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Data Quality Standards for Sea Otter Monitoring in Glacier Bay National Park, Alaska

Natural Resource Report NPS/SEAN/NRR—2018/1763

ON THE COVER
Sea otters resting near Boulder Island in Glacier Bay National Park and Preserve.
NPS/JAMIE WOMBLE

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September 2018

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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Please cite this publication as:

Womble, J. N., P. J. Williams, W. F. Johnson, and L. F. Taylor-Thomas. 2018. Data quality standards for sea otter monitoring in Glacier Bay National Park, Alaska. Natural Resource Report NPS/SEAN/NRR—2018/1763. National Park Service, Fort Collins, Colorado.

NPS 132/148547, September 2018

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Executive Summary

The purpose of this report is to document the standards used by the National Park Service (NPS) Southeast Alaska Network (SEAN) for activities related to the collection, processing, storage, analysis, and publication of monitoring data for sea otters as described in the Sea otter monitoring protocol for Glacier Bay National Park, Alaska version SO-2017.1 (Womble et al. 2018). The policies and procedures documented in this quality assurance plan complement the quality assurance methods for other monitoring activities conducted by the SEAN. The plan also serves as a guide for all SEAN personnel who are involved in protocol/program activities and as a resource for identifying memoranda, publications, and other literature that describe associated techniques and requirements in more detail and as a resource for end-users of program data.

Acknowledgments

The development of this monitoring program was funded by the NPS Southeast Alaska Network (SEAN), Southwest Alaska Network (SWAN), and the Glacier Bay Marine Management Fund. The development of this protocol has benefitted greatly from discussions with Mevin Hooten (United States Geological Survey [USGS], Colorado State University), George Esslinger, Dan Esler, Dan Monson (USGS, Alaska Science Center), Heather Coletti (NPS), and Michelle Kissling (United States Fish and Wildlife Service; USFWS). We appreciate the assistance of Nina Chambers (NPS) with document formatting and copy editing. Research and monitoring was conducted under U.S. Fish & Wildlife Service Scientific Research Permit #MA14762C-0 and NPS Scientific Research Permit GLBA-2016-SCI-022.

Introduction

The purpose of this report is to document the standards used by the National Park Service (NPS) Southeast Alaska Network (SEAN) for activities related to the collection, processing, storage, analysis, and publication of monitoring data for sea otters as described in Sea Otter Monitoring Protocol for Glacier Bay National Park, Alaska Version SO-2017.1 (Womble et al. 2018). The policies and procedures documented in this quality assurance plan complement the standard quality assurance and quality control activities conducted by the SEAN (Johnson and Moynahan 2008).

Protocol Overview

This protocol outlines how monitoring data are collected, managed and reported for the sea otter "Vital Sign," as a part of the SEAN Vital Signs Monitoring Program. The study design, data collection methods, and analytical protocols have been previously documented in three publications in *Ecology* (Williams et al. 2017a, Williams et al. 2018) and *Methods in Ecology and Evolution* (Williams et al. 2017b).

Conceptual Framework for Monitoring

Sea otters are an apex consumer in the nearshore regions of the North Pacific Ocean and are known to influence and structure nearshore marine communities (e.g., Estes and Palmisano 1974). Sea otters were virtually extirpated from southeastern Alaska by 1911 due to the commercial fur trade; however, approximately 400 sea otters were reintroduced to southeastern Alaska in the 1960s (Kenyon 1969). By 1988, sea otters had expanded into lower Glacier Bay and the U.S. Geological Survey began aerial survey monitoring efforts to monitor the colonization, distribution, and abundance of sea otters in Glacier Bay through 2012 (Esslinger 2013). Sea otters are currently one of the most abundant marine mammals in Glacier Bay and were selected as a vital sign by the SEAN in 2015.

Monitoring the spatial distribution and abundance of sea otters in GLBA has been justified and prioritized for a number of reasons.

(1) Sea otters are recognized as an apex or keystone species due to their ability to limit prey populations and influence nearshore marine community structure. The effects of sea otter predation in nearshore communities are well-documented in rocky substrate habitats in the North Pacific Ocean (Estes and Palmisano 1974). The top down influences on nearshore prey species include maintaining a more diverse nearshore ecosystem. There is also interest in understanding the potential top-down effects and bottom-up responses in Glacier Bay where unconsolidated sediments are more common.

(2) Sea otters recently (around 1988) colonized and expanded into much of Glacier Bay and currently are one of the most abundant marine mammals in the park. From 1988 to 2012, the USGS and Glacier Bay National Park maintained a research and monitoring effort quantifying the abundance of sea otters, foraging behavior of sea otters, and benthic invertebrate communities to study the role that colonizing sea otters play in structuring nearshore marine communities in Glacier Bay (Estes and Duggins 1995, Donnellan et al. 2002, Bodkin et al. 2007, Esslinger et al. 2013, Weitzman 2013). Prior efforts provide

baseline data and a solid foundation for the development of new approaches for monitoring sea otters in Glacier Bay and a framework that incorporates a contemporary model-based design and digital aerial photographs.

(3) The founding legislation and purpose statement of Glacier Bay National Park and Preserve is "to protect the dynamic tidewater glacial landscape and associated natural successional processes for science and discovery in a wilderness setting." Specifically, "Glacier Bay National Park and Preserve protects a natural biophysical landscape that is continually changing through large-scale natural disturbance followed by the biological succession of plants and animals, and accompanied by an evolving physical environment" (Glacier Bay National Park and Preserve Foundation Statement 2010). The ongoing colonization of Glacier Bay by sea otters offers a unique opportunity to study succession in the nearshore marine ecosystem. Quantifying and understanding the colonization, spatial distribution, and abundance of sea otters in Glacier Bay will be important for understanding top-down and bottom-up processes in the nearshore marine communities.

(4) The development of a robust quantitative framework for monitoring sea otters will be important for evaluating population status, spatial distribution, and abundance within Glacier Bay and contributing to Alaska-wide estimates of abundance of sea otters by informing the USFWS stock assessments for sea otters in Alaska, which are required under the Marine Mammal Protection Act of 1972.

