for seabirds in the USTP and presents methods grouped according to attributes of interest and also by species or guild.

Lastly, the guide presents a species monitoring prioritization process in response to the results of a companion monitoring gap analysis for the USTP. The prioritization considered the degree of species and geographic knowledge gaps, threat level to each species, and the stewardship responsibility of the USTP (proportion of population nesting within the USTP) so that scientists are able to make informed decisions considering priority species.

INTRODUCTION

The U.S. Tropical Pacific (USTP) includes islands and waters of the State of Hawaii and various other territories, possessions, and other islands that have an association with the United States (Figure 1). The USTP includes five geographic subregions: 1) the Main Hawaiian Islands, encompassing the larger islands from Hawaii Island west to Niihau; 2) the Northwestern Hawaiian Islands (NWHI) from Nihoa west to Kure Atoll; 3) the Mariana Islands, including Guam and the Commonwealth of the Northern Mariana Islands (CNMI); 4) American Samoa, including Rose Atoll and Swains Island; and 5) the Pacific Remote Islands Marine National Monument, which includes Palmyra Atoll, Kingman Reef, Wake Atoll, Johnston Atoll, Jarvis, Howland, and Baker.

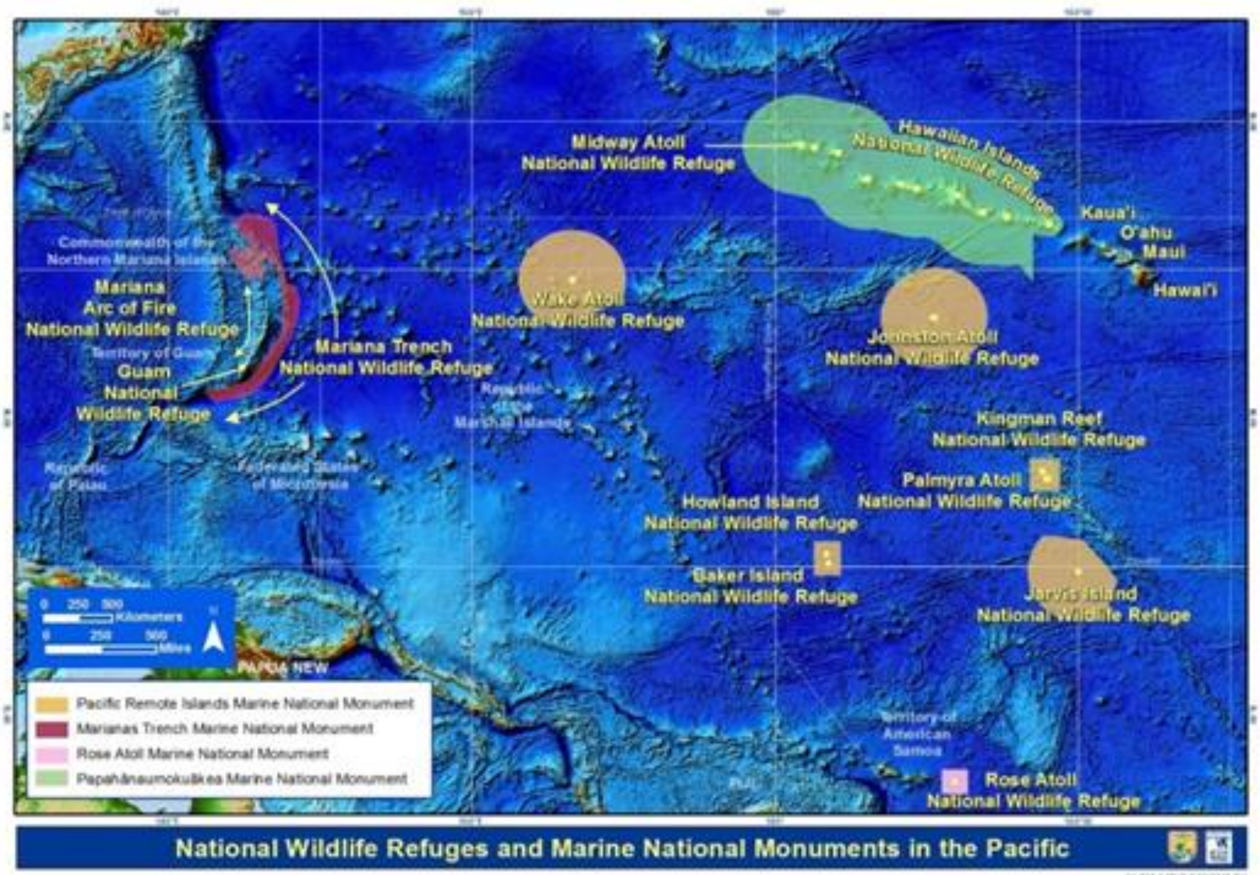

Figure 1. Geographic extent of the U.S. Tropical Pacific.

The islands within the USTP contain some of the largest tropical seabird colonies in the world and are of global importance to multiple seabird species, some of which occur only in this region (Harrison 1990, USFWS 2005). Tens of millions of individual seabirds representing more than 31 species breed in this region, and many more forage in its waters (Fefer et al. 1983, USFWS 2005). Monitoring these species is important not only to assess their status and conservation needs, but also to help assess the status of the marine environment as a whole. Results of long-term monitoring efforts have shown that seabirds can serve as indicators of local and large-scale changes in marine ecosystems because variation in their demography often is correlated with abundance and distribution of their prey (Montevecchi 1993, Karpouzi et al.

2007, Piatt et al. 2007). Thus, information about variation in survival, reproduction, and other demographic attributes of seabirds can be used to evaluate the spatial and temporal changes in prey composition and abundance (Dearborn et al. 2001, Cury et al. 2011). Seabird species with broad geographic distributions can be especially valuable as environmental indicators because patterns of spatial variation in their demography may reflect broad oceanographic and climatic patterns (Schreiber 2001, Kappes et al. 2010, Oro et al. 2010, Cubaynes et al. 2011, Weimerskirch et al. 2012).

The majority of seabirds in the USTP nest on small islands that are protected as federal, state, or territorial wildlife refuges, or in remote montane areas on larger islands. Many of these species spend the majority of their time at sea and only return to land to breed (Harrison 1990). As a result, breeding colony surveys often provide the most accurate and efficient method of assessing and monitoring population size and trend (Citta et al. 2007), though population estimates based on at-sea surveys have provided important data in some cases (Spear et al. 1995, Clarke et al. 2003, Spear and Ainley 2007). During a time of global seabird decline and shifting ranges, it is imperative to conduct consistent, comprehensive assessments of the abundance and distribution of seabirds in the USTP.

Data gathered over the last several decades indicate that the numbers of seabirds attending many breeding colonies are declining, with some species reduced to scattered relict populations (Paleczny et al. 2015). Systematic, standardized inventories of colonies and long-term monitoring are essential to determine breeding population sizes and trends as well as to identify the need for and effectiveness of conservation programs. Seabird populations can be dramatically impacted by human activities including fisheries, oil extraction and transportation, persistent organic pollutants, commercial harvest, introductions of invasive species, disturbance, and anthropogenic increases in predator populations (USFWS 2005, Wiley et al. 2013). Scientific information about current distribution and abundance of seabird species is needed for a variety of reasons ranging from resource and public-use management to assessing the impacts of sea level rise, informing fisheries stock assessments, location and efficacy of marine protected areas, appropriate siting for new offshore energy infrastructure, and geographic planning for preventing and responding to oil spills or seabird-fisheries interactions. Unfortunately, planning and implementation of many seabird conservation measures sometimes are hindered by limited or outdated data or data that is not managed, analyzed, or reported in a timely manner.

In order to better understand seabird surveys and monitoring programssurveys in the USTP, identify gaps in geographic and species information, and provide guidance to help facilitate future monitoring, Pacific Rim Conservation (PRC) and the USFWS conducted a gap analysis (VanderWerf and Young 2017). This gap analysis revealed that survey protocols for some seabird species in the USTP have not been standardized among sites or have been changed over time, making spatial and temporal comparisons for status and trends of populations and quantification of long-term demographic parameters problematic. Survey methods may need to be updated to ensure common protocols across the USTP. Inventories of some species in the USTP are either incomplete or outdated (>30 years old). Application of new technologies (e.g., acoustic surveys, remote cameras, radar) may reduce expense, increase efficiency, reduce on-island impacts, and enhance the sustainability of seabird surveys at remote sites.

The purpose of this document is to provide guidance to managers, biologists, researchers, and citizen scientists who are interested in seabird survey methods that are intended specifically for use with species and sites in the USTP. In conjunction with the gap report (VanderWerf and Young 2017), this guide is intended to be informative rather than prescriptive and to provide a platform for working collaboratively on priority seabird monitoring projects in the USTP. Similar guidance is available for seabirds in the Caribbean (Haynes-Sutton et al. 2014). This guide is designed to help the user choose a survey method that is best suited to his/her objectives, available resources, and capacity. It assumes that some seabird survey practitioners will have little or no previous seabird monitoring experience and thus provides techniques suitable for both beginners and experts. This guide also describes situations where monitoring can be conducted only during limited time periods (rapid assessments) and also in scenarios where long term, regular access is possible. This guide also describes several aspects of seabird biology that can complicate monitoring (e.g., delayed maturation, variation in breeding frequency, and variation in breeding seasonality) and how to account for these issues in monitoring. Although providing detailed methods about some of the more complex techniques (e.g., mark-recapture analyses, distance-based estimates of abundance) is beyond the scope of this guide, references are provided about where to obtain more information on these topics.

ESTABLISHING A MONITORING PROGRAM

Defining goals and objectives

Establishing clearly defined management goals and survey objectives is essential to designing an effective monitoring program. Goals (or management objectives) are general statements that articulate a specific desired condition of the resource that the program is designed to monitor, such as a stable or increasing breeding population size. Monitoring (or sampling) objectives identify the specific attribute(s) to be measured and often a desired level of confidence in the data, such as 80% power to detect a 30% decline in the population over a 15-year period. Meeting a sampling objective means it is possible to reliably evaluate progress toward achieving a management objective.

For a particular site, some basic questions could be the following:

- Which species of seabirds are present at the site?
- How many breeding pairs or individuals of each species are present?
- How are their numbers changing over time?
- What factors (natural or human-induced) are linked to these changes?
- What conservation measures are needed?
- If management has been done, was it effective at achieving the desired species response?

These questions may subsequently lead to more refined ones such as the following:

- Is there seasonal or annual variation in the abundance of each species?
- Are any changes in abundance over time related to changes in the environment at the site, external factors such as climate change, or other factors?
- How accurately can a population be counted?
- Which demographic parameters (adult survival, breeding success, dispersal, etc.) are most important in driving population numbers?
- Is the local community aware of the site or species and are they engaged in its conservation?
- Is the population genetically distinct?

Priority survey needs in the USTP

As part of the monitoring gap analysis (VanderWerf and Young 2017), managers were asked to describe the main objectives of their monitoring programs. The objectives varied among respondents, and all programs had multiple objectives. The most common objective was to monitor population size and trend of species present at the site, which was an objective of every program. The second and third most common objectives, for 96% of programs, were to monitor species distribution and measure effects of threats and/or response to management actions. The fourth most common objective (93%) was to monitor population and breeding biology. The least common objective was scientific research, though research was still an objective for two-thirds of the programs. Throughout the remainder of this guide, the survey methods are categorized according to which type(s) of questions they seek to address:

1. Population size and trend
2. Distribution
3. Breeding biology
4. Effects of threats and response to management activities

Designing a monitoring program

Investing time in careful planning of a monitoring program will reduce the potential for errors and increase the chance of achieving the goals. Starting with modest survey objectives and building upon them once you have demonstrated the ability to achieve them is advisable (Bibby 2000). Even if a comprehensive monitoring program is ultimately desired, it can be useful to define interim monitoring objectives that can be used as milestones in reaching a final goal.

In designing a monitoring program and sustaining it over the long-term, one must consider the amount of time and effort required during each of the steps in the “life cycle” of an individual survey and the larger program that it informs, which may include: identifying one or more management objectives and preparing sampling objectives, obtaining funding and any permissions and permits; deciding which species to monitor; choosing monitoring methods and designing protocols and data entry forms; assembling equipment and supplies; hiring or training staff or volunteers; traveling to the site and conducting the surveys (including reconnaissance visits if needed); entering, archiving, and analyzing data; preparing reports and publications, and communicating the results to decision-makers, managers, funders, and the local community. Often the preliminary and follow-up activities take more time than the surveys themselves. Think about whether or not you can make surveys more sustainable in the long-term by integrating them with other on-going surveys, seeking ways to minimize costs, seeking partnerships or enlisting volunteers to assist with the work, and training participants to prepare funding proposals to help support future work. Consider ways of minimizing your impacts and disturbance to wildlife and sensitive habitats during your monitoring activities.

