REPORT OF MARINE BIRD

AND MARINE MAMMAL COMPONENT,

PUGET SOUND AMBIENT MONITORING PROGRAM,

FOR JULY 1992 TO DECEMBER 1999 PERIOD

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January 31, 2005 Final Revision
of January 26, 2001 Manuscript

EXECUTIVE SUMMARY

The Washington Department of Wildlife, now part of the Washington Department of Fish and Wildlife (WDFW), was given responsibility in 1991 through legislatively provisoed funds to design and implement monitoring plans for marine birds, waterfowl, and marine mammals under the Puget Sound Ambient Monitoring Program (PSAMP). Study design was contracted out and aerial surveys began the summer of 1992. The avian abundance data emphasized in this report are to be used as indices to characterize and interpret spatial and temporal trends or patterns.

Both summer and winter aerial surveys have been conducted each year between 1992 and 1999. In 1993 the surveys were extended to include the western portion of the Strait of Juan de Fuca. These surveys sampled the entire marine shoreline of greater Puget Sound by two strata between 1993 and 1997: nearshore (< 20 meters [m]) and offshore (> 20 m). They annually covered 13% to 15% of the nearshore and 3% to 5% of the offshore marine waters in Puget Sound up to the Canadian border and out to the west entrance to the Strait of Juan de Fuca. The area covered by the summer survey was reduced, due to budget cuts, to the northern two thirds of greater Puget Sound after the summer of 1996 while the winter survey coverage has remained similar from 1993-1999. All of this survey data are capable of being mapped down to 1' blocks of latitude and longitude using global positioning satellite systems (GPS) and new intensive methods of recording observation data. The 1992-99 survey data has been incorporated into PC-based computer database and geographic information systems (GIS) as set up by the initial study design developed by contract for this program. These data are also stored using ARC software on Unix hardware in the Wildlife Resources Data Systems (WRDS) section at WDFW in Olympia. This latter data set is available through programs at WRDS (MAPSYS) in different standardized map products that provide a menu-driven input of the type of data desired for display. Either line, point, or density polygon data may be displayed from either of these database and mapping systems.

An overview of species distribution and abundance is described for summer and winter populations of marine birds and waterfowl, from PSAMP aerial surveys. Gulls and terns usually comprised 70-73% of the summer observations with four gull species comprising the majority: Glaucous-winged gull *(Larus glaucescens)*, California gull *(L. californicus)*, Heermann's gull *(L. heermanni)*, and Bonaparte’s gull *(L. philadelphia)*. Waterfowl comprised 61-67% of the winter observations. The total numbers of birds seen during the winter aerials were usually 3 times greater than those recorded during the summer, with the top ten identified species or species groups seen on the winter aerials listed in decreasing order: scoters (*Melanitta perspicillata, M. fusca, and M. nigra*), dunlins *(Calidris alpina)*, gulls *(Larus glaucescens, L. philadelphia, L. canus, L. thayeri)*, snow geese *(Chen caerulescens)*, American wigeon *(Anas americana)*, bufflehead *(Bucephala albeola)*, mallards *(Anas platyrynchos)*, western grebe *(Aechmophorus occidentalis)*, goldeneyes *(Bucephala islandica and B. clangula)*, and scaup *(Aythya marila and A. affinis)*.

Key species, including alcid, loon, grebe, and diving duck species, selected by criteria described in the project's implementation plan (Nysewander et al. 1993), were examined for monitoring purposes using several parameters: indices of population estimates and associated confidence limits, densities, and counts. Temporal and spatial trends of selected species (bay and sea ducks) have been presented by this PSAMP component (1998 Puget Sound Research Conference) and these will be reviewed in this document along with additional findings for other species such as grebes and alcids. This report contains over 52 maps and additional figures displaying either densities or counts of these species during winter and summer seasons. The recent PSAMP aerial surveys have generally provided tighter confidence limits than historical data. Comparisons of future PSAMP aerial survey data with the 1992-99 PSAMP data offer the best opportunity by which population trends could be evaluated in the future.

A comparison of nearly identical winter aerial transects conducted during both 1978-79 MESA and 1992-99 PSAMP efforts revealed the following trends: 1) significant decreases (grebes, loons, scoters, scaup, oldsquaw, pigeon guillemot, marbled murrelet, cormorants, and black brant); 2) stable or more slowly decreasing patterns (rhinoceros auklets, goldeneyes, bufflehead, and gulls species); and 3) some degree of increase (harlequin ducks and probably mergansers). A preliminary review of a similar comparison with aerial survey efforts in Hood Canal between 1982-86 and 1992-99 also suggests significant declines in marine bird numbers have occurred here also. Comparisons of 1992-93 winter PSAMP aerial survey counts with USFWS aerial counts by Nisqually National Wildlife Refuge personnel were also examined for certain bays in south Puget Sound where both methodologies overlapped. Discrepancies in both methodologies and the resulting data were examined.

Comparisons of aerial and boat survey data were conducted in a limited fashion in three different ways: simultaneous transects, sequential transects, and indices derived by intensive sampling by each platform type of a selected area. The data derived from simultaneous transects and the indices derived from the intensive sampling provided the most satisfactory results. Many of the marine bird species have air to boat ratios of <1, ranging from 0.15 to 0.50 for many of the diving loon, grebe, and diving duck species on which PSAMP monitoring focuses. These correction factors are needed for interpretation of indices of density derived from PSAMP surveys if total biomass or population estimates are needed for modeling or other exercises.

The random replicate boat surveys of greater Port Orchard marine waters in February-March 1997 demonstrated other ways of gathering density indices with tighter confidence limits for species with highly clumped distributions (e.g. western grebes), as well as gathering data for small evasive species largely missed by aerial surveys such as murrelets and horned grebes.

Potential problems with data quality, error levels, software errors, and sources of these in the PSAMP aerial data were evaluated and recommendations were formulated and implemented that would correct or lessen these. Statisticians reviewed the study design during 1997 and software programs were revised or created to address the recommendations that resulted from this process.

Brief summaries are also provided for other past or ongoing project tasks and products:

1) Creation of synthesized historical digital database for comparable bird surveys;
2) Creation of an improved digital bathymetry database for study area;
3) Survey of winter resident shorebirds;
4) Survey for adult/juvenile ratios of marbled murrelets at sea in Washington;
5) Monitoring of population levels of harbor seals;
6) Contaminant monitoring in Puget Sound harbor seals;

7) Life history and reproductive success of harbor seals;
8) Resident gray whale monitoring and identification;
9) Creation of MAPSYS software and map products in ARC/UNIX environment;
10) Observations of other marine mammal species seen from aerial surveys.

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ACKNOWLEDGMENTS

Projects of this scope depend upon a wide variety of people for help to succeed and this project owes thanks to many. Dave Nysewander, Joe Evenson, Bryan Murphie, and Tom Cyra are the present project staff conducting these surveys, but Warren Michaelis, Janet Stein, Matt Nixon, Wendy Parsons, Howard Ferguson, and Cliff Rice played key roles in the projects at different times in the past. All deserve thanks and credit for their contributions.

The design and formation of this project in its early stages owes much to efforts of Lora Leschner, Don Kraege, and others. Glenn Ford at Ecological Consulting Inc. (ECI) helped create and establish the initial computer programs needed. The Puget Sound Action Team is thanked for their review and continuing support. The skills and cooperation of numerous state and commercial pilots were critical for the aerial surveys to be completed under winter conditions. We would also like to acknowledge the WDFW aircraft program, as well as Sound Flight and Puget Sound Seaplanes for their support providing the aircraft and pilots necessary for this project.

The various boat surveys associated with air/boat comparisons and adult/juvenile ratios of marbled murrelets would have been impossible but for the assistance of additional department staff from both Regions 4 and 6 as well as the Oil Spill Response and Wildlife Diversity sections in Olympia. Lora Leschner, Jack Smith, Eric Cummins, and Leni Oman/Tom Hooper are due thanks for providing personnel from these programs. As a result, the following individuals provided invaluable help: Jeff Skriletz, Barry Troutman, Jeff Bernatowicz, Ann Lettenberger, and Bill Ritchie.

The marine mammal studies have been coordinated, led, or advised by Steve Jeffries, who leads the Marine Mammal Investigations project (WDFW). His expertise and coordination with other agencies such as U. S. National Marine Fisheries Service and Canada’s Department of Fisheries and Oceans have been essential. Steve would undoubtedly wish to thank numerous personnel that have helped him with the various seal projects, key among these individuals are Dyanna Lambourn, Monique Lance, Harriet Huber, Peter Ross, and others.

A number of others have been key to success in several other endeavors associated with the PSAMP activities coordinated by WDFW over the last seven years. Cascadia Research Collective, specifically John Calambokidis and Joe Evenson, have contributed significantly on whale and shorebird contracts respectively. Glenn Ford with ECI was instrumental in working with Brian Cosentino in WRDS at WDFW to create the improved digital database for bathymetry in all marine waters of western Washington. Don Saul, also with WRDS at WDFW, has created MAPSYS, a computer program in the ARC environment of GIS, which archives and displays the PSAMP aerial survey data through a set of standardized map products that can be altered per need. Brian, Don, and their supervisor, Shelly Snyder, have all been quite helpful in meeting our GIS and archival needs.

Numerous folks reviewed this document and gave us helpful feedback. Don Kraege was instrumental in helping incorporate all of this review and helped decide how to best incorporate these into this version.

1. INTRODUCTION

1.1 Background and Objectives

The Wildlife Management Program of the Washington Department of Wildlife was given responsibility in 1991 to design and implement monitoring plans for marine birds, waterfowl, and marine mammals under the Puget Sound Ambient Monitoring Program (Monitoring Management Committee, 1988). The bird and mammal portions of the Puget Sound Ambient Monitoring Program (PSAMP) were not funded until the 1991-93 biennium. Study designs for the bird portion of the task, along with consolidation of historical databases, were contracted November 20, 1991 to Ecological Consulting Inc. (ECI). Some of the present project staff began in mid May 1992 under the Game Division of the Wildlife Management Program to direct, conduct, and coordinate this task. The final implementation plan was produced in March 1993 (Nysewander et al., 1993), even though surveys and contract fieldwork were begun during the summer of 1992 and the winter of 1992-93. In March 1994, the state wildlife and fisheries agencies were merged into Washington Department of Fish and Wildlife (WDFW). This merger has not appreciably changed program funding, even though one additional staff position was added in 1995 to address recommendations of the 1995 national review of the PSAMP program.

The Monitoring Management Committee (MMC) set down the following goals for monitoring of bird resources under PSAMP in 1988:

- 1) Monitor the abundance of selected avian species to identify any significant changes or trends that may be related to pollution, habitat loss, or disturbance.
- 2) Monitor the reproductive success and contaminant levels in birds.

The first goal was addressed by WDFW. An aerial survey methodology was used to document the habitat use, densities, and trends for selected key species over time throughout all of greater Puget Sound, for two annual periods: summer and winter. Certain species were selected for emphasis in monitoring by the project's implementation plan (Nysewander et al., 1993) using criteria related to usage of or dependence upon marine waters of Puget Sound, peaks of abundance during our survey windows, and other concerns due to limited numbers or special vulnerability to humanly caused mortality.

The U. S. Fish and Wildlife Service addressed the second goal in developing and implementing a monitoring plan (Mahaffy 1994) evaluating contaminant levels in marine birds. The U. S. Fish and Wildlife Service also has an ongoing seabird colony monitoring effort in Washington State, which operates out of their refuge system. This monitoring covers reproductive success for certain limited sets of species. The 1993-95 pilot study examining adult/juvenile ratios of marbled murrelets found in marine waters of greater Puget Sound (Stein and Nysewander 1999) was an exploratory effort evaluating the practicality and feasibility of evaluating reproductive success of one non-colonial marine bird species in the study area.

The purpose of the marine mammal component of PSAMP, as stated by MMC, was to provide consistent population estimates of the marine mammals living in Puget Sound, and to increase the level of knowledge of toxic body burdens and their effects on marine mammals. The harbor seal is considered the most appropriate species for monitoring first as it is the most common resident marine mammal that breeds throughout Puget Sound. The marine mammal component of PSAMP is also looking at life history and reproductive success of seals through its capture and marking program, following known age seals.

1.2 Tasks Included in This Project

The following tasks were performed directly by the PSAMP staff in the Wildlife Management Program. The results of these activities will be a primary focus of this document.

1) Conduct summer and winter aerial surveys over the inland marine waters of greater Puget Sound.
2) Incorporate this survey data into the database and GIS mapping programs (CAMRIS) set up by the initial study design for this project. Comparisons will be made between data for the 1992-99 surveys and that in the 1979-80 database.
3) Evaluate various types of air/boat survey comparisons conducted in both seasons.

Some combination of efforts of PSAMP staff, other department regional or research staff, and federal marine mammal scientists performed a second group of tasks. Results from these will either be briefly summarized or referred to other reports.

1) Quantify the ratio observed for juvenile and adult marbled murrelets in Puget Sound in August.
2) Monitor harbor seal populations by aerial surveys and photography on haul out sites during August-September.
3) Monitor contaminant levels in harbor seals at certain sites along with attempts to examine how these may relate to the seals' foraging areas and reproductive success.

A third group of tasks involved contracts with the private sector. These results will also be briefly summarized, referenced to another report, or used for comparison with present ongoing surveys (i.e. recent aerial surveys and historical data).

1) Create a synthesized historical database of marine birds and waterfowl from three past surveys, with the largest amount of data coming from the MESA study (part of the Marine Ecosystems Analysis Puget Sound Project funded by EPA through the National Oceanic and Atmospheric Administration [NOAA]) conducted in 1978 and 1979.
2) Survey and evaluate the nature of gray whale use of Puget Sound during spring/summer periods. This work also included photographic identification, data archival, and creation of a photographic catalog of summer resident gray whales of the inner marine waters of Washington and British Columbia.

3) Conduct censuses (aerial and land based) of winter resident shorebirds utilizing Puget Sound.
4) Create an improved digital database for bathymetry in greater Puget Sound and adjacent marine waters.

2. METHODS

2.1 Continuous Aerial Transects

The surveys utilized a DeHaviland Beaver floatplane for all surveys except the first 1992 summer survey when a Cessna 206 with floats was used. The DeHaviland Beaver was chosen for its greater margins of safety and longer fuel range. The plane flew at 80-90 knots (kt) at an altitude of approximately 65 meters (m) above sea level. The use of an on-board computer linked to a global positioning unit (GPS) provided a record of time and position every 5 to 10 seconds during the survey. Two observers recorded all birds seen along a 50 m wide strip on each side, along with observation times to the nearest 5 seconds. A third person operated a laptop computer, monitored the GPS unit and output, and directed the pilot to different census routes. A computer program then interpolated this track line with the sightings using the time of the sightings relative to the time of position fixes generated on the track line by the GPS. The sampling protocols and methodology, described in greater detail in the marine bird and mammal implementation plan (Nysewander et al., 1993), follow the general methods developed over the last two decades in California and the Pacific Northwest (Briggs et al., 1981, 1987, 1991).

The aerial surveys were stratified by effort into two basic levels: higher densities found near shorelines and lower densities found offshore or in open waters. Some portion of every nearshore habitat (<ca. 20 m) was sampled by transects that followed the shoreline in a roughly parallel pattern whereas the offshore habitat (>ca. 20 m) was sampled in a zigzag pattern. A turning angle of 90 degrees was initially used on the zigzag pattern. To reduce variance on estimates of bird concentrations found in certain deeper waters, sharper turn angles were subsequently used after the first year, thereby increasing the percentage of offshore area sampled. The flights were extended after the first year to include the Washington state side of the western half of the Strait of Juan de Fuca. After the first year, the nearshore habitat was surveyed in two different ways: 1) the parallel fashion described above for nearshore habitat that was relatively narrow; and 2) a more intensive zigzag or “S” pattern where the nearshore habitat stretched extensively offshore such as at a river mouth or estuary.

The PSAMP aerial surveys recorded all bird species seen on the transect from the high tide line down, but data analyses for monitoring purposes have concentrated on the following set of species: pigeon guillemot (*Cepphus columba*), common murre (*Uria aalge*), rhinoceros auklet (*Cerorhinca monocerata*), marbled murrelet (*Brachyramphus marmoratus*), western grebe (*Aechmophorus occidentalis*), bufflehead (*Bucephala albeola*), two species of goldeneye (*Bucephala islandica and B. clangula*), three species of scoters (*Melanitta perspicillata*, *M. fusca, and M. nigra*), greater and lesser scaup (*Aythya marila and A. affinis*), and harlequin duck (*Histrionicus histrionicus*).

The survey data has been incorporated into both computer databases and GIS mapping programs in both the PC and Unix formats. These data are available through standard map products for all species by counts, densities, distribution, or indices of population estimates with associated confidence limits. A synthesized historical database of comparable data from studies as far back as 1978 was created through contract. Comparisons of our present work with this historical database have allowed status and trends to be evaluated, especially for selected marine species that are restricted to marine waters.

2.2 Correction Factors for Aerial Surveys

Aircraft-based observers miss some fraction of the birds present in the transect, the fraction being greatest for dark diving birds. Several alcid species fall into this category during the summer surveys while sea and bay ducks along with loons and grebes are the species of concern during winter. This bias is not a problem in the detection of population trends as long as all surveys are carried out from the same platform. The bias does, however, make the estimation of absolute population size difficult. One solution to this difficulty is to establish a correction factor derived from the ratio of comparable counts taken by aircraft based observers to those taken by ship or land based observers.

The summer and winter species groups were thought to allow for some differences in methodology, due in part to differing numbers of personnel available for manning both the aerial and boat survey platforms simultaneously. The alcids tend to use straits, open water, and island shorelines in summer whereas the diving ducks and grebes in winter are more associated with bays and mainland shorelines. The alcids are more likely to move out of or into an area depending upon changes of tides, rips, and various current characteristics; hence it becomes more important to sample the same area as nearly concurrently as possible. The winter species group might be contained by the geography and habitat characteristics of certain bays and appear to exhibit less movement out of a study area; thus, an option was explored one winter where one survey type was conducted sequentially right after the other as long as wind or weather conditions did not change. A third option was to run replicates of an intensive random survey coverage of an area by boat and compare this with the results of both that year’s aerial survey in that area and results from all previous aerial surveys of that same area.

2.3 Quality Assurance and Quality Control of Data

As our surveys progressed, we came to realize that there were several potential sources of error that could enter into our summaries, interpretations, and mapping of survey results:

1) Errors of data transcription and computer data entry;
2) Errors derived by the fact that digitization of land and sea boundaries into contracted software are not as precise as those used by GPS;
3) Errors resulting from inaccuracies of random GPS distortion by the Department of Defense (surveys before 2000);
4) Errors created by insufficient GPS readings for certain locations which the computer

software would then omit or occasionally estimate some mistaken mean between known locations;

5) Errors or omissions created by contracted software in at least the two following ways:
    A) Faulty translation of data into presentations by MESA regions or sub regions;
    B) Decision by software on observations seen at end of transects where surveys go over land or must stop for a period until the plane can reposition itself for continuing surveys;
6) Errors in software analysis that arise due to special characteristics of certain species relative to our aerial surveys (e.g. harlequin ducks and horned grebes [covered later]).

In light of these sources of error, the following procedures were utilized to either minimize these when possible or evaluate what degree of error was involved.

1) Checks made on errors in computer entry of observations:
    A) Review computer printouts in comparison with transcriptions of observations;
    B) Print out maps of selected species to see if data are mapped in some erroneous fashion and then figure out source of error.
    C) Run data through error checking computer programs developed by staff.
2) Evaluation of data manipulation and analysis resulting from processing with survey computer software:
    A) Compare results between databases (interpolated observations) and products used in CAMRIS mapping that were derived from SYNPOL software (ECI contract).
    B) Compare both raw counts and extrapolated densities for certain areas and species with surveys done at the same time by other agencies or departmental staff.