(5) Sea otters also are designated as a vital sign in Kenai Fjords National Park and Katmai National Park and Preserve and are monitored by the SWAN (Coletti et al. 2016). Monitoring sea otters across Alaska parks provides the opportunity to contribute to a broader understanding of the species status and ecology.

(6) Sea otters are highly susceptible to injury from marine contaminants and oil spills given their nearshore distribution, diet, and small home ranges (Lipscomb et al. 1993, 1994, Rebar et al. 1995, Monson et al. 2011), thus understanding the spatial distribution and abundance of sea otters in Glacier Bay will provide important baseline data.

Protocol Activities and Modules

In 2015, sea otters were identified as a vital sign by the National Park Service's Southeast Alaska Network (SEAN) Monitoring Program due to their role as a keystone species in the nearshore marine ecosystem. The primary objectives of the monitoring program are to use contemporary field and analytical methods to monitor the abundance and spatial distribution of sea otters in Glacier Bay. A spatio-temporal statistical model representing current knowledge of sea otter abundance and distribution, including underlying ecological processes governing colonization dynamics in Glacier Bay, was constructed using multiple sources of data collected on sea otters between 1993 and 2012 and will accommodate future data to be collected via aerial photographic surveys. Specifically, a partial differential equation that incorporates knowledge of sea otter ecology and behavior including habitat preferences, maximum growth rates, and observations of sea otters was developed and embedded within a Bayesian hierarchical framework to accommodate uncertainty in the data collection process, the ecological process, and the model parameters. Development and testing of a new monitoring design and field methods were initiated in 2016 with a suite of objectives aimed at improving the safety of aerial surveys, the reliability of abundance and distribution information for informing park managers, and general program sustainability. Contemporary methods for obtaining digital imagery and counting sea otters from the imagery were developed to replace prior observer-based methods. Aerial photographic surveys will be conducted and digital imagery will be archived as a permanent record enabling independent verification of counts of sea otters and quantification of habitat covariates. New methods for estimating availability at the time of sampling utilize replicate counts, from repeated images of a group of sea otters, within an N-mixture model framework to estimate detection probability.

The new monitoring design implements an iterative optimal dynamic sampling scheme to increase sampling efficiency, providing the most information from the data that can be collected affordably. The spatio-temporal model will be used to generate forecasts of sea otter abundance and associated uncertainty for subsequent monitoring periods. Forecasts then will be used as a template to select a set of survey transects that minimize the uncertainty in model-based forecasts of predicted abundance of sea otters. Optimal survey designs will be updated following each year data are collected, and therefore are dynamic through time. A set of random transects also will be selected to supplement, validate, and compare abundance estimates of sea otters among sampling approaches. Reallocation of effort among survey types will be considered in the future as another means to optimize program performance and efficiency.

The combination of using (1) aerial photographs for collecting data, (2) advanced and flexible statistical models that incorporate our understanding of the ecological system, permitting rigorous estimates of occupancy, abundance, and colonization dynamics, and (3) a sampling framework that explicitly links our statistical model and future data to be collected, will improve monitoring efficiency, and our ecological understanding of sea otters in Glacier Bay.

Measurable Objectives

(1) Monitor the abundance and spatial distribution of sea otters in Glacier Bay (Figure 1);

(2) Utilize a dynamic spatio-temporal model and flexible statistical framework that can account for multiple sources of uncertainty and accommodate multiple data types and that results in an iteratively refined model using survey results as a primary means to advance ecological learning;

(3) Implement optimal dynamic survey designs to increase sampling efficiency to maximize program sustainability, increase safety, and improve the precision of parameter estimates; and

(4) Provide reliable quantitative information regarding the spatial distribution and abundance of sea otters to assess the status of sea otters in Glacier Bay, inform Alaska-wide stock assessments by USFWS, and inform decisions regarding management actions that may have the potential to impact sea otters and their prey.

Figure 1. Map of Glacier Bay National Park and Preserve in Alaska.

Module Descriptions

(1) Site Reconnaissance. Data associated with aerial photographic transects that are sampled annually (Table 1).

(2) Observations. Data associated with the areas (transects) surveyed for abundance and spatial distribution (Table 1).

(3) Derived data. Modeling of quantities of interest for monitoring including summary statistics or other derivative measures based on data collected (Table 1).

Table 1. Project activity matrix for sea otter monitoring.

Modules	Activity		Description	QA SOP	QC SOP
Site Reconnaissance	1	Transects	Aerial Photographic Transects (Random, Optimal, Abundance)	SOP 10	SOP 10
Observations	2	Aerial Photographs	Aerial photographs documenting otter content along each transect	SOP 6	SOP 13
	3	Tracklog from GPS	Tracklog from GPS used to geo-reference aerial photos	SOP 4	SOP 15
	4	Counts of Sea Otters	Number of otters in each photo broken down into two age classes. Covariates are also recorded here.	SOP 8	SOP 14 SOP 19
Derived Data	5	Detection probability	Probability that sea otters are not available at surface to be photographed	SOP 9	SOP 9
	6	Estimated Abundance	Estimated abundance of sea otters	SOP 9	SOP 9
	7	Bathymetry	Bathymetry layer for Glacier Bay	SOP 20	SOP 20
	8	Slope	Slope layer for Glacier Bay	SOP 20	SOP 20
	9	Boundary	Boundary layer for Glacier Bay	SOP 20	SOP 20

Sampling Design

Optimal Dynamic Sampling Designs and Rationale

A sampling design that provides precise and reliable estimates of abundance, distribution, and colonization dynamics is required for sea otter vital sign monitoring. A dynamic survey design allows investigators to explicitly incorporate models of spatio-temporal processes that characterize the colonization dynamics of a spreading population. Dynamic sampling is concerned with selecting monitoring locations that optimally improve inference about a process of interest (e.g., abundance and distribution). Dynamic sampling designs incorporate data collected during previous surveys to inform optimal sampling locations for future surveys. Optimal dynamic sampling increases sampling efficiency by surveying the areas that will aid in inference the most. Optimal dynamic sampling designs are considerably more efficient than static sampling designs, allowing managers to obtain a greater understanding of the system with fewer resources (Wikle and Royle 1999, Hooten et al. 2012).