Survey resources needed. Resources needed for many types of surveys include the following:

- Personnel: Trained people who are capable of doing all phases of the monitoring, including the surveys, data entry, data analysis, interpretation, and reporting.
- Transportation: Vehicles and boats and the funds and staff to operate or hire them.
- Field equipment: binoculars, spotting scopes, tripods, rangefinders, GPS units, playback systems, cameras, measuring tapes, field guides, notebooks, etc.
- Field clothes: Suitable footwear, hats, pants, raincoats, etc. to keep staff safe during field work.

- General field supplies: data forms, maps, notebooks, pencils, storage bags for samples, string for circular plots, flagging tape and markers or metal tags, etc.
- Sleeping and eating equipment: tents, tarps, sleeping bags and pads, stoves, coolers and ice, pots and pans, utensils, etc.
- Communications equipment: cell phones, radios, satellite phones, emergency contact information and plan.

Training, accuracy, and precision. Training personnel to ensure they are fully competent in all aspects of the monitoring protocols is an important part of the planning process. Training can help to reveal weaknesses in observer abilities before the actual surveys begin, increase the accuracy and precision of results, and enable observers to work more quickly and efficiently. Personnel may need training in several areas, including: identifying bird species by sight and sound; counting or estimating numbers of birds; measuring and laying out study plots; filling in data forms (paper or electronic); and learning the protocol. Accuracy is how close a measurement is to the actual number. Precision is a statistical measure of the amount of variation among samples, i.e., how repeatable it is. For example, an observer can be very precise (get the same number of birds each time they count) even when they are not accurate (their count is not close to the actual number of birds). Accuracy can be increased by avoiding bias in sampling design (random location of plots, use of quality base maps, consistent timing of surveys, well-trained observers, automated techniques for measuring or counting, etc.). Precision is usually enhanced by increasing the number of samples and using the best available methodology. Sampling bias is one of the biggest problems undermining survey quality and utility. Ways to reduce bias include the following: ensuring that all areas or habitats in a site are sampled; and standardizing surveys according to observers, time of day, weather conditions, moon phase (for nocturnal species), area covered, and the amount of time spent surveying, and when possible, calibrating observers.

Another issue related to accuracy is detection probability. In any survey, it can be difficult for an observer to count every bird (or nest) present. This is particularly true for species that nest in underground burrows or rock crevices and for species that may not be present throughout the day. If some birds are inadvertently missed, then the survey results will be negatively biased and inaccurate. Therefore, it is desirable to estimate the likelihood that all birds or nests have been observed, which is called the detection probability. This value can then be used to adjust the counts to produce a more accurate estimate of the actual number of birds in a given area. There are several ways to do this, including comparing the numbers counted by two independent observers at the same time (double observer), repeating the counts over a short time period (repeated counts), or dividing the count into time intervals and noting how many new individuals are seen in the intervals (removal counts). Each of these techniques has advantages and limitations, and different techniques may be more suitable in certain circumstances. For most seabird colony surveys, the most practical approach for measuring detectability is repeated counts. Thomas et al. (2010) also provide information about how to estimate and account for detection probability during surveys designed to measure abundance.

BIOLOGICAL AND SITE CONSIDERATIONS

Tropical seabirds are different from temperate seabirds in several important ways, and specific aspects of their life histories need to be considered when designing a monitoring program. There are several distinct foraging guilds of tropical seabirds that have similar life history characteristics, and which often can be monitored using similar methods. Understanding the breeding biology and the general foraging guilds of seabird species will allow better selection of monitoring methods. The following section presents information about relevant aspects of tropical seabird life histories and information about colony sites in the USTP that can be useful in designing a monitoring program.

Biology of USTP seabirds

Foraging guilds. Seabird species in the USTP are generally recognized as belonging to one of the following five foraging guilds based on their mode of prey capture and target prey species (Harrison et al. 1983):

(1) Albatrosses that forage by sitting on the water surface and seizing prey;
(2) Pelecaniformes (boobies, frigatebirds, and tropicbirds) that forage by plunge diving for fishes and squid, or by stealing food from other species (frigatebirds);
(3) "Tuna birds" that forage in flocks above ocean predators (e.g., tunas, dolphins, whales). The tuna birds include two taxonomically distinct groups: 1) Wedge-tailed, Christmas, and Newell's Shearwaters, and 2) Sooty Terns, White Terns, and Brown and Black Noddies.
(4) Petrels that forage primarily on organisms that surface at night (e.g., squid and lantern fishes). These include Bonin, Hawaiian and Bulwer's Petrels and Band-rumped and White-throated Storm-Petrels.
(5) Neuston-feeding terns that forage upon small organisms near the water surface, including Gray-backed Terns and Blue-gray Noddies. Storm-petrels also can be placed in this group.

Although there is some overlap among these foraging strategies (i.e., some species can employ multiple foraging methods), guilds are a useful tool for describing the diversity of seabird foraging strategies (Harrison et al. 1983, Harrison 1990). Foraging guilds also can be useful when designing a monitoring program that employs indicator species. Dearborn et al. (2001) showed that reproductive success among species in a guild usually is similar and determined by the same external factors, because in many species of birds, food availability directly affects reproductive output and guild members, by definition, tend to forage on similar prey. Exceptions to this are tuna birds, where both terns and shearwaters are members of the same guild, but exhibit very different breeding phenology and synchronicity.

Life span. The vast majority of seabirds are long-lived and it is assumed that even the smallest of species in the USTP can live for at least 20 years. For example, even diminutive White Terns are known to live at least 36 years (Niethammer and Patrick 1998), and larger species like Laysan Albatrosses and Great Frigatebirds, can live and reproduce for at least 66 years (Juola et al. 2006, USFWS 2018). Many aspects of seabird life history are shaped by their long lifespans. Factors that increase adult mortality therefore tend to have greater negative effects on population size and growth than factors that decrease reproduction or survival of juveniles (Wilcox and Donlan 2007, Finkelstein et al. 2008, Zydelas et al. 2009, Bakker et al. 2017). Many seabird populations can withstand several seasons of poor reproduction without experiencing a long-term population decline. This is not to suggest that chick mortality is unimportant, but rather that adult mortality typically affects population size more quickly and more severely. The importance of adult survival is another reason why many surveys focus on estimates of breeding adults rather than counts of all individuals.

Breeding phenology and synchrony. Timing and synchrony of the breeding season are important life history traits to consider in selecting monitoring methods. Species in which most or all individuals consistently breed during the same season generally are easier to monitor. For such species, nearly all breeding attempts often can be counted during a single visit and the timing of the visit can be reliably planned. In contrast, the situation is more complicated for species that breed year round (e.g., White Terns), have an extended breeding seasons (e.g., Red-tailed Tropicbirds), or nest irregularly in response to environmental conditions (e.g., Sooty Terns). A single monitoring visit will not yield a complete count of the number of breeding pairs in an asynchronous species because only a fraction of the population may be nesting at any given time. In such cases, multiple visits are required to adequately monitor the number of breeding attempts. Information about the breeding season and synchrony are available for all species in the literature, but timing may vary among locations, so information from the target population should be used when planning such surveys.

In general, Procellariforms (albatrosses, shearwaters, and petrels) tend to be fairly synchronous in breeding each year; with most eggs are laid within a 2-4 week period, and their phenology does not vary much among years in response to oceanographic conditions (Warham 1990, Surman et al. 2012, VanderWerf and Young 2016). The annual timing of monitoring for these species therefore can remain consistent from year to year. If the goal is to monitor the number of nesting pairs and it is possible to make only one visit to a colony, the visit should be timed to coincide with the end of the egg laying period, when the highest number of nests with eggs will be present. During surveys, it is useful to note nests that appear to have been abandoned or depredated recently, and to include those nests in the total count if appropriate. If the goal is to monitor the number of young produced and only a single visit can be made, the visit should occur at the end of the chick-rearing period, before fledging begins. If a measure of hatching rate is desired, then periodic checks during incubation will be needed, or at a minimum, another visit just after hatching. This approach was used to monitor the number of Wedge-tailed Shearwater raised at Kaena Point, Oahu (VanderWerf et al. 2014).

Species with asynchronous breeding include tropicbirds, boobies, noddies, and terns. Nesting phenology of these species can vary among years depending on environmental conditions (Surman et al. 2012, Catry et al. 2013). Before setting dates for a long-term monitoring program for species, reconnaissance surveys should be conducted at regular intervals for at least a year to determine the nesting phenology, peak and range of laying dates, and the timing of each stage of reproductive cycle (arrival, egg laying, hatching, and fledging). The phenology of a species can differ among sites, even if they are nearby, so phenological data should be collected from the target colony if possible. For example, Red-tailed Tropicbirds on Oahu begin nesting in January in some years, which is about a month earlier than those on Kauai (VanderWerf and Young 2014). Mean incubation counts are a good method for monitoring numbers of asynchronous nesters, in which repeated counts of all nests with eggs are made at intervals equal to the incubation period of the species, so nests counted on each visit are different (see below for more details). To measure nest success in asynchronous species, it may be necessary to mark individual nests and monitor them on repeated visits, or, if the location of plots is permanently marked, to count the number of active nests at different stages on repeated visits using a plot-based design.

Many seabird colonies in the USTP support more than one species of seabird. If the nesting phenologies of those species are similar, then it may be possible to monitor all the species present during the same visits. If their phenologies differ, then it will be necessary to make separate visits to monitor all of the target species. The number and timing of surveys needed also depends on goals of the monitoring and available resources; if at least some portions of the breeding season of different species overlap, then it may be possible to monitor different stages of the breeding cycle for different species on the same visits. In some of the largest seabird colonies that consist of multiple species, there is at least one species of seabird breeding during any given month throughout the year.

Breeding frequency. Measuring the size of seabird breeding populations can be complicated by breeding frequency, or the number of breeding attempts per year or season made by each pair. Some species, like albatrosses, petrels, and shearwaters, lay one egg per breeding attempt and will not re-lay in the same season if their nest fails. In contrast, terns, tropicbirds, and boobies may attempt to re-nest following failure, depending on when in the breeding cycle failure occurs. Some species may re-nest even if their first nesting attempt is successful. For example, 25% of White Terns pairs on Oahu raised two chicks per year and a few pairs even raised three chicks per year (VanderWerf and Downs 2018). Black Noddies are also known to nest more than once per year (Gauger 2000). If re-nesting occurs but is not considered, estimates of breeding population size based on numbers of nests will be inflated. If a species is known to re-nest, then nest counts can be corrected in order to obtain a more accurate estimate of the true breeding population size. For example, if 100 breeding attempts were observed in a colony, but it is known from monitoring of individual nest sites or banded birds that 10 of these were re-nesting attempts by the same pairs, then the actual number of breeding pairs was 90. Information about breeding frequency is available in the literature for most species, but the frequency of re-nesting may vary among locations and years, so it is best to use correction factors calculated from the target population. Determining the frequency of re-nesting requires monitoring of banded birds or detailed monitoring of individually marked nest sites, with the assumption that nesting attempts in the same location are made by the same pair. Because breeding frequency may vary among years, it may take several years of monitoring to obtain a reliable estimate. If it is not known whether re-nesting occurs, annual counts of nests or breeding pairs still can serve as an index of abundance that can be used to monitor population trend, recognizing actual population size may be somewhat lower depending on the frequency of re-nesting.

In some seabird species, particularly large species like albatrosses, not all individuals attempt to breed every year, with some birds occasionally skipping a year of breeding. Whether a bird skips breeding in a given year may depend on their individual body condition, their reproductive success in the previous year, and food availability and other environmental factors (Fisher 1976, Weimerskirch 1992, Jouventin and Dobson 2002). For example, Laysan and Black-footed albatrosses skip breeding about once every five years on average (Fisher 1976, VanderWerf and Young 2011). For these species, the number of nests observed each year therefore is an underestimate of the breeding population. Obtaining an accurate estimate of the complete breeding population size in species like albatross requires long-term banding and mark-recapture analyses (Converse et al. 2009, VanderWerf and Young 2011).

Age at first breeding. Many seabirds have delayed recruitment, which means they do not begin breeding until one or more years after fledging. This delay is often 3-5 years in smaller species like terns (Niethammer and Patrick 1998, Schreiber et al. 2002), but it can be much longer in larger species, such as 8-9 years in albatrosses (Bradley and Wooller 1991, Van Ryzin and Fisher 1976, VanderWerf and Young 2016). In species that take a longer time to reach breeding age, a greater portion of the total population consists of young, sub-adult birds that have not yet started breeding; these individuals often are referred to as "prebreeders". Prebreeders may visit breeding colonies sporadically, or not at all, until they are ready to breed. Determining the age at first breeding and counting the number of prebreedeers usually requires long-term banding and mark-recapture analyses. For example, in Laysan Albatross at Kaena Point on Oahu, long-term mark-recapture data revealed that prebreeders comprised 44% of the total population on average (VanderWerf and Young 2016). Age at first breeding is not well known for some species and warrants further study. Prebreeders that spend most of their time at sea "floating" can play an important role in buffering a population against threats that occur at breeding colonies. For example, the Short-tailed Albatross was thought to have been driven to extinction by hunting and disturbance at the breeding colonies, but the species was rescued by a pool of prebreeders that had been at sea and eventually returned to breed (Hasegawa and DeGange 1982). Age at first breeding may not be fixed in a species, and may vary among years or sites in relation to habitat condition, prey availability, or population trends, and this variation can reveal subtle aspects of population dynamics. An abundance of young breeding birds may signal a growing colony with good food resources, whereas an abundance of older prebreeders may indicate some limit to breeding opportunities, such as a shortage of mates, nest sites, or food.