2.4 Data Analysis

Nine different FORTRAN computer programs (GPSLOG, SIGHT, GPSVEC, INTERP, SYNPIX, SYNPOL, PSMAP, PSPOP, and PSALLOC) were developed by contract with Ecological Consulting, Inc. (ECI) for use in data collection, transcription, analysis, and display in CAMRIS, a GIS software application. These FORTRAN programs were constructed to address both current surveys as well as certain past survey efforts. The first four were used for data collection, transcription, and data summary or organization in preparation for either mapping or analyses. SYNPIX and PSMAP were primarily oriented towards mapping and graphic display while SYNPOL, PSPOP, and PSALLOC were designed for data analyses, production of indices and associated confidence limits, and allocation of future efforts to reduce variances. During 1996-97, WDFW contracted with ECI for an improved data logging/mapping program, which replaced GPSLOG with DLOG software. ECI has also provided software support and minor modifications upon request numerous times over the last seven years.

Closer examination of both raw data input, displayed data, and summaries produced by these software programs revealed that there were errors of various sorts in some of these software packages. PARADOX was the agency PC computer standard for database management in 1992-99, and has programming features built into it. Since 1996, we have replaced many of the original FORTRAN software with PARADOX programs that are menu driven and perform the same functions with fewer errors inherent in the previous software. We still use GPSVEC, INTERP, and SYNPIX in 1999. PSMAP is still necessary for mapping historical data in its present format.

3. RESULTS RELATED TO AERIAL SURVEYS

Early PSAMP data were used in a paper presented January 1994 in Vancouver, British Columbia on the status, trends, and potential threats related to marine birds and waterfowl in the Strait of Georgia, Puget Sound, and the Strait of Juan de Fuca (Mahaffy *et al.* 1994). At that time only the 1992 summer and the 1992-93 winter aerial survey data were available. Data are now also available from the following six years of aerial surveys and will be added to the overall patterns of species distribution, composition, and relative abundance discussed.

PSAMP aerial surveys recorded all bird species seen below the high tide line, but the monitoring goals and data summary emphasize certain alcid, diving duck, loon, and grebe species. Some of these same species were also evaluated by air/boat comparisons. The following overview section will summarize all major species, but all other data review and analysis will tend to concentrate on the following set of species: pigeon guillemot (*Cepphus columba*), common murre (*Uria aalge*), rhinoceros auklet (*Cerorhinca monocerata*), western grebe (*Aechmophorus occidentalis*), bufflehead (*Bucephala albeola*), two species of goldeneye (*Bucephala islandica and B. clangula*), three species of scoters (*Melanitta perspicillata, M. fusca, and M. nigra*), and greater and lesser scaup (*Aythya marila and A. affinis*). Marbled murrelet (*Brachyramphus marmoratus*) and harlequin duck (*Histrionicus histrionicus*) will also receive some attention from PSAMP efforts and analysis.

3.1 PSAMP Aerial Surveys Overview

Comparisons between 1978-79 MESA surveys and the 1992-99 PSAMP aerial surveys will be examined in more detail for certain species at certain sites in a later section. In general, however, the overall distribution patterns appear relatively similar to those reported by Wahl *et al.* (1981). The numbers used in the overviews reported here will often include the count totals (or percentages of these), including at times those seen off transects. These types of counts were sometimes those most comparable with those done historically for certain areas and certain species. The total counts may also give a feel for the overall numbers that utilized greater Puget Sound. However, total unadjusted counts can often be misleading due to differences of survey coverage. For instance, the 1992-93 surveys did not cover the larger survey area covered by 1993-96 summer and 1993-99 winter surveys. For monitoring purposes, densities adjusted by survey effort for observations seen only on transect will be the required focus. Later sections will map, discuss, and note any qualifications for selected species that might apply to extrapolated densities derived from the observations seen only on transects.

Greater Puget Sound contains more than 3,200 kilometers (km) of marine shoreline. The PSAMP aerial surveys flew between 3,070 and 3,432 km of transects along nearshore habitat and between 1,846 and 3,458 km of transects through the offshore habitat each summer or winter aerial survey period (Appendices 1-14). The totals included varying degrees of replicate surveys during the first several seasons, but the major effort from 1993-94 through the present was to cover, at least once without any sizeable gap, some portion of every sub region throughout greater Puget Sound during each survey period. There was neither time nor funding available for replicates. Starting in summer 1993, both summer and winter flights were also extended to include the U.S. side of the western half of the Strait of Juan de Fuca out to Neah Bay. An effort was also made starting at this same time to increase the percentage of coverage of open water, to reduce variance on estimates for species encountered in concentrated feeding flocks.

Budget cuts in 1997 led to the summer survey effort being reduced in 1997 and subsequent summers. The same survey pattern covering nearshore and offshore waters was continued 1997-99 north of a line between Port Gamble and Edmonds. The rationale behind this selection was that observed diversity, density, and abundance of marine birds in central and south Puget Sound was evenly low each summer and might need survey less often. The summer species for which management usually had questions were primarily all found to the north of this line. Four species groups were compared using the 1992-96 survey data and it verified that large percentages of the total birds counted were seen in the northern reduced survey area. The following are the ranges of annual percentages for each species or species group between the northern survey and the overall survey totals: gulls and terns (80.7 to 91.2%), cormorants (89.3 to 97.8%), rhinoceros auklets (96.2 to 99.6%), and pigeon guillemots (75.5 to 93.7%). Only the latter species would frequently have up to 25% of the summer population distributed in the southern and central Puget Sound. This factor will later play a role in the development of a different monitoring strategy for pigeon guillemots using boats at colony sites during the breeding season.

The CAMRIS computer program tallied 2,033.9 square kilometers (km2) of nearshore habitat and 5,943.8 km2 of offshore habitat in the inner marine waters of Washington State, which includes the American side of the western Strait of Juan de Fuca. Except for the 1997-99 summer surveys, the percentage (%) of each total habitat area sampled by the PSAMP aerial surveys ranged per each survey period from 13% to 15% for nearshore and 3% to 5% for the offshore habitat component.

3.1.1 Summer Surveys and Bird Distribution/Abundance

Summer surveys recorded the following: 1) gull and tern flocks generally distributed themselves along or near shorelines, with feeding flocks of certain species, such as Heermann's gull (*Larus heermanni*), concentrating in the northern two-thirds of Washington's inner marine waters; 2) feeding flocks of alcids such as common murres and rhinoceros auklets occurred in deeper, more exposed waters in the northern two-thirds of Puget Sound; 3) molting/feeding flocks of ducks were found along shores and river deltas; and 4) other marine birds including cormorants, pigeon guillemots, harlequin ducks, and great blue herons (*Ardea herodias*) frequented shorelines near breeding or molting sites. Southern and central Puget Sound contained lower densities than areas to the north or along the shores of the Strait of Juan de Fuca (Figure 1).

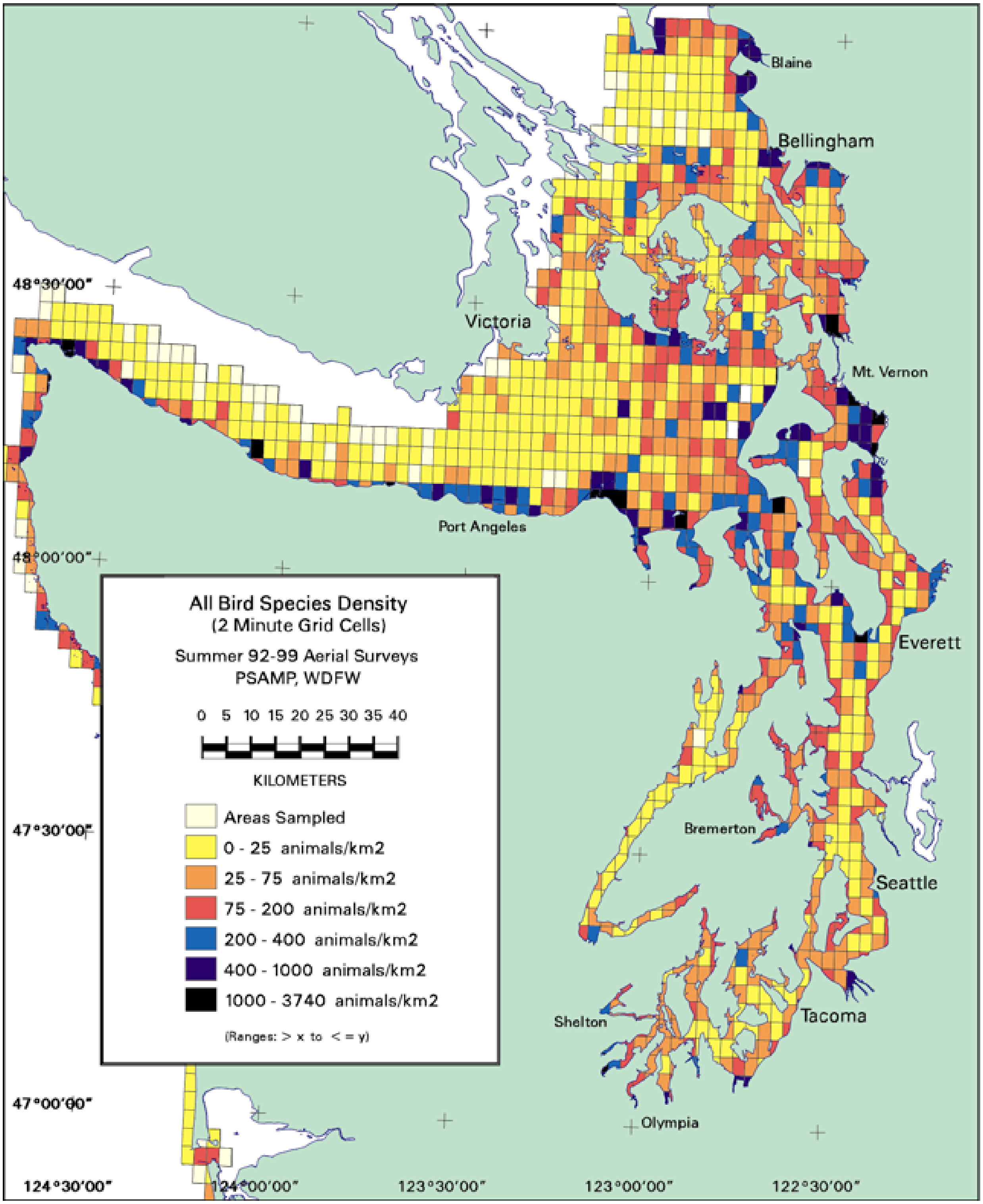


Figure 1. Overall Mean Densities for Marine Birds Derived from July 1992-99 Summer Aerial Surveys.

The total number of marine birds and waterfowl counted both on and off transects in July varied from 70,114 to 130,720 between 1992 and 1996 (Table 1). The 1992 survey area did not include the additional area of the western portion of the Strait of Juan de Fuca surveyed during 1993-99. If observations were summarized for the prior five years for the same reduced area surveyed during 1997-99, then a comparison of all eight years shows total counts that varied from 27,045 to 118,224 (Table 1) with the highest counts seen during 1992-93 and the lowest during 1998-99. Comparisons of densities showed similar patterns, except that 1997 data recorded higher densities comparable to those seen in 1992-93.

There are several variables that need discussion at this point:

1) Counts on transects were always the higher priority for survey crews in the beginning years, but counts off transects have received even less emphasis in later years of the surveys, except for certain notable large concentrations of birds such as western grebes. For comparable data between years for counts, you should examine only the counts from the “on transect” efforts; in this case, the total counts overall still varied from 25,363 to 90,265 for the comparable area sampled all eight years (Table 1). The densities for similar survey areas are even more comparable indices and will be used later to evaluate trends in the trend section of this document, but actual counts are included here for a feeling of the total numbers involved in these surveys and habitats.
2) One survey crew primarily conducted surveys from 1992 to 1995 while a second crew continued after this with some overlap. Again, one new survey crewmember began in 1998 with some overlap with past crew. Here again these changes in personnel do not appear to relate to the different numbers recorded over the years, as the changes in numbers for different species do not occur the same year as the crew changes. The crew changes are most likely to affect recognition of certain difficult species such as marbled murrelets or species differentiation within species groups such loons or gulls, but other species groups (e.g. rhinoceros auklets and scoters) do not present this type of challenge after initial training.

At any rate, the major differences in summer numbers appear to be associated with each survey capturing different timing of certain species' migration through Puget Sound, especially that of gulls. Different weather cycles such as El Nino and La Nina have been in effect different years and have influenced the timing of different migration patterns through western Washington.

Gulls and Terns

Gulls and terns accounted for 67-74% of the total birds observed on transect (with one exception in 1993 of 84%), with an average of 72.9% during each July survey (Figure 2). The total number of gulls and terns counted both on and off transects in July varied from 37,722 to 88,179 between 1992 and 1996, while overall density means varied from 108 birds/km^2 in 1993 to 27 birds/km^2 in 1999 (Table 2). If observations on transect were summarized for the prior five years for the same reduced area surveyed 1997-99, then a comparison of eight years shows total counts that ranged from 17,316 to 75,379, with the highest counts seen during 1992 and the lowest during 1998 (Table 2). Densities showed a similar pattern, with the exception that 1997 densities were also high.

Table 1. Comparisons of total counts of marine birds and waterfowl obtained during PSAMP July aerial surveys, 1992-99.

	Counts Only On Transect		Counts On and Off Transect		Density[b]	C. L.
Years	Full Survey Area	Northern Two Thirds	Full Survey Area	Northern Two Thirds	Birds\ Km^2	95%
1992	101,580	84,931	114,823	97,066	120.50	21.24
1993	99,922	90,265	130,720	118,224	137.50	29.40
1994	72,175	62,428	96,889	85,880	69.19	10.72
1995	49,931	41,522	70,597	60,646	56.36	9.85
1996	58,979	51,495	70,114	62,039	80.80	21.85
1997	x[a]	65,399	x[a]	66,087	129.80	25.58
1998	x[a]	35,408	x[a]	36,862	61.13	11.71
1999	x[a]	25,363	x[a]	27,045	41.15	8.97

Notes: [a] Entire survey area not covered as in original study design.
[b] Density calculated for northern two thirds survey area.

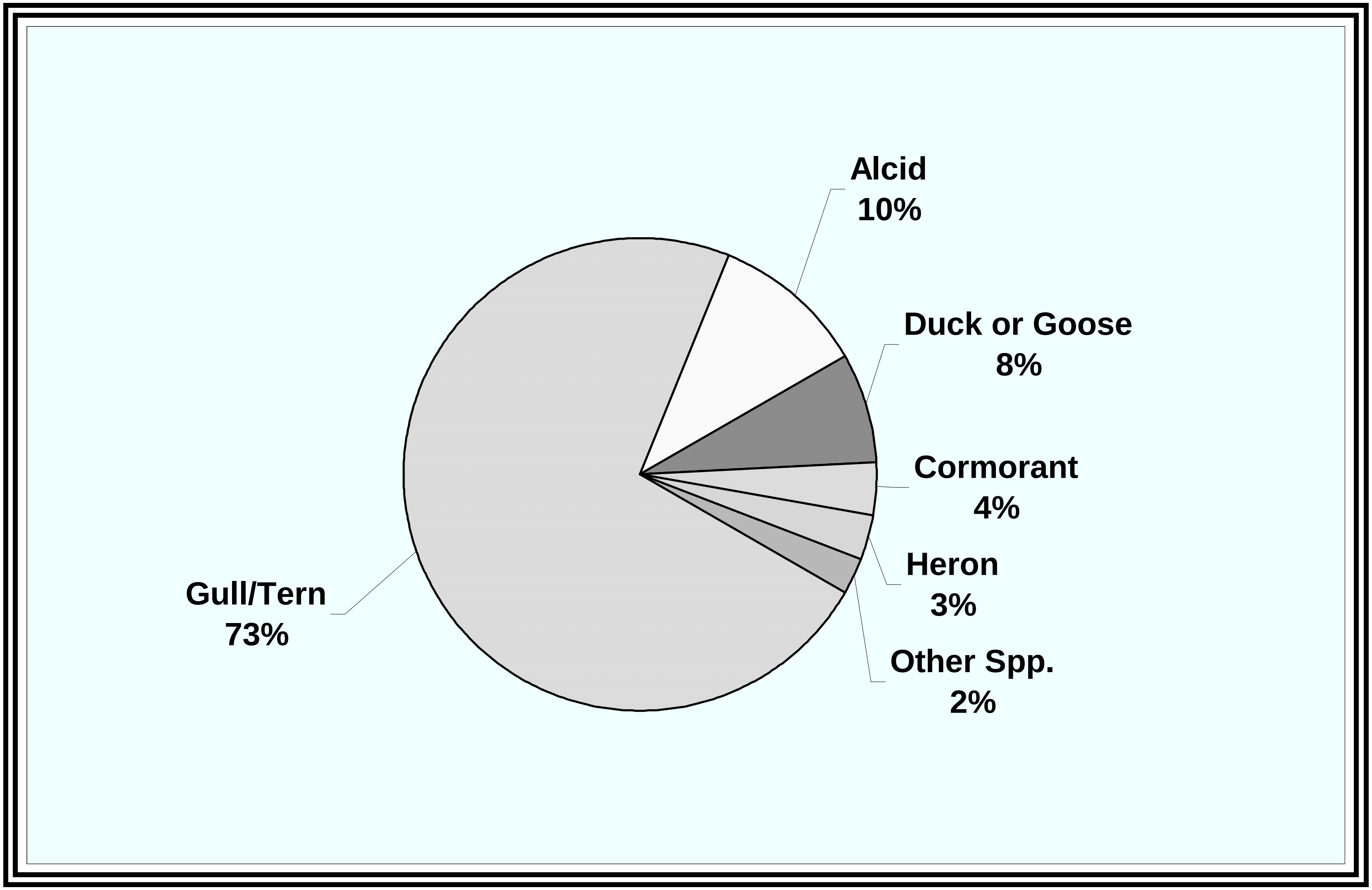


Figure 2. Composition of Marine Bird Populations Seen on PSAMP Summer Surveys in Greater Puget Sound 1992-99.

Table 2. Comparisons of total counts and densities of gulls and terns obtained during PSAMP July aerial surveys, 1992-99.

	Counts Only On Transect		Densities[b]	
Years	Full Survey Area	Northern Two Thirds	Birds Per Km^2	95% C.L.
1992	77,587	62,586	82.15	15.78
1993	82,650	75,379	107.94	27.51
1994	52,903	45,538	47.76	8.83
1995	35,607	29,015	36.10	6.35
1996	39,493	35,172	51.41	18.03
1997	x[a]	44,169	82.26	22.75
1998	x[a]	23,779	40.05	9.12
1999	x[a]	17,316	27.23	7.30

Notes: [a] Entire survey area not covered as in original study design.
[b] Density calculated for northern two thirds survey area.

Each year's survey data always included a large unidentified gull component, which varied in size due to numerous immature plumages, large concentrated flocks of differing species, hybrids, and the crew's varying skill in separating these out. Gull species were not a key focus of our surveys, but 30-40% were usually identified to species. Four species comprised the majority of species identified: Glaucous-winged gulls (*Larus glaucescens*; range of 46-88%), Bonaparte's gull (*Larus philadelphia*; 8-23%), Heermann's gull (1-19%), and California and ring-billed gulls (*L. californicus and* delawarensis*;* 3-11%). Glaucous-winged gulls were the only resident breeding gulls in our study area, with the other three species migrating into or through Puget Sound during the summer. Western x glaucous-winged gull intergrades (*Larus occidentalis x glaucescens*) were also present, but were not numerous.

The density map for summer gull distribution for all species between 1992 and 1999 (Figure 3) illustrates that gulls were most abundant along the Strait of Juan de Fuca, the southern portion of the San Juan Islands, Admiralty Inlet, and certain mainland shores and estuaries such as the Skagit River delta. Glaucous-winged gulls were distributed throughout the region, with concentrations near breeding colonies. Certain species (e.g. California, Heermann's, Bonaparte's gull) had higher counts any one year, but this was not thought to reflect an increase in this species' population; the survey most likely captured a particular surge of migration. Different species of gulls did demonstrate different geographical or habitat usage patterns: Heermann's gulls favored the Strait of Juan de Fuca and nearby portions of San Juan Islands and Admiralty Inlet (Figure 4); California gulls, mixed in with ring-billed gulls, concentrated along mouths of rivers such as the Skagit (Figure 5); Bonaparte's gulls concentrated during July in the San Juan Islands, Whidbey/Camano Island area, and the Admiralty Inlet vicinity (Figure 6).