Dynamic sampling designs are conceptually straightforward (Figure 2), and analogous to adaptive resource management (Holling 1978). First, a dynamic spatio-temporal process is modeled using baseline data.

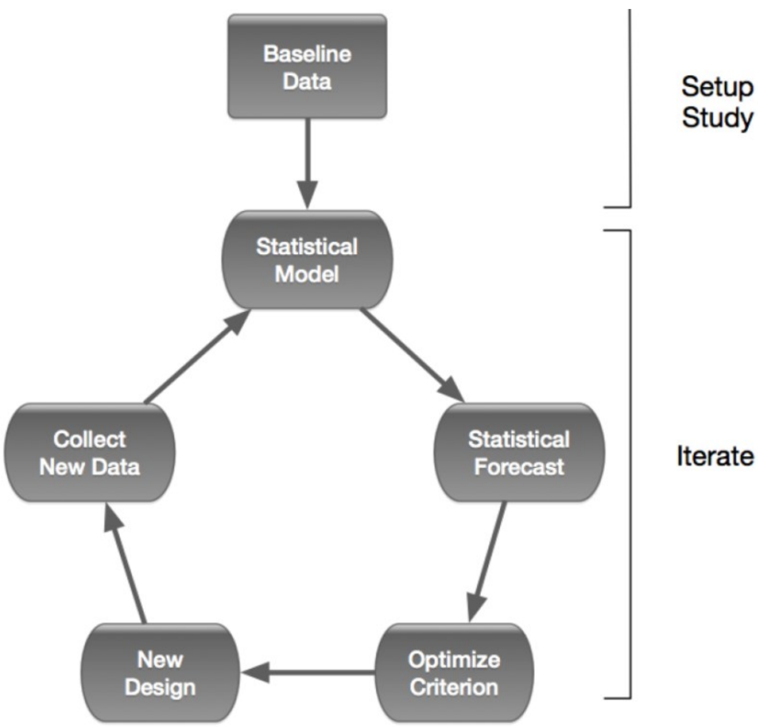

Figure 2. Schematic of optimal dynamic sampling. First, baseline data are used to fit a statistical model. Next the statistical model is used to make a forecast. After the forecast is made, potential designs are evaluated based on an optimization criterion. The design that optimizes the design criterion is optimal. After the optimal design is selected, new data are collected and the model is re-fit using the new data. The cycle then repeats through time, improving our model, and hence understanding of the ecological system.

Next, the model is used to make a statistical forecast. A statistical forecast is a procedure for making predictions about the future based on available data. The statistical forecast also includes estimates of uncertainty about the predictions. After a statistical forecast is made, the goal of an optimal dynamic design is to locate the set of spatial locations to survey that will provide the "best" information for improving future forecasts. "Best" is quantified with a design criterion that is optimized. The design criterion is often associated with minimizing prediction uncertainty, but could also include multi-model uncertainty, cost, or some combination of objectives (e.g., Williams and Kendall 2017). The design criterion maps actions (i.e., the potential designs that are being considered) and the statistical forecasts, to a number that represents some benefit (or cost) associated with each potential design and the predicted future state of nature (Williams and Hooten 2016). The optimal survey design is the design that maximizes the benefit (or minimizes the cost) represented by the design criterion. New data are then collected using the optimal design, and the statistical model is refit using the new data. This entire process (i.e., Figure 2) is repeated through time, updating our ecological understanding by reducing uncertainty in our statistical model.

Hybrid sampling designs combine traditional sampling techniques (e.g., design-based surveys) with dynamic designs to identify an optimal dynamic sampling design (e.g., Hooten et al. 2009). Hybrid sampling is advantageous when fully dynamic designs are prohibitively computationally intensive due to the space of possible sampling designs being large, or when survey effort varies in time (e.g., due to changing operating budgets), and investigators must choose to add sample locations when additional funding is available, or alternatively, remove sample locations as funding becomes more restrictive (e.g., Hooten et al. 2012). Hybrid designs leverage the advantages of traditional, design-based approaches, with the advantages of an optimal dynamic sampling design.

Spreading populations are ideal candidates for optimal dynamic designs or hybrid designs because spreading populations have significant spatio-temporal interactions. Additionally, the spatio-temporal processes that regulate population spread are usually of ecological interest (e.g., processes that influence species invasions, re-establishment of apex predators). Optimal dynamic designs maximize the efficiency in learning about these spatio-temporal processes.

Survey Design Considerations

Survey design considerations are characterized by Figure 2, and include baseline data, a statistical model that will be used to make a forecast of sea otter distribution and abundance using the baseline data, and a design criterion that quantifies the utility of sampling each site, with respect to survey objectives. A summary of design consideration choices are provided in Table 2.

Table 2. Summary of design considerations for optimal dynamic survey design.

Component	Description
Baseline data	Three data sources including: Design-based surveys in 1999-2004, 2006, and 2012. Intensive sample units in 1999-2004, 2006, and 2012. Distributional surveys in 1993, 1995-1998, 2005, 2009, 2010.
Statistical model	A dynamic spatio-temporal statistical model described in Williams et al. (2017).
Statistical forecast	Forecast of abundance and uncertainty to future monitoring period to identify optimal sampling areas.
Optimization criterion	Minimize uncertainty in forecasted abundance. Design criterion described in detail in Williams et al. (2018).
New design	Combination of: Transects that minimize the optimization criterion Random transects Optimal abundance flight

Baseline Data

Sea otter data collected by the USGS between 1993 and 2012 (Esslinger et al. 2013, 2015) provide an excellent source of baseline data to develop a statistical model for characterizing occupancy, abundance, and colonization dynamics (Williams et al. 2017). Ancillary baseline data include distributional surveys conducted by the USGS in 1993-1998, 2004, 2005, 2006, 2009, and 2010, and a data set for estimating detection probability during these aerial surveys.

