Prepared In Cooperation with the National Park Service

# Survey Design Considerations for Monitoring Marine Predator Populations in Glacier Bay, Alaska: Results and Post-hoc Analyses of Surveys Conducted in 1999-2003

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Administrative Report

**U.S. Department of the Interior**
**U.S. Geological Survey**

**U.S. Department of the Interior**
DIRK KEMPTHORNE, Secretary

**U.S. Geological Survey**
Mark D. Myers, Director

U.S. Geological Survey, Reston, Virginia: 2008



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## Abbreviations, Acronyms, and Symbols

| Abbreviations, Acronyms, and Symbols | Meaning |
|---|---|
| ADFG | Alaska Department of Fish and Game |
| ASCII | American Standard Code for Information Interchange (a character encoding for text based on the English alphabet) |
| CV | Coefficient of variation |
| dLOG | Real-time computer data-entry system used to record bird and mammal sightings |
| ECI | Ecological Consulting, Inc., Portland, OR |
| ESRI | Environmental Systems Research Institute, Redlands, CA |
| GIS | Geographic Information System |
| GPS | Global Positioning System |
| PLGR | Rockwell Precision Lightweight Global-positioning Receiver |
| RV | Research Vessel |
| SD | Standard Deviation |
| SSA | Static Sample Area |
| SSS | Static Sample Size |
| UNESCO | United Nations Educational, Scientific, and Cultural Organization |
| USFWS | U. S. Fish and Wildlife Service |
| USGS | U. S. Geological Survey |
| USNPS | U. S. National Park Service |
| VHF | Very High Frequency (radio frequency 30-300 MHz) |

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## Abstract

Between 1999 and 2003, the U.S. Geological Survey (USGS) conducted 10 bay-wide surveys during summer and winter for marine birds and mammals in Glacier Bay, Alaska. These surveys were extensive and designed to assess the distribution and abundance of marine predators in relation to bio-physical features of the marine ecosystem. Here we conduct a post-hoc analysis of these surveys to determine how they could be re-designed and/or reduced in effort while retaining efficiency in data collection and statistical power to detect population trends. We used Monte Carlo methods to sample our database of historical transect data, simulate new survey datasets, and examine the resulting population estimates and variability of those estimates. Our main conclusions were: (1) 4-8 km is a robust transect length for marine predator surveys. (2) Sampling about 8% of Glacier Bay, or about 100 km$^2$, would yield reasonably precise and accurate population estimates for most species. (3) Stratification of habitat into coastal and offshore strata would increase sampling efficiency and reduce variance of population estimates. (4) Species are spatially segregated among strata, and appropriate allocation of survey effort among strata is species-dependent. (5) Finally, even with an intensive monitoring effort, it may require 10-20 years to detect large (50%) declines in populations of most species, and even longer for some species. This is largely due to the inherent variability of marine predator survey data, and we are not likely to improve on this level of sensitivity without significant increases in survey effort.

## Introduction

Glacier Bay (Fig. 1) is a large, rugged fjord in the southeast panhandle of Alaska that provides habitat for a diverse assemblage of marine birds and mammals. Productivity of the Glacier Bay marine ecosystem is enhanced by several unique local factors, including a high-volume input of freshwater from glaciers in the upper bay and strong tidal mixing of waters in the lower bay, leading to high pelagic production in stratified waters of the middle bay (Etherington et al. 2007). This high productivity supports large concentrations of zooplankton and forage fish in pelagic waters (Abookire et al. 2002, Robards et al. 2003, Arimitsu et al. 2007b, 2008) and of benthic invertebrates nearshore (Bodkin et al. 2007). In turn, these forage resources support large numbers of marine birds and mammals (Robards et al. 2003, Bodkin et al. 2007). Several of these species are endangered (e.g., humpback whale, *Megaptera novaeangliae*), threatened (e.g., Steller sea lion, *Eumetopius jubatus*) or currently under consideration for listing under the Endangered Species Act (e.g., Kittlitz's Murrelet, *Brachyramphus brevirostris*). While many species' populations are relatively stable, some are changing rapidly. For example, Kittlitz's Murrelet and Marbled Murrelet populations have declined markedly during the last 15 years (Piatt et al. 2007, Drew and Piatt 2008). Among marine mammals, harbor seal (*Phoca vitulina*) populations declined by 75% in 10 years (Mathews and Pendleton 2006) while sea otter (*Enhydra lutris*) populations increased from zero to thousands of animals in 20 years (Bodkin et al. 2007).

The Glacier Bay marine ecosystem lies within the bounds of Glacier Bay National Park and Preserve. Rapid declines in the populations of marine predators of Glacier Bay are of concern to park managers, particularly where there is potential for park users to be a cause of those declines. Increasing populations are not typically considered a problem; however, increases in some marine species can have profound impacts on their habitats and communities (Duggins 1983, Estes et al.1998, Bodkin et al. 2007) and therefore are also of potential concern. The park service is interested in monitoring populations efficiently and with enough accuracy to detect population changes over relatively short time spans (years or decades) that would allow for prompt management action. In this report, we perform post-hoc analysis of historical survey data to address survey design questions about transect length, habitat stratification and sample size. Results of these analyses will be useful for designing future monitoring protocols for detecting change in marine bird and mammal populations of Glacier Bay and similar coastal waters.

Historical data for assessing population trends of the common marine predators of Glacier Bay are limited. Other than anecdotal observations gathered by staff and visitors to the park (e.g., Wik and Streveler 1968), and long-term studies of humpback whales (Neilson and Gabriele 2007) and harbor seals (Mathews and Pendleton 2006), almost no systematic, quantitative monitoring data on marine bird and mammal populations were collected until the 1990s or 2000s. For many marine bird or mammal species that gather annually at rookeries, counts of nests and/or individuals attending nests is a standard approach for monitoring population trends (Dragoo et al. 2007, Mathews and Pendleton 2006). However, most of the species inhabiting Glacier Bay are either non-colonial or breed in very small, dispersed colonies, so colony count data are restricted to only a few species. Only Black-legged Kittiwakes colonies have undergone repetitive, standardized censusing (Hooge et al. 1998). A few other species [e.g., Common Murres (*Uria aalge*), Pigeon Guillemot (*Cepphus columba*), Glaucous-winged Gull and Arctic Tern (*Sterna arctica*)] have been censused at one or more small colonies (Zador 1999, Zador and Piatt 1999, Arimitsu et al. 2007a), generally on one-time or irregular annual visits.

In general, water-based counts of birds at sea offer an efficient means of monitoring a wide variety of both colonial and non-colonial waterbirds, including loons, grebes, geese, seaducks, cormorants, gulls, terns, murrelets and other alcids (Klosiewski and Laing 1994). Many factors can affect counts at sea (see below), but standardized estimates of the number of birds observed per square kilometer of water surface surveyed offer a robust metric for assessing changes in marine bird and mammal populations over time (Piatt et al. 2007). In Glacier Bay, the first standardized surveys at sea were conducted by Duncan and Climo (1991) in the Beardslee Islands during 1987-1991. Piatt et al. (1991) conducted the first bay-wide surveys for marine birds and mammals using survey protocols developed by the U.S. Fish and Wildlife Service (USFWS) for use in Prince William Sound after the *Exxon Valdez* oil spill (Klosiewski and Laing 1994). Lindell (2005) conducted surveys of Glacier Bay and nearby Icy Strait for Marbled Murrelets (*Brachyramphus marmoratus*) from 1993 to 1999 using protocols developed for ship-based surveys in Alaska (Gould and Forsell 1989).

In 1999, the USGS initiated an intensive survey of forage fish and marine predators in Glacier Bay (and Icy Strait), and used standardized USFWS methods to survey marine predators on a series of transects that included the entire shoreline of the bay, and a parallel fine-scale grid of offshore transects that extended systematically from the mouth to the head of Glacier Bay (Robards et al. 2003). The purpose of the USGS surveys was to evaluate the spatial distribution of prey and predator resources at a fine scale with respect to bathymetry and oceanography. The extent of the surveys was far greater than needed to simply census marine predator populations for trends. At the request of the park, however, this sampling regime was extended over time to include seasonal and inter-annual surveys of the entire bay (Bodkin et al. 2002; Robards et al. 2003), a 5-year (1999-2003) project that was possible because USGS investigators were in Glacier Bay conducting other studies (e.g, Arimitsu et al. 2003, Robards et al. 2003, Bodkin et al. 2007), substantially subsidizing the costs of vessels and staff needed for the surveys. Other than experimental line transects for murrelets that were conducted in 2007 (Kirchhoff 2008), and a subsample of the USGS marine predator transects that were surveyed in 2008 (J.F. Piatt, USGS, unpubl. data), no monitoring data have been collected on marine predator populations since 2003 (except for humpback whales, harbor seals and sea otters).

Natural resource managers for Glacier Bay National Park and Preserve are interested in resuming long-term monitoring surveys for marine birds and mammals within Glacier Bay. Given that the surveys USGS conducted in 1999-2003 were not designed for monitoring, and coverage was greater than needed for monitoring purposes, we were asked to examine our 5-year dataset and determine how much sampling would be needed for an efficient monitoring effort. In this report, we examine our historical database in post-hoc fashion to see how different sampling procedures would have influenced the outcome of analyses, in particular the confidence we could have in population estimates and power to detect trends. Here we consider three different aspects of sampling: 1) Effect of transect length on variance of population estimates; 2) Effect of sampling intensity on population estimates and their variance; and, 3) Effect of sampling stratification by habitat on population estimates and their variance. All of these topics relate to sampling issues. We do not address issues concerning other aspects of the survey protocol. Previous research has shown that sources of variation in counts of marine birds and mammals at sea include skill levels of individual observers, distance of animals from the survey vessel and their relative visibility, timing of the survey, and environmental conditions (Tasker et al. 1984, van der Meer and Camphuysen 1996, Clarke et al. 2003, Romano et al. 2007, Spear et al. 2004). Assessment of the importance of these factors was beyond the scope of the study. As much as possible, the survey data were collected using the same sampling design, data-collection protocols, observers and vessels among years.

In the following sections, we first present basic findings of the surveys conducted in 1999-2003, describing the distribution patterns of most species observed during the study, and consider seasonal and annual changes in species composition, abundance and distribution. In the database used for post-hoc analyses of sampling design, we included only data collected within Glacier Bay proper (hereafter, “Glacier Bay” refers to the bay only, including all waters north from its entrance at Icy Strait, and excluding the waters of Icy Strait, the Outer Coast, or other coastal waters of the park). Additionally, we selected eight focus species (a list of all species appears in Appendix 1) for statistical analyses of various sampling scenarios. These species were selected because they exhibited a wide range of abundance and distribution patterns. With this group to represent the marine predator community, we conducted statistical tests to examine effects of transect length, sampling effort and stratification on population estimates, variance of those estimates and power to detect population trends for each of the representative species. Finally, we discuss the implications of animal distribution and sampling strategy on the design of long-term monitoring protocols.

# Distribution and Abundance of Marine Predators in Glacier Bay

We conducted boat-based surveys of marine birds and mammals in Glacier Bay, Alaska, from 1999 to 2003. The purpose of these surveys was to determine the distribution and abundance of marine predators and forage fishes in relation to oceanography and bathymetry, and results from this intensive study have been previously reported in Robards et al. (2003). This dataset on marine bird and mammals of Glacier Bay provided information useful to design of long-term monitoring surveys for these species. Here, we provide an overview of the findings on the seasonal distribution and abundance of the dominant species occurring in Glacier Bay, based on the 1999-2003 surveys, to provide necessary background to the later sections of this report which present findings related to survey design.

## Methods

### Study Area

The rapid recession of a neoglacial ice-sheet within the last 250 years exposed Glacier Bay, a Y-shaped fjord in southeast Alaska (Fig. 2). Glacier Bay is currently 100 km long, and varies in width from 4 to 8 km in the lower bay. The bay widens to ~15 km in the middle bay, and then narrows again to as little as 2 km in the upper bay (Fig. 2). Numerous glaciers, of which ten are tidewater glaciers, discharge ice and turbid water into the upper arms and inlets. Connected to the Gulf of Alaska via Icy Strait, Glacier Bay has a complex bathymetry, including numerous sills and basins up to 457 m deep (Fig. 3). Tides in the bay range from an average of 3.7 m at Bartlett Cove to 4.2 m in the upper part of the Bay.

We defined the study area for the 1999-2003 surveys to include Glacier Bay and the portion of Icy Strait adjoining the mouth of Glacier Bay. Icy Strait is oceanographically distinct from Glacier Bay and is not within the boundaries of Glacier Bay National Park and Preserve. For these reasons, we restricted our analyses to data from Glacier Bay proper. The findings from our surveys of Icy Strait are provided in Appendix 2 for comparison. In addition, during 1999 only, we also surveyed Dundas Bay, following the grounding of a tourist vessel there. Data from the single visit to Dundas Bay are not included in our analysis, but are reported in Appendix 3.

## Survey Platforms

Our surveys were conducted from several research vessels over the five years of the study. Vessels included the Alaska Department of Fish and Game (ADFG) R/V *Pandalus*, the U. S. Fish and Wildlife Service (USFWS) *Predator,* the U. S. National Park Service (USNPS) *Capelin*, and the USGS boats, the R/V *Alaskan Gyre, Lutris II*, *David Grey,* and *Sigma-t* (Table 1). Ground speed for vessels was approximately 11-15 km/h (6-8 knots). Surveys were conducted using sampling strips of either 200 m (100 m on either side) or 300 m (150 m on either side) wide, and 200 m or 300 m respectively in front of the vessel, depending on the height of the viewing platform (Table 1).

## Survey Layout and Timing

The 1999-2003 study was designed to document the distribution and abundance of marine predators and forage fish within the park. Therefore, the entire area of Glacier Bay was sampled systematically to ensure that all areas of the bay would be surveyed during summer. The entire coastline of Glacier Bay was surveyed, and pelagic areas were sampled with a grid of transects spaced 2.5 km apart (Fig. 4). Transects consisted of the track between two points either along the shoreline, or running perpendicular to the shore across the bay (Fig. 4). Thus lengths of transects were arbitrary, dependent on the physical shape of the study area. Due to logistical constraints, approximately half of the pelagic and coastal transects were run consecutively, alternating between the two types to minimize running time. The remaining transects were run as efficiently as possible but required some transiting between transects.

To examine seasonal patterns of use of Glacier Bay by marine birds and mammals, a subset of summer transects (approximately 40%) were also surveyed during the winter. To make winter surveys as efficient as possible, sampled transects were generally contiguous, with endpoints of the systematic offshore transects running to the beginning of the next coastal transect (Fig. 4). In summary, a total of 10 surveys of Glacier Bay were conducted, five during summer and five during winter (Table 2).

## Data Collection

We surveyed using strip-transect protocols established by the USFWS for census of marine bird and mammal communities (Gould et al. 1982, Gould and Forsell 1989), and modified slightly for surveying nearshore areas from small boats (Klosiewski and Laing 1994, Agler et al. 1998). Transects were defined *a priori* from a random starting point. All marine birds and mammals observed on the water within the strip-transect were recorded continuously. Following Klosiewski and Laing (1994), all birds flying within the strip transect boundaries were counted, even though this tends to overestimate absolute densities slightly (Gould and Forsell 1989, Clarke et al. 2003, Spear et al. 2004). All marine birds and mammals sighted on surveys were identified to the lowest classification level possible (Appendix 1). The following behaviors were recorded: sitting on the water, flying, feeding, standing on flotsam or jetsam, flying with a fish held in the bill, and sitting on the water with a fish held in the bill.

Bird and mammal sightings were entered directly into a real-time computer data-entry system (dLOG; Ford Consulting, Portland OR) that also recorded time and location (using GPS) for each observation. We used a Rockwell Precision Lightweight Global-positioning Receiver (PLGR) to obtain accurate position data (accuracy of ± 10 m at speeds < 36 km/h). During surveys, one crew member entered data into a laptop computer, located in the wheelhouse, while two observers surveyed from the best vantage points on each research vessel. Observers were skilled in identifying marine birds and mammals, and trained in survey protocols each year. Some observers participated in surveys in all 5 years, and at least one observer with prior experience in Glacier Bay was present on each vessel in every year. Observers actively scanned ahead of and alongside the survey vessel, and species identifications were confirmed using 7–10 power binoculars. Observers frequently calibrated their estimates of distance using range-finders, radar or a buoy pulled behind the vessel. If weather conditions were unsuitable for sighting small seabirds at 200-300 m (i.e., above a 3 on the Beaufort Wind Force Scale), surveys were discontinued until conditions improved. Ancillary data on weather, sea conditions, and observation conditions were recorded at the beginning of transects and updated as necessary. Additionally, we recorded bird behavior or plumages, and species of fish held by birds.

### Data Analysis

To calculate marine predator densities, transect lengths were calculated using GIS and then multiplied by the survey width to determine area sampled. The total number of marine predators (by species) counted within a transect strip was divided by the total sample area to yield density (marine predators/km$^2$).

To contrast the distribution patterns of different taxa, we prepared plots of distribution for the eight focus species as well as combined seasonal distributions. Specifically, we were interested in identifying areas of consistently high use by multiple species, as well as specific differences in use of habitats between species. Areas of high use (multi-species) indicate the availability of resources of value to marine birds and mammals, for example, forage fish. Density surfaces were kriged using ArcMap GIS and using the quadratic kernel method in ArcMAP.

## Results

During summer surveys, we quantified observations of 46 marine bird species (Table 3) and 6 marine mammal species within Glacier Bay (Table 4). During winter surveys, we quantified observations of 35 marine bird species (Table 5) and 6 marine mammal species (Table 4). See Appendix 1 for a complete listing of all species. We found that waterfowl and seabirds were the dominant groups within Glacier Bay, with waterfowl slightly outnumbering seabirds (Table 3; Fig. 5). Below, we summarize information on summer and winter densities for seabirds, waterfowl, and marine mammals, and describe their general distribution patterns.

### Marine Predator Densities

Seabirds.--Within Glacier Bay, seabird densities varied widely among seasons and years (Tables 3 and 5). During summer, the seabird community was dominated by Arctic Terns, Black-legged Kittiwakes, Glaucous-winged Gulls, Mew Gulls (*L. canus*), Marbled, Kittlitz's and unidentified *Brachyramphus* Murrelets, and Pigeon Guillemots. Together these seven species accounted for 84-94% of all seabirds observed across the five summer surveys. Black-legged Kittiwakes and Glaucous-Winged Gulls were the predominant gulls. Marbled Murrelets greatly outnumbered Kittlitz's Murrelets in summer surveys of all years. Both murrelet species were much less common in Glacier Bay during the winter (Tables 3 and 5).

Many seabird species found commonly in Glacier Bay during summer moved out of the bay for the winter. Gulls and Pigeon Guillemots accounted for a large proportion (69-92%) of seabirds observed on winter surveys (Fig. 6). Densities during winter were generally lower than from summer (Tables 3 and 5); however, densities of seabirds observed were much more variable on the winter surveys (Tables 3 and 5).

Waterfowl.--As a group, waterfowl (birds using both marine and freshwater habitats; e.g., loons, ducks) were the most abundant birds seen on both summer and winter surveys. Over the 10 surveys, waterfowl represented 51-63% of all summer bird observations and 71-79% of all winter bird observations. Sea ducks (e.g., scoters, goldeneyes , Bufflehead *Bucephala albeola*, Harlequin Duck *Histrionicus histrionicus*, and mergansers) were abundant in Glacier Bay, making up between 72-86% of summer waterbirds and 90-95% of winter waterbirds. In contrast to the seabird group, the species composition of waterbirds varied markedly between seasons. Scoters (*Melanitta spp*.) dominated the summer survey observations of waterfowl, but were the second most common species group in winter (Fig. 7). Barrow's Goldeneye (*Bucephala islandica*) and Common Goldeneye (*B. clangula*) were rarely observed on summer surveys, but as a group were the most common waterfowl observed on the winter surveys (Fig. 7). Common Mergansers (*Mergus merganser*) and Red-Breasted Mergansers (*M. serrator*) were common on summer surveys but rare in winter. Harlequin Ducks were common in all surveys, making up 5-11% of summer waterfowl and 3-4% of winter waterfowl. Of the remaining waterfowl, Canada Geese (*Branta canadensis*) were the next most common, though they made up only 1-4% of the waterfowl observations on any given survey.

Marine mammals.--Harbor seals were the most commonly sighted marine mammal species during both summer and winter, followed by sea otters and harbor porpoise (*Phocoena phocoena*; Table 4). Humpback whales were common in summer but largely absent during winter months. Steller sea lions were sighted more frequently in the winter surveys (Table 4).

## Marine Predator Distributions

Patterns of distribution in Glacier Bay differed among species, and in general, each species occupied some unique areas of the bay each year. For example, Kittlitz's Murrelet during summer tended to occupy waters adjacent to tide-water glaciers in the upper west arm and often concentrated at the entrance to the east arm (Fig. 8) where a high volume of glacial freshwater enters the bay from Adams Inlet (Etherington et al. 2007). In contrast, Barrow's Goldeneye was entirely coastal and concentrated in the same bays each winter (Fig. 9). When we considered distribution patterns over the 5 years of the study (Fig. 10), these species-specific patterns become more evident. Once again, the 5-year pattern shows that Kittlitz's commonly occupy waters at the entrance to the east arm, and near tidewater glaciers in the upper arms (Fig. 10). In contrast, Arctic Terns were concentrated at the heads of glaciated fjords, Harlequin Ducks were found along the shoreline and mostly in the upper bay, while Glaucous-winged Gulls were fairly evenly dispersed over the entire bay, both nearshore and offshore (Fig. 10). Some species showed a high degree of spatial overlap, particularly in winter (Fig. 11).

We created a kriged surface for the 8 representative species that we used for post-hoc analyses of sampling scenarios (Fig. 12a-12h; see following sections). Because these 8 species comprised more than 50% of the total number of birds and mammals observed on all transects, they provided substantial insight into the patterns of marine predator distribution in Glacier Bay. These species ranged in dispersion and abundance from very abundant and aggregated nearshore species (e.g., Surf Scoter, Fig. 12h and Common Merganser, Fig. 12c) to more dispersed and less abundant nearshore species (e.g.,Harlequin Duck, Fig. 12b and Pigeon Guillemot, Fig 12 g), and from common offshore pelagic species (e.g., Black-legged Kittiwake, Fig. 12a and Marbled Murrelet, Fig. 12f) to more dispersed and less numerous pelagic species (e.g., Kittlitz's Murrelet, 12e and Harbor Seal, 12d). To look at general seasonal use by all bird species we consolidated and mapped all summer bird species and all winter bird species observations (Fig. 13), we found that certain areas of the bay comprised hotspots, presumably because oceanographic features concentrate prey and therefore predators. These findings deserve further analysis in their own right, but here we are interested in the implications for long-term monitoring.

## Discussion

We used the more comprehensive summer surveys to construct density surfaces for eight focus species (Fig. 12a-12h). Following our examination of possible sampling scenarios (below), these data can be used to help design species-specific sampling plans or to compare against future survey designs to ensure adequate sampling. We also mapped the use of Glacier Bay for all species both in the summer and in the winter. These composite maps are useful for identifying areas of high resource value. Areas of combined high-use in summer included: Sitakaday Narrows, Hugh Miller Inlet, Berg Bay, Fingers Bay, Tarr Inlet, Muir Inlet, and Adams Inlet. Areas that experienced high multi-species use during the winter included the Beardslee Islands, Sitakaday Narrows, Berg Bay, and Adams Inlet. Future integration of oceanographic data, nearshore and pelagic production, and forage resources may provide additional insight on factors that influence the patterns of distribution revealed in the maps (e.g., Arimitsu et al. 2007b, 2008), but that is beyond the scope of this report, which focuses on issues of sampling and sources of variance in estimating populations.

Our observations over 5 years of summer and winter surveys demonstrated high temporal and spatial variability in marine predator distribution in Glacier Bay, and the degree of variability differed considerably among species. Some species or species groups overlapped considerably in distribution while others were highly segregated. Some species were mostly coastal in distribution, while others were more pelagic. Some species were concentrated in the upper bay, some in the lower bay, and others were found everywhere. Some were highly aggregated, while others were dispersed.

After we address sampling issues related to transect length, placement and sampling intensity (below), we will revisit these findings about marine predator distribution and abundance and answer some basic questions before designing a monitoring protocol for Glacier Bay. For example, will monitoring be designed to estimate populations or simply detect trends? Will it be designed to monitor all species, or just selected species? Will some species require too much effort to justify the expense? Will surveys be designed to monitor the entire bay, or just selected parts of the bay? Will monitoring involve seasonal, annual or semi-annual sampling? These questions are inter-related and must all be addressed simultaneously before settling on a final monitoring plan for Glacier Bay.

# Survey Design I: Effects of Transect Length and Sampling Effort on Variance of Population Estimates

The lengths of marine survey transects vary among studies— typically from a km to tens of km— depending on the shape and size of the study area, species of interest, logistical needs and survey goals. In many studies, the choice of transect length is often arbitrary, and unimportant for mapping species distributions. However, autocorrelation among transects often creates statistical problems when transect data are used to estimate population size (Schneider 1990). The optimal transect length would be one that eliminated autocorrelation among transects while maximizing sample size, therefore increasing the power to detect trend. Binning data into transects of at least 3-10 km in length can eliminate autocorrelation effects for many species (Fauchald et al. 2000, Yen et al. 2004, Huettmann and Diamond 2006, Piatt et al. 2007). This is usually because this length of transect often captures the scale of aggregation of seabirds and their prey (Schneider and Piatt 1986, Piatt 1990, Fauchald et al. 2000). For example, if birds are aggregated in 5 km patches then a sequential series of 1 km transects will often be autocorrelated as one travels through the patch. Sequential transects of 5 km length, however, are much less likely to be autocorrelated.

Previous studies have focused on autocorrelation, addressing the problems associated with using non-independent transects (Schneider 1990), but do not address the question of how transect length influences the variation around estimates of mean transect density (or population estimates). Additionally, none of the previous research on this problem has addressed surveys in a fjord system characterized by high spatial and temporal environmental gradients (e.g., extreme tides), as are found in Glacier Bay.

Here, we examine the effects of transect length and sample size on population estimates, and the variance around those estimates, by conducting a post-hoc analysis of the 1999-2003 survey data from Glacier Bay. Our goal was to identify a transect length that is statistically robust, and does a good job of sampling a suite of species with different behaviors, population sizes and distributions. In addition, we wanted to identify how many transects must be surveyed to provide “reasonable” confidence limits to population estimates; i.e., limits that are similar in range to those obtained in historical surveys. In other words, how small can our sample of transects get before increasing confidence limits impair our ability to detect population change. Examination of these two study design parameters—transect length and sample size— will help design more effective, efficient sampling strategies for marine predators in Glacier Bay.

## Methods

### Transect Length

We used Monte Carlo simulations to evaluate the effect of transect length on population estimates and their variance. The basic approach was to split a sample of transects into smaller and smaller segments (or "bins"), and compare the means and variance of estimates made from whole transects with those made from transects created by binning into smaller lengths. To reduce variability from other sources, we used a subset of transects from the total Glacier Bay database that were collected by a single set of observers, from a single vessel, and in a single year (2000). Given these restrictions, 16 km was the longest transect length for which we could obtain at least 20 samples, the minimum sample size we considered acceptable. A total of 21 transects at least 16 km each in length were selected from the original data set. Each of the 21 transects was reduced to 16 km exactly, and then split in half sequentially to form segments of 8 km, 4 km, 2 km, 1 km, 500 m, and 250 m (seven different lengths in total). We evaluated surveys at seven different spatial scales to determine which yielded the lowest CV.

Impacts of transect length on population estimates and the variance around each estimate were evaluated by examining the sampling distribution for each parameter. Sampling distributions were estimated using Monte Carlo simulations of 5000 iterations. Each iteration consisted of randomly drawing 21 samples, with replacement, from the set of transects for each length. From each sample we calculated the index of population size for each species and its CV using the ratio estimator (Caughley 1977, Williams et al. 2001):

$$re = \frac{\sum c_i}{\sum a_i}$$

where $c_i$ is the number of individuals counted in transect $i$, and $a_i$ is the area surveyed in transect $i$. The total population of each species was calculated as:

$$P.num = re * sa$$

where $sa$ is the total surveyed area, in our case 1288.56 km$^2$.

For each species, the variance of the ratio estimator ($Vre$) was calculated as:

$$Vre = \left(\frac{re^2}{n}\right)\left(\frac{sd(c_i)}{mean(c_i)}\right) + \left(\frac{sd(a_i)}{mean(a_i)}\right) - \frac{2 * \operatorname{cov}(c_i, a_i) * n}{(n-1) * mean(a_i) * mean(c_i)}$$

where $n$ is the number of samples (in this case 21), and $\operatorname{cov}(c_i,a_i)$ is the covariance between counts and transect area.

The variance of the population estimator ($P.Var$) and its coefficient of variation ($P.CV$) were calculated as:

$$P.Var = Vre * sa^2$$

$$P.CV = \frac{\sqrt{pVar}}{P.num}$$

Following this methodology, 5000 estimations of population size and their corresponding coefficients of variation were obtained for each combination of species and transect length. Population size estimates and CVs for each species were plotted against transect length, providing insights into the effect of transect length for each of the eight species. This simulation, using a static sample size, is hereafter referred to as SSS.

This analysis was then re-run on the same dataset; however, instead of choosing 21 samples, we chose samples at each length to equal the area of the 21 16-km transects; that is to say 42 at 8 km, 84 at 4 km, etc. This simulation using static sample area, hereafter referred to as SSA, meant that sample size doubled with each step down from 16 km. Population estimates and CVs were all calculated using the same formulas. As with the previous simulation (based on static sample size), we plotted population estimates and CVs at each of the transect lengths.

Both simulations using either SSS or SSA provide information about the effect of changing transect length. However, our goal was to look for some "optimal" transect length that would account for both of these factors. Thus we plotted the median CV values for both simulations on the same graph. This gave us a visual representation of how CVs for SSS and SSA varied simultaneously across the range of transect lengths.

## Sampling Effort

Based on the results of the transect length simulations (above) we selected an "optimal" length for the combined eight focus species, and then we examined how changing the number of transects sampled affected the population estimate and variance. In the original 1999-2003 survey design, we sampled about 21% of the entire surface area of Glacier Bay, which is far greater than needed for calculating a robust population estimate (Klosiewski and Laing 1994, Morrison et al. 2001). We wanted to know how far we could reduce the original survey effort without significantly reducing accuracy or precision of the population estimates. Our goal was to work toward designing the most efficient survey possible by balancing statistical power with logistics and sampling effort.

To that end, additional Monte Carlo simulations were performed to evaluate how population estimates and variances would vary with decreasing numbers of transects. For this purpose, we used the 2000 dataset of summer transects in Glacier Bay. Based on the analysis of optimal transect length (above), we created a sampling population of transects whose lengths were all between 4 and 8 km in length. Transects that were less than 4 km in length were deleted, transects between 4 and 8 km in length were retained, and transects that were longer than 8 km were split in half. This process was repeated until all remaining transects were less than 8 km and over 4 km, yielding a total of 197 transects. For purposes of comparison, use of all 197 sample transects in an analysis was considered 100%. Numbers of sample transects analyzed included 2% and 5-100% in intervals of 5% of the original sample size. For each percentage level, 5000 iterations were performed. For each iteration at each percentage level, a subsample of transects was selected at random, with replacement. Population size estimates and CVs were calculated for each species as described above.

Estimates of population size and CV of the population size estimates were plotted against percentage sampling level for each species. The percentage level was then selected that provided, for most species, population estimates similar to the ones obtained using all transects, without a significant increase in CV.

## Results

### Transect Length

As transect length increased, and sample size was held constant, CV decreased markedly for each of the 8 species (Fig. 14). In contrast, estimates of population size were fairly constant across transect lengths for many species, falling off only with the smallest transect lengths (Fig. 14). Species with highly clumped distributions (e.g., scoters and mergansers) tended to be biased towards very low population estimates and high CVs when transects were small or moderate in length. In contrast, even at the smallest transect lengths, population estimates were not biased for dispersed and abundant species such as Marbled Murrelet and Pigeon Guillemot (Fig. 14)

As expected for the Static Sample Size (SSS) simulation, the CV decreased and the range of simulated population estimates narrowed with increased transect length (Fig. 14). For most species, the reduction in the full range of estimates was accompanied by a reduction in the size of the quartiles surrounding the population medians. Pigeon Guillemots and Black-legged Kittiwakes exhibited less of a decrease in the size of the quartiles surrounding the population medians as transect length increased, although population estimates for these two species did show a decrease in overall range. This is probably because Pigeon Guillemots and Black-legged Kittiwakes were more evenly distributed in Glacier Bay than the other species. For all species, population size estimates, the range of variability in estimates, and the CVs were generally stabilized at transect lengths of about 4 to 8 km.

When sample area was held constant across transect lengths, the SSA simulation revealed median population densities that were stable across the range of transect lengths (Fig. 15). However, the variability of the estimate, as reflected by the CV and the quartile bars, increased with increasing transect length (Fig. 15). The low CVs associated with short transects is a result of two factors (1) increases in sample size, and, (2) large numbers of zero values at the shortest transect lengths.

When median CVs for both the SSS and SSA simulations were plotted together, most species showed a convergence in variability with transect length at approximately 4-8 km (Fig. 16). Most species were relatively more sensitive to changes in the sample area associated with transect length than in the change in sample size at the same length. Although there is no statistical test to determine the “optimal” transect length, this analysis suggests that transects should be at least 4 km in length to maximize power to detect change. Transects can be longer, but little power is gained by increasing transects beyond about 8 km in length.

### Sampling Effort

When a small percentage of the available transects (n=197) was used for estimating population size in the post-hoc simulations, all species showed a negative bias (i.e., a low estimate of population size) in their median population estimates as well as a wide range of estimates (Fig. 17). The more extreme low medians and quartiles resulted when high numbers of zero values that typically arise from short transects drove bootstrapped population estimates down in magnitude. This effect was most evident for species that were highly aggregated, such as Harlequin Ducks and Surf Scoters, for which a small sample size has a higher likelihood of including large numbers of transects with zero observations. On the other hand, at low sample sizes, there was also a potential for very high population estimates, due to the possibility that a small number of samples could contain large numbers of animals. For all species, the range of estimates decreased steadily (i.e., precision increased) as the number of transects increased (Fig. 17), reaching an asymptote for each species when higher numbers of transects were sampled. For well-dispersed species (e.g., murrelet, guillemot), there was little bias in estimates even at sampling efforts of only 10%, whereas more aggregated species (e.g., scoter, seal) began to exhibit downward bias at sampling efforts of 30-40% (Fig. 17).

There was broad similarity in the shapes of the CV curves for all species (Fig. 17). As the number of transects sampled increased from 2% to 30% of maximum sampling effort, there was a rapid decline in median CVs of 0.3 to 0.5 depending on the species. As amount of area sampled continued to increase, the decrease in CV was less than 0.1 for all species. Of the eight species modeled, Surf Scoters and Common Mergansers, the most aggregated species, had the highest CVs and the least improvement across the entire range of survey intensity. Quartile values followed similar trends with the major tightening of the inner quartile ranges occurring as survey intensity increased from 2-50% of the original coverage.

## Discussion

Our examination of transect length and survey intensity was based on simulations. We were able to see the high CVs that are the consequence of a design with a few very long transects, as well as the negative bias of a design with a few short transects. For all species examined, median population size estimates and their associated CVs stabilized at transect lengths of 4 to 8 km. Our analysis demonstrates that for a group of species representing very different degrees of aggregation and levels of abundance, transects can be both too long (16 km) and too short (0.25-2 km). A transect length in the middle range of 4 to 8 km appeared to offer the best balance of variance to the number of sampling units. Perhaps most revealing was the mixed plots of SSS and SSA simulations. In effect, they showed that below 4 km each incremental increase in transect length for the SSS simulation had a greater decrease in CV than the associated increase in CV related to decreases in sample size for the SSA simulation. These plots also showed that after 8 km there was little decrease in CVs associated with the SSS simulation. Although the SSA simulations showed only moderate increases in CVs from 8 km to 16 km, it represented a doubling of sampling effort. Based on these findings we suggest that for mixed species surveys, transects should be no shorter than 4 km and no longer than 8 km.

By modeling the population estimates and the associated CVs, we were able to determine that for the species we investigated, there was little improvement in population estimates above 20-40% of the original sample coverage, depending on the species. Further, improvement in the precision of estimates began to level off at 15-30% of the original coverage, depending on species. The original coverage of Glacier Bay used for these analyses involved sampling 21% of the total surface area of the bay. Thus, for the purposes of population monitoring, sampling about 8% of the entire bay area would yield reasonably precise population estimates for most species. Sampling as little as 3% of the bay would be adequate for the more common and dispersed species such as Marbled Murrelets or Pigeon Guillemots.

## Survey Design II: Stratification, Optimization, and Power to Detect Change

To continue our investigation of survey design for marine birds and mammals in Glacier Bay, we examined the effect of habitat stratification on our estimates of marine predator population size. Stratification is a commonly used statistical technique that allocates samples based on a specified classification scheme to decrease bias and variability of the sample. Although *a priori* stratification is preferable, *post hoc* stratification can be used, particularly to test strata for their utility and to correct for bias (Anganuzzi and Buckland 1993). Little precision in the estimates is lost if the size of strata in the post-stratification can be accurately measured from a database or map. Additionally, *post hoc* stratification can be used to assist in refining survey design. Marine birds and mammals have broad geographic affinities, including associations with depth, shoreline and bottom substrate, water temperature and salinity (Gould et al. 1982, Merkel et al. 2002, Piatt and Springer 2004, Bodkin et al. 2007). Given well-established associations between bathymetry and fish (Smith and Gavaris 1993, Macpherson 2003, Arimitsu et al. 2008) and other top trophic-level marine predators (Hunt et al. 1990, Yen et al. 2004, Ladd et al. 2005), bathymetry was chosen as a logical starting point for examining possible sampling strata in Glacier Bay. Although stratification can be applied to any measurable factor, generic factors such as depth and geographic location are the most appropriate for multiple species analysis due to their broad influence on marine habitat.

### Methods

Our plan was to use bathymetry to stratify Glacier Bay. Bathymetry provides a simple and biologically meaningful variable for stratification. However, we encountered a problem with the application of a simple three-class bathymetric stratification. Many of the coastal transects, particularly in the East and West arms of Glacier Bay, were classified as being in the two deeper strata due to the steep bathymetric terrain in those areas. This meant that we could not distinguish between an observation made in 15 m of water and one made in 120 m of water on the same transect because many of these coastal transects included depths ranging from shallow to deep. Because deeper depth strata made up the majority of Glacier Bay, there was potential for incorrectly extrapolating coastal populations to pelagic waters offshore. To address this problem we modified the depth strata classification using GIS to classify transects as coastal (≤ 300 m) and pelagic (>300 m from shore; Fig. 18) areas. Thus coastal transects were treated as such, regardless of the range of depths observed on the coastal transect. Portions of pelagic transects were perpendicular to the coastline and came within 300 m of shore were also deemed coastal. The remaining transects perpendicular to the coastline were classified as pelagic-shallow (<120 m) or pelagic-deep (>120 m).

Broader scale geographic affinity has also been used for evaluating marine bird surveys (Merkel et al. 2002, Clarke et al. 2003). We based our broad-scale geographic strata (Fig. 19) on the oceanographically distinct regions of Glacier Bay suggested by Robards et al. (2003) and (Etherington et al. 2007). Together the coastal/depth classifications and geographic classifications yielded 11 strata (Table 6).

Earlier we noted that 46 marine bird species and 6 marine mammal species were observed on the summer boat surveys of Glacier Bay (Tables 3 and 4). Several were very rare (e.g., minke whale), or their use of terrestrial or shoreline habitats made accurate sampling by boat questionable (e.g., Surfbird or Black Oystercatcher). We therefore excluded these rare species and shorebirds from our analysis. Many of the other rare species were grouped with similar species to allow their sightings to contribute to an estimated population total for broader taxa. In cases where species identification was difficult, we also grouped species into broader taxa (e.g., Scoter, Gull, Murrelet, Goldeneye, Merganser, Loon, or Grebe). Not recording or not analyzing unidentified birds always causes bias, whereas grouping or partitioning the unknowns in some reasonable manner at least reduces the magnitude of error. We considered that population estimates for individual species from the 37,007 Surf Scoters and 28,143 White-winged Scoters observed seemed rather meaningless if we were to exclude the 19,137 unidentified scoters that significantly contributed to the total for each of these species, although in unknown proportions. Instead we chose to analyze Scoters as a group and leave it to the data-users to partition the population into species depending on their knowledge or need. The problem of unidentified birds recorded on surveys is inherent to observational studies. The magnitude of this problem can only be minimized by appropriately trained and experienced observers; however, 100% identification to species is not an attainable goal.

For our statistical analysis we considered marine birds and mammals in two groupings. First, we combined similar species and included unidentified birds as appropriate, but maintained individual species of particular importance (e.g., all marine mammal species) and species with frequent observations (i.e., Pigeon Guillemot, Harlequin Duck, Black-legged Kittiwake, Arctic Tern). We considered murrelets to be of particular importance and justified an exception to our procedures, analyzing Kittlitz's, Marbled, and unidentified *Brachyramphus* Murrelets as three separate species. Our rationale was based on several factors. Paramount was our concern that declines in one of the Murrelet species might be masked by a different trend in the other. The status of the Kittlitz's Murrelet as a candidate species under the Endangered Species Act creates a compelling reason for managers to identify their trends and population sizes. Furthermore, Kittlitz's Murrelets were a relatively stable proportion of the murrelets identified of between 8% and 12%. The combination of species of interest and more general taxa groupings yielded 22 species or species groups. Additionally, we tried a more general combination of species, combining 18 of these 22 groups into 6 larger groups based on their general type of foraging strategy, to yield a total of 10 taxa (Table 7). This simplified grouping was evaluated to examine whether multi-species groupings could be used as "conglomerate" species and help us evaluate designs that might be the best compromise for multi-species survey design.

Population estimates were derived from the average density of birds observed on the surveyed transects within each stratum, and the transects were considered a valid systematic sample. Most of the offshore samples were straight East-West transects spaced at constant intervals perpendicular to the long axis of the arm or bay. During the summer surveys, the nearshore was almost completely sampled. In contrast, winter surveys sampled less than half of the nearshore habitats.

Average density was calculated using the ratio estimator method (Caughley 1977, Cochran 1977) with each transect in a stratum contributing in proportion to its length, creating a weighted average density. Average density was calculated for each stratum by dividing the sum of birds observed in the stratum by the total area surveyed within that stratum, i.e., the sum of individual transect sample areas within a stratum. The population estimate for each species in each stratum was calculated by multiplying the average density by the total area of the stratum as determined from the GIS coverage. A measure of sampling error was based on the variation between the transect segments sampling each stratum and calculated according to the ratio estimate formula for variance of the mean density. We also calculated variability of the population index as the standard deviation among the total population estimates among the five survey years. This measure appropriately included variation perhaps related to differences in population size, timing, weather, vessel, observers, and other factors that differed among the survey years, but it did not include variability due to differences in density between the transects within a year.

Optimal allocation, also called Neyman allocation, is the determination of the "best" proportional allotment of effort to minimize the variance across individual strata while incorporating the cost of the survey (Snedecor and Cochran 1967). To minimize total variance, the number of sample units in each stratum should be proportional to stratum size x Standard Deviation (among sample units in that stratum) / (square root of cost per sample unit in that stratum). We assumed equal cost in all strata. Although this may not be strictly true, we felt the differences in cost were not large and our primary concern was in generating the lowest variance. We performed this calculation for the 22 and 10 species taxa groupings and for the 11 and 2 strata models, in both summer and winter.

We calculated the power to detect change over time using the CVs from the annual population sizes estimated for the eight focus species. Note that for this analysis all species of scoters were grouped. The CV for scoters as a group was probably lower than the CV for Surf Scoters alone due to the highly clumped distributions of Surf Scoters. Power calculations were made using the approximate formula proposed by Gerrodette (1987). This formula has five parameters: *n*, the number of samples; *r*, the rate of change of the quantity being measured; *CV,* the coefficient of variation; *alpha* type I error; and *beta* type II error. Given any four of these variables, the fifth can be calculated. For our purposes we used an *alpha* of 0.05 and a *beta* of 0.20 for all cases. Three cases were modeled: a 50% decline in population over 20 years, a 50% decline in 15 years, and a 50% decline in 10 years. This translates into annual declines of 3.41%, 4.52%, and 6.7% respectively. Power is dependent on the variability of the data set, the number of samples, the significance level *alpha*, and 1- *beta*. Since power is dependent upon a wide range of parameters and we were working on a multi-species survey design, we did not attempt to model power for all species. Instead, we present some examples, using the eight focus species, to demonstrate the range of power outcomes for the diversity of marine predators found in Glacier Bay.

## Results

As expected, there were clear differences in the distribution of different species within Glacier Bay. Benthic feeders such as Common Mergansers were clearly associated with shallow areas, while pursuit divers such as Kittlitz's Murrelets were sighted more often in deeper areas. Overlaying survey sightings on the bathymetry of Glacier Bay allowed us to assess the approximate average depths at which species were sighted. Results from our 8 focus species showed a wide range of average depths used by each species (Fig. 20). These results supported our decision to stratify using a combination of bathymetry and distance to coastline, and suggested that sampling proportions of these areas could affect estimated densities. Therefore we do not present any non-stratified estimates of density or populations. As suggested in our methods, the initial plan to classify strictly by bathymetry had an unforeseen bias toward classifying many coastal transects as >60 m in depth, even though the transects also included shallow areas. This led to the adoption of a simpler model with coastal and non-coastal zones.

Overlays of our 22 taxa groupings were used to look at seasonal use of strata. Although use of both bathymetric and geographic strata was different among species, most exhibited similar use of strata in both summer and winter (Fig. 21). We were surprised that this was true of the geographic as well as bathymetric strata given that there is a shift in densities from the arms of the bay to the lower portions of the bay in winter (Fig. 13). Using 11 strata and the 22 species groupings, the estimated summer population estimates for 17 species had a smaller estimated sampling error using within-year transect (spatial) variation compared to the among-years estimate of variation. More important was that the two variance estimates were so similar; they agreed within a factor of 2 in 18 of 22 species. This suggested that survey conditions and/or survey observations within Glacier Bay were not highly variable in the 5 survey years.

As expected, population estimates using the 2 and 11 strata were similar. The precision of the 2 strata estimate was improved by using 11 strata for all species except Pigeon Guillemot; however, improvements in precision were relatively small. In part, this is an "assumption-dependent" result because the formulas assume there is complete independence among all strata. The population estimates should remain fairly constant irrespective of the stratification, unless biased by unequal sampling intensity. The additional stratification provided a slight within-year decrease in CVs of approximately 5% among transects within sample years (Table 8). For between-year population estimates, the situation was reversed with CVs slightly lower for the two strata model.

We calculated optimal sampling allocations for all taxa combinations and strata models for both summer and winter surveys (Tables 9, 10); however, as noted above, we found little improvement in the CVs for the 11 strata model. This indicated that the geographic component was not important for the majority of species. Likewise we found little utility in the 10 taxa groupings. Consolidating species into larger groups added little to the analysis since the individual species had relatively similar optimal allocations. Therefore, optimal allocation results presented here use the 2 strata model and the 22 taxa. Complete "optimal allocation" results for all models and all groupings can be found in Appendices 4-10.

For summer surveys the optimal allocation calculations indicated that there was a clear difference between the "best" sampling allocation for seabirds and the "best" sampling allocation for water birds (Table 9). For example, optimal Kittlitz's Murrelet allocations would be 96% offshore and 4% coastal. Conversely, optimal allocation for mergansers would be 77% coastal and 23% offshore. More generally, for the eight focus species during summer surveys, five would benefit from allocations that favored a greater ratio of offshore survey effort. When we looked at the 22 taxa as a whole we saw a similar result with optimal allocation of 14 of the taxa favoring greater offshore sampling, 1 taxa favoring an even split, and 7 favoring greater coastal sampling (Table 9). On winter surveys the results were similar. For the eight focus species, optimal allocation for five taxa favored greater sampling in offshore strata, two taxa were split fairly evenly, and one taxa favored greater sampling in the coastal strata. This result was mirrored in the larger group of 22 taxa, where 16 favored greater sampling effort in the offshore areas, 1 taxa favored an even split, and 3 favored allocations with greater sampling in the coastal strata; 2 species had one or no observations and no conclusions could be drawn (Table 10). Although the allocations differed substantially among species, they were relatively consistent between summer and winter seasons for a given species. A notable exception was the merganser group. Optimal allocation for this group favored the coastal stratum in the summer and the offshore stratum in the winter.

Our examination of statistical power indicated that there was great range in our ability to detect change depending on the species in question (Fig. 22). For example, the among-year population CV for Pigeon Guillemot (0.097, Table 8) was the lowest of all taxa. Assuming one survey per year, we calculated the time to detect a population decline of 50% over three time periods, 10, 15, or 20 years, to be 6, 8, and 9 years respectively. This indicates that, using the current survey design, the Pigeon Guillemot population, on a trajectory leading to a 50% loss in population could be identified as declining well before the 50% loss in animals. At the other end of the spectrum were Black-legged Kittiwakes. The among-year population CV for Black-legged Kittiwakes (0.563, Table 8) was the third highest of all taxa during the summer months. Only Cormorants and Goldeneyes had higher levels of among-year variation (Table 8). These higher CVs resulted in longer times to achieve the minimum acceptable power (0.80). In the case of Black-legged Kittiwakes, that translated into 19, 24, and 29 years to detect simulated population changes of 50% over time periods of 10, 15, or 20 years respectively. In other words given the variability in observations using the current survey design, declines in Black-legged Kittiwake populations on a trajectory for a 50% population change cannot be detected until well after the population has declined. Differences between species are obvious in the individual power graphs (Fig. 22). The remaining species were intermediate between these two extremes. The among-year population CV for Kittlitz's Murrelet was 0.25 (Table 8). For this example, the three levels of decline returned minimum times of 11, 14, and 17 years (Fig. 22). Marbled Murrelets had a lower interannual CV of 0.105, resulting in relatively shorter times to detect change of 8, 11, and 13 years (Fig. 22). Harbor seals required relatively long times to detect the 50% population changes with 16, 21, and 25 years. Since these curves are based upon the interannual CVs, one can look at species with similar CVs and get an idea of detection times without graphing them. All of the marine mammals tended to have large CVs leading to long detection times. Marine birds showed little or no such similarity. Both waterfowl and seabirds showed a wide range of CVs (0.04-0.70) within each group. Thus few generalities could be made about seabird or waterfowl populations.

The primary difference between summer and winter surveys was that for the majority of species, CVs were higher on the winter surveys. This translates to longer times to detect change. A worst-case scenario for our data set was represented by Black-legged Kittiwakes. With a between-year CV of 1.01, we had to extend the x axis (number of years) to reach the minimum acceptable power in any of the curves (Fig. 23). The higher among-year variation (CV) characteristic of most taxa on the winter surveys suggests that detecting population changes based on those surveys may be problematic. Two species that did not follow the trend of higher winter CVs were Harbor seals and Steller sea lions (Fig. 24). Both of these species had considerably lower CVs based on winter surveys than on summer surveys, so that power to detect population changes was better when using the winter survey dataset. It should also be noted that winter surveys included fewer transect samples.

## Discussion

Stratification is a common technique applied both *a priori* and *a posteriori*. Post-stratification is required to remove bias due to disproportionate (nonrandom) sampling. In our case, not stratifying coastal and offshore transects would have lead to over-estimates of coastal species, some on the order of doubling the population estimates. We experimented with various groupings of species and two stratification models. Results from our stratification models suggest that a simple model based on whether transects were coastal or offshore could perform nearly as well as the much more complicated 11 strata model that mixed geography and bathymetry. Geography seems to be less useful for stratification than we had anticipated for most species.

Ideally, *a priori* stratification can be used to design an efficient survey that can achieve a desired level of precision. We found that the optimal sampling allocations differed considerably among taxa. As noted previously, the coastal areas of Glacier Bay were disproportionately oversampled in our original survey design. Our optimization results showed that even proportional sampling would not be ideal for estimating densities for most seabirds. The current sampling allocation for summer had similar sampling proportions in coastal and offshore areas. The only seabird species for which this design was optimal was the Black-legged Kittiwake. Population estimates for waterfowl, including dabbling ducks, Goldeneye, Harlequin Ducks, and Mergansers, could have benefited from even more disproportionate sampling in coastal areas. One monitoring strategy would be to design a survey that was optimal for one or several similar species of concern (e.g., murrelet population estimates would be most precise if 80-96% of sampling were offshore). This optimization would also have the consequence of making population estimates for coastal species, such as mergansers, less precise. If the goal is to monitor multiple species, proportionate sampling in the coastal and offshore strata would be the most appropriate choice.

Power analysis provided insight about the ability of the current survey design to identify changes in population sizes. We were able to determine that for most species, the time frame for detecting even a relatively large population decline of 6.7% per year with annual sampling was more than 10 years, and for many species was considerably longer. Given the CV levels we calculated, for most species, any detection of population changes that were not dramatic (e.g., 2.5% per year) is unlikely in less than 20 years. This limits the ability of managers to respond before population declines are severe. Thus efforts should be focused on decreasing CVs to increase the power to detect change.

The most important strategy for decreasing CVs, and thus increasing power to detect population change, would be to increase the sample size. If we look at each of the surveys as point estimates, replicating surveys within a season should increase precision of annual population estimates, increasing power by increasing samples. This assumes that there are no within-season population fluctuations. To assure that this assumption is met, consideration must be given to within-season bird movements and controlled with a narrow temporal window. Better observer training to increase the proportion of observations made to the species-level would also be useful. More research into other sources of variation could indicate future stratification factors. For example, surveys could be structured to collect data at similar stages in the tide cycle or similar times of day, thus controlling for tide and current or diurnal effects (Speckman et al. 2000)

Although multiple samples within a given season should provide better precision, if resources for surveys are limited, decisions on the number of surveys per year (or whether surveys are even conducted every year) will need to be considered. Based on the 1999-2003 surveys of Glacier Bay our ability to detect even large changes (6.7% per year) in population size is at least a decade for many species. Collecting multiple samples in one year and then not sampling for two years would yield the same number of overall samples, but the estimates should be more precise, making them more likely to detect changes in population size. This assumes that managers are only interested in long-term trends and not the among-year variability.

## Survey Design III: Other Methodological Considerations and Framework for Design Decisions

The marine surveys conducted in Glacier Bay from 1999 to 2003 provide extensive information on the distribution, numbers, and seasonality of marine birds and mammals that use Glacier Bay and Icy Strait. It is clear that Glacier Bay and Icy Strait, despite their proximity, provide very different marine habitats. Both species composition and numbers confirm that the oceanography of Icy Strait is more similar to offshore North Pacific oceanic regime, while Glacier Bay has a coastal fjord regime (Etherington et al. 2007). These two areas should not be combined when assessing population sizes or trends as their ecological differences are substantial. Combining these distinct areas would only add variability and potentially mask real changes in Glacier Bay populations.

Summer surveys indicated that while marine birds and mammals use all portions of the bay, several areas were focal points for many species in all seasons. These areas included Russell Island, the Skidmore Complex, Sitakaday Narrows, Berg Bay, Adams Inlet, and the middle of the East arm near Wachusett Inlet. During summer surveys we also noted that Tarr Inlet, Muir Inlet, and the base of the East Arm were additional areas of concentrated use by marine birds. Compared to summer survey results, winter bird concentrations were lower in the northern reaches of Glacier Bay and highest in the south. Glacier Bay appears to be an important overwintering site for many waterfowl species. In addition to the high-use areas in summer surveys, we noted that Fingers Bay and the Beardslee

Islands were also high-use areas during winter surveys. It is notable that during the colder winter months these areas of high use tended to be well sheltered.

## Transect Length and Sampling Effort

Our simulations indicated that transects in the 4-8 km range could provide precise and accurate population estimates for most if not all species. Our simulations using data collected previously in Glacier Bay suggests that sampling about 8% of the total surface area of Glacier Bay (or about 100 $km^2$) would be a conservative approach for monitoring because it would yield reasonably precise population estimates for even the most variable species. Less than half that effort could be used to monitor common, widely distributed species.

## Stratification, Optimization, and Power to Detect Change

Our comparisons of various stratification schemes provided us with strong evidence that the original sampling plan could be more efficient for sampling some species in Glacier Bay. The surveys conducted from 1999 to 2003 were biased because coastal areas were sampled out of proportion to their availability. Use of depth-based stratification makes good biological sense as it is based upon our understanding of marine bird and mammal foraging behavior and habitat use, not arbitrary classifications (Block and Brennan 1993).

Sampling theory suggests that stratification of samples can increase both precision and accuracy if the samples within each stratum are more homogeneous than samples from other strata (Cochran 1977). The difficulty is identifying the proper strata, particularly across a range of species. Ideally, strata would be developed for a species or group of similar species. While our two-strata design appeared to work well in controlling the bias due to disproportionate sampling, the optimal allocation calculations indicated that for most seabirds there was too much sampling effort concentrated in the coastal stratum. Conversely, for many of the waterfowl species, coastal sampling could have been even higher. Clearly, no single design can be optimized for all species. We suggest that in cases where surveys are focused on one or a small number of species, the results of our optimization of effort can be a guide. For example, if the species of concern were Kittlitz's Murrelets, our optimization analysis would suggest that coastal sampling effort be reduced from the historical 65% to 4% of the total. In cases where all species are to be recorded, we suggest that proportionate sampling of strata is a prudent approach. That would mean a sampling effort of 26% coastal and 74 % offshore; intermediate between the actual survey and the optimal survey for Kittlitz's Murrelet. While no single stratification design can compensate for all of the habitat variables influencing the distribution of all species, our modified depth/coastal stratification did a reasonably good job across all species.

## Additional Methodological Concerns

In addition to physical layout issues addressed in this report, several aspects of survey design should be addressed in future surveys. These additional concerns can be grouped into two basic categories: observer training and species detectability. Observers for the boat-based surveys conducted in Glacier Bay were all given basic training in bird identification. However, over the five years of surveys, personnel, including those doing the training, changed. Efforts should be made to have observers from previous surveys assist in training new observers to maximize continuity between surveys. The *Brachyramphus* murrelet observations provide a vivid illustration as to the importance of observer training. In the five years of surveys, unidentified murrelets accounted for between 22% and 58% of all murrelets. Fortunately, the proportion of Kittlitz's Murrelets was relatively stable at 8-12% of all murrelets. This was in marked contrast to Marbled and unidentified murrelets whose proportions varied inversely. This leads to large uncertainties regarding murrelet (particularly Marbled) populations. Splitting up the unknown murrelets by the ratio of Marbled to Kittlitz's Murrelets would have added dramatically to the variability of Kittlitz's Murrelets since the unknown to Marbled ratio was so volatile. The decision of how to treat unidentified birds can be an important factor in estimating populations. For any long-term monitoring program, a clear written protocol needs to be in place and any changes made through time should be noted with the date of implementation (Oakley et al. 2003).

The surveys in Glacier Bay were conducted using standard marine boat-survey methodology. This method, based on a simple strip transect, has generally lacked any measure of species detection rate or function. Recent research and common sense have shown that the likelihood of observing a bird or mammal will decrease with distance (Buckland et al. 2001, Peery et al. 2006). Development of detection functions for use with future strip-transect surveys would be a significant advance in this methodology. A detection function is typically associated with a certain species (size, coloring, group size); however, a measure of detectability also could be used to examine and develop corrections for the variance associated with individual observers, platforms, and specific ocean conditions. Line transect methods implicitly account for detectability; however, strip transects can also provide this information. For strip transects, binning the observations into 50 m increments could provide sufficient resolution to identify differences, while also providing a relatively simple methodology. This method is also flexible. When there are many concurrent observations of birds, this additional information could be ignored. As long as a representative sample of the data includes this information, the detection function could be calculated accurately.

## Framework for Survey Design Decisions

There are several factors that need to be considered before a survey design is selected. Most important is the primary objective of the surveys. For example, is the main objective to identify long-term trends of an entire community, describe the distribution (and changes in distribution) of various species in relation to habitat characteristics, or monitor a species of special interest and estimate total population size? These are distinct objectives that may require different designs. No single design will be optimal for all species. Multi-species surveys are the most complicated because they must strike a balance and will not be optimized for any one species. The specifics of balancing a single design will be determined by data needs of the resource managers.

The original survey that we designed for marine predators in 1999 provided extensive (and first-time) information on the distribution of marine birds and mammals throughout Glacier Bay; but this survey design has a number of disadvantages for long-term monitoring. The design is distinctly unbalanced in favor of coastal versus offshore sampling, it requires a large effort involving multiple vessels in order to be completed in time enough to avoid seasonal variability, and the effort is at least 3 times greater than needed to monitor populations with appropriate statistical power.