Caspian terns (*Sterna caspia*) were the most common terns seen during most of the summer, but concentrations of common terns (*Sterna hirundo*) migrated through during July and August and our survey data captured this periodically. Caspian terns were recorded with the highest numbers (counts up to 1,167 in 1995) between 1993 and 1997, but they were seen every year in some portion of greater Puget Sound (Figure 7). The major changes in abundance and distribution appeared to occur midway through the 1992-99 period after the Navy displaced their breeding colony in the Everett area by building structures on sites used by breeding terns.

Alcids

The proportion of summer marine bird populations composed of alcids ranged from 5.9% to 14.6%, averaging 10.3% over the eight summers in the core survey area covered every year. Five species were commonly observed and are listed by percentages seen of species identified: rhinoceros auklet (35.7%), common murre (31.3%), pigeon guillemot (29.6%), marbled murrelet (1.5%), and tufted puffin (<0.1%). There is some evidence that observers improved in their identification of alcids after the first year. Nearly 1,500 unidentified alcid observations were recorded in 1992 whereas there were usually less than 100 of this category in following years. Observers improved in recognizing marbled murrelets with practice from the air, but air/boat comparisons later suggested that considerable inconsistency continued in observer recognition of low numbers of this small cryptic species, given the type of plane used and the range of water conditions under which the surveys are normally conducted.

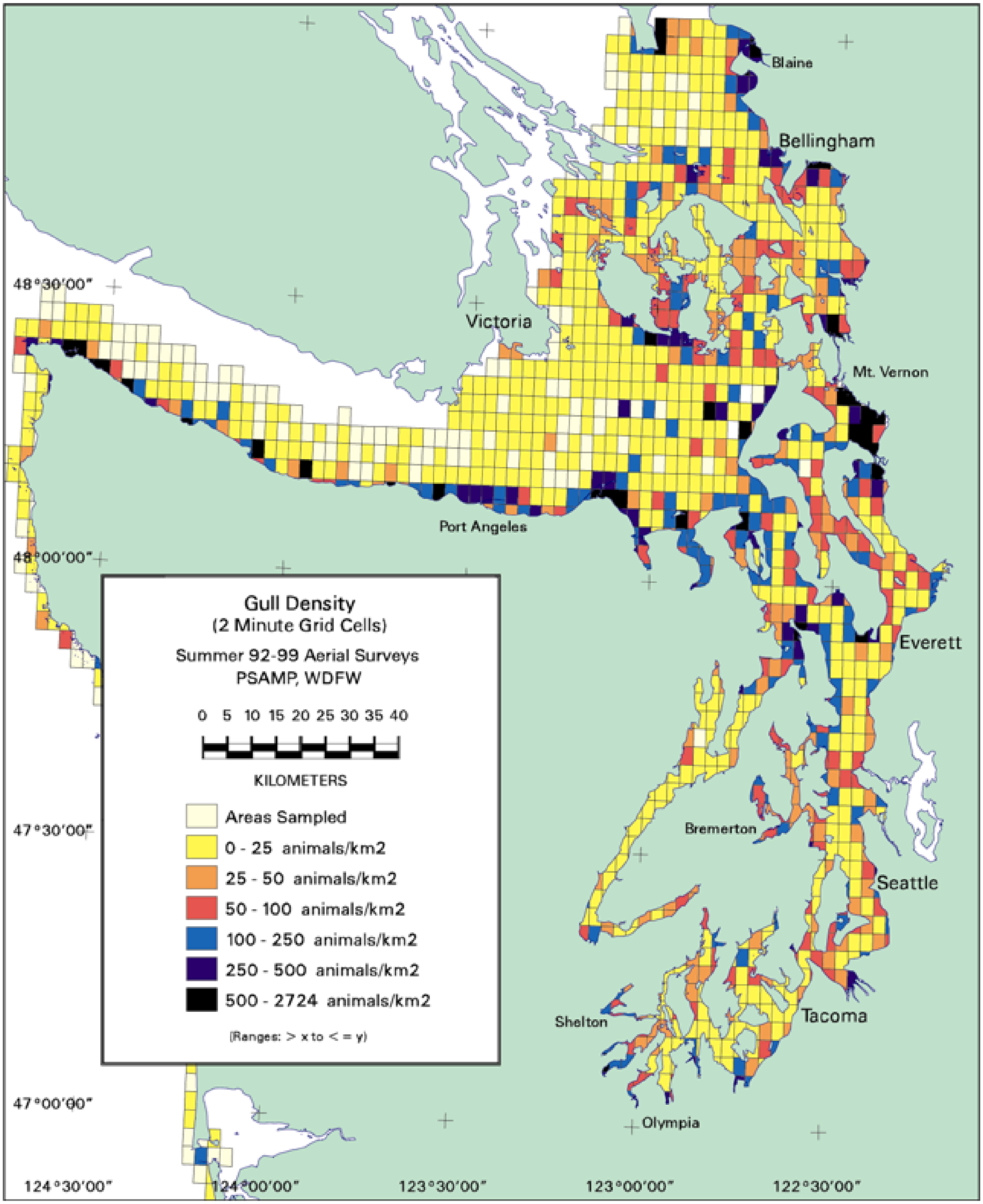


Figure 3. Overall Mean Densities For All Gull Species Derived From July 1992-99 Aerial Surveys.

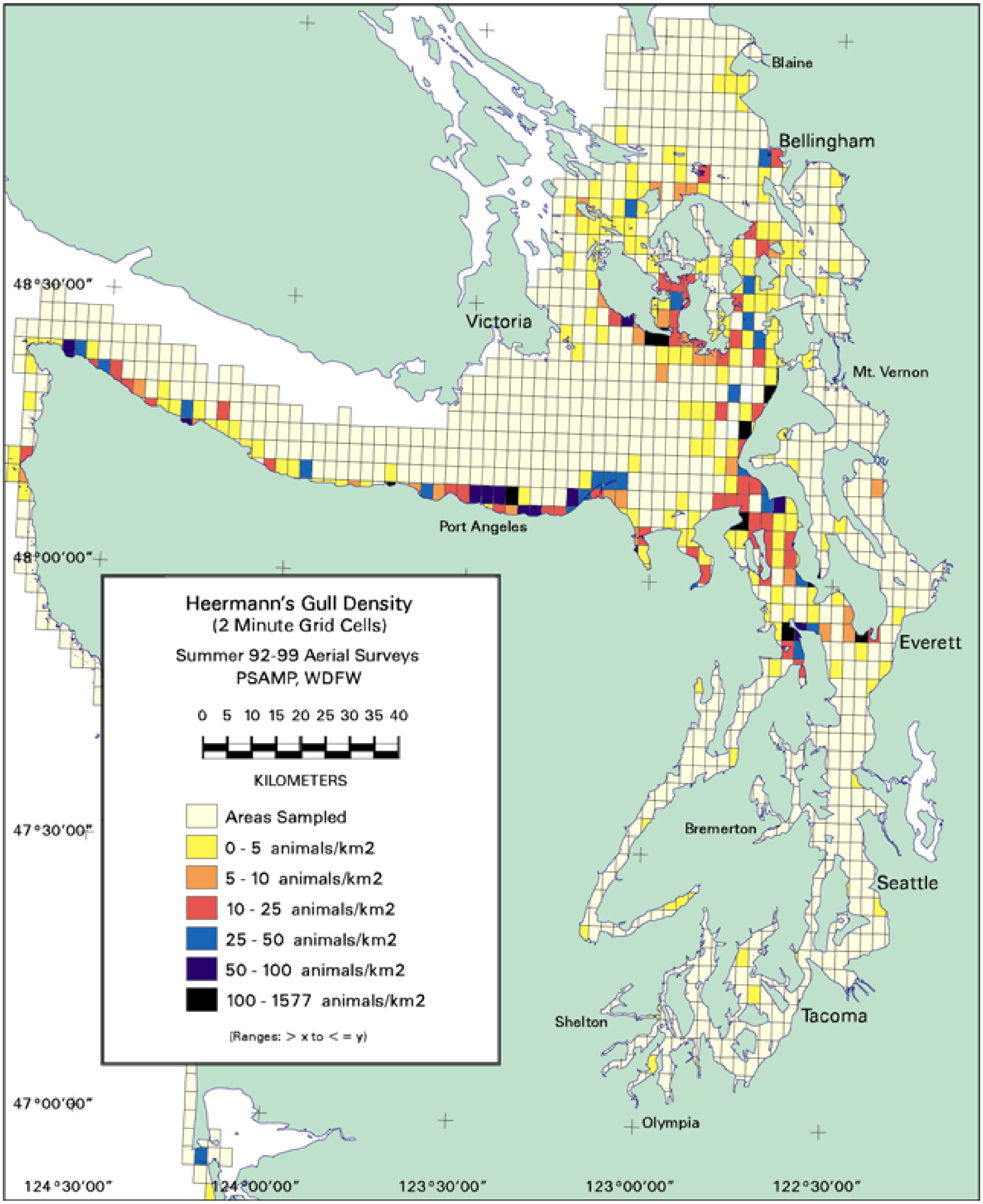


Figure 4. Mean Densities for Heermann's Gull Derived From July 1992-99 Aerial Surveys.

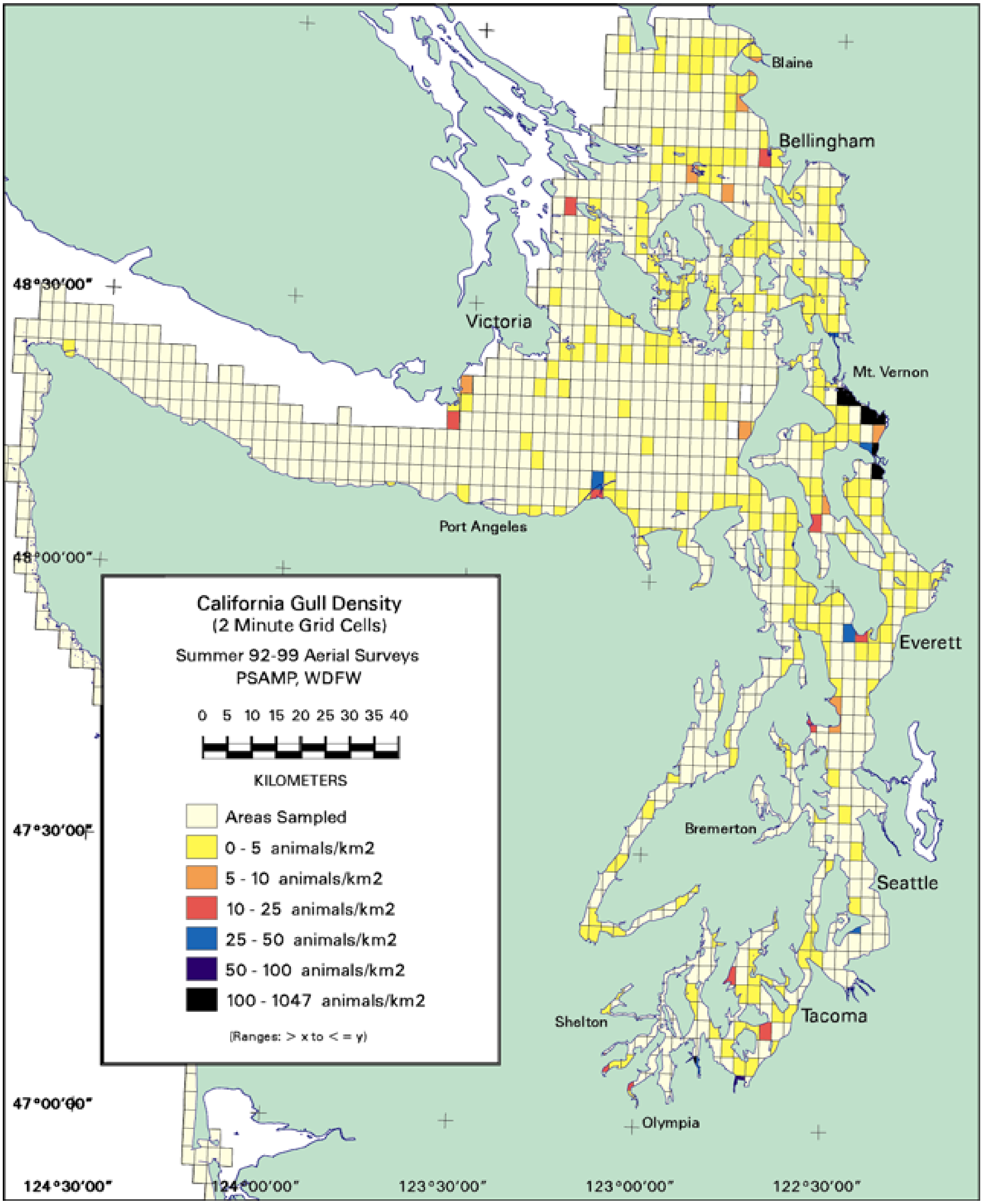


Figure 5. Mean Densities for California Gull Derived From July 1992-99 Aerial Surveys.

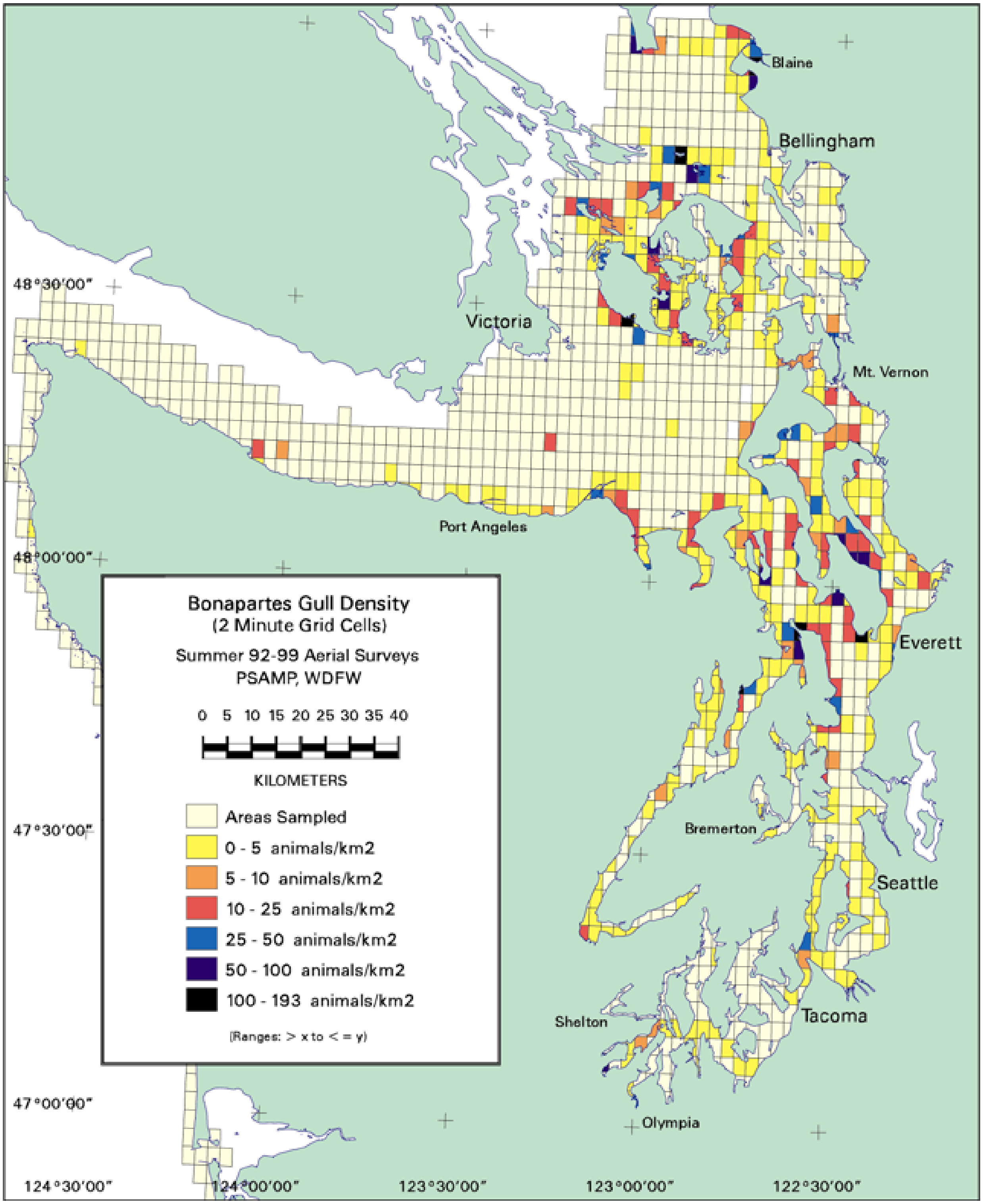


Figure 6. Mean Densities for Bonaparte's Gull Derived From July 1992-99 Aerial Surveys.

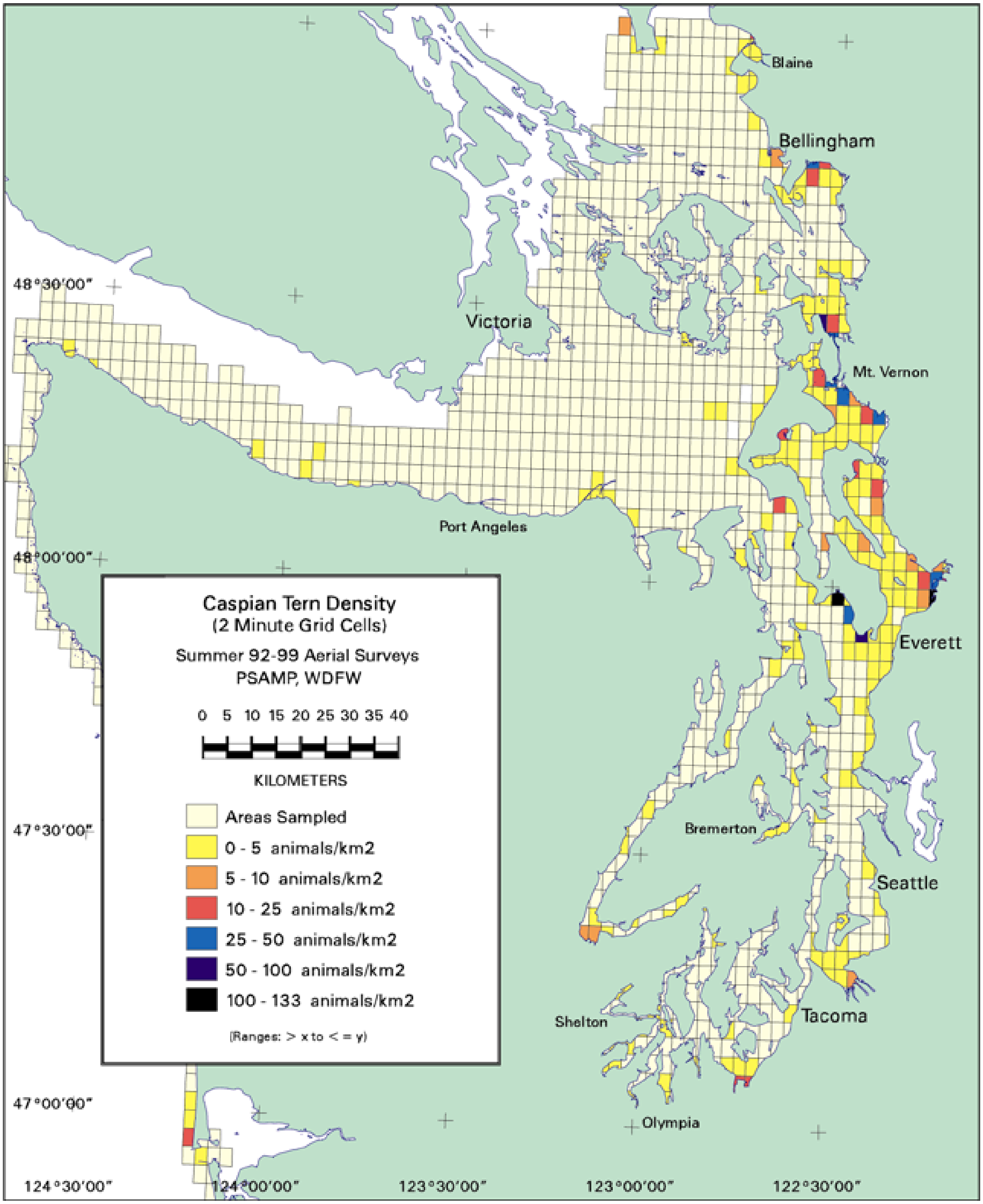


Figure 7. Mean Densities for Caspian Tern Derived From July 1992-99 Aerial Surveys.