The design-based survey consisted of a probabilistic aerial survey described in detail in Bodkin and Udevitz (1999). Briefly, this survey consisted of one observer in an airplane flying pre-determined linear transects across Glacier Bay. Transects were placed systematically across Glacier Bay with a random initial transect location. Transects were stratified based on two criteria, seafloor depth and distance from the shore. Areas with depths <40 m received a higher sampling effort than areas with depth >40 m, and areas closer to the shoreline received higher sampling effort. Transects were flown in years 1999-2004, 2006, and 2012. Transects were 400 m wide, indicated by strut marks on the aircraft, flown at velocity 29 m/sec, and at a height of 91 m. Observers searched for and located groups of ≥ 1 sea otters within transects and subsequently counted individuals within groups.

Sea otter distribution surveys were conducted in Glacier Bay by one or more observers in a fixed-wing aircraft. In an attempt to survey all shoreline habitat <40 m in depth, swaths were flown parallel to the shoreline at an altitude of 152 m during calm sea conditions. Distribution surveys were flown in 1993-1998, 2004, 2005, 2006, 2009, and 2010 (Williams et al. 2017). Sea otter counts and flight tracks were recorded on nautical charts and later digitized in ArcGIS (ESRI, Redlands, CA).

The design-based survey observation methods undercounted sea otters due to imperfect detection (e.g., diving sea otters are often uncounted). To estimate detection probability, additional data were collected in intensive search units (ISUs). ISUs were a randomly selected subset of 469 units from the design-based survey. ISU data were collected each year the design-based surveys occurred. At these 469 sites, after a group of sea otters was detected and counted using the procedures from the design-based survey, five concentric circles were flown around groups so observers could obtain precise counts of abundance within the group. The concentric circles were flown in 3.6 minutes, a time chosen based on the aerobic dive limit of sea otters (Thometz et al. 2015; so diving sea otters could be included in the counts when they resurfaced).

Statistical Model

Williams et al. (2017a) developed a spatio-temporal occupancy abundance model for characterizing colonization dynamics, and Williams et al. (*In Review*) rigorously implemented the model to the baseline sea otter data described above. For this application we used the model from Williams et al. (2018) and forecast population spread into the future. As future data are collected, the model will be refit to the new data, and revised as necessary. A full description of the model, and directions to implement and update the model are reported in SOP 9.

Design Criterion

A design criterion based on minimizing prediction uncertainty of the total expected abundance was selected. That is, we want to minimize

$$q_d = \frac{1}{K}\sum_{k=1}^{K}\left(u_{total,T+1,d}^{(k)} - \frac{1}{K}\sum_{k=1}^{K}u_{total,T+1,d}^{(k)}\right)^2$$

where $k=1,\ldots,K$ corresponds to the k^{th} MCMC iteration, $\boldsymbol{q_d}$ *is* the value of the design criterion for a specific design $\boldsymbol{d}$, $u_{\text{total},T+1,\text{d}}$ is the sum of the forecasted process in time $T+1$ across Glacier Bay, estimated using real data, $\mathbf{y}_1, \ldots, \mathbf{y}_T$, *and* future data $\mathbf{y}_{T+1,d}$. Future data are unavailable prior to the survey. Lacking such data, multiple imputation (Rubin 1996, Hooten et al. 2017, Scharf et al. 2017) is used. The document SOP 10 provides a complete description of the design criterion, and directions for finding the optimal design. Additionally, Williams et al. (2018) rigorously describes optimizing sampling designs for sea otters based on this design criterion.

Survey Design

The sea otter survey design consists of up to three types of sampling, and therefore is a hybrid approach (e.g., Hooten et al. 2009). The sampling types include: (1) selecting a random sample of transects, (2) selecting an optimized sample of transects by minimizing model-based prediction variance, described in the previous section, and (3) selecting an optimized survey route by maximizing the predicted abundance of sea otters observed during the flight. The data from each sampling type will be combined cohesively in our model to produce one estimate of abundance (see Williams et al. 2017a for details of how multiple data sources can be combined to generate a posterior distribution of estimated abundance). Each of these survey types is described below in more detail. Initially, without informative prior information on how to distribute sampling effort among sample types and sampling frequency, we distributed effort equally across each sampling type, and each sampling type is to be conducted every year. Effort allocation (both among sampling types and sampling frequency) will be re-assessed after sufficient data have been collected to evaluate the properties of each sampling type. We predicted that it will take approximately 7 years of annual data collection to permit evaluation of the properties of each sampling type. Seven years was chosen because it is approximately how many years of data that are available from each of the design-based and distributional surveys. Annual data collection will provide a rich data set that will permit examining trade-offs between abundance estimates and sampling frequency that we will use in future analyses to optimally identify sampling frequency. Furthermore, recent evidence (Williams et al. *In Review*) suggests the sea otter population in Glacier Bay is approaching (or at) carrying capacity. Thus, collecting data annually during this period will provide valuable insight into regulating mechanisms of the sea otter population in Glacier Bay. After this seven-year period, we will calculate the optimal effort allocation among sampling types and optimal temporal frequency of data collection. This framework is flexible and can be adjusted annually to meet budgetary constraints so that any combination of these survey types could be conducted each year. Additionally, subsequent to data being collected from each of these survey types, the data can be used to examine the efficacy of the survey types, so that future monitoring can be based on the amount of information gained per unit effort of each survey type. Detailed documentation of the site selection procedure and computation methods for selecting sites are provided in SOP 10.