Based on our analysis of the 1999-2003 survey data from Glacier Bay, we can imagine several more efficient survey designs, each with pros and cons with respect to logistics and monetary costs (Table 11). The "best" design will depend largely on the question it is designed to answer. For example, surveys could be designed to:

(1) Detect long-term trends in population size of the marine predator community as a whole, or for some specific member(s) of the community (Table 11). The amount of spatial sampling ($km^2$) and percentage allocation of effort to different strata would depend on which species (or taxonomic group) the survey was meant to monitor. By conducting surveys 3 times in one year, but sampling only once every 3 years, efficiency could be increased with little or no loss of power to detect trends. Alternatively, managers may wish to have data collected on an annual basis in order to:

(2) Detect interannual changes and detect impacts of acute events (e.g., oil spills). It would cost more to maintain these surveys over the long-term (Table 11). However, if it is important to assess interannual variability, or even seasonal variability, another approach would be to conduct small scale sampling of an accessible area with a logistically simple sampling design. You might not be able to infer changes to the entire bay, or estimate bay-wide populations, but you might observe phenomena you would otherwise miss (e.g., timing of seasonal migrations, rapid decline or disappearance of a species). For example, repetitive one-day surveys of the shoreline of the Beardslee Islands could provide a rich dataset on most species within Glacier Bay (e.g., Duncan and Climo 1991). Perhaps combining a small-scale index survey with tri-annual monitoring surveys would be most efficient. Finally, resource managers may wish to:

(3) Detect changes in the distribution of marine predators in the bay, particularly in relation to oceanography and bathymetry. Because Glacier Bay is a dynamic ecosystem, we expect that many habitat features will change in the future. As glacial sedimentation affects bathymetry, freshwater runoff affects currents, long-term temperature fluctuations affect glacial melt and precipitation, and sea level rise affects shorelines, we should expect continuous evolution of habitats in Glacier Bay. To capture these changes, managers may choose to sample the bay at a fine scale—such as used in the original 1999 design—and essentially assess marine predator distribution in every nook and cranny of the bay (including closed or non-motorized waters). This approach comes at a higher cost, but might only need to be done every 5 or 10 years (Table 11).

Decisions also need to be made about transect layout. A design using randomly placed 4-8 km transects could provide unbiased estimates of abundance for all species and can control for unknown sampling bias; however, when some variable, e.g. bathymetry, is known to influence use, a stratified design can be more efficient (Sokal and Rohlf 1995). We have identified depth (modified based on distance from shore) as a critical habitat factor for some species, and sampling should definitely be stratified by coastal and offshore habitats.

A design with two habitat strata would have the advantage of generating lower CVs for the largest number of species. However, a stratified design can be complicated to construct and no single stratified design would be optimal for all species. Our examination of optimal allocation of effort showed that there are marked differences in how we might design a survey for a given species (Table 11). The question then becomes whether Glacier Bay managers wants to focus their monitoring efforts toward a narrow range of species or continue monitoring for all species. Although the exact allocation of effort will be based on a number of factors including logistics, a redesigned multi-species survey should include a larger ratio of offshore to coastal survey transects.

Randomized designs can also have high logistical costs because of long transit times between transects. In fact, the systematic sampling grid used in the original 1999 survey design offers higher sampling efficiency because a nearly continuous grid can be sampled with virtually no down time between transects. As long as the survey grid is split into optimal-sized transects (4-8 km), and statistical biases are recognized or compensated for (Piatt et al. 2007, Drew and Piatt 2008), systematic surveys can be a very efficient way to survey at sea for marine predators. Additionally, random transects by their very nature may fail to sample in areas of concern to the park, another consideration to be evaluated prior to deciding on a final sampling design.

A final consideration in developing a monitoring framework for marine predators is that at-sea surveys are not the only tool available for monitoring populations, and in some cases, not the best tool. For example, pinnipeds such as harbor seals and Steller sea lions are routinely counted while hauled out on ice or rock substrates during summer, making it relatively easy to obtain accurate and precise counts of entire Glacier Bay populations (Mathews and Pendleton 2006). In the case of sea otters, aerial surveys have been very successful in providing accurate and precise population estimates by surveying a stratified sample of transects and estimating a detection probability specific to each survey (Bodkin and Udevitz 1999). As for harbor seals, some colonial seabirds such as kittiwakes, gulls, murres, and cormorants breed at only a few locations within Glacier Bay, and it is relatively easy to monitor these sites and obtain accurate counts of individuals as well as to assess breeding performance (Zador and Piatt 1999, Dragoo et al. 2007). Any or all of these primary censusing methods should be used, when possible, to monitor marine predator populations in Glacier Bay.

In conclusion, we have presented a few sampling scenarios, but others may also be considered by park resource managers. Once park managers identify the primary and secondary goals for future surveys, and realistically assess what resources will be available to conduct those surveys, selecting a final survey design should be straightforward.

Regardless of the specific design chosen, there are a number of methodological adjustments that could decrease sample variation and increase the power to test survey data for changes in species abundances or population sizes:

- For multi-species surveys, transects should be in the 4-8 km range. This range allows for the largest number of transects (sample size) while accounting for the effects of spatial autocorrelation among transects.

- Randomly sampling about 100 $km^2$ of Glacier Bay annually would yield a simple and statistically robust population estimate for most of the common species found in Glacier Bay. Confidence limits around these estimates could be improved for many species by dividing the survey into coastal and offshore strata, and sampling in those strata proportionately.

- For measuring long-term trends or estimating populations, annual sampling may be unnecessary. With respect to statistics and logistics it may be better to replicate surveys 3 or more times within a season, but conduct them only once every few years. Repetitive surveys in a narrow temporal window will lower the within-year variance, increasing power to detect trends among years. In any case, it will require 10-20 years of surveys to detect moderate to strong negative trends.

- For most species, summer surveys provided lower CVs leading to more precise population estimates and greater power to detect change.

## Acknowledgements

This project was an outgrowth of inventory and monitoring projects funded by the USGS and USNPS. We thank both organizations for their long standing funding support. We thank the Glacier Bay National Park staff for their hospitality and logistical support during our surveys. We sincerely thank boat captains Jim de la Bruere and Greg Snedgen for putting in long hours as well as aiding with logistics and research aboard their respective research vessels, the *Alaskan Gyre* and *David Grey*. Additionally, we acknowledge the crew of the RV *Pandalus* who aided in conducting our first survey in 1999. Numerous volunteers, assistants, interpreter rangers, law-enforcement rangers aided in the field efforts and reporting of this project. Specifically, we thank Mayumi Arimitsu, Brenda Ballachey, Tim Bowman, Beth Brindle, Chola Dick, Janene Driscell, Dan Esler, George Esslinger, Patricia Gaines, Jennifer De Groot, Philip and Elizabeth Hooge, Kim Kloecker, Kathy Kuletz, Dan Monson, Mary Beth Moss, Martin Robards, Mark Romano, Jon Schroeder, Martin Schultz, Emily Scott, Greg Snedgen, Chad Soiseth, Suzann Speckman, Jim Taggart, and Rusty Yerxa for their assistance. For those we failed to mention, know that your omission was unintentional. Robert Stehn provided extensive statistical help and was a wealth of information regarding optimal sampling schemes. We thank Tom Van Pelt, Matt Kirchoff, Lyman McDonald, Tony DeGange and Karen Oakley for reviewing this report. Use of any trade names or products is for descriptive purposes only and does not imply endorsement of the U.S. Government.

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Table 1. Vessels used as platforms for surveys of marine predators in Glacier Bay, AK.

| Boat | Length (m) | Years | Observers | Height (m) | Strip Width (m) |
|---|---|---|---|---|---|
| *Alaskan Gyre* | 16 | 1999-2003 | 2 | 3.7 | 300 |
| *Capelin* | 12 | 2001-2003 | 2 | 2 | 300 |
| *David Grey* | 9 | 2000 | 2 | 2.4 | 200 |
| *Lutris II* | 9 | 1999-2003 | 2 | 1.5 | 200 |
| *Pandalus* | 22 | 1999 | 2 | 3.4 | 300 |
| *Sigma-t* | 8 | 2002 | 2 | 1.5 | 200 |

Table 2. Summary of marine predator surveys conducted in Glacier Bay, AK 1999-2003, that provide the basis for post-hoc analyses related to future survey designs used in this report.

| Year | Dates | Number of Transects | Total Length (km) | Sampled Area ($km^2$) |
|---|---|---|---|---|
| Summer | | | | |
| 1999 | June 10-26 | 110 | 1106.2 | 316.4 |
| 2000 | June 17-23 | 109 | 1090.1 | 270.1 |
| 2001 | June 16-21 | 105 | 1101.2 | 276.0 |
| 2002 | June 7-13 | 109 | 1056.0 | 258.5 |
| 2003 | June 9-14 | 109 | 1000.0 | 263.5 |
| Winter | | | | |
| 1999 | Nov. 5-18 | 39 | 427.3 | 106.2 |
| 2000 | March 17-23 | 42 | 452.8 | 111.5 |
| 2001 | March 12-21 | 43 | 432.6 | 109.5 |
| 2002 | March 17-23 | 47 | 481.9 | 115.8 |
| 2003 | March 18-21 | 48 | 460.6 | 124.5 |

Table 3. Mean annual density (num/km$^2$) and standard deviation of marine birds observed on surveys of Glacier Bay, AK during summer, 1999-2003. All data were collected between June 7th and June 26th.

| Group | Subgroup | 1999 (N=110) | | 2000 (N=109) | | 2001 (N=105) | | 2002 (N=109) | | 2003 (N=109) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Density | SD | Density | SD | Density | SD | Density | SD | Density | SD |
| **Waterbirds** | | | | | | | | | | | |
| | **Loon** | | | | | | | | | | |
| | Common Loon | 0.07 | 0.29 | 0.19 | 0.28 | 0.16 | 0.38 | 0.15 | 0.38 | 0.09 | 0.36 |
| | Pacific Loon | 0.27 | 1.39 | 0.33 | 1.69 | 0.16 | 0.32 | 0.08 | 0.51 | 0.07 | 0.27 |
| | Red-throated Loon | 0.09 | 0.16 | 0.00 | 0.00 | 0.08 | 0.18 | 0.12 | 0.30 | 0.07 | 0.24 |
| | Yellow-billed Loon | 0.01 | 0.02 | 0.00 | 0.00 | 0.01 | 0.06 | 0.01 | 0.04 | 0.00 | 0.00 |
| | Unidentified Loon | 0.28 | 0.97 | 0.30 | 0.85 | 0.18 | 0.33 | 0.08 | 0.20 | 0.06 | 0.20 |
| | **Sea Ducks** | | | | | | | | | | |
| | Barrow's Goldeneye | 0.14 | 0.25 | 0.28 | 0.68 | 0.14 | 0.60 | 0.64 | 1.95 | 0.12 | 0.38 |
| | Common Goldeneye | 0.02 | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.08 | 0.00 | 0.00 |
| | Unidentified Goldeneye | 0.07 | 0.19 | 0.04 | 0.34 | 0.01 | 0.06 | 0.05 | 0.31 | 0.01 | 0.09 |
| | Bufflehead | 0.01 | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.34 | 0.01 | 0.03 |
| | Long-tailed Duck | 0.02 | 0.14 | 0.05 | 0.45 | 0.04 | 0.15 | 0.32 | 1.83 | 0.03 | 0.13 |
| | Harlequin Duck | 3.47 | 6.97 | 6.09 | 12.77 | 4.63 | 8.13 | 6.33 | 8.29 | 8.52 | 27.53 |
| | Common Merganser | 13.01 | 21.38 | 11.84 | 26.83 | 15.17 | 29.41 | 11.64 | 15.87 | 23.56 | 44.74 |
| | Red-breasted Merganser | 0.07 | 0.28 | 0.24 | 0.46 | 0.06 | 0.50 | 0.05 | 0.23 | 0.05 | 0.16 |
| | Unidentified Merganser | 0.17 | 0.80 | 0.46 | 4.93 | 0.03 | 0.08 | 0.09 | 0.18 | 0.01 | 0.04 |
| | Black Scoter | 0.03 | 0.11 | 0.09 | 0.31 | 0.04 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Surf Scoter | 13.73 | 34.41 | 26.56 | 41.52 | 19.73 | 75.56 | 21.79 | 57.37 | 23.76 | 110.25 |
| | White-winged Scoter | 15.10 | 62.56 | 21.57 | 39.83 | 25.84 | 95.33 | 17.80 | 45.39 | 11.59 | 24.98 |
| | Unidentified Scoter | 25.87 | 130.26 | 1.79 | 3.07 | 12.14 | 89.57 | 11.38 | 48.76 | 7.73 | 153.26 |
| | **Other Waterbirds** | | | | | | | | | | |
| | Red-necked Grebe | 0.00 | 0.00 | <0.01 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.10 |
| | Horned Grebe | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | <0.01 | 0.06 | 0.02 | 0.19 |
| | Unidentified Grebe | <0.01 | 0.05 | <0.01 | 0.04 | <0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Trumpeter Swan | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | <0.01 | 0.02 |
| | Canada Goose | 3.13 | 8.37 | 3.05 | 7.51 | 2.00 | 5.42 | 0.81 | 2.49 | 2.71 | 5.96 |
| | Black Brant | 0.00 | 0.66 | 0.00 | 0.00 | 0.01 | 0.04 | 0.02 | 0.07 | 0.02 | 0.05 |
| | Mallard | 1.21 | 2.48 | 2.81 | 4.26 | 1.10 | 2.22 | 1.61 | 2.35 | 0.97 | 3.78 |

Table 3. Continued**.**

| Group | Subgroup | 1999 (N=110) | | 2000 (N=109) | | 2001 (N=105) | | 2002 (N=109) | | 2003 (N=109) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Density | SD | Density | SD | Density | SD | Density | SD | Density | SD |
| | Gadwall | 0.01 | 0.20 | 0.04 | 0.41 | 0.01 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Northern Pintail | 0.00 | 0.00 | 0.02 | 0.05 | 0.00 | 0.00 | 0.03 | 0.08 | 0.00 | 0.00 |
| | Green-winged Teal | 0.01 | 0.03 | 0.29 | 0.60 | 0.01 | 0.21 | 0.03 | 0.08 | 0.06 | 0.16 |
| | Blue-winged Teal | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.12 | 0.00 | 0.00 |
| | American Wigeon | 0.01 | 0.02 | 0.10 | 0.51 | 0.34 | 0.97 | 0.30 | 0.60 | 0.02 | 0.04 |
| | Northern Shoveler | 0.00 | 0.01 | 0.22 | 0.73 | 0.01 | 0.07 | 0.12 | 0.32 | 0.01 | 0.14 |
| | Greater Scaup | 0.00 | 0.00 | <0.01 | 0.02 | 0.04 | 0.09 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Unidentified Duck | 0.10 | 0.41 | 0.21 | 0.77 | 0.09 | 0.43 | 0.08 | 0.20 | 0.07 | 0.18 |
| **Waterbird Total** | | 76.90 | | 76.58 | | 82.02 | | 73.56 | | 79.55 | |
| **Seabirds** | | | | | | | | | | | |
| | **Tern** | | | | | | | | | | |
| | Arctic Tern | 1.68 | 7.06 | 0.96 | 2.55 | 3.45 | 7.93 | 3.00 | 5.14 | 1.47 | 4.33 |
| | Aleutian Tern | 0.00 | 0.11 | <0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Caspian Tern | <0.01 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Unidentified Tern | 0.00 | 0.00 | <0.01 | 0.02 | 0.00 | 0.00 | <0.01 | 0.05 | 0.00 | 0.00 |
| | **Murrelets** | | | | | | | | | | |
| | Kittlitz's Murrelet | 1.60 | 3.58 | 1.48 | 3.85 | 1.98 | 15.04 | 1.25 | 2.44 | 1.54 | 5.08 |
| | Marbled Murrelet | 11.47 | 14.85 | 4.48 | 6.46 | 9.65 | 13.84 | 8.46 | 13.04 | 8.23 | 13.27 |
| | Brachyramphus Murrelet | 5.81 | 14.05 | 8.40 | 15.54 | 4.84 | 8.09 | 3.07 | 6.63 | 2.76 | 4.82 |
| | Ancient Murrelet | 0.00 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | <0.01 | 0.02 | 0.00 | 0.00 |
| | **Other Alcid** | | | | | | | | | | |
| | Tufted Puffin | 0.05 | 0.57 | 0.05 | 0.16 | 0.07 | 0.32 | 0.08 | 0.19 | 0.07 | 0.23 |
| | Common Murre | 0.07 | 0.27 | 0.06 | 0.54 | 0.50 | 4.02 | 0.16 | 0.39 | 0.14 | 2.41 |
| | Unidentified Murre | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.03 | 0.50 | 0.00 | 0.00 |
| | Pigeon Guillemot | 5.70 | 6.62 | 6.26 | 6.89 | 6.69 | 9.18 | 6.75 | 8.21 | 6.78 | 42.97 |
| | **Gull** | | | | | | | | | | |
| | Black-legged Kittiwake | 7.17 | 39.90 | 4.97 | 10.96 | 20.61 | 57.44 | 20.60 | 34.74 | 36.18 | 53.66 |
| | Bonaparte's Gull | 0.09 | 0.33 | 0.01 | 0.07 | 1.62 | 4.78 | 0.96 | 2.32 | 0.00 | 0.03 |
| | Glaucous-winged Gull | 5.46 | 10.67 | 4.35 | 11.43 | 7.86 | 14.63 | 11.58 | 24.21 | 7.91 | 15.28 |
| | Herring gull | 0.41 | 1.91 | 0.37 | 1.30 | 0.39 | 0.98 | 0.31 | 0.79 | 0.44 | 1.04 |
| | Mew Gull | 2.19 | 4.27 | 4.24 | 7.21 | 3.46 | 5.01 | 3.14 | 4.28 | 2.32 | 5.06 |

Table 3. Continued**.**

| Group | Subgroup | 1999 (N=110) | | 2000 (N=109) | | 2001 (N=105) | | 2002 (N=109) | | 2003 (N=109) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Density | SD | Density | SD | Density | SD | Density | SD | Density | SD |
| | Unidentified Gull | 4.26 | 35.10 | 4.52 | 8.57 | 1.71 | 3.86 | 2.02 | 4.15 | 3.98 | 6.36 |
| | **Other Seabirds** | | | | | | | | | | |
| | Double-crested Cormorant | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 |
| | Pelagic Cormorant | 1.73 | 7.02 | 0.87 | 2.00 | 0.25 | 0.49 | 0.26 | 0.61 | 0.94 | 2.40 |
| | Red-faced Cormorant | 0.01 | 0.09 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.07 |
| | Unidentified Cormorant | 0.06 | 0.72 | 0.04 | 0.29 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Fork-tailed Storm-petrel | <0.01 | 0.03 | 0.00 | 0.04 | 0.00 | 0.09 | <0.01 | 0.02 | 0.00 | 0.00 |
| | Parasitic Jaeger | 0.02 | 0.06 | <0.01 | 0.02 | 0.00 | 0.04 | 0.03 | 0.37 | 0.03 | 0.12 |
| | Unidentified Shearwater | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.11 |
| | Unidentified Storm-petrel | 1.17 | 3.41 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Unidentified Jaeger | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.20 |
| | Red-necked Phalarope | 0.00 | 0.04 | <0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Seabird Total** | | 48.95 | | 41.08 | | 63.06 | | 61.72 | | 72.83 | |

Table 4. Mean annual densities (num/km$^2$) of marine mammal species, observed on surveys of Glacier Bay, AK during summer and winter, 1999-2003. Note that the area surveyed in summer was approximately 2.5 times the area surveyed in winter.

| Season | Common Name | 1999 (n=110) | | 2000 (n=109) | | 2001 (n=105) | | 2002 (n=109) | | 2003 (n=109) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Den. | SD | Den. | SD | Den. | SD | Den. | SD | Den. | SD |
| Summer | | | | | | | | | | | |
| | Killer Whale | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Harbor Porpoise | 0.15 | 0.45 | 0.13 | 0.32 | 0.26 | 0.78 | 0.21 | 0.61 | 0.16 | 0.47 |
| | Unidentified Porpoise | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.11 |
| | Humpback Whale | 0.06 | 0.31 | 0.11 | 0.46 | 0.07 | 0.40 | 0.02 | 0.12 | 0.09 | 0.46 |
| | Harbor Seal | 0.62 | 1.58 | 0.95 | 2.88 | 1.00 | 3.44 | 0.42 | 1.25 | 0.59 | 1.45 |
| | Sea Otter | 0.29 | 1.28 | 0.62 | 4.47 | 1.05 | 6.96 | 0.67 | 2.85 | 1.31 | 8.31 |
| | Steller Sea Lion | 0.04 | 0.14 | 0.17 | 0.59 | 0.16 | 0.84 | 0.12 | 0.53 | 0.07 | 0.30 |
| | | 1999 (n=39) | | 2000 (n=42) | | 2001 (n=43) | | 2002 (n=47) | | 2003 (n=48) | |
| Winter | | Den. | SD | Den. | SD | Den. | SD | Den. | SD | Den. | SD |
| | Harbor Porpoise | 0.25 | 0.68 | 0.76 | 1.73 | 0.89 | 2.54 | 0.21 | 0.66 | 0.04 | 0.37 |
| | Humpback Whale | 0.01 | 0.09 | 0.02 | 0.12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Minke Whale | 0.00 | 0.00 | 0.01 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Harbor Seal | 0.86 | 2.96 | 0.31 | 0.87 | 0.43 | 1.29 | 1.06 | 3.17 | 0.12 | 0.79 |
| | Sea Otter | 1.22 | 5.93 | 0.64 | 1.98 | 1.91 | 8.03 | 0.92 | 3.59 | 0.69 | 1.64 |
| | Steller Sea Lion | 0.46 | 0.73 | 0.62 | 1.31 | 0.58 | 1.07 | 0.49 | 0.96 | 0.33 | 0.69 |

Table 5. Mean annual density (num/km$^2$) and standard deviation of marine birds observed on surveys of Glacier Bay, AK during winter, 1999-2003. Surveys were conducted in March (2000-2003) or November (1999). Note that the area surveyed in summer was approximately 2.5 times the area surveyed in winter.

| | 1999 (N=110) | | 2000 (N=109) | | 2001 (N=105) | | 2002 (N=109) | | 2003 (N=109) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Density | SD | Density | SD | Density | SD | Density | SD | Density | SD |
| **Waterbirds** | | | | | | | | | | |
| **Loon** | | | | | | | | | | |
| Common Loon | 0.54 | 0.76 | 0.27 | 0.81 | 0.27 | 1.03 | 0.19 | 0.54 | 0.28 | 0.53 |
| Yellow-billed Loon | 0.00 | 0.00 | 0.05 | 0.35 | 0.01 | 0.04 | 0.00 | 0.00 | 0.02 | 0.10 |
| Red-throated Loon | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.04 | 0.00 | 0.00 |
| Pacific Loon | 0.08 | 0.25 | 0.11 | 0.28 | 0.20 | 1.29 | 0.11 | 0.33 | 0.00 | 0.00 |
| Unidentified Loon | 0.55 | 1.22 | 0.23 | 0.55 | 0.06 | 0.23 | 0.20 | 0.40 | 0.02 | 0.09 |
| **Goldeneye** | | | | | | | | | | |
| Barrow's Goldeneye | 27.74 | 36.57 | 27.52 | 34.87 | 21.70 | 29.67 | 34.66 | 69.52 | 6.44 | 7.48 |
| Common Goldeneye | 0.38 | 1.42 | 1.31 | 2.30 | 1.04 | 2.61 | 1.58 | 4.95 | 0.18 | 0.47 |
| Unidentified Goldeneye | 6.11 | 14.42 | 18.97 | 39.37 | 8.84 | 28.81 | 6.23 | 12.18 | 1.29 | 2.35 |
| **Scoter** | | | | | | | | | | |
| Black Scoter | 0.96 | 2.69 | 0.46 | 2.87 | 1.15 | 5.54 | 0.27 | 0.97 | 0.42 | 1.47 |
| Surf Scoter | 11.48 | 21.13 | 9.93 | 24.53 | 10.01 | 22.83 | 11.95 | 24.20 | 1.69 | 2.77 |
| White-winged Scoter | 6.96 | 8.50 | 5.91 | 18.77 | 5.93 | 14.16 | 4.10 | 9.70 | 1.75 | 3.95 |
| Unidentified Scoter | 5.32 | 15.90 | 5.75 | 14.44 | 1.45 | 5.63 | 1.38 | 3.03 | 0.24 | 0.60 |
| **Other Waterbirds** | | | | | | | | | | |
| Red-necked Grebe | 0.27 | 0.70 | 0.01 | 0.04 | 0.02 | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 |
| Western Grebe | 0.00 | 0.00 | 0.03 | 0.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Horned Grebe | 0.95 | 1.51 | 0.35 | 1.14 | 0.99 | 2.09 | 0.51 | 1.48 | 0.57 | 1.03 |
| Unidentified Grebe | 0.40 | 0.97 | 0.30 | 0.70 | 0.08 | 0.19 | 0.29 | 0.62 | 0.03 | 0.17 |
| Canada Goose | 1.21 | 3.97 | 1.76 | 5.00 | 1.14 | 3.76 | 0.72 | 2.80 | 0.54 | 2.83 |
| Mallard | 14.47 | 21.00 | 14.12 | 21.72 | 5.53 | 9.33 | 3.28 | 5.22 | 1.73 | 5.18 |
| Gadwall | 8.58 | 47.69 | 0.18 | 0.78 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| American Wigeon | 0.20 | 0.73 | 0.05 | 0.33 | 0.05 | 0.33 | 0.00 | 0.00 | 0.02 | 0.15 |
| Green-winged Teal | 0.23 | 1.31 | 0.05 | 0.19 | 0.00 | 0.00 | 0.03 | 0.21 | 0.03 | 0.17 |
| Northern Pintail | 0.02 | 0.13 | 0.01 | 0.04 | 0.01 | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 |
| Northern Shoveler | 0.00 | 0.00 | 0.01 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Bufflehead | 3.79 | 7.25 | 4.24 | 7.90 | 4.08 | 9.10 | 3.84 | 7.69 | 1.38 | 1.84 |
| Harlequin Duck | 3.72 | 7.98 | 4.63 | 8.92 | 2.70 | 4.64 | 2.98 | 4.92 | 1.13 | 2.97 |
| Long-tailed Duck | 1.47 | 2.63 | 0.14 | 0.51 | 1.47 | 8.43 | 1.70 | 8.97 | 0.10 | 0.37 |
| Common Merganser | 0.85 | 4.36 | 0.53 | 1.02 | 0.93 | 4.74 | 0.85 | 3.96 | 1.94 | 12.26 |
| Red-breasted Merganser | 1.36 | 3.43 | 0.58 | 1.11 | 2.73 | 6.33 | 1.18 | 2.52 | 1.09 | 1.57 |
| Unidentified Merganser | 2.65 | 4.13 | 4.09 | 18.90 | 4.56 | 14.22 | 5.96 | 30.29 | 0.44 | 1.74 |
| Unidentified Duck | 4.09 | 11.35 | 0.74 | 2.23 | 0.21 | 1.26 | 0.77 | 2.83 | 0.13 | 0.62 |
| **Waterbird Total** | 104.38 | | 102.31 | | 75.14 | | 82.77 | | 21.46 | |
| **Seabirds** | | | | | | | | | | |
| **Alcid** | | | | | | | | | | |
| Common Murre | 0.08 | 0.36 | 0.01 | 0.04 | 3.99 | 23.87 | 0.28 | 1.17 | 0.26 | 0.95 |
| Pigeon Guillemot | 4.39 | 7.67 | 6.75 | 9.94 | 6.52 | 8.03 | 7.35 | 10.68 | 3.36 | 3.34 |
| Unidentified Alcid | 0.00 | 0.00 | 0.04 | 0.23 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Brachyramphus Murrelet** | | | | | | | | | | |
| Marbled Murrelet | 0.81 | 1.79 | 2.04 | 4.86 | 6.16 | 27.71 | 2.04 | 7.76 | 0.25 | 0.48 |
| Kittlitz's Murrelet | 0.06 | 0.30 | 2.21 | 5.87 | 0.30 | 1.02 | 0.64 | 2.06 | 0.15 | 0.57 |
| Unid. Brachyramphus | 1.12 | 2.28 | 3.18 | 5.52 | 7.44 | 28.13 | 0.77 | 1.26 | 0.24 | 0.49 |

Table 5. Continued

| | 1999 (N=110) | | 2000 (N=109) | | 2001 (N=105) | | 2002 (N=109) | | 2003 (N=109) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Density | SD | Density | SD | Density | SD | Density | SD | Density | SD |
| **Gull** | | | | | | | | | | |
| Glaucous-winged Gull | 11.19 | 28.35 | 5.45 | 8.13 | 13.62 | 15.15 | 13.23 | 23.26 | 5.25 | 4.37 |
| Herring gull | 0.29 | 0.88 | 0.25 | 0.76 | 0.23 | 1.08 | 0.11 | 0.35 | 0.04 | 0.14 |
| Mew Gull | 5.69 | 11.56 | 0.87 | 2.16 | 11.48 | 56.33 | 0.21 | 0.80 | 0.15 | 0.41 |
| Unidentified Gull | 19.35 | 29.86 | 7.79 | 13.02 | 5.64 | 16.76 | 2.97 | 7.19 | 0.15 | 0.47 |
| Black-legged Kittiwake | 14.75 | 53.32 | 3.64 | 16.18 | 1.70 | 5.47 | 4.05 | 13.66 | 1.12 | 4.28 |
| **Other Seabirds** | | | | | | | | | | |
| Double-crested Cormorant | 0.18 | 0.73 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pelagic Cormorant | 1.65 | 3.43 | 0.96 | 2.21 | 3.04 | 8.66 | 1.38 | 2.53 | 2.07 | 4.85 |
| Unidentified Cormorant | 0.16 | 0.60 | 0.13 | 0.46 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Fork-tailed Storm-petrel | 0.09 | 0.24 | 0.00 | 0.00 | 0.04 | 0.20 | 0.00 | 0.00 | 0.00 | 0.00 |
| Unidentified Petrel | 0.17 | 1.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Unidentified Shearwater | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.09 |
| **Seabird Total** | 60.00 | | 33.31 | | 60.16 | | 33.01 | | 13.06 | |

Table 6. Listing of 11 strata classifications (based on transect type, depth, and geography) and their associated areas in Glacier Bay. See Figure 19 for locations of these strata within Glacier Bay.

| Depth Strata | Depth Code | Geographic Strata | Geographic Code | Area ($km^2$) |
|---|---|---|---|---|
| Coastal | C | Central Bay | CB | 117.09 |
| Shallow | S | Central Bay | CB | 279.14 |
| Deep | D | Central Bay | CB | 197.44 |
| Coastal | C | East Arm | EA | 67.69 |
| Shallow | S | East Arm | EA | 59.66 |
| Deep | D | East Arm | EA | 24.75 |
| Coastal | C | Lower Bay | LB | 64.14 |
| Shallow | S | Lower Bay | LB | 163.98 |
| Coastal | C | West Arm | WA | 74.47 |
| Shallow | S | West Arm | WA | 179.61 |
| Deep | D | West Arm | WA | 30.43 |

Table 7. Summary of seasonal counts and frequencies for common marine bird species observed in Glacier Bay, AK. Species are listed individually, as well as grouped into 10 and 22 taxa (see Methods). Columns indicate the frequency of transects with birds present, the percentage of transects with birds, and the total number observed on all summer and all winter transects (n from 1999-2003 combined).

| # Groups | | | | Summer (n=955) | | | Winter (n=418) | | |
|---|---|---|---|---|---|---|---|---|---|
| 10 | 22 | Common name | Functional Group | # Transects with Obs. | % Transects with Obs. | Total Observed | # Transects with Obs. | % Transects with Obs. | Total Observed |
| 1 | 1 | Kittlitz's Murrelet | Diving Piscivorous | 319 | 33% | 2180 | 44 | 11% | 300 |
| 1 | 2 | Marbled Murrelet | Seabird | 604 | 63% | 11930 | 97 | 23% | 659 |
| 1 | 3 | Unidentified Brachyramphus | | 583 | 61% | 6979 | 134 | 32% | 780 |
| 2 | 4 | Pelagic Cormorant | | 141 | 15% | 1161 | 132 | 32% | 908 |
| 2 | 4 | Unidentified Cormorant | | 10 | 1% | 31 | 10 | 2% | 20 |
| 2 | 4 | Double-crested Cormorant | | 0 | 0% | 0 | 4 | 1% | 13 |
| 2 | 5 | Pigeon Guillemot | | 537 | 56% | 8946 | 208 | 50% | 3750 |
| 2 | 6 | Common Murre | | 28 | 3% | 253 | 29 | 7% | 77 |
| 2 | 6 | Tufted Puffin | | 46 | 5% | 89 | 0 | 0% | 0 |
| 3 | 7 | Surf Scoter | Benthic-feeding | 178 | 19% | 30363 | 125 | 30% | 6626 |
| 3 | 7 | White-winged Scoter | Waterfowl | 224 | 23% | 25393 | 118 | 28% | 2679 |
| 3 | 7 | Unidentified Scoter | | 87 | 9% | 17000 | 81 | 19% | 2114 |
| 3 | 7 | Black Scoter | | 9 | 1% | 41 | 41 | 10% | 418 |
| 4 | 8 | Canada Goose | Grazing Waterfowl | 71 | 7% | 3292 | 29 | 7% | 292 |
| 4 | 8 | Mallard | Dabbling Waterfowl | 84 | 9% | 2117 | 102 | 24% | 2694 |
| 4 | 8 | Gadwall | | 0 | 0% | 0 | 9 | 2% | 521 |
| 4 | 8 | American Wigeon | | 11 | 1% | 205 | 5 | 1% | 84 |
| 4 | 8 | Green-winged Teal | | 13 | 1% | 108 | 6 | 1% | 41 |
| 4 | 8 | Northern Shoveler | | 13 | 1% | 96 | 1 | 0% | 2 |
| 4 | 8 | Northern Pintail | | 0 | 0% | 0 | 2 | 0% | 3 |
| 5 | 9 | Barrow's Goldeneye | Diving Waterfowl | 50 | 5% | 358 | 177 | 42% | 14318 |
| 5 | 9 | Unidentified Goldeneye | | 15 | 2% | 51 | 142 | 34% | 5640 |
| 5 | 9 | Common Goldeneye | | 0 | 0% | 0 | 58 | 14% | 623 |
| 5 | 10 | Harlequin Duck | | 193 | 20% | 7983 | 103 | 25% | 1621 |
| 5 | 11 | Common Merganser | | 218 | 23% | 20723 | 52 | 12% | 1494 |
| 5 | 11 | Unidentified Merganser | | 23 | 2% | 210 | 87 | 21% | 2098 |
| 5 | 11 | Red-breasted Merganser | | 22 | 2% | 129 | 104 | 25% | 1017 |

Table 7. Continued

| # Groups 10 | # Groups 22 | Common name | Functional Group | Summer (n=955) # Transects with Obs. | Summer % Transects with Obs. | Summer Total Observed | Winter (n=418) # Transects with Obs. | Winter % Transects with Obs. | Winter Total Observed |
|---|---|---|---|---|---|---|---|---|---|
| 5 | 12 | Bufflehead | | 0 | 0% | 0 | 118 | 28% | 2386 |
| 5 | 12 | Unidentified Duck | | 20 | 2% | 77 | 32 | 8% | 476 |
| 5 | 12 | Unidentified Scaup | | 23 | 2% | 311 | 0 | 0% | 0 |
| 5 | 12 | Long-tailed Duck | | 25 | 3% | 120 | 0 | 0% | 0 |
| 5 | 12 | Greater Scaup | | 2 | 0% | 12 | 0 | 0% | 0 |
| 6 | 13 | Glaucous-winged Gull | Surface-feeding | 496 | 52% | 10230 | 240 | 57% | 1926 |
| 6 | 13 | Unidentified Gull | Seabird | 249 | 26% | 4588 | 168 | 40% | 1570 |
| 6 | 13 | Mew Gull | | 232 | 24% | 4227 | 76 | 18% | 804 |
| 6 | 13 | Bonaparte's Gull | | 11 | 1% | 728 | 0 | 0% | 0 |
| 6 | 13 | Herring gull | | 107 | 11% | 540 | 29 | 7% | 83 |
| 6 | 13 | Unidentified tubenose | Planktivorous | 3 | 0% | 370 | 1 | 0% | 4 |
| 6 | 13 | Fork-tailed Storm-petrel | Seabird | 0 | 0% | 0 | 9 | 2% | 10 |
| 6 | 13 | Unidentified Shearwater | | 0 | 0% | 0 | 1 | 0% | 1 |
| 6 | 14 | Black-legged Kittiwake | Surface-feeding | 414 | 43% | 24203 | 92 | 22% | 1610 |
| 6 | 15 | Arctic Tern | Seabird | 104 | 11% | 2909 | 0 | 0% | 0 |
| 7 | 16 | Horned Grebe | Piscivorous Diving | 0 | 0% | 0 | 73 | 17% | 508 |
| 7 | 16 | Unidentified Grebe | Waterfowl | 0 | 0% | 0 | 44 | 11% | 176 |
| 7 | 16 | Red-necked Grebe | | 0 | 0% | 0 | 14 | 3% | 37 |
| 7 | 16 | Western Grebe | | 0 | 0% | 0 | 2 | 0% | 5 |
| 7 | 17 | Unidentified Loon | | 115 | 12% | 322 | 50 | 12% | 103 |
| 7 | 17 | Common Loon | | 92 | 10% | 181 | 67 | 16% | 135 |
| 7 | 17 | Pacific Loon | | 92 | 10% | 259 | 19 | 5% | 47 |
| 7 | 17 | Red-throated Loon | | 36 | 4% | 99 | 1 | 0% | 1 |
| 7 | 17 | Yellow-billed Loon | | 0 | 0% | 0 | 4 | 1% | 4 |
| 8 | 18 | Steller Sea Lion | Piscivorous | 73 | 8% | 328 | 84 | 20% | 306 |
| 8 | 19 | Harbor Porpoise | Marine Mammal | 104 | 11% | 269 | 63 | 15% | 195 |
| 8 | 20 | Harbor Seal | | 223 | 23% | 1296 | 67 | 16% | 333 |
| 9 | 21 | Humpback Whale | Filter-feeding | 35 | 4% | 57 | 0 | 0% | 0 |
| 9 | 21 | Minke Whale | Marine Mammal | 0 | 0% | 0 | 1 | 0% | 1 |
| 10 | 22 | Sea Otter | Benthic Feeding | 96 | 10% | 890 | 67 | 16% | 456 |

Table 8. Comparison of simulated population estimates (listed in descending order of abundance) for marine predator species in Glacier Bay, AK during summer and winter surveys. Simulations provided standard deviations, coefficients of variation, and standard errors obtained under two different stratification scenarios, two strata (Coastal-Offshore) and 11 strata (Coastal-Offshore by geographic region).

| | 11 strata | | | | | 2 strata | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Among Years | | | Within Year | | Among Years | | | Within Year | |
| Species | Sim. Pop. Estimates | SD | CV | Pop. SE | CV | Sim. Pop. Estimates | SD | CV | Pop. SE | CV |
| **Summer** | | | | | | | | | | |
| Scoters | 34635 | 17054 | 0.492 | 9716 | 0.281 | 31244 | 11301 | 0.362 | 10422 | 0.334 |
| Kittiwake | 11674 | 6643 | 0.569 | 4004 | 0.343 | 11230 | 6323 | 0.563 | 4242 | 0.378 |
| Marbled Murrelet | 10529 | 1952 | 0.185 | 1111 | 0.105 | 10875 | 1810 | 0.166 | 1541 | 0.142 |
| unid. Murrelet | 8310 | 4047 | 0.487 | 981 | 0.118 | 8557 | 4502 | 0.526 | 1258 | 0.147 |
| Kittlitz's Murrelet | 3271 | 894 | 0.273 | 637 | 0.195 | 3042 | 772 | 0.254 | 665 | 0.219 |
| Gulls | 8883 | 594 | 0.067 | 1147 | 0.129 | 9000 | 376 | 0.042 | 1385 | 0.154 |
| Mergansers | 7130 | 2111 | 0.296 | 2246 | 0.315 | 7227 | 2182 | 0.302 | 2681 | 0.371 |
| Pigeon Guillemot | 4081 | 767 | 0.188 | 516 | 0.126 | 3761 | 365 | 0.097 | 457 | 0.122 |
| Harlequin Duck | 2819 | 744 | 0.264 | 577 | 0.205 | 2818 | 719 | 0.255 | 643 | 0.228 |
| Dabbling ducks | 1945 | 465 | 0.239 | 703 | 0.361 | 1968 | 536 | 0.272 | 832 | 0.423 |
| Arctic Tern | 1125 | 490 | 0.436 | 424 | 0.377 | 1066 | 447 | 0.420 | 502 | 0.471 |
| Sea Otter | 741 | 347 | 0.468 | 286 | 0.386 | 793 | 373 | 0.470 | 381 | 0.480 |
| Loons | 635 | 325 | 0.512 | 131 | 0.207 | 658 | 341 | 0.518 | 169 | 0.256 |
| Harbor Seal | 630 | 311 | 0.493 | 152 | 0.242 | 627 | 281 | 0.449 | 198 | 0.316 |
| Cormorants | 589 | 381 | 0.648 | 169 | 0.288 | 617 | 407 | 0.660 | 206 | 0.333 |
| Steller Sea Lion | 326 | 160 | 0.489 | 92 | 0.281 | 358 | 175 | 0.489 | 112 | 0.313 |
| Murre, Puffin | 289 | 109 | 0.376 | 92 | 0.318 | 318 | 124 | 0.389 | 119 | 0.375 |
| Diving ducks | 190 | 112 | 0.591 | 59 | 0.309 | 192 | 114 | 0.594 | 70 | 0.367 |
| Harbor Porpoise | 179 | 43 | 0.239 | 50 | 0.282 | 200 | 55 | 0.273 | 67 | 0.334 |
| Goldeneye | 139 | 98 | 0.700 | 46 | 0.333 | 140 | 98 | 0.702 | 52 | 0.370 |
| Humpback Whale | 46 | 24 | 0.519 | 17 | 0.368 | 47 | 22 | 0.466 | 23 | 0.498 |
| Grebes | 0 | 0 | | 0 | | 0 | 0 | | 0 | |
| **Winter** | | | | | | | | | | |
| Goldeneye | 21625 | 10748 | 0.497 | 5834 | 0.270 | 24474 | 16566 | 0.677 | 8892 | 0.363 |
| Scoters | 9419 | 3962 | 0.421 | 2040 | 0.217 | 10220 | 3579 | 0.350 | 2578 | 0.252 |
| Gulls | 7426 | 4498 | 0.606 | 992 | 0.134 | 7592 | 4717 | 0.621 | 1421 | 0.187 |
| Kittiwake | 4237 | 3632 | 0.857 | 1607 | 0.379 | 4264 | 4315 | 1.012 | 2516 | 0.590 |
| Mergansers | 3733 | 1572 | 0.421 | 1464 | 0.392 | 4313 | 1875 | 0.435 | 2203 | 0.511 |
| Pigeon Guillemot | 3499 | 1106 | 0.316 | 578 | 0.165 | 4058 | 1131 | 0.279 | 904 | 0.223 |
| unid. Murrelet | 2930 | 2686 | 0.917 | 787 | 0.268 | 2900 | 2588 | 0.892 | 913 | 0.315 |
| Marbled Murrelet | 1666 | 1101 | 0.661 | 462 | 0.277 | 1667 | 846 | 0.507 | 567 | 0.340 |
| Kittlitz's Murrelet | 1066 | 982 | 0.922 | 374 | 0.351 | 974 | 820 | 0.841 | 448 | 0.460 |
| Dabbling ducks | 2417 | 2180 | 0.902 | 600 | 0.248 | 2948 | 2581 | 0.875 | 827 | 0.280 |
| Diving ducks | 1834 | 587 | 0.320 | 356 | 0.194 | 2525 | 967 | 0.383 | 740 | 0.293 |
| Harlequin Duck | 1549 | 576 | 0.372 | 370 | 0.239 | 1680 | 649 | 0.386 | 497 | 0.296 |
| Cormorants | 1489 | 839 | 0.563 | 455 | 0.305 | 1495 | 701 | 0.469 | 620 | 0.415 |
| Murre, Puffin | 563 | 561 | 0.997 | 182 | 0.324 | 521 | 425 | 0.815 | 235 | 0.451 |
| Grebes | 550 | 199 | 0.362 | 131 | 0.239 | 587 | 206 | 0.351 | 163 | 0.278 |
| Harbor Porpoise | 526 | 329 | 0.626 | 144 | 0.274 | 545 | 343 | 0.630 | 217 | 0.398 |
| Loons | 484 | 191 | 0.395 | 136 | 0.281 | 518 | 191 | 0.370 | 173 | 0.334 |
| Steller Sea Lion | 467 | 148 | 0.317 | 102 | 0.219 | 392 | 121 | 0.308 | 131 | 0.335 |
| Sea Otter | 324 | 72 | 0.223 | 118 | 0.362 | 444 | 70 | 0.157 | 200 | 0.449 |
| Harbor Seal | 222 | 58 | 0.262 | 73 | 0.330 | 285 | 60 | 0.211 | 113 | 0.397 |
| Humpback Whale | 1 | 2 | | 1 | | 1 | 1 | | 1 | |
| Arctic Tern | 0 | 0 | | | | 0 | 0 | | 0 | |

Table 9. Calculations of optimal allocation of sampling effort among strata based on results of summer surveys, 1999-2003, in Glacier Bay, AK. These calculations were made using the simple two strata model applied to the 22 species groups (Table 7).

| Group | | | Density ($km^2$) | | Abundance | | | Between Year Var. | |
|---|---|---|---|---|---|---|---|---|---|
| | Strata | Species | Mean | SE | Mean | SE | CV | SD | Optimal Allocation |
| 1 | Coastal | Kittlitz's Murrelet | 1.03 | 0.14 | 332 | 45 | 0.14 | 101 | 4.10% |
| | Offshore | Kittlitz's Murrelet | 2.9 | 0.39 | 2710 | 367 | 0.14 | 821 | 95.90% |
| 2 | Coastal | Marbled Murrelet | 8.55 | 1.43 | 2766 | 463 | 0.17 | 1035 | 19.90% |
| | Offshore | Marbled Murrelet | 8.67 | 0.69 | 8109 | 646 | 0.08 | 1444 | 80.10% |
| 3 | Coastal | Unid. Brachyramphus | 3.9 | 0.62 | 1262 | 200 | 0.16 | 447 | 3.60% |
| | Offshore | Unid. Brachyramphus | 7.8 | 2 | 7295 | 1872 | 0.26 | 4185 | 96.40% |
| 4 | Coastal | Cormorant | 1.06 | 0.35 | 343 | 114 | 0.33 | 254 | 25.60% |
| | Offshore | Cormorant | 0.29 | 0.12 | 273 | 114 | 0.42 | 255 | 74.40% |
| 5 | Coastal | Pigeon Guillemot | 8.81 | 0.18 | 2851 | 59 | 0.02 | 131 | 14.00% |
| | Offshore | Pigeon Guillemot | 0.97 | 0.13 | 910 | 125 | 0.14 | 279 | 86.00% |
| 6 | Coastal | Murre - Puffin | 0.25 | 0.11 | 81 | 34 | 0.43 | 77 | 21.30% |
| | Offshore | Murre - Puffin | 0.25 | 0.05 | 237 | 44 | 0.19 | 98 | 78.70% |
| 7 | Coastal | Scoter | 70.93 | 2.96 | 22938 | 956 | 0.04 | 2139 | 6.80% |
| | Offshore | Scoter | 8.88 | 4.86 | 8305 | 4543 | 0.55 | 10158 | 93.20% |
| 8 | Coastal | Dabbling Duck | 5.92 | 0.77 | 1915 | 249 | 0.13 | 557 | 74.60% |
| | Offshore | Dabbling Duck | 0.06 | 0.03 | 54 | 29 | 0.55 | 66 | 25.40% |
| 9 | Coastal | Goldeneye | 0.43 | 0.13 | 138 | 42 | 0.3 | 93 | 85.50% |
| | Offshore | Goldeneye | 0 | 0 | 3 | 2 | 0.89 | 5 | 14.50% |
| 10 | Coastal | Harlequin Duck | 8.25 | 1.04 | 2668 | 337 | 0.13 | 753 | 67.80% |
| | Offshore | Harlequin Duck | 0.16 | 0.06 | 150 | 55 | 0.37 | 123 | 32.20% |
| 11 | Coastal | Merganser | 21.66 | 2.76 | 7004 | 891 | 0.13 | 1993 | 76.90% |
| | Offshore | Merganser | 0.24 | 0.1 | 223 | 93 | 0.42 | 207 | 23.10% |
| 12 | Coastal | Diving Duck | 0.54 | 0.16 | 174 | 53 | 0.3 | 117 | 69.50% |
| | Offshore | Diving Duck | 0.02 | 0.01 | 18 | 8 | 0.44 | 18 | 30.50% |
| 13 | Coastal | Gull | 20.22 | 1.1 | 6538 | 357 | 0.05 | 798 | 29.00% |
| | Offshore | Gull | 2.63 | 0.32 | 2462 | 302 | 0.12 | 676 | 71.00% |

Table 9. Continued

| Group | Strata | Species | Density ($km^2$) Mean | Density ($km^2$) SE | Abundance Mean | Abundance SE | Abundance CV | Between Year Var. SD | Optimal Allocation |
|---|---|---|---|---|---|---|---|---|---|
| 14 | Coastal | Kittiwake | 23.94 | 6.96 | 7743 | 2251 | 0.29 | 5034 | 50.50% |
| | Offshore | Kittiwake | 3.73 | 0.82 | 3486 | 764 | 0.22 | 1708 | 49.50% |
| 15 | Coastal | Arctic Tern | 2.95 | 0.59 | 955 | 192 | 0.2 | 430 | 66.00% |
| | Offshore | Arctic Tern | 0.12 | 0.04 | 110 | 34 | 0.31 | 77 | 34.00% |
| 16 | Coastal | Grebe | 0 | 0 | 0 | 0 | | 0 | NA |
| | Offshore | Grebe | 0 | 0 | 0 | 0 | | 0 | NA |
| 17 | Coastal | Loon | 0.68 | 0.12 | 222 | 39 | 0.17 | 87 | 10.30% |
| | Offshore | Loon | 0.47 | 0.13 | 437 | 117 | 0.27 | 262 | 89.70% |
| 18 | Coastal | Sea Lion | 0.22 | 0.06 | 70 | 18 | 0.26 | 41 | 9.00% |
| | Offshore | Sea Lion | 0.31 | 0.07 | 288 | 63 | 0.22 | 141 | 91.00% |
| 19 | Coastal | Harbor Porpoise | 0.22 | 0.03 | 71 | 9 | 0.13 | 20 | 8.90% |
| | Offshore | Harbor Porpoise | 0.14 | 0.03 | 129 | 32 | 0.25 | 72 | 91.10% |
| 20 | Coastal | Harbor Seal | 1.23 | 0.14 | 397 | 47 | 0.12 | 105 | 14.80% |
| | Offshore | Harbor Seal | 0.25 | 0.1 | 230 | 93 | 0.4 | 208 | 85.20% |
| 21 | Coastal | Cetacean | 0.04 | 0.01 | 14 | 3 | 0.23 | 7 | 9.00% |
| | Offshore | Cetacean | 0.03 | 0.01 | 32 | 12 | 0.36 | 26 | 91.00% |
| 22 | Coastal | Sea Otter | 0.68 | 0.11 | 221 | 34 | 0.16 | 77 | 7.50% |
| | Offshore | Sea Otter | 0.61 | 0.16 | 572 | 148 | 0.26 | 331 | 92.50% |

Table 10. Calculations of optimal allocation based on results of winter surveys, 1999-2003, in Glacier Bay, AK. These calculations were made using the simple two strata model applied to the 22 species groups.

| | | | Density (#/km$^2$) | | Abundance | | | Between Year Var. | |
|---|---|---|---|---|---|---|---|---|---|
| Group | Strata | Species | Mean | SE | Mean | SE | CV | SD | Optimal Allocation |
| 1 | Coastal | Kittlitz Murrelet | 0.43 | 0.21 | 139 | 67 | 0.48 | 151 | 7.1% |
| | Offshore | Kittlitz Murrelet | 0.89 | 0.32 | 835 | 302 | 0.36 | 676 | 92.9% |
| 2 | Coastal | Marbled Murrelet | 1.12 | 0.30 | 361 | 97 | 0.27 | 217 | 8.6% |
| | Offshore | Marbled Murrelet | 1.40 | 0.38 | 1307 | 355 | 0.27 | 795 | 91.4% |
| 3 | Coastal | Unid. Brachyramphus | 1.03 | 0.38 | 333 | 124 | 0.37 | 277 | 3.8% |
| | Offshore | Unid. Brachyramphus | 2.75 | 1.17 | 2567 | 1095 | 0.43 | 2449 | 96.2% |
| 4 | Coastal | Cormorant | 1.82 | 0.16 | 588 | 53 | 0.09 | 118 | 6.3% |
| | Offshore | Cormorant | 0.97 | 0.29 | 906 | 271 | 0.30 | 606 | 93.7% |
| 5 | Coastal | Pigeon Guillemot | 8.08 | 1.37 | 2612 | 442 | 0.17 | 989 | 46.7% |
| | Offshore | Pigeon Guillemot | 1.55 | 0.19 | 1447 | 175 | 0.12 | 390 | 53.3% |
| 6 | Coastal | Murre - Puffin | 0.02 | 0.01 | 6 | 2 | 0.44 | 6 | 0.5% |
| | Offshore | Murre - Puffin | 0.55 | 0.20 | 516 | 189 | 0.37 | 422 | 99.5% |
| 7 | Coastal | Scoter | 26.85 | 4.95 | 8682 | 1602 | 0.18 | 3582 | 67.1% |
| | Offshore | Scoter | 1.65 | 0.29 | 1538 | 272 | 0.18 | 608 | 32.9% |
| 8 | Coastal | Dabbling Duck | 8.43 | 3.10 | 2728 | 1002 | 0.37 | 2240 | 66.7% |
| | Offshore | Dabbling Duck | 0.24 | 0.18 | 221 | 173 | 0.78 | 386 | 33.3% |
| 9 | Coastal | Goldeneye | 44.08 | 7.94 | 14257 | 2569 | 0.18 | 5744 | 11.0% |
| | Offshore | Goldeneye | 10.93 | 7.69 | 10218 | 7191 | 0.70 | 16080 | 89.0% |
| 10 | Coastal | Harlequin Duck | 3.55 | 0.53 | 1149 | 172 | 0.15 | 384 | 25.5% |
| | Offshore | Harlequin Duck | 0.57 | 0.19 | 531 | 173 | 0.33 | 388 | 74.5% |
| 11 | Coastal | Merganser | 9.88 | 1.51 | 3196 | 487 | 0.15 | 1090 | 22.1% |
| | Offshore | Merganser | 1.19 | 0.64 | 1117 | 595 | 0.53 | 1330 | 77.9% |
| 12 | Coastal | Diving Duck | 6.44 | 1.02 | 2081 | 329 | 0.16 | 735 | 35.0% |
| | Offshore | Diving Duck | 0.47 | 0.23 | 443 | 211 | 0.48 | 472 | 65.0% |
| 13 | Coastal | Gull | 8.84 | 3.01 | 2859 | 972 | 0.34 | 2173 | 19.2% |
| | Offshore | Gull | 5.06 | 1.52 | 4734 | 1418 | 0.30 | 3172 | 80.8% |
| 14 | Coastal | Kittiwake | 2.77 | 1.41 | 897 | 455 | 0.51 | 1017 | 9.6% |
| | Offshore | Kittiwake | 3.60 | 1.58 | 3367 | 1476 | 0.44 | 3300 | 90.4% |
| 15 | Coastal | Arctic Tern | 0.00 | 0.00 | 0 | 0 | | 0 | NA |
| | Offshore | Arctic Tern | 0.00 | 0.00 | 0 | 0 | | 0 | NA |

Table 10. Continued

| | | | Density (#/km$^2$) | | Abundance | | | Between Year Var. | |
|---|---|---|---|---|---|---|---|---|---|
| Group | Strata | Species | Mean | SE | Mean | SE | CV | SD | Optimal Allocation |
| 16 | Coastal | Grebe | 1.65 | 0.27 | 535 | 87 | 0.16 | 194 | 69.0% |
| | Offshore | Grebe | 0.06 | 0.01 | 53 | 14 | 0.26 | 30 | 31.0% |
| 17 | Coastal | Loon | 0.57 | 0.14 | 183 | 44 | 0.24 | 99 | 19.4% |
| | Offshore | Loon | 0.36 | 0.07 | 335 | 64 | 0.19 | 142 | 80.6% |
| 18 | Coastal | Sea Lion | 0.64 | 0.11 | 208 | 37 | 0.18 | 82 | 26.1% |
| | Offshore | Sea Lion | 0.20 | 0.04 | 184 | 36 | 0.20 | 80 | 73.9% |
| 19 | Coastal | Harbor Porpoise | 0.31 | 0.10 | 102 | 31 | 0.31 | 70 | 7.9% |
| | Offshore | Harbor Porpoise | 0.47 | 0.13 | 443 | 125 | 0.28 | 280 | 92.1% |
| 20 | Coastal | Harbor Seal | 0.74 | 0.07 | 240 | 23 | 0.09 | 51 | 51.7% |
| | Offshore | Harbor Seal | 0.05 | 0.01 | 45 | 7 | 0.16 | 16 | 48.3% |
| 21 | Coastal | Cetacean | 0.00 | 0.00 | 1 | 1 | 0.89 | 1 | 100.0% |
| | Offshore | Cetacean | 0.00 | 0.00 | 0 | 0 | | 0 | 0.0% |
| 22 | Coastal | Sea Otter | 1.00 | 0.15 | 325 | 47 | 0.15 | 106 | 35.7% |
| | Offshore | Sea Otter | 0.13 | 0.03 | 120 | 29 | 0.25 | 66 | 64.3% |

Table 11. Detecting change in marine predator populations of Glacier Bay, AK: Comparison of possible choices of survey designs based on hypothetical survey objectives.

| Primary Objective | % allocation of transects among strata | | Frequency of surveys | | Approximate area ($km^2$) surveyed | Relative Cost |
|---|---|---|---|---|---|---|
| | Nearshore | Offshore | no./ yr | Interval. | | |
| *Detect trends in population size of:* | | | | | | |
| All marine birds and mammals | 26 | 74 | 3 | 3 | 100 | Moderate |
| Seabirds | 6 | 94 | 3 | 3 | 100 | Moderate |
| Diving ducks | 86 | 14 | 3 | 3 | 100 | Moderate |
| Species of concern: | | | | | | |
| *Brachyramphus murrelets* | 8 | 92 | 3 | 3 | 50 | Low |
| Harbor seal | 15 | 85 | 3 | 3 | 75 | Low |
| *Detect interannual change* | | | | | | |
| Whole-bay | 26 | 74 | 3 | 1 | 100 | High |
| Index site | 26 | 74 | 4-8 | 1 | 25 | Low |
| *Detect changes in distribution* | 26 | 74 | 1 | 5-10 | 275 | High |

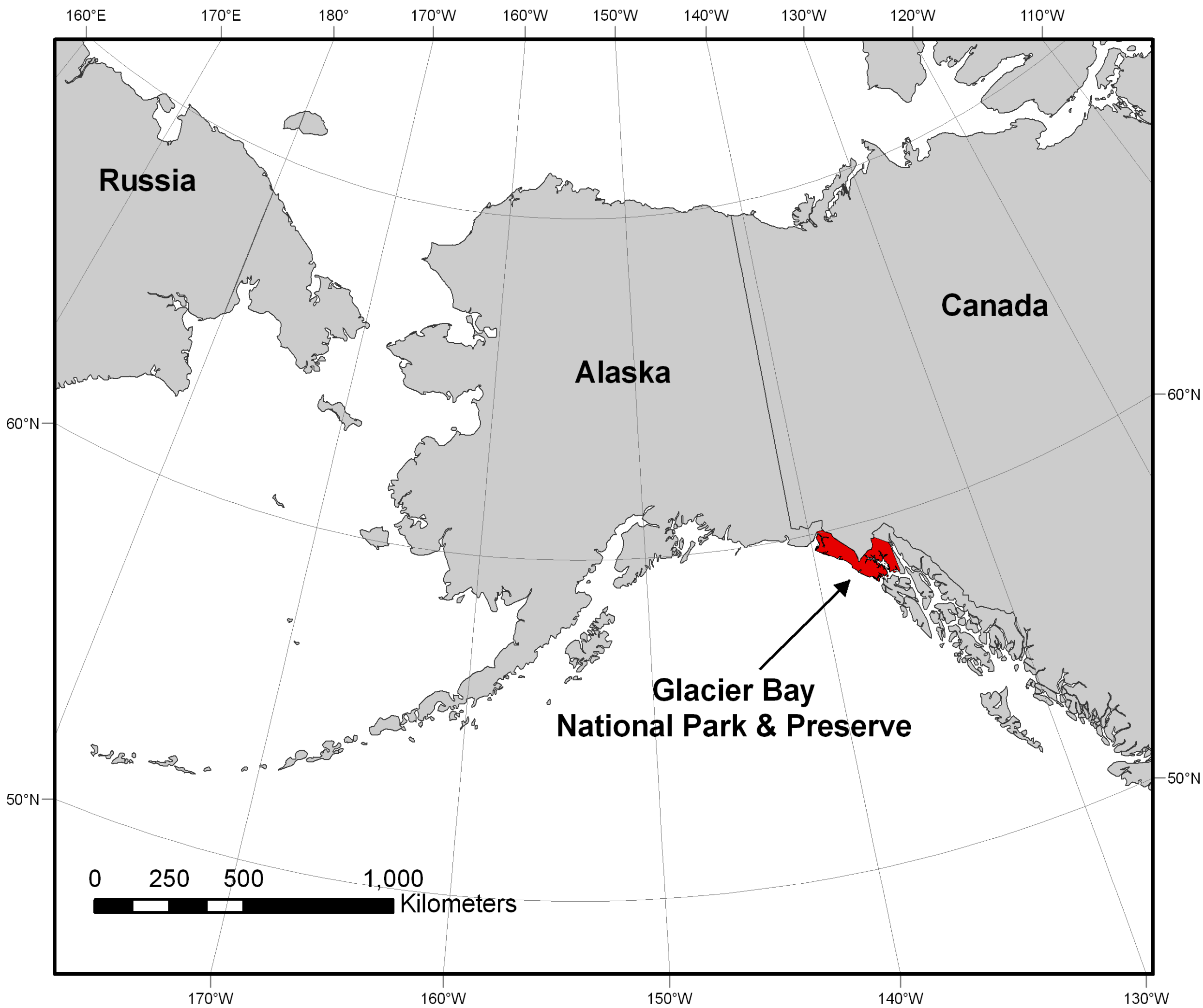



Figure 1. Location of Glacier Bay National Park & Preserve (in red) on the Northwestern coast of the North American continent.