Rhinoceros auklets were mostly seen in deeper waters (> 20 m) in the northern two-thirds of greater Puget Sound, feeding in tiderips and channels (Figure 8). Their overall mean density for offshore waters did not vary much, ranging from 6.28 to 7.62 auklets per square kilometer (km^2) during July 1992-97, with somewhat lower levels in 1998-99 of 5.07 and 4.36 respectively. On the other hand, common murre densities were highly variable each year in July, depending upon success at, and timing of, migrations from colonies outside of greater Puget Sound; their densities varied during 1992-99 anywhere from 0.10 to 14.01 murres per km^2 in the same deeper waters. When murres were present, they occupied similar deeper water habitats in the northern portion of greater Puget Sound (Figure 9). Rhinoceros auklets were usually found within 50-80 kilometers of their breeding colonies at Smith, Protection, or Tatoosh Islands whereas the murres could be seen any one year in these same areas or others such as moving eastward through the Strait of Juan de Fuca and near Victoria.

Pigeon guillemots were the most widely distributed alcid species found in moderate or higher numbers throughout greater Puget Sound year round. They occurred primarily along shorelines near breeding sites and nearby feeding areas during July (Figure 10), with certain very high concentrations found near colony sites (e.g. Protection and Sucia Islands). The density of pigeon guillemots in the nearshore waters still varied considerably because of their movements during the day to or from colonies, with densities that ranged from 3.60 to 10.19 birds per km^2. Our aerial survey design works best when birds are not moving much geographically during a diurnal period because time of day can not be standardized for survey of all sites. The diurnal movement of this species in the breeding season creates high confidence limits around indices estimates. Hence the surveys capture the general marine habitat usage patterns of this species over eight years, but the large confidence limits suggest a different approach be used for monitoring trends over time, a change that will be discussed later in the trend section.

Marbled murrelets were seen regularly from aerial surveys in low numbers, usually in nearshore waters, at certain sites in the San Juan Islands, the Strait of Juan de Fuca, the Whidbey/Camano Islands areas, near both the Skagit and the Snohomish River deltas, northern portions of Hood Canal, and near or north of the Nisqually River delta vicinity in the south sound. The pilot study conducted using boat surveys by this PSAMP component 1993-95 (Stein and Nysewander 1999) mapped and tracked murrelet numbers and productivity at the major concentration sites in greater Puget Sound; see this report for a better sense of concentrations and numbers associated with these. The lower numbers seen by the aerial surveys, displayed in Figure 11 as point observations over the eight summers, illustrate how this species of concern distributes itself along selected marine habitats in greater Puget Sound.

The remaining alcid species recorded during the summer, tufted puffin (*Fratercula cirrhata*), was occasionally seen in low numbers, primarily in the vicinity of Smith or Protection Islands. Occasional birds were seen either in Admiralty Inlet or in the Rosario Straits or Cattle Pass vicinities of the San Juan Islands. Puffins were also seen near and just to the east of Neah Bay, but these birds probably were from colonies on the outer coast of Washington.

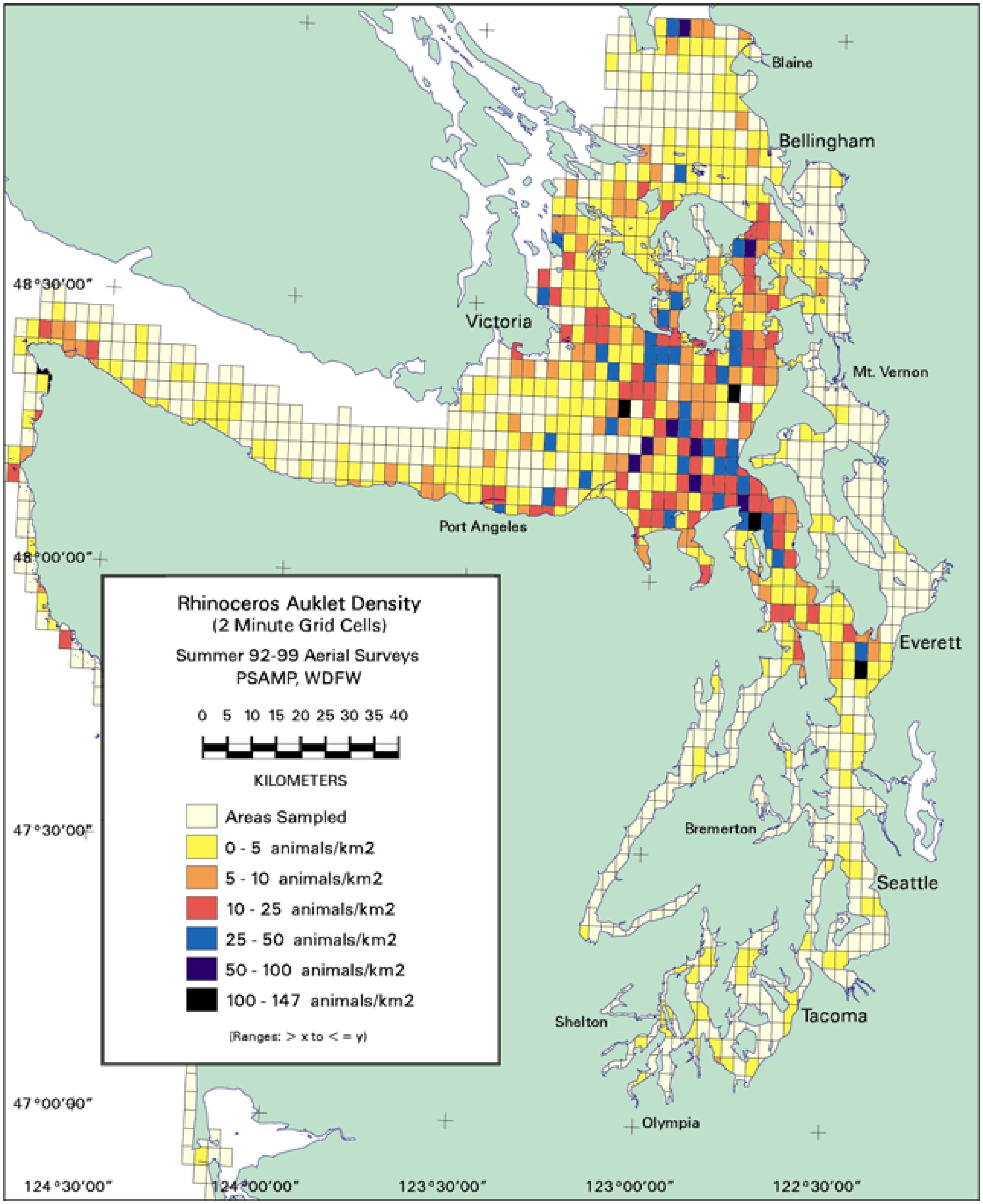


Figure 8. Mean Densities for Rhinoceros Auklets Derived From July 1992-99 Aerial Surveys.

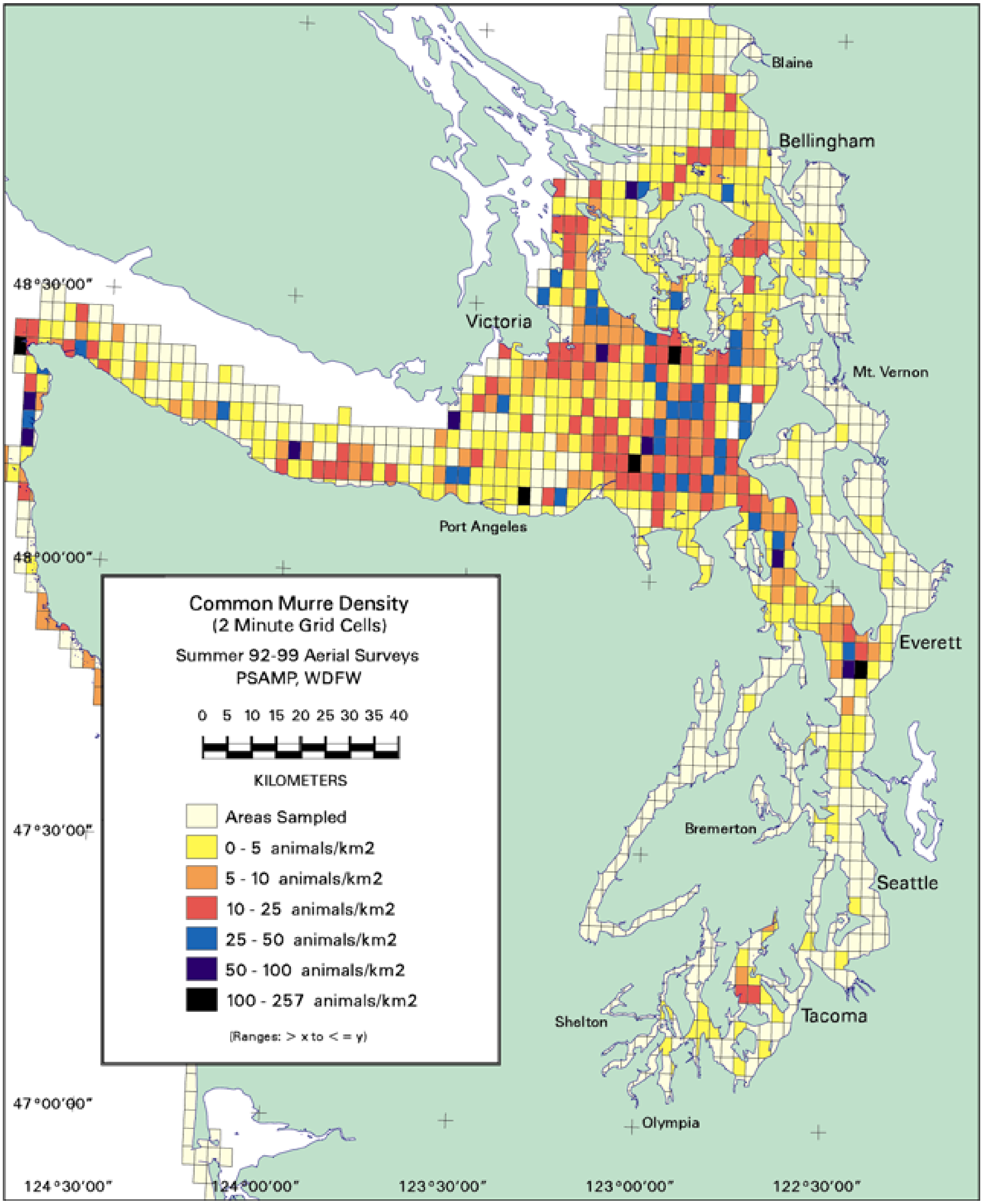


Figure 9. Mean Densities for Common Murres Derived From July 1992-99 Aerial Surveys.

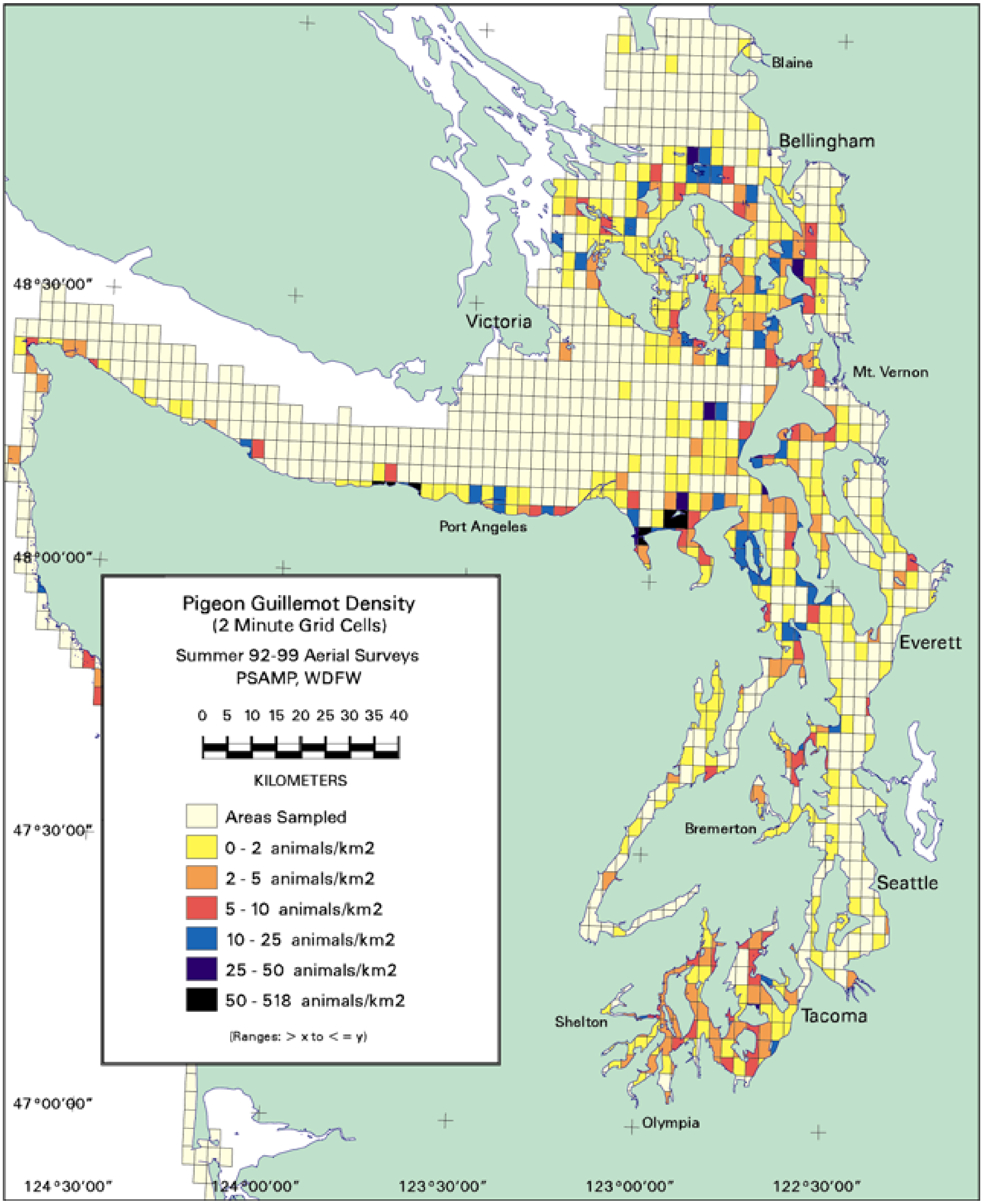


Figure 10. Mean Densities for Pigeon Guillemots Derived From July 1992-99 Aerial Surveys.

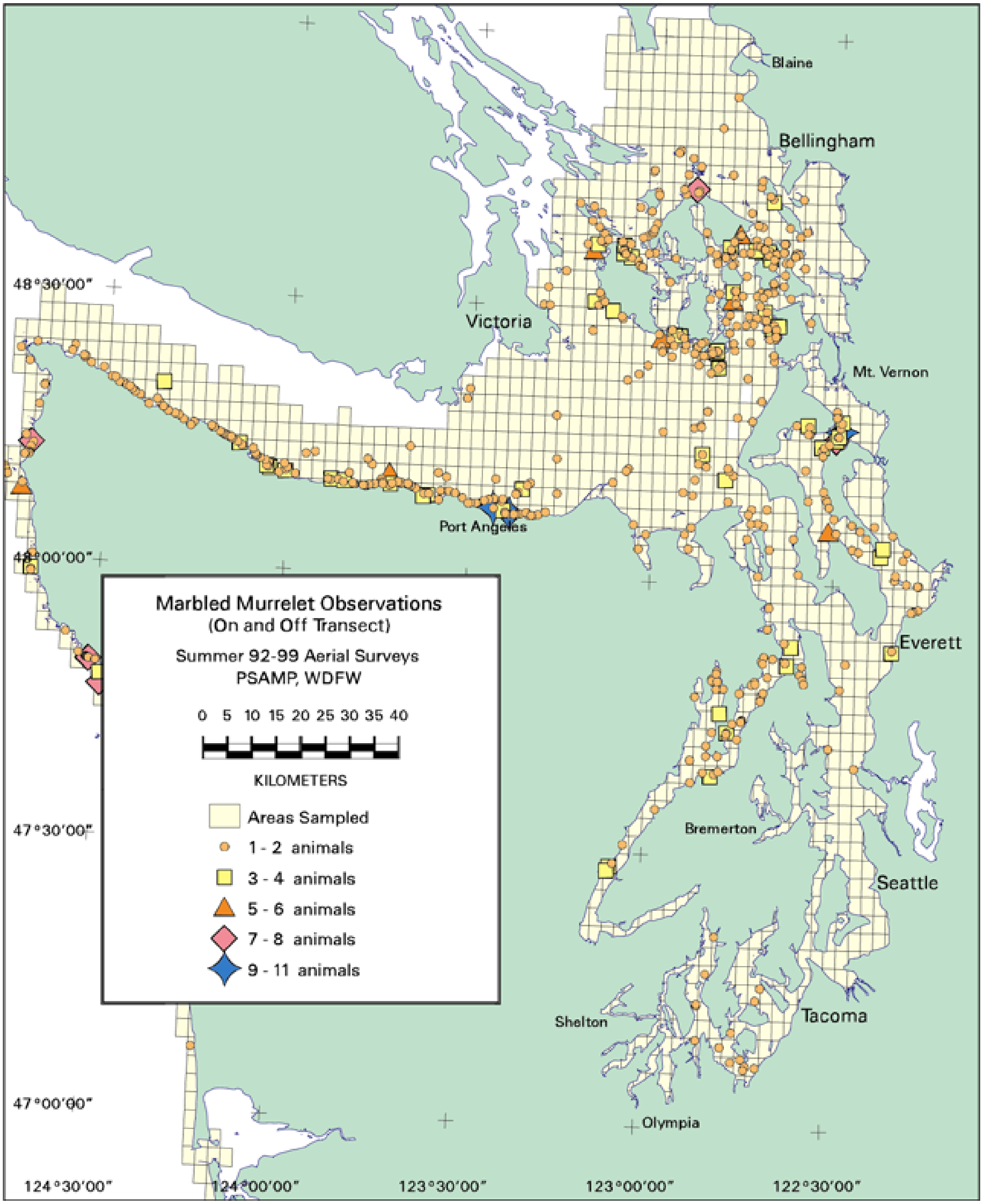


Figure 11. Observations of Marbled Murrelets Seen During July 1992-99 Aerial Surveys.

Ducks and Geese

The proportion of summer bird populations seen that was composed of ducks and geese ranged from 3.9% to 12.7 % any one year, averaging 7.5% of all birds seen during the 1992-99 summer surveys. Scoters comprised 58.6% of the waterfowl observed. A total of 88.6% of the scoters identified to species were surf scoters. The numbers of scoters staying in greater Puget Sound over the summer is less than that seen in the winter by an order of magnitude or more. Between 3,000 and 7,000 molting and non-breeding scoters were seen annually 1992-96, primarily concentrating around locations including Penn Cove, Boundary Bay, Smith Island, Padilla Bay, portions of the southeastern shoreline of the Strait of Juan de Fuca, and portions of the Whidbey and Camano Islands vicinity (Figure 12). In 1997 and 1998, these numbers dropped to less than 1,000 scoters, but close to 1,300 scoters were seen July 1999, concentrating again in many of these same areas. The PSAMP surveys did not usually survey on the west coast of the Olympic Peninsula, but in 1996 there was coverage and scoter concentrations were noted there also (Figure 12).