Random Transects

The first survey type is a random sample of transects. Random transects are a type of probabilistic, design-based survey, and therefore have desirable characteristics (unbiased estimates of abundance) and are widely used for wildlife surveys. To select random transects, we first identified a survey area (Figure 3). In 2017, the survey area was 68 km x 56 km, and omitted parts of the arms of Glacier Bay. In 2018, we expanded the survey area to include all of Glacier Bay (72 km x 60 km), including the arms. After the survey area was selected, it was partitioned into a grid with 400 m x 400 m cells. The cell size was chosen because previous data were collected at a range of 400 m, and for computational tractability (smaller cell sizes were not computationally feasible). Then rows of the grid (representing the transects) are randomly selected. The number of transects (n_{rt}) selected can vary depending on available funding. Initially, 20 transects were chosen for the first sampling year (i.e., 2017) based on the number of transects that could be flown given a flight-time restriction of 4 hours, with 1.5 hours of travel between the Juneau origin and Glacier Bay (Figure 3). New random transects are selected each year the survey is conducted.

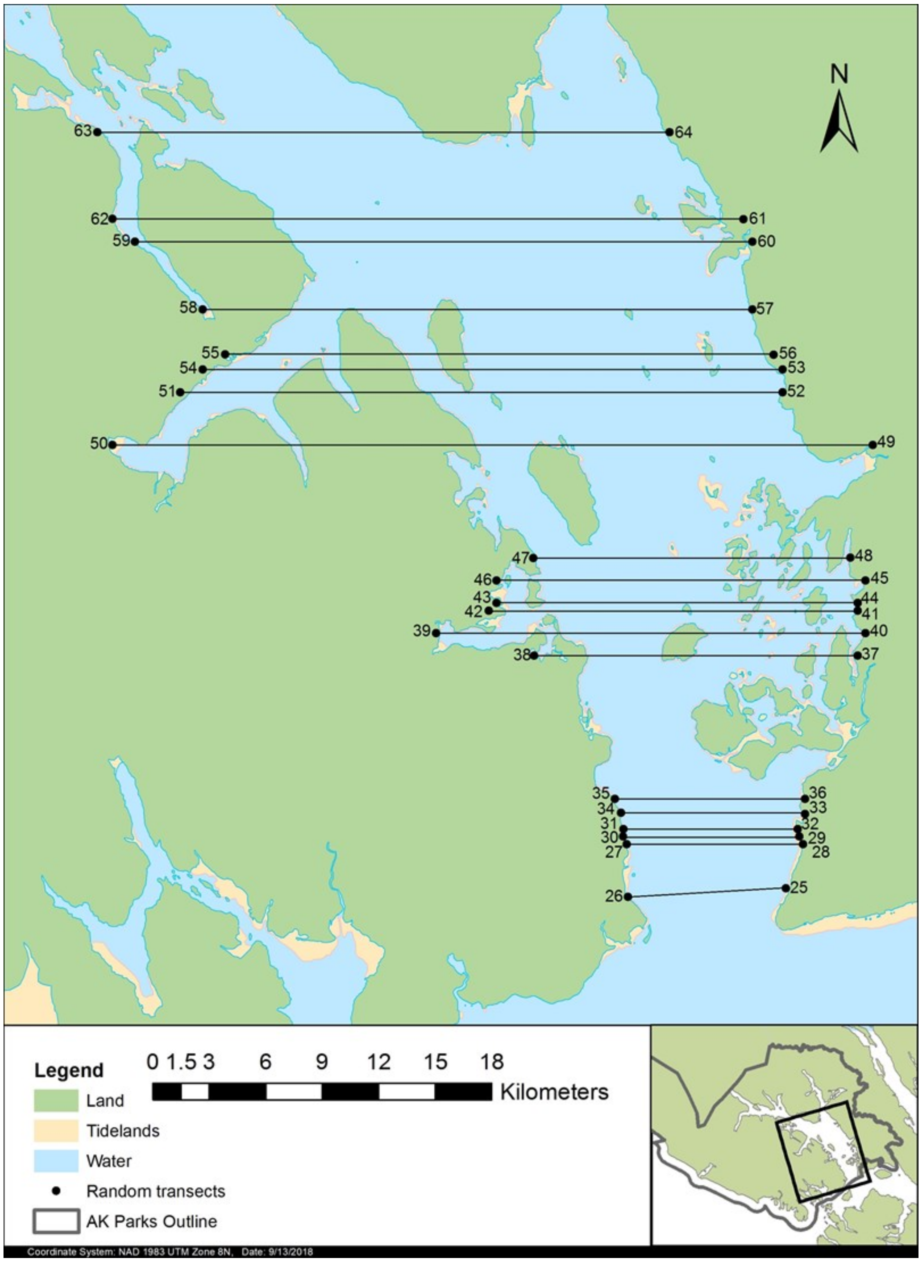

Figure 3. Examples of locations of n_{rt} = 20 randomly selected transects along which aerial photographic surveys are flown.

Optimal Transects

The second survey type is an optimized sample of transects that minimize a design criterion that represents objectives of the SEAN monitoring program. Specifically, the design criterion is the posterior prediction uncertainty described above; transects are selected such that the optimal transects minimize the variance in our model-based predictions of sea otter abundance and distribution. The design criterion can be updated to meet any changing objectives of the SEAN monitoring program.

To select the optimal transects, we first condition on the random transects that were selected in Figure 3. That is, to avoid redundancy in the type of information collected between the random transects and the optimal transects, the attributes of the random locations are documented, and the optimal transects account for the information already collected in the random transects. To select the optimal set of n_{opt} transects, we first consider a large number of potential designs m (e.g., m=64 potential designs, where 64 was chosen based on the number of computation cores we could access using a cloud computing service), where each potential design was the set of n_{rt} and n_{opt} transects, and each design of n_{opt} was different from all other designs. For each of the m potential designs, we estimated the design criterion (e.g., prediction uncertainty), and then selected the design that minimized the design criterion. For reference, we call this the *optimal random design*.