Metapopulations. Many seabird populations can be considered a metapopulation, which is a population of populations interacting through dispersal and immigration (Hanski 1994). Strictly speaking, most seabirds do not act as true metapopulations because subpopulations rarely are extirpated, recolonized, or created, but the methods for describing dispersal, colony formation and growth, and other aspects of metapopulation dynamics are useful for seabird monitoring, particularly in environments that are being modified as a result of human pressure and climate change (Buckley and Downer 1992, Inchausti and Weimerskirch 2002, Oro 2003, Kildaw et al. 2005, Schippers et al. 2011). While individual surveys may be tailored to specific colonies, ultimately the goal is to understand the status and trends among of regional populations. To do so, it's important to understand population dynamics across all breeding sites. In addition, some colonies can act as "source" populations where high levels of reproductive success lead to population growth and can fuel emigration, while other sites act as "sinks" where lower levels of reproduction cause population decline or emigration. Management of any species of seabird in the USTP requires a broader view than just a single colony because population trends on one island can affect populations on others. For example, VanderWerf et al. (2016) showed that Christmas Shearwaters that hatched on Kure Atoll and Midway Atoll visited both islands, and that most visits were made by young birds, with some birds recruiting to the non-natal island to breed as adults. Obtaining this information was made possible by cooperation and sharing of data from both islands.

Site considerations

The overall area within which you will select your survey site(s) is called the sampling frame or inference space. If the objective of the survey is to identify the most important sites for all seabirds throughout an entire island, the sampling frame should include the full range of sites representing nesting habitats of all seabirds on the island. If the objective is to survey seabirds in a group of islands, the sampling frame should include representative sites from all islands in the group. If the proposed study site is small and the habitat is open, then it may be possible to do a complete count (census) of all the birds in the study site. If the species nests in more than one habitat type, then the sampling frame should include representative sites within each habitat type. It is important to define the sampling frame clearly because this will determine the area about which you can draw conclusions, and this requires considering where the boundaries of the site lie. For example, does the sampling frame consist of a single islet in an atoll or the whole atoll? Does it include just a certain habitat type on an island, or all habitats and thus the entire island? Does it include a single mountain top with suitable habitat, or the entire island? How should small outlying colonies in isolated habitat patches be treated? This can be important, for example, when estimating population size or nesting success based on counts of nests in a series of study plots. If plots are located only in a certain habitat type within a mosaic of habitat types, then the estimates can be applied only to that particular habitat. There is no single answer that universally applies to all situations. However the study site is defined, it is important to record the definition of the sampling frame and, if possible, to map its boundaries.

Timing and number surveys

The complexity of tropical seabird nesting cycles can make it difficult to answer even some basic questions, such as which species are present at a site, the size and trend of a population, and the breeding success. Single annual counts generally only yield an estimate of the minimum number of breeding pairs. Repeated visits throughout the year often are needed to accurately measure the population size, but the number and timing of visits depends on the colony and the species present. Many colonies are challenging to access and the schedule can be disrupted by external factors such as the weather, the availability of transportation and subsequent access. It is important to plan in advance which information is most needed to accomplish high priority monitoring goals, and to focus on gathering those data first on the initial visit(s); additional data needed for lower priority goals can be collected on subsequent visits if possible. The timing of surveys should remain consistent among years, unless the timing of previous surveys is determined to be inappropriate to collect the data needed. Differences in survey dates among years are a common source of bias that can affect interpretation and usefulness of the data.

MONITORING METHODS

Selecting methods and designing protocols

This section describes a variety of methods that are used to monitor seabirds and discusses methods that are most appropriate for particular purposes and species in the USTP. The methods are grouped into sections according to the main objectives that were previously described (see page 8). Table 1 provides a summary of methods and the questions each method can be used to answer, in the same order in which they are presented below. Some of the methods described are relatively simple and can be implemented with little training, but, depending on experience level, some techniques may require training, specialized equipment, and additional information that is beyond the scope of this guide. In such cases, references are recommended that provide more details about sample sizes, analytic methods, and other aspects of the methodology. In particular, Citta et al. (2007) and Kendall et al. (2009) discuss several aspects of seabird monitoring specifically in the USTP, including number, size, and location of sampling plots, efficacy of mean incubation counts in relation to breeding synchrony, sample sizes needed to detect a desired degree of change, and several other considerations.

Table 1. Summary of seabird monitoring methods and which questions they can answer. Some methods can be used for more than one purpose; upper case letters (P) indicate a primary use, lower case letters (s) indicate secondary use.

Method	Pop. size & trend	Distribution	Effects of threats, management	Breeding biology
Colony/nest census	P		P	s
Mean incubation count	P		P	s
Nest/roosting/fly by counts	P	s	s	
Plot-based designs	P		P	
Distance-based methods	P		P	
Mark-recapture	P	P	P	
Aerial surveys	P	P	s	
At-sea counts from shore	P			
At-sea counts from vessels	P	P		
Nest/burrow occupancy	P		P	
Radar	P	P	s	
Acoustic sampling	P	P	s	
Automated cameras	P	P		
Colony mapping	P	P	s	
Photo points	P	P	P	s
At-sea tracking		P		
Hatching success			P	P
Fledging success			P	P
Overall breeding success			P	P
Daily nest survival			P	P
Nesting phenology			s	P
Tissue sampling			P	
Plastic/bolus collection			P	

Population size

Measuring population size and trend is fundamental to understanding the status and conservation needs of a species, and designing effective management strategies. As previously mentioned, this was the most common monitoring goal identified by seabird managers in the USTP (VanderWerf and Young 2017). Population size is often measured first because many methods of measuring population trend require repeated measures of some aspect of population size. A complete census of all individuals in a population is often difficult to obtain, and in some cases only a portion of the population can be counted, such as breeders. Several methods are commonly used to monitor various aspects of population size in seabirds. The following subsections discuss some of the most useful, starting with the simplest and ending with more complex methods.

Censuses: total colony & nest counts. A census is a complete count, and can be done of all birds, breeding birds, or active nests. In some cases, it may be feasible to count both the number of breeders (or nests) and non-breeders simultaneously. This method generally can be used only in small to medium-sized colonies, or when a large number of observers are available to count, and the detection probability is high (ideally >95%; Citta et al. 2007). One advantage of a census is that the resulting data are relatively simple and may require little or no analysis. However, it is advisable to verify the accuracy of the census by conducting repeated counts in some areas to provide a detection rate and error estimate for the total count. Citta et al. (2007) provided details about how to estimate the detection probability. A census is more accurate for synchronous breeders; for asynchronous breeders or breeders that skip, a single count will underestimate the actual population because not all birds may be present at a given time. During a census it also can be useful to record information about nest contents or stage in the breeding cycle for each nest, numbers of abandoned eggs or dead chicks, and information about habitat and location of nests (e.g. using a GPS unit) in order to describe distribution of nests and habitat associations. In hot environments, which are typical in most areas of the USTP, censuses with potential to disturb birds should avoid the middle of the day to prevent causing heat stress to adults, chicks, or eggs. In some cases, it can be useful to temporarily mark nests, burrows, or adults with non-toxic, biodegradable materials as they are counted to avoid double-counting.

Mean incubation counts. The number of breeding pairs in a colony is in some ways the most important measure of population size. Especially for species with asynchronous nesting, one of the best methods of measuring the breeding population size are “mean incubation counts”, which are counts of nests with eggs conducted at intervals that are the same as the incubation period of the species being monitored. For example, if the incubation period for eggs of a particular species is 35 days, then repeated nest counts would be made 35 days apart over the entire time period during which nests are active. These are also sometimes called “minimum incubation counts” because they provide a measure of the minimum number of breeding pairs. This method is particularly useful for species that have asynchronous or aseasonal breeding, in which a single count would miss some nests. The sampling interval ensures that nests are not counted twice, but potential errors can arise if adults sit on inviable eggs longer than the usual incubation period, or if many nests fail shortly after laying, which would cause them to be missed. As discussed by Citta et al. (2007), the advantages of this method are that birds do not have to be marked or handled, breeding population size can be calculated with a small number of counts, and the resulting data are relatively simple and do not require specialized analytical methods. The main disadvantage is that the number of breeding pairs will be overestimated if some pairs nest more than once per season. Citta et al. (2007) discuss other aspects of this method and provide more details on analytic methods.

Nesting, roosting, and fly-by point counts. In some situations where it is not practical to conduct a complete count of breeding pairs, an alternative is to count all nests that are visible, or all birds that are roosting in or flying past a particular area. This method can be useful if the nesting area is inaccessible, if visiting the nesting area would cause unacceptable disturbance, for non-breeders or roosts used outside the breeding season, or to quantify activity around a foraging area or some other resource. If the counts are repeated, then they can be used to monitor population changes over time (population trend).

Several aspects of the survey methods may vary depending on the goals of the monitoring program, the species involved, and details of the location, and it may be necessary to conduct reconnaissance visits to refine the methodology. However, once the best methods are determined, it is imperative that they remain consistent thereafter to reduce bias. For example, the frequency and season at which counts should be done may vary among species and sites. If the nesting phenology is not known, then monthly surveys throughout the year may be needed as a starting point. After the phenology and best months are determined, the frequency and months can be adjusted, as appropriate. Similarly, if the seabird activity patterns at the monitoring site are not known, then reconnaissance visits at different times of day may be needed to determine the optimal time(s) when most birds are present. The length of the survey also will vary depending on many factors and it will require study to optimize. Once determined, the month, time of day, length of the count, and the time of year should be standardized for future counts. In situations where birds are nesting or roosting in one area and birds are also commuting past, it is often best to make separate counts of sitting birds, birds flying in, and birds flying out. Although called "point counts", it may be advantageous to move around a little in order to maximize the coverage of the survey. For example, moving may be necessary to view different sections of a cliff that cannot all be viewed from the exact same location, as long as the strategy is repeatable on future visits. It is useful to maintain a record of the area counted like a photo or a map.

Plot-based designs. This method is used primarily for abundant species for which it is not feasible to conduct a complete census of all individuals or nests because there are too many or they occur over a very large area. Instead, the number of birds or nests is counted in a number of small standardized plots located throughout the colony or area, and the resulting average density per plot is extrapolated over the entire area sampled to obtain an estimate of the total population size. Plots should be of a standard size and shape; a rule of thumb is that they cumulatively should sample about 10% of the total population or area. Circular plots are preferred in some cases because their shape minimizes boundary effects and they can be constructed easily with a center point and string. Square plots may be suitable in other situations and can be marked on the corners. Plots usually are located randomly throughout the area, but in some cases it may be appropriate to locate them uniformly using a grid pattern. Using the same plots each year and permanently marking them can increase consistency and improve ability to detect population changes over time.

Plot selection is crucial to ensure that the sample adequately represents the population. Although optimal plot size will depend on nest density, it is recommended that each plot encompass a minimum of 20 nests. The variance in calculations will be high if there are large numbers of plots with zero nests; increasing plot size to include more nests in each plot (and have a larger proportion of the colony area sampled) will increase accuracy. The minimum number of plots will depend on variance in density and the desired level of statistical robustness. Citta et al. (2007) found that relatively precise estimates (95% confidence of detecting an effect size of 10%) of reproductive success for the Black Noddy and Red-tailed Tropicbird can be achieved by monitoring between 5–7 plots.

Selecting the area for placement of plots is also crucial. A random sampling design should be used in areas where the entire colony can be accessed, and where the habitat and nest density is relatively uniform. This can be done by gridding the habitat on a map, numbering the potential plots, and then using a random number generator to select plot locations. In situations where it is not possible to access the whole colony, if nests are clustered, or the habitat is not uniform, stratified random sampling should be used, in which plots are selected randomly within each cluster or habitat type. For example, if you have grassland and open sand habitats, then there would be two strata and plots should be placed randomly in each of them. See Citta et al. (2007) for more details on plot location. It is useful to maintain a record of the area counted like a photo or a map.

Distance-based methods. This method is used primarily for abundant species when it is not feasible to conduct a complete census. It is also useful for species that are widely dispersed and do not nest in dense colonies. A variety of distance-based methods have been described (Bibby 2000, Sutherland 2006), the methods used most often for seabirds involve measuring the distance of birds or nests from a point or a line, and then using the distribution of distances to estimate population density. If the area in which the species being surveyed is known, then the density can be used to calculate actual abundance and population size.