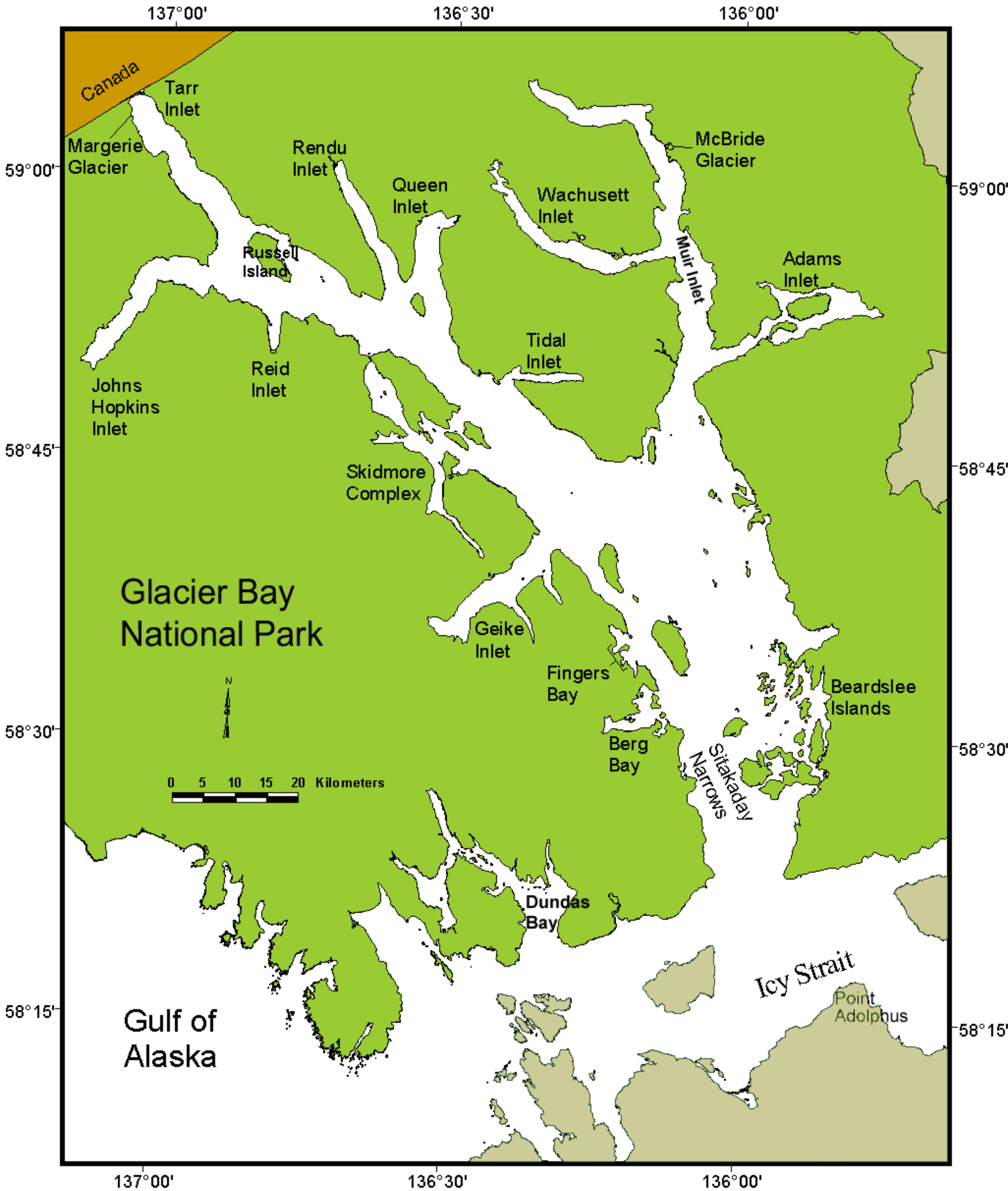



Figure 2. Glacier Bay study area, with place names used throughout the report.

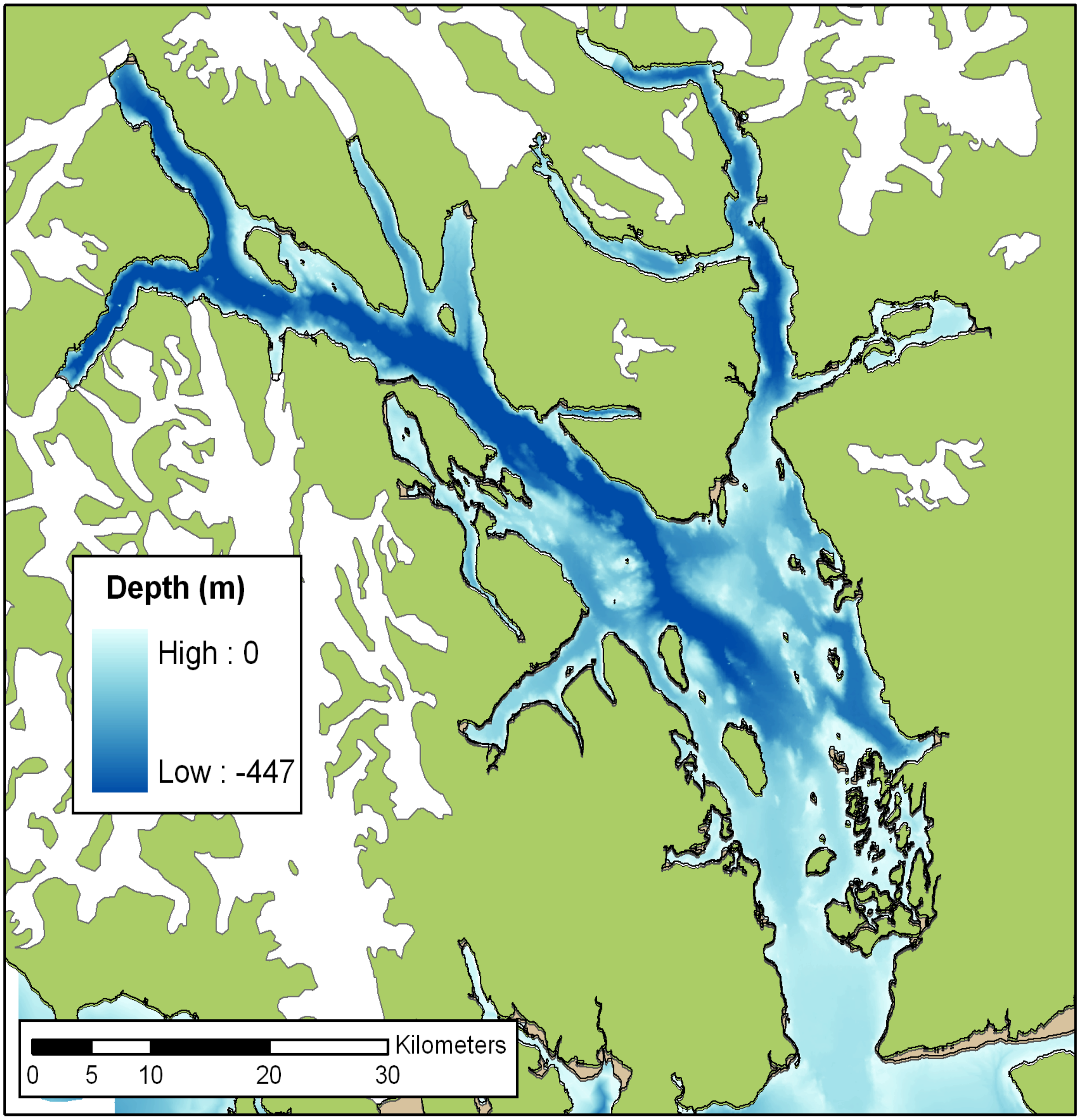



Figure 3. Bathymetry of Glacier Bay, AK. Depths presented as color gradient from lowest (447 m) to highest (0 m) depths below sea level. Data obtained from Geiselman et al. 1997 and binned into 100 m blocks for analysis.

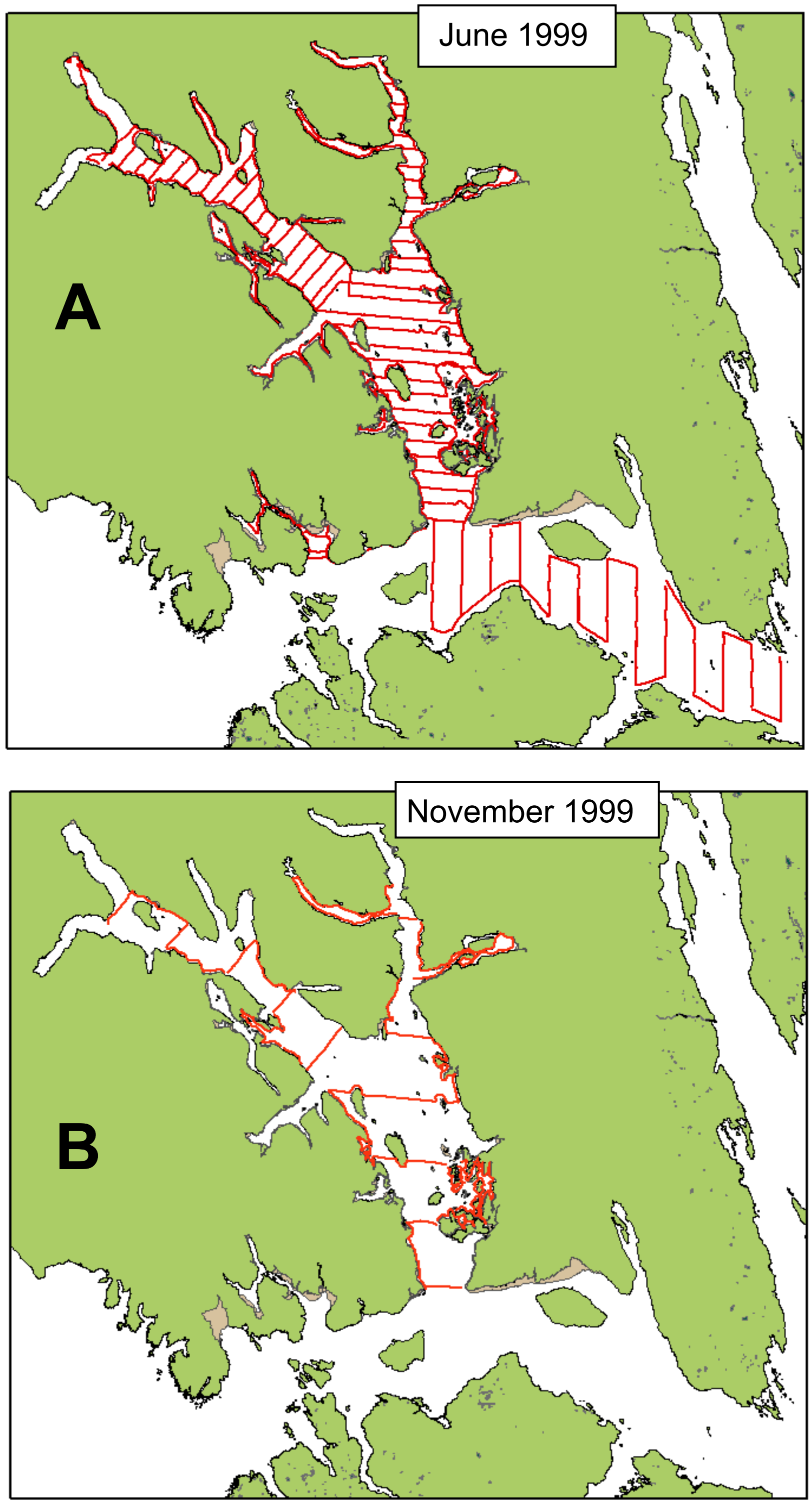



Figure 4. Location of transects used to survey marine birds and mammals in Glacier Bay and Icy Strait in summer (A) and winter (B) of 1999. Subsequent years (2000-2003) followed the same transects (except Dundas Bay).

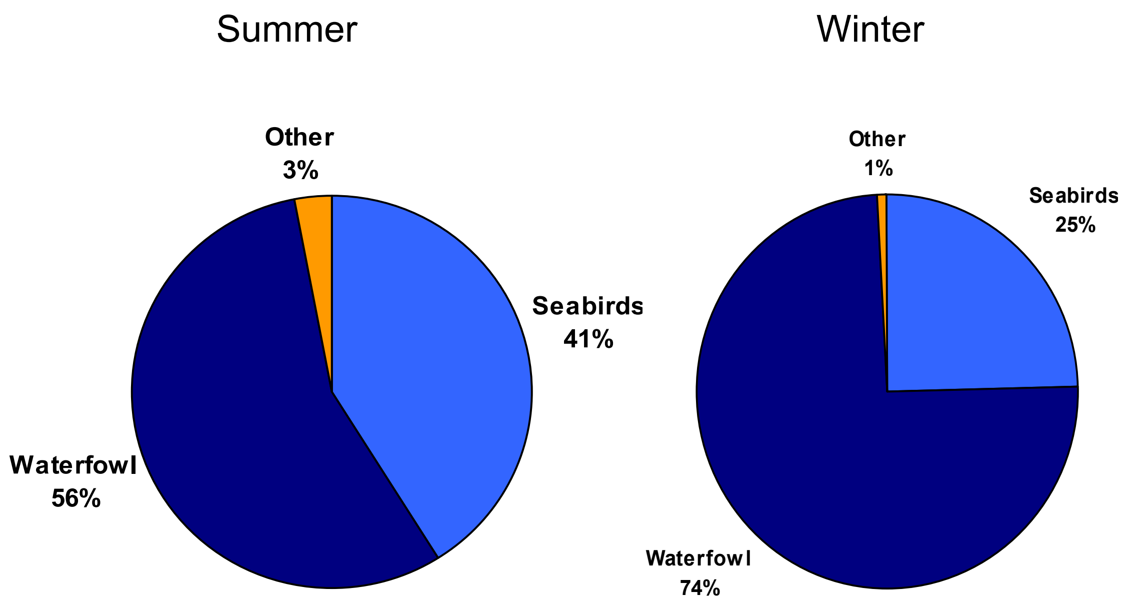



Figure 5. Comparison of marine bird community composition between summer and winter in Glacier Bay, AK 1999-2003.

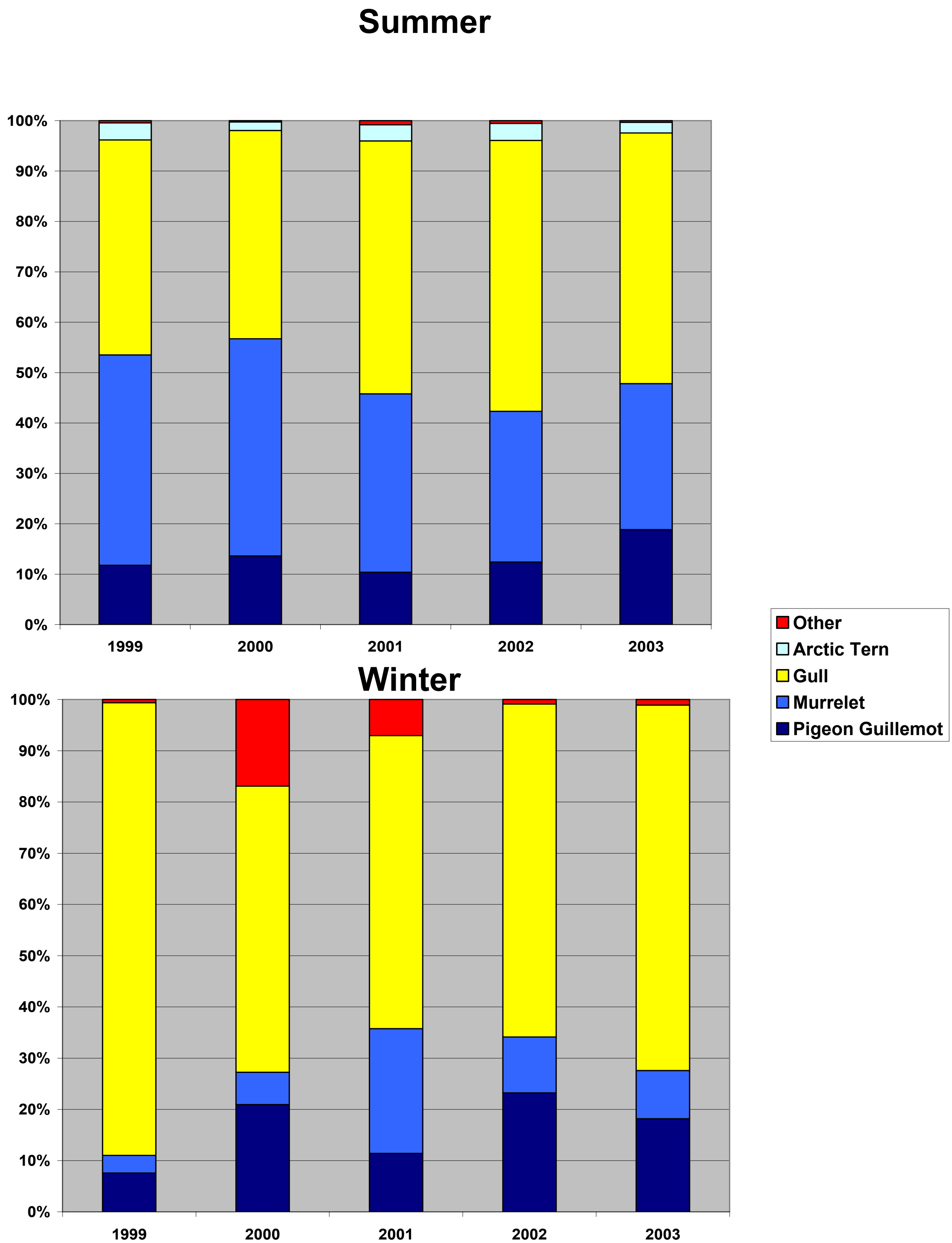



Figure 6. Composition of the seabird portion of bird communities in Glacier Bay, AK during summer and winter, 1999-2003.

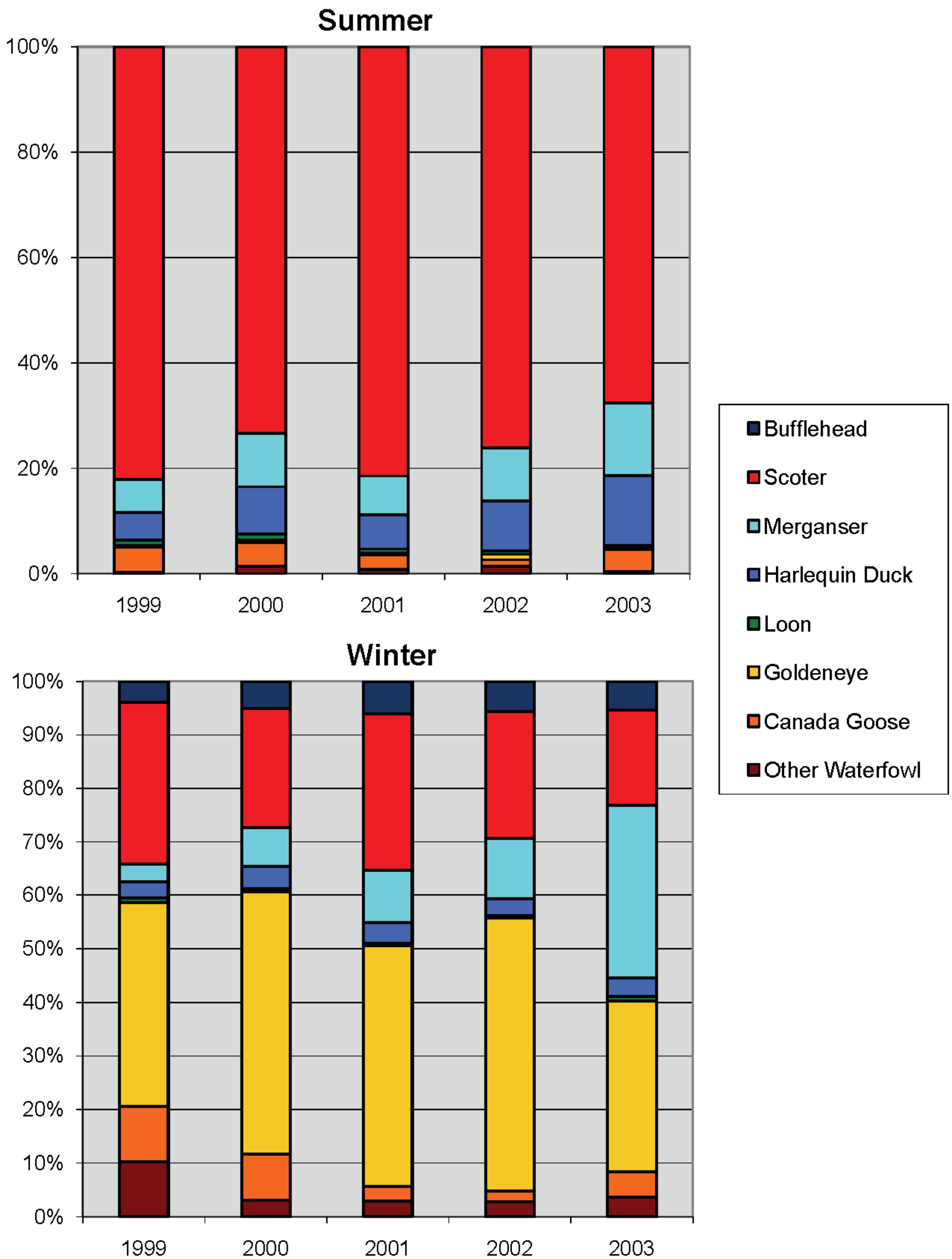



Figure 7. Composition of the waterbird portion of bird communities in Glacier Bay AK during summer and winter, 1999-2003.

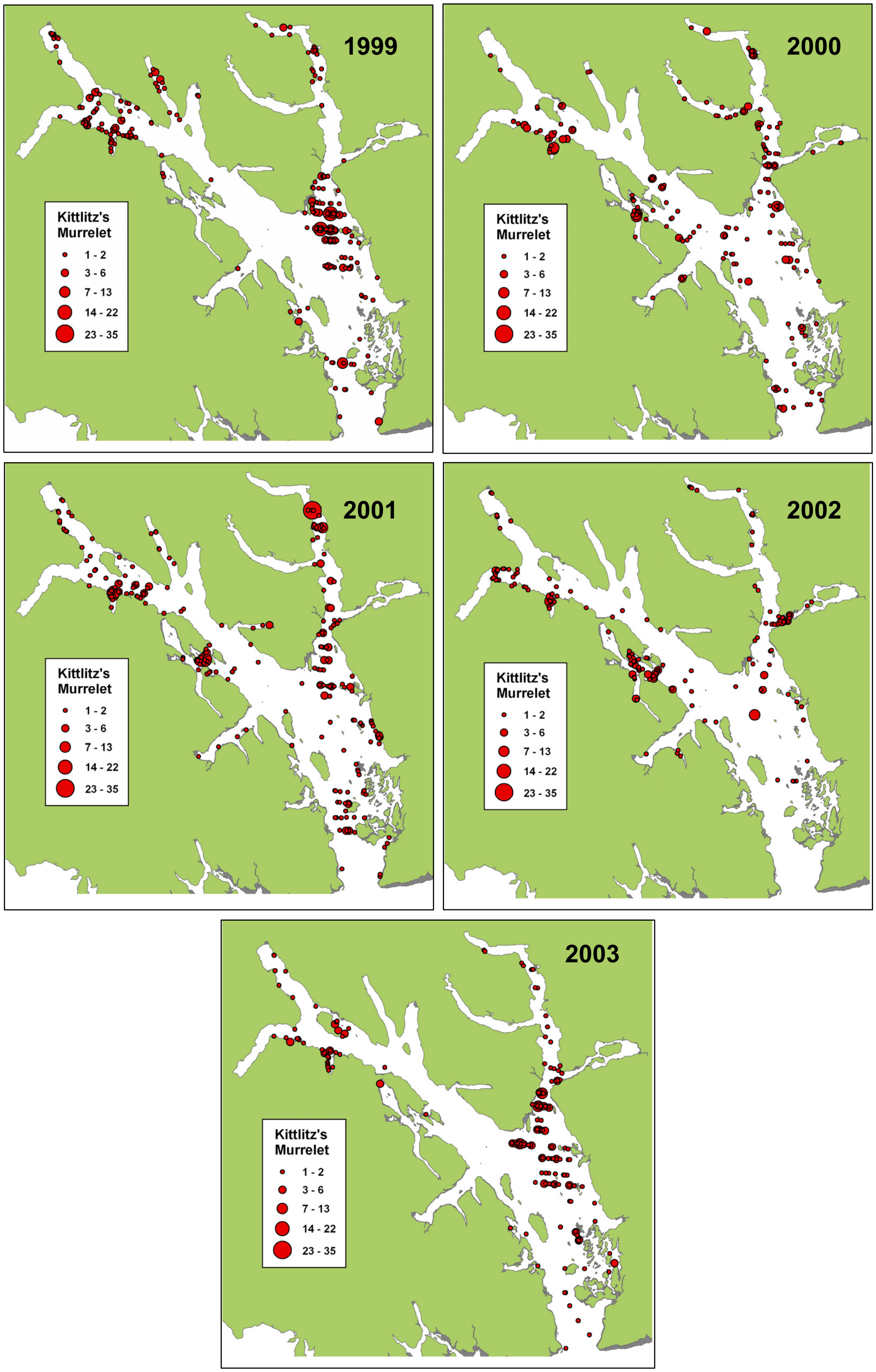



Figure 8. Distribution of Kittlitz's Murrelet on summer surveys in Glacier Bay, AK 1999-2003. Circles represent individual observations, with the size of the circle varying with the number of birds.

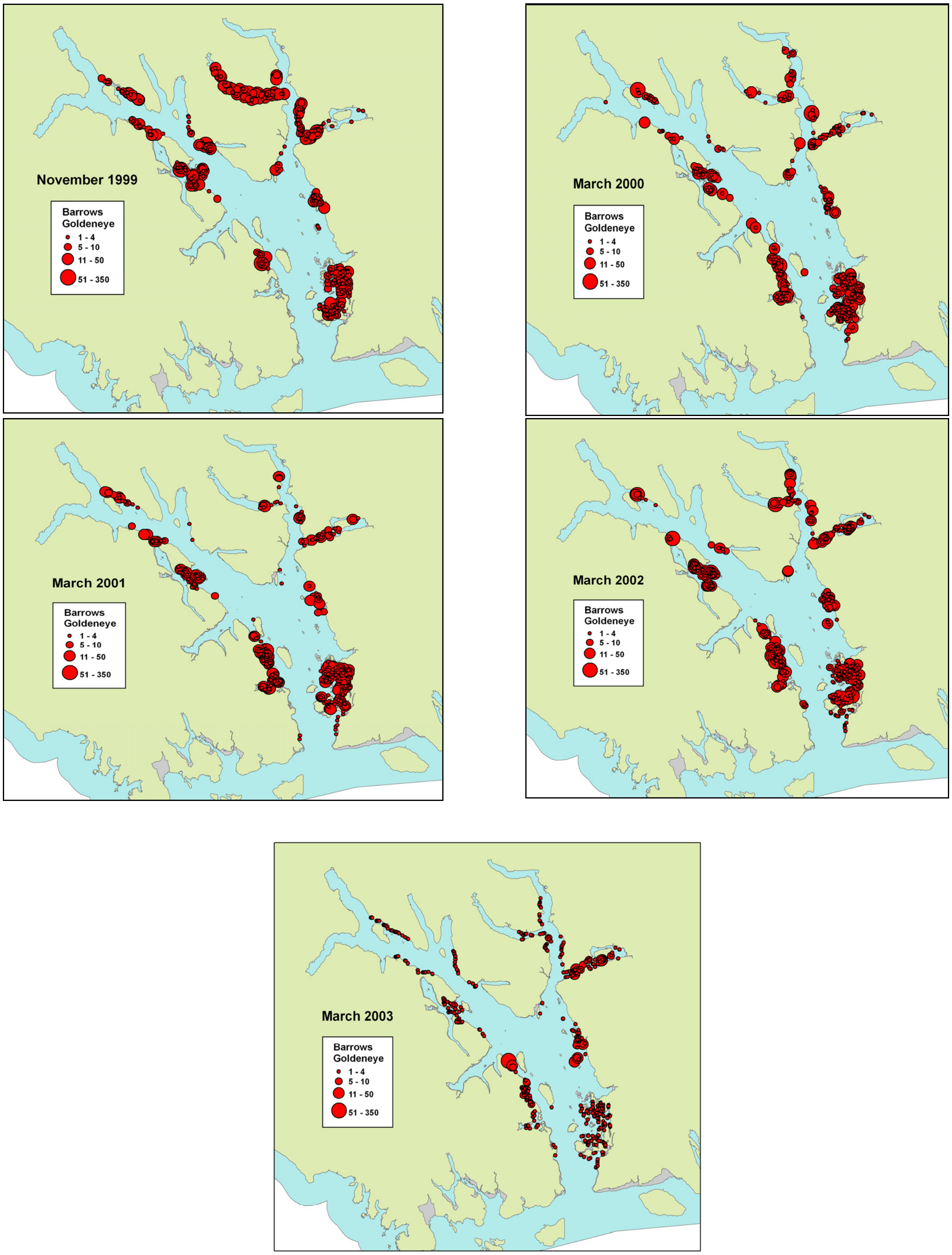



Figure 9. Distribution of Barrow's Goldeneye on winter surveys in Glacier Bay, AK 1999-2003. Circles represent individual observations, with the size of the circle varying with the number of birds.

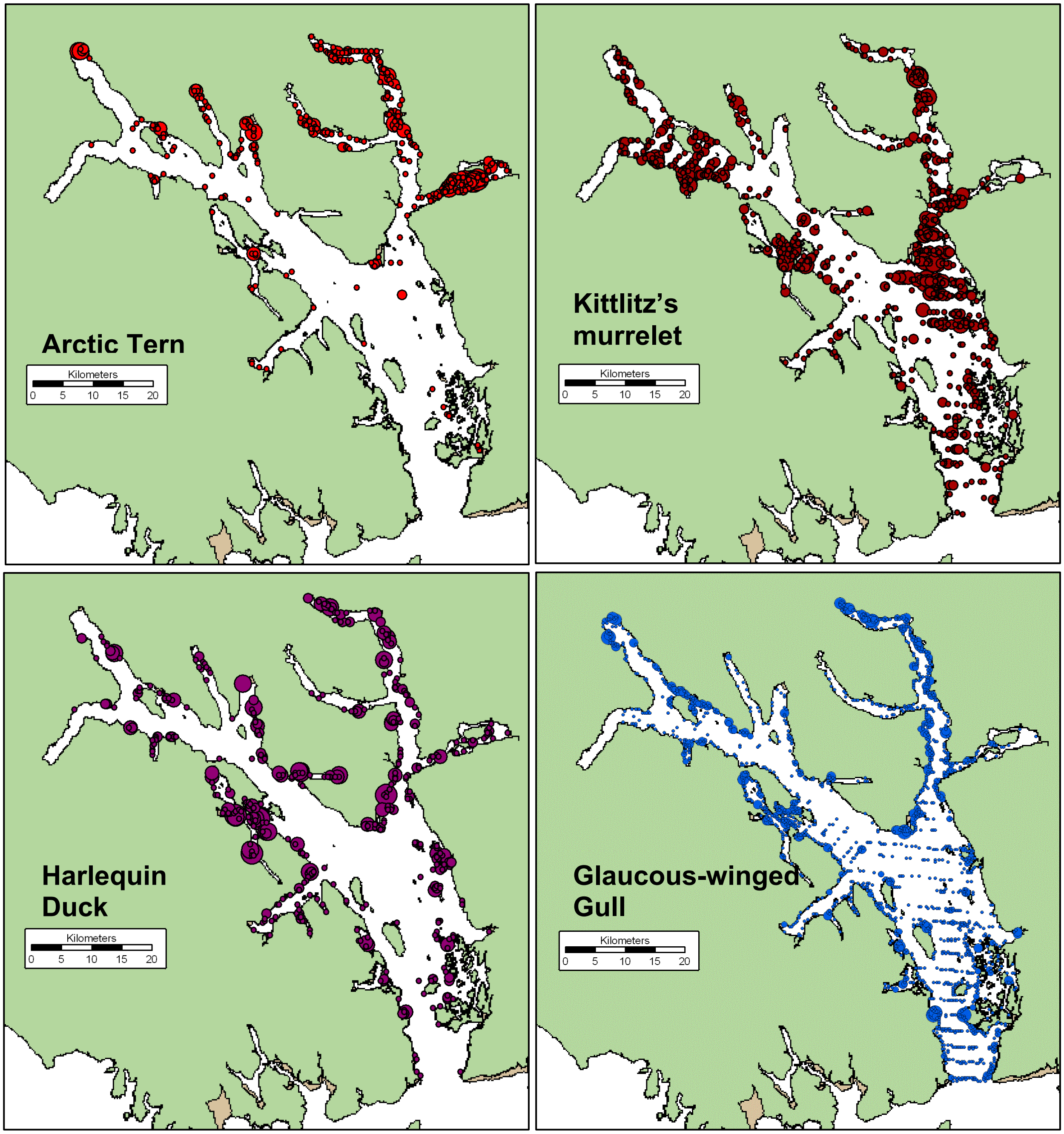



Figure 10. Distribution of Arctic Tern, Kittlitz's Murrelet, Harlequin Duck and Glaucous-winged Gull in Glacier Bay, AK during summer, 1999-2003. Records from all years are combined in maps for each species. Circles represent individual observations, with the size of the circle varying with the number of birds. Note that the sizes of the circles are relative and not comparable between species. These maps illustrate the diverse patterns of distributions among species.

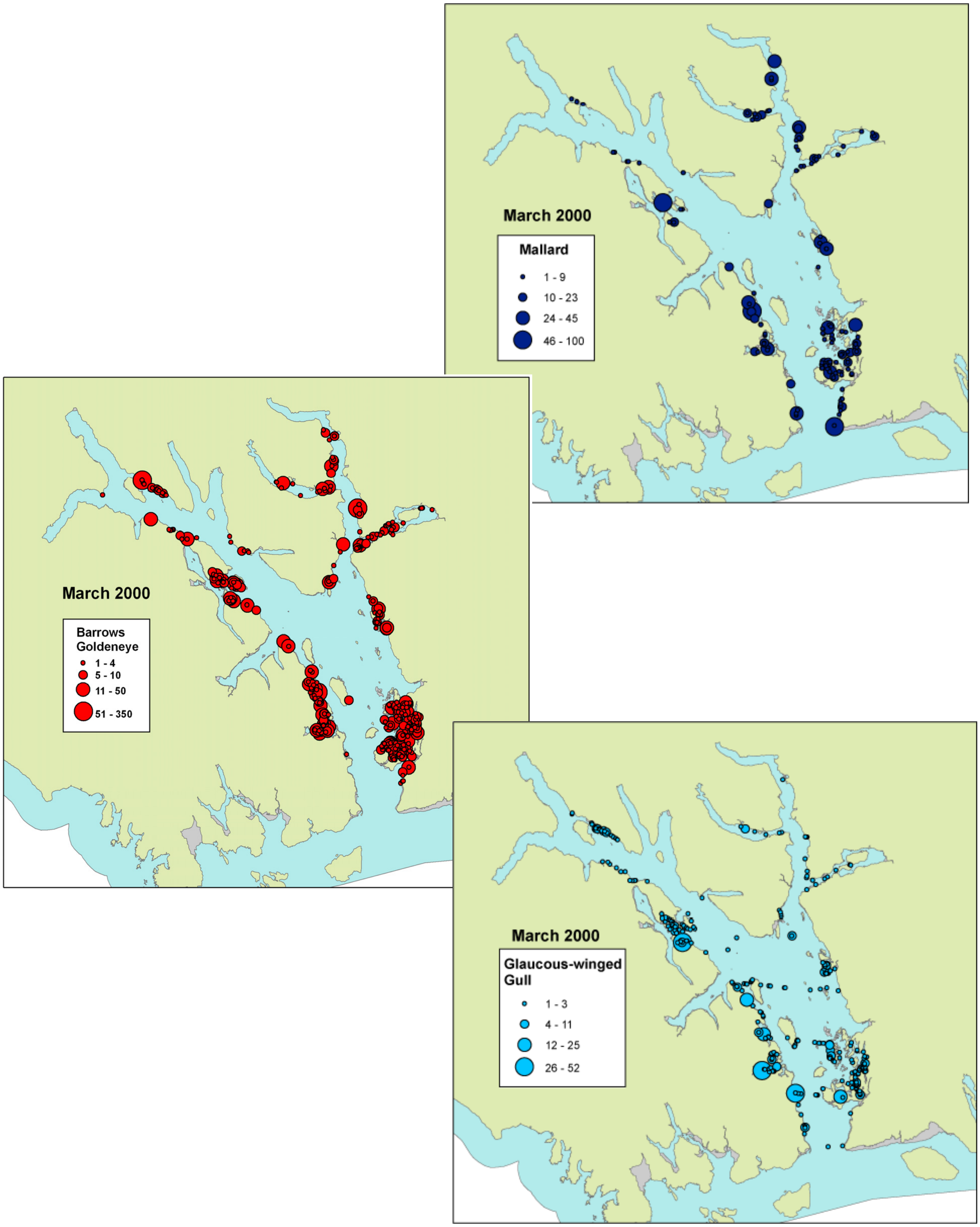



Figure 11. Distribution of Mallards, Barrow's Goldeneyes, and Glaucous-winged Gulls on winter surveys in Glacier Bay, AK, March 2000. Circles represent individual observations, with the size of the circle varying with the number of birds.

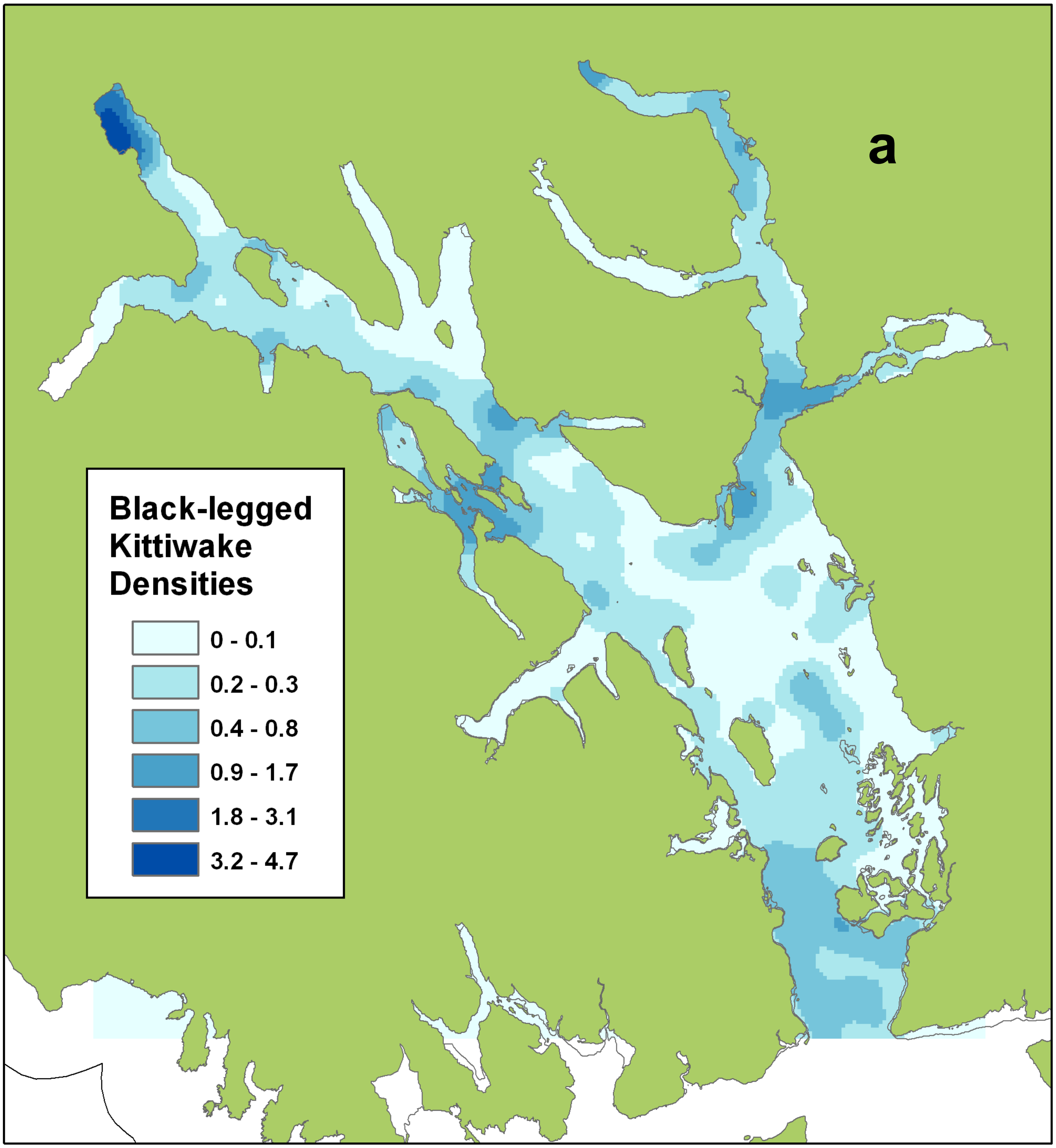



Figure 12a. Mean summer density (birds/km$^2$) of Black-legged Kittiwakes in Glacier Bay. Densities averaged over five years (1999-2003) using kriging.

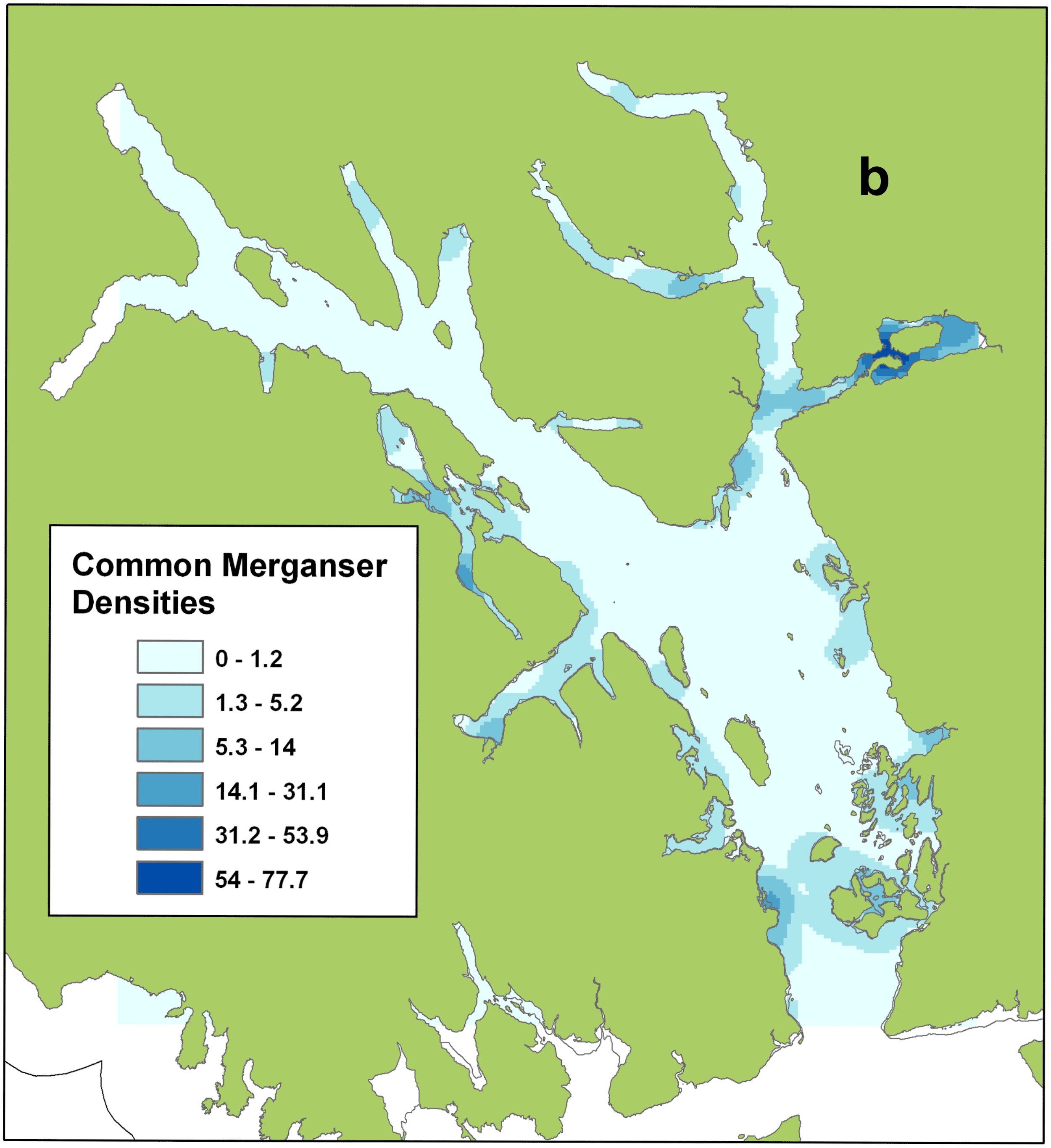



Figure 12b. Mean summer density (birds/km$^2$) of Common Mergansers in Glacier Bay. Densities averaged over five years (1999-2003) using kriging.

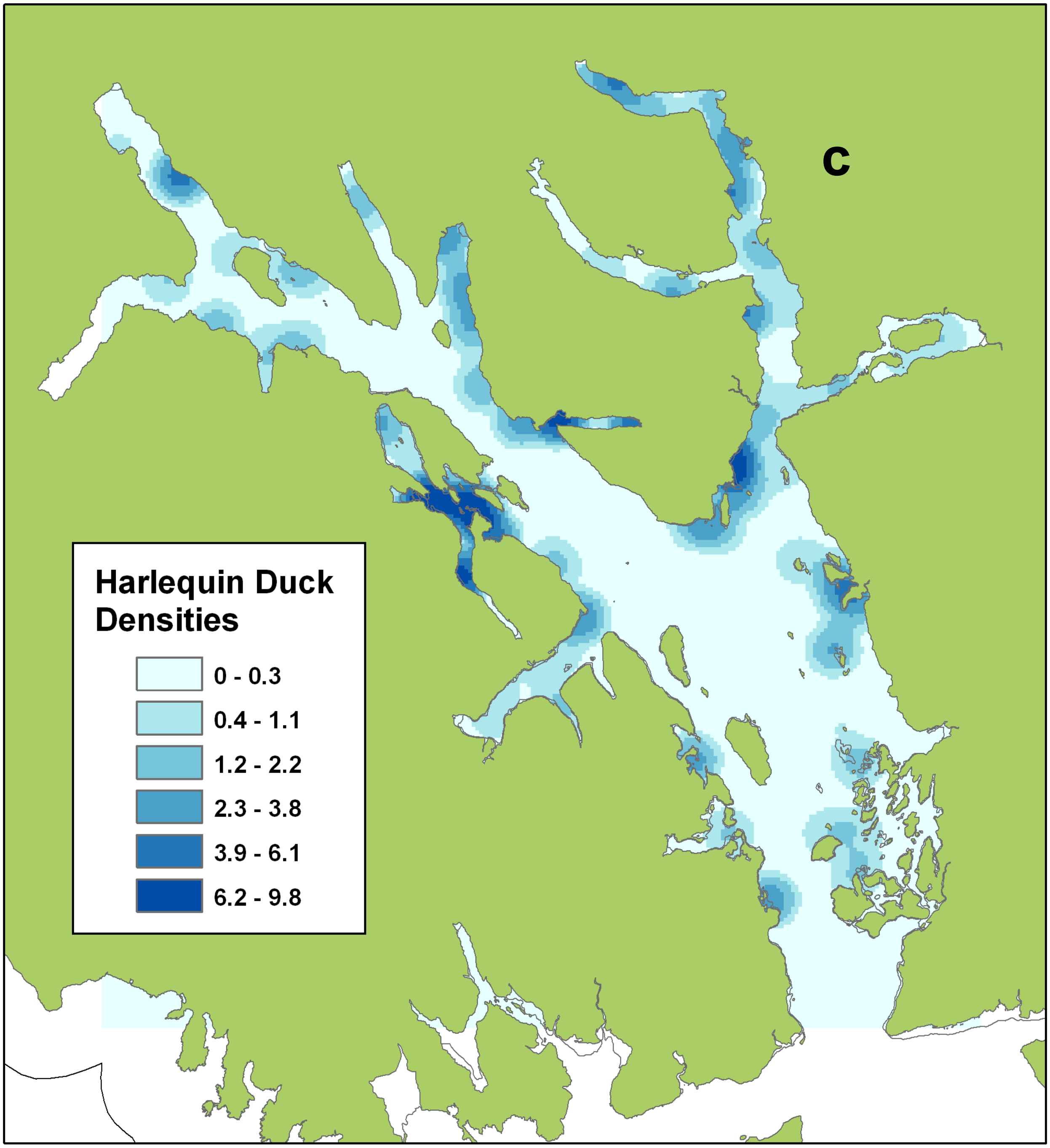



Figure 12c. Mean summer density (birds/km$^2$) of Harlequin Ducks in Glacier Bay. Densities averaged over five years (1999-2003) using kriging.

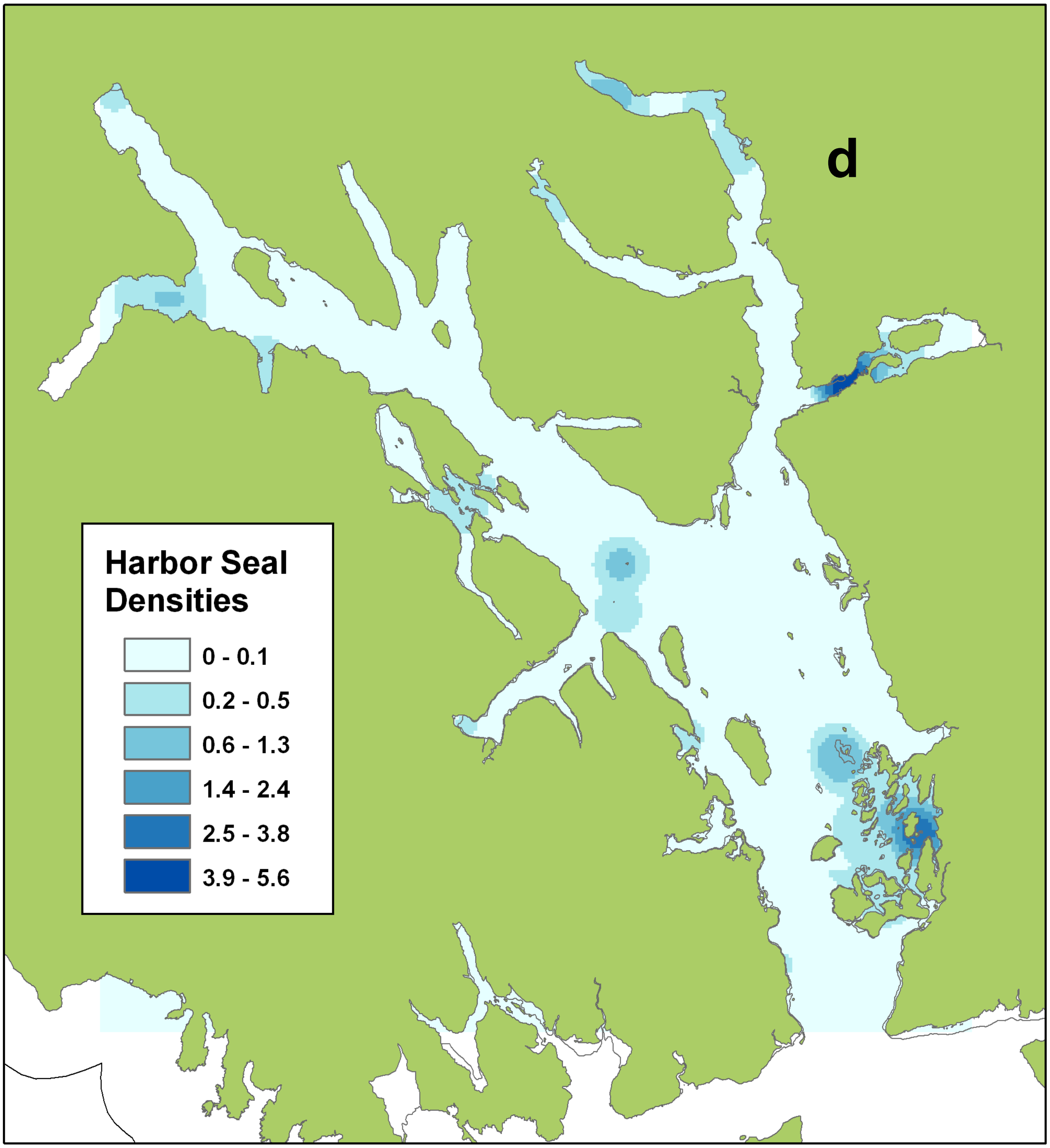



Figure 12d. Mean summer density (seals/km$^2$) of Harbor Seals in Glacier Bay. Densities averaged over five years (1999-2003) using kriging.

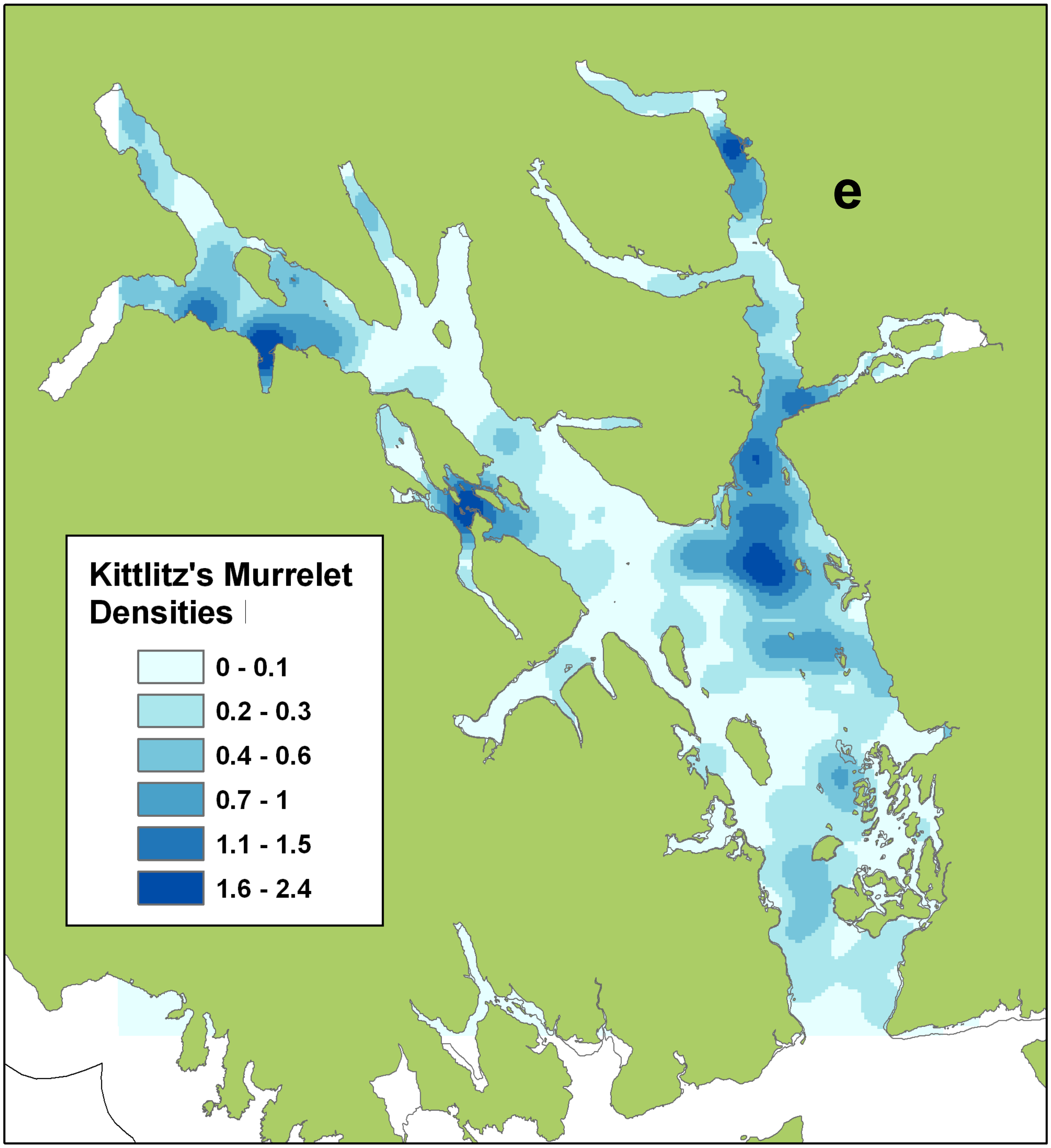



Figure 12e. Mean summer density (birds/km$^2$) of Kittlitz's Murrelet in Glacier Bay. Densities averaged over five years (1999-2003) using kriging.