Five other species or groups of species of waterfowl were seen each summer and are listed in decreasing order of abundance by percentage of waterfowl observed: Canada geese (*Branta canadensis*, 13.9%), dabbling duck species (10.6%, composed primarily of mallards, *Anas platyrhynchos*); harlequin ducks (10.4%); mergansers (4.5%) of which most were common mergansers (*Mergus merganser*); and miscellaneous smaller numbers of other diving duck species including goldeneyes (*Bucephala spp.*) and scaup (*Aythya spp.*). The PSAMP aerial surveys are designed primarily for species constrained to marine waters. Hence, they do not adequately sample or survey species such as Canada geese and dabbling ducks that can readily leave the marine waters for lakes, parks, and other non-marine habitats. The July aerial surveys show Canada geese commonly occurring in the San Juan Islands, but these surveys occur after the peak of goose nesting in May and hence also do not capture, for instance, the use of numerous small islands in the San Juan Islands for nesting. The July survey data does illustrate how Canada goose densities are often high close to urban areas (Figure 13), which contrasts with the tendency for marine water bird densities to often diminish in the vicinity of urban areas.

Mergansers were recorded during the summer aerial surveys as primarily either common mergansers or unidentified mergansers because many were in eclipse or basic plumage. Few red-breasted and hooded mergansers (*Mergus serrator* and *Lophodytes cucullatus*) were recorded by the aerial surveys, but the vast majority of the unidentified mergansers in July were probably common mergansers, because this species was identified whenever groups were checked in more detail. Common mergansers occurred primarily near the mouths of major rivers in July (Figure 14). The unidentified merganser category has been combined with that of common mergansers for purposes of illustrating this distribution pattern. Common mergansers nest on major river drainages and bring their young down river before they can fly. The July survey data captures their arrival at and use of the interface of the rivers with the marine waters.

Harlequin ducks are regularly seen in certain rocky and cobble/gravel shoreline habitats in relatively low numbers by the summer surveys (Figure 15). These specific sites were used every

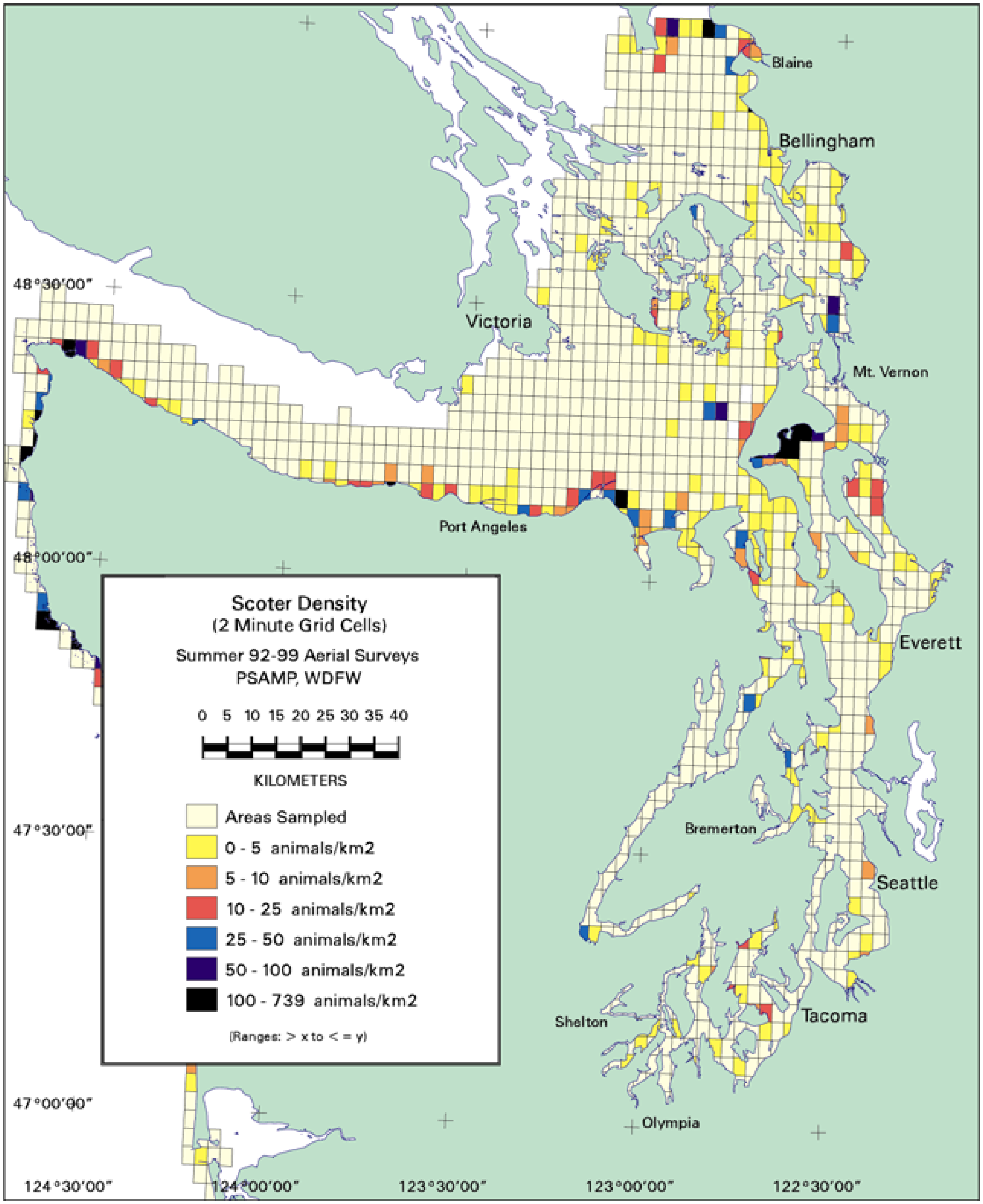


Figure 12. Mean Densities for Scoters Derived from July 1992-99 Aerial Surveys.

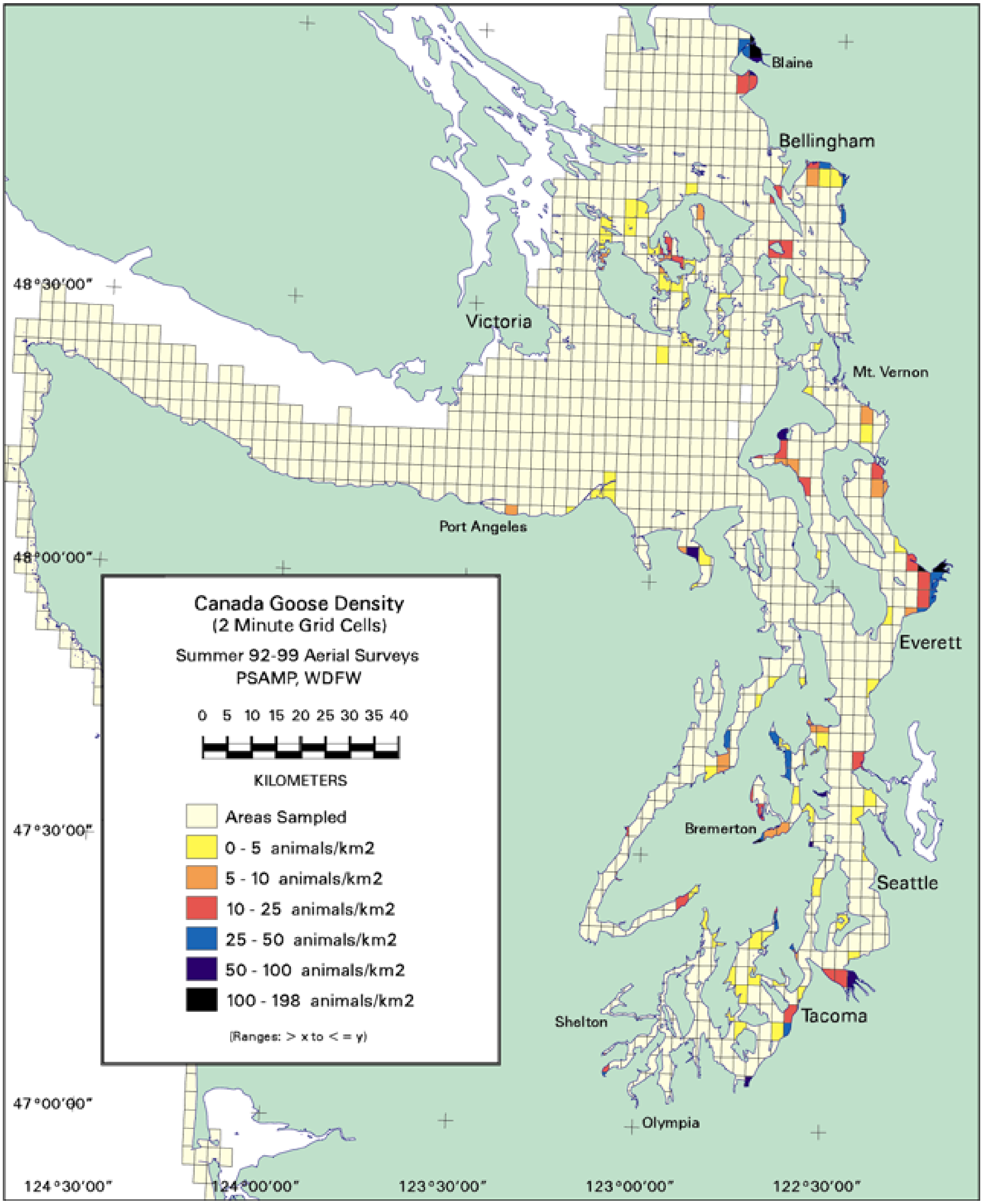


Figure 13. Mean Densities for Canada Geese Derived from July 1992-99 Aerial Surveys..

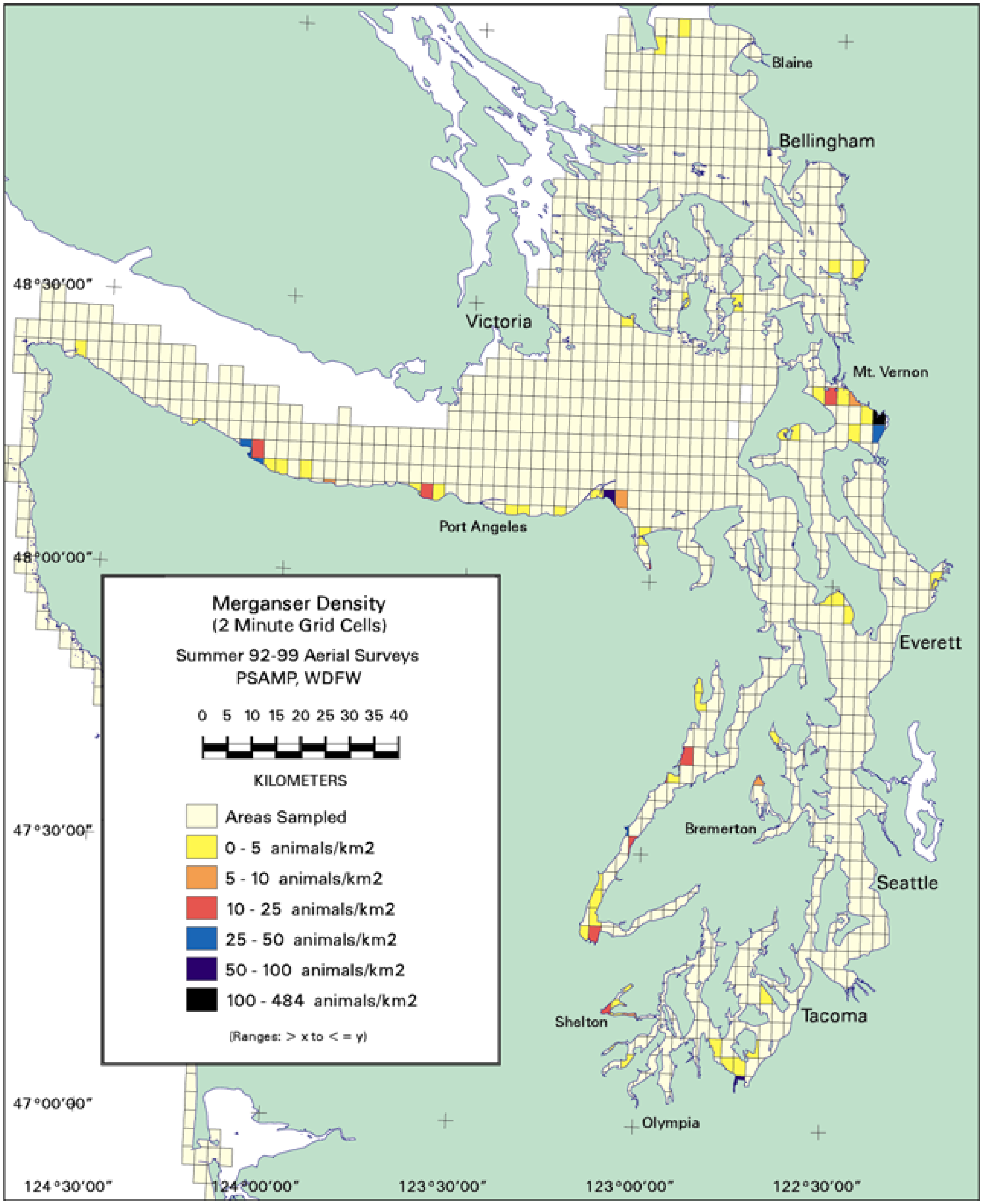


Figure 14. Mean Densities for Mergansers Derived from July 1992-99 Aerial Surveys..

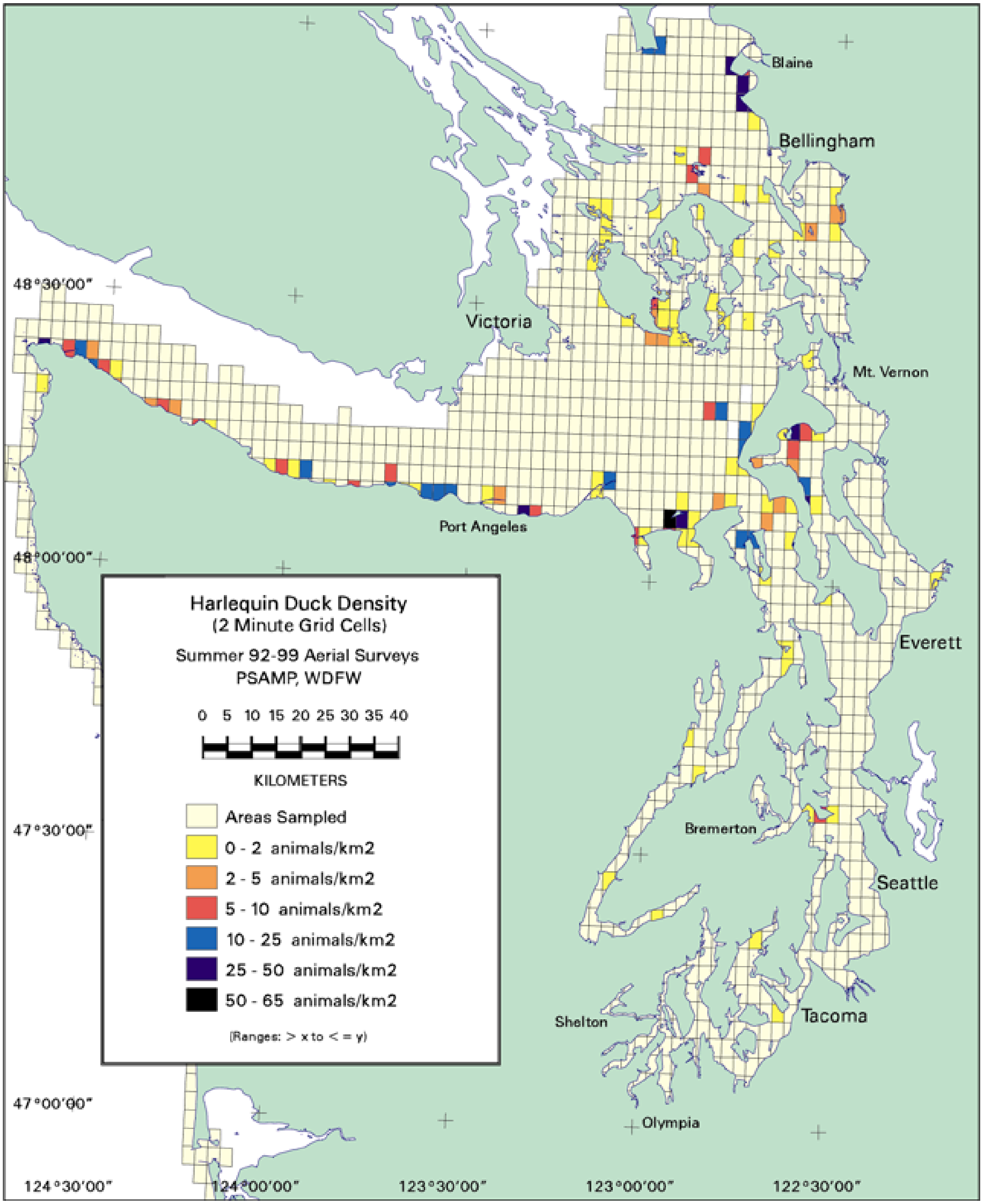


Figure 15. Mean Densities for Harlequin Ducks Derived from July 1992-99 Aerial Surveys.

year, both for summer and winter foraging or resting. With only a few exceptions, all of these sites were found in nearshore habitats along the Strait of Juan de Fuca, northern or more exposed portions of Admiralty Inlet and Whidbey Island, Oak Harbor vicinity of Whidbey Island, reefs or shorelines of some of the more exposed smaller islands of the San Juan Islands, and the shoreline from Cherry Point north to Point Roberts.

There is some evidence that the aerial survey crew experienced a learning curve in recognizing harlequin ducks on the PSAMP aerial surveys because counts on transect increased from 150 in 1992 to 545 in 1993. Thereafter, the total counts on transect ranged from 346 to 671 during the summers of 1994-97. The transect counts dropped down to 213 and 281 in 1998 and 1999 respectively. Less than 100 harlequins (usually much less) were seen additionally off transects any one year. Harlequins often refrain from flushing during aerial surveys and move closely along the shoreline, sometimes cryptically blending in with the background in their eclipse plumage. However, initial training and refresher training for observers has minimized this variable bias. Varying light and water conditions encountered at different tidal stages by the present survey design may still mean that some percentage of this species may be missed any one year. The low numbers and clumped distribution provide an additional challenge for monitoring this species with the present design because confidence limits will likely be large. Excluding the first summer, the nearshore component of the survey data found overall harlequin densities to vary from 1.73 to 3.83 harlequins per km^2. Overall densities for any one stratum are somewhat misleading for this species because their clumped distribution and absence from many areas lower the overall density considerably. Areas with the higher concentrations often had harlequins in densities that ranged from 25 to 65 birds per km^2 (Figure 15).

Cormorants

Three species of cormorants made up 3.1% of the total birds seen on transects: double-crested cormorant (*Phalacrocorax auritus*) pelagic cormorant (*P. pelagicus*), and Brandt's cormorant (*P. penicillatus*). Only the first two species breed in the greater Puget Sound area, with breeding areas were all found on either islands, rocky cliffs, or old pilings in the northern half of our survey area. Cormorant numbers and distributions in summer are generally restricted to waters close to these breeding colonies (Figure 16). The one non-breeding cormorant (Brandt's cormorant), was most commonly seen during July in the Strait of Juan de Fuca and near the southern portions of the San Juan Islands.

Cormorants are easy to recognize from the air, but species distinction is more difficult; hence there is a large category of unidentified cormorants in each year's survey data. The total number of cormorants seen any one year on transect ranged from 1,313 to 2,695. Of these, 22% were identified to species with the following percentages by species: double-crested (56.9%), pelagic (25.6%), and Brandt's (17.5%).