Several statistical packages are available for analysis of distance data. The most frequently used one is Program DISTANCE (see Thomas et al. 2010 for a review), which can be downloaded at <http://distancesampling.org/Distance/>. Analysis of distance data can be complicated by several factors, including variation among observers in estimation of distances, variation in habitat or survey conditions that affect probability of detecting birds or nests, and many others. Selecting the locations of points or lines used in distance sampling is important to ensure unbiased and adequate sampling of the population (Marques et al. 2010). Distances can be measured with a tape measure or range finder, or estimated by the observer. Although estimating distances is faster, it requires training to ensure accuracy. Camp et al (2009) used a variable circular plot method to estimate abundance of White Terns in the Mariana Islands, where the species nests in trees widely spaced throughout forested areas. If the extent of forested area used by White Terns on the islands is known, the density estimate could be used to estimate the population size. Even if the extent of the population is unknown, the population density can serve as an index of abundance and used to monitor population trend from repeated estimates of density over time.

Mark-recapture and survival. Marking birds and then recapturing or resighting them later is a common method of estimating population size. Because mark-recapture methods also are the primary tool used to estimate survival and several other demographic parameters, those monitoring techniques are included in this subsection. A minimum of two visits is needed to mark and then recapture individuals in order to estimate population size; more frequent visits will allow use of more sophisticated analytical techniques that yield more precise population estimates and also allow estimation of survival. Seabirds usually are marked with leg bands, but some species, such as frigatebirds, are marked with patagial (wing) tags because their legs are so short (Dearborn et al. 2003). In addition to a metal band from the US Geological Survey Bird Banding Laboratory, sometimes a second, or auxiliary band, is placed on the other leg. Auxiliary bands often are made of a durable plastic and have larger, but still unique, letters or numbers that can be read from a distance without having to recapture the bird (e.g. VanderWerf et al. 2014). Using two bands (double-banding) also can reduce bias by allowing birds that lose one band to be identified (Kendall et al. 2009).

Analysis of the simplest mark-recapture data sets consisting of just two visits is relatively straightforward, and is often called the Lincoln-Peterson estimator of population size (Adams 1951). Analysis of data sets involving multiple marking and recapture occasions over one or more years is more complex and requires specialized techniques that are beyond the scope of this guide (Kendall et al. 2009, Grimm et al. 2014). In general, to estimate population size the visits should be made close together in time so that it can be assumed there is no mortality. To estimate survival, visits must be made at longer yet regular (such as yearly) intervals. Various statistical packages are available to conduct such analyses, including Program MARK (White and Burnham 1999, Cooch and White 2005; available for download at < http://www.phidot.org/software/mark/downloads/ >). If multiple marking occasions are made close in time within a year and done over multiple years, then methods known as “robust design” can be used to simultaneously estimate population size, survival, and emigration (Kendall et al. 1995, Converse et al. 2009). In the USTP, VanderWerf et al. (2015) used robust design methods to estimate annual survival, immigration, emigration, and population size of Christmas Shearwaters on Kure Atoll. Kendall et al. (2009) investigated survival of Laysan and Black-footed albatrosses using a modified version of the robust design method intended to be less invasive.

Aerial surveys. Seabirds have been surveyed by aircraft in some areas for many years. Aerial surveys can be useful for counting birds in inaccessible or dangerous locations. Some seabirds are good subjects for aerial surveys because they are relatively large and nest and roost on the surface. The advent of high resolution digital imagery from cameras mounted on aircraft including helicopters, airplanes and drones has enabled archiving of data, automated digital analyses, and greatly improved accuracy and utility of aerial survey methods (Buckland et al. 2012). For example, the U.S. Navy has counted birds visually by helicopter on Farallon de Medinilla in the Commonwealth of the Northern Mariana Islands, where unexploded ordnance from military training makes surveys on land dangerous, but only large species such as frigatebirds and boobies can be detected and roughly counted (Camp et al. 2014). On Kaula Islet, which also is dangerous access by foot because of unexploded ordnance, the U.S. Navy has used high-resolution photographs taken from an airplane that are processed later using a computer algorithm to identify species (Normandeau Associates and APEM 2016). Using this method, it is possible to identify and count small species like Brown Noddies, Sooty Terns, and Gray-backed Terns, but it is not possible to distinguish birds that are roosting vs. nesting.

Satellite imagery also can be used to monitor certain species. For example, the location and size of Emperor Penguin (*Aptenodytes forsteri*) colonies in Antarctica has been monitored using satellite photos and has improved knowledge about the status of that species (Barber-Meyer et al. 2007, Fretwell et al. 2012). Satellite imagery was recently used to estimate population sizes and distribution of Wandering Albatrosses (Fretwell et al. 2017), and efforts are underway to investigate use of satellite imagery to monitor Laysan Albatross at Kaena Point, Oahu and Midway (R. Suryan pers. comm.), and this technology may become useful for other species in the future.

More recently, development of drones capable of carrying high resolution cameras and new imaging techniques have allowed wider application of this method for a variety of species, including geese (Chabot and Bird 2012), terns (Chabot et al. 2015), penguins (Ratcliffet al. 2015), and perhaps most relevant, conduct rapid population estimates of the Tristan Albatross (*Diomedea dabbenena*; McClelland et al. 2016). Efforts also are underway to develop methods of estimating Laysan Albatross numbers with drones, using the small Kaena Point colony as a test accuracy (K. Fraiola unpubl. data). The effectiveness of high resolution imagery from unmanned aircraft also has been investigated recently for conducting finer-scale monitoring such as measuring reproductive success (Sarda-Palomera et al. 2012, 2017).

Previous concerns about the accuracy and precision of the counts, as well as the potential disturbance caused by drones are now being addressed. Hodgson et al. (2018) conducted calibration counts comparing human observers to drones at various altitudes in an artificial seabird colony (created with decoys) to determine accuracy of various methods. The following three groups were compared: humans counting by scope on the ground, drone counts using automated software for detecting the number of birds, and counts made by humans from images recorded by drones. They found that drone-derived data were between 43% and 96% more accurate than data from the traditional ground-based collection method and that counts from drone imagery can be semi-automated with a high degree of accuracy. Although disturbance will vary by species, several recent studies have been conducted to quantify the impacts drones may have on unhabituated individuals in the wild using standard aerial survey protocols (Brown 1990, Borrelle and Fletcher 2017, Barnas et al. 2018). Species-specific disturbance rates will need to be examined from various altitudes before adopting this technology on a region wide scale to minimized potential disturbance.

Other measures of abundance

In some cases, it is not possible to estimate total population size or the number of breeding pairs, but it is still desirable to monitor abundance of at least some portion of the population. In such cases, it may be possible to monitor birds away from breeding areas or to measure some other aspect of abundance that is correlated with the total population size and can serve as an index of abundance. Several methods for measuring abundance of seabirds in different circumstances are described below.

At-sea counts from shore. This method can be especially useful in situations where birds regularly forage close to shore or pass by during migration or while commuting to or from a nesting colony or roosting site, or if nesting colonies are located in remote areas or inaccessible cliffs. Such counts are sometimes called "sea watches." Points and peninsulas are particularly good vantage points from which to conduct sea watches because seabirds are often concentrated and closer to shore, and an elevated position can provide better views of birds, especially if high waves are present. High-powered optics such as spotting scopes are necessary in most locations. Sea watches have greatest value if they are conducted in a standardized manner, at the same location, time of day, and length of time. The advantages of this method are that it can be used in many situations and the resulting data are relatively simple to analyze, and that it often can be used to collect data on several species simultaneously. Sea watches by birders also can be used as a part of citizen science projects (http://www.trektellen.nl/site/yeartotals/1993/2017). A potential drawback to this method is that changes in numbers of birds observed over time could be caused by shifts in movement patterns, and not in abundance.

At-sea counts from vessels. At-sea counts from vessels have been a standard method of determining distribution and abundance of seabirds in the USTP and other areas for many years (Tasker et al. 1984, Gould and Forsell 1989). Some at-sea counts are dedicated surveys specifically designed to observe birds and other animals at sea (Pitman 1986), while others have been done opportunistically while transiting between islands for other purposes (Pyle and Eilerts 1986, VanderWerf et al. 2006). Dedicated surveys often follow a grid pattern to provide more thorough and standardized coverage of the survey area. Some areas of the USTP have received little at-sea survey effort, so even opportunistic surveys can provide important information. When conducted over a large area, at-sea surveys can be used to estimate total population size, which has been done for Newell's Shearwater (Spear et al. 1995).

During at-sea surveys, one or more observers either count all the birds observed to the horizon, or only those within a certain distance from the vessel; the latter is typically preferred. If birds are counted within a prescribed distance or the distance to each bird is estimated, then the data can be used to estimate density and abundance per unit area. If all birds are noted regardless of distance, then the data would be used to estimate relative abundance. Observations often are broken into standardized time intervals, often 10 minutes or 1 hour, with a geographic location recorded for each interval, so that geographic variation in abundance can be measured. Noting locations of feeding flocks can be useful for determining foraging areas. A complete description of the methods for establishing a marine transect program and conducting surveys at sea is beyond the scope of this guide. For more information about monitoring seabirds at sea, readers are encouraged to consult Balance (2007) and (Ronconi and Burger (2009).

Observing and identifying birds at sea can be challenging because of rough sea conditions, movement of the boat, the distance of many birds from the vessel, and because some species are difficult to identify. Reliable at-sea survey data usually can be collected only by experienced observers, and acquiring the necessary experience and skill requires training and practice. For general information about identification of seabirds, consult Harrison (1987), Onley and Scofield (2007), Howell (2012), or regional field guides, such as Pratt et al. (1987). Criteria for identification of several particularly difficult groups of seabirds in the USTP is available in Howell et al. (1996), Pyle et al. (2016).

Nest/burrow occupancy. Instead of counting the number of nest sites or burrows that are used each year, another method of monitoring relative abundance and population trend is to measure the proportion of an area or nest sites that are used each year. This method is often called "occupancy", and it can be applied in situations where there is a discrete site that is used for several years in a row and may be defended, such as a burrow, ledge, cup, or territory, or units in a larger area such as sections of a nesting colony. A decline in occupancy rate of such sites often indicates a decrease in number of breeding pairs and, in turn, population size. There is a large body of literature about measuring occupancy, including a software program designed especially for analyzing occupancy data, called PRESENCE, which is based on models originally proposed by MacKenzie et al. (2002). The software program, user guides, and numerous papers relating to occupancy monitoring and data analysis are available at the following website: https://www.mbr-pwrc.usgs.gov/software/presence.html. In very large colonies or geographic areas, measuring occupancy can be a more practical alternative to counting the number of nests or mapping the perimeter of the colony. Care must be taken, however, to also consider that nesting areas may shift in geographic location over time, which requires observers to be aware of potentially corresponding increases in occupancy, or creation of new nest sites, in alternate areas.

Radar. Radar has been used to monitor seabirds that are difficult to locate due to the remote location and sensitive nature of their colonies as well as their nocturnal behavior. Marine radar units sensitive enough to detect flying seabirds (and other species) can be mounted on a vehicle, used at a fixed location, or even flown by helicopter to remote locations. Radar survey data usually are used as an index of relative abundance that can detect changes in population over time; they do not provide a measure of the actual number of birds. Radar surveys have been valuable for measuring population trends of Hawaiian Petrels and Newell's Shearwaters, and have become one of the most valuable monitoring methods for these species (Cooper and Day 1998, Day et al. 2003a, Raine et al. 2017a).

Acoustic monitoring. Acoustic sampling is another method that has been used primarily to survey seabirds that are difficult to detect because they nest in remote locations and are nocturnal at the colony. Acoustic monitoring can be done in person by listening for calls at night, or remotely using automated recording units. Automated recording units require less labor and can provide several advantages but may have limitations in some areas (Digby et al. 2013). Typically, the recording units are deployed for an extended period in or near an area where seabirds are suspected to occur, and the recordings are then digitally analyzed for a species of interest using a template (Acevedo and Villanueva-Rivera 2006, Buxton and Jones 2012). The units can be powered by internal batteries or an external source, such as a solar panel and large rechargeable battery. They can be programmed to record continuously, only between certain hours, or for a certain number of minutes per hour in order to extend battery life and memory capacity.

As with radar, acoustic monitoring usually does not provide a measure of the actual number of birds present, but the number of detections per unit time can serve as an index of abundance. However, there have been several recent studies that correlated numbers of acoustic detections with actual population numbers (Borker et al. 2014, Oppel et al. 2014). Acoustic sampling has been valuable for measuring recovery of seabirds after implementation of management actions, such as predator eradication (Croll et al. 2016). Remote acoustic monitoring also has been an important method for determining the presence and relative abundance of Hawaiian Petrel and Newell's Shearwater in montane areas of the Hawaiian Islands (A. Raine, J. Penniman, pers. comm.), and has been the primary tool for determining presence and measuring abundance of nocturnal seabirds in a remote colony on Ta'u in American Samoa (Titmus 2017).