To further optimize the optimal random design, we use an exchange algorithm. The exchange algorithm works by first exchanging Transect 1 in the optimal random design, with neighboring transects (first the transect above it, then the transect below it). After one transect is exchanged, we estimate the design criterion of the model using the exchanged transect instead of the original transect. If the design criterion is improved using the exchanged transect, the exchanged transect is kept, and the original transect is removed. This process is then conducted for transects 2,…,n_{opt} , and repeated again for transects 1,…, n_{opt} until no further exchanges improve the design criterion. The remaining transects are the optimal design (Figure 4).

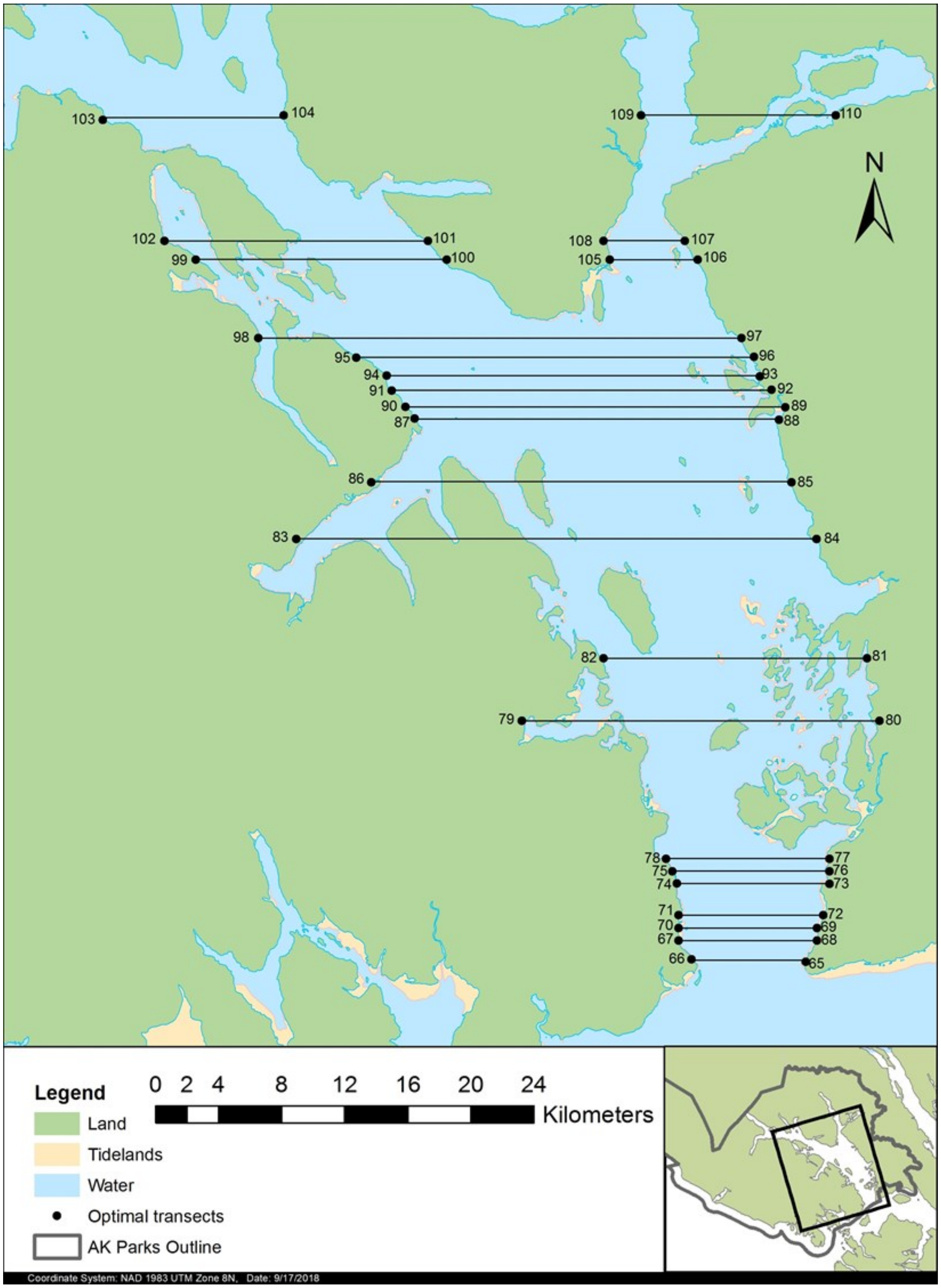

Figure 4. Examples of locations of n_{opt} = 20 optimal transects along which aerial photographic surveys are flown. Optimal transects are selected by optimizing a sample of transects by minimizing model-based prediction variance in model-based predictions of sea otter abundance.

Optimal Abundance Transects

The third sampling type is a model-based method that is analogous to stratification in the design-based sampling framework. That is, we want to sample more intensively in areas where sea otters are more likely to occur. To select the optimal survey route for sampling areas where sea otters are likely to be, we use a model-based forecast of sea otter abundance for the upcoming sampling year. We then identify the optimal flight route for visiting areas that were forecasted to have the most sea otters (Figure 5). The optimal flight route balances surveying the areas of highest forecasted abundance with the navigational technology of the aircraft. For example, in July 2017, 35 transects were used and each transect was 6 km in length, which made it feasible to cover small patches of high predictive abundance.

After data are collected from each of these surveys, we can examine the gain in information obtained from each sampling type, and further optimize sampling for future years. In addition, the model is flexible and can accommodate data from other types of surveys. Further, we can assess the amount of sampling effort that will be required in future years (potentially reducing the amount of survey days and effort) by comparing the precision of model parameters from a model fit to the full data set that was collected to a model fit to a restricted data set, where some transects are omitted, representing less sampling effort. Increased precision in model parameters helps to identify the effect size and significance level of each parameter in our model. Thus, by comparing the precision of model parameters from a model fit to the full data set that was collected to a model fit to a restricted data set, we are effectively conducting a power analysis among the differing survey types. Optimal dynamic surveys are aimed at identifying the survey design that most increases parameter precision. Thus, optimal dynamic survey designs are analogous to power analyses that are commonly used in phenomenological statistical models.