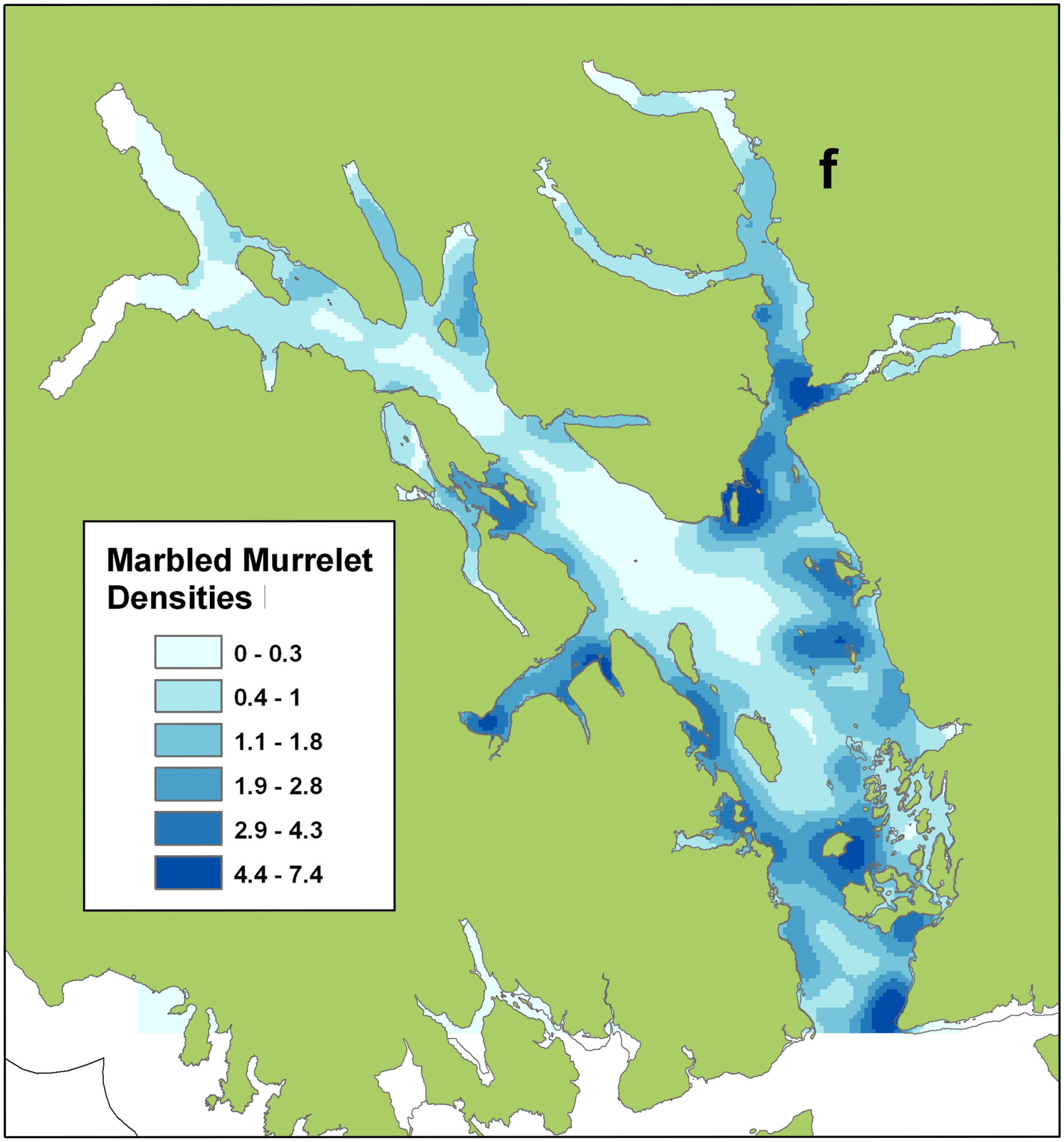



Figure 12f. Mean summer density (birds/km$^2$) of Marbled Murrelets in Glacier Bay. Densities averaged over five years (1999-2003) using kriging

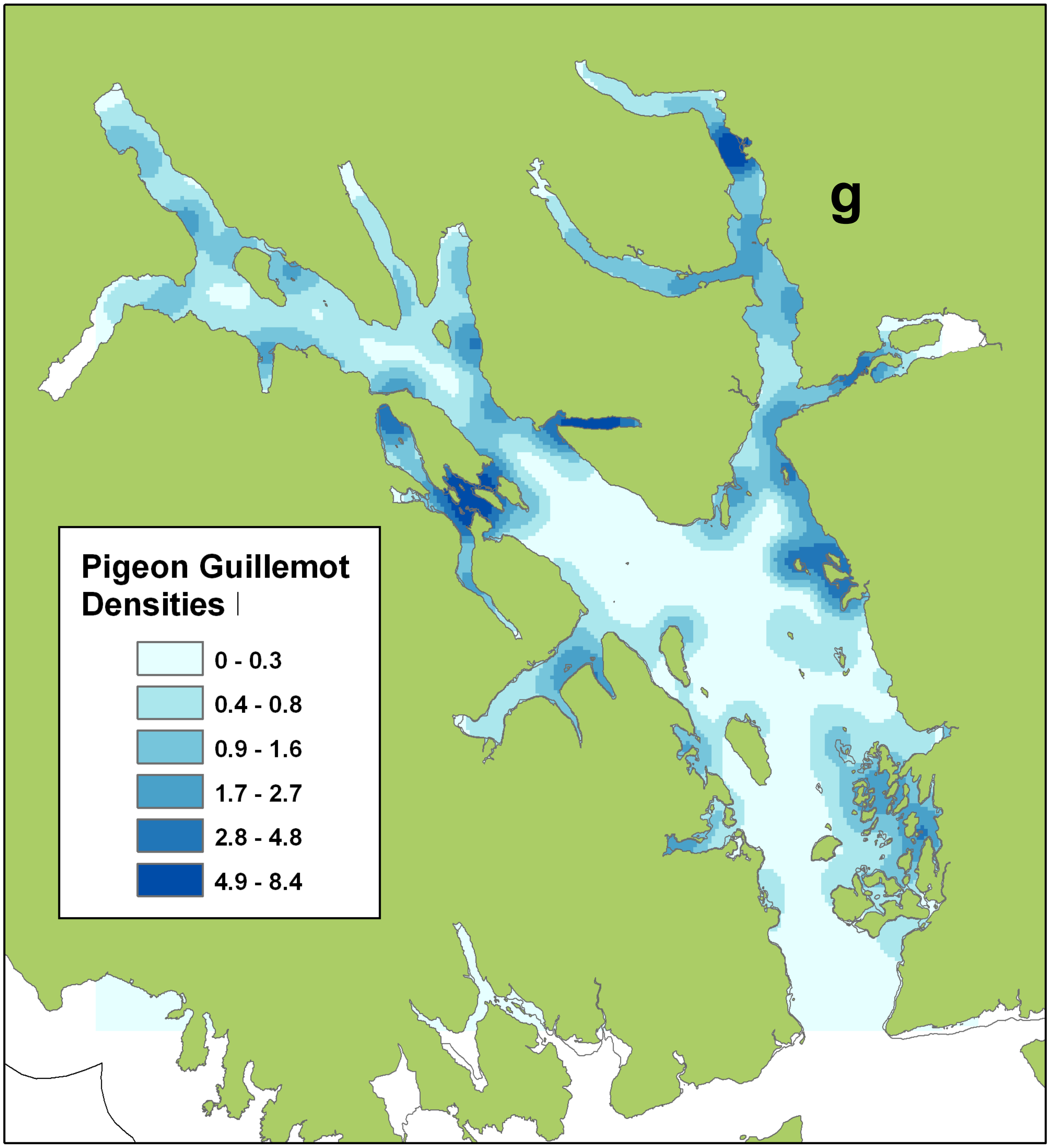



Figure 12g. Mean summer density (birds/km$^2$) of Pigeon Guillemots in Glacier Bay. Densities averaged over five years (1999-2003) using kriging.

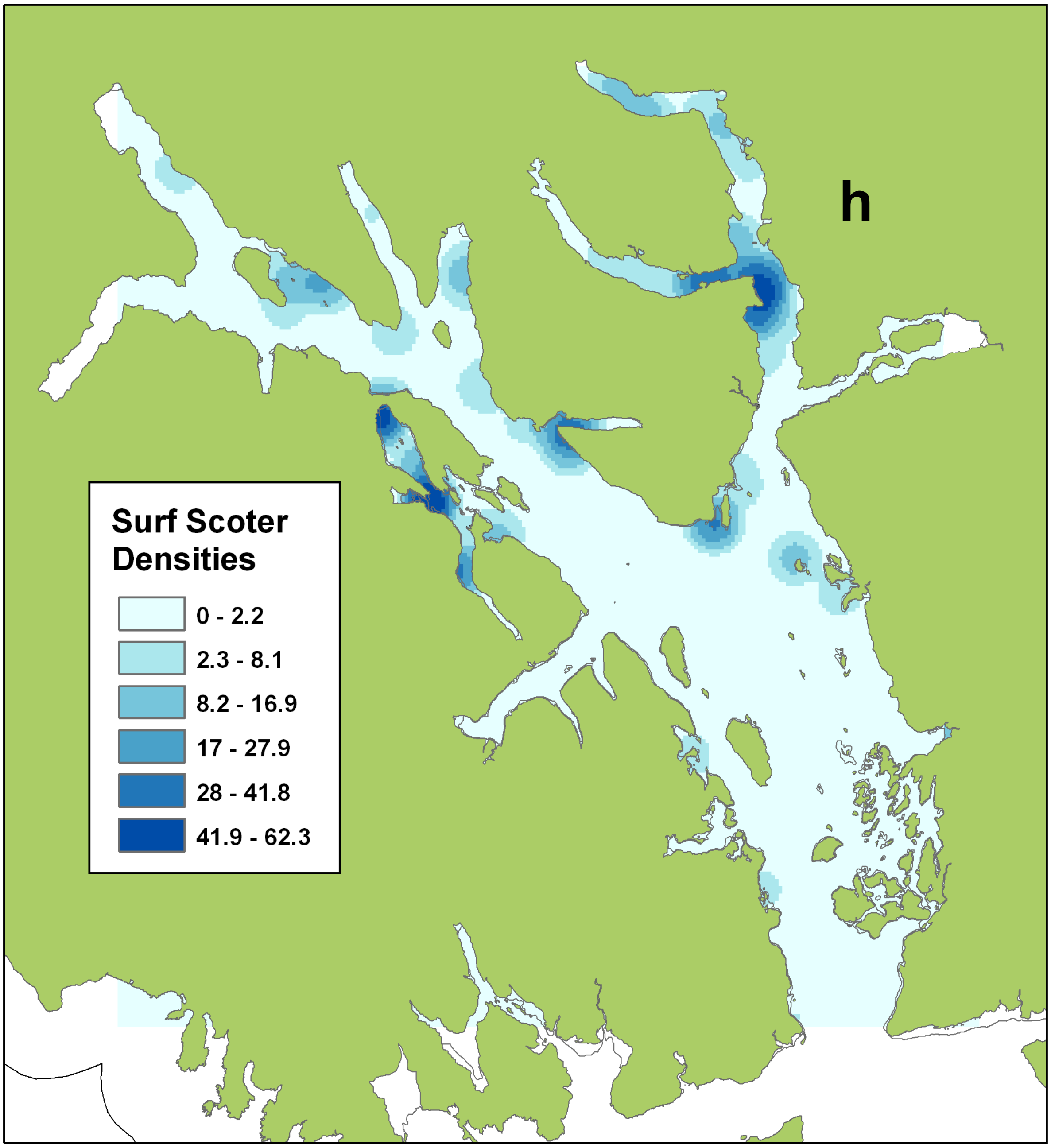



Figure 12h. Mean summer density (birds/km$^2$) of Surf Scoters in Glacier Bay. Densities averaged over five years (1999-2003) using kriging.

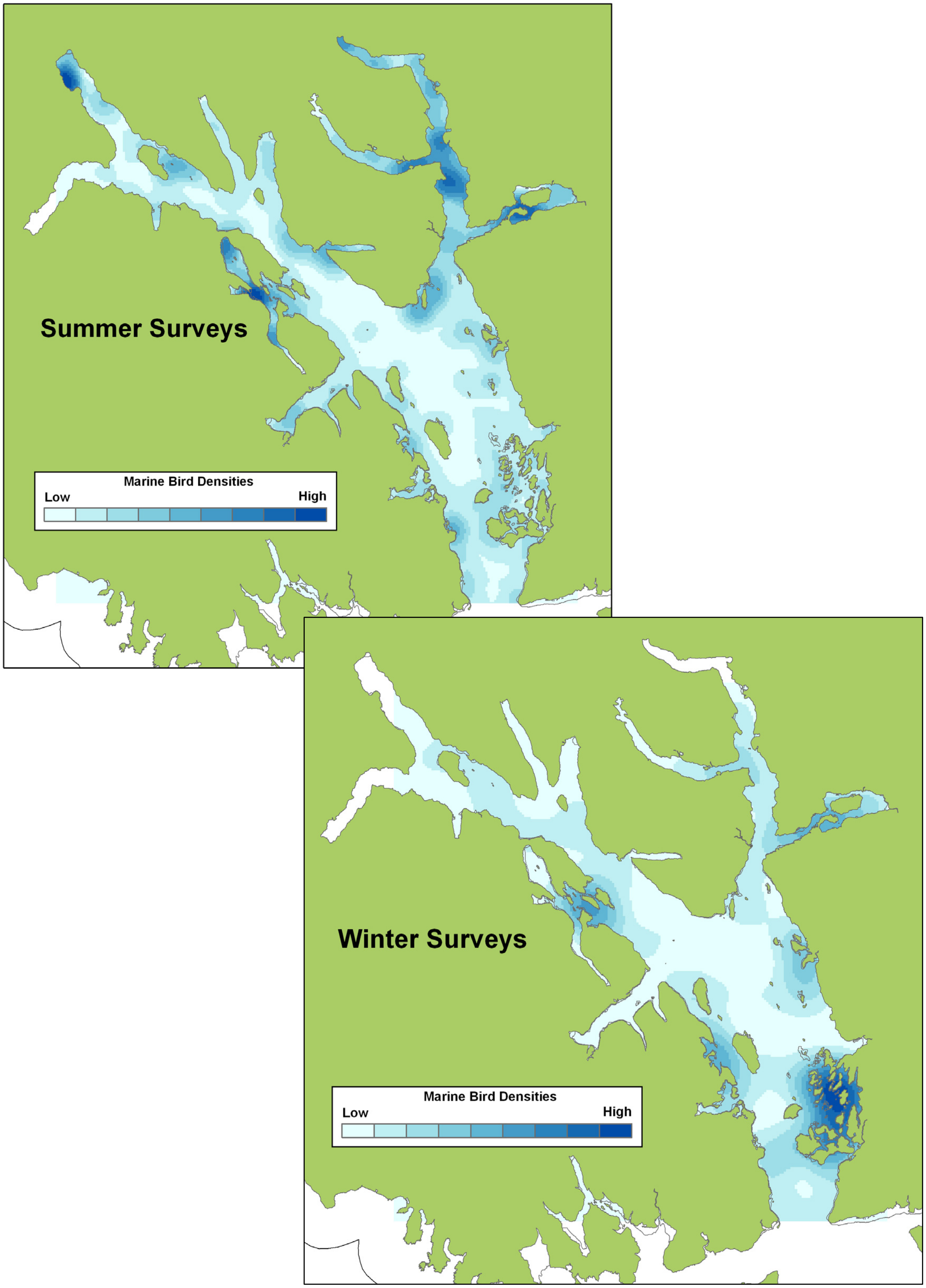



Figure 13. Relative density of marine birds in summer and winter in Glacier Bay, AK. Density maps of all birds sighted on summer surveys (top) and winter surveys (bottom) (1999-2003) were interpolated using ordinary kriging. This surface illustrates the areas of seasonal high and low bird densities.

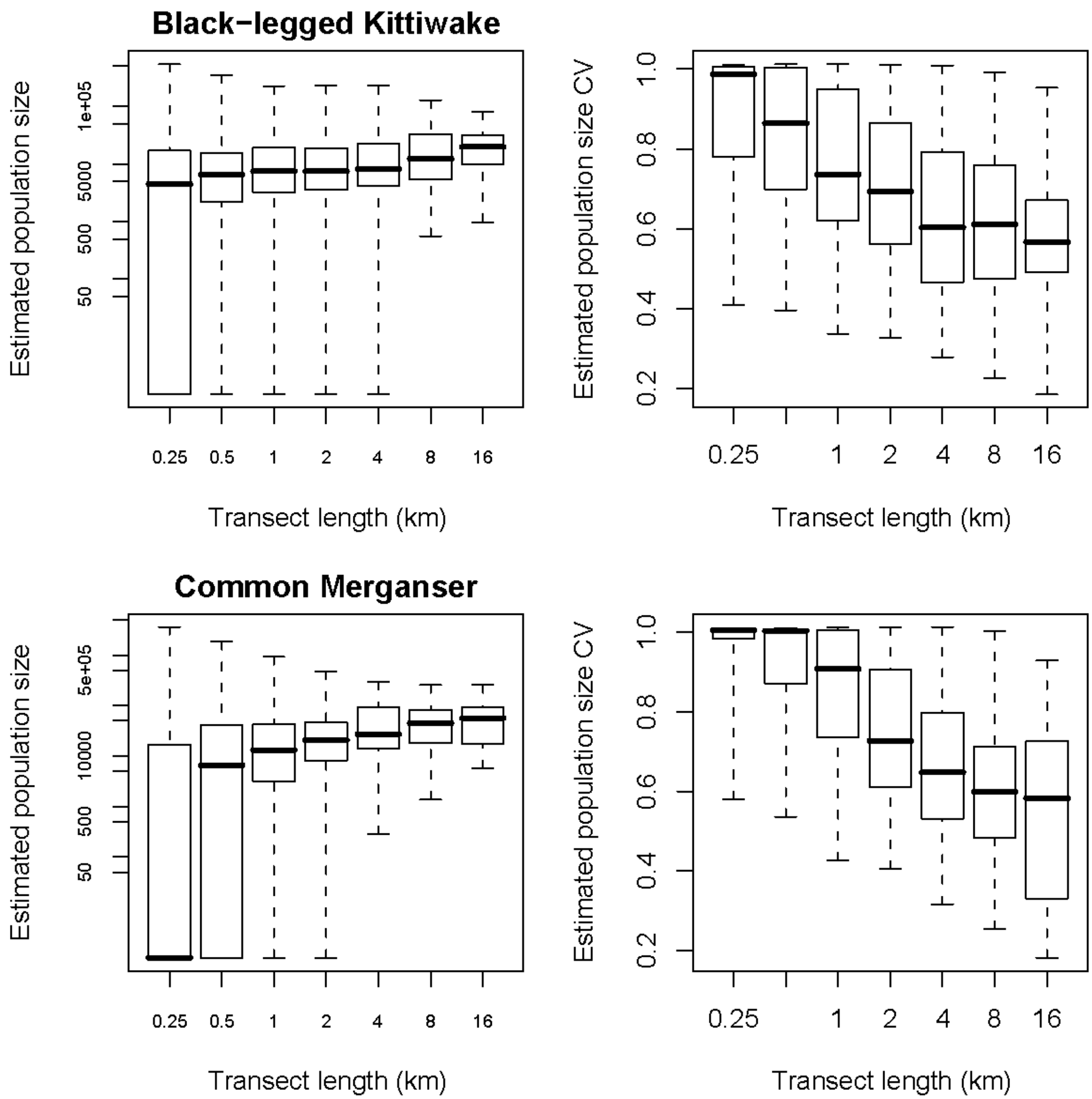



Figure 14. Simulated population size estimates and variation (CV) around the estimates for 8 marine predator species over a range of transect lengths. In these simulations, the number of samples (n=21) was held constant regardless of transect length. Note log scale for population estimates. Heavy bars represent median values, boxes represent the 25-75% range, and the broken lines indicate the range of values.

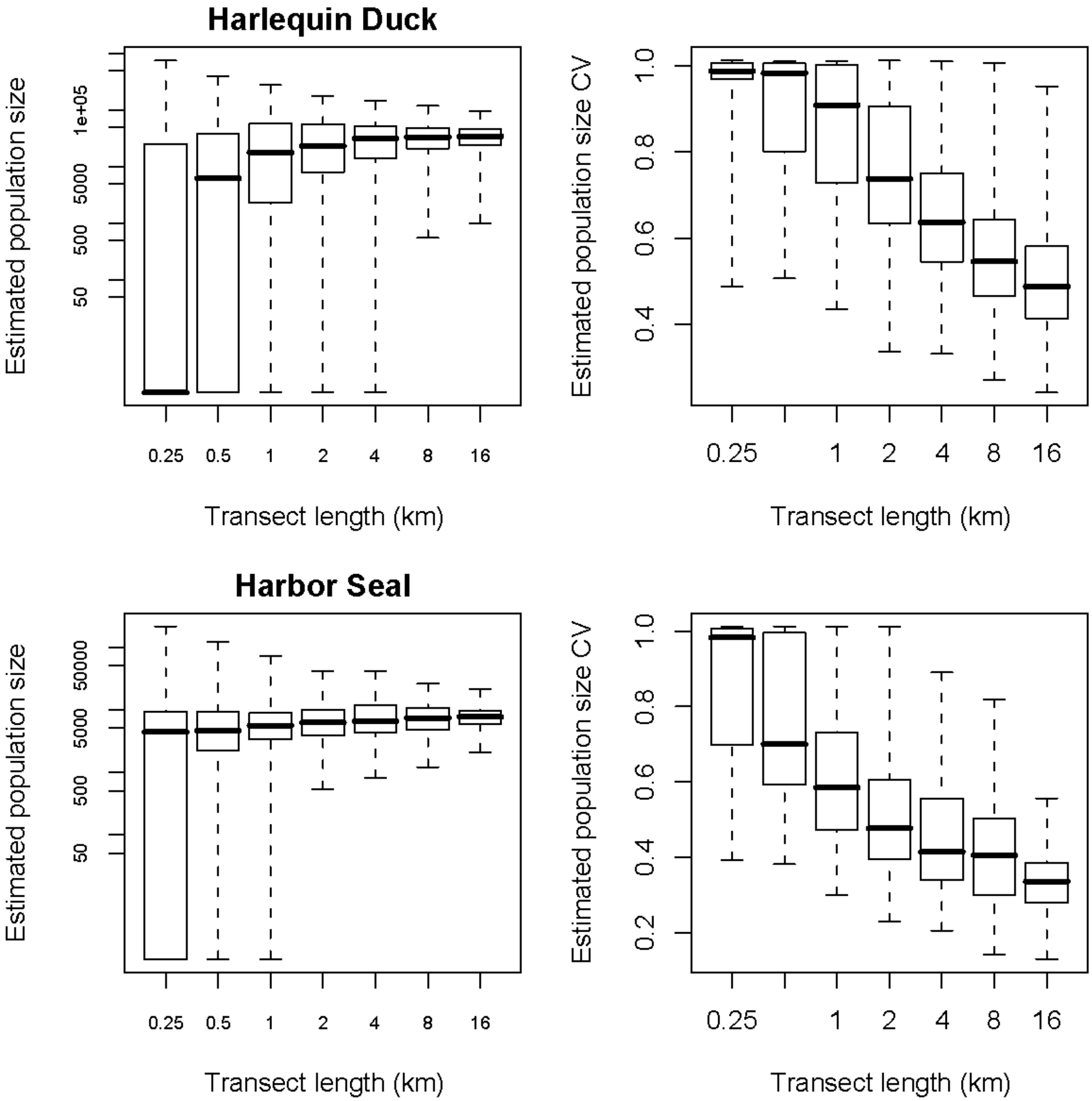



Figure 14 continued. Simulated population size estimates and variation (CV) around the estimates for marine predators over a range of transect lengths. In these simulations, the number of samples (21) was held constant regardless of transect length. Note log scale for population estimates. Heavy bars represent median values, boxes represent the 25-75% range, and the broken lines indicate the range of values.

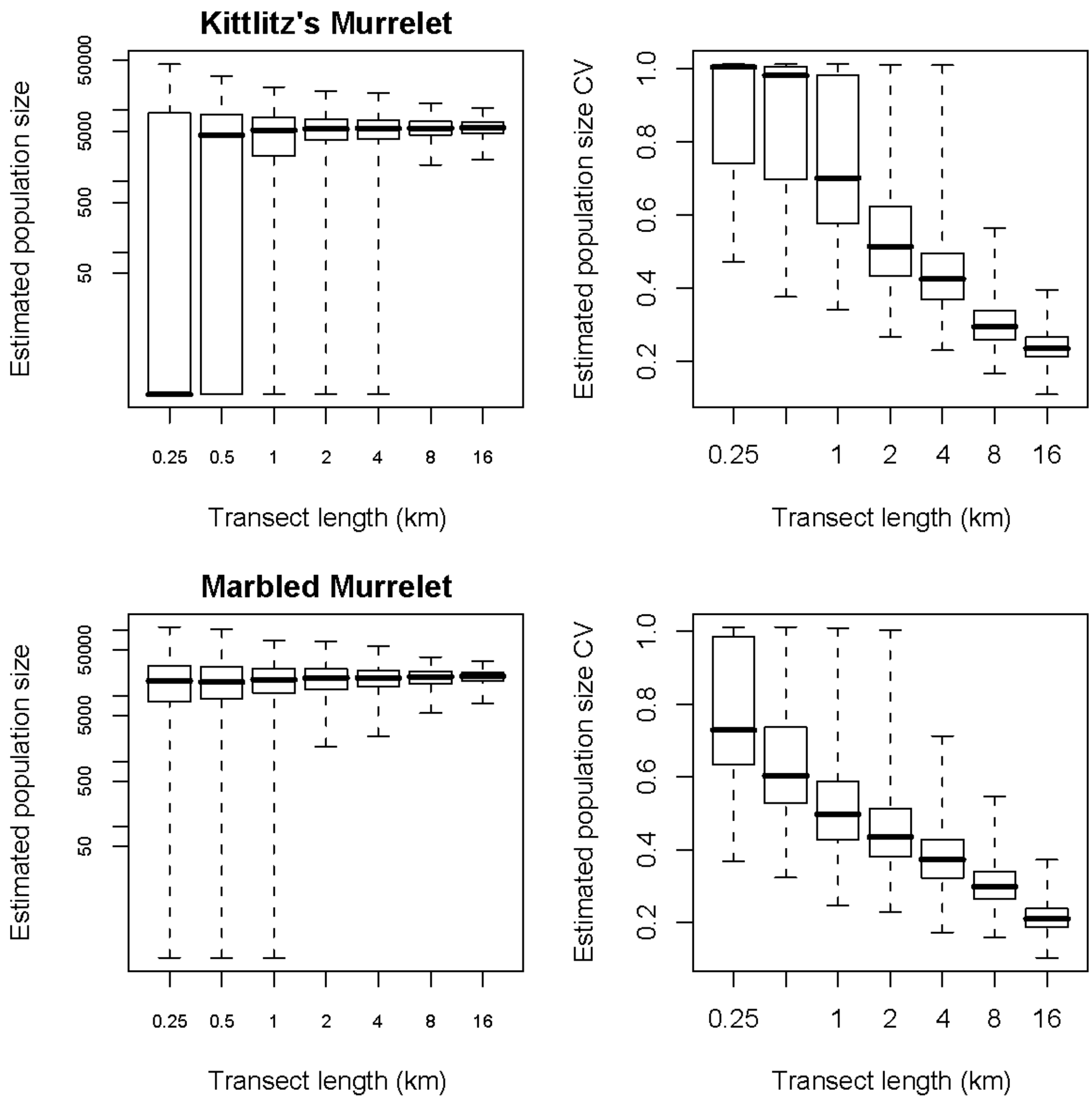



Figure 14 continued. Simulated population size estimates and variation (CV) around the estimates for marine predators over a range of transect lengths. In these simulations, the number of samples (21) was held constant regardless of transect length. Note log scale for population estimates. Heavy bars represent median values, boxes represent the 25-75% range, and the broken lines indicate the range of values.

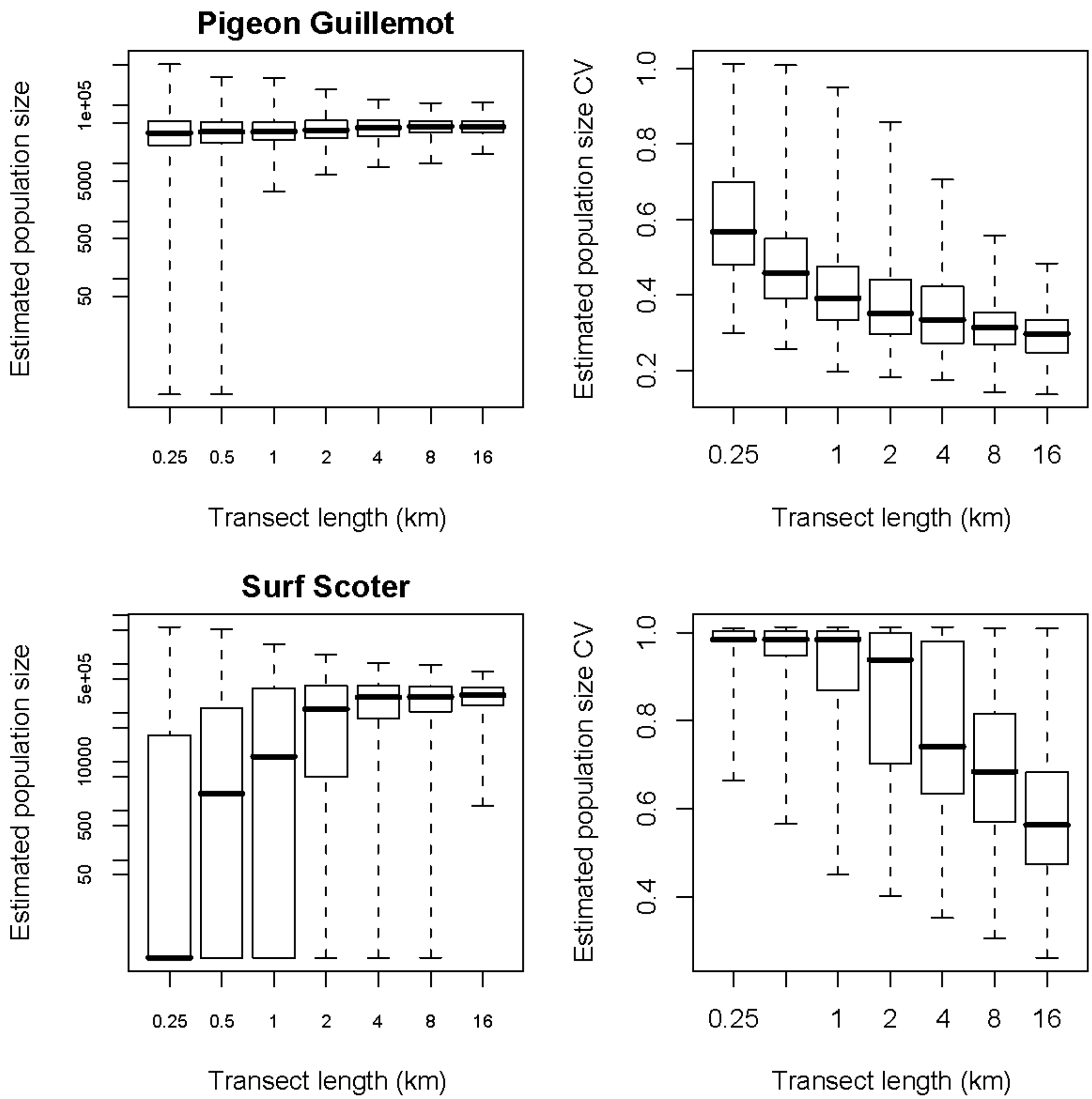



Figure 14 continued. Simulated population size estimates and variation (CV) around the estimates for marine predators over a range of transect lengths. In these simulations, the number of samples (21) was held constant regardless of transect length. Note log scale for population estimates. Heavy bars represent median values, boxes represent the 25-75% range, and the broken lines indicate the range of values.

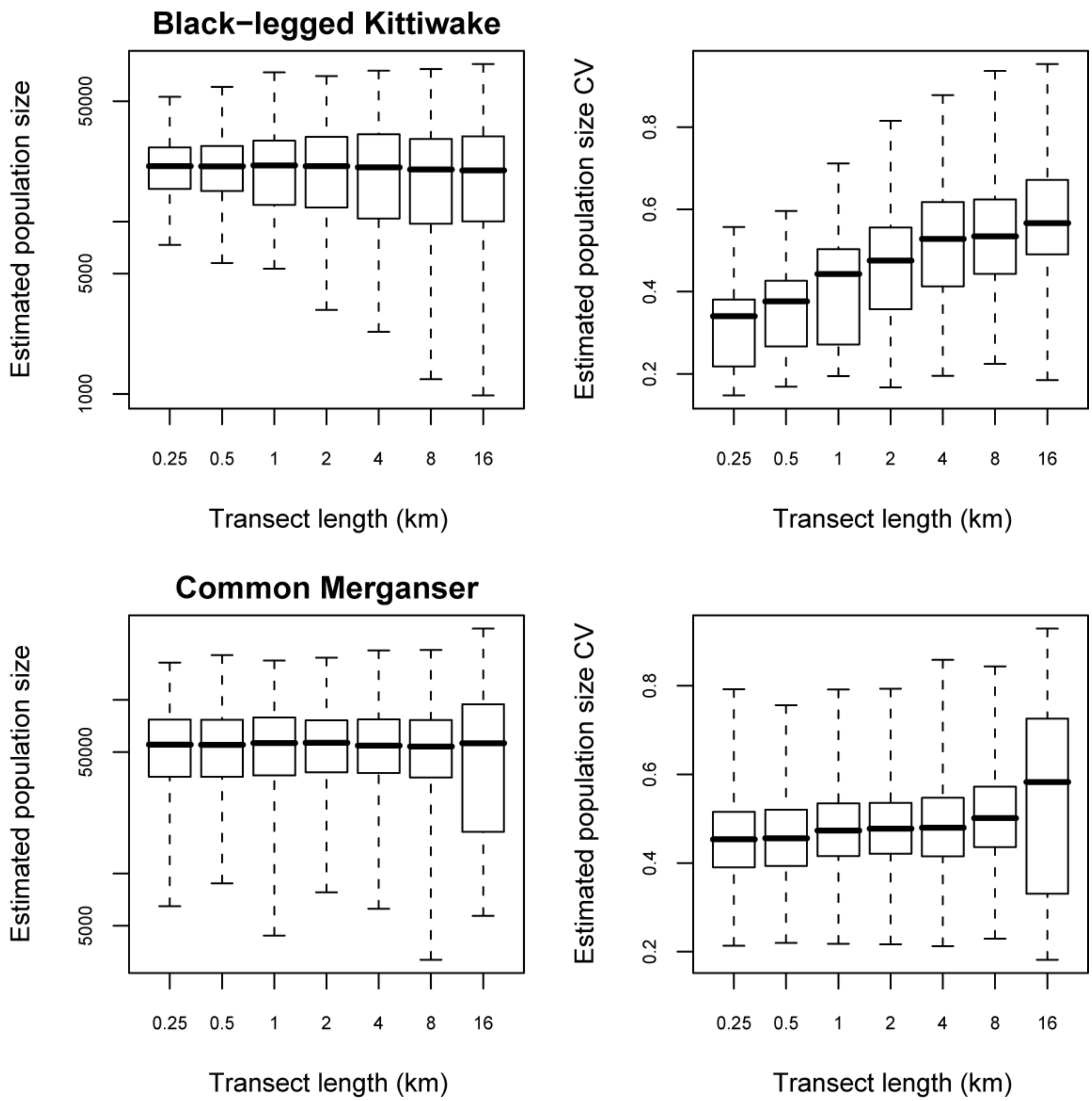



Figure 15. Simulated population size estimates and variation (CV) around the estimates for 8 marine predator species over a range of transect lengths. In these simulations, the sample area was held constant while the number of transects varied (see methods). Note log scale for population estimates. Heavy bars represent median values, boxes represent the 25-75% range, and the broken lines indicate the range of values.

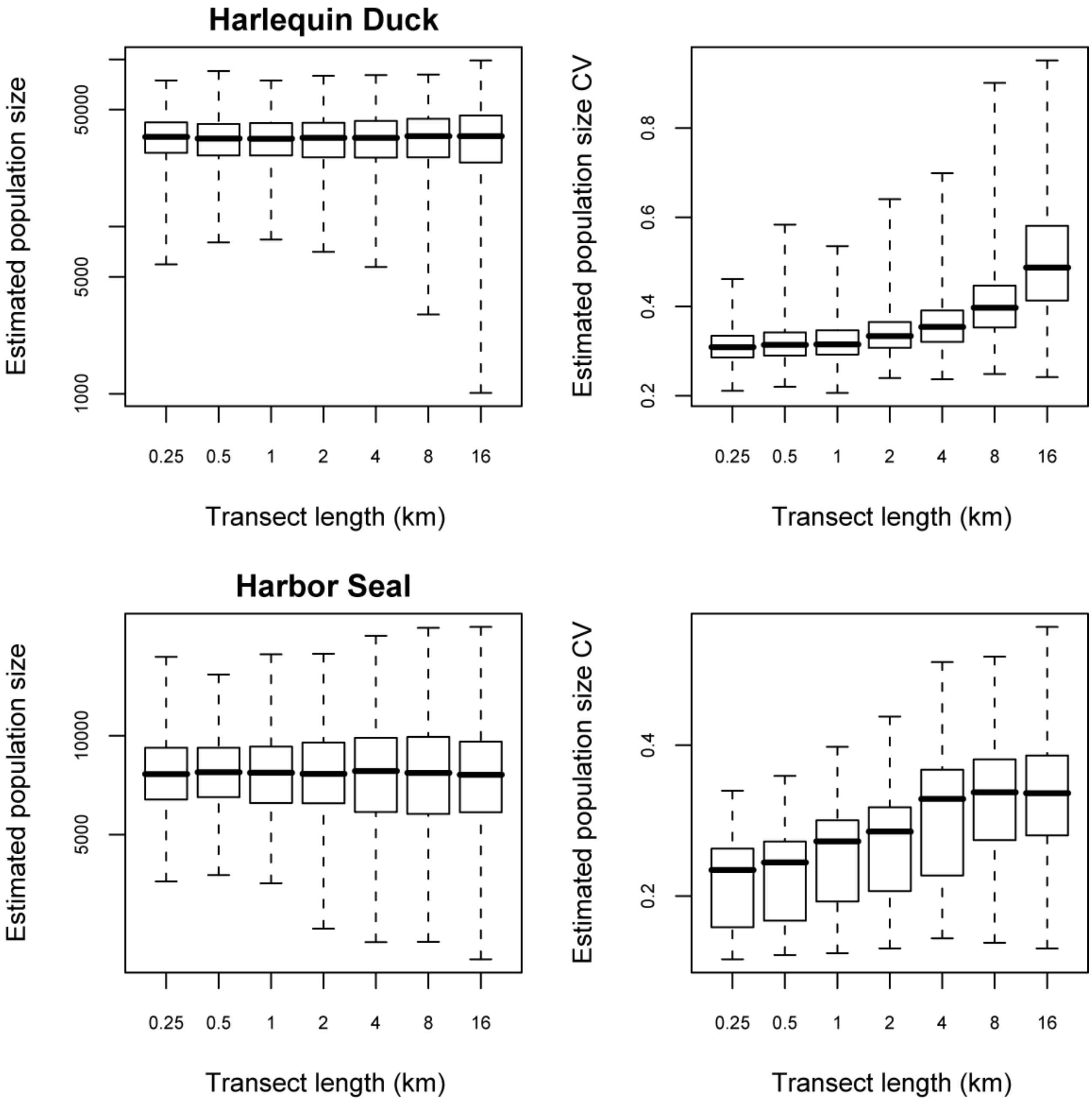



Figure 15 continued. Simulated population size estimates and variation (CV) around the estimates for marine predators over a range of transect lengths. In these simulations, the sample area was held constant while the number of transects varied (see methods). Note log scale for population estimates. Heavy bars represent median values, boxes represent the 25-75% range, and the broken lines indicate the range of values.

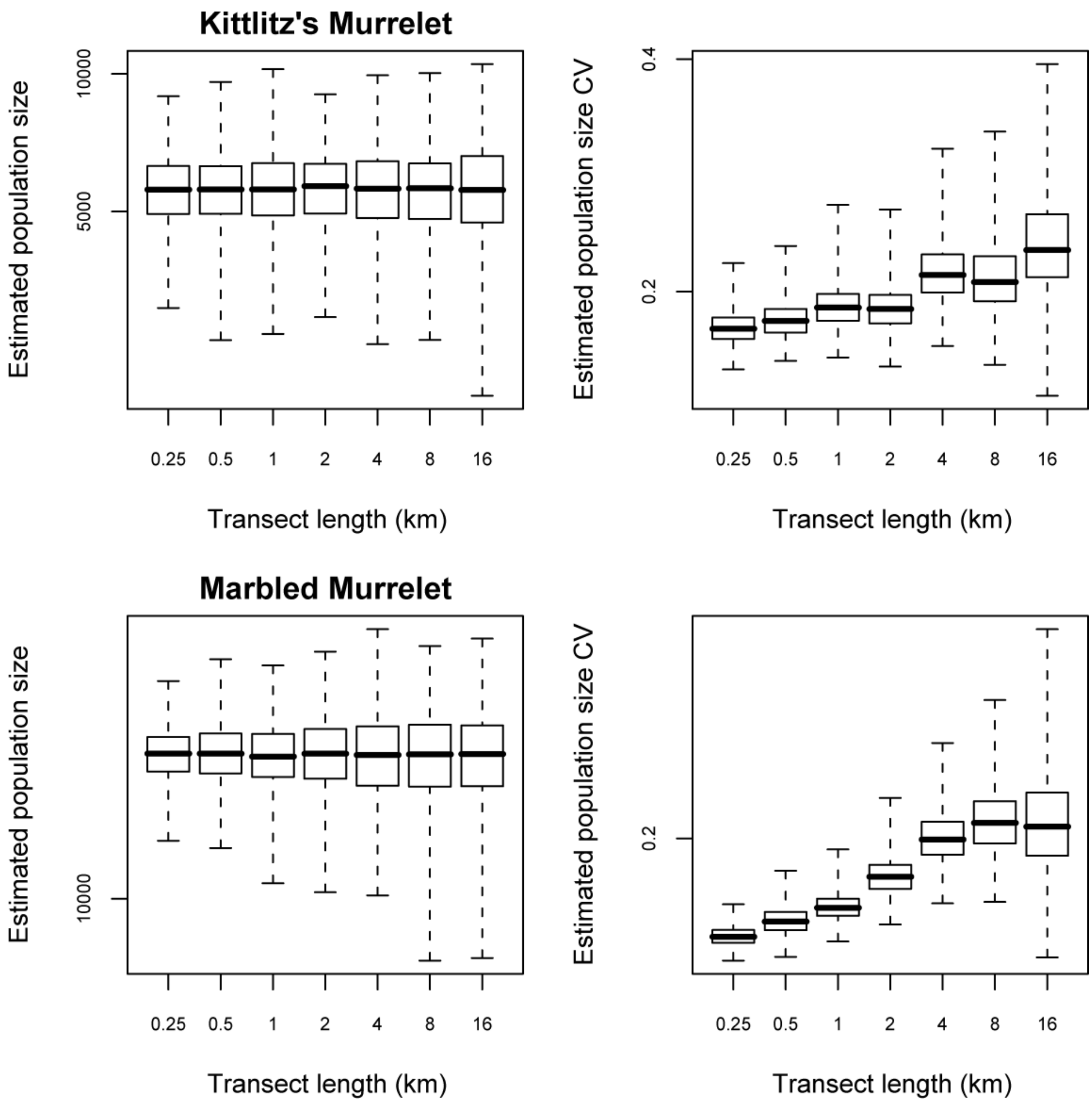



Figure 15 continued. Simulated population size estimates and variation (CV) around the estimates for marine predators over a range of transect lengths. In these simulations, the sample area was held constant while the number of transects varied (see methods). Note log scale for population estimates. Heavy bars represent median values, boxes represent the 25-75% range, and the broken lines indicate the range of values.

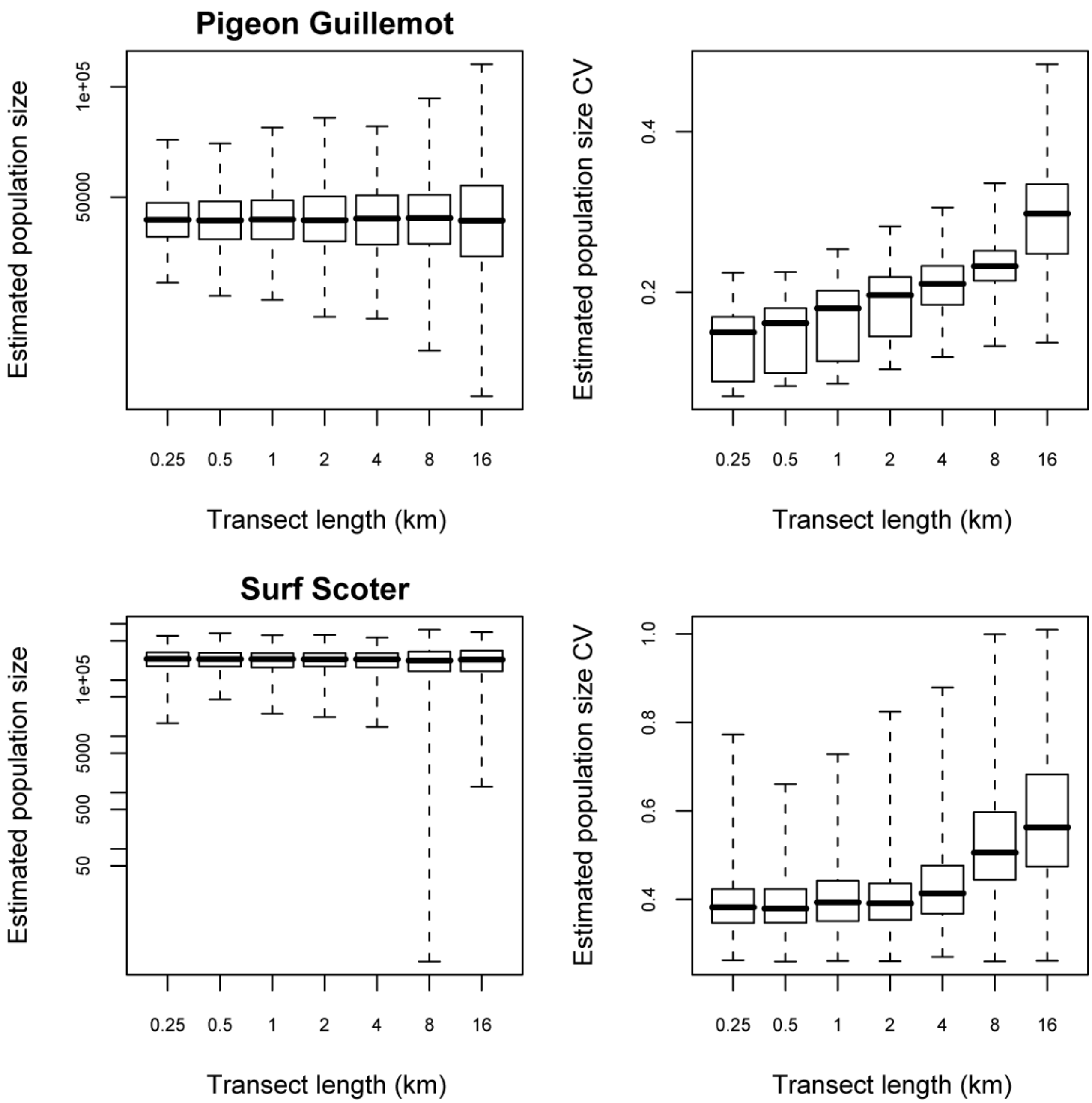



Figure 15 continued. Simulated population size estimates and variation (CV) around the estimates for marine predators over a range of transect lengths. In these simulations, the sample area was held constant while the number of transects varied (see methods). Note log scale for population estimates. Heavy bars represent median values, boxes represent the 25-75% range, and the broken lines indicate the range of values.

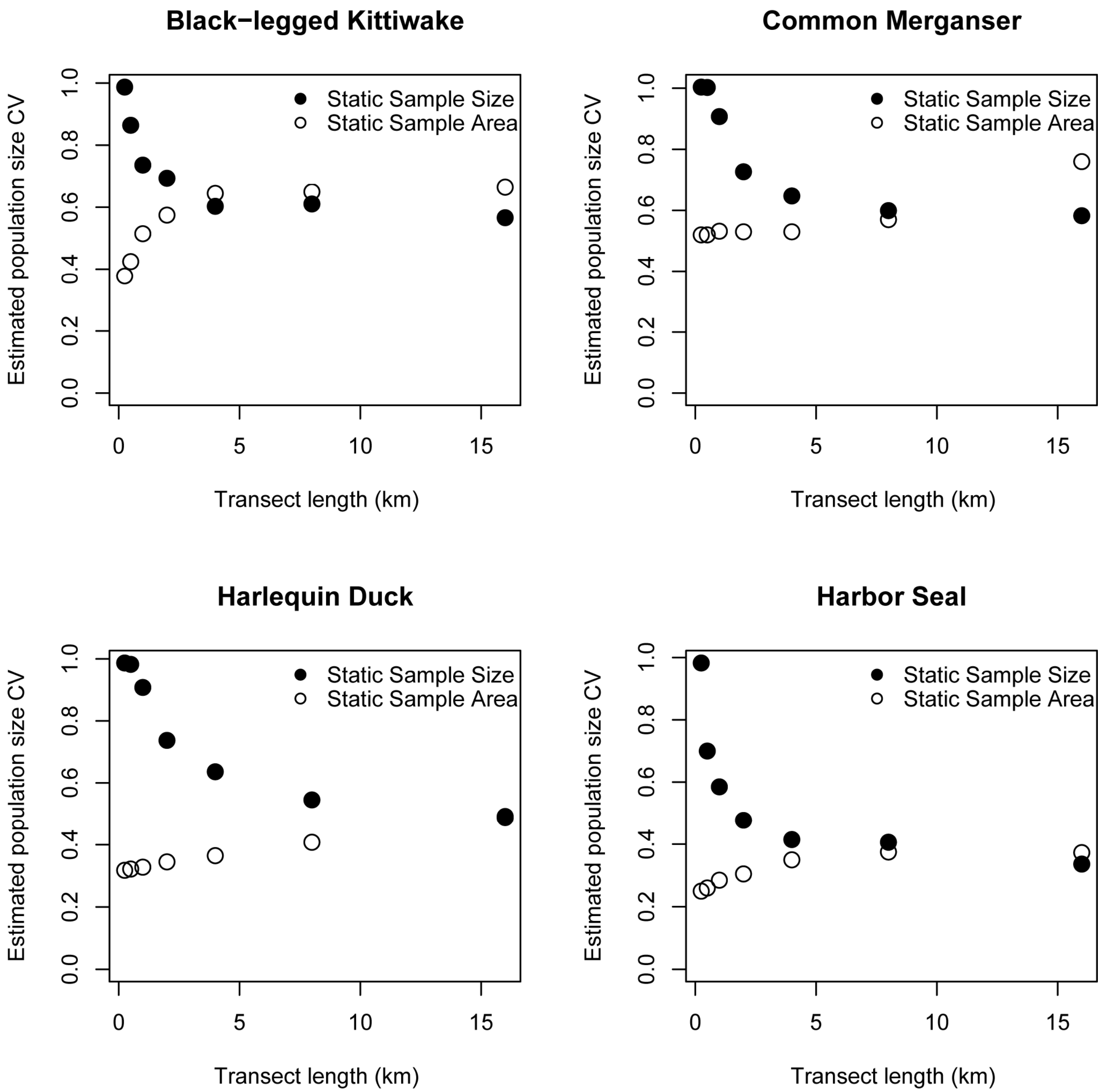



Figure 16. Median estimates of variation (CV) in population size for 8 marine predator species over a range of transect lengths, where simulations were conducted with static sample size (solid circles) or static sample area (hollow circles).

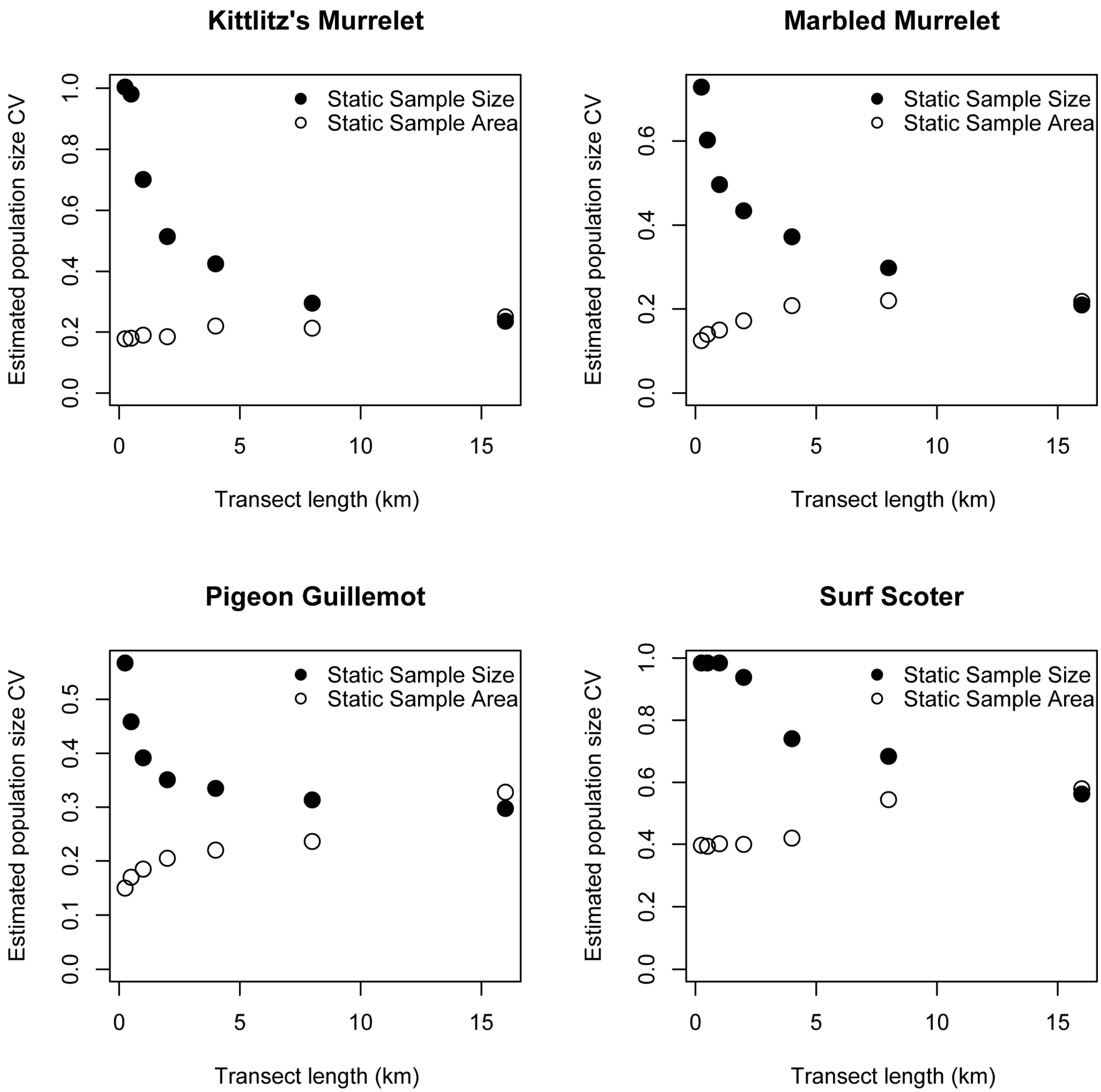



Figure 16 continued. Median estimates of variation (CV) in population size of marine predators over a range of transect lengths, where simulations were conducted with static sample size (solid circles) or static sample area (hollow circles).

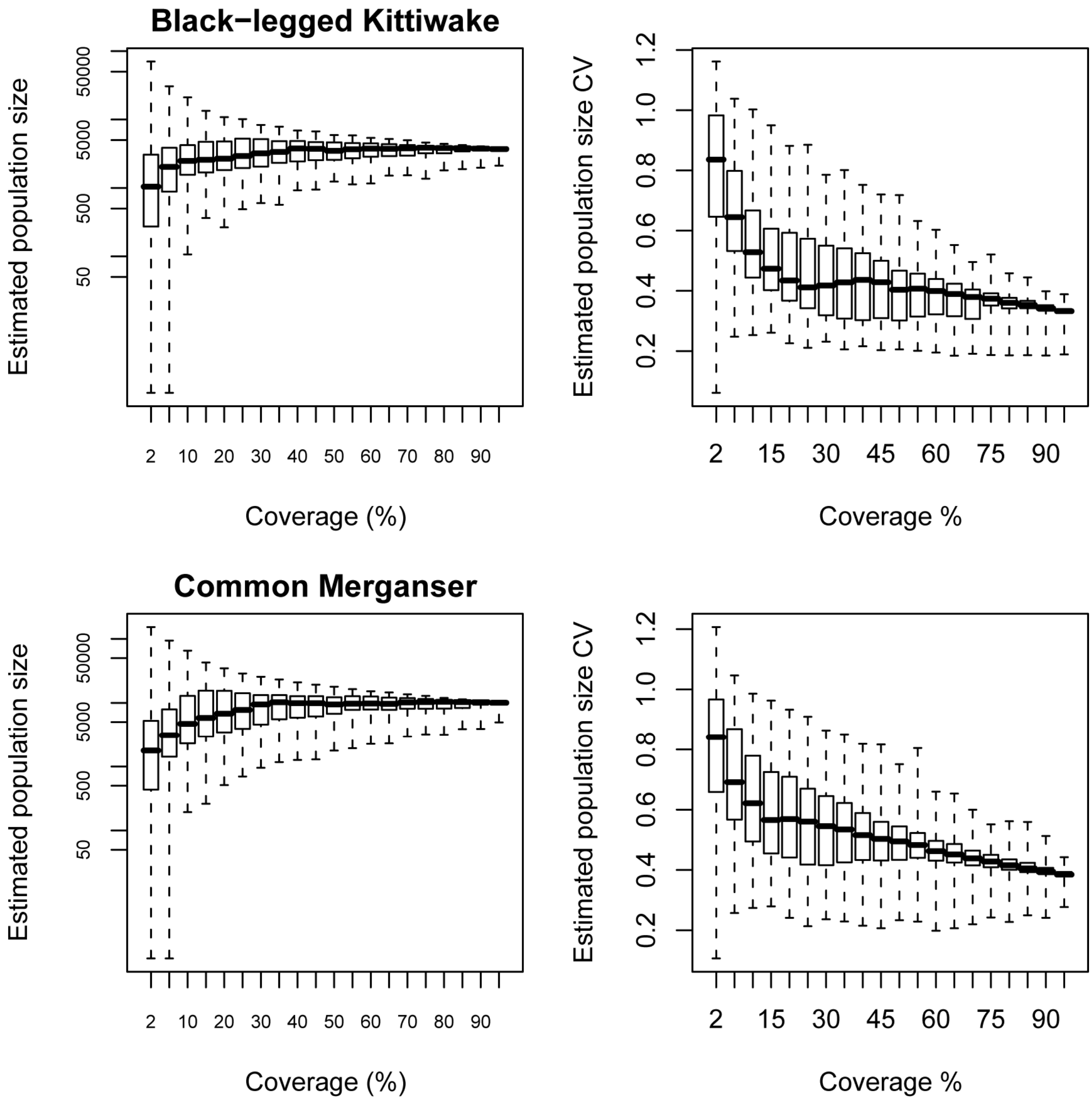



Figure 17. Effect of sampling effort on population estimates and their variation (CV) for 8 marine predator species in Glacier Bay, AK. Simulated population estimates generated by random selection of a subset (2-95%) of transects from the original survey dataset (100% coverage). Note log scale for population size. Heavy bars represent median values, boxes represent the 25-75% range, and the broken lines indicate the range of values.