Automated cameras. The use of automated remote cameras, or "camera traps" is another non-invasive method of surveying for rare or cryptic species or for collecting data over extended time periods or in remote locations where it is not possible for observers to remain present for extended periods of time (O'Connell et al. 2010, Kucera and Barrett 2011). Although camera traps are most often used to document presence and distribution, methods have been developed that can be used to estimate population density and other measures of abundance in some circumstances (Rowcliffe et al. 2008, 2011). If methods are sufficiently standardized, it is also possible to use the frequency of photographs as an index of abundance that can be used to measure population trend. Refer to O'Connell et al. (2010) for more details regarding selection of locations for camera traps and analysis of the resulting data. Swann et al. (2011) provided guidance on desirable features and choosing cameras although the capabilities and models of cameras change rapidly.

Population Trend

In addition to estimating the population size of a species, or some other index of abundance, it's often necessary to determine the population trend over a specified time period. Measuring population trend is fundamental to understanding the status and conservation needs of a species. Even abundant species can require management if their numbers are declining. Total population size is typically abbreviated as N. The population may be further broken down into subgroups that are defined by age class (adults and juveniles), reproductive status (e.g., breeders and non-breeders), or other biologically relevant criteria. Changes in N are influenced by multiple demographic mechanisms, including birth, death, immigration, and emigration. The proportional change in N from one year to the next is abbreviated by λ. When $\lambda > 1$, the population is growing, when $\lambda < 1$ the population is decreasing, and when $\lambda = 1$ the population is stable. A basic approach to calculating λ is to conduct counts of the population size through time, such as every year, and to use these data to estimate the average change (Hatch 2003, Doherty et al. 2004). An advantage of this method is that it is relatively simple and can be accomplished without measuring reproductive success or marking individuals to estimate survival. A disadvantage is that it does not provide information about why the population is increasing or decreasing or which life-history stages are influencing change over time.

Alternatively, population trend can be calculated using estimates of demographic parameters including adult and juvenile survival and annual fecundity. Such calculations can be done using a population matrix model, and various population matrix calculators are available (e.g. http://calculator.vhex.net/calculator/linear-algebra/leslie-matrix, http://bandicoot.maths.adelaide.edu.au/Leslie_matrix/leslie.cgi). It is recommended to obtain some background information about such models before attempting to use them (Caswell 2001, Williams et al. 2002). Population trend also can be calculated with a simple formula (Pulliam 1988, VanderWerf 2009): $\lambda = P_A + P_J\beta$, where P_A is adult survival, P_J is juvenile survival, and β is mean number of fledglings per pair per year.

Distribution

Distribution, or range, is another fundamental aspect of a species biology that is important for assessing conservation status. It was the second most common reason for conducting seabird surveys in the USTP (VanderWerf and Young 2017). Species that are more widely distributed and have a larger range and occur in more locations are, in general, more secure (IUCN criteria). Many of the methods used to survey population size and abundance also are used to assess distribution. Methods like colony counts, nest counts, roosting counts, and counts from vessels or shore also demonstrate presence and thus distribution. Several methods that are especially useful for measuring distribution are described below.

Mapping colony boundaries. A common method of measuring seabird distribution on land is to delineate the extent of a nesting colony by mapping the boundaries. Walking the perimeter of the colony with a hand-held GPS unit can provide a reasonably accurate map and size. Repeated measures of colony size can be used to measure and map changes in distribution over time. If the density of nests also is measured using a series of plots, then the number of nests can be estimated given the area. If the density of nests can be assumed to remain constant over time, then the geographic size of the colony can be used as an index of abundance. This method may be useful for species that nest in very large, dense colonies, such as Sooty Terns. If an aerial photograph of the colony is available and the distance is known between landmarks visible in the photograph, it may be possible to measure the size of the colony from the photograph.

Photo points. Photo points are permanent locations from which repeated photographs are taken over time. Such photographs can provide measures of geographic extent of a colony, an index of abundance, and appearance of erosion, vegetation, and other physical features over time.

Depending on the visibility of the species and the resolution of the images recorded, it may be possible to count birds or nests and use the resulting data as an index of abundance or nesting phenology. Photo points can be useful in situations where it is not possible to directly map colony boundaries because of inaccessible terrain or because doing so would cause unacceptable disturbance to the colony. For photo points to be effective, it is necessary to relocate their position reliably and precisely on each visit, and to standardize the equipment, height, and angle of the camera. Relocating the exact position can be accomplished using GPS coordinates, by their position in relation to landmarks, or by lining up objects in the field of view. Many cameras can record GPS information as part of the meta-data associated with each photograph, obviating the need for an external GPS device and making it easier to store and transfer geographic information simultaneously with the image.

Acoustic monitoring. As described above, acoustic sampling is an important method for determining the presence and distribution of species that are hard to detect because they nest underground in remote locations and are nocturnal at the colony. Acoustic sampling also can be useful for detecting rare species that are encountered infrequently. This has been one of the primary methods used to document the presence of White-throated Storm-Petrels in the Pacific Remote Islands NWR, and Band-rumped Storm-Petrels on Kahoolawe (J. Bruch, pers. comm.), and on Hawaii Island (N. Galase, pers. comm.).

At-sea tracking. Although seabirds spend the majority of their lives at sea, most seabird monitoring has been done on land in their breeding colonies. With the recent advent of various types of tracking devices, it has become possible to collect detailed data about seabirds at sea. Prior to this, the primary method for determining the distribution of seabirds at sea was visual counts from vessels. In the last two decades, this field has been revolutionized by the development of small tracking devices that can be attached to seabirds and used to gather data about their distribution and movements at sea (Hart and Hyrenbach 2009, Wakefield et al. 2009). This information is particularly useful for designing marine protected areas and assessing threats to seabirds at sea, such as interactions with various fisheries and offshore energy development (Arcos et al. 2012, Thaxter et al. 2012, Young et al. 2015, Lascelles et al. 2016).

Several different types of devices are available that vary widely in cost and in the precision of the location data recorded, including those that determine locations via satellite, global positioning systems (GPS), and geolocation light sensing (GLS). This technology is developing rapidly and it is beyond the scope of this guide to review all the different options (Bridge et al. 2011, Kays et al. 2015). The most appropriate device depends on the size and suspected movement patterns of the species to be tracked and the goals of the monitoring. To reduce any negative effects on the birds, the weight of the device must not exceed 3% of body weight, and keeping it under 2% is preferable (Phillips et al. 2003, Fair and Jones 2010, Vandenabeele et al. 2012). Some tags transmit the location data, either by satellite or to antennas in the case of some GPS devices, and thus they do not have to be retrieved from the bird. In contrast, GLS tags and some GPS tags log the data but do not transmit it and thus must be retrieved from the bird, which can be difficult. Satellite tags provide the highest precision, but they are the most expensive and usually are heavier. GLS tags and some GPS tags are smaller and less expensive. GLS tags have the greatest error in location and are thus not useful for examining short-distance or short duration movements (Livosky et al. 2012).

Banding/mark-recapture. The original purpose of bird banding was to enable identification of individual birds to allow re-sighting and follow them through time in order to track movements and survival; bird banding is in wide use today and frequently applied in seabird studies and population monitoring. Information about band recoveries has provided useful, and sometimes surprising, insights into the movement of many seabird species (e.g. Brothers et al. 1997, Dearborn et al. 2003).

Breeding biology

Reproduction is fundamental to population biology and it can be one of the easier parameters to measure in some seabird species. Various aspects of reproduction can provide important information and insights into population dynamics, threats, and conservation needs. Whereas counts of the breeding population size provide information about the population in a particular year, reproductive data can provide an early warning about changes in breeding population size that might be expected in the future (Schreiber 1980). Reproductive success can be used to measure the effects of climatic change (Polovina et al. 1994) or shifts in oceanic prey communities (Kitaysky and Golubova 2000). Different measures of breeding can provide information that can be used to answer various questions. For example, low hatching rate can indicate a low fertility, potential exposure to chemical contaminants, poor incubation, or disturbance at the nest. Low fledging rate can indicate food limitation. Changes in nesting phenology or length of the nesting cycle can indicate changes in climatic patterns and food availability. Measuring more than one aspect of reproduction sometimes is needed to obtain a complete understanding of threats or the efficacy of management actions.

Hatching success. Hatching success is the proportion of eggs that hatch. Depending on the goals of the monitoring, measures of hatching success can use the proportion of all eggs that hatch, or the proportion of nests in which at least one egg hatches. For example, if the goal is to measure predation, then it might be appropriate to measure the proportion of nests in which at least one egg hatches, because predation often involves all eggs in a nest. If the goal is to measure effect of food resources available to parents during laying, which can affect clutch size, egg size, and egg viability, then it might be best to measure hatching rate of all eggs.

Fledging success. Fledging success is the proportion of chicks that fledge. As with hatching success and depending on the monitoring goals, fledging success can be based on the proportion of all chicks that fledge, or the proportion of nests with chicks in which at least one chick fledges. These measures are the same for species that lay a single egg and thus can have only a single chick per nest.

Overall breeding success. The simplest measure of overall breeding success is the proportion of breeding attempts that result in a fledged chick. This measure is the product of hatching success and fledging success and is often called “apparent nest success” (Jehle et al. 2004).

Daily nest survival probability. Although measures of apparent nest success are intuitive and are useful for comparison with other studies, they often are biased and usually are overestimates of true nest success because nests that fail are less likely to be found (Mayfield 1961, Johnson 1979). It is therefore desirable to calculate the daily nest survival rate (dsr) if possible, which provides a less biased estimate of nest success, using the number of nest mortalities and the number of exposure days. The probability (S) that a nest would survive for the entire length of the nesting cycle (t) and thus result in a fledged chick, can be calculated using the formula: $S = (dsr)^t$ where t is the length in days of the complete nesting cycle for a particular species. Several methods of estimating dsr are available (see Jehle et al. 2004 and Jones and Geupel 2007 for reviews). Although they are all sometimes referred to as "Mayfield" estimates, they differ in several ways that may cause some methods to be more suitable for different circumstances and monitoring schedules. The method employed by Program MARK (White and Burnham 1999, Dinsmore et al. 2002) is somewhat more restrictive because it requires knowledge of nest ages and that the last monitoring visit occur before all nests have either failed or fledged. The dsr often is more sensitive for detecting changes in breeding success, such as might occur because of introduction or removal of a predator (VanderWerf and Raine 2016).

Nesting phenology. Nesting phenology is the temporal pattern of breeding activity throughout the year. A simple measure of phenology can be obtained during rapid assessments by recording the proportion of nests at various stages of the nesting cycle (nest construction, eggs, chick sizes, fledged juveniles, etc.). More frequent visits that record egg laying dates and nest stages at multiple times during the year provide more precise information. Nesting phenology can vary geographically or temporally depending on climate and food availability, and changes in phenology over time may be one of the first indications of a threat or perturbation (Montevecchi 1993, Devney et al. 2009, Surman et al. 2012).

Effects of threats and response to management

Measuring the effects of threats and response to management actions designed to combat threats are crucial for effective seabird conservation. Measuring the effect of threats can reveal whether management is necessary and help prioritize which actions are needed most. Monitoring the response to management is the foundation of an adaptive approach in which actions can be modified when necessary.

Predation and predator control. Predation can affect various life stages of seabirds, including eggs, chicks, breeding adults, and non-breeding adults. Different survey methods are needed to measure the effect of predation and predator control depending on which life stages are taken by predators. Some predators, such as rats and mice, most often take eggs and small chicks, but they also can take adults, especially among smaller seabird species. Larger predators, such as feral cats, dogs, mongooses, and pigs are able to take all life stages including adults. Ants may not prey directly on seabirds but can impede development and cause death of chicks through the acid they secrete and nest desertion by adults because of irritation (Plentovich et al. 2009, 2018). Monitoring the effects of predation and of measures aimed at reducing predation therefore must be focused on the life stage(s) at risk.

If most predation occurs at nests on eggs or chicks, then measuring hatching success, fledging success, overall breeding success, or daily nest survival probability is appropriate using the previously described methods. If predation is severe and large-scale removal of predators is practical and expected to result in large and rapid increases in nest success, then simply monitoring changes in spatial or temporal differences in hatching or fledging rates may be sufficient to detect an effect of predation or predator control (Smith et al. 2002). Examples of large and rapid responses in fledging rates of seabirds following predator control include Bonin Petrels on Midway (Seto 1994), and Red-tailed Tropicbirds and Wedge-tailed Shearwaters on

Oahu (Marie et al. 2014, VanderWerf and Young 2014, VanderWerf et al. 2014). However, measuring daily nest survival probability rather than the proportion of nests that reach a certain stage can provide a better method for assessing efficacy of predator control because the improvement in nest success may be initially small and then increase over time as more predators are removed. Estimates of daily nest survival are generally more sensitive and provide greater statistical power to detect changes in nest survival (see Jehle et al. 2004 and Jones and Geupel 2007 for reviews).