The highest counts or densities were seen in 1992 and 1994, with the lowest seen 1993, 1995, and 1997-99. Cormorants routinely move their colony breeding sites between years. Bald eagles have been frequently seen disrupting and dispersing numerous seabird colonies including

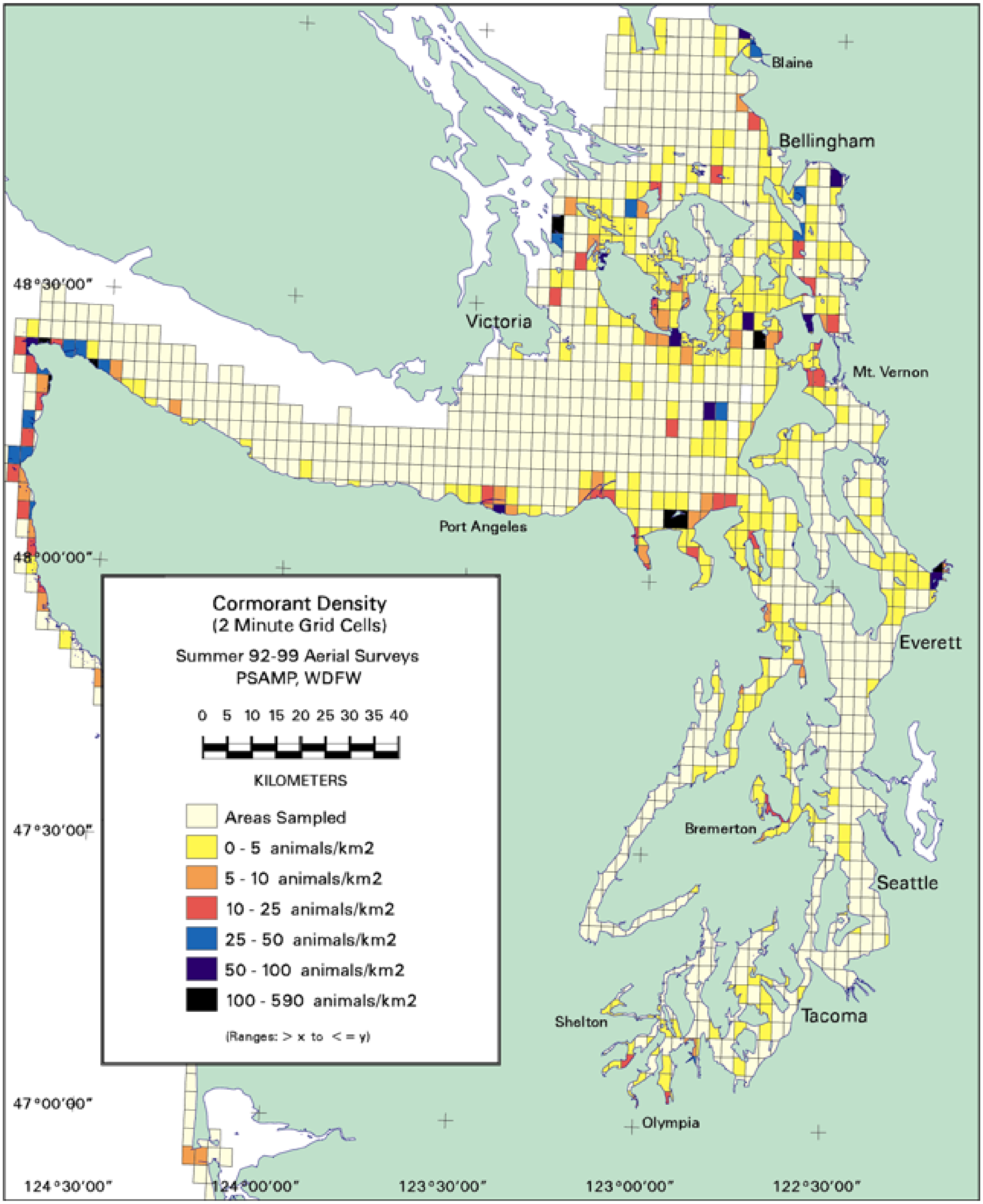


Figure 16. Mean Densities for Cormorants Derived from July 1992-99 Aerial Surveys.

cormorants in the straits and northern islands, and may have also played a role in this type of variation. It is clear that cormorants are no longer recovering from the bounty days, but the amount of annual variation makes it difficult to know if their numbers are stable or decreasing. Monitoring at colony sites over an extended period of years will most likely answer this more effectively than monitoring at sea during the breeding season. The densities seen overall in the PSAMP aerial surveys ranged from 1.20 to 3.11 birds per km^2 during 1992-99. The mean densities seen in the nearshore strata (<20 m), their preferred habitat, ranged annually from 5.17 to 9.66 birds per km^2.

Great Blue Herons

Great blue herons made up 2.4% of the birds identified to species during the summer and were the most widespread, common wading bird seen. The PSAMP aerial surveys were not designed to focus on a species such as herons because the transects covered different geographic areas with no survey timing standardized relative to tide levels. Because times are included in the database for each geographic position taken every 5-7 seconds, observations by tidal stage could be analyzed at a later date for certain sites. In the meantime, great blue herons would be most numerous in survey data during tides when some portion of the intertidal zone was exposed, and least numerous during high tides when they might be roosting or at a breeding site away from the marine waters. Hence the survey data as summarized here says something about presence of this species, but not necessarily anything about its absence from any particular area any one year. Nevertheless, the survey data over 8 years gives a reasonable sense of the marine habitat used throughout greater Puget Sound by this species (Figures 17 and 18), with river mouths, their nearby estuaries, and shallow bays (e.g. Samish and Padilla Bays) being especially attractive.

Mean annual densities for the nearshore strata varied from 2.95 seen per km^2 in 1992, to 10.03-10.60 in 1993-94, to 5.39-7.01 herons per km^2 during 1995-99. The 1992 data seems anomalous, but the reasons for this are unclear. If the 1992 data are removed from consideration, then both total counts and densities suggest some type of decrease in recent years. Recent anecdotal observations from the public and professional biologists have reported eagles disrupting heron rookeries, breeding success being very low, and rookeries being abandoned or moved. Visual comparisons of densities between 1992-94 and 1995-99 (Figures 17 and 18) give some credence to the allegation that the population of great blue herons is changing, whether it be moving colony sites, decreasing numbers of birds, or some other scenario. The PSAMP surveys support the idea that this species needs more focused surveys in the near future to evaluate the type of change that may be occurring.

Other Bird Species

The other species of birds that accounted for most of the remaining 3.8% of identified species seen July 1992-99 included northwestern crows (*Corvus caurinus*), thirteen other species of shorebirds, three species of grebes, three species of loons with common loons *(Gavia immer)* most consistent and numerous, belted kingfishers (*Ceryle alcyon*), bald eagles (*Haliaeetus leucocephalus*), and ospreys (*Pandion haliaetus*).

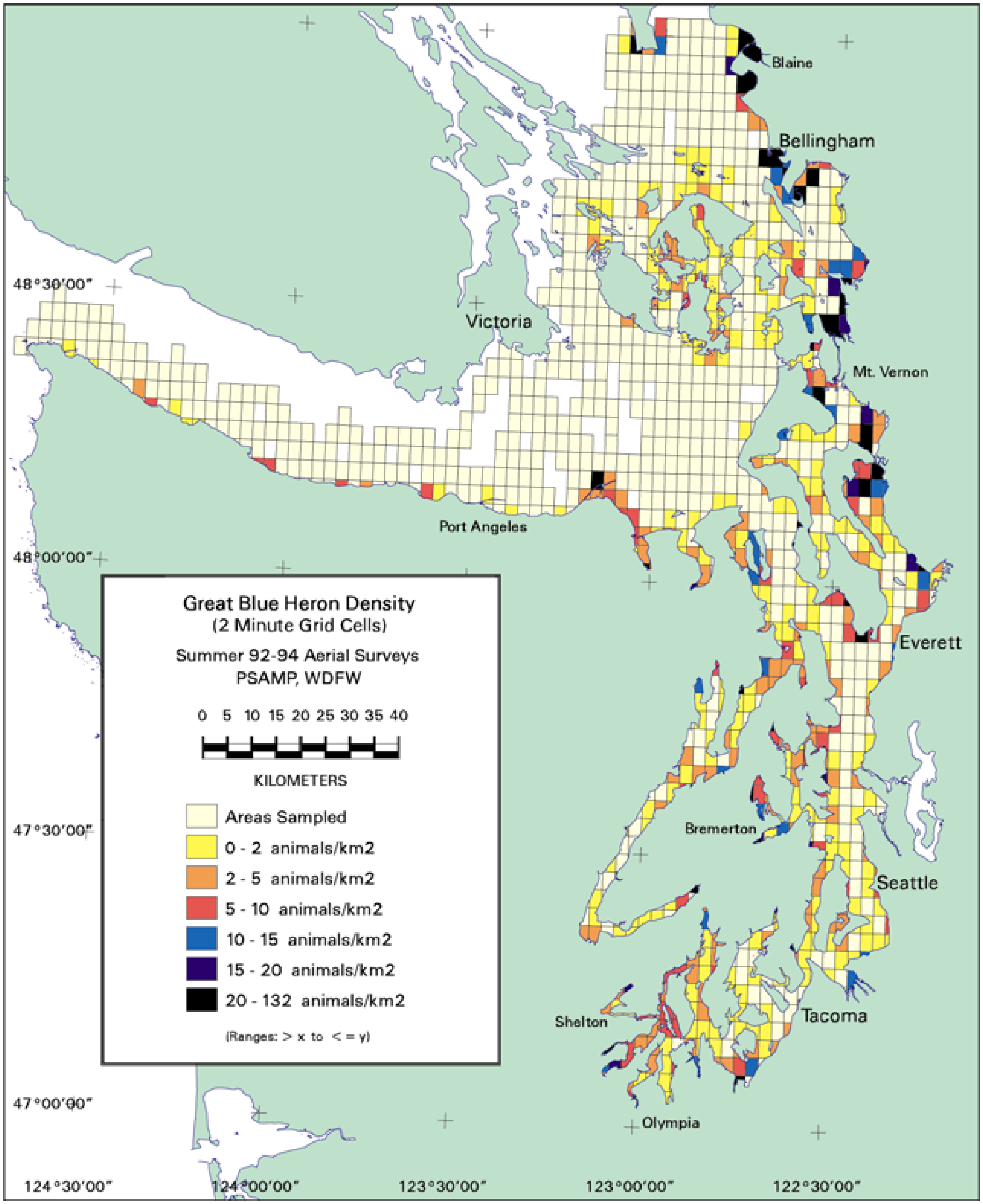


Figure 17. Mean Densities for Great Blue Herons Derived from July 1992-94 Aerial Surveys.

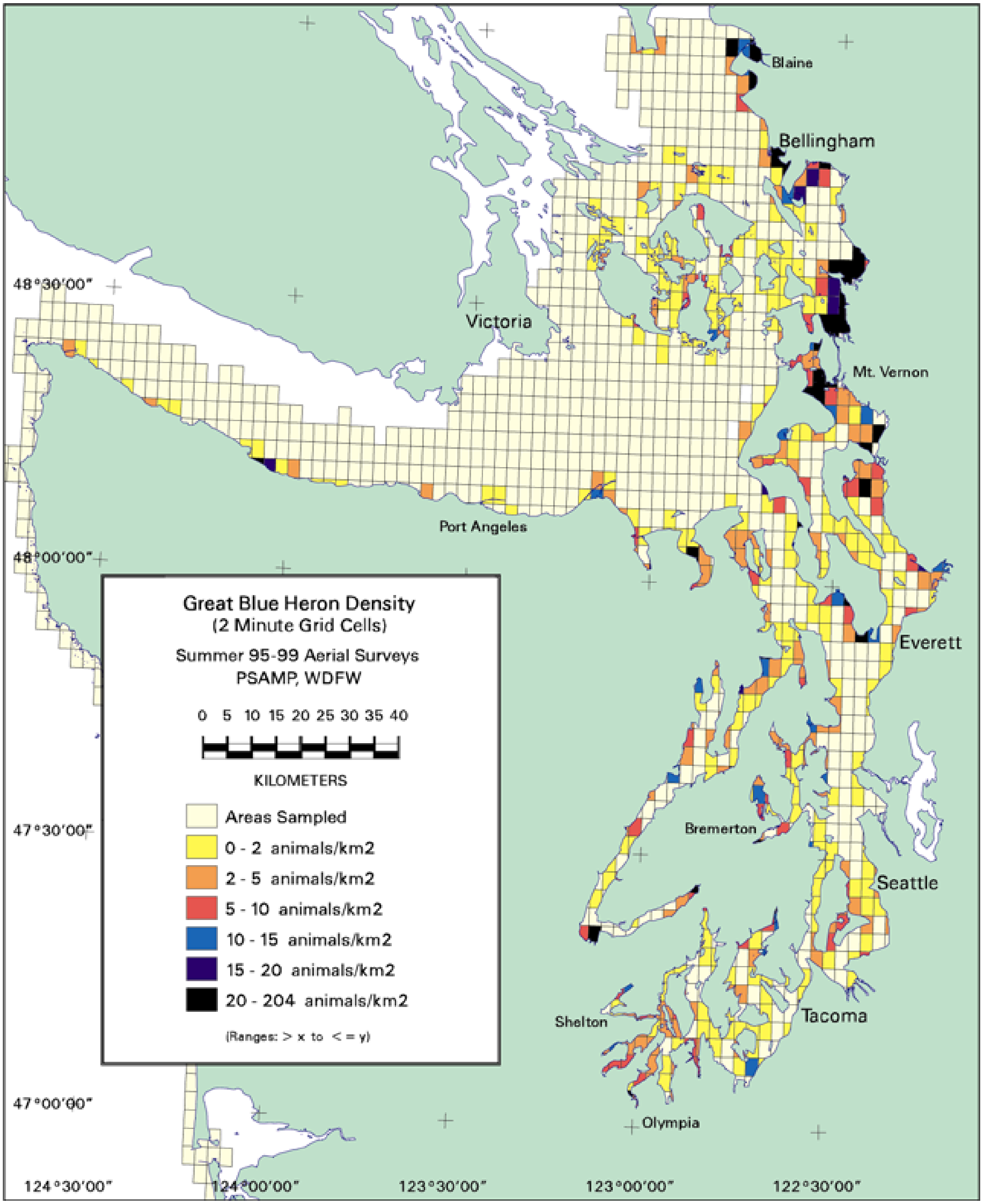


Figure 18. Mean Densities for Great Blue Herons Derived from July 1995-99 Aerial Surveys. .

3.1.2 Winter Surveys

Summer survey data involved certain variables in the beginning years, as discussed previously, such as different geographic coverage at first as well as some degree of different emphasis on secondary counting of birds off transect. The first winter surveys also experienced similar difficulties. Concern that too much attention to species off transect might pull observers' attention from observations on transect led us to reduce off-transect effort to just large concentrations of certain diving species such as western grebes.

Although the aerial survey design focused on densities derived from on-transect counts of diving marine bird species, for valid comparisons it is important to note that our transects only sampled a certain percentage of the total birds present. This percentage is higher for diving birds than other species such as dabbling ducks and geese that can also utilize freshwater and non-marine habitats. Comparing counts on and off transect for all marine bird species during the first several winters (when more effort was made to include numbers off transect), counts on transects made up 60-65% of the total number of birds seen by PSAMP crews. If the count totals for both on and off transects during PSAMP aerial surveys are considered, these totals are still less than the totals seen for all western Washington state midwinter waterfowl inventories. For example, in 1994 winter, PSAMP surveys counted 140,795 on transect, while approximately another 70,000 were noted off transect. The midwinter waterfowl inventory for all of western Washington totaled 353,000. In this document, density indices rather than population indices are stressed when evaluating trends, because we are not convinced that densities extrapolated to areas are accurate portrayals of total population levels. Our surveys are most likely not stratified in enough detail at this time to allow that type of extrapolation.

PSAMP aerial surveys have continued to include all bird species seen on transect as a secondary complement to other waterfowl surveys occurring at the same time. Other statewide surveys might be better focused and designed for certain species such as swans; however, PSAMP surveys have added some additional observations for marine areas not covered by other surveys.

The winter surveys also differed among themselves in several additional aspects:

1) The more extended freezing weather occurring during the 1992-93 surveys (means in January ranged from 5-10 degrees F cooler) drove many of the swans, geese, and dabbling duck species to the marine waters and shorelines, because freshwater areas froze over. The 1993-94 and 1995-99 winter aerial surveys encountered much warmer weather with relatively few freezing conditions and some of the same waterfowl species were not concentrated as much on the marine shorelines by the time the PSAMP surveys occurred.

2) Survey track lines for the nearshore habitat were done differently beginning in 1993-94 for certain estuaries with wide shallow intertidal areas (i.e. Skagit, Samish, and Padilla Bay areas). Instead of one linear parallel pass along the shoreline, a zigzag pattern was used that ranged between the high tide line and the beginning of deeper water (>20 m). This was done to sample more of the available habitat and reduce variation in estimates that occurs when species concentrate in large numbers in a linear fashion along a narrow

portion of the nearshore habitat. The densities and extrapolations that derive from this more intensive sampling might be closer to actual population levels, but the total raw counts would be lower for certain species such as dabbling ducks.

3) Additional survey areas in the western Strait of Juan de Fuca were covered starting in 1993-94 and thereafter, but not covered in the 1992-93 winter survey.

4) For varied biological and administrative reasons, the PSAMP aerial surveys were asked during the first several winters of this decade to not survey the Skagit and Padilla/Samish Bay areas until after hunting season finished. Timing of the hunting season has varied annually, but usually finished near the end of December. In recent winters, the hunting season has continued into January and the surveys have concluded in northern survey areas before the end of the season. This procedure did introduce variability for certain species. For instance, at the end of hunting season, the distribution pattern of geese, swans, and dabbling ducks changes because they begin to use more inland sites than they do during hunting season. Because PSAMP surveys do not include inland areas, counts of geese and dabbling ducks will often not include the total numbers utilizing portions of western Washington. WDFW has in place specialized surveys that are better suited for these species. As stated before, the PSAMP surveys are best suited for those species that consistently use marine waters in some fashion such as sea ducks, diving ducks, alcids, grebes, etc. Hence this variable in methodology was not felt to impact significantly the main focus of PSAMP monitoring.

5) The Federal Aviation Administration (FAA) tightened flight restrictions for government agencies for low-level flights near urbanized areas around 1996-97. Given the FAA changes, some of the shoreline track lines that PSAMP surveys were using in southern and central Puget Sound had to be eliminated because the plane would now be too close to developed areas. Survey data for the five winters during 1992-97 were summarized for 33 small bays or inlets of concern and analyzed to see what percentage of sea duck populations would be missed if these areas were not censused in the future. This analysis determined that the following four species would lose between 5.43% and 5.97% of the total count if these areas were discontinued: scoters (5.97%); scaup (5.71%); goldeneyes (5.43%); and bufflehead (5.49%). As a result, 26 of these sites were discontinued completely while 7 others were flown in some modified fashion with only one pass through especially sensitive areas, the plane positioned usually farther offshore. This should reduce the totals counts by up to 5-6%, but densities should be affected less because survey effort will have decreased as well. Bufflehead densities might be affected most, because the habitat coverage discontinued was the shallow heads of small bays this species utilizes. Any decrease in densities after 1997 might have to take this survey change into consideration.

Overall Bird Distribution and Abundance

The winter pattern of overall bird distribution observed by PSAMP surveys differed numerically as well as geographically from that of summer (Figure 19). These changes included:

- Marine bird numbers on transect increased by a factor of approximately four from summer to winter for comparable survey areas in any one year during 1992-99 (ranging from 32,000 to 102,000 in summer and ranging from 130,000 to 399,000 in winter).
- A much larger number of birds used the southern Puget Sound during winter than summer.
- Waterfowl usage increased along shorelines and river deltas, with certain estuaries (e.g. Skagit River delta, Padilla Bay) containing large numbers of geese and other waterfowl.
- Grebes and loons migrated into marine waters in notable concentrations and used protected waters (deeper waters with relatively low currents) in all of greater Puget Sound excluding the Strait of Juan de Fuca, and portions of the San Juan Islands.

A total of 398,645 birds were recorded on transect during the 1992-93 winter compared to the range of 203,904 - 268,206 seen 1994-97 and that of 129,578 - 138,570 seen 1997-99 on similar transects (Table 3). Densities varied similarly (Table 3), with the highest mean for both strata combined of 305.54 birds per km^2 seen in 1992-93, and the lowest means of 100.05 - 111.36 seen in 1997-99. The density for the high-density strata, the nearshore, varied from a high of 1,284.93 birds per km^2 in 1992-93 to lows of 335.84 - 367.23 per km^2 during the 1997-99 winters.