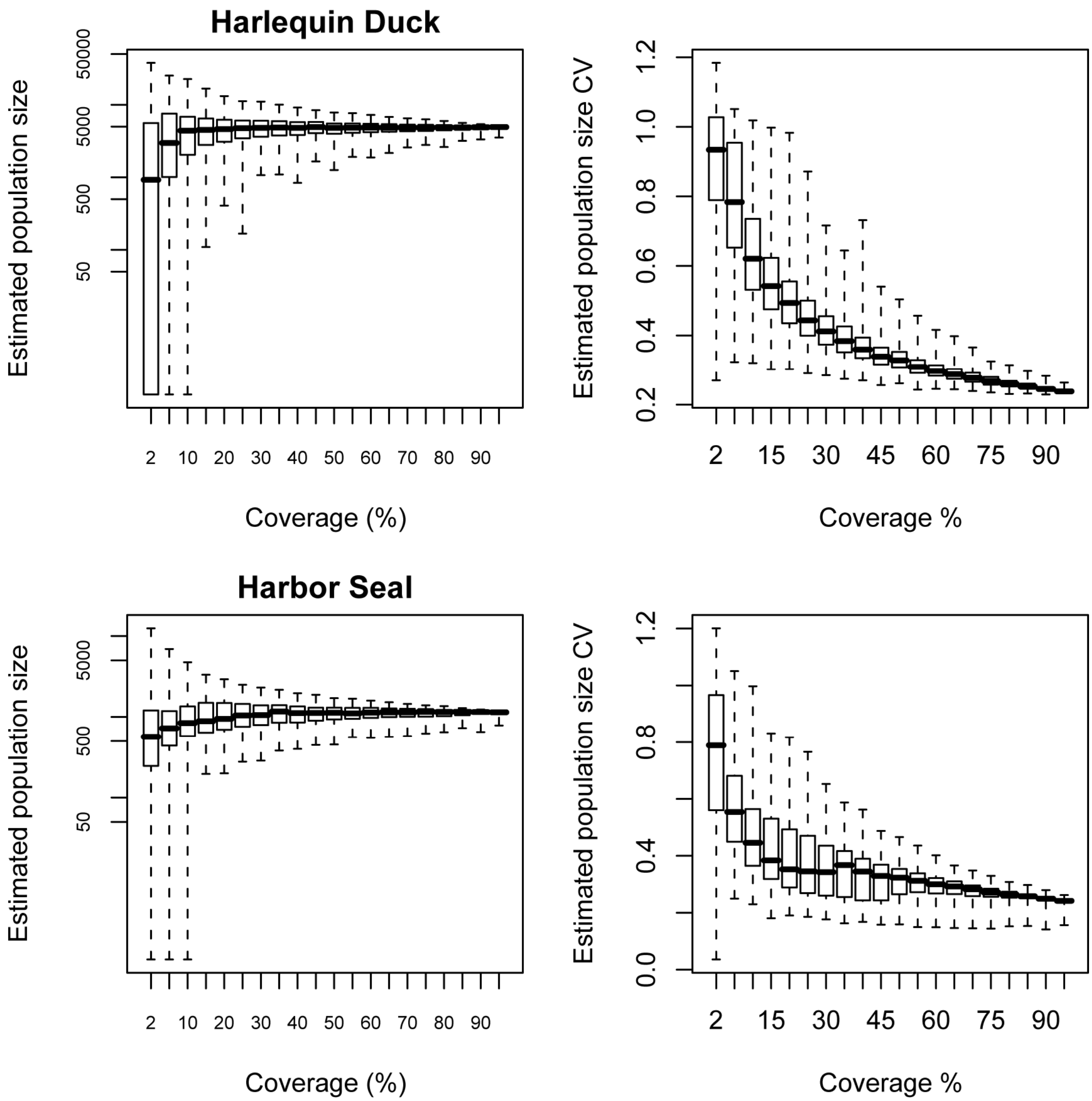



Figure 17. Effect of sampling effort on population estimates and their variation (CV) for 8 marine predator species in Glacier Bay, AK. Simulated population estimates generated by random selection of a subset (2-95%) of transects from the original survey dataset (100% coverage). Note log scale for population size. Heavy bars represent median values, boxes represent the 25-75% range, and the broken lines indicate the range of values

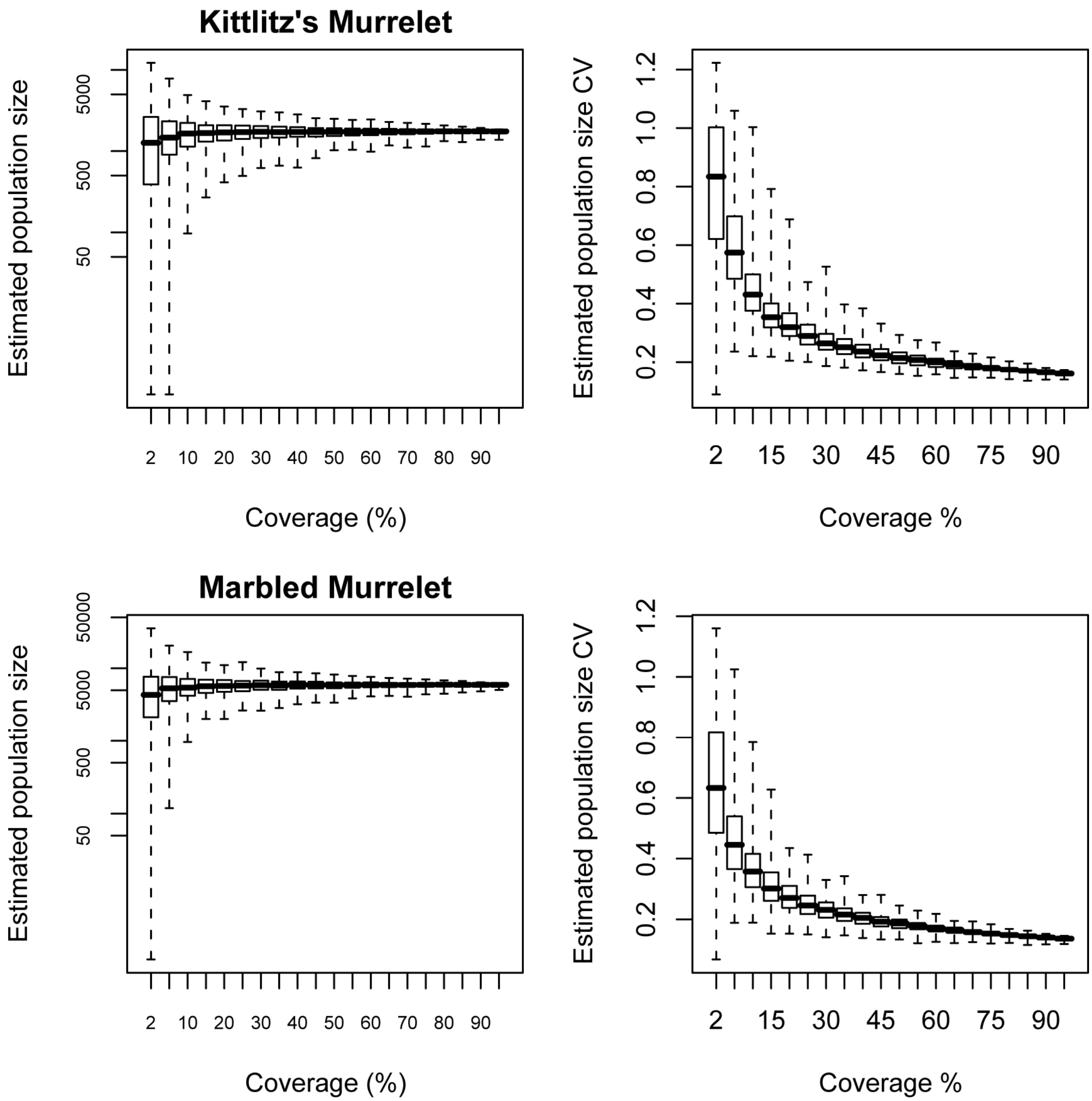
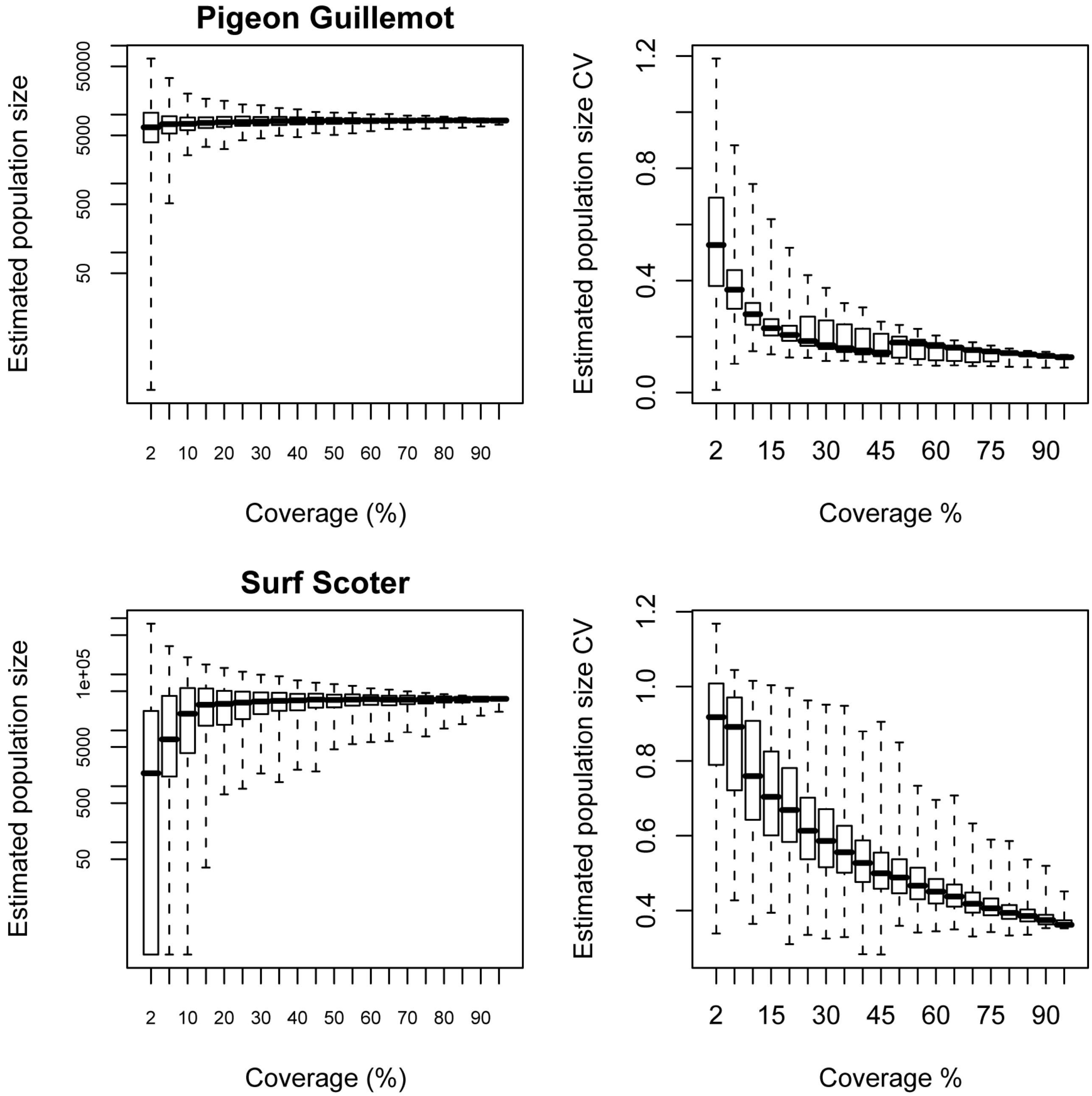



Figure 17. Effect of sampling effort on population estimates and their variation (CV) for 8 marine predator species in Glacier Bay, AK. Simulated population estimates generated by random selection of a subset (2-95%) of transects from the original survey dataset (100% coverage). Note log scale for population size. Heavy bars represent median values, boxes represent the 25-75% range, and the broken lines indicate the range of values

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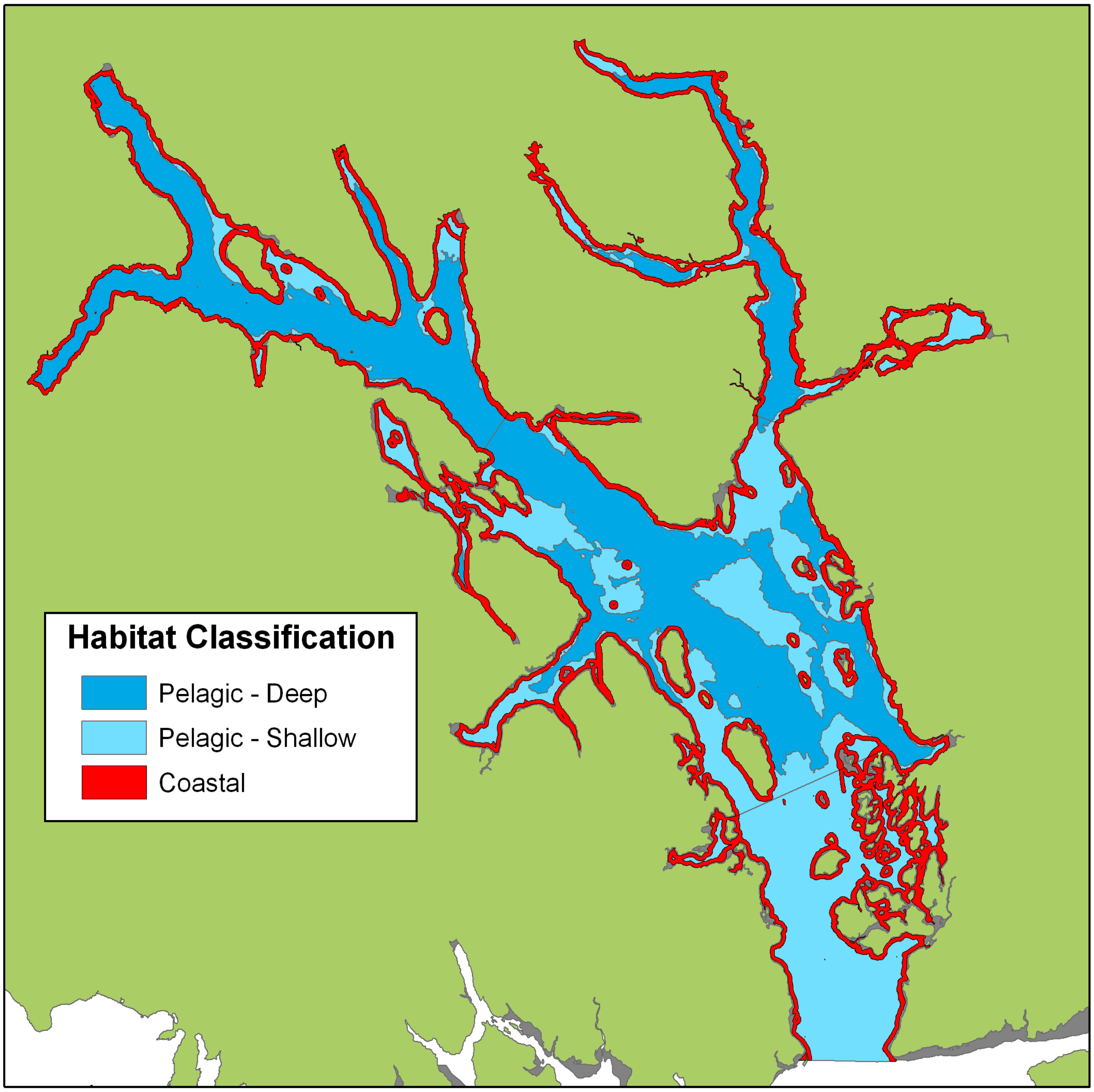



Figure 18. Map of modified bathymetry classes for Glacier Bay, AK. This classification used a combination of proximity to shore and bathymetry to create three sampling strata.

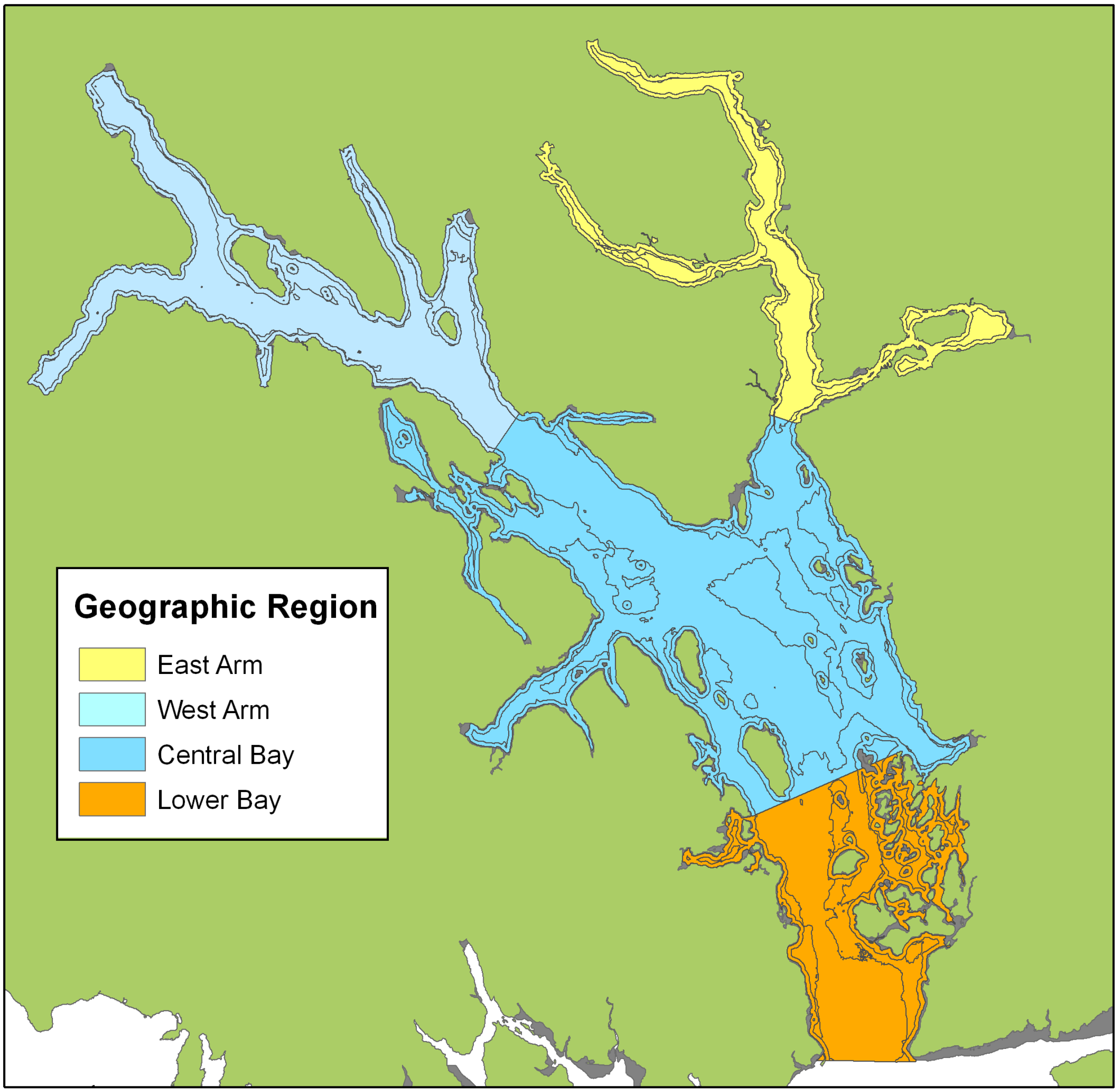



Figure 19. Map of geographic classes for Glacier Bay, AK, used to examine broad-scale geographic associations of marine predators with different areas of the bay. Note the modified bathymetry classes are visible as grey lines.

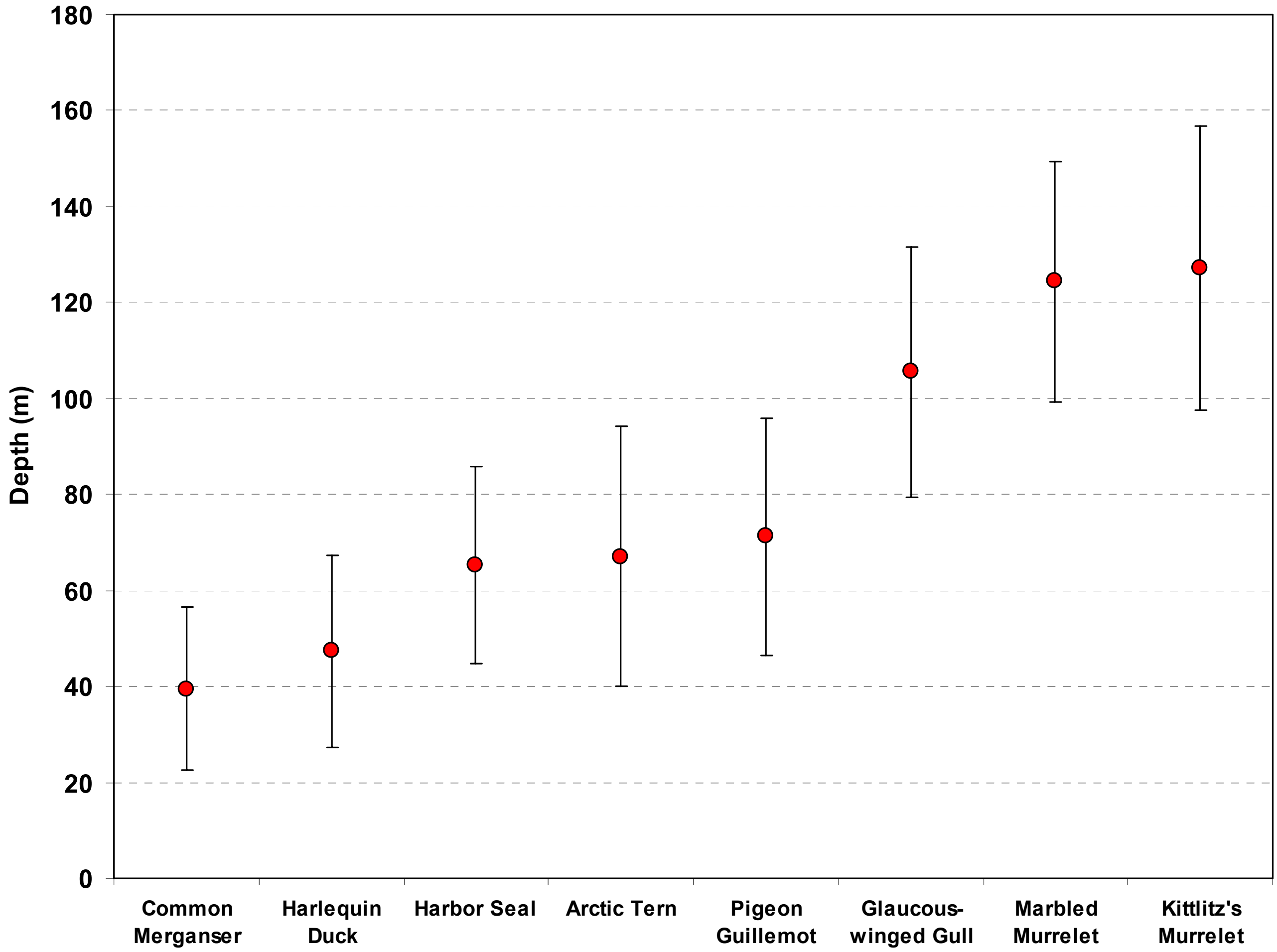



Figure 20. Mean depth at which eight common species were observed at sea on summer surveys in Glacier Bay, June, 1999-2003.

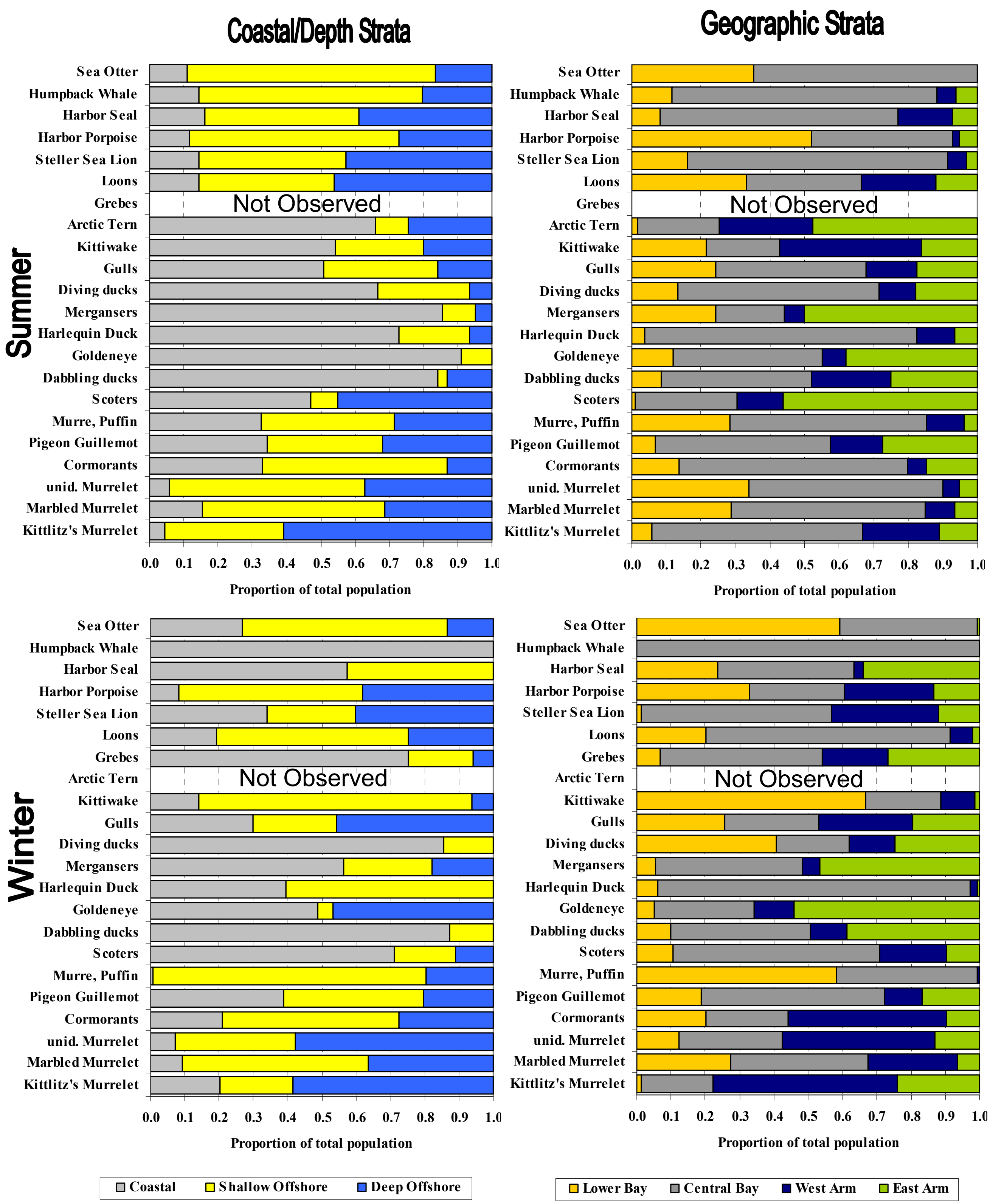
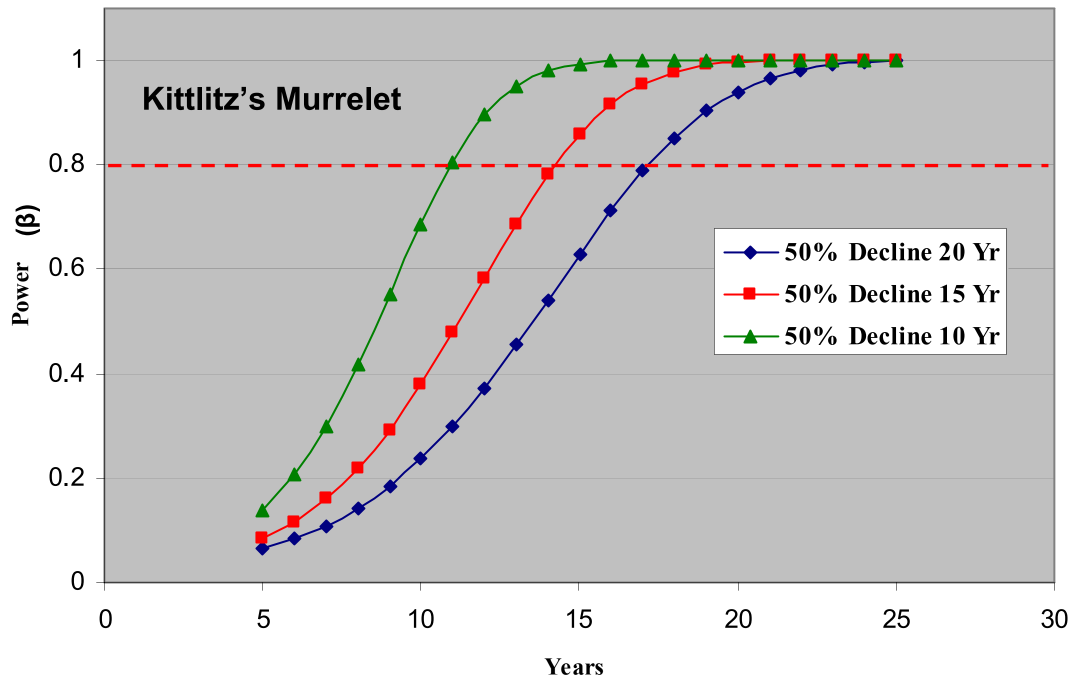



Figure 21. Proportional use of coastal/depth strata (on the left) and geographic strata (on the right) by different species during summer (top) and winter (bottom) surveys.



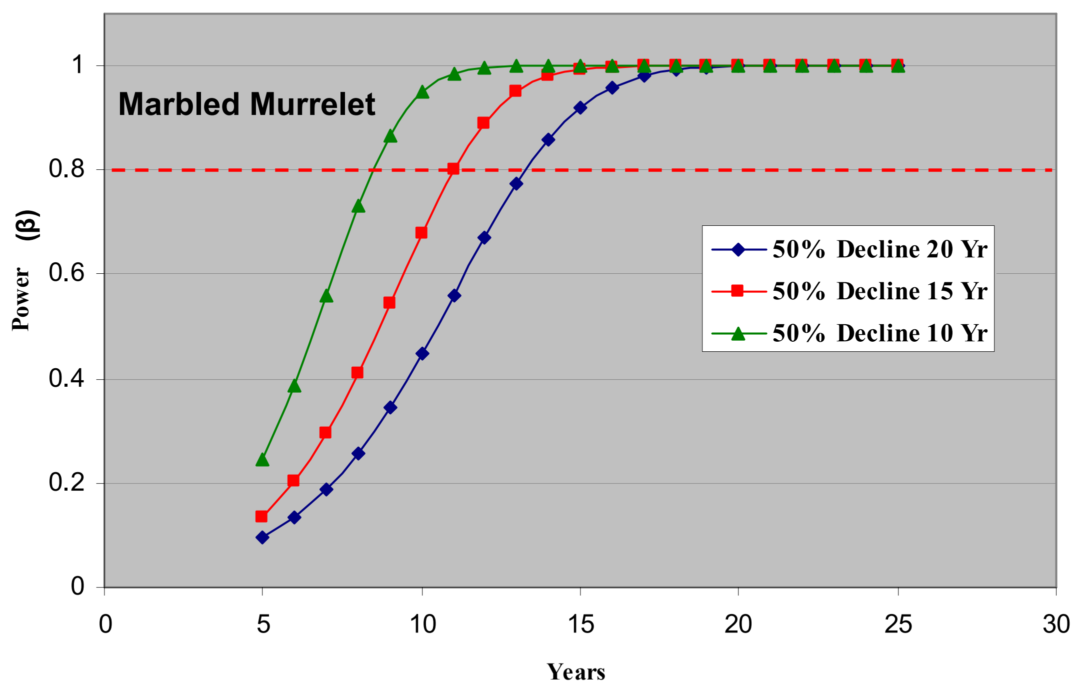
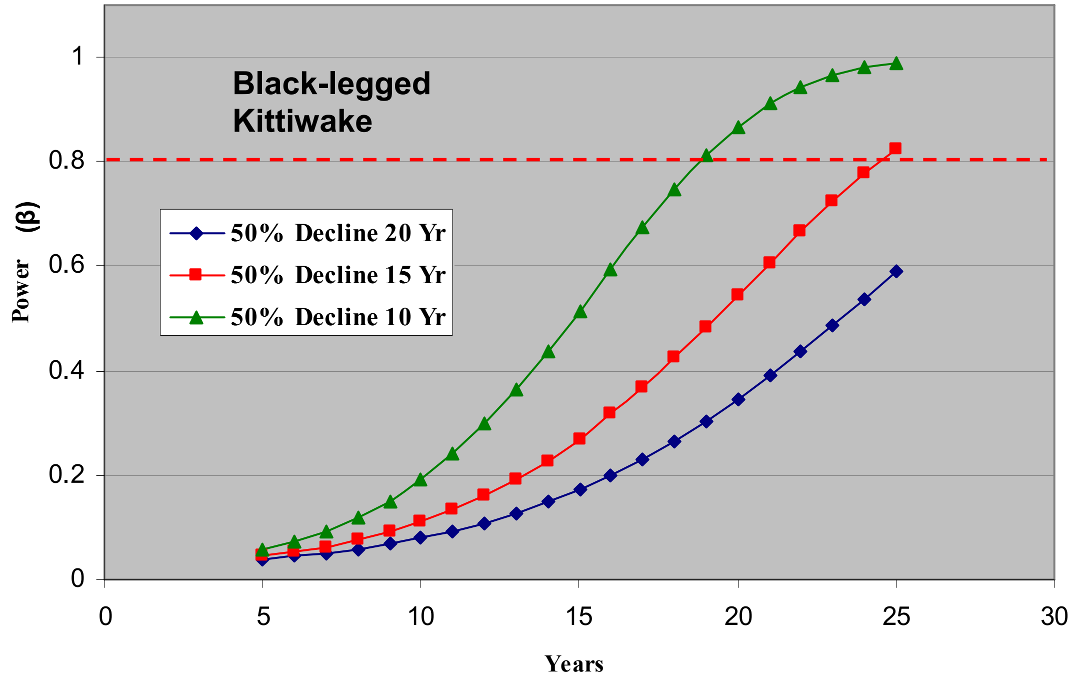




Figure 22. Power curves for detecting 50% declines in populations of eight different marine predator species in Glacier Bay. Colored curves illustrate the estimated power to detect declines that occur over three possible time periods (10, 15, and 20 years).



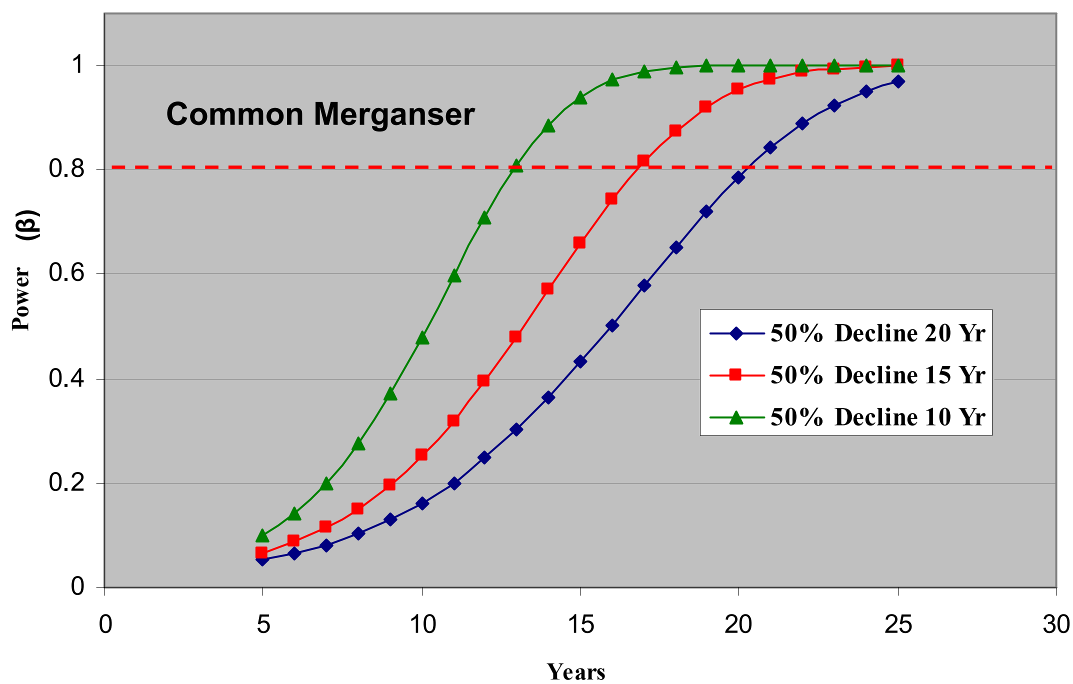
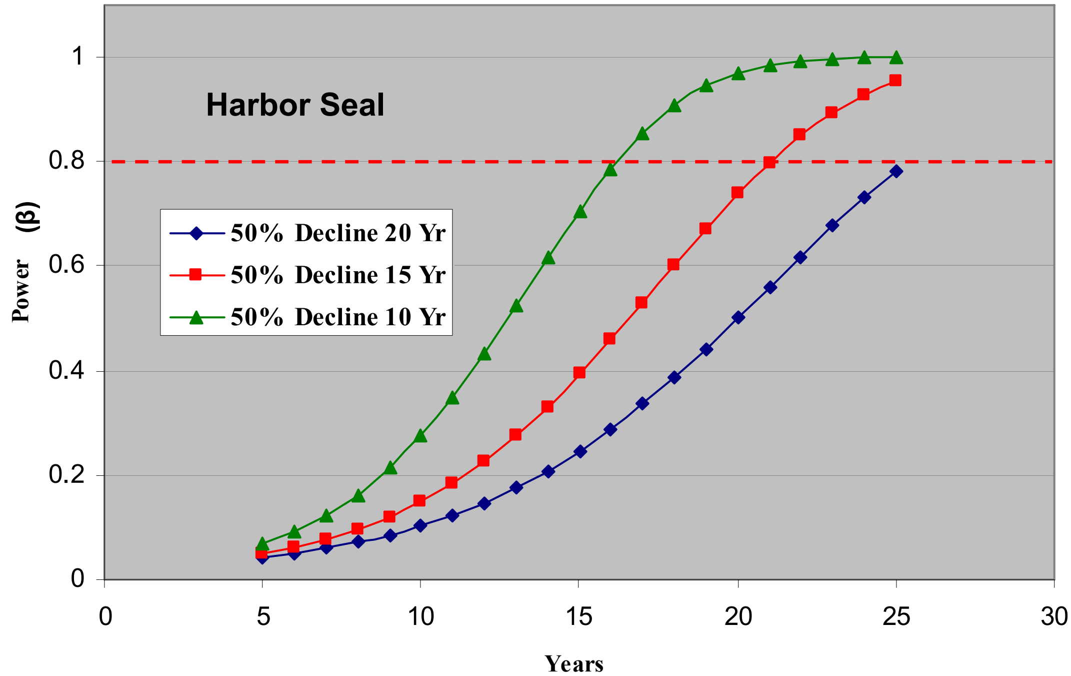




Figure 22. Continued.



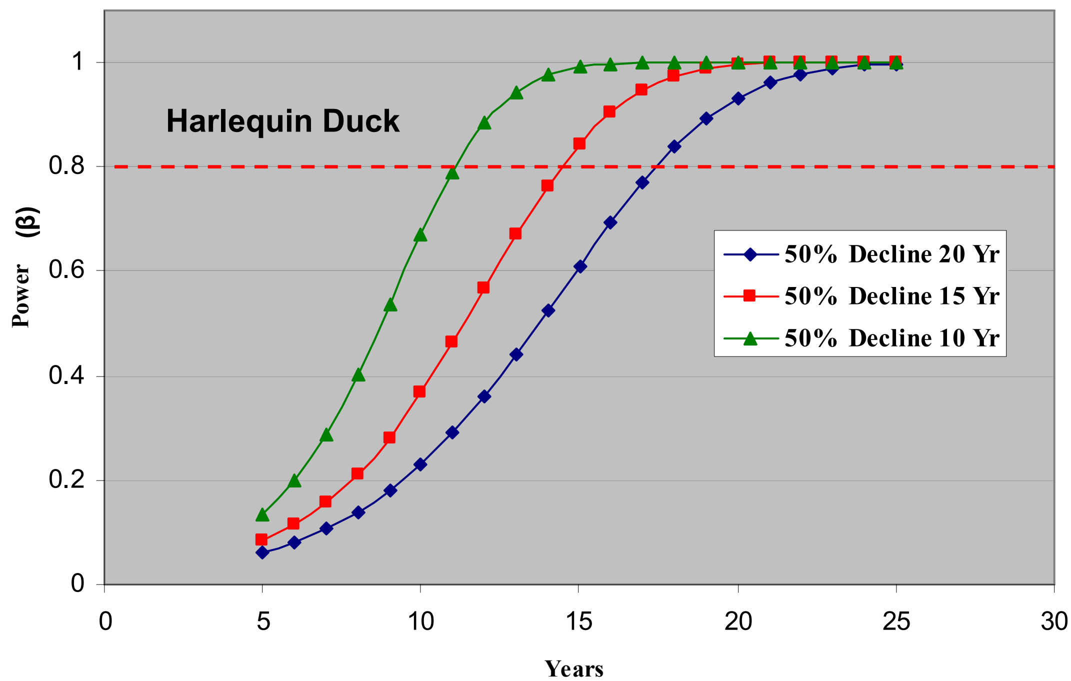
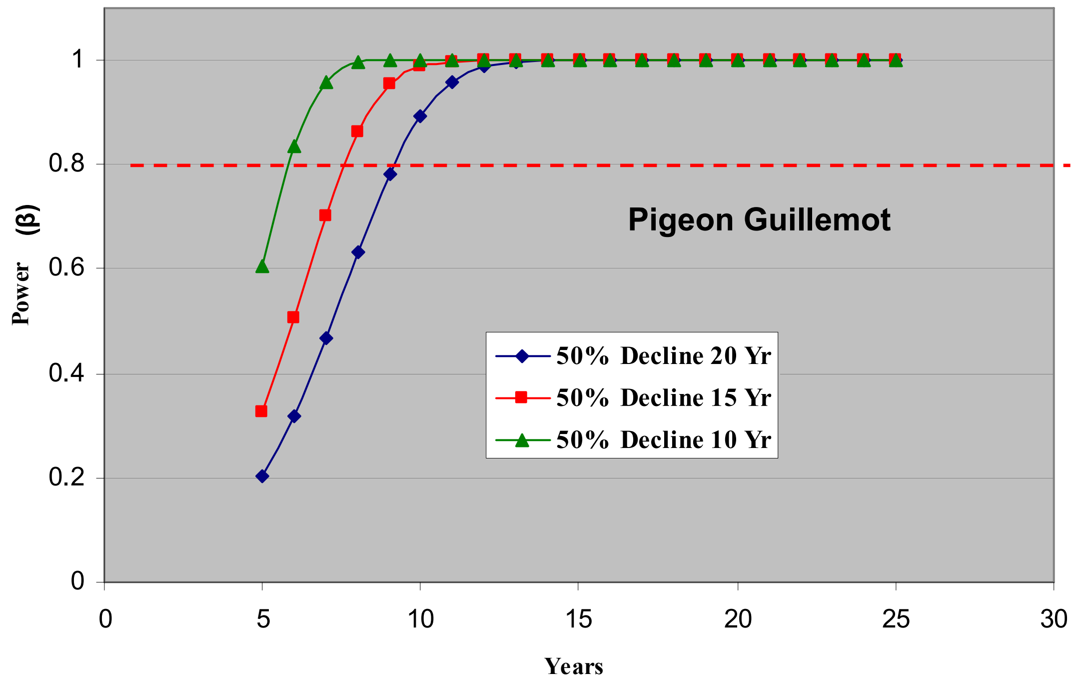




Figure 22. Continued.



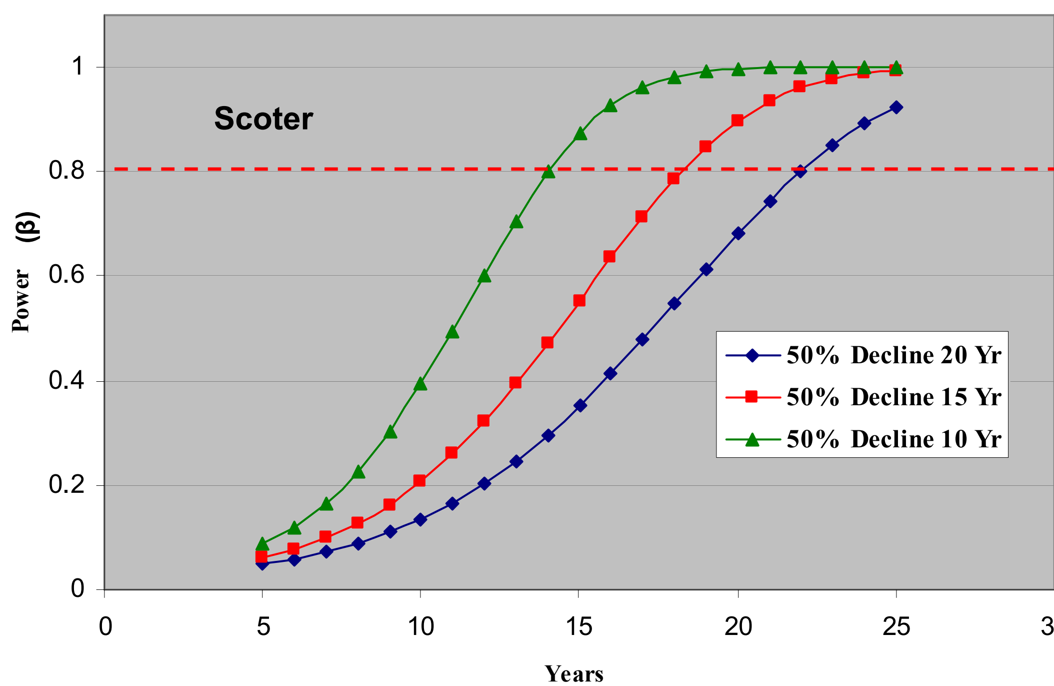
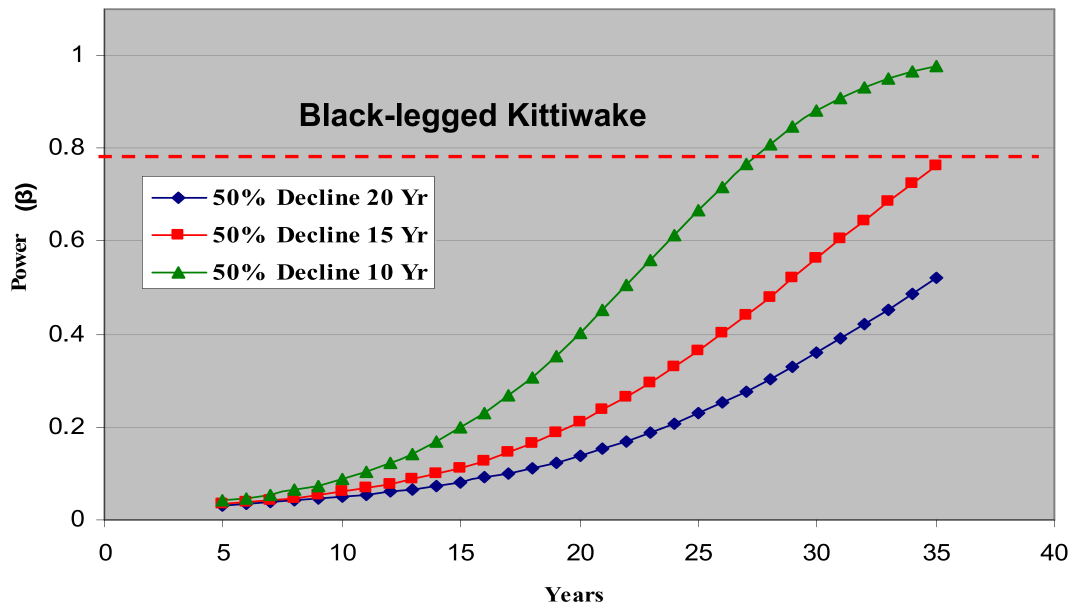




Figure 22. Continued.



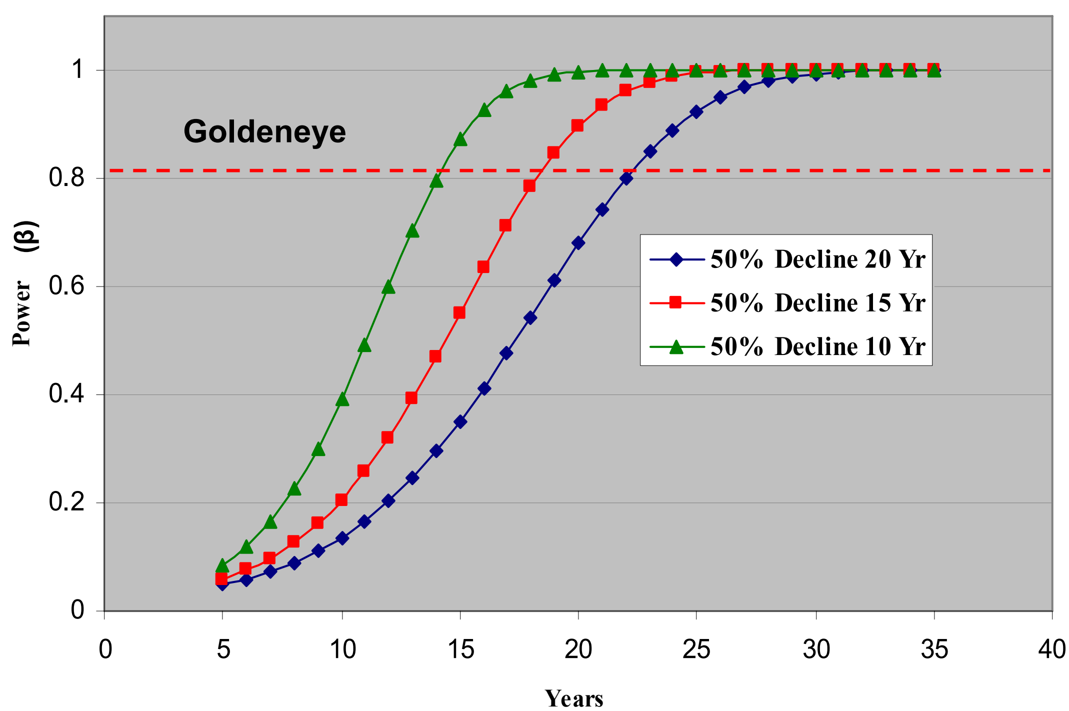
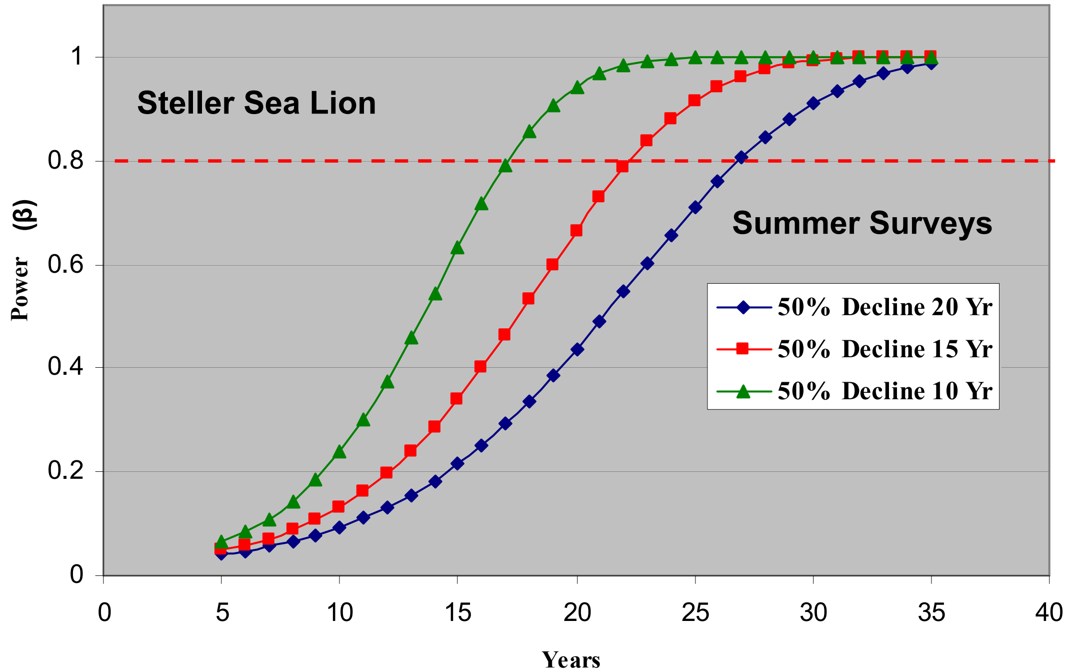




Figure 23. Power curves for detecting 50% declines in populations of Black-legged kittiwake (highest CV) and Goldeneye (most common birds) during winter surveys in Glacier Bay, AK over three different time periods (10, 15 and 20 years).



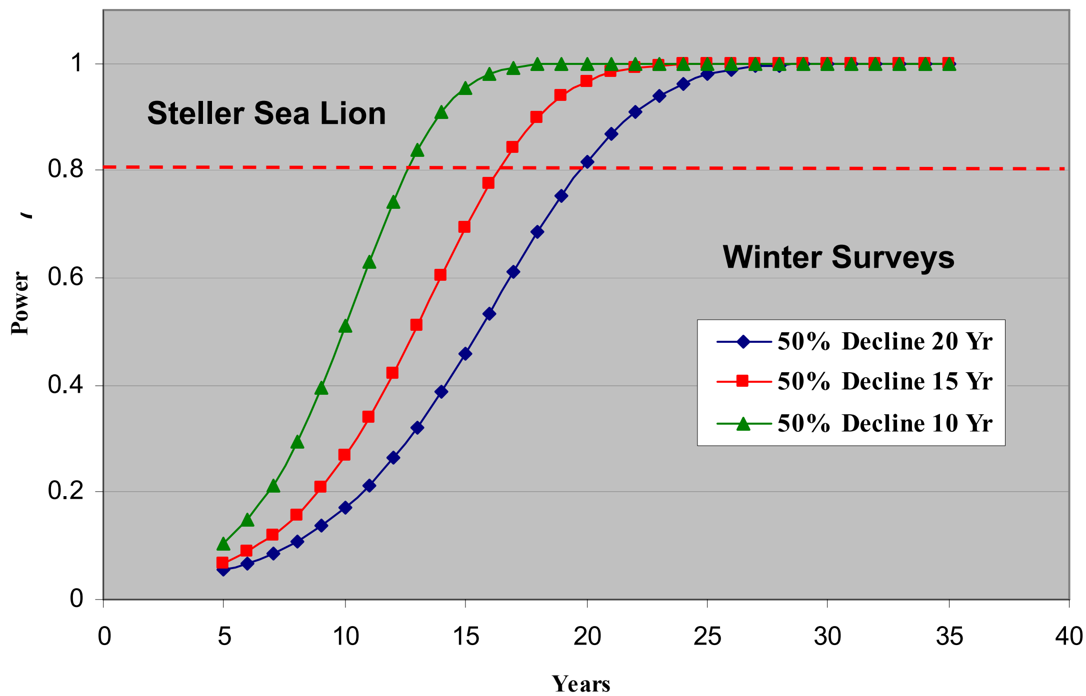




Figure 24. Power curves for detecting 50% declines in populations of Steller Sea Lion based on summer surveys (top) and winter surveys (bottom) from Glacier Bay, AK, November 1999 and March 2000-2003.