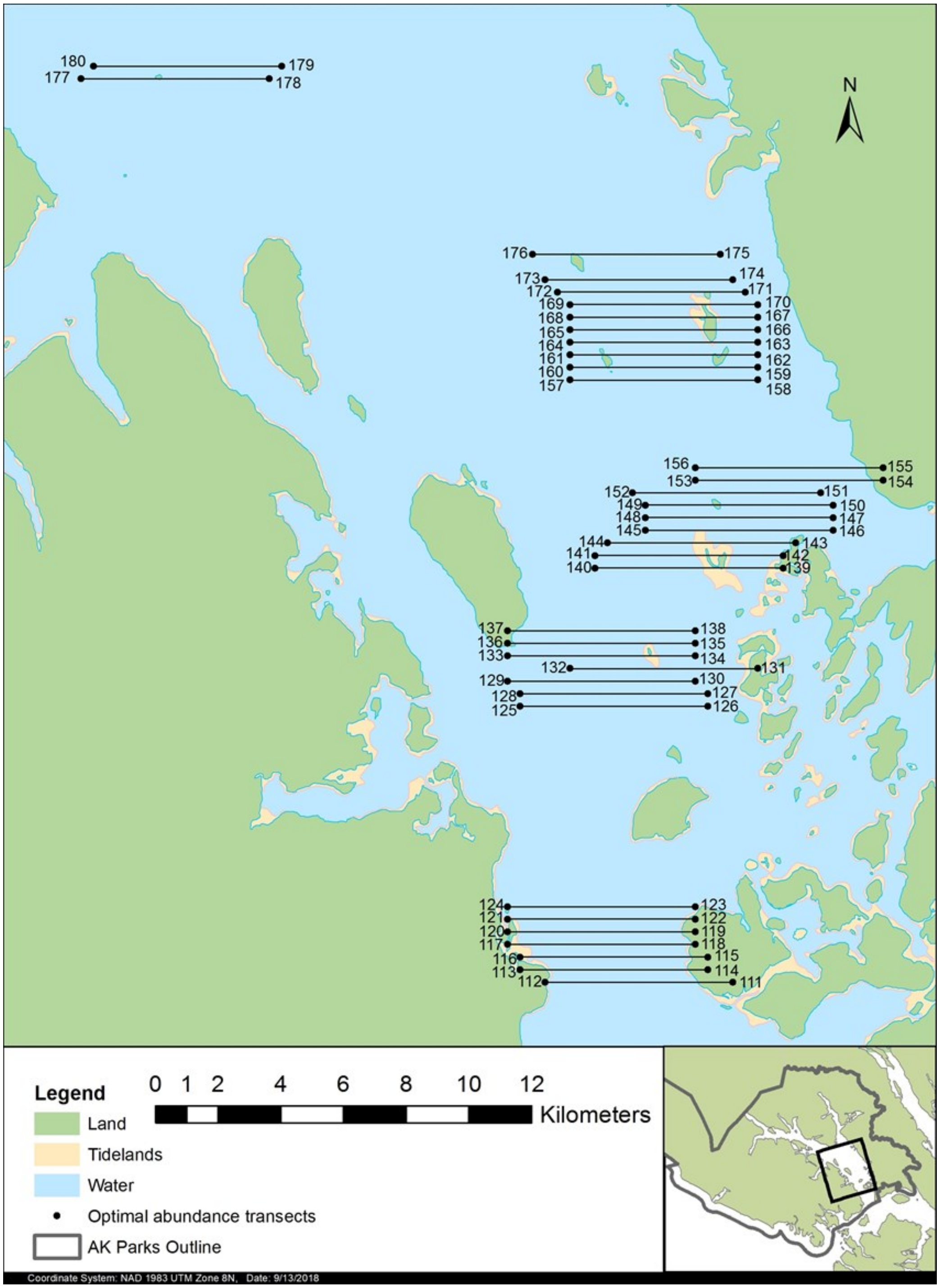

Figure 5. Examples of locations of optimal abundance transects along which aerial photographic surveys are flown. Optimal abundance transects are selected by optimizing a survey route by maximizing the predicted abundance of sea otters observed during previous surveys.

Data Quality Objectives

This section is intended to demonstrate how this project generates data of known and documented quality, resulting in complete, accurate, and transferable information. Table 3 shows Data Quality Values (DQVs).

Table 3. Data Quality Values (DQVs) to be considered in development of quality assurance plans for sea otter monitoring in GLBA.

Category	Data Quality Value	Definition	Protocol Considerations
Intrinsic Data Quality	Accuracy	Measurements reflect the true value of the parameter being observed. This applies to measures (length, width, position) or classes (species, types, or categories). Includes components of precision and bias. [Measurements reflect what was recorded in the field]	The quantities of interest cannot be observed directly in the field. Quantities of ecological interest are obtained from unbiased estimators that use the field data. Bias and precision are properties of the estimators. The data are assumed to be accurate representations of what was recorded in the field during aerial photographic surveys. New data will be used annually to evaluate model performance using model checking procedures (Conn et al. 2018). Model checking allows us to evaluate how well fitted models are able to reproduce observed data. If models are not able to simulate data similar to observed data (as assessed using test statistics), models will be re-evaluated.
	Representativeness	Measurements represent conditions at the time of sampling. Combined with accuracy, leads to repeatable data collection. [Statistical Inference]	Observations represent conditions at the time of sampling.
Contextual Data Quality	Comparability	The degree to which data can be compared among sample locations, data sources, or periods of time.	Abundance metrics derived from the area frame are comparable within areas of inference through time.
	Completeness	All data/measures required to evaluate accuracy representativeness are present; incomplete data sets (either at a location, across sampling locations, or over time) lose utility or relevance. Data records contain values as planned across the period of record.	All data/measures required to evaluate accuracy representativeness are as complete as possible. Field conditions can be challenging, and incomplete datasets may occur. Incomplete data sets are still valuable and are analyzed using model-based inference that accommodates missing records. Data records contain values that are as complete as possible across the period of record.