Ducks, Geese, and Swans

The 1992-99 PSAMP winter surveys found waterfowl species to average 68.3% of all birds counted on transect, with a range of 59.8% to 76.2% any one year. Diving ducks comprised 45.6% (range of 27.7% to 66.2% any one year) of the waterfowl, depending upon the influx of dabbling duck species into the marine habitat. The actual diving duck numbers and densities were more consistent from year to year (Table 4) because they did not have the flexibility of utilizing other habitats, not surveyed by PSAMP, which dabbling duck species could use. Actual on-transect counts of diving ducks ranged from 52,782 to 98,290 any one year during 1992-99. The four most numerous species groups are listed by order of percentages of diving ducks seen during the 1992-99 winter periods (Tables 5-6 and Figure 20): scoters (36.3%; range of 33.2-40.8%/year), bufflehead (23.3%; range of 22.2-25.1%/year), goldeneyes (16.6%; range of 15.4-18.1%/year), and scaup (8%; range of 6.1-10.1%/year).

Of all the scoters counted on transect during 1992-99 winter surveys, a range of 33-61 percent any one year were identified to species. Of these, surf scoters comprised 55-80%, white-winged scoters comprised 18-40%, and black scoters made up 3-9%. Both Barrow’s and common goldeneyes occur frequently throughout greater Puget Sound. During the first five winters the PSAMP aerial survey data only identified 2-7% of goldeneyes to species, but during the last two winters 42 to 47% were identified, suggesting that common goldeneyes were more numerous, especially in the straits and northern areas, which agreed with studies by Hirsch (1980) in those

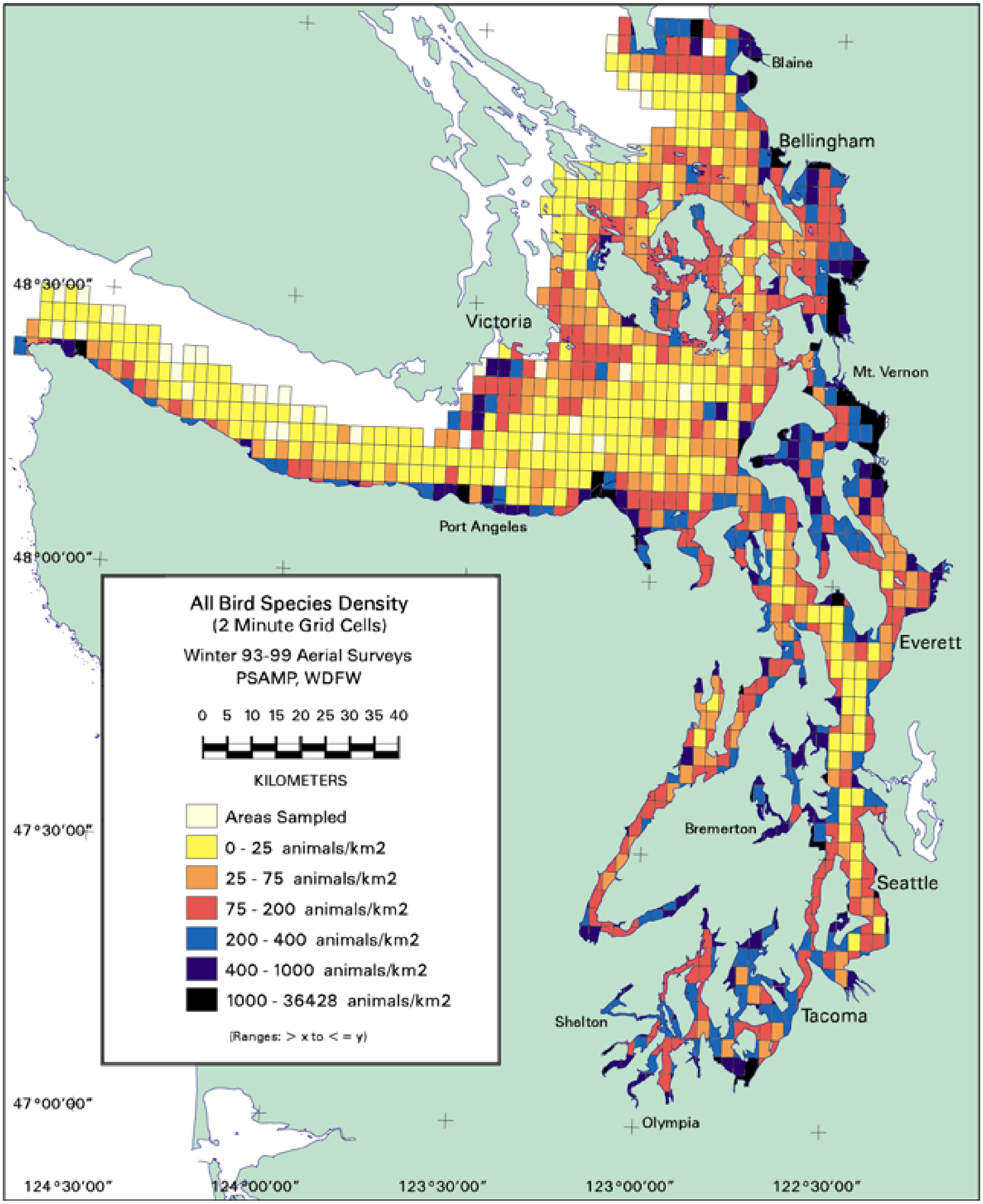


Figure 19. The Overall Mean Bird Densities Derived from Winter Aerial Surveys 1992-99.

Table 3. Comparisons of total counts and densities of marine birds observed on transect during PSAMP aerial surveys, December-February 1992-99.

Years	Total Counts	Densities (Both Strata Combined)		Density (Nearshore Strata)	
	Both Strata[1]	Birds\ Km^2	95% C. L.	Birds\ Km^2	95% C. L.
1992-93	398,645	305.54	134.98	1,284.93	630.50
1993-94	203,904	163.74	43.25	621.82	190.97
1994-95	268,206	214.35	38.37	733.52	162.79
1995-96	221,586	171.21	44.38	568.03	194.08
1996-97	262,852	202.68	68.70	727.24	301.99
1997-98	129,578	100.05	16.63	335.84	71.18
1998-99	138,570	111.36	15.31	367.23	61.38

Notes:

[1] Deep strata (>20 m) and nearshore strata (<20 m) combined.

Table 4. Comparisons of total counts and densities of diving and dabbling ducks observed on transect during PSAMP December-February aerial surveys 1992-99.

	Diving Ducks					Dabbling Ducks				
	Counts	Densities, Both Strata Combined[1]		Density, Nearshore strata		Counts	Densities, Both Strata Combined[1]		Density, Nearshore strata	
Years	Both Strata[1]	Per Km^2	95% C.L.	Per Km^2	95% C.L.	Both Strata[1]	Per Km^2	95% C.L.	Per Km^2	95% C.L.
1992-93	84,095	50.07	6.51	215.34	29.69	191,551	155.15	106.72	722.48	499.28
1993-94	69,621	42.25	5.15	166.78	21.44	68,394	53.04	29.77	233.78	131.96
1994-95	98,290	60.94	6.07	239.86	24.19	82,554	64.50	30.60	284.75	135.64
1995-96	75,205	46.77	4.10	182.11	16.92	54,856	37.11	18.19	158.89	80.10
1996-97	69,597	42.63	5.63	165.11	23.37	102,606	72.26	41.87	318.39	185.63
1997-98	52,782	35.86	6.53	144.45	28.73	24,066	15.70	5.82	69.15	25.81
1998-99	55,487	36.69	4.53	146.44	19.51	36,124	27.05	11.65	119.30	51.66

Notes:

[1] Deep strata (>20 m) and nearshore strata (<20 m) combined.

Table 5. Comparisons of total counts and densities of scoter (3 spp.) and bufflehead observed on transect during PSAMP December-February aerial surveys 1992-99.

	Scoter (3 spp.)					Bufflehead				
	Counts	Densities, Both Strata Combined[1]		Density, Nearshore strata		Counts	Densities, Both Strata Combined[1]		Density, Nearshore strata	
Years	Both Strata[1]	Per Km^2	95% C.L.	Per Km^2	95% C.L.	Both Strata[1]	Per Km^2	95% C.L.	Per Km^2	95% C.L.
1992-93	32,521	15.97	2.92	64.76	12.46	18,652	13.38	2.67	60.41	12.46
1993-94	23,112	14.95	3.32	53.56	13.13	16,164	10.24	1.37	44.38	3.04
1994-95	34,549	19.39	3.19	70.43	9.86	22,332	14.86	1.99	64.32	8.81
1995-96	26,034	15.40	2.02	56.12	7.35	17,315	11.06	2.12	47.45	9.35
1996-97	26,187	16.29	2.81	59.76	10.64	16,923	10.11	1.20	42.88	5.27
1997-98	21,511	13.94	2.36	55.00	10.21	12,126	8.00	1.23	34.12	5.45
1998-99	21,052	14.52	2.64	56.32	11.25	13,954	8.80	1.17	36.73	5.12

Notes:

[1] Deep strata (>20 m) and nearshore strata (<20 m) combined.

Table 6. Comparisons of total counts and densities of goldeneye (2 spp.) and scaup (2 spp.) observed on transect during PSAMP December-February aerial surveys 1992-99.

	Goldeneye (2 spp.)					Scaup (2 spp.)				
	Counts	Densities, Both Strata Combined[1]		Density, Nearshore strata		Counts	Densities, Both Strata Combined[1]		Density, Nearshore strata	
Years	Both Strata[1]	Per Km^2	95% C.L.	Per Km^2	95% C.L.	Both Strata[1]	Per Km^2	95% C.L.	Per Km^2	95% C.L.
1992-93	14,140	6.49	0.84	27.99	3.72	6,352	5.84	2.39	26.48	11.09
1993-94	12,587	6.41	0.83	25.58	3.41	4,262	3.08	1.35	13.62	5.98
1994-95	16,926	9.27	1.07	38.34	4.48	9,969	6.60	2.81	29.05	12.47
1995-96	11,568	5.57	0.67	21.97	2.66	6,060	4.95	2.16	21.15	9.52
1996-97	10,892	5.28	0.65	20.62	2.63	4,423	3.49	2.73	15.37	12.08
1997-98	8,554	4.40	0.51	17.27	2.11	4,839	4.82	2.66	20.88	11.79
1998-99	9,070	4.79	0.65	18.95	2.62	4,250	3.54	1.50	15.69	6.64

Notes:
[1] Deep strata (>20 m) and nearshore strata (<20 m) combined.

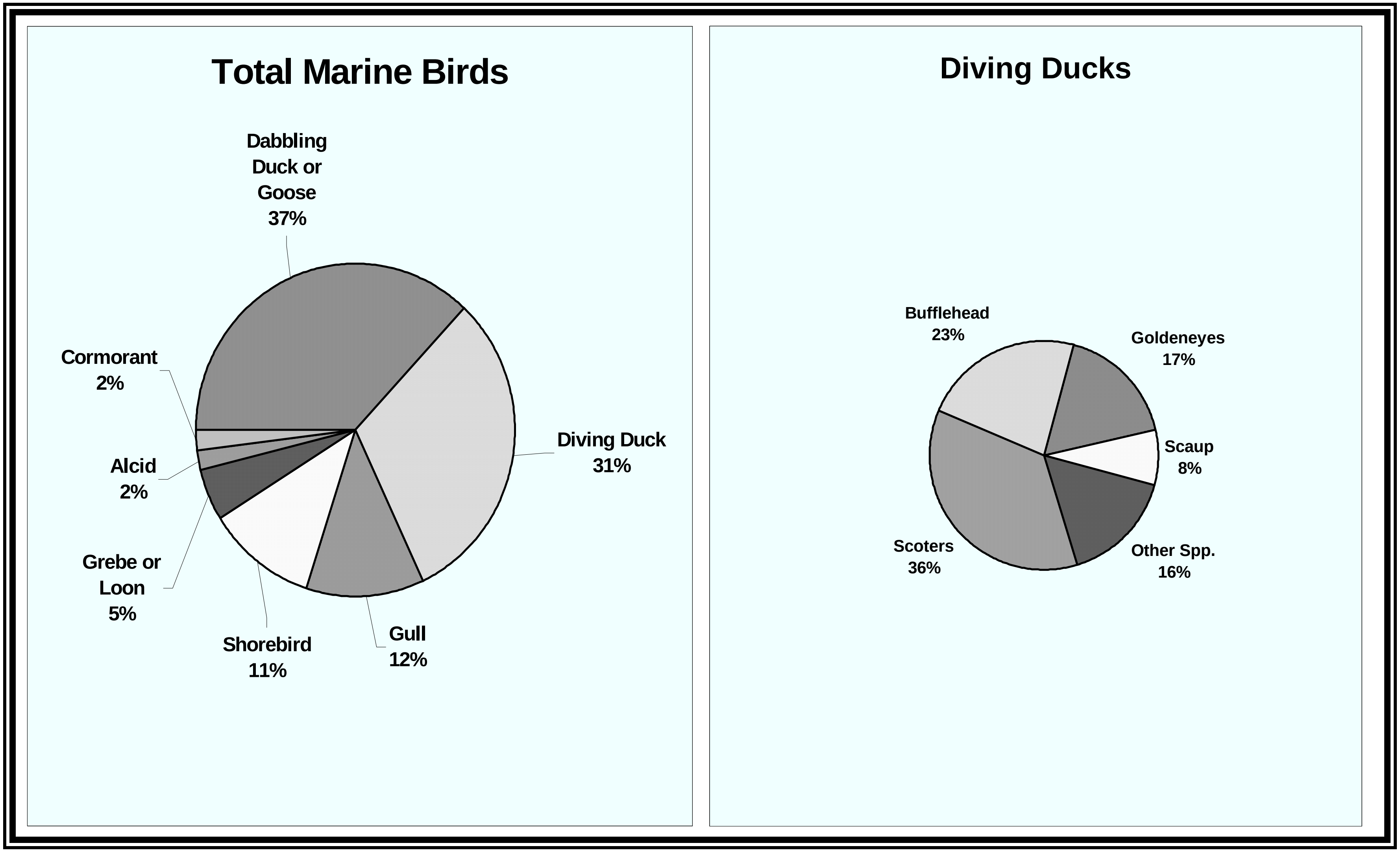


Figure 20. Composition of Marine Bird Populations Seen on PSAMP Winter Surveys in Greater Puget Sound 1992-99.

same northern areas. However, in some of the bays and inlets of southern and central Puget Sound, Barrow's goldeneyes could often be more numerous than Common Goldeneyes. Nearly all of the scaup counted in PSAMP winter surveys are likely to be greater scaup, but some lesser scaup may well be present because they are common in the Columbia River drainage and mouth.

Hirsch (1980) combined data from the MESA surveys with thesis work and evaluated how marine diving ducks partition, overlap, and utilize both macro and microhabitats of the nearshore marine environment. The patterns observed for habitat use by PSAMP aerial surveys follow similar patterns overall although the following differences in percentages of species composition were noted: scoters (36% by PSAMP vs. 33% by Hirsch), goldeneyes (17% vs. 5%) bufflehead (23% vs. 33%) and scaup (8% vs. 24%). These differences occur in part because PSAMP study area also included southern and central Puget Sound (a different species composition) in combination with the northern MESA area covered by Hirsch, but differing degrees of species declines (i.e. scaup) may also be affecting these changing compositions.

Scoters were found throughout most of the nearshore marine waters in western Washington and exhibited the highest overall mean densities for these nearshore waters of the four most numerous species of diving ducks. Although northern areas contained notable concentrations (e.g. Boundary Bay, Bellingham Bay, and Padilla-Samish Bay), higher densities and larger total numbers of scoters were found in the southern and central portions of Puget Sound (Figures 21-22). Mean overall densities in nearshore waters varied annually from 55.0 to 70.4 birds per km^2 between 1992-99 (Table 5).

Bufflehead were also found throughout most of the nearshore marine waters, but their distribution pattern differed in that they tended to favor shallower waters and heads of bays or inlets (Figures 23-24). Especially large numbers would also frequent the shorelines of the southern Strait of Juan de Fuca during certain years. Their mean overall densities in nearshore waters were slightly less than scoters and varied annually from 34.1 to 64.3 birds per km^2 1992-99 (Table 5).

Goldeneyes were found almost everywhere, in lower numbers at least, in the inland marine waters of Washington (Figures 25-26), although their densities on average were somewhat higher in the southern and central portions of greater Puget Sound than in the northern areas. Goldeneyes would often be present when no other sea duck species was present. Their more consistent density meant that confidence limits were usually quite good for density indices calculated. Densities were considerably less than scoters or bufflehead with a mean overall annual density for nearshore waters that varied from 17.3 to 38.3 birds per km^2 in 1992-99 (Table 6).

Scaup were numerically less abundant than even goldeneyes, and their distribution pattern was highly clumped, usually in shallower waters (Figures 27-28). This would mean that larger flocks would be seen in any one location with correspondingly larger confidence limits associated with these observations. Nevertheless, the mean overall densities for nearshore waters were still somewhat similar to goldeneyes because of the lower total number. Densities varied from 13.6 to 29.1 birds per km^2 1992-99 in nearshore waters (Table 6).

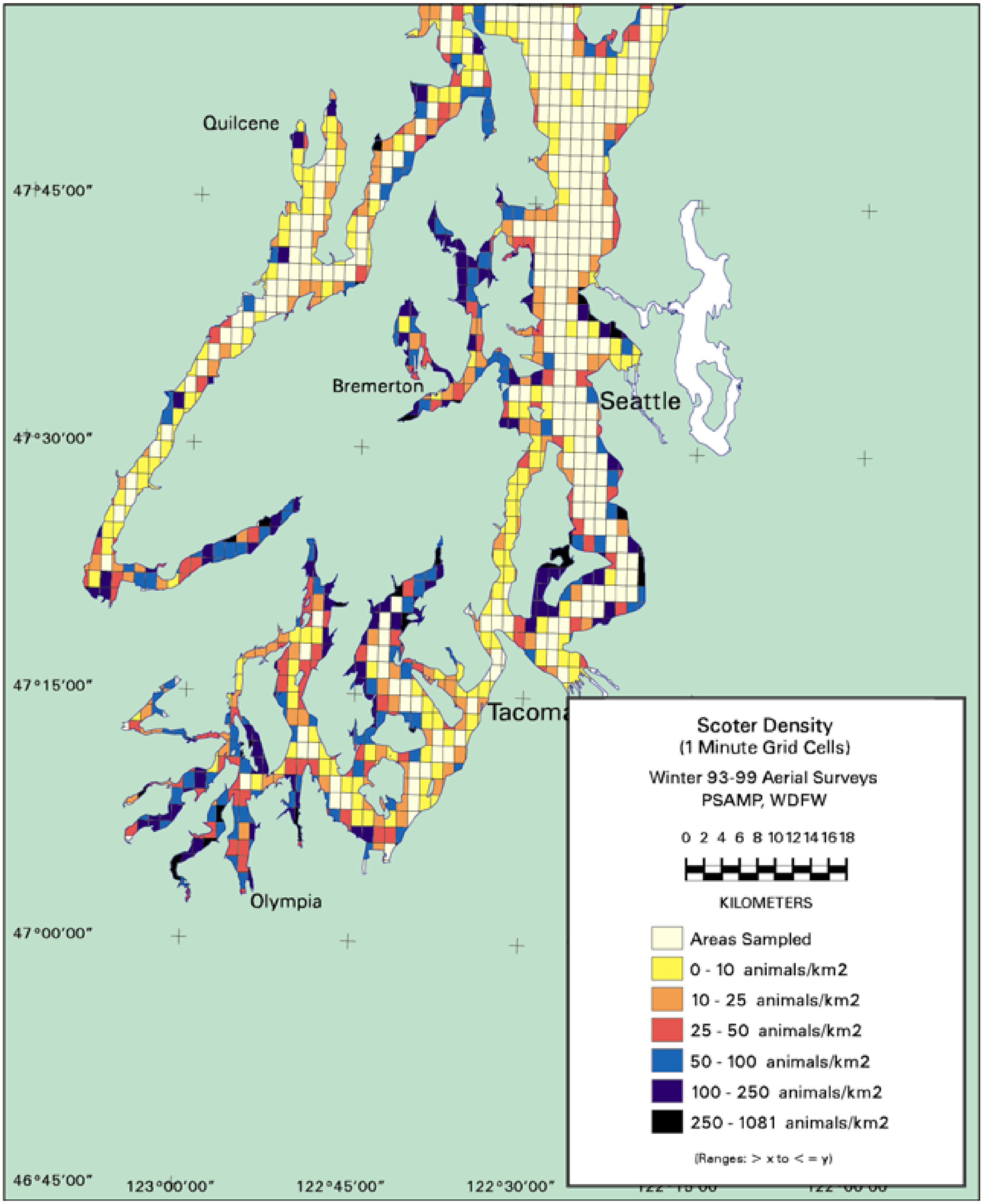


Figure 21. Mean Densities for Scoters (3 spp.) in Southern and Central Puget Sound Derived from Winter 1992-99 Aerial Surveys.