# Appendices

## Appendix 1. Species list for all marine birds and mammals sighted on summer and winter surveys in Glacier Bay and Icy Strait.

| Common Name | Latin Name | 4-Letter Codes |
|---|---|---|
| Common Loon | *Gavia immer* | COLO |
| Yellow-billed Loon | *Gavia adamsii* | YBLO |
| Red-throated Loon | *Gavia stellata* | RTLO |
| Pacific Loon | *Gavia pacifica* | PALO |
| Unidentified Loon | *Gavia spp.* | UNLO |
| Unidentified Grebe | *Podicipedidae spp.* | UNGR |
| Red-necked Grebe | *Podiceps grisegena* | RNGR |
| Western Grebe | *Aechmophorus occidentalis* | WEGR |
| Horned Grebe | *Podiceps auritus* | HOGR |
| Trumpeter Swan | *Cygnus buccinator* | TRSW |
| Canada Goose | *Branta canadensis* | CAGO |
| Unidentified Duck | *Anatinae spp.* | UNDU |
| Mallard | *Anas platyrhynchos* | MALL |
| Gadwall | *Anas strepera* | GADW |
| Northern Pintail | *Anas acuta* | NOPI |
| Green-winged Teal | *Anas crecca* | GWTE |
| Blue-winged Teal | *Anas discors* | BWTE |
| American Wigeon | *Anas americana* | AMWI |
| Northern Shoveler | *Anas clypeata* | NOSH |
| Greater Scaup | *Aythya marila* | GRSC |
| Unidentified Goldeneye | *Bucephala spp.* | UNGO |
| Common Goldeneye | *Bucephala clangula* | COGO |
| Barrow's Goldeneye | *Bucephala islandica* | BAGO |
| Bufflehead | *Bucephala albeola* | BUFF |
| Long-tailed Duck | *Clangula hyemalis* | LTDU |
| Harlequin Duck | *Histrionicus histrionicus* | HADU |
| Unidentified Scoter | *Melanitta spp.* | UNSC |
| White-winged Scoter | *Melanitta fusca* | WWSC |
| Surf Scoter | *Melanitta perspicillata* | SUSC |
| Black Scoter | *Melanitta nigra* | BLSC |
| Unidentified Merganser | *Mergus or Lophodytes spp.* | UNME |
| Common Merganser | *Mergus merganser* | COME |
| Red-breasted Merganser | *Mergus serrator* | RBME |
| Unidentified Petrel | *Pterodroma or Bulweria or Procellaria spp.* | UNPE |
| Unidentified Phalarope | *Phalaropus spp.* | UNPH |
| Unidentified Shearwater | *Procellariidae spp.* | UNSH |
| Unidentified Storm-petrel | *Oceanodroma, Hydrobates, Pelagodroma,orOceanites spp.* | UNSP |
| Fork-tailed Storm-petrel | *Oceanodroma furcata* | FTSP |
| Unidentified Alcid | *Alcidae spp./Laridae spp.* | UNAL |
| Unidentified Cormorant | *Phalacrocorax spp* | UNCO |
| Double-crested Cormorant | *Phalacrocorax auritus* | DCCO |
| Pelagic Cormorant | *Phalacrocorax pelagicus* | PECO |

Appendix 1. Continued.

| Common Name | Latin Name | 4-Letter Codes |
|---|---|---|
| Red-faced Cormorant | *Phalacrocorax urile* | RFCO |
| Red-necked Phalarope | *Phalaropus lobatus* | RNPH |
| Unidentified Jaeger | *Stercorarius spp.* | UNJA |
| Parasitic Jaeger | *Stercorarius parasiticus* | PAJA |
| Unidentified Gull | *Larinae spp.* | UNGU |
| Glaucous-winged Gull | *Larus glaucescens* | GWGU |
| Herring gull | *Larus argentatus* | HEGU |
| Mew Gull | *Larus canus* | MEGU |
| Bonaparte's Gull | *Larus philadelphia* | BOGU |
| Black-legged Kittiwake | *Rissa tridactyla* | BLKI |
| Unidentified Tern | *Sterninae spp.* | UNTE |
| Arctic Tern | *Sterna paradisaea* | ARTE |
| Aleutian Tern | *Sterna aleutica* | ALTE |
| Caspian Tern | *Sterna caspia* | CATE |
| Ancient Murrelet | *Synthliboramphus antiquus* | ANMU |
| Common Murre | *Uria aalge* | COMU |
| Unidentified Murre | *Uria spp.* | UNMU |
| Unidentified Phalarope | *Phalaropus spp.* | UNPH |
| Pigeon Guillemot | *Cepphus columba* | PIGU |
| Kittlitz's Murrelet | *Brachyramphus brevirostris* | KIMU |
| Marbled Murrelet | *Brachyramphus marmoratus* | MAMU |
| Brachyramphus Murrelet | *Brachyramphus spp* | BRMU |
| Parakeet Auklet | *Aethia psittacula* | PAAU |
| Rhinoceros Auklet | *Cerorhinca monocerata* | RHAU |
| Tufted Puffin | *Fratercula cirrhata* | TUPU |
| Bald Eagle | *Haliaeetus leucocephalus* | BAEA |
| Marine Mammals | | |
| Killer Whale | *Orcinus orca* | KIWH |
| Harbor Porpoise | *Phocoena phocoena* | HAPO |
| Unidentified Porpoise | *Phocoenidae spp.* | UNPO |
| Dall's Porpoise | *Phocoenoides dalli* | DAPO |
| Humpback Whale | *Megaptera novaeanglia* | HUWH |
| Minke Whale | *Balaenoptera acutorostrata* | MIWH |
| Harbor Seal | *Phoca vitulina* | HASE |
| Sea Otter | *Enhydra lutris* | SEOT |
| River Otter | *Lontra canadensis* | RIOT |
| Steller Sea Lion | *Eumetopias jubatus* | STSL |

Appendix 2. Mean Densities (num/km$^2$) of marine birds and mammals observed on surveys of Icy Strait during summer, 1999-2003. Species listed in taxonomic order and summed by groups and subgroups. Note that the area surveyed in Glacier Bay was nearly 3 times that surveyed in Icy Strait.

| Group | Subgroup | 1999 | | 2000 | | 2001 | | 2002 | | 2003 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Density | SD | Density | SD | Density | SD | Density | SD | Density | SD |
| Waterbirds | | | | | | | | | | | |
| | **Loon** | | | | | | | | | | |
| | Common Loon | 0.1 | 0.2 | <0.1 | 0.1 | 0 | 0 | 0.1 | 0.3 | 0.2 | 0.5 |
| | Yellow-billed Loon | 0 | 0 | 0 | 0 | <0.1 | 0.1 | 0 | 0 | 0 | 0 |
| | Red-throated Loon | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Pacific Loon | <0.1 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 |
| | Unidentified Loon | 0.1 | 0.2 | 0 | 0 | <0.1 | 0.1 | <0.1 | 0.1 | 0.1 | 0.2 |
| | **Scoter** | | | | | | | | | | |
| | Surf Scoter | <0.1 | 0.1 | 0 | 0 | <0.1 | 0.2 | 0.7 | 1.9 | 0 | 0 |
| | White-winged Scoter | <0.1 | 0.1 | 0.1 | 0.3 | 0 | 0 | 0.1 | 0.5 | 0.1 | 0.3 |
| | Unidentified Scoter | 0.1 | 0.3 | 0 | 0 | 0 | 0 | 0.1 | 0.7 | 0 | 0 |
| | Other Waterbirds | | | | | | | | | | |
| | Black Brant | 0.4 | 1.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Common Merganser | 0.1 | 0.5 | 0.2 | 0.6 | 0.1 | 0.3 | 0 | 0.1 | 0.2 | 0.7 |
| | Harlequin Duck | <0.1 | 0 | 0 | 0 | 0.1 | 0.3 | <0.1 | 0.1 | 0 | 0 |
| | Long-tailed Duck | <0.1 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Seabirds | | | | | | | | | | | |
| | **Alcid** | | | | | | | | | | |
| | Parakeet Auklet | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 |
| | Rhinoceros Auklet | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Ancient Murrelet | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Common Murre | 0.2 | 0.3 | 0.1 | 0.6 | 0.1 | 0.3 | 0.2 | 0.5 | 1.7 | 5.6 |
| | Unidentified Murre | 0 | 0 | 0 | 0 | 0 | 0.1 | 0 | 0.1 | 0 | 0 |
| | Pigeon Guillemot | 0.3 | 0.5 | 0.3 | 0.5 | 0.3 | 0.8 | 0.3 | 0.6 | 0.2 | 0.3 |
| | Tufted Puffin | 0.4 | 1.3 | 0 | 0.1 | 0 | 0.2 | 0 | 0.1 | 0 | 0.1 |
| | **Murrelet** | | | | | | | | | | |
| | Kittlitz's Murrelet | <0.1 | 0.1 | 0.1 | 0.2 | <0.1 | 0.1 | 0.1 | 0.2 | 0.1 | 0.3 |
| | Marbled Murrelet | 5.3 | 8.7 | 2.5 | 4.3 | 12.8 | 18.6 | 7.9 | 12.8 | 9 | 17 |
| | Unid. Brachyramphus | 1.1 | 2.1 | 11.7 | 23.8 | 8.2 | 11.4 | 5.5 | 10.2 | 2.4 | 2.6 |

Appendix 2. Continued

| Group | Subgroup | 1999 | | 2000 | | 2001 | | 2002 | | 2003 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Density | SD | Density | SD | Density | SD | Density | SD | Density | SD |
| | **Gull** | | | | | | | | | | |
| | Black-legged Kittiwake | 3.3 | 7.9 | 1.6 | 5.4 | 4.4 | 12.8 | 2 | 4.3 | 8.9 | 22.3 |
| | Bonaparte's Gull | 0.1 | 0.4 | 0 | 0 | 0 | 0 | 0.1 | 0.4 | 0 | 0 |
| | Glaucous-winged Gull | 2 | 2.9 | 1 | 2.7 | 0.8 | 1.4 | 3.6 | 8.2 | 1.3 | 2.1 |
| | Herring gull | 0.3 | 0.9 | 0.2 | 0.4 | 0.1 | 0.4 | 0.4 | 0.9 | 0.3 | 1 |
| | Mew Gull | 0.6 | 1.5 | 0.3 | 0.9 | <0.1 | 0.1 | 0.1 | 0.3 | 0 | 0 |
| | Unidentified Gull | 0.1 | 0.2 | 0.5 | 0.9 | 0.2 | 0.3 | 1.6 | 5.7 | 0.2 | 0.4 |
| | **Other Seabirds** | | | | | | | | | | |
| | Fork-tailed Storm-petrel | 0 | 0.1 | 0 | 0.1 | 0.1 | 0.2 | 0 | 0 | 0 | 0 |
| | Unidentified Cormorant | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Pelagic Cormorant | 0 | 0 | 0.3 | 1 | 0 | 0.1 | 0 | 0.1 | 0.7 | 3.2 |
| | Unidentified Phalarope | 0.1 | 0.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Red-necked Phalarope | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Parasitic Jaeger | 0 | 0 | 0 | 0 | 0 | 0.1 | 0 | 0.1 | 0 | 0.1 |

Appendix 3. Marine birds and mammals sighted on marine surveys conducted in Dundas Bay AK, in June 1999. Both densities (num/$km^2$) and raw counts are provided.

| Common Name | Density | Counts |
|---|---|---|
| Common Loon | 0.03 | 2 |
| Unidentified Loon | 0.11 | 3 |
| Canada Goose | 0.06 | 4 |
| Unidentified Goldeneye | 0.27 | 17 |
| Long-tailed Duck | 0.02 | 1 |
| Harlequin Duck | 0.19 | 12 |
| Unidentified Scoter | 0.36 | 19 |
| White-winged Scoter | 4.35 | 71 |
| Surf Scoter | 2.36 | 69 |
| Unidentified Merganser | 0.16 | 10 |
| Common Merganser | 0.22 | 14 |
| Unidentified Cormorant | 0.17 | 3 |
| Pelagic Cormorant | 2.97 | 76 |
| Unidentified Gull | 76.28 | 4646 |
| Glaucous-winged Gull | 19.56 | 138 |
| Herring gull | 0.38 | 3 |
| Mew Gull | 3.89 | 61 |
| Black-legged Kittiwake | 130.20 | 1144 |
| Caspian Tern | 0.03 | 2 |
| Pigeon Guillemot | 2.70 | 53 |
| Marbled Murrelet | 2.86 | 22 |
| Brachyramphus Murrelet | 0.49 | 9 |
| Black Oystercatcher | 0.17 | 3 |
| Bald Eagle | 1.41 | 45 |
| Northwestern Crow | 0.35 | 22 |
| Harbor Porpoise | 0.50 | 13 |
| Harbor Seal | 0.79 | 18 |
| Sea Otter | 3.85 | 58 |
| River Otter | 0.05 | 3 |
| Steller Sea Lion | 0.02 | 1 |

Appendix 4. Summer (June) densities (num/km$^2$), population estimates, and estimates of optimal allocation of sampling effort for 22 species and 11 strata within Glacier Bay, AK. Totals are indicated by a grey background. See Table 6 for Depth and Geographic strata definitions, and Table 7 for species group definitions.

| | | | | Density | | Population Estimate | | | | | 5 yr Mean | | | Between Year Var. | | Mean Within Year Var. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth | Geog. | | | Mean | Mean | | | | | | | | | SD | Optimal | Mean | | Optimal |
| Strata | Strata | Species | Group | 5yrs | SE | 1999 | 2000 | 2001 | 2002 | 2003 | Mean | SE | CV | 5yrs | Allocation | SE | C.V. | Allocation |
| C | LB | Kittlitz's Murrelet | 1 | 0.29 | 0.10 | 8 | 23 | 42 | 3 | 17 | 19 | 6 | 0.32 | 14 | 0.3% | 9 | 0.49 | 0.2% |
| C | CB | | | 0.98 | 0.26 | 55 | 116 | 209 | 169 | 25 | 115 | 31 | 0.27 | 69 | 2.7% | 44 | 0.38 | 2.1% |
| C | WA | | | 1.80 | 0.16 | 170 | 93 | 154 | 134 | 118 | 134 | 12 | 0.09 | 27 | 0.7% | 51 | 0.38 | 1.5% |
| C | EA | | | 1.03 | 0.23 | 44 | 113 | 52 | 110 | 31 | 70 | 15 | 0.22 | 35 | 0.8% | 30 | 0.43 | 0.8% |
| S | LB | | | 1.49 | 0.28 | 241 | 327 | 324 | 53 | 277 | 244 | 45 | 0.18 | 101 | 5.5% | 129 | 0.53 | 8.5% |
| S | CB | | | 4.28 | 0.96 | 1112 | 304 | 666 | 624 | 1519 | 845 | 190 | 0.22 | 424 | 28.0% | 382 | 0.45 | 30.4% |
| S | WA | | | 2.63 | 0.62 | 91 | 117 | 81 | 0 | 111 | 80 | 19 | 0.24 | 42 | 0.4% | 56 | 0.70 | 0.7% |
| S | EA | | | 5.54 | 1.45 | 0 | 209 | 214 | 165 | 98 | 137 | 36 | 0.26 | 80 | 0.7% | 161 | 1.17 | 1.6% |
| D | CB | | | 2.22 | 0.52 | 838 | 813 | 236 | 228 | 988 | 621 | 144 | 0.23 | 323 | 30.1% | 244 | 0.39 | 27.4% |
| D | WA | | | 2.99 | 0.88 | 654 | 429 | 1169 | 195 | 240 | 538 | 159 | 0.30 | 355 | 21.3% | 285 | 0.53 | 20.6% |
| D | EA | | | 7.86 | 3.58 | 35 | 410 | 1385 | 159 | 357 | 469 | 214 | 0.46 | 478 | 9.5% | 260 | 0.55 | 6.2% |
| Total | | Kittlitz's Murrelet | 1 | 2.60 | 0.32 | 3248 | 2953 | 4533 | 1842 | 3781 | 3271 | 400 | 0.12 | 894 | | 637 | 0.19 | |
| C | LB | Marbled Murrelet | 2 | 9.16 | 2.35 | 1213 | 252 | 635 | 371 | 468 | 588 | 151 | 0.26 | 337 | 3.0% | 161 | 0.27 | 2.3% |
| C | CB | | | 11.15 | 2.00 | 1939 | 473 | 1576 | 1588 | 950 | 1305 | 234 | 0.18 | 524 | 8.6% | 251 | 0.19 | 6.5% |
| C | WA | | | 5.40 | 0.87 | 367 | 248 | 520 | 262 | 615 | 402 | 64 | 0.16 | 144 | 1.5% | 121 | 0.30 | 2.0% |
| C | EA | | | 6.73 | 1.73 | 578 | 93 | 507 | 845 | 254 | 456 | 117 | 0.26 | 262 | 2.5% | 148 | 0.32 | 2.2% |
| S | LB | | | 15.14 | 3.04 | 1108 | 3166 | 3188 | 1177 | 3775 | 2483 | 499 | 0.20 | 1116 | 25.6% | 582 | 0.23 | 21.1% |
| S | CB | | | 11.69 | 2.10 | 4118 | 1546 | 1723 | 2036 | 2120 | 2309 | 415 | 0.18 | 928 | 25.7% | 685 | 0.30 | 30.0% |
| S | WA | | | 5.69 | 2.04 | 65 | 157 | 426 | 33 | 185 | 173 | 62 | 0.36 | 138 | 0.6% | 130 | 0.75 | 0.9% |
| S | EA | | | 11.11 | 6.61 | 113 | 0 | 286 | 0 | 976 | 275 | 164 | 0.60 | 366 | 1.3% | 113 | 0.41 | 0.6% |
| D | CB | | | 5.70 | 0.89 | 2224 | 1173 | 755 | 1695 | 2112 | 1592 | 250 | 0.16 | 558 | 21.8% | 418 | 0.26 | 25.8% |
| D | WA | | | 1.64 | 0.65 | 49 | 149 | 762 | 405 | 111 | 295 | 118 | 0.40 | 263 | 6.6% | 122 | 0.41 | 4.8% |
| D | EA | | | 10.93 | 2.49 | 357 | 189 | 947 | 714 | 1053 | 652 | 149 | 0.23 | 332 | 2.8% | 283 | 0.43 | 3.7% |
| Total | | Marbled Murrelet | 2 | 8.37 | 0.69 | 12132 | 7445 | 11325 | 9125 | 12619 | 10529 | 873 | 0.08 | 1952 | | 1111 | 0.11 | |
| C | LB | Unid. Murrelet | 3 | 3.60 | 0.68 | 413 | 231 | 199 | 124 | 187 | 231 | 44 | 0.19 | 98 | 0.7% | 68 | 0.30 | 1.2% |
| C | CB | | | 4.99 | 0.98 | 771 | 892 | 608 | 505 | 144 | 584 | 115 | 0.20 | 257 | 3.5% | 119 | 0.20 | 3.7% |
| C | WA | | | 3.31 | 0.45 | 247 | 246 | 372 | 230 | 139 | 247 | 33 | 0.13 | 74 | 0.6% | 56 | 0.23 | 1.1% |
| C | EA | | | 2.82 | 0.69 | 242 | 366 | 120 | 158 | 67 | 191 | 47 | 0.25 | 105 | 0.8% | 57 | 0.30 | 1.0% |
| S | LB | | | 12.41 | 4.71 | 1116 | 5300 | 1678 | 238 | 1843 | 2035 | 772 | 0.38 | 1726 | 33.3% | 483 | 0.24 | 20.8% |
| S | CB | | | 11.12 | 2.25 | 3434 | 3323 | 1723 | 1501 | 998 | 2196 | 445 | 0.20 | 995 | 23.1% | 696 | 0.32 | 36.1% |
| S | WA | | | 4.29 | 1.30 | 299 | 117 | 102 | 98 | 37 | 131 | 40 | 0.30 | 89 | 0.3% | 85 | 0.65 | 0.7% |
| S | EA | | | 10.84 | 4.05 | 338 | 278 | 643 | 83 | 0 | 268 | 100 | 0.37 | 224 | 0.7% | 189 | 0.71 | 1.2% |
| D | CB | | | 4.91 | 1.44 | 1015 | 3159 | 953 | 721 | 998 | 1369 | 403 | 0.29 | 901 | 29.5% | 321 | 0.23 | 23.5% |
| D | WA | | | 2.14 | 0.43 | 271 | 242 | 709 | 405 | 296 | 385 | 76 | 0.20 | 171 | 3.6% | 155 | 0.40 | 7.3% |
| D | EA | | | 11.30 | 4.06 | 288 | 1514 | 1105 | 93 | 374 | 674 | 242 | 0.36 | 542 | 3.8% | 222 | 0.33 | 3.5% |
| Total | | Unid. Murrelet | 3 | 6.60 | 1.44 | 8435 | 15669 | 8209 | 4154 | 5081 | 8310 | 1810 | 0.22 | 4047 | | 981 | 0.12 | |

Appendix 4. Continued.

| | | | | Density | | Population Estimate | | | | | 5 yr Mean | | | Between Year Var. | | Mean Within Year Var. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth Strata | Geog. Strata | Species | Group | Mean 5yrs | Mean SE | 1999 | 2000 | 2001 | 2002 | 2003 | Mean | SE | CV | SD 5yrs | Optimal Allocation | Mean SE | C.V. | Optimal Allocation |
| C | LB | Cormorant | 4 | 0.35 | 0.13 | 23 | 12 | 21 | 0 | 57 | 23 | 8 | 0.37 | 19 | 1.4% | 16 | 0.71 | 2.1% |
| C | CB | | | 0.77 | 0.31 | 245 | 68 | 5 | 49 | 86 | 90 | 37 | 0.41 | 82 | 11.5% | 46 | 0.51 | 11.0% |
| C | WA | | | 1.09 | 0.37 | 33 | 56 | 53 | 61 | 203 | 81 | 28 | 0.34 | 62 | 5.5% | 42 | 0.52 | 6.5% |
| C | EA | | | 2.16 | 1.19 | 463 | 231 | 35 | 0 | 0 | 146 | 81 | 0.55 | 180 | 14.6% | 103 | 0.71 | 14.3% |
| S | LB | | | 0.32 | 0.17 | 24 | 31 | 20 | 13 | 178 | 53 | 28 | 0.53 | 63 | 12.3% | 29 | 0.55 | 9.8% |
| S | CB | | | 0.79 | 0.40 | 116 | 110 | 0 | 59 | 499 | 157 | 79 | 0.50 | 176 | 41.7% | 112 | 0.72 | 45.3% |
| S | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | CB | | | 0.14 | 0.06 | 113 | 41 | 19 | 12 | 10 | 39 | 17 | 0.44 | 39 | 12.9% | 19 | 0.50 | 11.1% |
| D | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| Total | | Cormorant | 4 | 0.47 | 0.14 | 1017 | 549 | 152 | 195 | 1032 | 589 | 171 | 0.29 | 381 | | 169 | 0.29 | |
| C | LB | Pigeon Guillemot | 5 | 4.71 | 0.49 | 426 | 321 | 231 | 239 | 292 | 302 | 32 | 0.10 | 71 | 3.9% | 70 | 0.23 | 3.4% |
| C | CB | | | 11.23 | 0.67 | 999 | 1378 | 1320 | 1535 | 1339 | 1314 | 78 | 0.06 | 175 | 17.8% | 277 | 0.21 | 24.9% |
| C | WA | | | 8.61 | 0.45 | 553 | 628 | 575 | 755 | 697 | 642 | 34 | 0.05 | 75 | 4.9% | 125 | 0.20 | 7.2% |
| C | EA | | | 8.97 | 0.86 | 657 | 432 | 804 | 497 | 646 | 607 | 58 | 0.10 | 131 | 7.7% | 140 | 0.23 | 7.3% |
| S | LB | | | 0.25 | 0.05 | 56 | 10 | 29 | 66 | 40 | 40 | 9 | 0.22 | 20 | 2.8% | 28 | 0.69 | 3.5% |
| S | CB | | | 1.80 | 0.28 | 205 | 329 | 574 | 297 | 374 | 356 | 55 | 0.15 | 123 | 21.1% | 132 | 0.37 | 20.0% |
| S | WA | | | 2.71 | 1.35 | 39 | 0 | 81 | 33 | 259 | 82 | 41 | 0.50 | 92 | 2.4% | 56 | 0.67 | 1.3% |
| S | EA | | | 10.55 | 6.07 | 0 | 70 | 357 | 0 | 879 | 261 | 150 | 0.58 | 336 | 7.2% | 295 | 1.13 | 5.6% |
| D | CB | | | 0.43 | 0.08 | 161 | 165 | 38 | 144 | 87 | 119 | 22 | 0.19 | 49 | 12.0% | 50 | 0.42 | 10.7% |
| D | WA | | | 0.77 | 0.12 | 173 | 56 | 106 | 168 | 185 | 137 | 22 | 0.16 | 49 | 7.7% | 53 | 0.38 | 7.3% |
| D | EA | | | 3.68 | 1.79 | 81 | 110 | 105 | 106 | 696 | 220 | 107 | 0.49 | 239 | 12.4% | 191 | 0.87 | 8.8% |
| Total | | Pigeon Guillemot | 5 | 3.24 | 0.27 | 3350 | 3499 | 4221 | 3840 | 5493 | 4081 | 343 | 0.08 | 767 | | 516 | 0.13 | |
| C | LB | Murre - Puffin | 6 | 0.05 | 0.04 | 0 | 16 | 0 | 0 | 0 | 3 | 3 | 0.89 | 6 | 1.1% | 3 | 1.01 | 0.6% |
| C | CB | | | 0.48 | 0.29 | 27 | 8 | 209 | 5 | 32 | 56 | 35 | 0.61 | 77 | 25.8% | 52 | 0.92 | 17.2% |
| C | WA | | | 0.10 | 0.05 | 2 | 4 | 0 | 23 | 8 | 7 | 4 | 0.50 | 8 | 1.8% | 5 | 0.64 | 1.0% |
| C | EA | | | 0.15 | 0.13 | 0 | 0 | 0 | 51 | 0 | 10 | 9 | 0.89 | 20 | 3.9% | 9 | 0.84 | 1.6% |
| S | LB | | | 0.51 | 0.16 | 64 | 10 | 88 | 66 | 188 | 83 | 26 | 0.31 | 58 | 27.4% | 51 | 0.61 | 23.7% |
| S | CB | | | 0.12 | 0.04 | 9 | 0 | 23 | 45 | 45 | 24 | 8 | 0.34 | 18 | 10.4% | 14 | 0.59 | 8.0% |
| S | WA | | | 0.30 | 0.17 | 26 | 0 | 20 | 0 | 0 | 9 | 5 | 0.55 | 11 | 1.0% | 9 | 0.93 | 0.7% |
| S | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | CB | | | 0.30 | 0.04 | 40 | 103 | 66 | 108 | 97 | 83 | 12 | 0.14 | 26 | 20.6% | 51 | 0.62 | 40.7% |
| D | WA | | | 0.07 | 0.04 | 25 | 0 | 0 | 0 | 37 | 12 | 7 | 0.57 | 16 | 8.0% | 13 | 1.02 | 6.4% |
| D | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| Total | | Murre - Puffin | 6 | 0.23 | 0.04 | 193 | 141 | 407 | 298 | 407 | 289 | 49 | 0.17 | 109 | | 92 | 0.32 | |

Appendix 4. Continued.

| | | | | Density | | Population Estimate | | | | | 5 yr Mean | | | Between Year Var. | | Mean Within Year Var. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth Strata | Geog. Strata | Species | Group | Mean 5yrs | Mean SE | 1999 | 2000 | 2001 | 2002 | 2003 | Mean | SE | CV | SD 5yrs | Optimal Allocation | Mean SE | C.V. | Optimal Allocation |
| C | LB | Scoter | 7 | 9.36 | 1.75 | 504 | 641 | 186 | 938 | 731 | 600 | 112 | 0.19 | 251 | 0.7% | 289 | 0.48 | 1.1% |
| C | CB | | | 78.36 | 16.84 | 15254 | 8484 | 1793 | 8879 | 11464 | 9175 | 1972 | 0.21 | 4410 | 21.5% | 4814 | 0.52 | 34.2% |
| C | WA | | | 42.30 | 11.84 | 1748 | 3873 | 2025 | 6703 | 1401 | 3150 | 882 | 0.28 | 1972 | 6.1% | 1377 | 0.44 | 6.2% |
| C | EA | | | 151.67 | 44.24 | 6894 | 9047 | 23467 | 5897 | 6025 | 10266 | 2995 | 0.29 | 6696 | 18.9% | 5259 | 0.51 | 21.6% |
| S | LB | | | 0.37 | 0.19 | 145 | 10 | 0 | 0 | 149 | 61 | 31 | 0.52 | 70 | 0.5% | 45 | 0.75 | 0.5% |
| S | CB | | | 2.08 | 0.80 | 285 | 256 | 103 | 1100 | 306 | 410 | 157 | 0.38 | 352 | 2.9% | 327 | 0.80 | 3.9% |
| S | WA | | | 59.45 | 47.81 | 0 | 157 | 589 | 8302 | 0 | 1809 | 1455 | 0.80 | 3253 | 4.1% | 1578 | 0.87 | 2.9% |
| S | EA | | | 11.46 | 5.22 | 225 | 765 | 429 | 0 | 0 | 284 | 129 | 0.46 | 289 | 0.3% | 151 | 0.53 | 0.2% |
| D | CB | | | 1.41 | 0.68 | 56 | 401 | 1179 | 325 | 0 | 392 | 189 | 0.48 | 422 | 4.9% | 188 | 0.48 | 3.2% |
| D | WA | | | 2.28 | 1.03 | 1086 | 0 | 195 | 84 | 684 | 410 | 185 | 0.45 | 413 | 3.1% | 332 | 0.81 | 3.6% |
| D | EA | | | 135.42 | 111.94 | 691 | 189 | 37943 | 622 | 951 | 8079 | 6679 | 0.83 | 14934 | 37.1% | 6231 | 0.77 | 22.6% |
| Total | | Scoter | 7 | 27.52 | 6.06 | 26887 | 23823 | 67908 | 32848 | 21711 | 34635 | 7627 | 0.22 | 17054 | | 9716 | 0.28 | |
| C | LB | Dabbling Duck | 8 | 2.97 | 0.72 | 113 | 366 | 75 | 163 | 235 | 190 | 46 | 0.24 | 103 | 8.5% | 104 | 0.54 | 7.8% |
| C | CB | | | 3.43 | 1.10 | 375 | 956 | 151 | 307 | 217 | 401 | 129 | 0.32 | 288 | 43.5% | 210 | 0.52 | 28.9% |
| C | WA | | | 1.02 | 0.44 | 180 | 32 | 15 | 148 | 4 | 76 | 33 | 0.43 | 73 | 7.0% | 37 | 0.49 | 3.2% |
| C | EA | | | 17.93 | 1.90 | 1302 | 1394 | 1483 | 665 | 1223 | 1213 | 129 | 0.11 | 288 | 25.1% | 660 | 0.54 | 52.5% |
| S | LB | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | CB | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | WA | | | 1.20 | 1.07 | 182 | 0 | 0 | 0 | 0 | 36 | 33 | 0.89 | 73 | 2.9% | 39 | 1.08 | 1.4% |
| S | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | CB | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | WA | | | 0.16 | 0.14 | 0 | 0 | 0 | 140 | 0 | 28 | 25 | 0.89 | 56 | 12.9% | 29 | 1.04 | 6.1% |
| D | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| Total | | Dabbling Duck | 8 | 1.55 | 0.17 | 2152 | 2749 | 1723 | 1423 | 1679 | 1945 | 208 | 0.11 | 465 | | 703 | 0.36 | |
| C | LB | Goldeneye | 9 | 0.07 | 0.03 | 0 | 11 | 0 | 10 | 3 | 5 | 2 | 0.44 | 5 | 3.1% | 4 | 0.89 | 3.7% |
| C | CB | | | 0.47 | 0.13 | 49 | 61 | 12 | 117 | 33 | 55 | 16 | 0.29 | 35 | 43.0% | 34 | 0.62 | 53.6% |
| C | WA | | | 0.22 | 0.05 | 8 | 4 | 25 | 25 | 21 | 17 | 4 | 0.24 | 9 | 6.9% | 10 | 0.60 | 10.0% |
| C | EA | | | 0.90 | 0.36 | 38 | 61 | 37 | 163 | 5 | 61 | 24 | 0.40 | 54 | 38.0% | 30 | 0.49 | 26.9% |
| S | LB | | | 0.02 | 0.01 | 0 | 0 | 0 | 13 | 0 | 3 | 2 | 0.89 | 5 | 9.0% | 3 | 1.01 | 5.9% |
| S | CB | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | CB | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| Total | | Goldeneye | 9 | 0.11 | 0.03 | 96 | 137 | 74 | 328 | 62 | 139 | 44 | 0.31 | 98 | | 46 | 0.33 | |

Appendix 4. Continued.

| Depth Strata | Geog. Strata | Species | Group | Density / km² Mean 5yrs | Density / km² Mean SE | Population Estimate 1999 | 2000 | 2001 | 2002 | 2003 | 5 yr Mean Mean | SE | CV | Between Year Var. SD 5yrs | Between Year Var. Optimal Allocation | Mean Within Year Var. Mean SE | C.V. | Mean Within Year Var. Optimal Allocation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C | LB | Harlequin Duck | 10 | 2.39 | 0.40 | 128 | 179 | 77 | 246 | 136 | 153 | 25 | 0.17 | 57 | 2.6% | 93 | 0.60 | 5.2% |
| C | CB | | | 12.78 | 2.57 | 815 | 1706 | 870 | 1425 | 2663 | 1496 | 301 | 0.20 | 673 | 57.1% | 496 | 0.33 | 50.8% |
| C | WA | | | 6.78 | 1.00 | 422 | 225 | 538 | 670 | 666 | 505 | 75 | 0.15 | 167 | 9.0% | 196 | 0.39 | 12.7% |
| C | EA | | | 7.68 | 0.56 | 359 | 572 | 604 | 534 | 531 | 520 | 38 | 0.07 | 85 | 4.2% | 179 | 0.34 | 10.6% |
| S | LB | | | 0.03 | 0.03 | 0 | 0 | 0 | 26 | 0 | 5 | 5 | 0.89 | 11 | 1.3% | 5 | 1.02 | 0.8% |
| S | CB | | | 0.48 | 0.31 | 0 | 134 | 345 | 0 | 0 | 96 | 60 | 0.63 | 135 | 19.3% | 89 | 0.93 | 15.3% |
| S | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | CB | | | 0.03 | 0.02 | 0 | 0 | 0 | 24 | 19 | 9 | 5 | 0.55 | 11 | 2.2% | 8 | 0.90 | 1.9% |
| D | WA | | | 0.04 | 0.04 | 37 | 0 | 0 | 0 | 0 | 7 | 7 | 0.89 | 15 | 1.9% | 8 | 1.02 | 1.2% |
| D | EA | | | 0.49 | 0.44 | 0 | 0 | 0 | 145 | 0 | 29 | 26 | 0.89 | 58 | 2.5% | 29 | 1.00 | 1.5% |
| Total | | Harlequin Duck | 10 | 2.24 | 0.26 | 1760 | 2816 | 2433 | 3071 | 4016 | 2819 | 333 | 0.12 | 744 | | 577 | 0.20 | |
| C | LB | Merganser | 11 | 19.90 | 5.04 | 2144 | 1689 | 1692 | 233 | 624 | 1276 | 323 | 0.25 | 723 | 16.7% | 534 | 0.42 | 11.9% |
| C | CB | | | 17.62 | 1.36 | 1973 | 1430 | 2460 | 2302 | 2149 | 2063 | 159 | 0.08 | 355 | 15.0% | 646 | 0.31 | 26.3% |
| C | WA | | | 3.53 | 1.12 | 68 | 227 | 254 | 151 | 613 | 263 | 83 | 0.32 | 187 | 5.0% | 148 | 0.56 | 3.8% |
| C | EA | | | 48.79 | 13.25 | 2040 | 1989 | 2580 | 2627 | 7277 | 3303 | 896 | 0.27 | 2005 | 49.0% | 2076 | 0.63 | 48.8% |
| S | LB | | | 0.72 | 0.35 | 161 | 72 | 10 | 0 | 347 | 118 | 57 | 0.49 | 128 | 7.6% | 63 | 0.54 | 3.6% |
| S | CB | | | 0.07 | 0.03 | 27 | 12 | 0 | 0 | 34 | 15 | 6 | 0.42 | 14 | 1.0% | 15 | 1.02 | 1.0% |
| S | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | EA | | | 1.69 | 1.51 | 0 | 209 | 0 | 0 | 0 | 42 | 37 | 0.89 | 83 | 0.7% | 49 | 1.18 | 0.4% |
| D | CB | | | 0.14 | 0.06 | 0 | 41 | 47 | 0 | 107 | 39 | 18 | 0.45 | 39 | 3.9% | 38 | 0.97 | 3.7% |
| D | WA | | | 0.03 | 0.03 | 0 | 0 | 0 | 28 | 0 | 6 | 5 | 0.89 | 11 | 0.7% | 6 | 1.07 | 0.4% |
| D | EA | | | 0.11 | 0.10 | 0 | 0 | 0 | 0 | 34 | 7 | 6 | 0.89 | 14 | 0.3% | 7 | 0.96 | 0.1% |
| Total | | Merganser | 11 | 5.67 | 0.75 | 6412 | 5669 | 7043 | 5341 | 11184 | 7130 | 944 | 0.13 | 2111 | | 2246 | 0.31 | |
| C | LB | Diving Duck | 12 | 0.32 | 0.11 | 3 | 11 | 29 | 46 | 12 | 20 | 7 | 0.34 | 15 | 5.2% | 19 | 0.92 | 9.7% |
| C | CB | | | 0.49 | 0.20 | 1 | 149 | 20 | 86 | 33 | 58 | 24 | 0.41 | 54 | 33.0% | 35 | 0.61 | 33.2% |
| C | WA | | | 0.35 | 0.16 | 10 | 20 | 0 | 79 | 21 | 26 | 12 | 0.48 | 27 | 10.8% | 15 | 0.58 | 9.0% |
| C | EA | | | 1.01 | 0.33 | 13 | 161 | 63 | 51 | 55 | 69 | 22 | 0.32 | 49 | 17.6% | 39 | 0.57 | 21.5% |
| S | LB | | | 0.03 | 0.03 | 24 | 0 | 0 | 0 | 0 | 5 | 4 | 0.89 | 10 | 8.3% | 3 | 0.70 | 4.5% |
| S | CB | | | 0.05 | 0.04 | 0 | 0 | 0 | 45 | 0 | 9 | 8 | 0.89 | 18 | 18.6% | 9 | 0.99 | 14.2% |
| S | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | CB | | | 0.01 | 0.01 | 8 | 0 | 0 | 0 | 10 | 4 | 2 | 0.55 | 4 | 6.5% | 3 | 0.98 | 7.9% |
| D | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| Total | | Diving Duck | 12 | 0.15 | 0.04 | 59 | 341 | 112 | 305 | 131 | 190 | 50 | 0.26 | 112 | | 59 | 0.31 | |

Appendix 4. Continued.

| | | | | Density / $km^2$ | | Population Estimate | | | | | 5 yr Mean | | | Between Year Var. | | Mean Within Year Var. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth Strata | Geog. Strata | Species | Group | Mean 5yrs | Mean SE | 1999 | 2000 | 2001 | 2002 | 2003 | Mean | SE | CV | SD 5yrs | Optimal Allocation | Mean SE | C.V. | Optimal Allocation |
| C | LB | Gull | 13 | 14.24 | 2.44 | 1075 | 1354 | 1132 | 443 | 563 | 913 | 156 | 0.17 | 350 | 7.1% | 373 | 0.41 | 8.3% |
| C | CB | | | 15.05 | 1.57 | 2121 | 1473 | 1093 | 2118 | 2007 | 1762 | 184 | 0.10 | 412 | 15.3% | 506 | 0.29 | 20.6% |
| C | WA | | | 15.24 | 3.37 | 736 | 829 | 937 | 2248 | 925 | 1135 | 251 | 0.22 | 561 | 13.3% | 303 | 0.27 | 7.9% |
| C | EA | | | 40.83 | 4.61 | 1989 | 1913 | 3620 | 3347 | 2948 | 2763 | 312 | 0.11 | 697 | 15.0% | 842 | 0.30 | 19.8% |
| S | LB | | | 5.39 | 0.90 | 1454 | 929 | 775 | 436 | 822 | 883 | 147 | 0.17 | 329 | 17.2% | 215 | 0.24 | 12.3% |
| S | CB | | | 3.29 | 0.56 | 552 | 840 | 999 | 282 | 578 | 650 | 111 | 0.17 | 248 | 15.6% | 229 | 0.35 | 15.7% |
| S | WA | | | 1.23 | 0.40 | 0 | 20 | 61 | 33 | 74 | 37 | 12 | 0.32 | 27 | 0.3% | 36 | 0.95 | 0.4% |
| S | EA | | | 2.25 | 1.27 | 113 | 0 | 0 | 165 | 0 | 56 | 31 | 0.56 | 70 | 0.6% | 60 | 1.08 | 0.5% |
| D | CB | | | 1.62 | 0.23 | 725 | 412 | 368 | 325 | 426 | 451 | 63 | 0.14 | 142 | 12.6% | 113 | 0.25 | 11.0% |
| D | WA | | | 0.62 | 0.06 | 136 | 112 | 142 | 98 | 74 | 112 | 11 | 0.10 | 25 | 1.4% | 43 | 0.38 | 2.7% |
| D | EA | | | 2.00 | 0.72 | 104 | 110 | 298 | 66 | 17 | 119 | 43 | 0.36 | 95 | 1.8% | 43 | 0.36 | 0.9% |
| Total | | Gull | 13 | 7.06 | 0.21 | 9003 | 7991 | 9426 | 9562 | 8435 | 8883 | 266 | 0.03 | 594 | | 1147 | 0.13 | |
| C | LB | Black-legged Kittiwake | 14 | 7.07 | 2.68 | 934 | 90 | 901 | 78 | 265 | 454 | 172 | 0.38 | 385 | 2.8% | 253 | 0.56 | 2.4% |
| C | CB | | | 4.37 | 1.04 | 383 | 336 | 327 | 1044 | 469 | 512 | 121 | 0.24 | 271 | 3.6% | 242 | 0.47 | 4.2% |
| C | WA | | | 67.12 | 23.76 | 668 | 950 | 5009 | 7164 | 11200 | 4998 | 1770 | 0.35 | 3957 | 33.7% | 3690 | 0.74 | 41.0% |
| C | EA | | | 35.12 | 12.21 | 771 | 788 | 3532 | 1330 | 5465 | 2377 | 826 | 0.35 | 1848 | 14.3% | 1302 | 0.55 | 13.2% |
| S | LB | | | 8.90 | 2.74 | 1687 | 368 | 373 | 1824 | 3042 | 1459 | 450 | 0.31 | 1006 | 18.9% | 649 | 0.44 | 15.9% |
| S | CB | | | 2.80 | 0.64 | 863 | 244 | 747 | 178 | 737 | 554 | 127 | 0.23 | 284 | 6.4% | 225 | 0.41 | 6.6% |
| S | WA | | | 1.53 | 0.85 | 0 | 0 | 102 | 131 | 0 | 47 | 26 | 0.56 | 58 | 0.2% | 32 | 0.68 | 0.1% |
| S | EA | | | 0.58 | 0.52 | 0 | 0 | 71 | 0 | 0 | 14 | 13 | 0.89 | 29 | 0.1% | 16 | 1.12 | 0.1% |
| D | CB | | | 1.86 | 0.56 | 516 | 309 | 472 | 132 | 1163 | 518 | 156 | 0.30 | 349 | 11.2% | 265 | 0.51 | 11.0% |
| D | WA | | | 2.36 | 0.87 | 481 | 75 | 1063 | 349 | 148 | 423 | 157 | 0.37 | 351 | 7.2% | 145 | 0.34 | 3.9% |
| D | EA | | | 5.34 | 1.80 | 656 | 16 | 509 | 106 | 306 | 318 | 107 | 0.34 | 240 | 1.6% | 172 | 0.54 | 1.5% |
| Total | | Black-legged Kittiwake | 14 | 9.28 | 2.36 | 6959 | 3174 | 13103 | 12338 | 22794 | 11674 | 2971 | 0.25 | 6643 | | 4004 | 0.34 | |
| C | LB | Arctic Tern | 15 | 0.11 | 0.05 | 0 | 0 | 18 | 10 | 6 | 7 | 3 | 0.44 | 7 | 0.7% | 6 | 0.95 | 0.8% |
| C | CB | | | 0.26 | 0.12 | 0 | 83 | 39 | 31 | 2 | 31 | 14 | 0.44 | 30 | 5.9% | 22 | 0.70 | 5.0% |
| C | WA | | | 2.85 | 0.77 | 271 | 50 | 424 | 186 | 128 | 212 | 57 | 0.27 | 128 | 16.0% | 122 | 0.58 | 17.8% |
| C | EA | | | 10.86 | 2.53 | 483 | 274 | 1256 | 1119 | 544 | 735 | 171 | 0.23 | 382 | 43.3% | 403 | 0.55 | 53.4% |
| S | LB | | | 0.01 | 0.01 | 8 | 0 | 0 | 0 | 0 | 2 | 1 | 0.89 | 3 | 0.9% | 2 | 1.04 | 0.5% |
| S | CB | | | 0.09 | 0.04 | 9 | 49 | 0 | 30 | 0 | 17 | 9 | 0.49 | 19 | 6.3% | 16 | 0.89 | 6.0% |
| S | WA | | | 0.74 | 0.23 | 26 | 20 | 0 | 49 | 19 | 23 | 7 | 0.31 | 16 | 0.8% | 18 | 0.81 | 1.1% |
| S | EA | | | 0.91 | 0.81 | 113 | 0 | 0 | 0 | 0 | 23 | 20 | 0.89 | 45 | 1.9% | 24 | 1.06 | 1.2% |
| D | CB | | | 0.05 | 0.04 | 65 | 0 | 9 | 0 | 0 | 15 | 11 | 0.76 | 25 | 11.7% | 15 | 1.00 | 8.1% |
| D | WA | | | 0.09 | 0.08 | 0 | 0 | 0 | 84 | 0 | 17 | 15 | 0.89 | 33 | 10.1% | 8 | 0.49 | 2.9% |
| D | EA | | | 0.74 | 0.19 | 69 | 0 | 35 | 66 | 51 | 44 | 11 | 0.25 | 25 | 2.5% | 28 | 0.63 | 3.3% |
| Total | | Arctic Tern | 15 | 0.89 | 0.17 | 1043 | 475 | 1781 | 1574 | 750 | 1125 | 219 | 0.19 | 490 | | 424 | 0.38 | |

Appendix 4. Continued.

| | | | | Density | | Population Estimate | | | | | 5 yr Mean | | | Between Year Var. | | Mean Within Year Var. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth Strata | Geog. Strata | Species | Group | Mean 5yrs | Mean SE | 1999 | 2000 | 2001 | 2002 | 2003 | Mean | SE | CV | SD 5yrs | Optimal Allocation | Mean SE | C.V. | Optimal Allocation |
| C | LB | Grebe | 16 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | NA | 0 | | NA |
| C | CB | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | NA | 0 | | NA |
| C | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | NA | 0 | | NA |
| C | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | NA | 0 | | NA |
| S | LB | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | NA | 0 | | NA |
| S | CB | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | NA | 0 | | NA |
| S | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | NA | 0 | | NA |
| S | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | NA | 0 | | NA |
| D | CB | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | NA | 0 | | NA |
| D | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | NA | 0 | | NA |
| D | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | NA | 0 | | NA |
| Total | | Grebe | 16 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | | 0 | | |
| C | LB | Loon | 17 | 0.57 | 0.10 | 33 | 51 | 55 | 26 | 18 | 37 | 6 | 0.17 | 14 | 1.5% | 10 | 0.27 | 1.3% |
| C | CB | | | 0.52 | 0.13 | 103 | 101 | 42 | 37 | 23 | 61 | 15 | 0.25 | 34 | 6.5% | 19 | 0.31 | 4.6% |
| C | WA | | | 0.48 | 0.10 | 32 | 34 | 60 | 44 | 10 | 36 | 7 | 0.20 | 16 | 2.0% | 12 | 0.35 | 2.0% |
| C | EA | | | 1.25 | 0.26 | 106 | 152 | 56 | 53 | 55 | 84 | 18 | 0.21 | 39 | 4.4% | 22 | 0.27 | 3.2% |
| S | LB | | | 1.06 | 0.32 | 137 | 388 | 196 | 66 | 79 | 173 | 52 | 0.30 | 117 | 31.6% | 104 | 0.60 | 35.9% |
| S | CB | | | 0.30 | 0.05 | 53 | 73 | 92 | 30 | 45 | 59 | 10 | 0.17 | 22 | 7.1% | 34 | 0.58 | 14.2% |
| S | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | EA | | | 0.45 | 0.41 | 56 | 0 | 0 | 0 | 0 | 11 | 10 | 0.89 | 23 | 0.9% | 12 | 1.06 | 0.6% |
| D | CB | | | 0.23 | 0.07 | 56 | 144 | 66 | 24 | 29 | 64 | 19 | 0.30 | 43 | 19.8% | 28 | 0.44 | 16.5% |
| D | WA | | | 0.30 | 0.17 | 0 | 112 | 0 | 154 | 0 | 53 | 30 | 0.56 | 66 | 19.6% | 46 | 0.86 | 17.3% |
| D | EA | | | 0.95 | 0.51 | 92 | 173 | 0 | 0 | 17 | 57 | 30 | 0.54 | 68 | 6.6% | 35 | 0.61 | 4.4% |
| Total | | Loon | 17 | 0.50 | 0.12 | 669 | 1229 | 567 | 433 | 277 | 635 | 145 | 0.23 | 325 | | 131 | 0.21 | |
| C | LB | Sea Lion | 18 | 0.23 | 0.11 | 3 | 3 | 16 | 46 | 6 | 15 | 7 | 0.48 | 16 | 2.4% | 9 | 0.63 | 1.6% |
| C | CB | | | 0.37 | 0.14 | 11 | 83 | 93 | 7 | 25 | 44 | 16 | 0.38 | 37 | 9.9% | 34 | 0.79 | 10.8% |
| C | WA | | | 0.04 | 0.03 | 0 | 4 | 0 | 0 | 12 | 3 | 2 | 0.66 | 5 | 0.8% | 3 | 1.06 | 0.7% |
| C | EA | | | 0.07 | 0.05 | 0 | 21 | 0 | 4 | 0 | 5 | 4 | 0.75 | 8 | 1.3% | 5 | 0.92 | 0.8% |
| S | LB | | | 0.29 | 0.10 | 32 | 82 | 98 | 26 | 0 | 48 | 16 | 0.34 | 37 | 13.8% | 27 | 0.57 | 12.0% |
| S | CB | | | 0.55 | 0.15 | 53 | 219 | 138 | 89 | 45 | 109 | 29 | 0.26 | 64 | 29.1% | 61 | 0.56 | 32.1% |
| S | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | CB | | | 0.33 | 0.09 | 48 | 165 | 38 | 48 | 155 | 91 | 25 | 0.28 | 57 | 36.4% | 51 | 0.56 | 38.0% |
| D | WA | | | 0.03 | 0.03 | 0 | 0 | 0 | 28 | 0 | 6 | 5 | 0.89 | 11 | 4.6% | 6 | 1.07 | 2.9% |
| D | EA | | | 0.11 | 0.09 | 0 | 32 | 0 | 0 | 0 | 6 | 6 | 0.89 | 13 | 1.7% | 6 | 1.01 | 1.0% |
| Total | | Sea Lion | 18 | 0.26 | 0.06 | 149 | 608 | 383 | 248 | 243 | 326 | 71 | 0.22 | 160 | | 92 | 0.28 | |

# Appendix 4. Continued

| | | | | Density | | Population Estimate | | | | | 5 yr Mean | | | Between Year Var. | | Mean Within Year Var. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth Strata | Geog. Strata | Species | Group | Mean 5yrs | Mean SE | 1999 | 2000 | 2001 | 2002 | 2003 | Mean | SE | CV | SD 5yrs | Optimal Allocation | Mean SE | C.V. | Optimal Allocation |
| C | LB | Harbor Porpoise | 19 | 0.12 | 0.04 | 2 | 6 | 3 | 18 | 9 | 8 | 3 | 0.33 | 6 | 2.3% | 4 | 0.56 | 1.9% |
| C | CB | | | 0.23 | 0.02 | 18 | 27 | 24 | 33 | 33 | 27 | 3 | 0.09 | 6 | 4.1% | 10 | 0.36 | 7.8% |
| C | WA | | | 0.08 | 0.03 | 2 | 8 | 7 | 13 | 0 | 6 | 2 | 0.36 | 5 | 2.2% | 4 | 0.61 | 1.9% |
| C | EA | | | 0.43 | 0.05 | 17 | 26 | 32 | 37 | 36 | 29 | 3 | 0.11 | 7 | 3.1% | 12 | 0.40 | 5.5% |
| S | LB | | | 0.52 | 0.14 | 145 | 72 | 137 | 13 | 59 | 85 | 22 | 0.26 | 50 | 49.9% | 46 | 0.54 | 51.8% |
| S | CB | | | 0.03 | 0.02 | 9 | 24 | 0 | 0 | 0 | 7 | 4 | 0.64 | 9 | 11.5% | 6 | 0.96 | 8.7% |
| S | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | CB | | | 0.05 | 0.02 | 24 | 0 | 38 | 0 | 10 | 14 | 7 | 0.46 | 15 | 25.1% | 11 | 0.78 | 21.4% |
| D | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | EA | | | 0.04 | 0.04 | 0 | 0 | 0 | 13 | 0 | 3 | 2 | 0.89 | 5 | 1.9% | 3 | 0.95 | 1.0% |
| Total | | Harbor Porpoise | 19 | 0.14 | 0.02 | 216 | 162 | 241 | 128 | 148 | 179 | 19 | 0.11 | 43 | | 50 | 0.28 | |
| C | LB | Harbor Seal | 20 | 1.86 | 0.31 | 86 | 197 | 140 | 72 | 102 | 120 | 20 | 0.17 | 45 | 3.7% | 54 | 0.45 | 6.7% |
| C | CB | | | 0.50 | 0.13 | 35 | 124 | 33 | 47 | 51 | 58 | 15 | 0.26 | 34 | 5.1% | 19 | 0.32 | 4.3% |
| C | WA | | | 0.75 | 0.03 | 55 | 52 | 64 | 56 | 52 | 56 | 2 | 0.03 | 4 | 0.4% | 19 | 0.35 | 2.8% |
| C | EA | | | 2.43 | 0.51 | 156 | 137 | 313 | 124 | 91 | 164 | 35 | 0.21 | 77 | 6.8% | 90 | 0.55 | 11.8% |
| S | LB | | | 0.11 | 0.06 | 16 | 0 | 59 | 13 | 0 | 18 | 10 | 0.55 | 22 | 4.6% | 14 | 0.79 | 4.4% |
| S | CB | | | 0.51 | 0.36 | 18 | 61 | 413 | 15 | 0 | 101 | 70 | 0.69 | 157 | 40.1% | 91 | 0.90 | 34.8% |
| S | WA | | | 0.22 | 0.12 | 13 | 0 | 20 | 0 | 0 | 7 | 4 | 0.57 | 8 | 0.3% | 7 | 1.06 | 0.4% |
| S | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | CB | | | 0.17 | 0.11 | 16 | 51 | 0 | 0 | 174 | 48 | 29 | 0.61 | 66 | 23.7% | 38 | 0.79 | 20.7% |
| D | WA | | | 0.31 | 0.16 | 99 | 19 | 159 | 0 | 0 | 55 | 28 | 0.51 | 64 | 14.7% | 39 | 0.71 | 13.7% |
| D | EA | | | 0.06 | 0.05 | 0 | 0 | 18 | 0 | 0 | 4 | 3 | 0.89 | 7 | 0.5% | 4 | 1.01 | 0.4% |
| Total | | Harbor Seal | 20 | 0.50 | 0.11 | 494 | 641 | 1219 | 327 | 470 | 630 | 139 | 0.22 | 311 | | 152 | 0.24 | |
| C | LB | Cetacean | 21 | 0.05 | 0.03 | 3 | 12 | 0 | 0 | 0 | 3 | 2 | 0.68 | 5 | 3.4% | 2 | 0.66 | 2.2% |
| C | CB | | | 0.04 | 0.01 | 6 | 2 | 0 | 9 | 7 | 5 | 1 | 0.32 | 3 | 4.3% | 4 | 0.83 | 7.3% |
| C | WA | | | 0.07 | 0.04 | 0 | 8 | 0 | 2 | 17 | 5 | 3 | 0.54 | 6 | 5.3% | 3 | 0.65 | 4.2% |
| C | EA | | | 0.03 | 0.01 | 1 | 3 | 6 | 0 | 0 | 2 | 1 | 0.47 | 2 | 1.6% | 2 | 0.96 | 2.1% |
| S | LB | | | 0.02 | 0.01 | 8 | 0 | 0 | 0 | 10 | 4 | 2 | 0.55 | 4 | 8.1% | 3 | 0.96 | 9.2% |
| S | CB | | | 0.09 | 0.06 | 9 | 12 | 69 | 0 | 0 | 18 | 12 | 0.64 | 26 | 57.0% | 14 | 0.77 | 45.0% |
| S | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | CB | | | 0.02 | 0.01 | 8 | 0 | 0 | 12 | 10 | 6 | 2 | 0.38 | 5 | 15.6% | 6 | 0.98 | 26.6% |
| D | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | EA | | | 0.06 | 0.05 | 0 | 0 | 18 | 0 | 0 | 4 | 3 | 0.89 | 7 | 4.7% | 4 | 1.01 | 3.4% |
| Total | | Cetacean | 21 | 0.04 | 0.01 | 35 | 37 | 92 | 23 | 43 | 46 | 11 | 0.23 | 24 | | 17 | 0.37 | |

Appendix 4. Continued.

| | | | | Density | | Population Estimate | | | | | 5 yr Mean | | | Between Year Var. | | Mean Within Year Var. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth | Geog. | | | Mean | Mean | | | | | | | | | SD | Optimal | Mean | | Optimal |
| Strata | Strata | Species | Group | 5yrs | SE | 1999 | 2000 | 2001 | 2002 | 2003 | Mean | SE | CV | 5yrs | Allocation | SE | C.V. | Allocation |
| C | LB | Sea Otter | 22 | 2.53 | 0.60 | 80 | 160 | 277 | 55 | 240 | 162 | 39 | 0.24 | 87 | 4.8% | 116 | 0.72 | 8.4% |
| C | CB | | | 0.40 | 0.23 | 3 | 71 | 3 | 154 | 5 | 47 | 27 | 0.56 | 59 | 6.0% | 45 | 0.96 | 6.0% |
| C | WA | | | 0.01 | 0.00 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0.89 | 1 | 0.0% | 0 | 1.05 | 0.0% |
| C | EA | | | 0.01 | 0.01 | 0 | 0 | 0 | 4 | 0 | 1 | 1 | 0.89 | 1 | 0.1% | 1 | 0.80 | 0.0% |
| S | LB | | | 1.47 | 0.59 | 72 | 51 | 186 | 648 | 248 | 241 | 97 | 0.40 | 216 | 30.5% | 169 | 0.70 | 31.3% |
| S | CB | | | 1.26 | 0.56 | 0 | 73 | 333 | 149 | 692 | 249 | 111 | 0.44 | 247 | 42.0% | 191 | 0.77 | 42.6% |
| S | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | CB | | | 0.14 | 0.11 | 177 | 0 | 0 | 24 | 0 | 40 | 31 | 0.77 | 69 | 16.6% | 37 | 0.91 | 11.6% |
| D | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| Total | | Sea Otter | 22 | 0.59 | 0.12 | 332 | 355 | 799 | 1035 | 1184 | 741 | 155 | 0.21 | 347 | | 286 | 0.39 | |

Appendix 5. Summer (June) densities (num/km$^2$), population estimates, and estimates of optimal allocation of sampling effort for 22 species and 2 strata within Glacier Bay, AK.

| | | | Density | | Population Estimate | | | | | 5 yr Mean | | | Between Year Var. | | Mean Within Year Var. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Mean | Mean | | | | | | | | | SD | Optimal | Mean | | Optimal |
| Strata | Species | Group | 5yrs | SE | 1999 | 2000 | 2001 | 2002 | 2003 | Mean | SE | CV | 5yrs | Allocation | SE | CV | Allocation |
| Coastal | Kittlitz's Murrelet | 1 | 1.03 | 0.14 | 273 | 342 | 462 | 408 | 176 | 332 | 45 | 0.14 | 101 | 4.1% | 79 | 0.24 | 4.0% |
| Offshore | \| | 1 | 2.90 | 0.39 | 3018 | 2427 | 3176 | 1270 | 3661 | 2710 | 367 | 0.14 | 821 | 95.9% | 661 | 0.24 | 96.0% |
| | Total | 1 | 2.42 | 0.27 | 3291 | 2770 | 3638 | 1678 | 3836 | 3042 | 345 | 0.11 | 772 | | 740 | 0.24 | |
| Coastal | Marbled Murrelet | 2 | 8.55 | 1.43 | 4100 | 1056 | 3317 | 3088 | 2271 | 2766 | 463 | 0.17 | 1035 | 19.9% | 405 | 0.15 | 8.6% |
| Offshore | \| | 2 | 8.67 | 0.69 | 8612 | 7244 | 8024 | 6174 | 10490 | 8109 | 646 | 0.08 | 1444 | 80.1% | 1486 | 0.18 | 91.4% |
| | Total | 2 | 8.64 | 0.64 | 12712 | 8300 | 11341 | 9263 | 12761 | 10875 | 809 | 0.07 | 1810 | | 1892 | 0.17 | |
| Coastal | Unid. Murrelet | 3 | 3.90 | 0.62 | 1677 | 1756 | 1322 | 1011 | 544 | 1262 | 200 | 0.16 | 447 | 3.6% | 175 | 0.14 | 4.6% |
| Offshore | \| | 3 | 7.80 | 2.00 | 6813 | 15239 | 6388 | 3032 | 5005 | 7295 | 1872 | 0.26 | 4185 | 96.4% | 1246 | 0.17 | 95.4% |
| | Total | 3 | 6.80 | 1.60 | 8490 | 16995 | 7710 | 4043 | 5549 | 8557 | 2013 | 0.24 | 4502 | | 1421 | 0.17 | |
| Coastal | Cormorant | 4 | 1.06 | 0.35 | 800 | 383 | 106 | 106 | 323 | 343 | 114 | 0.33 | 254 | 25.6% | 156 | 0.45 | 28.6% |
| Offshore | \| | 4 | 0.29 | 0.12 | 281 | 200 | 47 | 82 | 756 | 273 | 114 | 0.42 | 255 | 74.4% | 134 | 0.49 | 71.4% |
| | Total | 4 | 0.49 | 0.14 | 1081 | 583 | 154 | 188 | 1079 | 617 | 182 | 0.30 | 407 | | 290 | 0.47 | |
| Coastal | Pigeon Guillemot | 5 | 8.81 | 0.18 | 2657 | 2733 | 2939 | 2995 | 2929 | 2851 | 59 | 0.02 | 131 | 14.0% | 370 | 0.13 | 32.2% |
| Offshore | \| | 5 | 0.97 | 0.13 | 694 | 688 | 924 | 806 | 1440 | 910 | 125 | 0.14 | 279 | 86.0% | 269 | 0.30 | 67.8% |
| | Total | 5 | 2.99 | 0.13 | 3351 | 3421 | 3863 | 3801 | 4369 | 3761 | 163 | 0.04 | 365 | | 639 | 0.17 | |
| Coastal | Murre - Puffin | 6 | 0.25 | 0.11 | 30 | 28 | 231 | 77 | 39 | 81 | 34 | 0.43 | 77 | 21.3% | 68 | 0.84 | 19.5% |
| Offshore | \| | 6 | 0.25 | 0.05 | 169 | 138 | 225 | 232 | 420 | 237 | 44 | 0.19 | 98 | 78.7% | 97 | 0.41 | 80.5% |
| | Total | 6 | 0.25 | 0.04 | 199 | 166 | 456 | 310 | 459 | 318 | 55 | 0.17 | 124 | | 166 | 0.52 | |
| Coastal | Scoter | 7 | 70.93 | 2.96 | 25517 | 22409 | 25061 | 22023 | 19682 | 22938 | 956 | 0.04 | 2139 | 6.8% | 8496 | 0.37 | 32.7% |
| Offshore | \| | 7 | 8.88 | 4.86 | 1959 | 1151 | 27780 | 9015 | 1620 | 8305 | 4543 | 0.55 | 10158 | 93.2% | 6038 | 0.73 | 67.3% |
| | Total | 7 | 24.83 | 4.02 | 27475 | 23560 | 52841 | 31039 | 21303 | 31244 | 5054 | 0.16 | 11301 | | 14533 | 0.47 | |
| Coastal | Dabbling Duck | 8 | 5.92 | 0.77 | 2039 | 2918 | 1586 | 1289 | 1741 | 1915 | 249 | 0.13 | 557 | 74.6% | 830 | 0.43 | 84.2% |
| Offshore | \| | 8 | 0.06 | 0.03 | 131 | 0 | 0 | 137 | 0 | 54 | 29 | 0.55 | 66 | 25.4% | 54 | 1.01 | 15.8% |
| | Total | 8 | 1.56 | 0.19 | 2171 | 2918 | 1586 | 1425 | 1741 | 1968 | 240 | 0.12 | 536 | | 885 | 0.45 | |
| Coastal | Goldeneye | 9 | 0.43 | 0.13 | 100 | 144 | 70 | 315 | 60 | 138 | 42 | 0.30 | 93 | 85.5% | 52 | 0.38 | 86.8% |
| Offshore | \| | 9 | 0.00 | 0.00 | 0 | 0 | 0 | 14 | 0 | 3 | 2 | 0.89 | 5 | 14.5% | 3 | 0.99 | 13.2% |
| | Total | 9 | 0.11 | 0.03 | 100 | 144 | 70 | 328 | 60 | 140 | 44 | 0.31 | 98 | | 55 | 0.39 | |
| Coastal | Harlequin Duck | 10 | 8.25 | 1.04 | 1754 | 2730 | 2072 | 2851 | 3935 | 2668 | 337 | 0.13 | 753 | 67.8% | 628 | 0.24 | 61.3% |
| Offshore | \| | 10 | 0.16 | 0.06 | 28 | 138 | 356 | 205 | 24 | 150 | 55 | 0.37 | 123 | 32.2% | 137 | 0.91 | 38.7% |
| | Total | 10 | 2.24 | 0.26 | 1783 | 2867 | 2428 | 3056 | 3959 | 2818 | 322 | 0.11 | 719 | | 765 | 0.27 | |

Appendix 5. Continued.