Another method of demonstrating whether predation or predator control is affecting a seabird population is to monitor population size. Because it may take several years for the change in population size to be detected, monitoring some aspect of nest success may yield an answer more quickly. For example, after all predators were excluded from Kaena Point Natural Area Reserve on Oahu, nesting success of Wedge-tailed Shearwaters increased immediately, and the number of breeding pairs increased gradually over three years (VanderWerf et al. 2014). Similarly, the number of Bonin Petrels on Midway Atoll increased dramatically after black rats were eradicated (Seto 1994). The number of Wedge-tailed Shearwater pairs nesting on Mokuauia Islet off Oahu increased shortly after each of two rat eradications (Marie et al. 2014).

During surveys, it is also useful to document signs of predation, such as chewed or broken eggs, and dead chicks with evidence of predation. These are often the first sign that predation is a problem. However, simply noting evidence of predation is not sufficient for monitoring predation or effect of predator control because predators sometimes leave no evidence, and depredated nests may simply be empty, providing no clues to the cause of failure.

Predation on adults can be more difficult to document depending on the predator. Evidence of predation found during surveys, such as remains of carcasses, can be useful in identifying the predator and simply documenting that predation is occurring, and in some cases this may be sufficient to justify management. Evaluating the severity of predation and the response to predator control may require monitoring adult survival, which as described above, is more difficult and can take several years of data to detect a trend.

Once predators are controlled, it is also possible that new species may colonize the site, particularly smaller species that are more vulnerable to predation. Colonization of a site by such species also can be evidence of the effect of predator control.

Habitat disturbance and management. As with predation, habitat disturbance or modification can affect various seabird life stages. In order to measure the effect of habitat disturbance on a seabird population and efficacy of efforts to restore or improve habitat, it is necessary to focus on the life stages or processes likely to be affected.

Habitat disturbance can affect the size or location of nesting colonies, and a decline in range or shift in location can reveal negative effects of changes in habitat. Measuring and mapping the size and distribution of a seabird colony, as described above, can provide fundamental baseline about habitat suitability, and monitoring changes over time can reveal negative effects of disturbance or beneficial responses to management.

Seabirds may continue to attempt to breed in an area even if the habitat quality declines, in which case a decline in reproductive success may be the first evidence of habitat disturbance. Similarly, monitoring trends in reproduction over time using the previously described methods can show whether management actions aimed at improving habitat quality are achieving the desired effect(s).

Another method of demonstrating whether habitat disturbance or habitat management is having an effect on a seabird population is to monitor population size. If population size increases over time after a habitat improvement program is implemented and no other factors are suspected to have played a role in the population change, then habitat improvement likely is responsible. It may take several years for the change in population size to be detected, however, and monitoring some aspect of nest success may yield an answer more quickly. Habitat improvement also may allow new species to colonize a site.

Marine pollution, plastics, and, contaminants. Pollution, including plastics and chemical contaminants, is another serious and widespread threat to seabirds being monitored with increasing frequency (Azzarello and Van Vleet 1987, Guruge et al. 2001, Ryan et al. 2009). Plastics and other contaminants are ubiquitous in the marine environment and virtually all seabirds are exposed to them at sea (Rapp et al. 2017, Youngren et al. 2018), or at their breeding colonies, such as lead from paint on buildings at Midway Atoll (Finkelstein et al. 2016). Pollution may directly kill adult or young seabirds, as occurs through ingestion of plastic (Sievert and Sileo 1993), and contaminants also can affect reproduction and other aspects of seabird demography (Fry et al. 1986). Contaminant levels in seabirds can be quantified using a wide range of samples, but the type and quantity of tissue required will vary according to the specific test being conducted.

A common method of studying and measuring ingestion of plastic and associated contaminants is collection of seabird boluses, which are the undigested food remains regurgitated by adult and juvenile albatrosses and some other seabirds (Xavier et al. 2005, Rapp et al. 2017, Youngren et al. 2018). Juvenile seabirds usually regurgitate a single large bolus shortly before fledging, while adults regurgitate undigested food remains more often throughout the year, so their boluses tend to be smaller and more difficult to find. These boluses provide a measure of plastic ingestion and also can be used to measure contaminants and isotopic components of diet (Nilsen et al. 2014). For example, the proportion of plastic in boluses of juvenile Laysan and Black-footed albatrosses varied in relation to where the adults from each colony foraged, indicating variation in exposure to plastic concentrations at sea (Young et al. 2009, Hyrenbach et al. 2017). If a goal of the study is to quantify the proportion of the bolus composed of plastic, then it is important to collect boluses shortly after they are regurgitated because insects, crabs, and other arthropods may consume organic portions of the bolus, such as squid beaks (Hyrenbach et al. 2017). If the goal is to simply quantify the amount of plastic, then older boluses may be acceptable, provided it is possible to determine which pieces of plastic constitute a single bolus. Boluses can be stored at room temperature in a sealed container. More details on bolus collection and processing are provided by Hyrenbach et al. (2017).

Contaminants also can be assessed from tissue or diet samples collected from seabirds. Lavers and Bond (2016) found that high levels of ingested plastic (from stomach and bolus contents) were correlated with increased concentrations of chlorine, iron, lead, manganese, and rubidium in feathers of Bonin Petrels and Laysan albatrosses. Blood and feather samples, which can be collected directly or indirectly from live birds, can be used for certain contaminants analyses, as can bone, tissue, and egg contents from dead specimens. The specific contaminants being analyzed will dictate the specific tissues, amounts needed, and sample storage protocols.

Abandoned or infertile eggs also can be used to measure presence and concentration of contaminants. For example, the Seabird Tissue and Archival Monitoring Project (referred to as STAMP), a collaborative effort by the USFWS and the National Institute of Standards and

Technology uses the cryogenic banking of seabird eggs to monitor long-term (100-year) trends in persistent, potentially harmful bioaccumulative contaminants.

SCENARIO-BASED SURVEYING

Rapid assessments/reconnaissance surveys

Because of logistical or time constraints it is sometimes feasible to visit an island or colony just once and/or for a limited amount of time. This type of survey is often called a rapid assessment. Similar short-duration visits can also be made to sites that have not been surveyed before in order to gather initial information needed to make decisions about future visits. In such cases they are often called a preliminary site assessment or reconnaissance survey. Because limited time is available on such visits, it may not be possible to gather all types of information, and activities and data collection must be prioritized. Although these priorities can vary depending on the monitoring goals and information needs, the most important types of information are often, in order of decreasing priority: which species are present, location(s) of breeding colonies, stage of breeding (roosting, courting, incubation, feeding chicks, etc.), and the number of nests or breeding pairs in each species. In addition, information about any obvious threats or management concerns also usually is high priority. Examples of rapid assessments of the avifauna of entire island in the USTP include Farallon de Medinilla in the CNMI (Lusk et al. 2000), Lehua Islet near Kauai in the main Hawaiian Islands (VanderWerf et al. 2007), and Swain's Island in American Samoa (Titmus et al. 2016).

Before conducting a rapid assessment, it is advisable to do a literature search for any existing data from the site, and to obtain a map, aerial photograph, or some other image of the location (e.g., Google Earth). The map or image should be examined in advance to assess accessibility of the site, general habitat, possible access routes, and to plan activities while at the site. If previous information is available, then the visit should be planned to coincide with the likelihood of seeing the maximum numbers and diversity of birds. If no previous information is available, data from nearby locations can be used instead. Previous reports also can an idea of the species present (at least at the time of those surveys). Always determine land ownership and acquire written permission to enter and survey any private land.

The most important goal of rapid assessments often is to determine which species are present at the site. Different methods may be needed to detect different species depending on their life histories, and strategies should be considered for maximizing detection of a variety of species. If possible, start with an overview by selecting a vantage point from which a large proportion of the site or colony can be viewed while causing minimal disturbance. Approaching a site too closely or rapidly can cause sensitive species to flush or take shelter, potentially disrupting breeding behavior, causing damage to nests, and making it harder to observe birds. It is important to make a thorough description of the site on the first visit. Sketch a map, take photographs, or make notes on an existing map or photograph (see section on mapping the colony below). Take notes on the distribution of nests, vegetation, human activities, possible threats, and other relevant features. Remember that the rapid assessment or reconnaissance survey will be used to plan subsequent visits, assess management needs, and enable monitoring of changes in the future.

Keep your methods simple but make detailed notes of what you observe. Take photographs, including panoramas and videos if your camera has that capacity, and be sure to save the images with your report. If time allows, note the stage of the nesting cycle for each species, and attempt to roughly count or estimate the number of nests or individuals of each species, and note whether each number is an actual count or a rough estimate. This information is important to ensure that future observers are able to properly interpret the information. For sites that are complex or support several seabird species, it may be necessary to do several reconnaissance surveys over the course of a year in order to obtain a comprehensive assessment.

Special approaches will be needed for particular groups of species, such as nocturnal species and those that nest in burrows or rock crevices. For nocturnal shearwaters and petrels, surveys should be done at night when the birds are more active and visible, and playbacks of recorded calls or human “war-whoops” can be used to attract birds or induce them to call (Tennyson and Taylor 1990, Podolsky and Kress 1992, Lawrence et al. 2008). If it is not possible to do surveys at night, conduct searches during the day by inspecting burrows or crevices with a flashlight or burrow scope if available, or by reaching in by hand and gently feeling for birds, eggs, or chicks. However, reaching into burrows is not recommended in areas that contain other animals that could injure you, such as coconut crabs or other large land crabs, or mammalian predators. For species that nest on steep cliffs or small islets that cannot be searched directly, such as tropicbirds, terns, and noddies in some areas, it may be possible to document only the location and number of birds flying around or landing. Sometimes the presence of feathers, dropping, or smell can provide clues about the location of nests, even if the birds themselves are not visible. In such cases, collect or photograph feathers, and record the location of droppings or strong seabird scent.

Whole-island and species-specific surveying

Another scenario is to thoroughly survey a diverse assemblage of multiple seabird species on an entire island or large colony. This situation assumes that the number and length of visits is not so limited, or that observers can be present for an extended period, so that substantial time can be spent gathering as much information as possible about each species. Even with unlimited time, planning is needed to ensure the most appropriate methods are used and data collection protocols allow accomplishment of the survey goals. The subsections below provide recommendations and supplemental information (in addition to the section on methods above) about survey methods that can be used to answer questions about different species or foraging guilds of seabirds. A summary of recommended methods for collecting information on population size and reproduction in different groups of species is provided in Table 2.

Table 2. Methods recommended for monitoring population size and reproductive success of different seabird groups. The best method may differ from those listed below depending on the monitoring goals and logistical constraints related to specific locations. Consult text above for more information.

Guild/Species	**Population size/relative abundance**	**Reproductive success**	**Rapid assessment info feasible**
Albatrosses	Census or plots	Census or plots	Presence, abundance, phenology
Burrowing petrels + shearwaters - coastal	Census, plots, occupancy	Census or plots	Presence, rough abundance, phenology
Burrowing petrels + shearwaters -	Colony mapping+plots if dense, else radar or	Plots	Presence, phenology

montane	songmeters		
Boobies, frigatebirds, tropicbirds	Census, plots, mean incubation counts	Census, plots, mean incubation counts	Presence, abundance, phenology
Terns+noddies-ground	Colony mapping+plots, mean incubation counts, occupancy	Plots	Presence, rough abundance, phenology
Terns+noddies - tree	Census, plots (trees), occupancy	Census or plots	Presence, rough abundance, phenology
Terns+noddies - cliff	Plots	Census or plots	Presence

Albatrosses. Because albatrosses are large, diurnal, nest and roost on the ground surface, and not that sensitive to human disturbance, it is relatively easy to count the numbers of nests and individuals in a colony. Albatrosses are fairly synchronous breeders, and a single count near the end of egg-laying can yield an accurate count of the number of nests each year. A complete census is conducted annually even in the largest albatross colony on Midway Atoll, though this is labor-intensive. However, as explained above, the number of nests observed each year is an underestimate of the actual breeding population because some adults skip breeding each year (Kendall et al. 2009). The proportion of adults that skip breeding each year averages about 20% in Laysan and Black-footed albatrosses (Rice and Kenyon 1962, Fisher 1976, VanderWerf and Young 2012). A single count made just after hatching can be used to accurately measure hatching success. All nests can be monitored in smaller colonies like those on Oahu and Kauai (Young et al. 2009), but in large colonies it is necessary to use study plots. For either scenario, nests should be individually marked to allow identification on repeated visits. Measuring fledging success is more difficult because chicks begin to leave the nest site and walk around when they are 2–3 months old, so chicks need to be banded to determine which nest they came from and thus how many have survived (Young and VanderWerf 2008, 2014).

Monitoring survival of adult and juvenile albatross requires long-term banding and repeated recapture or resighting efforts. At least 4–5 years of data are required to estimate adult survival and at least 10 years are required to measure juvenile survival and recruitment because some birds do not begin breeding until 10 years of age, occasionally even later (VanderWerf and Young 2016). In small colonies, it may be feasible to band and resight all breeders and non-breeders; in larger colonies, study plots must be used to sample individuals. Kendall et al. (2009) provide detailed recommendations for improving monitoring efforts designed to measure survival of albatross and other colonial seabirds, including the use of study plots with buffer areas to account for local movements, double banding to prevent loss of information associated with band loss, and multiple capture periods per season that allow use of robust design models to monitor albatrosses.