Table 3 (continued). Data Quality Values (DQVs) to be considered in development of quality assurance plans for sea otter monitoring in GLBA.

Category	Data Quality Value	Definition	Protocol Considerations
Representa-tional Data Quality	Consistent representation	Use of standard definitions when describing data quality or resource quality based on data.	Standard field definitions are specified in the SOPs.
Data Accessibility	Secure	Access to data, products, and systems limited to appropriate audiences.	No sensitive data are being collected as part of this protocol.

Measurement Quality Objectives and Performance Standards

See Table 4 for quality objectives/units for each measure or quality indicator.

Table 4. Measurement quality objectives and performance standards for sea otter abundance surveys.

Measure/Quality Indicator	Quality Objective/Units
PHOTO_FILE_NAME	Photo collected by camera; 36 megapixel; JPEG with embedded EXIF data
PHOTO_TIMESTAMP	Collected by camera; yyyy-mm-dd hh:mm:ss
LATITUDE_WGS84	Collected by GPS; +/- 10 meters horizontal accuracy, decimal degrees
LATITUDE_WGS84	Collected by GPS; +/- 10 meters horizontal accuracy, decimal degrees
ALTITUDE	Collected by GPS; +/- 3 meters, meters
SURVEY_TYPE	Determined from photo; Categorical, “Abundance”, “Optimal”, “Random”, “External”
COUNT_ADULT	Based on count from photo; integer between 0-1,000
COUNT_PUP	Based on count from photo; integer between 0-1,000
KELP_PRESENT	Determined from photo; Binary, 0 = Kelp absent, 1 = Kelp present
LAND_PRESENT	Determined from photo; Binary, 0 = Land absent, 1 = Land present
IMAGE_QUALITY	Reader’s evaluation of photo image quality: ‘Good’, ‘Reduced’, or ‘Unusable”. Reduced indicates issues such as blurry focus that makes an exact count of sea otters difficult. Unusable indicates an issue such as file corruption that prevents the image from being at all recognizable.
COUNTED_BY	Initials of photo counter
COUNTED_DATE	yyyy-mm-dd
QUALITY_FLAG	Determined by data technician: Categorical, ‘0’, ‘1’, ‘2’, ’3’. This attribute indicates whether there is a technical fault in the data row making it unsuitable for analysis purposes. If this attribute is null or ‘0’, then every attribute in the record meets the mandatory validation criteria. If this attribute is ‘1’, then at least one required attribute is missing. If this attribute is ‘2’, then the photo file name or timestamp is not unique. If this attribute is ‘3’, then some other mandatory quality requirement was violated.

Table 5. Measurement quality objectives and performance standards for estimating availability during sea otter abundance surveys.

Measure/Quality Indicator	**Quality Objective/Units**
PHOTO_FILE_NAME	Photo collected by camera; 36 megapixel; JPEG with embedded EXIF data
PHOTO_TIMESTAMP	Collected by camera; yyyy-mm-dd hh:mm:ss
LATITUDE_WGS84	Collected by GPS; +/- 10 meters horizontal accuracy, decimal degrees between 58.0 and 60.0
LONGITUDE_WGS84	Collected by GPS; +/- 10 meters horizontal accuracy, decimal degrees between -135.0 and -138.0
ALTITUDE	Collected by GPS; +/- 3 meters, meters
SURVEY_TYPE	Determined from photo; Categorical, “Abundance”, “Optimal”, “Random”, “External”
COUNT_ADULT	Based on count from photo; integer between 0 and 1,000
COUNT_PUP	Based on count from photo; integer between 0 and 1,000
KELP_PRESENT	Determined from photo; Binary, 0 = Kelp absent, 1 = Kelp present
LAND_PRESENT	Determined from photo; Binary, 0 = Land absent, 1 = Land present
IMAGE_QUALITY	Reader’s evaluation of image quality: ‘Good’, ‘Reduced’, or ‘Unusable”. Reduced indicates issues such as blurry focus that makes an exact count of sea otters difficult. Unusable indicates an issue such as file corruption that prevents the image from being at all recognizable
COUNTED_BY	Initials of photo counter
COUNTED_DATE	yyyy-mm-dd
QUALITY_FLAG	Determined by data manager: Categorical, ‘0’, ‘1’, ‘2’, ‘3’. This attribute indicates whether there is a technical fault in the data row making it unsuitable for analysis purposes. If this attribute is null or ‘0’, then every attribute in the record meets the mandatory validation criteria. If this attribute is ‘1’, then at least one required attribute is missing. If this attribute is ‘2’, then the photo file name or timestamp is not unique. If this attribute is ‘3’, then some other mandatory quality requirement was violated.
DETECTION_GROUP	Determined from photo; integer between 1 and 9,999
DETECTION_REPETITION	Determined from photo; for each DETECTION_GROUP there must be one record in the CSV reflecting repetition 1 and one record reflecting repetition 2.

Table 6. Data source and measurement quality objectives for boundary layers for sea otter monitoring. Data layers are from Geiselman et al. 1997.

Measure/Quality Indicator	**Quality Objective/Units**
BATHYMETRY	Grid format; linear unit = meters, 100 X 100, NAD_1927_UTM_Zone_8N
SLOPE	Grid format; linear unit = meters, 25 X 25, NAD_1927_UTM_Zone_8N
BOUNDARY	Polygon format; linear unit = meters, NAD_1927_UTM_Zone_8N

Data quality is maintained through detailed quality control procedures detailed in each deliverable's SOP. These procedures include explanation of effecting remediation when specific quality exceptions are encountered.

Taxonomic Standards

Enhydra lutris kenyoni – Northern sea otters (Wilson 1991)

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NPS 132/148547, September 2018

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U.S. Department of the Interior

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