| | | | Density | | Population Estimate | | | | | 5 yr Mean | | | Between Year Var. | | Mean Within Year Var. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Mean | Mean | | | | | | | | | SD | Optimal | Mean | | Optimal |
| Strata | Species | Group | 5yrs | SE | 1999 | 2000 | 2001 | 2002 | 2003 | Mean | SE | CV | 5yrs | Allocation | SE | CV | Allocation |
| Coastal | Merganser | 11 | 21.66 | 2.76 | 6228 | 5634 | 6983 | 5345 | 10828 | 7004 | 891 | 0.13 | 1993 | 76.9% | 2679 | 0.38 | 89.5% |
| Offshore | \| | 11 | 0.24 | 0.10 | 216 | 188 | 71 | 27 | 612 | 223 | 93 | 0.42 | 207 | 23.1% | 108 | 0.49 | 10.5% |
| | Total | 11 | 5.74 | 0.78 | 6444 | 5822 | 7055 | 5373 | 11441 | 7227 | 976 | 0.14 | 2182 | | 2787 | 0.39 | |
| Coastal | Diving Duck | 12 | 0.54 | 0.16 | 27 | 356 | 108 | 258 | 121 | 174 | 53 | 0.30 | 117 | 69.5% | 69 | 0.40 | 61.4% |
| Offshore | \| | 12 | 0.02 | 0.01 | 38 | 0 | 0 | 41 | 12 | 18 | 8 | 0.44 | 18 | 30.5% | 15 | 0.83 | 38.6% |
| | Total | 12 | 0.15 | 0.04 | 64 | 356 | 108 | 299 | 133 | 192 | 51 | 0.27 | 114 | | 84 | 0.44 | |
| Coastal | Gull | 13 | 20.22 | 1.10 | 6003 | 5733 | 6464 | 8035 | 6457 | 6538 | 357 | 0.05 | 798 | 29.0% | 1306 | 0.20 | 49.5% |
| Offshore | \| | 13 | 2.63 | 0.32 | 3327 | 2678 | 2761 | 1298 | 2244 | 2462 | 302 | 0.12 | 676 | 71.0% | 461 | 0.19 | 50.5% |
| | Total | 13 | 7.15 | 0.13 | 9330 | 8411 | 9225 | 9332 | 8701 | 9000 | 168 | 0.02 | 376 | | 1767 | 0.20 | |
| Coastal | Black-legged Kittiwake | 14 | 23.94 | 6.96 | 2690 | 2090 | 9032 | 9047 | 15858 | 7743 | 2251 | 0.29 | 5034 | 50.5% | 4114 | 0.53 | 58.0% |
| Offshore | \| | 14 | 3.73 | 0.82 | 4376 | 1139 | 2939 | 2759 | 6217 | 3486 | 764 | 0.22 | 1708 | 49.5% | 1032 | 0.30 | 42.0% |
| | Total | 14 | 8.92 | 2.25 | 7066 | 3228 | 11971 | 11807 | 22076 | 11230 | 2828 | 0.25 | 6323 | | 5147 | 0.46 | |
| Coastal | Arctic Tern | 15 | 2.95 | 0.59 | 765 | 426 | 1576 | 1336 | 674 | 955 | 192 | 0.20 | 430 | 66.0% | 499 | 0.52 | 77.0% |
| Offshore | \| | 15 | 0.12 | 0.04 | 187 | 63 | 36 | 219 | 48 | 110 | 34 | 0.31 | 77 | 34.0% | 52 | 0.47 | 23.0% |
| | Total | 15 | 0.85 | 0.16 | 953 | 489 | 1611 | 1555 | 722 | 1066 | 200 | 0.19 | 447 | | 551 | 0.52 | |
| Coastal | Grebe | 16 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | NA | 0 | | NA |
| Offshore | \| | 16 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | NA | 0 | | NA |
| | Total | 16 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | | 0 | | |
| Coastal | Loon | 17 | 0.68 | 0.12 | 281 | 353 | 208 | 158 | 109 | 222 | 39 | 0.17 | 87 | 10.3% | 41 | 0.18 | 8.0% |
| Offshore | \| | 17 | 0.47 | 0.13 | 366 | 938 | 415 | 273 | 192 | 437 | 117 | 0.27 | 262 | 89.7% | 164 | 0.37 | 92.0% |
| | Total | 17 | 0.52 | 0.12 | 646 | 1291 | 622 | 431 | 301 | 658 | 152 | 0.23 | 341 | | 205 | 0.31 | |
| Coastal | Sea Lion | 18 | 0.22 | 0.06 | 15 | 114 | 120 | 60 | 42 | 70 | 18 | 0.26 | 41 | 9.0% | 45 | 0.64 | 13.0% |
| Offshore | \| | 18 | 0.31 | 0.07 | 150 | 551 | 308 | 191 | 240 | 288 | 63 | 0.22 | 141 | 91.0% | 103 | 0.36 | 87.0% |
| | Total | 18 | 0.28 | 0.06 | 165 | 664 | 428 | 251 | 282 | 358 | 78 | 0.22 | 175 | | 147 | 0.41 | |
| Coastal | Harbor Porpoise | 19 | 0.22 | 0.03 | 40 | 69 | 65 | 102 | 81 | 71 | 9 | 0.13 | 20 | 8.9% | 17 | 0.24 | 8.5% |
| Offshore | \| | 19 | 0.14 | 0.03 | 206 | 113 | 213 | 27 | 84 | 129 | 32 | 0.25 | 72 | 91.1% | 64 | 0.50 | 91.5% |
| | Total | 19 | 0.16 | 0.02 | 247 | 181 | 278 | 129 | 165 | 200 | 24 | 0.12 | 55 | | 82 | 0.41 | |
| Coastal | Harbor Seal | 20 | 1.23 | 0.14 | 331 | 531 | 518 | 301 | 305 | 397 | 47 | 0.12 | 105 | 14.8% | 124 | 0.31 | 21.6% |
| Offshore | \| | 20 | 0.25 | 0.10 | 141 | 138 | 628 | 27 | 216 | 230 | 93 | 0.40 | 208 | 85.2% | 155 | 0.67 | 78.4% |
| | Total | 20 | 0.50 | 0.10 | 472 | 669 | 1146 | 328 | 521 | 627 | 126 | 0.20 | 281 | | 279 | 0.44 | |

Appendix 5. Continued.

| | | | Density | | Population Estimate | | | | | 5 yr Mean | | | Between Year Var. | | Mean Within Year Var. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Strata | Species | Group | Mean 5yrs | Mean SE | 1999 | 2000 | 2001 | 2002 | 2003 | Mean | SE | CV | SD 5yrs | Optimal Allocation | Mean SE | CV | Optimal Allocation |
| Coastal | Cetacean | 21 | 0.04 | 0.01 | 10 | 25 | 5 | 11 | 21 | 14 | 3 | 0.23 | 7 | 9.0% | 7 | 0.51 | 10.4% |
| Offshore | \| | 21 | 0.03 | 0.01 | 28 | 13 | 83 | 14 | 24 | 32 | 12 | 0.36 | 26 | 91.0% | 22 | 0.68 | 89.6% |
| | Total | 21 | 0.04 | 0.01 | 39 | 38 | 88 | 24 | 45 | 47 | 10 | 0.21 | 22 | | 29 | 0.63 | |
| Coastal | Sea Otter | 22 | 0.68 | 0.11 | 75 | 244 | 286 | 220 | 281 | 221 | 34 | 0.16 | 77 | 7.5% | 151 | 0.68 | 13.0% |
| Offshore | \| | 22 | 0.61 | 0.16 | 291 | 138 | 569 | 833 | 1032 | 572 | 148 | 0.26 | 331 | 92.5% | 350 | 0.61 | 87.0% |
| | Total | 22 | 0.63 | 0.13 | 365 | 382 | 855 | 1053 | 1313 | 793 | 167 | 0.21 | 373 | | 500 | 0.63 | |

Appendix 6. Winter (Nov. 1999 or March 2000-2003) densities (num/km$^2$), population estimates, and estimates of optimal allocation of sampling effort for 22 species and 11 strata within Glacier Bay, AK.

| | | | | Density | | Population Estimate | | | | | 5 yr Pop. Mean | | | Between Year Var. | | Mean Within Year Var. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth Strata | Geog. Strata | Species | Group | Mean 5yrs | Mean SE | 1999 | 2000 | 2001 | 2002 | 2003 | Mean | SE | CV | SD 5yrs | Optimal Allocation | Mean SE | CV | Optimal Allocation |
| C | LB | Kittlitz's Murrelet | 1 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| C | CB | | | 0.06 | 0.03 | 0 | 14 | 22 | 0 | 0 | 7 | 4 | 0.57 | 9 | 1.0% | 5 | 0.73 | 0.7% |
| C | WA | | | 1.95 | 1.38 | 0 | 602 | 0 | 79 | 45 | 145 | 103 | 0.71 | 230 | 15.6% | 84 | 0.58 | 7.4% |
| C | EA | | | 1.04 | 0.38 | 11 | 136 | 75 | 131 | 0 | 71 | 26 | 0.36 | 57 | 3.5% | 44 | 0.62 | 3.5% |
| S | LB | | | 0.03 | 0.03 | 0 | 0 | 0 | 0 | 25 | 5 | 4 | 0.89 | 10 | 1.5% | 5 | 0.95 | 0.9% |
| S | CB | | | 0.19 | 0.10 | 0 | 0 | 96 | 0 | 87 | 37 | 20 | 0.55 | 45 | 8.1% | 31 | 0.85 | 7.2% |
| S | WA | | | 3.80 | 3.40 | 0 | 579 | 0 | 0 | 0 | 116 | 103 | 0.89 | 231 | 6.4% | 61 | 0.53 | 2.2% |
| S | EA | | | 6.53 | 4.27 | 0 | 620 | 33 | 156 | 0 | 162 | 106 | 0.65 | 236 | 5.3% | 122 | 0.75 | 3.6% |
| D | CB | | | 0.13 | 0.07 | 0 | 0 | 73 | 0 | 108 | 36 | 20 | 0.56 | 46 | 11.6% | 25 | 0.68 | 8.1% |
| D | WA | | | 1.42 | 0.48 | 0 | 499 | 461 | 136 | 175 | 254 | 87 | 0.34 | 194 | 31.7% | 235 | 0.92 | 49.9% |
| D | EA | | | 3.91 | 2.10 | 0 | 416 | 52 | 700 | 0 | 234 | 125 | 0.54 | 280 | 15.2% | 235 | 1.01 | 16.5% |
| Total | | Kittlitz's Murrelet | 1 | 0.85 | 0.35 | 11 | 2866 | 813 | 1201 | 440 | 1066 | 439 | 0.41 | 982 | | 374 | 0.35 | |
| C | LB | Marbled Murrelet | 2 | 0.35 | 0.13 | 28 | 2 | 13 | 55 | 14 | 22 | 8 | 0.37 | 18 | 0.5% | 12 | 0.51 | 0.4% |
| C | CB | | | 0.82 | 0.28 | 46 | 148 | 216 | 61 | 12 | 96 | 33 | 0.35 | 74 | 3.5% | 52 | 0.53 | 3.6% |
| C | WA | | | 0.74 | 0.27 | 22 | 42 | 140 | 61 | 11 | 55 | 20 | 0.37 | 46 | 1.4% | 44 | 0.80 | 2.0% |
| C | EA | | | 2.86 | 0.96 | 35 | 312 | 226 | 380 | 16 | 194 | 65 | 0.34 | 146 | 4.0% | 126 | 0.65 | 5.0% |
| S | LB | | | 2.28 | 1.12 | 640 | 0 | 1045 | 184 | 0 | 374 | 183 | 0.49 | 409 | 27.0% | 283 | 0.76 | 27.3% |
| S | CB | | | 1.95 | 0.72 | 806 | 130 | 739 | 80 | 174 | 386 | 142 | 0.37 | 318 | 25.2% | 217 | 0.56 | 25.2% |
| S | WA | | | 3.93 | 1.67 | 0 | 331 | 116 | 110 | 42 | 120 | 51 | 0.43 | 114 | 1.4% | 95 | 0.79 | 1.7% |
| S | EA | | | 1.81 | 1.43 | 0 | 0 | 22 | 202 | 0 | 45 | 35 | 0.79 | 79 | 0.8% | 28 | 0.63 | 0.4% |
| D | CB | | | 0.39 | 0.16 | 0 | 109 | 183 | 0 | 252 | 109 | 45 | 0.41 | 100 | 11.2% | 55 | 0.50 | 9.0% |
| D | WA | | | 1.19 | 0.81 | 121 | 0 | 856 | 91 | 0 | 214 | 145 | 0.68 | 325 | 23.4% | 222 | 1.04 | 23.5% |
| D | EA | | | 0.86 | 0.54 | 0 | 76 | 182 | 0 | 0 | 52 | 32 | 0.62 | 72 | 1.7% | 54 | 1.04 | 1.9% |
| Total | | Marbled Murrelet | 2 | 1.32 | 0.39 | 1698 | 1148 | 3738 | 1225 | 522 | 1666 | 493 | 0.30 | 1101 | | 462 | 0.28 | |
| C | LB | Unid. Murrelet | 3 | 0.71 | 0.29 | 124 | 45 | 24 | 29 | 8 | 46 | 18 | 0.40 | 41 | 0.6% | 27 | 0.60 | 0.7% |
| C | CB | | | 0.60 | 0.23 | 58 | 92 | 176 | 12 | 12 | 70 | 27 | 0.39 | 61 | 1.8% | 33 | 0.47 | 1.5% |
| C | WA | | | 1.28 | 0.75 | 45 | 342 | 0 | 44 | 45 | 95 | 56 | 0.59 | 125 | 2.3% | 64 | 0.67 | 1.9% |
| C | EA | | | 1.96 | 0.97 | 11 | 406 | 159 | 71 | 16 | 133 | 66 | 0.49 | 147 | 2.4% | 62 | 0.47 | 1.6% |
| S | LB | | | 1.68 | 0.80 | 71 | 297 | 836 | 122 | 49 | 275 | 131 | 0.48 | 294 | 11.8% | 192 | 0.70 | 12.2% |
| S | CB | | | 2.30 | 0.92 | 387 | 518 | 1189 | 119 | 58 | 454 | 181 | 0.40 | 404 | 19.6% | 187 | 0.41 | 14.3% |
| S | WA | | | 10.63 | 5.89 | 0 | 1074 | 405 | 55 | 84 | 324 | 179 | 0.55 | 401 | 3.0% | 254 | 0.78 | 3.0% |
| S | EA | | | 5.08 | 1.99 | 87 | 331 | 87 | 124 | 0 | 126 | 49 | 0.39 | 110 | 0.7% | 109 | 0.87 | 1.0% |
| D | CB | | | 0.69 | 0.20 | 37 | 182 | 403 | 228 | 108 | 192 | 55 | 0.29 | 124 | 8.5% | 142 | 0.74 | 15.3% |
| D | WA | | | 4.42 | 2.22 | 0 | 1298 | 2305 | 363 | 0 | 793 | 399 | 0.50 | 893 | 39.4% | 603 | 0.76 | 42.0% |
| D | EA | | | 7.09 | 5.06 | 0 | 151 | 1770 | 100 | 95 | 423 | 302 | 0.71 | 675 | 9.9% | 278 | 0.66 | 6.4% |
| Total | | Unid. Murrelet | 3 | 2.33 | 0.95 | 820 | 4737 | 7353 | 1267 | 475 | 2930 | 1201 | 0.41 | 2686 | | 787 | 0.27 | |

Appendix 6. Continued.

| Depth Strata | Geog. Strata | Species | Group | Density Mean 5yrs | Density Mean SE | Population Estimate 1999 | 2000 | 2001 | 2002 | 2003 | 5 yr Pop. Mean Mean | SE | CV | Between Year Var. SD 5yrs | Optimal Allocation | Mean Within Year Var. Mean SE | CV | Optimal Allocation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C | LB | Cormorant | 4 | 2.23 | 0.38 | 237 | 77 | 149 | 105 | 146 | 143 | 24 | 0.17 | 54 | 3.0% | 49 | 0.34 | 3.2% |
| C | CB | | | 0.93 | 0.23 | 174 | 65 | 75 | 42 | 186 | 108 | 27 | 0.25 | 60 | 6.1% | 41 | 0.38 | 4.9% |
| C | WA | | | 0.88 | 0.23 | 89 | 125 | 59 | 44 | 11 | 65 | 17 | 0.26 | 39 | 2.5% | 49 | 0.75 | 3.7% |
| C | EA | | | 2.90 | 1.05 | 27 | 236 | 8 | 429 | 283 | 196 | 71 | 0.36 | 159 | 9.4% | 128 | 0.65 | 8.8% |
| S | LB | | | 0.96 | 0.33 | 0 | 149 | 348 | 214 | 74 | 157 | 53 | 0.34 | 120 | 17.0% | 98 | 0.63 | 16.4% |
| S | CB | | | 1.13 | 0.17 | 290 | 227 | 321 | 159 | 116 | 223 | 34 | 0.15 | 77 | 13.2% | 131 | 0.59 | 26.3% |
| S | WA | | | 14.89 | 11.78 | 49 | 0 | 0 | 165 | 2052 | 453 | 358 | 0.79 | 802 | 21.2% | 380 | 0.84 | 11.8% |
| S | EA | | | 0.46 | 0.29 | 0 | 0 | 0 | 16 | 42 | 11 | 7 | 0.64 | 16 | 0.3% | 15 | 1.31 | 0.4% |
| D | CB | | | 0.09 | 0.03 | 37 | 0 | 37 | 46 | 0 | 24 | 9 | 0.37 | 20 | 4.8% | 16 | 0.65 | 4.4% |
| D | WA | | | 0.60 | 0.36 | 0 | 0 | 0 | 363 | 175 | 108 | 65 | 0.60 | 145 | 22.5% | 110 | 1.02 | 20.1% |
| D | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| Total | | Cormorant | 4 | 1.18 | 0.30 | 904 | 877 | 997 | 1583 | 3086 | 1489 | 375 | 0.25 | 839 | | 455 | 0.31 | |
| C | LB | Pigeon Guillemot | 5 | 12.71 | 2.06 | 872 | 1187 | 936 | 792 | 288 | 815 | 132 | 0.16 | 295 | 7.1% | 188 | 0.23 | 6.2% |
| C | CB | | | 5.59 | 0.98 | 527 | 567 | 1144 | 639 | 397 | 655 | 115 | 0.18 | 257 | 11.3% | 231 | 0.35 | 13.8% |
| C | WA | | | 2.98 | 1.23 | 56 | 135 | 117 | 623 | 181 | 222 | 91 | 0.41 | 204 | 5.7% | 110 | 0.50 | 4.2% |
| C | EA | | | 7.07 | 3.79 | 49 | 534 | 99 | 1573 | 138 | 479 | 257 | 0.54 | 574 | 14.6% | 251 | 0.52 | 8.7% |
| S | LB | | | 1.78 | 0.52 | 604 | 297 | 348 | 184 | 25 | 292 | 86 | 0.29 | 192 | 11.8% | 184 | 0.63 | 15.4% |
| S | CB | | | 3.24 | 0.83 | 290 | 162 | 675 | 1114 | 959 | 640 | 165 | 0.26 | 368 | 27.3% | 351 | 0.55 | 35.4% |
| S | WA | | | 4.75 | 1.63 | 0 | 124 | 58 | 248 | 293 | 145 | 50 | 0.34 | 111 | 1.3% | 68 | 0.47 | 1.1% |
| S | EA | | | 2.42 | 0.76 | 0 | 124 | 87 | 47 | 42 | 60 | 19 | 0.32 | 42 | 0.4% | 44 | 0.73 | 0.6% |
| D | CB | | | 0.35 | 0.22 | 373 | 0 | 37 | 46 | 36 | 98 | 62 | 0.63 | 138 | 14.5% | 69 | 0.70 | 9.9% |
| D | WA | | | 0.27 | 0.15 | 0 | 150 | 0 | 91 | 0 | 48 | 28 | 0.57 | 62 | 4.2% | 44 | 0.91 | 4.0% |
| D | EA | | | 0.76 | 0.58 | 0 | 0 | 26 | 200 | 0 | 45 | 35 | 0.77 | 78 | 1.7% | 24 | 0.54 | 0.7% |
| Total | | Pigeon Guillemot | 5 | 2.78 | 0.39 | 2772 | 3281 | 3526 | 5557 | 2358 | 3499 | 495 | 0.14 | 1106 | | 578 | 0.17 | |
| C | LB | Murre - Puffin | 6 | 0.02 | 0.01 | 0 | 2 | 0 | 0 | 3 | 1 | 1 | 0.56 | 1 | 0.1% | 1 | 0.83 | 0.1% |
| C | CB | | | 0.03 | 0.02 | 0 | 0 | 9 | 0 | 8 | 3 | 2 | 0.55 | 4 | 0.4% | 3 | 0.89 | 0.7% |
| C | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| C | EA | | | 0.01 | 0.01 | 0 | 0 | 4 | 0 | 0 | 1 | 1 | 0.89 | 2 | 0.1% | 1 | 0.73 | 0.1% |
| S | LB | | | 2.26 | 1.13 | 0 | 0 | 1115 | 490 | 246 | 370 | 185 | 0.50 | 414 | 58.0% | 157 | 0.42 | 48.2% |
| S | CB | | | 0.52 | 0.29 | 65 | 0 | 353 | 40 | 58 | 103 | 57 | 0.55 | 127 | 21.4% | 85 | 0.82 | 31.2% |
| S | WA | | | 0.32 | 0.29 | 49 | 0 | 0 | 0 | 0 | 10 | 9 | 0.89 | 20 | 0.5% | 9 | 0.93 | 0.5% |
| S | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | CB | | | 0.27 | 0.13 | 0 | 0 | 110 | 46 | 216 | 74 | 36 | 0.49 | 82 | 19.4% | 37 | 0.50 | 19.3% |
| D | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| Total | | Murre - Puffin | 6 | 0.45 | 0.20 | 114 | 2 | 1591 | 575 | 532 | 563 | 251 | 0.45 | 561 | | 182 | 0.32 | |

Appendix 6. Continued.

| | | | | Density | | Population Estimate | | | | | 5 yr Pop. Mean | | | Between Year Var. | | Mean Within Year Var. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth Strata | Geog. Strata | Species | Group | Mean 5yrs | Mean SE | 1999 | 2000 | 2001 | 2002 | 2003 | Mean | SE | CV | SD 5yrs | Optimal Allocation | Mean SE | CV | Optimal Allocation |
| C | LB | Scoter | 7 | 25.60 | 4.89 | 1332 | 2142 | 2260 | 2076 | 400 | 1642 | 314 | 0.19 | 701 | 6.3% | 450 | 0.27 | 5.9% |
| C | CB | | | 34.94 | 10.49 | 8291 | 2985 | 6086 | 2535 | 559 | 4091 | 1229 | 0.30 | 2747 | 45.2% | 1661 | 0.41 | 39.7% |
| C | WA | | | 8.54 | 6.00 | 2613 | 425 | 0 | 53 | 90 | 636 | 447 | 0.70 | 1000 | 10.5% | 330 | 0.52 | 5.0% |
| C | EA | | | 23.74 | 6.30 | 1421 | 1637 | 840 | 3389 | 747 | 1607 | 426 | 0.27 | 953 | 9.1% | 646 | 0.40 | 8.9% |
| S | LB | | | 0.75 | 0.51 | 0 | 0 | 488 | 31 | 99 | 123 | 83 | 0.67 | 186 | 4.3% | 99 | 0.80 | 3.3% |
| S | CB | | | 5.31 | 1.10 | 903 | 259 | 964 | 1552 | 1569 | 1049 | 217 | 0.21 | 485 | 13.4% | 808 | 0.77 | 32.6% |
| S | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | EA | | | 1.86 | 0.93 | 58 | 0 | 33 | 140 | 0 | 46 | 23 | 0.50 | 52 | 0.2% | 34 | 0.75 | 0.2% |
| D | CB | | | 0.08 | 0.07 | 0 | 0 | 110 | 0 | 0 | 22 | 20 | 0.89 | 44 | 1.7% | 16 | 0.72 | 0.9% |
| D | WA | | | 1.01 | 0.90 | 905 | 0 | 0 | 0 | 0 | 181 | 162 | 0.89 | 362 | 9.1% | 88 | 0.49 | 3.2% |
| D | EA | | | 0.35 | 0.20 | 0 | 38 | 0 | 67 | 0 | 21 | 12 | 0.58 | 27 | 0.2% | 19 | 0.91 | 0.2% |
| Total | | Scoter | 7 | 7.48 | 1.41 | 15523 | 7486 | 10780 | 9842 | 3463 | 9419 | 1772 | 0.19 | 3962 | | 2040 | 0.22 | |
| C | LB | Dabbling Duck | 8 | 8.09 | 2.10 | 773 | 902 | 500 | 368 | 51 | 519 | 135 | 0.26 | 301 | 9.9% | 175 | 0.34 | 11.7% |
| C | CB | | | 5.45 | 1.94 | 1166 | 1306 | 158 | 88 | 474 | 638 | 227 | 0.35 | 507 | 30.4% | 288 | 0.45 | 35.1% |
| C | WA | | | 2.59 | 1.67 | 723 | 218 | 23 | 0 | 0 | 193 | 124 | 0.64 | 277 | 10.6% | 116 | 0.60 | 9.0% |
| C | EA | | | 13.36 | 6.92 | 2951 | 801 | 119 | 339 | 312 | 904 | 468 | 0.52 | 1047 | 36.3% | 478 | 0.53 | 33.7% |
| S | LB | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | CB | | | 0.26 | 0.23 | 258 | 0 | 0 | 0 | 0 | 52 | 46 | 0.89 | 103 | 10.4% | 43 | 0.83 | 8.8% |
| S | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | EA | | | 4.47 | 3.44 | 490 | 0 | 22 | 0 | 42 | 111 | 85 | 0.77 | 190 | 2.4% | 60 | 0.54 | 1.5% |
| D | CB | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| Total | | Dabbling Duck | 8 | 1.92 | 0.77 | 6361 | 3227 | 822 | 795 | 879 | 2417 | 975 | 0.40 | 2180 | | 600 | 0.25 | |
| C | LB | Goldeneye | 9 | 33.46 | 6.83 | 1849 | 2970 | 2703 | 2855 | 353 | 2146 | 438 | 0.20 | 979 | 5.0% | 518 | 0.24 | 4.3% |
| C | CB | | | 50.53 | 10.15 | 7490 | 5457 | 5347 | 9652 | 1633 | 5916 | 1188 | 0.20 | 2658 | 25.0% | 1587 | 0.27 | 24.0% |
| C | WA | | | 53.10 | 11.57 | 3414 | 6568 | 3052 | 5597 | 1141 | 3954 | 862 | 0.22 | 1926 | 11.5% | 1930 | 0.49 | 18.5% |
| C | EA | | | 44.82 | 8.81 | 3552 | 4863 | 1434 | 3762 | 1559 | 3034 | 596 | 0.20 | 1333 | 7.3% | 564 | 0.19 | 4.9% |
| S | LB | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | CB | | | 1.94 | 0.51 | 129 | 389 | 129 | 597 | 668 | 382 | 101 | 0.26 | 226 | 3.6% | 255 | 0.67 | 6.5% |
| S | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | EA | | | 31.68 | 8.64 | 1009 | 165 | 1479 | 933 | 333 | 784 | 214 | 0.27 | 478 | 1.0% | 369 | 0.47 | 1.2% |
| D | CB | | | 0.05 | 0.05 | 0 | 0 | 0 | 0 | 72 | 14 | 13 | 0.89 | 29 | 0.6% | 17 | 1.20 | 0.6% |
| D | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | EA | | | 90.41 | 71.87 | 0 | 0 | 24471 | 2499 | 0 | 5394 | 4288 | 0.79 | 9588 | 46.0% | 5196 | 0.96 | 40.0% |
| Total | | Goldeneye | 9 | 17.18 | 3.82 | 17443 | 20413 | 38615 | 25895 | 5758 | 21625 | 4807 | 0.22 | 10748 | | 5834 | 0.27 | |

Appendix 6. Continued.

| Depth Strata | Geog. Strata | Species | Group | Density Mean 5yrs | Density Mean SE | Population Estimate 1999 | 2000 | 2001 | 2002 | 2003 | 5 yr Pop. Mean Mean | SE | CV | Between Year Var. SD 5yrs | Between Year Var. Optimal Allocation | Mean Within Year Var. Mean SE | CV | Mean Within Year Var. Optimal Allocation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C | LB | Harlequin Duck | 10 | 3.28 | 0.70 | 147 | 312 | 276 | 272 | 45 | 211 | 45 | 0.21 | 100 | 6.2% | 92 | 0.44 | 6.5% |
| C | CB | | | 7.12 | 1.04 | 971 | 1167 | 841 | 846 | 344 | 834 | 122 | 0.15 | 272 | 30.6% | 227 | 0.27 | 29.5% |
| C | WA | | | 0.57 | 0.18 | 78 | 73 | 0 | 18 | 45 | 43 | 14 | 0.32 | 30 | 2.2% | 31 | 0.72 | 2.5% |
| C | EA | | | 0.31 | 0.06 | 27 | 21 | 32 | 4 | 20 | 21 | 4 | 0.21 | 10 | 0.6% | 14 | 0.68 | 1.1% |
| S | LB | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | CB | | | 2.23 | 0.72 | 581 | 550 | 900 | 0 | 174 | 441 | 142 | 0.32 | 319 | 60.5% | 276 | 0.62 | 60.4% |
| S | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | CB | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| Total | | Harlequin Duck | 10 | 1.23 | 0.20 | 1803 | 2123 | 2048 | 1140 | 629 | 1549 | 257 | 0.17 | 576 | | 370 | 0.24 | |
| C | LB | Merganser | 11 | 4.29 | 1.33 | 638 | 231 | 185 | 250 | 74 | 275 | 86 | 0.31 | 191 | 5.4% | 82 | 0.30 | 3.1% |
| C | CB | | | 2.52 | 0.60 | 257 | 152 | 559 | 375 | 130 | 295 | 71 | 0.24 | 158 | 8.1% | 104 | 0.35 | 7.2% |
| C | WA | | | 3.03 | 0.34 | 222 | 176 | 316 | 254 | 158 | 225 | 25 | 0.11 | 56 | 1.8% | 109 | 0.48 | 4.8% |
| C | EA | | | 34.22 | 9.14 | 133 | 1545 | 2369 | 3799 | 3736 | 2317 | 619 | 0.27 | 1384 | 41.1% | 1440 | 0.62 | 57.9% |
| S | LB | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | CB | | | 0.81 | 0.55 | 0 | 65 | 96 | 0 | 639 | 160 | 108 | 0.68 | 242 | 21.0% | 130 | 0.81 | 15.2% |
| S | WA | | | 1.90 | 1.70 | 0 | 289 | 0 | 0 | 0 | 58 | 52 | 0.89 | 116 | 1.5% | 31 | 0.53 | 0.6% |
| S | EA | | | 10.56 | 5.34 | 29 | 0 | 805 | 140 | 333 | 261 | 132 | 0.51 | 296 | 3.2% | 138 | 0.53 | 2.0% |
| D | CB | | | 0.26 | 0.18 | 0 | 0 | 293 | 0 | 72 | 73 | 51 | 0.70 | 114 | 13.9% | 44 | 0.60 | 7.3% |
| D | WA | | | 0.05 | 0.05 | 0 | 0 | 0 | 45 | 0 | 9 | 8 | 0.89 | 18 | 1.4% | 7 | 0.79 | 0.8% |
| D | EA | | | 1.00 | 0.68 | 0 | 0 | 234 | 0 | 63 | 59 | 41 | 0.68 | 91 | 2.4% | 32 | 0.53 | 1.1% |
| Total | | Merganser | 11 | 2.97 | 0.56 | 1280 | 2459 | 4857 | 4864 | 5205 | 3733 | 703 | 0.19 | 1572 | | 1464 | 0.39 | |
| C | LB | Diving Duck | 12 | 12.90 | 2.62 | 1313 | 905 | 888 | 882 | 151 | 828 | 168 | 0.20 | 376 | 40.6% | 257 | 0.31 | 32.6% |
| C | CB | | | 1.59 | 0.24 | 232 | 245 | 150 | 226 | 77 | 186 | 29 | 0.15 | 64 | 12.6% | 74 | 0.40 | 17.0% |
| C | WA | | | 4.01 | 0.64 | 500 | 259 | 281 | 272 | 181 | 299 | 48 | 0.16 | 107 | 13.4% | 113 | 0.38 | 16.7% |
| C | EA | | | 5.00 | 1.10 | 392 | 228 | 182 | 641 | 250 | 339 | 75 | 0.22 | 167 | 19.0% | 195 | 0.58 | 26.1% |
| S | LB | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | CB | | | 0.07 | 0.06 | 65 | 0 | 0 | 0 | 0 | 13 | 12 | 0.89 | 26 | 8.6% | 11 | 0.83 | 4.2% |
| S | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | EA | | | 6.88 | 2.46 | 0 | 41 | 348 | 296 | 166 | 170 | 61 | 0.36 | 136 | 5.7% | 70 | 0.41 | 3.4% |
| D | CB | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| Total | | Diving Duck | 12 | 1.46 | 0.21 | 2502 | 1678 | 1849 | 2317 | 825 | 1834 | 262 | 0.14 | 587 | | 356 | 0.19 | |

Appendix 6. Continued.

| Depth Strata | Geog. Strata | Species | Group | Density Mean 5yrs | Density Mean SE | Population Estimate 1999 | 2000 | 2001 | 2002 | 2003 | 5 yr Pop. Mean Mean | SE | CV | Between Year Var. SD 5yrs | Optimal Allocation | Mean Within Year Var. Mean SE | CV | Optimal Allocation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C | LB | Gull | 13 | 11.68 | 6.74 | 2676 | 430 | 247 | 208 | 187 | 749 | 432 | 0.58 | 967 | 8.9% | 258 | 0.34 | 4.3% |
| C | CB | | | 7.06 | 1.95 | 1523 | 614 | 1342 | 287 | 365 | 826 | 228 | 0.28 | 510 | 8.5% | 256 | 0.31 | 7.7% |
| C | WA | | | 7.34 | 2.59 | 1390 | 498 | 222 | 342 | 282 | 547 | 193 | 0.35 | 431 | 4.6% | 132 | 0.24 | 2.5% |
| C | EA | | | 10.81 | 5.26 | 694 | 217 | 2282 | 246 | 220 | 732 | 356 | 0.49 | 796 | 7.7% | 208 | 0.28 | 3.6% |
| S | LB | | | 4.80 | 1.97 | 462 | 446 | 2230 | 428 | 369 | 787 | 323 | 0.41 | 722 | 16.9% | 552 | 0.70 | 23.3% |
| S | CB | | | 4.14 | 0.50 | 1064 | 745 | 996 | 438 | 843 | 817 | 99 | 0.12 | 220 | 6.2% | 358 | 0.44 | 18.2% |
| S | WA | | | 6.84 | 3.21 | 636 | 165 | 58 | 55 | 126 | 208 | 98 | 0.47 | 218 | 1.0% | 93 | 0.45 | 0.7% |
| S | EA | | | 4.67 | 2.04 | 29 | 41 | 326 | 140 | 42 | 116 | 50 | 0.44 | 113 | 0.4% | 54 | 0.47 | 0.3% |
| D | CB | | | 2.94 | 0.50 | 1120 | 946 | 733 | 1049 | 252 | 820 | 140 | 0.17 | 312 | 12.5% | 218 | 0.27 | 15.7% |
| D | WA | | | 5.45 | 2.13 | 2231 | 400 | 1778 | 136 | 350 | 979 | 382 | 0.39 | 854 | 22.0% | 377 | 0.39 | 17.5% |
| D | EA | | | 14.17 | 9.93 | 194 | 227 | 3489 | 33 | 284 | 845 | 592 | 0.70 | 1324 | 11.3% | 395 | 0.47 | 6.1% |
| Total | | Gull | 13 | 5.90 | 1.60 | 12019 | 4728 | 13703 | 3362 | 3320 | 7426 | 2011 | 0.27 | 4498 | | 992 | 0.13 | |
| C | LB | Black-legged Kittiwake | 14 | 6.05 | 5.29 | 1905 | 29 | 4 | 0 | 3 | 388 | 339 | 0.87 | 759 | 5.6% | 215 | 0.55 | 3.0% |
| C | CB | | | 1.35 | 0.74 | 195 | 51 | 524 | 12 | 12 | 159 | 87 | 0.55 | 195 | 2.6% | 116 | 0.73 | 3.0% |
| C | WA | | | 7.04 | 4.13 | 78 | 467 | 94 | 1869 | 113 | 524 | 308 | 0.59 | 688 | 5.9% | 344 | 0.66 | 5.6% |
| C | EA | | | 0.16 | 0.04 | 11 | 16 | 16 | 11 | 0 | 11 | 3 | 0.24 | 6 | 0.0% | 9 | 0.81 | 0.1% |
| S | LB | | | 12.05 | 8.76 | 8353 | 1114 | 0 | 214 | 197 | 1976 | 1436 | 0.73 | 3212 | 61.0% | 1412 | 0.71 | 50.7% |
| S | CB | | | 3.02 | 1.77 | 323 | 130 | 289 | 2149 | 87 | 596 | 350 | 0.59 | 782 | 17.9% | 586 | 0.98 | 25.3% |
| S | WA | | | 5.50 | 2.93 | 0 | 41 | 58 | 193 | 544 | 167 | 89 | 0.53 | 199 | 0.7% | 145 | 0.87 | 1.0% |
| S | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | CB | | | 0.22 | 0.07 | 37 | 36 | 147 | 46 | 36 | 60 | 19 | 0.32 | 43 | 1.4% | 43 | 0.72 | 2.6% |
| D | WA | | | 1.31 | 0.39 | 121 | 250 | 395 | 409 | 0 | 235 | 71 | 0.30 | 158 | 3.3% | 180 | 0.77 | 7.1% |
| D | EA | | | 2.05 | 1.59 | 0 | 0 | 547 | 33 | 32 | 122 | 95 | 0.78 | 213 | 1.5% | 114 | 0.93 | 1.5% |
| Total | | Black-legged Kittiwake | 14 | 3.37 | 1.29 | 11022 | 2134 | 2072 | 4935 | 1024 | 4237 | 1624 | 0.38 | 3632 | | 1607 | 0.38 | |
| C | LB | Arctic Tern | 15 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | NA | 0 | | NA |
| C | CB | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | NA | 0 | | NA |
| C | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | NA | 0 | | NA |
| C | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | NA | 0 | | NA |
| S | LB | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | NA | 0 | | NA |
| S | CB | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | NA | 0 | | NA |
| S | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | NA | 0 | | NA |
| S | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | NA | 0 | | NA |
| D | CB | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | NA | 0 | | NA |
| D | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | NA | 0 | | NA |
| D | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | NA | 0 | | NA |
| Total | | Arctic Tern | 15 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | | 0 | | |

Appendix 6. Continued.

| | | | | Density | | Population Estimate | | | | | 5 yr Pop. Mean | | | Between Year Var. | | Mean Within Year Var. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth Strata | Geog. Strata | Species | Group | Mean 5yrs | Mean SE | 1999 | 2000 | 2001 | 2002 | 2003 | Mean | SE | CV | SD 5yrs | Optimal Allocation | Mean SE | CV | Optimal Allocation |
| C | LB | Grebe | 16 | 1.18 | 0.19 | 90 | 59 | 105 | 93 | 30 | 76 | 12 | 0.16 | 27 | 7.0% | 39 | 0.51 | 9.8% |
| C | CB | | | 2.42 | 0.23 | 365 | 226 | 299 | 325 | 203 | 284 | 27 | 0.10 | 61 | 28.2% | 100 | 0.35 | 46.1% |
| C | WA | | | 0.51 | 0.39 | 167 | 0 | 0 | 0 | 23 | 38 | 29 | 0.77 | 65 | 19.2% | 12 | 0.31 | 3.5% |
| C | EA | | | 1.61 | 0.52 | 204 | 113 | 186 | 30 | 13 | 109 | 35 | 0.32 | 78 | 20.9% | 70 | 0.64 | 18.6% |
| S | LB | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | CB | | | 0.13 | 0.05 | 65 | 32 | 32 | 0 | 0 | 26 | 11 | 0.42 | 24 | 18.9% | 24 | 0.92 | 18.5% |
| S | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | CB | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | EA | | | 0.30 | 0.19 | 0 | 0 | 26 | 0 | 63 | 18 | 11 | 0.62 | 25 | 5.9% | 15 | 0.86 | 3.6% |
| Total | | Grebe | 16 | 0.44 | 0.07 | 891 | 430 | 649 | 449 | 332 | 550 | 89 | 0.16 | 199 | | 131 | 0.24 | |
| C | LB | Loon | 17 | 0.81 | 0.19 | 99 | 50 | 31 | 59 | 23 | 52 | 12 | 0.23 | 27 | 2.9% | 15 | 0.29 | 1.8% |
| C | CB | | | 0.60 | 0.17 | 154 | 37 | 70 | 65 | 24 | 70 | 20 | 0.29 | 45 | 9.0% | 33 | 0.47 | 7.1% |
| C | WA | | | 0.44 | 0.27 | 122 | 21 | 0 | 9 | 11 | 33 | 20 | 0.62 | 45 | 5.8% | 11 | 0.34 | 1.5% |
| C | EA | | | 0.22 | 0.08 | 30 | 29 | 0 | 8 | 7 | 15 | 6 | 0.38 | 12 | 1.4% | 7 | 0.47 | 0.9% |
| S | LB | | | 0.42 | 0.17 | 36 | 149 | 139 | 0 | 25 | 70 | 28 | 0.40 | 62 | 17.3% | 60 | 0.87 | 18.2% |
| S | CB | | | 0.76 | 0.25 | 194 | 65 | 64 | 80 | 349 | 150 | 49 | 0.33 | 110 | 37.2% | 88 | 0.58 | 31.8% |
| S | WA | | | 0.50 | 0.29 | 49 | 0 | 0 | 28 | 0 | 15 | 9 | 0.58 | 20 | 1.0% | 12 | 0.79 | 0.7% |
| S | EA | | | 0.23 | 0.21 | 29 | 0 | 0 | 0 | 0 | 6 | 5 | 0.89 | 12 | 0.5% | 7 | 1.19 | 0.3% |
| D | CB | | | 0.26 | 0.08 | 112 | 146 | 73 | 0 | 36 | 73 | 23 | 0.32 | 52 | 24.8% | 74 | 1.00 | 37.7% |
| D | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| Total | | Loon | 17 | 0.38 | 0.07 | 823 | 495 | 378 | 248 | 474 | 484 | 85 | 0.18 | 191 | | 136 | 0.28 | |
| C | LB | Sea Lion | 18 | 0.09 | 0.07 | 25 | 2 | 0 | 0 | 0 | 6 | 4 | 0.80 | 10 | 1.4% | 3 | 0.49 | 0.5% |
| C | CB | | | 0.94 | 0.17 | 79 | 185 | 141 | 73 | 73 | 110 | 20 | 0.18 | 45 | 11.4% | 47 | 0.43 | 15.3% |
| C | WA | | | 1.43 | 0.43 | 67 | 239 | 70 | 123 | 34 | 106 | 32 | 0.30 | 72 | 11.5% | 50 | 0.47 | 10.4% |
| C | EA | | | 1.00 | 0.45 | 8 | 21 | 194 | 82 | 33 | 68 | 30 | 0.45 | 68 | 9.9% | 28 | 0.42 | 5.3% |
| S | LB | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | CB | | | 0.29 | 0.12 | 129 | 0 | 96 | 0 | 58 | 57 | 23 | 0.41 | 51 | 21.8% | 53 | 0.94 | 29.2% |
| S | WA | | | 1.15 | 0.84 | 147 | 0 | 0 | 28 | 0 | 35 | 25 | 0.73 | 57 | 3.7% | 14 | 0.40 | 1.2% |
| S | EA | | | 0.21 | 0.12 | 0 | 0 | 11 | 16 | 0 | 5 | 3 | 0.56 | 7 | 0.4% | 6 | 1.14 | 0.4% |
| D | CB | | | 0.14 | 0.06 | 37 | 73 | 0 | 91 | 0 | 40 | 17 | 0.41 | 37 | 22.2% | 27 | 0.67 | 20.9% |
| D | WA | | | 0.18 | 0.10 | 0 | 100 | 66 | 0 | 0 | 33 | 19 | 0.57 | 42 | 16.2% | 32 | 0.95 | 15.7% |
| D | EA | | | 0.11 | 0.10 | 0 | 0 | 0 | 33 | 0 | 7 | 6 | 0.89 | 13 | 1.7% | 7 | 1.10 | 1.2% |
| Total | | Sea Lion | 18 | 0.37 | 0.05 | 492 | 619 | 578 | 445 | 198 | 467 | 66 | 0.14 | 148 | | 102 | 0.22 | |

Appendix 6. Continued.

| | | | | Density | | Population Estimate | | | | | 5 yr Pop. Mean | | | Between Year Var. | | Mean Within Year Var. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth Strata | Geog. Strata | Species | Group | Mean 5yrs | Mean SE | 1999 | 2000 | 2001 | 2002 | 2003 | Mean | SE | CV | SD 5yrs | Optimal Allocation | Mean SE | CV | Optimal Allocation |
| C | LB | Harbor Porpoise | 19 | 0.14 | 0.07 | 11 | 27 | 4 | 0 | 3 | 9 | 4 | 0.49 | 10 | 0.8% | 7 | 0.77 | 0.9% |
| C | CB | | | 0.23 | 0.04 | 17 | 37 | 40 | 12 | 32 | 27 | 5 | 0.18 | 11 | 1.7% | 17 | 0.61 | 4.0% |
| C | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| C | EA | | | 0.88 | 0.41 | 19 | 52 | 182 | 26 | 16 | 59 | 28 | 0.47 | 63 | 5.6% | 37 | 0.62 | 5.1% |
| S | LB | | | 0.77 | 0.41 | 71 | 0 | 418 | 92 | 49 | 126 | 67 | 0.53 | 149 | 32.0% | 53 | 0.42 | 17.7% |
| S | CB | | | 0.45 | 0.18 | 65 | 227 | 129 | 0 | 29 | 90 | 36 | 0.40 | 81 | 20.9% | 71 | 0.79 | 28.8% |
| S | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | EA | | | 0.44 | 0.39 | 0 | 0 | 54 | 0 | 0 | 11 | 10 | 0.89 | 22 | 0.7% | 11 | 1.03 | 0.6% |
| D | CB | | | 0.03 | 0.02 | 0 | 0 | 37 | 0 | 0 | 7 | 7 | 0.89 | 15 | 5.3% | 8 | 1.05 | 4.4% |
| D | WA | | | 0.59 | 0.28 | 60 | 200 | 0 | 272 | 0 | 106 | 49 | 0.46 | 110 | 26.0% | 83 | 0.78 | 30.6% |
| D | EA | | | 1.51 | 0.67 | 0 | 227 | 156 | 67 | 0 | 90 | 40 | 0.44 | 89 | 7.0% | 65 | 0.72 | 7.9% |
| Total | | Harbor Porpoise | 19 | 0.42 | 0.12 | 243 | 770 | 1019 | 468 | 130 | 526 | 147 | 0.28 | 329 | | 144 | 0.27 | |
| C | LB | Harbor Seal | 20 | 0.94 | 0.15 | 90 | 38 | 44 | 80 | 48 | 60 | 9 | 0.16 | 21 | 10.8% | 22 | 0.37 | 12.1% |
| C | CB | | | 0.20 | 0.05 | 46 | 32 | 18 | 12 | 12 | 24 | 6 | 0.25 | 13 | 12.4% | 12 | 0.50 | 12.0% |
| C | WA | | | 0.03 | 0.03 | 11 | 0 | 0 | 0 | 0 | 2 | 2 | 0.89 | 4 | 2.7% | 2 | 0.92 | 1.3% |
| C | EA | | | 1.51 | 0.39 | 33 | 110 | 182 | 145 | 40 | 102 | 26 | 0.26 | 58 | 31.7% | 66 | 0.65 | 38.3% |
| S | LB | | | 0.03 | 0.03 | 0 | 0 | 0 | 0 | 25 | 5 | 4 | 0.89 | 10 | 12.9% | 4 | 0.82 | 5.7% |
| S | CB | | | 0.11 | 0.04 | 0 | 32 | 32 | 40 | 0 | 21 | 8 | 0.37 | 17 | 27.3% | 18 | 0.84 | 29.6% |
| S | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | EA | | | 0.32 | 0.20 | 29 | 0 | 11 | 0 | 0 | 8 | 5 | 0.63 | 11 | 2.2% | 5 | 0.64 | 1.1% |
| D | CB | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| Total | | Harbor Seal | 20 | 0.18 | 0.02 | 209 | 213 | 286 | 277 | 125 | 222 | 26 | 0.12 | 58 | | 73 | 0.33 | |
| C | LB | Cetacean | 21 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| C | CB | | | 0.01 | 0.01 | 0 | 5 | 0 | 0 | 0 | 1 | 1 | 0.89 | 2 | 100.0% | 1 | 1.07 | 100.0% |
| C | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| C | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | LB | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | CB | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | CB | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| Total | | Cetacean | 21 | 0.00 | 0.00 | 0 | 5 | 0 | 0 | 0 | 1 | 1 | 0.89 | 2 | | 1 | 1.07 | |

Appendix 6. Continued

| | | | | Density | | Population Estimate | | | | | 5 yr Pop. Mean | | | Between Year Var. | | Mean Within Year Var. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth Strata | Geog. Strata | Species | Group | Mean 5yrs | Mean SE | 1999 | 2000 | 2001 | 2002 | 2003 | Mean | SE | CV | SD 5yrs | Optimal Allocation | Mean SE | CV | Optimal Allocation |
| C | LB | Sea Otter | 22 | 2.85 | 0.68 | 375 | 145 | 151 | 143 | 101 | 183 | 44 | 0.24 | 98 | 21.0% | 107 | 0.59 | 32.3% |
| C | CB | | | 0.11 | 0.05 | 4 | 5 | 9 | 38 | 8 | 13 | 6 | 0.45 | 13 | 5.1% | 10 | 0.76 | 5.3% |
| C | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| C | EA | | | 0.02 | 0.02 | 0 | 0 | 0 | 0 | 7 | 1 | 1 | 0.89 | 3 | 0.6% | 1 | 0.95 | 0.4% |
| S | LB | | | 0.52 | 0.19 | 0 | 74 | 209 | 92 | 49 | 85 | 31 | 0.37 | 69 | 38.2% | 37 | 0.43 | 28.2% |
| S | CB | | | 0.18 | 0.07 | 0 | 65 | 32 | 80 | 0 | 35 | 15 | 0.41 | 33 | 21.6% | 29 | 0.83 | 27.2% |
| S | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | CB | | | 0.03 | 0.02 | 0 | 0 | 0 | 0 | 36 | 7 | 6 | 0.89 | 14 | 13.5% | 5 | 0.70 | 6.6% |
| D | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| Total | | Sea Otter | 22 | 0.26 | 0.03 | 380 | 289 | 401 | 353 | 201 | 324 | 32 | 0.10 | 72 | | 118 | 0.36 | |

Appendix 7. Winter (Nov. 1999 or March 2000-2003) density (num/km$^2$) and population estimates by strata and estimates of optimal allocation of sampling effort for 22 species and 2 strata within Glacier Bay, AK.

| | | | Density | | Population Estimate | | | | | 5 yr Mean | | | Between Year Var. | | Mean Within Year Var. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Strata | Species | Group | Mean 5yrs | Mean SE | 1999 | 2000 | 2001 | 2002 | 2003 | Mean | SE | CV | SD 5yrs | Optimal Allocation | Mean SE | CV | Optimal Allocation |
| Coastal | Kittlitz's Murrelet | 1 | 0.43 | 0.21 | 16 | 421 | 91 | 157 | 13 | 139 | 67 | 0.48 | 151 | 7.1% | 74 | 0.53 | 5.5% |
| Offshore | \| | 1 | 0.89 | 0.32 | 0 | 1893 | 664 | 1278 | 340 | 835 | 302 | 0.36 | 676 | 92.9% | 442 | 0.53 | 94.5% |
| | Total | 1 | 0.77 | 0.29 | 16 | 2314 | 755 | 1434 | 353 | 974 | 367 | 0.38 | 820 | | 516 | 0.53 | |
| Coastal | Marbled Murrelet | 2 | 1.12 | 0.30 | 141 | 582 | 474 | 548 | 59 | 361 | 97 | 0.27 | 217 | 8.6% | 146 | 0.41 | 8.4% |
| Offshore | \| | 2 | 1.40 | 0.38 | 1783 | 644 | 2617 | 1015 | 476 | 1307 | 355 | 0.27 | 795 | 91.4% | 547 | 0.42 | 91.6% |
| | Total | 2 | 1.33 | 0.30 | 1924 | 1225 | 3090 | 1562 | 535 | 1667 | 378 | 0.23 | 846 | | 694 | 0.42 | |
| Coastal | Unid. Murrelet | 3 | 1.03 | 0.38 | 259 | 850 | 352 | 149 | 56 | 333 | 124 | 0.37 | 277 | 3.8% | 126 | 0.38 | 4.6% |
| Offshore | \| | 3 | 2.75 | 1.17 | 713 | 3521 | 6952 | 1240 | 408 | 2567 | 1095 | 0.43 | 2449 | 96.2% | 904 | 0.35 | 95.4% |
| | Total | 3 | 2.30 | 0.92 | 972 | 4371 | 7304 | 1389 | 464 | 2900 | 1157 | 0.40 | 2588 | | 1030 | 0.36 | |
| Coastal | Cormorant | 4 | 1.82 | 0.16 | 564 | 559 | 402 | 662 | 754 | 588 | 53 | 0.09 | 118 | 6.3% | 232 | 0.39 | 12.2% |
| Offshore | \| | 4 | 0.97 | 0.29 | 436 | 417 | 625 | 1015 | 2040 | 906 | 271 | 0.30 | 606 | 93.7% | 575 | 0.63 | 87.8% |
| | Total | 4 | 1.19 | 0.25 | 1000 | 976 | 1027 | 1676 | 2795 | 1495 | 313 | 0.21 | 701 | | 807 | 0.54 | |
| Coastal | Pigeon Guillemot | 5 | 8.08 | 1.37 | 1799 | 3224 | 3069 | 3828 | 1138 | 2612 | 442 | 0.17 | 989 | 46.7% | 652 | 0.25 | 26.5% |
| Offshore | \| | 5 | 1.55 | 0.19 | 1427 | 833 | 1445 | 2067 | 1462 | 1447 | 175 | 0.12 | 390 | 53.3% | 626 | 0.43 | 73.5% |
| | Total | 5 | 3.22 | 0.40 | 3226 | 4057 | 4514 | 5895 | 2600 | 4058 | 506 | 0.12 | 1131 | | 1278 | 0.31 | |
| Coastal | Murre - Puffin | 6 | 0.02 | 0.01 | 0 | 4 | 11 | 0 | 13 | 6 | 2 | 0.44 | 6 | 0.5% | 4 | 0.66 | 0.5% |
| Offshore | \| | 6 | 0.55 | 0.20 | 119 | 0 | 1172 | 676 | 612 | 516 | 189 | 0.37 | 422 | 99.5% | 235 | 0.46 | 99.5% |
| | Total | 6 | 0.41 | 0.15 | 119 | 4 | 1183 | 676 | 625 | 521 | 190 | 0.36 | 425 | | 239 | 0.46 | |
| Coastal | Scoter | 7 | 26.85 | 4.95 | 12649 | 8424 | 10755 | 9489 | 2093 | 8682 | 1602 | 0.18 | 3582 | 67.1% | 2332 | 0.27 | 42.3% |
| Offshore | \| | 7 | 1.65 | 0.29 | 1783 | 341 | 1679 | 1916 | 1972 | 1538 | 272 | 0.18 | 608 | 32.9% | 1099 | 0.71 | 57.7% |
| | Total | 7 | 8.12 | 1.27 | 14432 | 8765 | 12434 | 11405 | 4065 | 10220 | 1601 | 0.16 | 3579 | | 3432 | 0.34 | |
| Coastal | Dabbling Duck | 8 | 8.43 | 3.10 | 6679 | 3761 | 1299 | 1092 | 807 | 2728 | 1002 | 0.37 | 2240 | 66.7% | 809 | 0.30 | 61.9% |
| Offshore | \| | 8 | 0.24 | 0.18 | 991 | 0 | 78 | 0 | 34 | 221 | 173 | 0.78 | 386 | 33.3% | 172 | 0.78 | 38.1% |
| | Total | 8 | 2.34 | 0.92 | 7670 | 3761 | 1378 | 1092 | 841 | 2948 | 1154 | 0.39 | 2581 | | 980 | 0.33 | |
| Coastal | Goldeneye | 9 | 44.08 | 7.94 | 15961 | 18585 | 12600 | 20162 | 3975 | 14257 | 2569 | 0.18 | 5744 | 11.0% | 2254 | 0.16 | 8.3% |
| Offshore | \| | 9 | 10.93 | 7.69 | 1545 | 606 | 42180 | 5636 | 1122 | 10218 | 7191 | 0.70 | 16080 | 89.0% | 8601 | 0.84 | 91.7% |
| | Total | 9 | 19.45 | 5.89 | 17506 | 19191 | 54780 | 25798 | 5098 | 24474 | 7408 | 0.30 | 16566 | | 10855 | 0.44 | |
| Coastal | Harlequin Duck | 10 | 3.55 | 0.53 | 1188 | 1513 | 1330 | 1306 | 410 | 1149 | 172 | 0.15 | 384 | 25.5% | 324 | 0.28 | 22.9% |
| Offshore | \| | 10 | 0.57 | 0.19 | 713 | 644 | 1094 | 0 | 204 | 531 | 173 | 0.33 | 388 | 74.5% | 377 | 0.71 | 77.1% |
| | Total | 10 | 1.34 | 0.23 | 1901 | 2157 | 2423 | 1306 | 614 | 1680 | 290 | 0.17 | 649 | | 701 | 0.42 | |

Appendix 7. Continued.

| Strata | Species | Group | Density Mean 5yrs | Density Mean SE | Population Estimate 1999 | 2000 | 2001 | 2002 | 2003 | 5 yr Mean Mean | 5 yr Mean SE | 5 yr Mean CV | Between Year Var. SD 5yrs | Between Year Var. Optimal Allocation | Mean Within Year Var. Mean SE | Mean Within Year Var. CV | Mean Within Year Var. Optimal Allocation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Coastal | Merganser | 11 | 9.88 | 1.51 | 1399 | 2766 | 3235 | 4543 | 4038 | 3196 | 487 | 0.15 | 1090 | 22.1% | 2061 | 0.64 | 47.9% |
| Offshore | \| | 11 | 1.19 | 0.64 | 40 | 341 | 3671 | 376 | 1156 | 1117 | 595 | 0.53 | 1330 | 77.9% | 776 | 0.70 | 52.1% |
| | Total | 11 | 3.43 | 0.67 | 1439 | 3106 | 6906 | 4919 | 5194 | 4313 | 839 | 0.19 | 1875 | | 2838 | 0.66 | |
| Coastal | Diving Duck | 12 | 6.44 | 1.02 | 2783 | 2106 | 2247 | 2579 | 692 | 2081 | 329 | 0.16 | 735 | 35.0% | 662 | 0.32 | 40.9% |
| Offshore | \| | 12 | 0.47 | 0.23 | 79 | 38 | 1250 | 714 | 136 | 443 | 211 | 0.48 | 472 | 65.0% | 331 | 0.75 | 59.1% |
| | Total | 12 | 2.01 | 0.34 | 2862 | 2144 | 3496 | 3293 | 828 | 2525 | 432 | 0.17 | 967 | | 992 | 0.39 | |
| Coastal | Gull | 13 | 8.84 | 3.01 | 6644 | 1692 | 3925 | 1028 | 1004 | 2859 | 972 | 0.34 | 2173 | 19.2% | 668 | 0.23 | 15.6% |
| Offshore | \| | 13 | 5.06 | 1.52 | 5151 | 3029 | 10740 | 2367 | 2380 | 4734 | 1418 | 0.30 | 3172 | 80.8% | 1254 | 0.26 | 84.4% |
| | Total | 13 | 6.03 | 1.68 | 11795 | 4721 | 14665 | 3395 | 3384 | 7592 | 2110 | 0.28 | 4717 | | 1922 | 0.25 | |
| Coastal | Black-legged Kittiwake | 14 | 2.77 | 1.41 | 2873 | 280 | 504 | 779 | 49 | 897 | 455 | 0.51 | 1017 | 9.6% | 499 | 0.56 | 6.5% |
| Offshore | \| | 14 | 3.60 | 1.58 | 9827 | 1552 | 1601 | 2968 | 884 | 3367 | 1476 | 0.44 | 3300 | 90.4% | 2466 | 0.73 | 93.5% |
| | Total | 14 | 3.39 | 1.53 | 12700 | 1832 | 2105 | 3747 | 933 | 4264 | 1930 | 0.45 | 4315 | | 2965 | 0.70 | |
| Coastal | Arctic Tern | 15 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | NA | 0 | | NA |
| Offshore | \| | 15 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | NA | 0 | | NA |
| | Total | 15 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | | 0 | | |
| Coastal | Grebe | 16 | 1.65 | 0.27 | 823 | 440 | 655 | 505 | 249 | 535 | 87 | 0.16 | 194 | 69.0% | 156 | 0.29 | 53.0% |
| Offshore | \| | 16 | 0.06 | 0.01 | 79 | 38 | 78 | 0 | 68 | 53 | 14 | 0.26 | 30 | 31.0% | 48 | 0.91 | 47.0% |
| | Total | 16 | 0.47 | 0.07 | 902 | 478 | 734 | 505 | 317 | 587 | 92 | 0.16 | 206 | | 204 | 0.35 | |
| Coastal | Loon | 17 | 0.57 | 0.14 | 368 | 160 | 125 | 181 | 79 | 183 | 44 | 0.24 | 99 | 19.4% | 49 | 0.27 | 9.3% |
| Offshore | \| | 17 | 0.36 | 0.07 | 476 | 379 | 234 | 113 | 476 | 335 | 64 | 0.19 | 142 | 80.6% | 166 | 0.49 | 90.7% |
| | Total | 17 | 0.41 | 0.07 | 844 | 539 | 359 | 294 | 555 | 518 | 86 | 0.17 | 191 | | 215 | 0.42 | |
| Coastal | Sea Lion | 18 | 0.64 | 0.11 | 145 | 268 | 330 | 196 | 102 | 208 | 37 | 0.18 | 82 | 26.1% | 76 | 0.36 | 19.6% |
| Offshore | \| | 18 | 0.20 | 0.04 | 317 | 151 | 195 | 188 | 68 | 184 | 36 | 0.20 | 80 | 73.9% | 108 | 0.58 | 80.4% |
| | Total | 18 | 0.31 | 0.04 | 462 | 420 | 525 | 384 | 170 | 392 | 54 | 0.14 | 121 | | 183 | 0.47 | |
| Coastal | Harbor Porpoise | 19 | 0.31 | 0.10 | 59 | 149 | 216 | 36 | 49 | 102 | 31 | 0.31 | 70 | 7.9% | 45 | 0.44 | 6.8% |
| Offshore | \| | 19 | 0.47 | 0.13 | 198 | 644 | 859 | 413 | 102 | 443 | 125 | 0.28 | 280 | 92.1% | 212 | 0.48 | 93.2% |
| | Total | 19 | 0.43 | 0.12 | 257 | 793 | 1075 | 449 | 151 | 545 | 154 | 0.28 | 343 | | 257 | 0.47 | |
| Coastal | Harbor Seal | 20 | 0.74 | 0.07 | 220 | 246 | 280 | 299 | 154 | 240 | 23 | 0.09 | 51 | 51.7% | 106 | 0.44 | 47.8% |
| Offshore | \| | 20 | 0.05 | 0.01 | 40 | 38 | 78 | 38 | 34 | 45 | 7 | 0.16 | 16 | 48.3% | 40 | 0.88 | 52.2% |
| | Total | 20 | 0.23 | 0.02 | 259 | 284 | 358 | 336 | 188 | 285 | 27 | 0.09 | 60 | | 146 | 0.51 | |