Another technique that is particularly useful for monitoring albatrosses is collection of boluses, which are the undigested food remains regurgitated by adults and juveniles. These boluses provide a measure of plastic ingestion and also can be used to measure isotopic components of diet and contaminants. For more information, see the previous section on pollution.

Burrowing shearwaters and petrels - coastal species. Most shearwaters and petrels that nest in coastal areas are not that difficult to monitor because they nest in relatively open sandy or rocky terrain where the nests are easy to find, but the effort required varies among species and depends on their body size and several aspects of their nest location. Wedge-tailed Shearwaters and Bonin Petrels are easier to monitor because they often nest in sandy substrate where their burrows are obvious (Byrd et al. 2003). In some areas, Wedge-tailed Shearwaters nest in rocky terrain, but most nests are in larger caves and crevices in which the birds are visible. Christmas Shearwaters nests are placed in a shallow scrape under dense vegetation or in rocky caves and require more searching although most are readily visible. Bulwer's Petrels, which are smaller and nest in smaller rock crevices, can be more difficult to detect depending on their nesting locations. Some individuals nest in larger caves or crevices where they are visible, but others may be deep inside small crannies or rubble into which it is not possible to see or reach. Bulwer's Petrels often reply to an imitation of their soft barking call, and this can used to detect them at night and locate them in places where they are not visible. The nests of Tristram's Storm-Petrels may not be hard to find, but because they are small it can be difficult to observe their contents. A burrow scope, consisting of a digital camera mounted on the end of a flexible hose and connected to a viewing screen, can be useful for examining the contents of very long, twisted, or narrow burrows.

Population size in burrowing shearwaters and petrels usually can be measured or estimated because the distribution of nests and extent of the colony is visible. In small colonies, it may be possible to conduct a complete census by counting every burrow. In larger colonies, an estimate of population size can be obtained by measuring the density of nests in a series of plots and then extrapolating to the entire area of the colony. For example, at Kaena Point on Oahu, the number of Wedge-tailed Shearwater nests was censused each year when the number of nests was relatively small, but as the number of nests grew in response to management, a plot system was used to estimate the number of nests, with both a census and plots used during a transition year to determine the size of plots needed to provide an accurate estimate (VanderWerf et al. 2014).

Monitoring the breeding biology of burrowing shearwaters and petrels is feasible but requires more effort than in some other species because the nests are underground. To determine nest contents, the following techniques can be used, in order of increasing effort required: looking into the burrow or crevice, using a flashlight if necessary, feeling gently by hand, and using a burrow scope if the burrow is too long or small to reach into by hand. Because breeding is fairly synchronous, a single visit at the end of egg-laying often can be used to determine the total number of nests, and a single visit at the end of hatching can be used to measure hatching success. However, if some nests are abandoned or depredated shortly after laying, a single visit may yield an underestimate of the number of nests, and several visits may be needed (e.g, Pravder et al. 2015). The timing of these visits is crucial to obtaining accurate estimates; depending on the degree of synchrony and frequency of abandonment and predation, a visit made to early may miss the last eggs laid, while a visit made too late may miss nests that are depredated or abandoned. It may be necessary to make several visits during each stage of the nesting cycle for one or more years to determine the breeding phenology, which can then be used to select the best time for each visit in subsequent years. Because chicks of these species usually don't leave the nest until they are close to fledging, it is not necessary to band chicks to distinguish them from others in order to monitor their survival, though banding is still useful for other purposes.

Burrowing shearwaters and petrels - montane species. Shearwaters and petrels that nest in burrows in montane areas are difficult to survey for several reasons. Their burrows are difficult to find because they usually are located under dense vegetation, on steep cliffs, or in extensive lava fields. They also are active and vocal at the colony only at night, when they are difficult to observe except with special equipment such as night-vision optics or thermal imagery. Conducting surveys in dense montane vegetation also can create pathways that predators can use to access the nests. In turn, obtaining estimates of population size is difficult because the extent of colonies and the density of nests within them are difficult to determine. In most cases, abundance of these species is monitored using an index of abundance, such as frequency of acoustic detections made by observers or with automated recording units, or radar targets observed per unit time. For example, radar was the primary monitoring method used by Day et al. (2003) and Raine et al. (2017) to document a decline in abundance of Newell's Shearwater on Kauai. Similarly, on the steep and densely vegetated slopes of Mt. Lata on the island of Tau in American Samoa, acoustic sampling has been the primary method used to detect and measure relative abundance of Tahiti and Herald petrels and Tropical Shearwaters (O'Connor and Rauzon 2002, Titmus 2017).

To determine the location and size of a population of montane nesting shearwaters or petrels, a step-down approach can be used to narrow the search area. In areas where they are suspected to occur but not confirmed, automated recording units deployed during the breeding season can be used to document the presence of birds in an area. In order to narrow down the ground search locations in large areas, it is recommended that recording units be moved (if practical) during the breeding season throughout the area where birds are suspected to occur. In areas with frequent calling where birds may have a higher likelihood of nesting, on-the-ground auditory surveys should be conducted, and if available, combined with thermal imaging to determine where birds may be landing. Data from the auditory and visual surveys can then be used to inform targeted ground searches for actual burrows thus reducing the search area and potential habitat damage in hard to traverse locations. In order to conduct any type of reproductive success monitoring, it is imperative to find actual burrows. Raine et al. (2017) have shown that combining methodologies yields the best results for locating colonies and finding burrows to monitor.

Because many montane shearwaters and petrels in the USTP are threatened by introduced mammalian predators, monitoring predation at nests is a priority for many of these species. Monitoring breeding success can be accomplished using the same methods described above for coastal species, but in general locating nests of montane species requires more effort. Each year, burrows with nesting activity should be located at the start of the season and monitored through fledging. If burrows are too deep to confirm the presence of an egg or chick visually, a burrow scope can be used to look inside, or remote cameras can be used to monitor activity at the burrow. Cameras can record parental attendance rates, chick emergence and fledging dates, predation events, and the identity of predators. If the contents of a burrow are unknown and it is not possible to determine whether an egg was present or a chick fledged, then the nest should not be included in measures of nest success. Finally, mapping all known current and previously used burrows in a colony can be a useful measure of colony distribution and size, and burrow occupancy can be used as another measure of population trend. It is also worth noting that human activities associated with monitoring nests and nest predation can create trails or otherwise increase accessibility of nests to predators. It therefore often is desirable to simultaneously control predators to avoid unintentionally increasing predation on nests.

Boobies, frigatebirds, and tropicbirds. These species are relatively easy to monitor in most situations because they are large, diurnal, and nest and roost on the ground or in small to medium trees or shrubs. However, all species in this group have protracted breeding seasons and do not nest synchronously, so single counts will not yield an accurate population estimate. Mean incubation counts conducted over several months have been used as the primary survey method in the USTP (Dearborn and Anders 2006, Citta et al. 2007, Russell and VanderWerf 2010, VanderWerf and Young 2014, VanderWerf and Raine 2016). Frigatebirds have particularly long nesting cycles, up to 15 months, and therefore may not nest on a regular annual cycle (Dearborn and Anders 2006). Brown and Masked boobies generally are the easiest of this group to monitor because they nest on the ground and their nests usually are visible. Red-footed Boobies and frigatebirds nest in vegetation ranging from low shrubs to large trees, and it may require extra effort to view nests that are located higher off the ground (e.g. Russell and VanderWerf 2010), though both species build large stick nests that usually are visible from below. A ladder or pole-mounted mirror can be used if necessary to examine nest contents of some higher nests. Brown Boobies and Red-tailed Tropicbirds nest on coastal cliffs in some areas; in such cases boat-based surveys may be the best method for observing nests (see the section below on cliff nesting terns).

All of these species can be sensitive to human disturbance so care is needed to avoid flushing birds from nests, which exposes eggs and chicks to overheating and predators and may cause parents to accidentally damage eggs or injure small chicks or knock them from the nest. Booby chicks are altricial (small and naked at hatching) and especially vulnerable, and Brown Boobies in particular are easily disturbed. If it is necessary for monitoring purposes to approach nests of these species and adults are likely to be flushed from nests, visits should be made during the cooler parts of the day and their duration should be as brief as possible to allow adults to return to the nest quickly. Adults and chicks of these species also may regurgitate if approached closely or handled; this can facilitate collection of diet samples, but it also causes stress to the birds and deprives them of food and should be avoided if possible.

Population size and trend of these species can be measured by censuses using mean incubation counts in smaller colonies. For larger colonies, population size and trend is best measured using plots to measure nest density and colony mapping to measure distribution. Monitoring reproductive success of these species is best accomplished by individually marking nests to help relocate them on each visit and then monitoring nests over time; this can be done as a census of the entire colony or using study plots. Citta et al. (2007) found that five plots were sufficient for monitoring reproduction of Red-footed Boobies. Nests of these species often become covered in guano over the season, so nest markers should be large enough to remain visible or positioned far enough away from the nest to avoid being obscured by guano.

Red-tailed Tropicbirds are somewhat more difficult to monitor than boobies and frigatebirds because their breeding is more asynchronous, with eggs laid over a several month period, and because they often nest under dense vegetation where their nests are more difficult to locate (Fleet 1974, Citta et al. 2007, VanderWerf and Young 2014). Because their nesting is asynchronous, mean incubation counts have been the primary monitoring method used for this species for many years at several locations in the NWHI; this method has proven to be fairly effective for monitoring abundance, though power to detect changes in abundance was limited at some sites because of small population sizes and possibly variation in effort among years (Citta et al. 2007). Plots may be needed to monitor Red-tailed Tropicbirds in larger colonies and in some situations where additional search effort is required to locate nests (VanderWerf and Raine 2016). Plot-based monitoring has been used on Midway Atoll, where the number of plots varied among years and compromised data analysis (Citta et al. 2007). In a small colony on Oahu, intensive monitoring of individually-marked nests at approximately weekly intervals has been used to census the population and measure breeding phenology and reproductive success (VanderWerf and Young 2014).

The White-tailed Tropicbird is the most difficult species in this group to monitor, and was the least monitored species of seabird in the USTP, because it nests in caves on steep cliffs, in tree cavities, or among the base of coconut palm fronds, all of which make it difficult to find nests (VanderWerf and Young 2018). If nests can be located and safely accessed, no special methods are needed to monitor them although the sample of nests is likely to be small. Cliffs are the primary nesting site on higher islands, such as the southeastern Hawaiian Islands, the Marianas, and American Samoa. Tree cavities are used in Palau, Midway Atoll, Palmyra Atoll, and American Samoa. Coconut palms are used on Palmyra and Christmas Island in the Line Islands, the Marshall Islands, and possibly other areas.

Large numbers of non-breeding boobies and frigatebirds visit colonies and may spend extended periods of time there even when not breeding. Frigatebirds in particular may roost in places where they do not nest, and in some locations there may be more non-breeders than breeders present. These non-breeders may constitute a large portion of the total population, and monitoring their numbers can provide important information about their population dynamics (Dearborn and Anders 2006). Frigatebirds also are known to move among islands, and birds may regularly visit multiple islands (Dearborn et al. 2003); effective monitoring of frigatebird numbers would be improved by simultaneous, coordinated efforts among islands.

Terns - ground nesters. Species in this group in the USTP include Sooty, Gray-backed, Least, and Little terns. These species all are sensitive to disturbance and may leave their nests if humans approach, exposing eggs and chicks to the elements and predators. Surveys should be done only during cooler hours of the day to avoid heat stress to eggs or small chicks, and should be brief to allow parents to return to the nest as quickly as possible. If predators are present near the colony, particularly frigatebirds, special care and discretion should be exercised to avoid flushing birds from nests and risking predation.

Least and Little terns nest only in scattered pairs in the USTP so counting and monitoring their abundance and reproduction is fairly straightforward. The only potential complication is that these species are difficult to distinguish and they may nest in the same location, as has occurred on Midway Atoll (Pyle et al. 2001), so care is needed to correctly identify species and their numbers.

Gray-backed Terns usually have fairly high breeding synchrony and nest in relatively small colonies. In many cases, it should be possible to conduct a complete census of the number of nests or adults. If colonies are larger or it is necessary to reduce disturbance, they also can be monitored using study plots and perimeter mapping as previously described in the section on plot-based methods (p. 16) and colony mapping (p. 22).

Sooty Terns usually nest in very large colonies and their breeding season can vary among years (Flint 1991, Jaquemet et al. 2007); both of these factors complicate monitoring. Most Sooty Tern colonies are much too large to census completely, and attempting to do so would cause considerable disturbance to the colony and probably failure of some nests to exposure or predators. The most practical method of measuring abundance of Sooty Terns is to use a series of plots to measure density of nests, and then map the perimeter of the colony using GPS. The combination of density and distribution can be used to calculate the number of nests. To reduce bias in the population estimate, the plots should be distributed throughout the colony and must be representative of any variation in density caused by differences in vegetation, substrate, etc.