Appendix 7. Continued.

| | | | Density | | Population Estimate | | | | | 5 yr Mean | | | Between Year Var. | | Mean Within Year Var. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Mean | Mean | | | | | | | | | SD | Optimal | Mean | | Optimal |
| Strata | Species | Group | 5yrs | SE | 1999 | 2000 | 2001 | 2002 | 2003 | Mean | SE | CV | 5yrs | Allocation | SE | CV | Allocation |
| Coastal | Cetacean | 21 | 0.00 | 0.00 | 0 | 4 | 0 | 0 | 0 | 1 | 1 | 0.89 | 1 | 100.0% | 1 | 1.03 | 100.0% |
| Offshore | \| | 21 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| | Total | 21 | 0.00 | 0.00 | 0 | 4 | 0 | 0 | 0 | 1 | 1 | 0.89 | 1 | | 1 | 1.03 | |
| Coastal | Sea Otter | 22 | 1.00 | 0.15 | 525 | 242 | 322 | 302 | 233 | 325 | 47 | 0.15 | 106 | 35.7% | 188 | 0.58 | 49.1% |
| Offshore | \| | 22 | 0.13 | 0.03 | 0 | 151 | 156 | 188 | 102 | 120 | 29 | 0.25 | 66 | 64.3% | 68 | 0.56 | 50.9% |
| | Total | 22 | 0.35 | 0.02 | 525 | 394 | 478 | 490 | 335 | 444 | 31 | 0.07 | 70 | | 255 | 0.57 | |

Appendix 8. Summer (June) densities (num/km$^2$), population estimates, and estimates of optimal allocation of sampling effort for 10 species and 11 strata within Glacier Bay, AK.

| | | | | Density | | Population Estimate | | | | | 5 yr Mean | | | Between Year Var. | | Mean Within Year Var. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth Stata | Geog. Strata | Species | Group | Mean 5yrs | Mean SE | 1999 | 2000 | 2001 | 2002 | 2003 | Mean | SE | CV | SD 5yrs | Optimal Allocation | Mean SE | CV | Optimal Allocation |
| C | LB | Murrelet | 1 | 13.05 | 2.94 | 1634 | 506 | 876 | 498 | 671 | 837 | 189 | 0.23 | 422 | 1.9% | 199 | 0.24 | 1.5% |
| C | CB | | | 17.11 | 2.33 | 2765 | 1481 | 2394 | 2262 | 1118 | 2004 | 272 | 0.14 | 609 | 5.1% | 329 | 0.16 | 4.7% |
| C | WA | | | 10.51 | 1.01 | 785 | 586 | 1046 | 626 | 871 | 783 | 75 | 0.10 | 168 | 0.9% | 164 | 0.21 | 1.5% |
| C | EA | | | 10.58 | 1.71 | 864 | 572 | 680 | 1113 | 352 | 716 | 116 | 0.16 | 259 | 1.2% | 210 | 0.29 | 1.7% |
| S | LB | | | 29.04 | 7.10 | 2466 | 8793 | 5190 | 1467 | 5895 | 4762 | 1163 | 0.24 | 2602 | 30.2% | 796 | 0.17 | 15.8% |
| S | CB | | | 27.09 | 3.85 | 8664 | 5174 | 4112 | 4161 | 4637 | 5349 | 761 | 0.14 | 1701 | 23.8% | 1409 | 0.26 | 33.7% |
| S | WA | | | 12.62 | 2.30 | 455 | 391 | 609 | 131 | 333 | 384 | 70 | 0.18 | 156 | 0.3% | 196 | 0.51 | 0.7% |
| S | EA | | | 27.49 | 6.50 | 450 | 487 | 1143 | 248 | 1074 | 680 | 161 | 0.24 | 359 | 0.6% | 344 | 0.51 | 1.0% |
| D | CB | | | 12.83 | 1.83 | 4078 | 5145 | 1943 | 2644 | 4099 | 3582 | 511 | 0.14 | 1142 | 22.6% | 764 | 0.21 | 25.8% |
| D | WA | | | 6.78 | 1.80 | 975 | 821 | 2640 | 1005 | 647 | 1217 | 323 | 0.27 | 722 | 9.2% | 413 | 0.34 | 9.0% |
| D | EA | | | 30.09 | 7.29 | 679 | 2113 | 3437 | 965 | 1783 | 1795 | 435 | 0.24 | 973 | 4.1% | 619 | 0.34 | 4.5% |
| Total | | Murrelet | 1 | 17.57 | 1.35 | 23815 | 26067 | 24068 | 15121 | 21480 | 22110 | 1693 | 0.08 | 3785 | | 2033 | 0.09 | |
| C | LB | Other Seabird | 2 | 5.11 | 0.53 | 450 | 349 | 252 | 239 | 349 | 328 | 34 | 0.10 | 76 | 3.1% | 69 | 0.21 | 2.6% |
| C | CB | | | 12.48 | 0.41 | 1271 | 1455 | 1534 | 1589 | 1456 | 1461 | 48 | 0.03 | 108 | 8.0% | 314 | 0.21 | 21.3% |
| C | WA | | | 9.80 | 0.74 | 588 | 688 | 627 | 839 | 909 | 730 | 55 | 0.08 | 123 | 5.8% | 157 | 0.22 | 6.8% |
| C | EA | | | 11.28 | 1.33 | 1121 | 663 | 839 | 548 | 646 | 763 | 90 | 0.12 | 202 | 8.6% | 224 | 0.29 | 8.8% |
| S | LB | | | 1.08 | 0.33 | 145 | 51 | 137 | 145 | 406 | 177 | 54 | 0.30 | 120 | 12.4% | 66 | 0.37 | 6.3% |
| S | CB | | | 2.72 | 0.48 | 329 | 438 | 597 | 401 | 918 | 537 | 94 | 0.17 | 210 | 26.2% | 198 | 0.37 | 22.7% |
| S | WA | | | 3.01 | 1.32 | 65 | 0 | 102 | 33 | 259 | 92 | 40 | 0.44 | 90 | 1.7% | 58 | 0.63 | 1.0% |
| S | EA | | | 10.55 | 6.07 | 0 | 70 | 357 | 0 | 879 | 261 | 150 | 0.58 | 336 | 5.3% | 295 | 1.13 | 4.2% |
| D | CB | | | 0.86 | 0.12 | 314 | 309 | 123 | 264 | 194 | 241 | 33 | 0.14 | 73 | 12.9% | 87 | 0.36 | 14.1% |
| D | WA | | | 0.83 | 0.15 | 197 | 56 | 106 | 168 | 222 | 150 | 27 | 0.18 | 61 | 6.9% | 54 | 0.36 | 5.6% |
| D | EA | | | 3.68 | 1.79 | 81 | 110 | 105 | 106 | 696 | 220 | 107 | 0.49 | 239 | 9.0% | 191 | 0.87 | 6.6% |
| Total | | Other Seabird | 2 | 3.94 | 0.36 | 4560 | 4189 | 4780 | 4332 | 6933 | 4959 | 450 | 0.09 | 1007 | | 599 | 0.12 | |
| C | LB | Scoter | 3 | 9.36 | 1.75 | 504 | 641 | 186 | 938 | 731 | 600 | 112 | 0.19 | 251 | 0.7% | 289 | 0.48 | 1.1% |
| C | CB | | | 78.36 | 16.84 | 15254 | 8484 | 1793 | 8879 | 11464 | 9175 | 1972 | 0.21 | 4410 | 21.5% | 4814 | 0.52 | 34.2% |
| C | WA | | | 42.30 | 11.84 | 1748 | 3873 | 2025 | 6703 | 1401 | 3150 | 882 | 0.28 | 1972 | 6.1% | 1377 | 0.44 | 6.2% |
| C | EA | | | 151.67 | 44.24 | 6894 | 9047 | 23467 | 5897 | 6025 | 10266 | 2995 | 0.29 | 6696 | 18.9% | 5259 | 0.51 | 21.6% |
| S | LB | | | 0.37 | 0.19 | 145 | 10 | 0 | 0 | 149 | 61 | 31 | 0.52 | 70 | 0.5% | 45 | 0.75 | 0.5% |
| S | CB | | | 2.08 | 0.80 | 285 | 256 | 103 | 1100 | 306 | 410 | 157 | 0.38 | 352 | 2.9% | 327 | 0.80 | 3.9% |
| S | WA | | | 59.45 | 47.81 | 0 | 157 | 589 | 8302 | 0 | 1809 | 1455 | 0.80 | 3253 | 4.1% | 1578 | 0.87 | 2.9% |
| S | EA | | | 11.46 | 5.22 | 225 | 765 | 429 | 0 | 0 | 284 | 129 | 0.46 | 289 | 0.3% | 151 | 0.53 | 0.2% |
| D | CB | | | 1.41 | 0.68 | 56 | 401 | 1179 | 325 | 0 | 392 | 189 | 0.48 | 422 | 4.9% | 188 | 0.48 | 3.2% |
| D | WA | | | 2.28 | 1.03 | 1086 | 0 | 195 | 84 | 684 | 410 | 185 | 0.45 | 413 | 3.1% | 332 | 0.81 | 3.6% |
| D | EA | | | 135.42 | 111.94 | 691 | 189 | 37943 | 622 | 951 | 8079 | 6679 | 0.83 | 14934 | 37.1% | 6231 | 0.77 | 22.6% |
| Total | | Scoter | 3 | 27.52 | 6.06 | 26887 | 23823 | 67908 | 32848 | 21711 | 34635 | 7627 | 0.22 | 17054 | | 9716 | 0.28 | |

Appendix 8. Continued.

| | | | | Density | | Population Estimate | | | | | 5 yr Mean | | | Between Year Var. | | Mean Within Year Var. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth Stata | Geog. Strata | Species | Group | Mean 5yrs | Mean SE | 1999 | 2000 | 2001 | 2002 | 2003 | Mean | SE | CV | SD 5yrs | Optimal Allocation | Mean SE | CV | Optimal Allocation |
| C | LB | Dabbling Duck | 4 | 2.97 | 0.72 | 113 | 366 | 75 | 163 | 235 | 190 | 46 | 0.24 | 103 | 8.5% | 104 | 0.54 | 7.8% |
| C | CB | | | 3.43 | 1.10 | 375 | 956 | 151 | 307 | 217 | 401 | 129 | 0.32 | 288 | 43.5% | 210 | 0.52 | 28.9% |
| C | WA | | | 1.02 | 0.44 | 180 | 32 | 15 | 148 | 4 | 76 | 33 | 0.43 | 73 | 7.0% | 37 | 0.49 | 3.2% |
| C | EA | | | 17.93 | 1.90 | 1302 | 1394 | 1483 | 665 | 1223 | 1213 | 129 | 0.11 | 288 | 25.1% | 660 | 0.54 | 52.5% |
| S | LB | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | CB | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | WA | | | 1.20 | 1.07 | 182 | 0 | 0 | 0 | 0 | 36 | 33 | 0.89 | 73 | 2.9% | 39 | 1.08 | 1.4% |
| S | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | CB | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | WA | | | 0.16 | 0.14 | 0 | 0 | 0 | 140 | 0 | 28 | 25 | 0.89 | 56 | 12.9% | 29 | 1.04 | 6.1% |
| D | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| Total | | Dabbling Duck | 4 | 1.55 | 0.17 | 2152 | 2749 | 1723 | 1423 | 1679 | 1945 | 208 | 0.11 | 465 | | 703 | 0.36 | |
| C | LB | Diving Duck | 5 | 22.68 | 4.72 | 2275 | 1890 | 1798 | 534 | 775 | 1454 | 303 | 0.21 | 677 | 12.5% | 591 | 0.41 | 10.4% |
| C | CB | | | 31.35 | 2.66 | 2838 | 3346 | 3362 | 3930 | 4879 | 3671 | 311 | 0.08 | 696 | 23.5% | 969 | 0.26 | 31.2% |
| C | WA | | | 10.87 | 1.85 | 508 | 477 | 818 | 925 | 1320 | 809 | 138 | 0.17 | 309 | 6.6% | 306 | 0.38 | 6.3% |
| C | EA | | | 58.38 | 13.13 | 2450 | 2783 | 3283 | 3375 | 7868 | 3952 | 889 | 0.22 | 1987 | 38.7% | 2043 | 0.52 | 38.0% |
| S | LB | | | 0.80 | 0.34 | 185 | 72 | 10 | 40 | 347 | 131 | 55 | 0.42 | 123 | 5.8% | 68 | 0.52 | 3.1% |
| S | CB | | | 0.60 | 0.27 | 27 | 146 | 345 | 45 | 34 | 119 | 54 | 0.45 | 121 | 6.9% | 110 | 0.92 | 6.0% |
| S | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | EA | | | 1.69 | 1.51 | 0 | 209 | 0 | 0 | 0 | 42 | 37 | 0.89 | 83 | 0.6% | 49 | 1.18 | 0.3% |
| D | CB | | | 0.18 | 0.07 | 8 | 41 | 47 | 24 | 136 | 51 | 20 | 0.39 | 44 | 3.6% | 45 | 0.88 | 3.5% |
| D | WA | | | 0.07 | 0.04 | 37 | 0 | 0 | 28 | 0 | 13 | 7 | 0.56 | 16 | 0.8% | 14 | 1.04 | 0.7% |
| D | EA | | | 0.60 | 0.42 | 0 | 0 | 0 | 145 | 34 | 36 | 25 | 0.70 | 56 | 1.0% | 36 | 0.99 | 0.6% |
| Total | | Diving Duck | 5 | 8.17 | 0.92 | 8326 | 8962 | 9663 | 9045 | 15392 | 10278 | 1159 | 0.11 | 2592 | | 2362 | 0.23 | |
| C | LB | Gull | 6 | 21.42 | 4.26 | 2009 | 1444 | 2051 | 531 | 833 | 1374 | 273 | 0.20 | 611 | 3.7% | 595 | 0.43 | 4.4% |
| C | CB | | | 19.69 | 2.26 | 2504 | 1891 | 1459 | 3194 | 2478 | 2305 | 264 | 0.11 | 591 | 6.6% | 622 | 0.27 | 8.4% |
| C | WA | | | 85.21 | 25.15 | 1675 | 1829 | 6370 | 9598 | 12254 | 6345 | 1873 | 0.30 | 4188 | 29.8% | 3828 | 0.60 | 32.9% |
| C | EA | | | 86.81 | 16.52 | 3243 | 2974 | 8408 | 5796 | 8958 | 5876 | 1118 | 0.19 | 2501 | 16.2% | 1968 | 0.33 | 15.4% |
| S | LB | | | 14.29 | 2.86 | 3149 | 1297 | 1148 | 2261 | 3864 | 2344 | 469 | 0.20 | 1048 | 16.4% | 781 | 0.33 | 14.8% |
| S | CB | | | 6.19 | 0.94 | 1423 | 1132 | 1746 | 490 | 1315 | 1221 | 186 | 0.15 | 416 | 7.9% | 363 | 0.30 | 8.3% |
| S | WA | | | 3.50 | 1.05 | 26 | 39 | 162 | 213 | 93 | 107 | 32 | 0.30 | 72 | 0.2% | 70 | 0.66 | 0.2% |
| S | EA | | | 3.73 | 1.63 | 225 | 0 | 71 | 165 | 0 | 92 | 40 | 0.44 | 90 | 0.2% | 100 | 1.08 | 0.3% |
| D | CB | | | 3.53 | 0.65 | 1306 | 720 | 849 | 457 | 1589 | 984 | 183 | 0.19 | 409 | 10.9% | 330 | 0.33 | 10.6% |
| D | WA | | | 3.07 | 0.91 | 617 | 187 | 1205 | 530 | 222 | 552 | 164 | 0.30 | 367 | 6.3% | 167 | 0.30 | 3.5% |
| D | EA | | | 8.07 | 2.24 | 829 | 126 | 842 | 238 | 374 | 482 | 134 | 0.28 | 299 | 1.7% | 200 | 0.42 | 1.4% |
| Total | | Gull | 6 | 17.23 | 2.46 | 17006 | 11640 | 24310 | 23474 | 31979 | 21682 | 3091 | 0.14 | 6912 | | 4495 | 0.21 | |

Appendix 8.  Continued.

| | | | | Density | | Population Estimate | | | | | 5 yr Mean | | | Between Year Var. | | Mean Within Year Var. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth Stata | Geog. Strata | Species | Group | Mean 5yrs | Mean SE | 1999 | 2000 | 2001 | 2002 | 2003 | Mean | SE | CV | SD 5yrs | Optimal Allocation | Mean SE | CV | Optimal Allocation |
| C | LB | Loon | 7 | 0.57 | 0.10 | 33 | 51 | 55 | 26 | 18 | 37 | 6 | 0.17 | 14 | 1.5% | 10 | 0.27 | 1.3% |
| C | CB | | | 0.52 | 0.13 | 103 | 101 | 42 | 37 | 23 | 61 | 15 | 0.25 | 34 | 6.5% | 19 | 0.31 | 4.6% |
| C | WA | | | 0.48 | 0.10 | 32 | 34 | 60 | 44 | 10 | 36 | 7 | 0.20 | 16 | 2.0% | 12 | 0.35 | 2.0% |
| C | EA | | | 1.25 | 0.26 | 106 | 152 | 56 | 53 | 55 | 84 | 18 | 0.21 | 39 | 4.4% | 22 | 0.27 | 3.2% |
| S | LB | | | 1.06 | 0.32 | 137 | 388 | 196 | 66 | 79 | 173 | 52 | 0.30 | 117 | 31.6% | 104 | 0.60 | 35.9% |
| S | CB | | | 0.30 | 0.05 | 53 | 73 | 92 | 30 | 45 | 59 | 10 | 0.17 | 22 | 7.1% | 34 | 0.58 | 14.2% |
| S | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | EA | | | 0.45 | 0.41 | 56 | 0 | 0 | 0 | 0 | 11 | 10 | 0.89 | 23 | 0.9% | 12 | 1.06 | 0.6% |
| D | CB | | | 0.23 | 0.07 | 56 | 144 | 66 | 24 | 29 | 64 | 19 | 0.30 | 43 | 19.8% | 28 | 0.44 | 16.5% |
| D | WA | | | 0.30 | 0.17 | 0 | 112 | 0 | 154 | 0 | 53 | 30 | 0.56 | 66 | 19.6% | 46 | 0.86 | 17.3% |
| D | EA | | | 0.95 | 0.51 | 92 | 173 | 0 | 0 | 17 | 57 | 30 | 0.54 | 68 | 6.6% | 35 | 0.61 | 4.4% |
| Total | | Loon | 7 | 0.50 | 0.12 | 669 | 1229 | 567 | 433 | 277 | 635 | 145 | 0.23 | 325 | | 131 | 0.21 | |
| C | LB | Pinniped-Porpoise | 8 | 2.22 | 0.27 | 91 | 207 | 160 | 135 | 118 | 142 | 18 | 0.12 | 39 | 2.3% | 55 | 0.39 | 4.4% |
| C | CB | | | 1.10 | 0.23 | 65 | 233 | 151 | 87 | 109 | 129 | 27 | 0.21 | 59 | 6.4% | 47 | 0.37 | 6.8% |
| C | WA | | | 0.87 | 0.03 | 57 | 64 | 71 | 69 | 64 | 65 | 2 | 0.03 | 5 | 0.3% | 20 | 0.30 | 1.8% |
| C | EA | | | 2.93 | 0.50 | 173 | 184 | 345 | 165 | 127 | 199 | 34 | 0.17 | 75 | 4.7% | 95 | 0.48 | 8.0% |
| S | LB | | | 0.92 | 0.24 | 193 | 153 | 294 | 53 | 59 | 151 | 40 | 0.27 | 90 | 13.5% | 62 | 0.41 | 12.6% |
| S | CB | | | 1.10 | 0.43 | 80 | 304 | 551 | 104 | 45 | 217 | 85 | 0.39 | 190 | 34.3% | 124 | 0.57 | 30.3% |
| S | WA | | | 0.22 | 0.12 | 13 | 0 | 20 | 0 | 0 | 7 | 4 | 0.57 | 8 | 0.2% | 7 | 1.06 | 0.3% |
| S | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | CB | | | 0.55 | 0.18 | 89 | 216 | 75 | 48 | 339 | 153 | 49 | 0.32 | 109 | 27.9% | 71 | 0.46 | 24.7% |
| D | WA | | | 0.34 | 0.15 | 99 | 19 | 159 | 28 | 0 | 61 | 27 | 0.44 | 60 | 9.8% | 45 | 0.74 | 10.1% |
| D | EA | | | 0.21 | 0.09 | 0 | 32 | 18 | 13 | 0 | 12 | 5 | 0.43 | 12 | 0.6% | 12 | 1.00 | 0.9% |
| Total | | Pinniped-Porpoise | 8 | 0.90 | 0.15 | 859 | 1412 | 1844 | 702 | 861 | 1136 | 192 | 0.17 | 428 | | 203 | 0.18 | |
| C | LB | Cetacean | 9 | 0.05 | 0.03 | 3 | 12 | 0 | 0 | 0 | 3 | 2 | 0.68 | 5 | 3.4% | 2 | 0.66 | 2.2% |
| C | CB | | | 0.04 | 0.01 | 6 | 2 | 0 | 9 | 7 | 5 | 1 | 0.32 | 3 | 4.3% | 4 | 0.83 | 7.3% |
| C | WA | | | 0.07 | 0.04 | 0 | 8 | 0 | 2 | 17 | 5 | 3 | 0.54 | 6 | 5.3% | 3 | 0.65 | 4.2% |
| C | EA | | | 0.03 | 0.01 | 1 | 3 | 6 | 0 | 0 | 2 | 1 | 0.47 | 2 | 1.6% | 2 | 0.96 | 2.1% |
| S | LB | | | 0.02 | 0.01 | 8 | 0 | 0 | 0 | 10 | 4 | 2 | 0.55 | 4 | 8.1% | 3 | 0.96 | 9.2% |
| S | CB | | | 0.09 | 0.06 | 9 | 12 | 69 | 0 | 0 | 18 | 12 | 0.64 | 26 | 57.0% | 14 | 0.77 | 45.0% |
| S | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | CB | | | 0.02 | 0.01 | 8 | 0 | 0 | 12 | 10 | 6 | 2 | 0.38 | 5 | 15.6% | 6 | 0.98 | 26.6% |
| D | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | EA | | | 0.06 | 0.05 | 0 | 0 | 18 | 0 | 0 | 4 | 3 | 0.89 | 7 | 4.7% | 4 | 1.01 | 3.4% |
| Total | | Cetacean | 9 | 0.04 | 0.01 | 35 | 37 | 92 | 23 | 43 | 46 | 11 | 0.23 | 24 | | 17 | 0.37 | |

Appendix 8. Continued.

| | | | | Density | | Population Estimate | | | | | 5 yr Mean | | | Between Year Var. | | Mean Within Year Var. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth Stata | Geog. Strata | Species | Group | Mean 5yrs | Mean SE | 1999 | 2000 | 2001 | 2002 | 2003 | Mean | SE | CV | SD 5yrs | Optimal Allocation | Mean SE | CV | Optimal Allocation |
| C | LB | Sea Otter | 10 | 2.53 | 0.60 | 80 | 160 | 277 | 55 | 240 | 162 | 39 | 0.24 | 87 | 4.8% | 116 | 0.72 | 8.4% |
| C | CB | | | 0.40 | 0.23 | 3 | 71 | 3 | 154 | 5 | 47 | 27 | 0.56 | 59 | 6.0% | 45 | 0.96 | 6.0% |
| C | WA | | | 0.01 | 0.00 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0.89 | 1 | 0.0% | 0 | 1.05 | 0.0% |
| C | EA | | | 0.01 | 0.01 | 0 | 0 | 0 | 4 | 0 | 1 | 1 | 0.89 | 1 | 0.1% | 1 | 0.80 | 0.0% |
| S | LB | | | 1.47 | 0.59 | 72 | 51 | 186 | 648 | 248 | 241 | 97 | 0.40 | 216 | 30.5% | 169 | 0.70 | 31.3% |
| S | CB | | | 1.26 | 0.56 | 0 | 73 | 333 | 149 | 692 | 249 | 111 | 0.44 | 247 | 42.0% | 191 | 0.77 | 42.6% |
| S | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | CB | | | 0.14 | 0.11 | 177 | 0 | 0 | 24 | 0 | 40 | 31 | 0.77 | 69 | 16.6% | 37 | 0.91 | 11.6% |
| D | WA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | EA | | | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| Total | | Sea Otter | 10 | 0.59 | 0.12 | 332 | 355 | 799 | 1035 | 1184 | 741 | 155 | 0.21 | 347 | | 286 | 0.39 | |

Appendix 9. Summer (June) densities (num/km$^2$), population estimates, and estimates of optimal allocation of sampling effort for 10 species and 2 strata within Glacier Bay, AK.

| | | | Density | | Population Estimate | | | | | 5 yr Mean | | | Between Year Var. | | Within Year Var. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Strata | Species | Group | Mean 5yrs | Mean SE | 1999 | 2000 | 2001 | 2002 | 2003 | Mean | SE | CV | SD 5yrs | Optimal Allocation | Mean SE | CV | Optimal Allocation |
| Coastal | Murrelet | 1 | 13.48 | 1.61 | 6049 | 3154 | 5101 | 4507 | 2991 | 4360 | 520 | 0.12 | 1162 | 8.0% | 529 | 0.12 | 6.6% |
| Offshore | \| | 1 | 19.37 | 2.20 | 18443 | 24910 | 17588 | 10477 | 19156 | 18115 | 2059 | 0.11 | 4604 | 92.0% | 2583 | 0.14 | 93.4% |
| | Total | 1 | 17.86 | 1.52 | 24492 | 28064 | 22688 | 14984 | 22146 | 22475 | 1914 | 0.09 | 4280 | | 3112 | 0.14 | |
| Coastal | Other Seabird | 2 | 10.13 | 0.17 | 3486 | 3144 | 3276 | 3178 | 3291 | 3275 | 53 | 0.02 | 120 | 6.4% | 458 | 0.14 | 32.3% |
| Offshore | \| | 2 | 1.52 | 0.29 | 1143 | 1026 | 1197 | 1120 | 2617 | 1421 | 269 | 0.19 | 601 | 93.6% | 332 | 0.23 | 67.7% |
| | Total | 2 | 3.73 | 0.22 | 4630 | 4170 | 4473 | 4298 | 5907 | 4696 | 280 | 0.06 | 625 | | 790 | 0.17 | |
| Coastal | Scoter | 3 | 70.93 | 2.96 | 25517 | 22409 | 25061 | 22023 | 19682 | 22938 | 956 | 0.04 | 2139 | 6.8% | 8496 | 0.37 | 32.7% |
| Offshore | \| | 3 | 8.88 | 4.86 | 1959 | 1151 | 27780 | 9015 | 1620 | 8305 | 4543 | 0.55 | 10158 | 93.2% | 6038 | 0.73 | 67.3% |
| | Total | 3 | 24.83 | 4.02 | 27475 | 23560 | 52841 | 31039 | 21303 | 31244 | 5054 | 0.16 | 11301 | | 14533 | 0.47 | |
| Coastal | Dabbling Duck | 4 | 5.92 | 0.77 | 2039 | 2918 | 1586 | 1289 | 1741 | 1915 | 249 | 0.13 | 557 | 74.6% | 830 | 0.43 | 84.2% |
| Offshore | \| | 4 | 0.06 | 0.03 | 131 | 0 | 0 | 137 | 0 | 54 | 29 | 0.55 | 66 | 25.4% | 54 | 1.01 | 15.8% |
| | Total | 4 | 1.56 | 0.19 | 2171 | 2918 | 1586 | 1425 | 1741 | 1968 | 240 | 0.12 | 536 | | 885 | 0.45 | |
| Coastal | Diving Duck | 5 | 30.87 | 3.47 | 8110 | 8863 | 9233 | 8770 | 14944 | 9984 | 1121 | 0.11 | 2506 | 86.3% | 2782 | 0.28 | 82.2% |
| Offshore | \| | 5 | 0.42 | 0.07 | 281 | 325 | 427 | 287 | 648 | 394 | 62 | 0.16 | 138 | 13.7% | 209 | 0.53 | 17.8% |
| | Total | 5 | 8.25 | 0.94 | 8391 | 9189 | 9660 | 9056 | 15592 | 10378 | 1180 | 0.11 | 2639 | | 2991 | 0.29 | |
| Coastal | Gull | 6 | 47.12 | 7.72 | 9458 | 8249 | 17072 | 18418 | 22989 | 15237 | 2496 | 0.16 | 5582 | 50.9% | 4784 | 0.31 | 56.0% |
| Offshore | \| | 6 | 6.48 | 0.89 | 7891 | 3879 | 5736 | 4275 | 8510 | 6058 | 834 | 0.14 | 1865 | 49.1% | 1298 | 0.21 | 44.0% |
| | Total | 6 | 16.92 | 2.29 | 17349 | 12127 | 22808 | 22693 | 31499 | 21295 | 2884 | 0.14 | 6449 | | 6082 | 0.29 | |
| Coastal | Loon | 7 | 0.68 | 0.12 | 281 | 353 | 208 | 158 | 109 | 222 | 39 | 0.17 | 87 | 10.3% | 41 | 0.18 | 8.0% |
| Offshore | \| | 7 | 0.47 | 0.13 | 366 | 938 | 415 | 273 | 192 | 437 | 117 | 0.27 | 262 | 89.7% | 164 | 0.37 | 92.0% |
| | Total | 7 | 0.52 | 0.12 | 646 | 1291 | 622 | 431 | 301 | 658 | 152 | 0.23 | 341 | | 205 | 0.31 | |
| Coastal | Pinniped-Porpoise | 8 | 1.67 | 0.19 | 386 | 713 | 702 | 462 | 428 | 539 | 63 | 0.12 | 140 | 13.7% | 137 | 0.25 | 18.3% |
| Offshore | \| | 8 | 0.69 | 0.15 | 497 | 801 | 1150 | 246 | 540 | 647 | 137 | 0.21 | 307 | 86.3% | 212 | 0.33 | 81.7% |
| | Total | 8 | 0.94 | 0.15 | 883 | 1514 | 1852 | 708 | 968 | 1185 | 192 | 0.16 | 429 | | 349 | 0.29 | |
| Coastal | Cetacean | 9 | 0.04 | 0.01 | 10 | 25 | 5 | 11 | 21 | 14 | 3 | 0.23 | 7 | 9.0% | 7 | 0.51 | 10.4% |
| Offshore | \| | 9 | 0.03 | 0.01 | 28 | 13 | 83 | 14 | 24 | 32 | 12 | 0.36 | 26 | 91.0% | 22 | 0.68 | 89.6% |
| | Total | 9 | 0.04 | 0.01 | 39 | 38 | 88 | 24 | 45 | 47 | 10 | 0.21 | 22 | | 29 | 0.63 | |
| Coastal | Sea Otter | 10 | 0.68 | 0.11 | 75 | 244 | 286 | 220 | 281 | 221 | 34 | 0.16 | 77 | 7.5% | 151 | 0.68 | 13.0% |
| Offshore | \| | 10 | 0.61 | 0.16 | 291 | 138 | 569 | 833 | 1032 | 572 | 148 | 0.26 | 331 | 92.5% | 350 | 0.61 | 87.0% |
| | Total | 10 | 0.63 | 0.13 | 365 | 382 | 855 | 1053 | 1313 | 793 | 167 | 0.21 | 373 | | 500 | 0.63 | |

Appendix 10. Winter (Nov. 1999 or March 2000-2003) densities (num/km$^2$), population estimates, and estimates of optimal allocation of sampling effort for 10 species and 11 strata within Glacier Bay, AK.

| | | | | Density | | Population Estimate | | | | | 5 yr Mean | | | Between Year Var. | | Within Year Var. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth Strata | Geog. Strata | Species | Group | Mean 5yrs | Mean SE | 1999 | 2000 | 2001 | 2002 | 2003 | Mean | SE | CV | SD 5yrs | Optimal Allocation | Mean SE | CV | Optimal Allocation |
| C | LB | Murrelet | 1 | 1.06 | 0.33 | 152 | 48 | 36 | 84 | 21 | 68 | 21 | 0.31 | 47 | 0.4% | 37 | 0.54 | 0.5% |
| C | CB | | 1 | 1.48 | 0.54 | 104 | 254 | 414 | 73 | 24 | 174 | 64 | 0.37 | 142 | 2.5% | 77 | 0.45 | 2.0% |
| C | WA | | 1 | 3.97 | 2.09 | 67 | 986 | 140 | 184 | 102 | 296 | 155 | 0.53 | 347 | 3.8% | 155 | 0.52 | 2.5% |
| C | EA | | 1 | 5.87 | 2.08 | 57 | 854 | 460 | 582 | 33 | 397 | 141 | 0.35 | 315 | 3.1% | 189 | 0.48 | 2.8% |
| S | LB | | 1 | 3.99 | 1.77 | 711 | 297 | 1881 | 306 | 74 | 654 | 289 | 0.44 | 647 | 15.7% | 458 | 0.70 | 16.6% |
| S | CB | | 1 | 4.44 | 1.52 | 1193 | 648 | 2024 | 199 | 320 | 877 | 299 | 0.34 | 669 | 19.5% | 370 | 0.42 | 16.1% |
| S | WA | | 1 | 18.37 | 10.77 | 0 | 1983 | 521 | 165 | 126 | 559 | 328 | 0.59 | 733 | 3.3% | 293 | 0.52 | 2.0% |
| S | EA | | 1 | 13.43 | 6.33 | 87 | 951 | 141 | 482 | 0 | 332 | 157 | 0.47 | 350 | 1.3% | 204 | 0.61 | 1.1% |
| D | CB | | 1 | 1.21 | 0.34 | 37 | 291 | 659 | 228 | 468 | 337 | 95 | 0.28 | 212 | 8.8% | 166 | 0.49 | 10.2% |
| D | WA | | 1 | 7.02 | 3.30 | 121 | 1798 | 3622 | 590 | 175 | 1261 | 593 | 0.47 | 1326 | 35.2% | 1012 | 0.80 | 40.1% |
| D | EA | | 1 | 11.87 | 5.38 | 0 | 643 | 2005 | 800 | 95 | 708 | 321 | 0.45 | 717 | 6.3% | 456 | 0.64 | 6.0% |
| Total | | Murrelet | 1 | 4.50 | 1.42 | 2529 | 8751 | 11903 | 3693 | 1437 | 5663 | 1789 | 0.32 | 4001 | | 1341 | 0.24 | |
| C | LB | Seabird | 2 | 14.95 | 1.99 | 1109 | 1267 | 1085 | 897 | 437 | 959 | 128 | 0.13 | 286 | 5.0% | 185 | 0.19 | 4.3% |
| C | CB | | 2 | 6.55 | 0.89 | 701 | 632 | 1228 | 682 | 592 | 767 | 104 | 0.14 | 234 | 7.4% | 231 | 0.30 | 9.8% |
| C | WA | | 2 | 3.86 | 1.16 | 145 | 259 | 175 | 667 | 192 | 288 | 86 | 0.30 | 193 | 3.9% | 134 | 0.47 | 3.6% |
| C | EA | | 2 | 9.99 | 4.68 | 76 | 770 | 111 | 2002 | 421 | 676 | 317 | 0.47 | 709 | 13.0% | 358 | 0.53 | 8.8% |
| S | LB | | 2 | 4.99 | 1.44 | 604 | 446 | 1812 | 887 | 345 | 819 | 237 | 0.29 | 529 | 23.4% | 354 | 0.43 | 21.0% |
| S | CB | | 2 | 4.89 | 0.87 | 645 | 389 | 1349 | 1313 | 1133 | 966 | 171 | 0.18 | 383 | 20.4% | 403 | 0.42 | 28.8% |
| S | WA | | 2 | 19.96 | 12.90 | 98 | 124 | 58 | 413 | 2345 | 608 | 393 | 0.65 | 878 | 7.2% | 426 | 0.70 | 4.7% |
| S | EA | | 2 | 2.88 | 0.74 | 0 | 124 | 87 | 62 | 83 | 71 | 18 | 0.26 | 41 | 0.3% | 53 | 0.74 | 0.5% |
| D | CB | | 2 | 0.70 | 0.22 | 411 | 0 | 183 | 137 | 252 | 197 | 60 | 0.31 | 135 | 10.2% | 95 | 0.49 | 9.7% |
| D | WA | | 2 | 0.87 | 0.41 | 0 | 150 | 0 | 454 | 175 | 156 | 74 | 0.48 | 166 | 8.1% | 129 | 0.82 | 8.4% |
| D | EA | | 2 | 0.76 | 0.58 | 0 | 0 | 26 | 200 | 0 | 45 | 35 | 0.77 | 78 | 1.3% | 24 | 0.54 | 0.5% |
| Total | | Seabird | 2 | 4.41 | 0.51 | 3789 | 4160 | 6114 | 7714 | 5975 | 5550 | 639 | 0.12 | 1429 | | 855 | 0.15 | |
| C | LB | Scoter | 3 | 25.60 | 4.89 | 1332 | 2142 | 2260 | 2076 | 400 | 1642 | 314 | 0.19 | 701 | 6.3% | 450 | 0.27 | 5.9% |
| C | CB | | 3 | 34.94 | 10.49 | 8291 | 2985 | 6086 | 2535 | 559 | 4091 | 1229 | 0.30 | 2747 | 45.2% | 1661 | 0.41 | 39.7% |
| C | WA | | 3 | 8.54 | 6.00 | 2613 | 425 | 0 | 53 | 90 | 636 | 447 | 0.70 | 1000 | 10.5% | 330 | 0.52 | 5.0% |
| C | EA | | 3 | 23.74 | 6.30 | 1421 | 1637 | 840 | 3389 | 747 | 1607 | 426 | 0.27 | 953 | 9.1% | 646 | 0.40 | 8.9% |
| S | LB | | 3 | 0.75 | 0.51 | 0 | 0 | 488 | 31 | 99 | 123 | 83 | 0.67 | 186 | 4.3% | 99 | 0.80 | 3.3% |
| S | CB | | 3 | 5.31 | 1.10 | 903 | 259 | 964 | 1552 | 1569 | 1049 | 217 | 0.21 | 485 | 13.4% | 808 | 0.77 | 32.6% |
| S | WA | | 3 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | EA | | 3 | 1.86 | 0.93 | 58 | 0 | 33 | 140 | 0 | 46 | 23 | 0.50 | 52 | 0.2% | 34 | 0.75 | 0.2% |
| D | CB | | 3 | 0.08 | 0.07 | 0 | 0 | 110 | 0 | 0 | 22 | 20 | 0.89 | 44 | 1.7% | 16 | 0.72 | 0.9% |
| D | WA | | 3 | 1.01 | 0.90 | 905 | 0 | 0 | 0 | 0 | 181 | 162 | 0.89 | 362 | 9.1% | 88 | 0.49 | 3.2% |
| D | EA | | 3 | 0.35 | 0.20 | 0 | 38 | 0 | 67 | 0 | 21 | 12 | 0.58 | 27 | 0.2% | 19 | 0.91 | 0.2% |
| Total | | Scoter | 3 | 7.48 | 1.41 | 15523 | 7486 | 10780 | 9842 | 3463 | 9419 | 1772 | 0.19 | 3962 | | 2040 | 0.22 | |

Appendix 10. Continued.

| Depth Strata | Geog. Strata | Species | Group | Density Mean 5yrs | Density Mean SE | Population Estimate 1999 | 2000 | 2001 | 2002 | 2003 | 5 yr Mean Mean | SE | CV | Between Year Var. SD 5yrs | Optimal Allocation | Within Year Var. Mean SE | CV | Optimal Allocation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C | LB | Dabbling Duck | 4 | 8.09 | 2.10 | 773 | 902 | 500 | 368 | 51 | 519 | 135 | 0.26 | 301 | 9.9% | 175 | 0.34 | 11.7% |
| C | CB | | 4 | 5.45 | 1.94 | 1166 | 1306 | 158 | 88 | 474 | 638 | 227 | 0.35 | 507 | 30.4% | 288 | 0.45 | 35.1% |
| C | WA | | 4 | 2.59 | 1.67 | 723 | 218 | 23 | 0 | 0 | 193 | 124 | 0.64 | 277 | 10.6% | 116 | 0.60 | 9.0% |
| C | EA | | 4 | 13.36 | 6.92 | 2951 | 801 | 119 | 339 | 312 | 904 | 468 | 0.52 | 1047 | 36.3% | 478 | 0.53 | 33.7% |
| S | LB | | 4 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | CB | | 4 | 0.26 | 0.23 | 258 | 0 | 0 | 0 | 0 | 52 | 46 | 0.89 | 103 | 10.4% | 43 | 0.83 | 8.8% |
| S | WA | | 4 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | EA | | 4 | 4.47 | 3.44 | 490 | 0 | 22 | 0 | 42 | 111 | 85 | 0.77 | 190 | 2.4% | 60 | 0.54 | 1.5% |
| D | CB | | 4 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | WA | | 4 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | EA | | 4 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| Total | | Dabbling Duck | 4 | 1.92 | 0.77 | 6361 | 3227 | 822 | 795 | 879 | 2417 | 975 | 0.40 | 2180 | | 600 | 0.25 | |
| C | LB | Diving Duck | 5 | 53.94 | 9.95 | 3946 | 4417 | 4053 | 4259 | 623 | 3460 | 639 | 0.18 | 1428 | 6.6% | 664 | 0.19 | 4.5% |
| C | CB | | 5 | 61.75 | 11.27 | 8951 | 7021 | 6896 | 11099 | 2184 | 7230 | 1320 | 0.18 | 2951 | 24.9% | 1570 | 0.22 | 19.3% |
| C | WA | | 5 | 60.71 | 11.70 | 4215 | 7077 | 3648 | 6141 | 1525 | 4521 | 872 | 0.19 | 1949 | 10.5% | 2046 | 0.45 | 16.0% |
| C | EA | | 5 | 84.36 | 10.48 | 4105 | 6657 | 4017 | 8206 | 5564 | 5710 | 710 | 0.12 | 1587 | 7.7% | 1778 | 0.31 | 12.6% |
| S | LB | | 5 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | CB | | 5 | 5.05 | 0.69 | 774 | 1004 | 1124 | 597 | 1482 | 996 | 136 | 0.14 | 304 | 4.3% | 582 | 0.58 | 12.1% |
| S | WA | | 5 | 1.90 | 1.70 | 0 | 289 | 0 | 0 | 0 | 58 | 52 | 0.89 | 116 | 0.3% | 31 | 0.53 | 0.1% |
| S | EA | | 5 | 49.11 | 14.51 | 1038 | 207 | 2631 | 1369 | 832 | 1215 | 359 | 0.30 | 803 | 1.4% | 293 | 0.24 | 0.8% |
| D | CB | | 5 | 0.31 | 0.19 | 0 | 0 | 293 | 0 | 144 | 87 | 52 | 0.60 | 117 | 2.4% | 61 | 0.70 | 1.8% |
| D | WA | | 5 | 0.05 | 0.05 | 0 | 0 | 0 | 45 | 0 | 9 | 8 | 0.89 | 18 | 0.2% | 7 | 0.79 | 0.1% |
| D | EA | | 5 | 91.41 | 72.52 | 0 | 0 | 24706 | 2499 | 63 | 5453 | 4326 | 0.79 | 9674 | 41.6% | 5215 | 0.96 | 32.7% |
| Total | | Diving Duck | 5 | 22.84 | 4.15 | 23028 | 26672 | 47369 | 34215 | 12417 | 28740 | 5217 | 0.18 | 11665 | | 6154 | 0.21 | |
| C | LB | Gull | 6 | 17.74 | 12.02 | 4581 | 459 | 251 | 208 | 190 | 1138 | 771 | 0.68 | 1724 | 8.7% | 381 | 0.33 | 3.4% |
| C | CB | | 6 | 8.41 | 2.57 | 1718 | 664 | 1866 | 299 | 377 | 985 | 300 | 0.31 | 672 | 6.2% | 346 | 0.35 | 5.6% |
| C | WA | | 6 | 14.38 | 4.24 | 1468 | 965 | 316 | 2211 | 395 | 1071 | 316 | 0.29 | 706 | 4.1% | 377 | 0.35 | 3.9% |
| C | EA | | 6 | 10.97 | 5.28 | 705 | 233 | 2298 | 257 | 220 | 743 | 357 | 0.48 | 798 | 4.3% | 211 | 0.28 | 2.0% |
| S | LB | | 6 | 16.85 | 8.42 | 8815 | 1560 | 2230 | 643 | 566 | 2763 | 1381 | 0.50 | 3088 | 39.9% | 1816 | 0.66 | 41.2% |
| S | CB | | 6 | 7.15 | 1.40 | 1387 | 874 | 1285 | 2587 | 930 | 1413 | 277 | 0.20 | 620 | 9.6% | 743 | 0.53 | 20.3% |
| S | WA | | 6 | 12.33 | 3.40 | 636 | 207 | 116 | 248 | 670 | 375 | 103 | 0.28 | 231 | 0.6% | 175 | 0.47 | 0.7% |
| S | EA | | 6 | 4.67 | 2.04 | 29 | 41 | 326 | 140 | 42 | 116 | 50 | 0.44 | 113 | 0.2% | 54 | 0.47 | 0.2% |
| D | CB | | 6 | 3.15 | 0.50 | 1157 | 983 | 879 | 1094 | 288 | 880 | 139 | 0.16 | 311 | 6.8% | 215 | 0.24 | 8.3% |
| D | WA | | 6 | 6.76 | 2.15 | 2352 | 649 | 2173 | 545 | 350 | 1214 | 386 | 0.32 | 863 | 12.2% | 454 | 0.37 | 11.3% |
| D | EA | | 6 | 16.22 | 11.51 | 194 | 227 | 4035 | 67 | 315 | 968 | 687 | 0.71 | 1536 | 7.2% | 375 | 0.39 | 3.1% |
| Total | | Gull | 6 | 9.27 | 2.43 | 23041 | 6861 | 15774 | 8297 | 4344 | 11664 | 3061 | 0.26 | 6846 | | 2174 | 0.19 | |

Appendix 10. Continued.

| Depth Strata | Geog. Strata | Species | Group | Density Mean 5yrs | Density Mean SE | Population Estimate 1999 | 2000 | 2001 | 2002 | 2003 | 5 yr Mean Mean | SE | CV | Between Year Var. SD 5yrs | Optimal Allocation | Within Year Var. Mean SE | CV | Optimal Allocation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C | LB | Loon | 7 | 1.99 | 0.32 | 189 | 109 | 136 | 152 | 53 | 128 | 20 | 0.16 | 46 | 3.8% | 41 | 0.32 | 3.5% |
| C | CB | | 7 | 3.02 | 0.39 | 519 | 263 | 370 | 391 | 227 | 354 | 46 | 0.13 | 103 | 15.6% | 102 | 0.29 | 15.9% |
| C | WA | | 7 | 0.95 | 0.66 | 289 | 21 | 0 | 9 | 34 | 71 | 49 | 0.70 | 110 | 10.6% | 22 | 0.31 | 2.1% |
| C | EA | | 7 | 1.83 | 0.55 | 234 | 141 | 186 | 37 | 20 | 124 | 37 | 0.30 | 83 | 7.3% | 73 | 0.59 | 6.6% |
| S | LB | | 7 | 0.42 | 0.17 | 36 | 149 | 139 | 0 | 25 | 70 | 28 | 0.40 | 62 | 13.1% | 60 | 0.87 | 13.2% |
| S | CB | | 7 | 0.89 | 0.24 | 258 | 97 | 96 | 80 | 349 | 176 | 48 | 0.27 | 108 | 27.6% | 111 | 0.63 | 29.2% |
| S | WA | | 7 | 0.50 | 0.29 | 49 | 0 | 0 | 28 | 0 | 15 | 9 | 0.58 | 20 | 0.8% | 12 | 0.79 | 0.5% |
| S | EA | | 7 | 0.23 | 0.21 | 29 | 0 | 0 | 0 | 0 | 6 | 5 | 0.89 | 12 | 0.4% | 7 | 1.19 | 0.2% |
| D | CB | | 7 | 0.26 | 0.08 | 112 | 146 | 73 | 0 | 36 | 73 | 23 | 0.32 | 52 | 18.8% | 74 | 1.00 | 27.4% |
| D | WA | | 7 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | EA | | 7 | 0.30 | 0.19 | 0 | 0 | 26 | 0 | 63 | 18 | 11 | 0.62 | 25 | 1.9% | 15 | 0.86 | 1.2% |
| Total | | Loon | 7 | 0.82 | 0.13 | 1714 | 925 | 1027 | 696 | 806 | 1034 | 160 | 0.15 | 358 | | 199 | 0.19 | |
| | | | | | | | | | | | | | | | | | | |
| C | LB | Pinniped-Porpoise | 8 | 1.16 | 0.20 | 127 | 68 | 47 | 80 | 51 | 75 | 13 | 0.17 | 29 | 1.7% | 24 | 0.32 | 1.9% |
| C | CB | | 8 | 1.38 | 0.22 | 141 | 254 | 198 | 96 | 118 | 161 | 26 | 0.16 | 57 | 6.3% | 56 | 0.34 | 8.2% |
| C | WA | | 8 | 1.46 | 0.43 | 78 | 239 | 70 | 123 | 34 | 109 | 32 | 0.29 | 71 | 5.0% | 50 | 0.46 | 4.6% |
| C | EA | | 8 | 3.38 | 1.18 | 60 | 183 | 559 | 254 | 89 | 229 | 80 | 0.35 | 179 | 11.4% | 72 | 0.31 | 6.1% |
| S | LB | | 8 | 0.80 | 0.40 | 71 | 0 | 418 | 92 | 74 | 131 | 66 | 0.50 | 147 | 22.7% | 57 | 0.43 | 11.6% |
| S | CB | | 8 | 0.85 | 0.20 | 194 | 259 | 257 | 40 | 87 | 167 | 40 | 0.24 | 89 | 16.6% | 102 | 0.61 | 25.3% |
| S | WA | | 8 | 1.15 | 0.84 | 147 | 0 | 0 | 28 | 0 | 35 | 25 | 0.73 | 57 | 1.6% | 14 | 0.40 | 0.5% |
| S | EA | | 8 | 0.97 | 0.51 | 29 | 0 | 76 | 16 | 0 | 24 | 13 | 0.52 | 28 | 0.7% | 20 | 0.82 | 0.6% |
| D | CB | | 8 | 0.17 | 0.05 | 37 | 73 | 37 | 91 | 0 | 48 | 14 | 0.30 | 32 | 8.3% | 35 | 0.73 | 12.1% |
| D | WA | | 8 | 0.78 | 0.30 | 60 | 300 | 66 | 272 | 0 | 140 | 55 | 0.39 | 122 | 20.6% | 107 | 0.77 | 24.2% |
| D | EA | | 8 | 1.62 | 0.66 | 0 | 227 | 156 | 100 | 0 | 97 | 40 | 0.41 | 89 | 5.0% | 64 | 0.66 | 4.8% |
| Total | | Pinniped-Porpoise | 8 | 0.97 | 0.18 | 944 | 1602 | 1884 | 1190 | 453 | 1214 | 224 | 0.18 | 501 | | 206 | 0.17 | |
| | | | | | | | | | | | | | | | | | | |
| C | LB | Cetacean | 9 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| C | CB | | 9 | 0.01 | 0.01 | 0 | 5 | 0 | 0 | 0 | 1 | 1 | 0.89 | 2 | 100.0% | 1 | 1.07 | 100.0% |
| C | WA | | 9 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| C | EA | | 9 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | LB | | 9 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | CB | | 9 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | WA | | 9 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | EA | | 9 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | CB | | 9 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | WA | | 9 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | EA | | 9 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| Total | | Cetacean | 9 | 0.00 | 0.00 | 0 | 5 | 0 | 0 | 0 | 1 | 1 | 0.89 | 2 | | 1 | 1.07 | |

Appendix 10. Continued.

| | | | | Density | | Population Estimate | | | | | 5 yr Mean | | | Between Year Var. | | Within Year Var. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth Strata | Geog. Strata | Species | Group | Mean 5yrs | Mean SE | 1999 | 2000 | 2001 | 2002 | 2003 | Mean | SE | CV | SD 5yrs | Optimal Allocation | Mean SE | CV | Optimal Allocation |
| C | LB | Sea Otter | 10 | 2.85 | 0.68 | 375 | 145 | 151 | 143 | 101 | 183 | 44 | 0.24 | 98 | 21.0% | 107 | 0.59 | 32.3% |
| C | CB | | 10 | 0.11 | 0.05 | 4 | 5 | 9 | 38 | 8 | 13 | 6 | 0.45 | 13 | 5.1% | 10 | 0.76 | 5.3% |
| C | WA | | 10 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| C | EA | | 10 | 0.02 | 0.02 | 0 | 0 | 0 | 0 | 7 | 1 | 1 | 0.89 | 3 | 0.6% | 1 | 0.95 | 0.4% |
| S | LB | | 10 | 0.52 | 0.19 | 0 | 74 | 209 | 92 | 49 | 85 | 31 | 0.37 | 69 | 38.2% | 37 | 0.43 | 28.2% |
| S | CB | | 10 | 0.18 | 0.07 | 0 | 65 | 32 | 80 | 0 | 35 | 15 | 0.41 | 33 | 21.6% | 29 | 0.83 | 27.2% |
| S | WA | | 10 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| S | EA | | 10 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | CB | | 10 | 0.03 | 0.02 | 0 | 0 | 0 | 0 | 36 | 7 | 6 | 0.89 | 14 | 13.5% | 5 | 0.70 | 6.6% |
| D | WA | | 10 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| D | EA | | 10 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| Total | | Sea Otter | 10 | 0.26 | 0.03 | 380 | 289 | 401 | 353 | 201 | 324 | 32 | 0.10 | 72 | | 118 | 0.36 | |

Appendix 11. Winter (Nov. 1999 or March 2000-2003) densities (num/km$^2$), population estimates, and estimates of optimal allocation of sampling effort for 10 species and 2 strata within Glacier Bay, AK.

| | | | Density | | Population Estimate | | | | | 5 yr Mean | | | Between Year Var. | | Mean Within Year Var. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Strata | Species | Group | Mean 5yrs | Mean SE | 1999 | 2000 | 2001 | 2002 | 2003 | Mean | SE | CV | SD 5yrs | Optimal Allocation | Mean SE | CV | Optimal Allocation |
| Coastal | Murrelet | 1 | 2.58 | 0.81 | 416 | 1853 | 917 | 854 | 128 | 833 | 262 | 0.31 | 586 | 6.0% | 283 | 0.34 | 5.9% |
| Offshore | \| | 1 | 5.04 | 1.52 | 2496 | 6058 | 10233 | 3532 | 1224 | 4709 | 1425 | 0.30 | 3186 | 94.0% | 1559 | 0.33 | 94.1% |
| | Total | 1 | 4.40 | 1.26 | 2912 | 7910 | 11149 | 4386 | 1352 | 5542 | 1586 | 0.29 | 3546 | | 1842 | 0.33 | |
| Coastal | Other Seabird | 2 | 9.91 | 1.31 | 2364 | 3787 | 3482 | 4490 | 1906 | 3206 | 422 | 0.13 | 945 | 23.1% | 785 | 0.24 | 21.2% |
| Offshore | \| | 2 | 3.07 | 0.52 | 1981 | 1249 | 3242 | 3757 | 4115 | 2869 | 485 | 0.17 | 1085 | 76.9% | 1012 | 0.35 | 78.8% |
| | Total | 2 | 4.83 | 0.48 | 4345 | 5036 | 6723 | 8247 | 6020 | 6074 | 607 | 0.10 | 1357 | | 1797 | 0.30 | |
| Coastal | Scoter | 3 | 26.85 | 4.95 | 12649 | 8424 | 10755 | 9489 | 2093 | 8682 | 1602 | 0.18 | 3582 | 67.1% | 2332 | 0.27 | 42.3% |
| Offshore | \| | 3 | 1.65 | 0.29 | 1783 | 341 | 1679 | 1916 | 1972 | 1538 | 272 | 0.18 | 608 | 32.9% | 1099 | 0.71 | 57.7% |
| | Total | 3 | 8.12 | 1.27 | 14432 | 8765 | 12434 | 11405 | 4065 | 10220 | 1601 | 0.16 | 3579 | | 3432 | 0.34 | |
| Coastal | Dabbling Duck | 4 | 8.43 | 3.10 | 6679 | 3761 | 1299 | 1092 | 807 | 2728 | 1002 | 0.37 | 2240 | 66.7% | 809 | 0.30 | 61.9% |
| Offshore | \| | 4 | 0.24 | 0.18 | 991 | 0 | 78 | 0 | 34 | 221 | 173 | 0.78 | 386 | 33.3% | 172 | 0.78 | 38.1% |
| | Total | 4 | 2.34 | 0.92 | 7670 | 3761 | 1378 | 1092 | 841 | 2948 | 1154 | 0.39 | 2581 | | 980 | 0.33 | |
| Coastal | Diving Duck | 5 | 63.96 | 9.11 | 21331 | 24970 | 19411 | 28590 | 9115 | 20683 | 2944 | 0.14 | 6584 | 11.2% | 3334 | 0.16 | 11.3% |
| Offshore | \| | 5 | 13.16 | 8.62 | 2378 | 1628 | 48195 | 6726 | 2618 | 12309 | 8064 | 0.66 | 18031 | 88.8% | 9011 | 0.73 | 88.7% |
| | Total | 5 | 26.22 | 6.71 | 23708 | 26598 | 67606 | 35316 | 11734 | 32992 | 8444 | 0.26 | 18881 | | 12344 | 0.37 | |
| Coastal | Gull | 6 | 11.61 | 4.28 | 9517 | 1972 | 4429 | 1807 | 1053 | 3755 | 1385 | 0.37 | 3096 | 18.7% | 971 | 0.26 | 9.8% |
| Offshore | \| | 6 | 8.66 | 2.23 | 14978 | 4581 | 12342 | 5336 | 3265 | 8100 | 2085 | 0.26 | 4663 | 81.3% | 3098 | 0.38 | 90.2% |
| | Total | 6 | 9.42 | 2.71 | 24495 | 6553 | 16770 | 7143 | 4318 | 11856 | 3412 | 0.29 | 7630 | | 4069 | 0.34 | |
| Coastal | Loon | 7 | 2.22 | 0.39 | 1192 | 600 | 780 | 687 | 328 | 717 | 126 | 0.18 | 281 | 37.2% | 163 | 0.23 | 23.0% |
| Offshore | \| | 7 | 0.42 | 0.08 | 555 | 417 | 312 | 113 | 544 | 388 | 73 | 0.19 | 164 | 62.8% | 188 | 0.49 | 77.0% |
| | Total | 7 | 0.88 | 0.12 | 1746 | 1017 | 1093 | 799 | 872 | 1105 | 151 | 0.14 | 337 | | 352 | 0.32 | |
| Coastal | Pinniped-Porpoise | 8 | 1.70 | 0.25 | 423 | 664 | 826 | 530 | 305 | 550 | 81 | 0.15 | 182 | 17.0% | 143 | 0.26 | 16.3% |
| Offshore | \| | 8 | 0.72 | 0.15 | 555 | 833 | 1133 | 639 | 204 | 673 | 137 | 0.20 | 307 | 83.0% | 255 | 0.38 | 83.7% |
| | Total | 8 | 0.97 | 0.17 | 978 | 1496 | 1959 | 1169 | 509 | 1222 | 218 | 0.18 | 488 | | 398 | 0.33 | |
| Coastal | Cetacean | 9 | 0.00 | 0.00 | 0 | 4 | 0 | 0 | 0 | 1 | 1 | 0.89 | 1 | 100.0% | 1 | 1.03 | 100.0% |
| Offshore | \| | 9 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.0% | 0 | | 0.0% |
| | Total | 9 | 0.00 | 0.00 | 0 | 4 | 0 | 0 | 0 | 1 | 1 | 0.89 | 1 | | 1 | 1.03 | |
| Coastal | Sea Otter | 10 | 1.00 | 0.15 | 525 | 242 | 322 | 302 | 233 | 325 | 47 | 0.15 | 106 | 35.7% | 188 | 0.58 | 49.1% |
| Offshore | \| | 10 | 0.13 | 0.03 | 0 | 151 | 156 | 188 | 102 | 120 | 29 | 0.25 | 66 | 64.3% | 68 | 0.56 | 50.9% |
| | Total | 10 | 0.35 | 0.02 | 525 | 394 | 478 | 490 | 335 | 444 | 31 | 0.07 | 70 | | 255 | 0.57 | |