(Saliva et al. 1989, Feare et al. 1997). Citta et al. (2007) suggested using automated pole-mounted cameras to photograph plots over time and using the resulting photographs to count nests and monitor their success, though this method has not been tried previously. Measuring reproductive success also is best done using plots in which individual nests are marked for identification. However, Sooty Tern chicks begin walking around the colony not long after hatching, so measuring survival of chicks to fledging is difficult.

Terns - tree nesters. Species in this group include White Tern, Brown Noddy (in some locations), and Black Noddy (in some locations). Although they all nest in trees, other aspects of their breeding biology differ and different methods are needed to monitor various aspects of their demography.

White Terns nest in trees, shrubs, occasionally on the ground, and even on human structures in some locations (Rauzon and Kenyon 1984, Niethammer and Patrick 1998, VanderWerf and Downs 2018). White Terns do not build a nest and lay their single egg on a flat surface and thus can be limited by availability of suitable sites in which to lay an egg; usually only a few nests are located in each tree and in some cases nests are dispersed over a large area and do not really form a colony (VanderWerf and Downs 2018). When nesting in tall trees, the best indication of the presence of White Terns often is the distinctive clusters of white droppings that accumulate under trees used regularly. The number of White Terns present in an area is likely to be highest at night and in the early morning before many birds have left to forage at sea (VanderWerf and Down 2018). White Terns breed year round in many areas, individual pairs may make more than one breeding attempt per year, and some pairs raise two or even three chicks per year (Carlile and Priddle 2015, VanderWerf and Downs in press). A single count of adults or nests therefore would underestimate the actual population size; mean incubation counts provide a more accurate measure of breeding population size although care must be taken to account for renesting attempts by individual pairs (see breeding frequency section above). Because they are often more widely dispersed, White Terns are one of few seabird species for which point counts and distance-based methods can be used to estimate abundance. For example, VanderWerf (2007) used point count data to calculate relative abundance of White Terns in Palau, and Camp et al. (2009) used distance data from point counts to estimate population density on Saipan in the Mariana Islands.

Black Noddies are the most difficult of the tree-nesting species to monitor because they often nest in large, dense colonies, nests are often densely clustered in tall trees, they have an asynchronous and variable nesting phenology, and may nest more than once per season in at least some locations (Gauger 2000, Citta et al. 2007). Mean incubation counts have been the primary method used to monitor Black Noddies in the NWHI, but Citta et al (2007) found that the number of nests was so variable over time that they concluded there was little chance of detecting changes in population size using this method and were not able to recommend a better alternative.

Several techniques can be used to facilitate monitoring of this species, depending on specific aspects of each colony. In locations with large trees, such as ironwood (*Casuarina equisetifolia*) or *Pisonia grandis*, there may be dozens of nests in a single tree and some nests may be 20–30 meters above the ground, making them difficult to see and monitor. In such situations, it may be possible to count the nests from the ground using binoculars, but monitoring reproductive success is difficult. If the nests are not too high it may be possible to use a small mirror or camera mounted on a pole to view or take photos or video of the nest contents, which can be viewed after the camera is lowered or by connecting it to a video monitor. One such device that is available commercially is called the "treetop peeper" (http://www.sandpipertech.com). It's also possible to make similar devices yourself. Most colonies are too large to be censused so plots have been used in most locations; Citta et al. (2007) found that seven plots were sufficient to monitor reproductive success of this species with 95% confidence.

One method for simplifying nest counts is to count nests in each tree individually and then sum the numbers for all trees. If the colony is very large and it is not possible to count all nests in every tree, then trees can be sampled by counting nests in random trees (if there is a practical method of identifying trees for selection) or in a fraction of trees (e.g., every other tree, every third tree, or even fewer in very large colonies). Similarly, if it is not possible to monitor success of all nests in a colony, then nests can be sampled by choosing nests only in randomly selected trees, or choosing only randomly selected nests in each tree. Another method that can provide an index of abundance is occupancy (Refer to the previous section on occupancy for more details). For example, the proportion of trees with active nests could be used as a quick measure of relative abundance that could be monitored over time. If nests are too high to mark for individual monitoring, photographs can be used to record the location of nests and assign unique identities for monitoring purposes to facilitate relocating the same nests on each visit.

Brown Noddies exhibit extreme geographic variation in nesting behavior so different methods are needed to monitor them in different areas. On some islands they nest primarily on flat ground in shallow scrapes, but on other islands they nest on ledges or caves in coastal cliffs, in stick nests on low shrubs, in tall trees, and even in coconut palms (*Cocos nucifera*) in locations such as Kwajalein and other atolls in the Marshall Islands (E. VanderWerf pers. obs.). Brown Noddy colonies usually are not as large or dense as those of Sooty Terns or Black Noddies. When nesting in tall trees they can be monitored using the same methods described above for Black Noddies. When nesting on flat ground or low shrubs it may be feasible to conduct a complete census, or if the colony is too large or time is limited, population size can be estimated using plot-based methods and mapping described for Sooty Terns. Nests in coconut palms are concealed among the bases of the palm fronds and are especially difficult to find and monitor; in this situation it may be necessary to use the number of adults flying over a nesting area at a particular time of day as a proxy for actual population size.

Terns - cliff nesters. Species in this group include Bridled Tern, Blue-gray Noddy, Brown Noddy, and Black Noddy in some locations. Estimating population size and other demographic parameters of these species often is difficult because of the location of their nests. In cases where at least some nests can be accessed on slopes or at the base of cliffs, these species can be monitored using the standard methods described above and no special techniques are needed. In other situations it may be possible to monitor some nests from a distance using binoculars or a telescope. The number of nests in such accessible or visible locations can be used as an index of abundance, but because they would be a non-random subset of all nests it is possible they may not be representative of the colony as a whole. For example, nests located in the lower portion of a colony that can be accessed by humans also would be more accessible to predators and may experience higher rates of nest failure than other sections of the colony. Similar biases could occur if certain areas of the colony are more subject to wind, rain, erosion, or storm wave surge.

Surveys by boat can be useful to monitor seabirds that nest on coastal cliffs in some areas. For example, O'Connor and Rauzon (2004) conducted boat surveys around the entire island of Tutuila in American Samoa. If such surveys are used to monitor long-term population trends, it is important to ensure that the methods remain consistent over time, including such factors as vessel size (which can affect stability and ability of observers to see birds), locations surveyed, and time of day. This technique might be useful for monitoring Black Noddies nesting on cliffs and in sea caves in the southeastern Hawaiian Islands.

SPECIES PRIORITIZATION

A species prioritization exercise was conducted to help managers decide which species in the USTP are most in need of improved surveying and how to allocate resources available (Table 3). There are several strategies that could be used to prioritize species and it should be emphasized that the process used here is based specifically on existing seabird monitoring and improvements needed in the USTP, as identified in a seabird monitoring gap analysis conducted by VanderWerf and Young (2018). This prioritization was based on four criteria: 1) USTP data gaps, which was a measure of how much information was available for a species; 2) USTP geographic gaps, which was a measure of the spatial range over which data have been collected; 3) degree of threat, based on a combination of status on the IUCN red list and under the U.S. Endangered Species Act (ESA) and related mandates; and 4) proportion of the worldwide population found in the USTP. The factors for geographic and data gaps indicate the extent to which current surveying is sufficient, in terms of both variety of data collected and the proportion of the species range represented in that data. The threat factor incorporates concern about the species status, which is based on population size, trend, and threats. The factor for USTP proportional population provides a larger perspective about stewardship responsibility of monitoring global biodiversity; data gaps for species that occur primarily in the USTP mean that information is lacking globally. This is similar to the idea of "Stewardship Species," which are species and subspecies for which the USTP supports over 50% of the global population (Citta et al. 2007).

Each species was given a score from 1 to 5 for each factor, with higher values indicating a greater survey need. The four scores were then summed for each species to obtain an overall prioritization score. Species were then ranked based on their total scores, with higher scores indicating a higher priority. Although the possible total score could range from 4 to 20, the actual species scores ranged from 5 to 15 (Table 3).

For data gaps, the score was based on surveying gaps identified by VanderWerf and Young (2018). Lower scores were given to species for which a wide variety of data are being collected currently. Higher scores also were given to species for which few types of data are collected, or species for which most or all surveying is historical only. An intermediate score was given to species with moderate amounts of information collected.

For geographic gaps, species were scored on a linear scale based on the proportion of islands in the USTP on which they are currently surveyed (VanderWerf and Young 2018), with higher scores given to species that are surveyed in a smaller portion of their range:

- 81-100% = 1
- 61-80% = 2
- 41-60% = 3
- 21-40% = 4
- 0-20% = 5

The threat factor score was an average of two scores: one based on IUCN criteria and the second based on status under the ESA and other US regulations. Scores for IUCN threat level were as follows:

- Least concern (LC) = 1
- Near threatened (NT) = 2
- Vulnerable (V) = 3
- Endangered (E) = 4
- Critically endangered (CR) = 5

Scores for status in the US relied on ESA listing and whether a species is considered a bird of Conservation Concern (BCC), which are species that potentially could become listed under the ESA without some type of management action (USFWS 2008). Scores under ESA and other US regulations were as follows:

- No listing status = 1
- Species of conservation concern = 2
- Threatened = 3
- Endangered = 5

For the proportion of the species population found in the USTP, worldwide population estimates for all species were taken from the IUCN Red List (IUCN 2017), and the estimated numbers of pairs breeding in the USTP were taken from Pyle and Pyle (2017) for Hawaii and the literature for species outside Hawaii. Higher scores were awarded to species with a greater proportion of their global population in the USTP as follows:

- 0-20% = 1
- 21-40% = 2
- 41-60% = 3
- 61-80% = 4
- 81-100% = 5

Table 3. Monitoring prioritization scores for seabird species in the U.S. Tropical Pacific, order from highest to lowest priority.

Species	Data gap score	Geographic gap score	Threat score	USTP range score	Total score	Rank
Bonin Petrel	5	4	1	5	15	1
Phoenix Petrel	5	5	3	1	14	2
Hawaiian Petrel	1	1	4	5	11	3
Tahiti Petrel	5	3	2	1	11	3
Tristram's Storm-Petrel	3	2	2	4	11	3
White-tailed Tropicbird	4	5	1	1	11	3
Blue-gray Noddy	5	4	1	1	11	3
Newell's Shearwater	1	1	3.5	5	10.5	8
Bulwer's Petrel	3	3	1	3	10	9
White-throated Storm-Petrel	5	1	3	1	10	9
Lesser Frigatebird	5	3	1	1	10	9
Great Frigatebird	4	3	1	2	10	9

Brown Noddy	4	4	1	1	10	9
Black Noddy	3	4	1	2	10	9
Gray-backed Tern	3	3	1	3	10	9
Black-footed Albatross	1	1	2	5	9	16
Laysan Albatross	1	1	2	5	9	16
Tropical Shearwater	5	2	1	1	9	16
Band-rumped Storm-Petrel	4	1	3	1	9	16
Red-tailed Tropicbird	2	3	1	3	9	16
White Tern	2	4	1	2	9	16
Sooty Tern	3	3	1	2	9	16
Christmas Shearwater	4	2	1.5	1	8.5	23
Herald Petrel	5	1	1.5	1	8.5	23
Least Tern	3	1	3	1	8	25
Little Tern	3	3	1	1	8	25
Short-tailed Albatross	1	1	4	1	7	27
Masked Booby	3	2	1	1	7	27
Red-footed Booby	3	2	1	1	7	27
Brown Booby	2	2	1	1	6	30
Wedge-tailed Shearwater	1	2	1	1	5	31
Least Tern	3	1	3	1	8	25
Little Tern	3	3	1	1	8	25

This prioritization system does not consider whether a species could serve as an indicator species. For example, the Wedge-tailed Shearwater ranked low because there already is a large amount of data being collected, the species is not threatened, and it has a wide global distribution, but these factors also make it suitable as an indicator species, in which data is relatively easy to collect and could be compared across geographic regions.

Citta et al. (2007) previously conducted a prioritization on what types of information should be gathered for species in the USTP. In summary, their findings supported the following monitoring goals listed in order of importance:

1. Breeding population size,
2. Reproductive success
3. Survival.

Citta et al. (2007) also recognized that the order of these priorities may vary among species or in certain circumstances (for example, if the breeding population size is harder to estimate than reproductive success). Breeding population size can be the most useful parameter to measure because in the long-term it reflects multiple demographic processes, including reproduction, survival, emigration and immigration. Although adult survival often is the most important component of population dynamics because seabirds are long-lived, it was ranked as the final monitoring priority because it is labor intensive to measure, technically challenging, logistically infeasible at some remote islands, and requires a long-term commitment of resources. A combination of the species priorities presented in this guide and the monitoring priorities presented by Citta et al. (2007) will serve as useful references for those designing seabird monitoring programs.

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