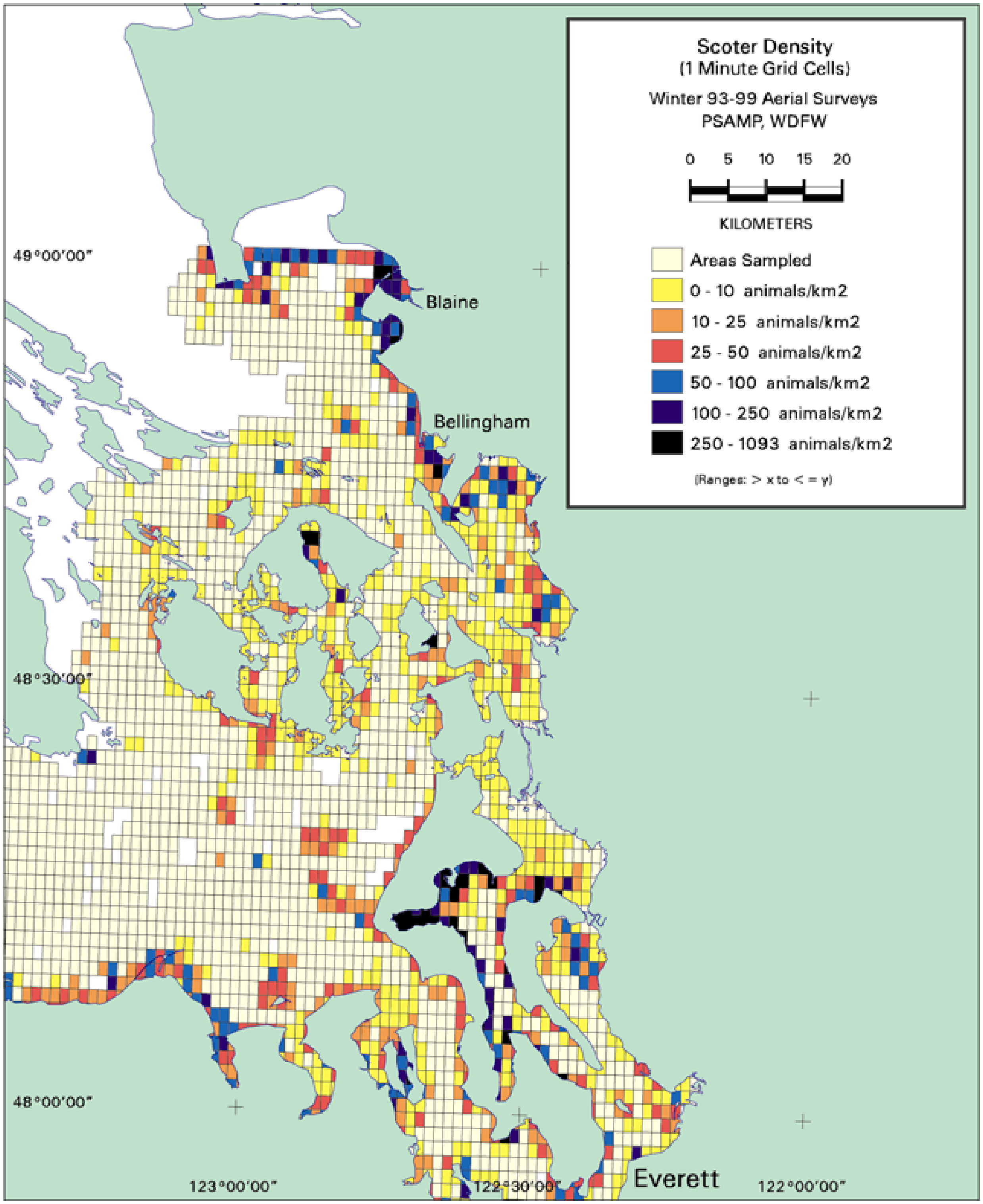


Figure 22. Mean Densities for Scoters (3 spp.) in Northern Greater Puget Sound Derived from Winter 1992-99 Aerial Surveys. .

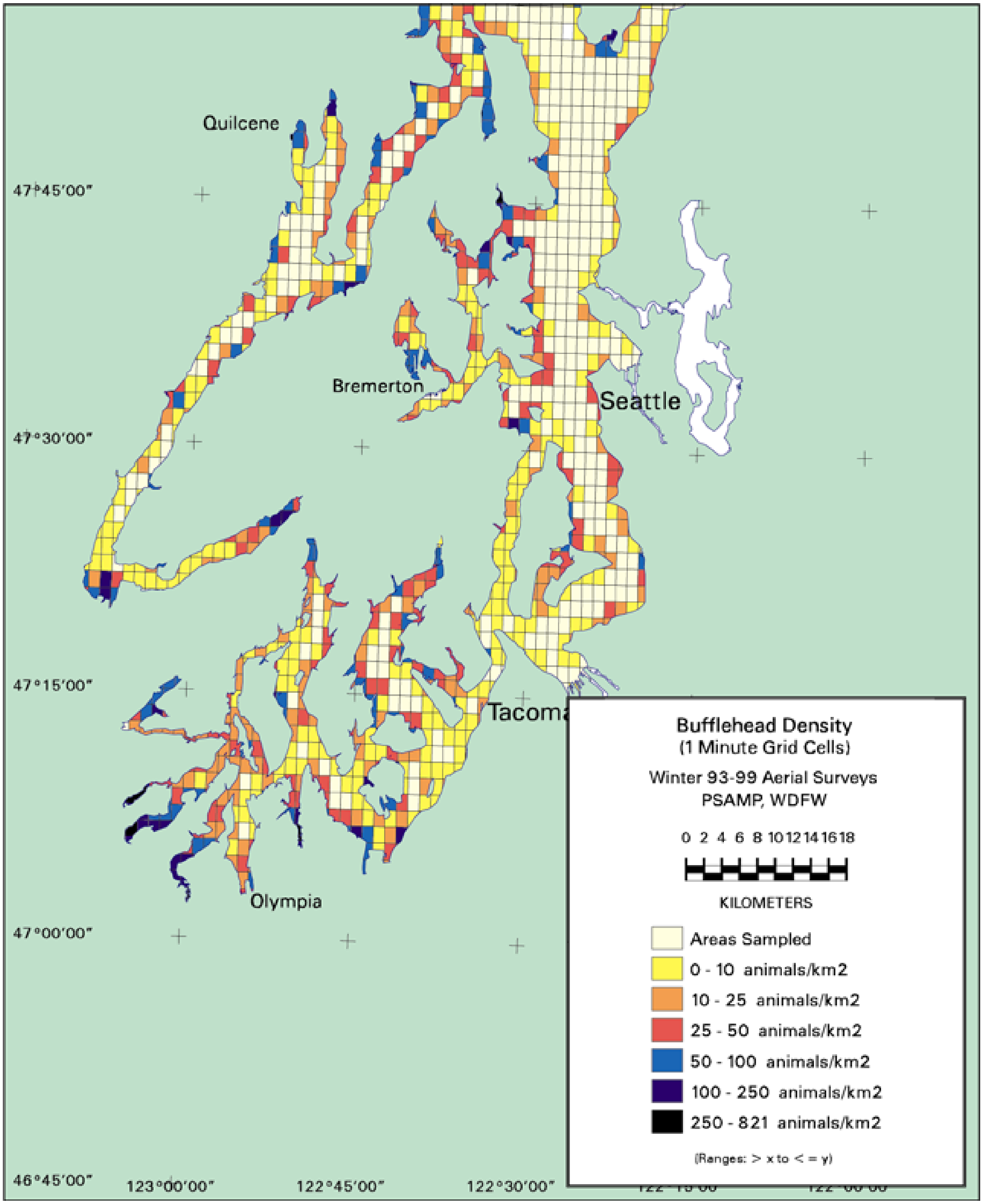


Figure 23. Mean Densities for Bufflehead in Southern and Central Puget Sound Derived from Winter 1992-99 Aerial Surveys.

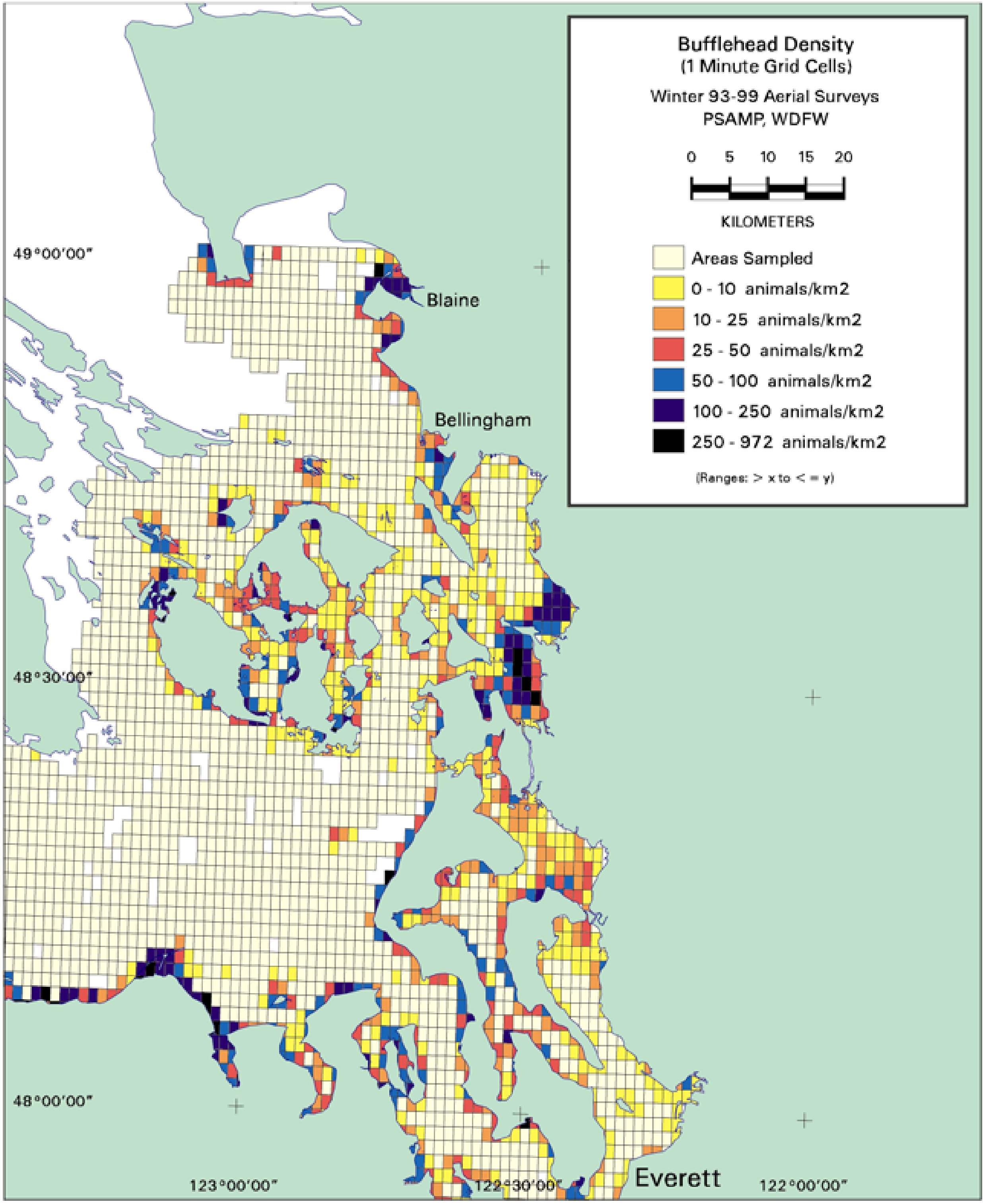


Figure 24. Mean Densities for Bufflehead in Northern Greater Puget Sound Derived from Winter 1992-99 Aerial Surveys.

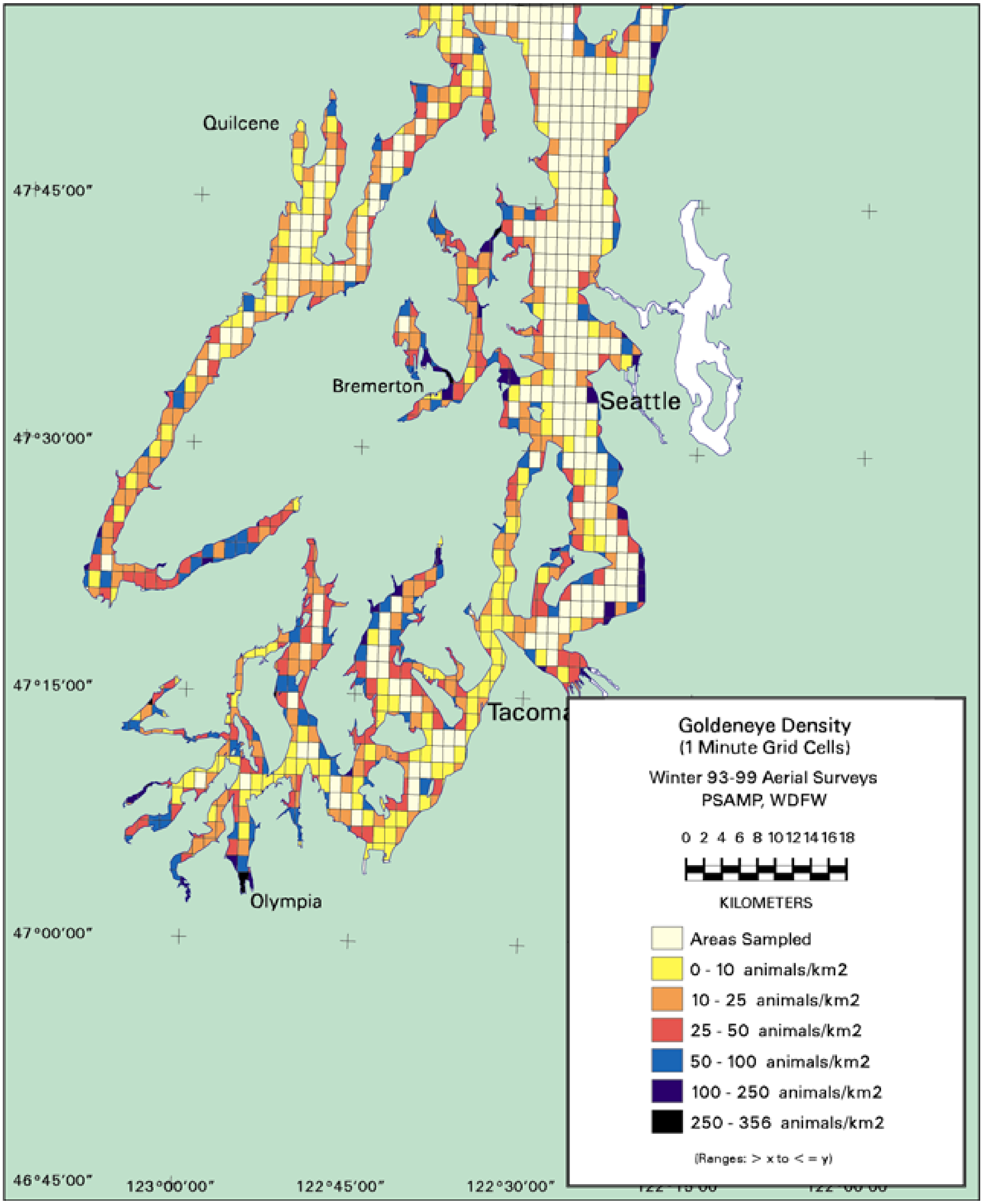


Figure 25. Mean Densities for Goldeneyes (2 spp.) in Southern and Central Puget Sound Derived from Winter 1992-99 Aerial Surveys.

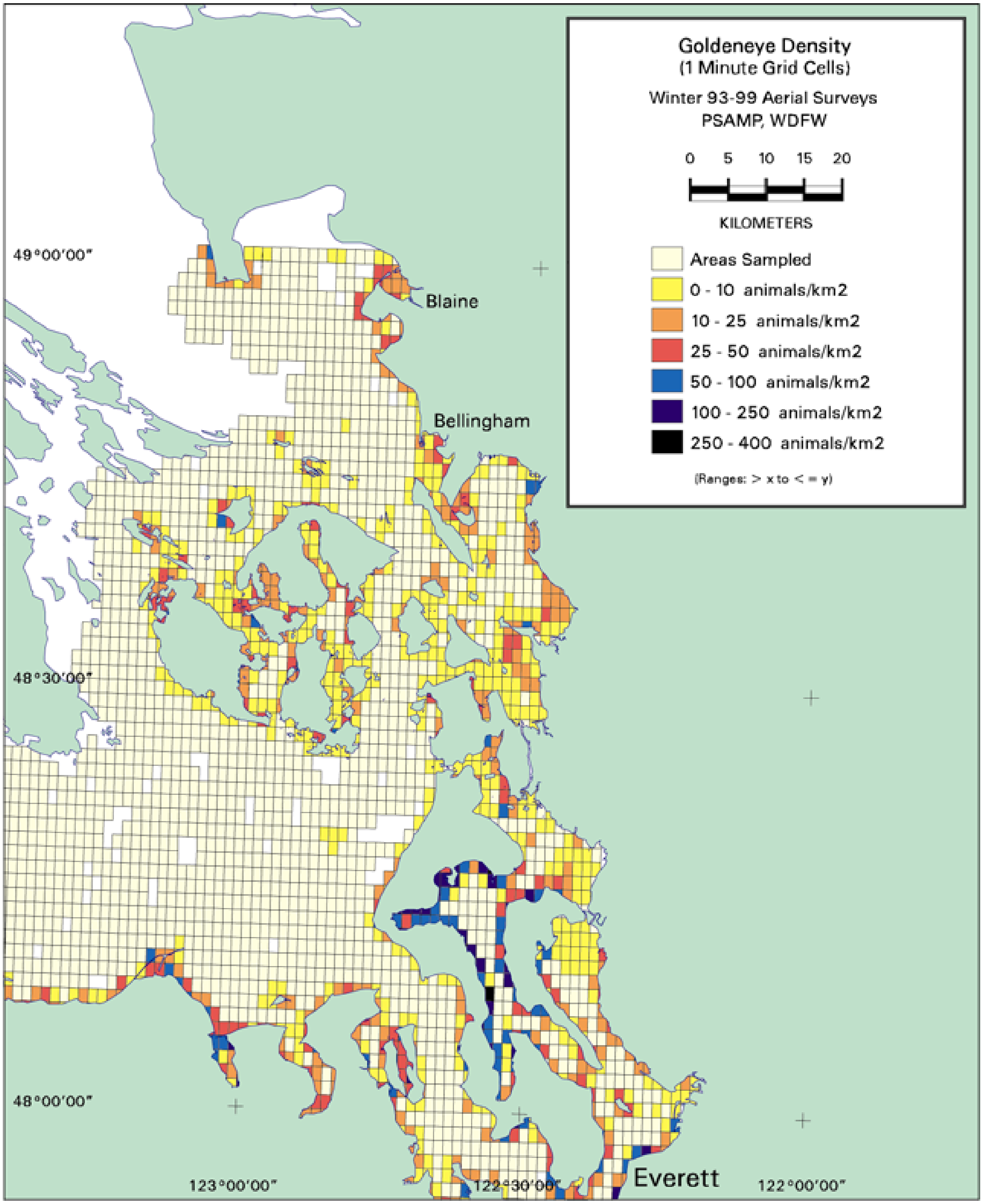


Figure 26. Mean Densities for Goldeneyes (2 spp.) in Northern Greater Puget Sound Derived from Winter 1992-99 Aerial Surveys.

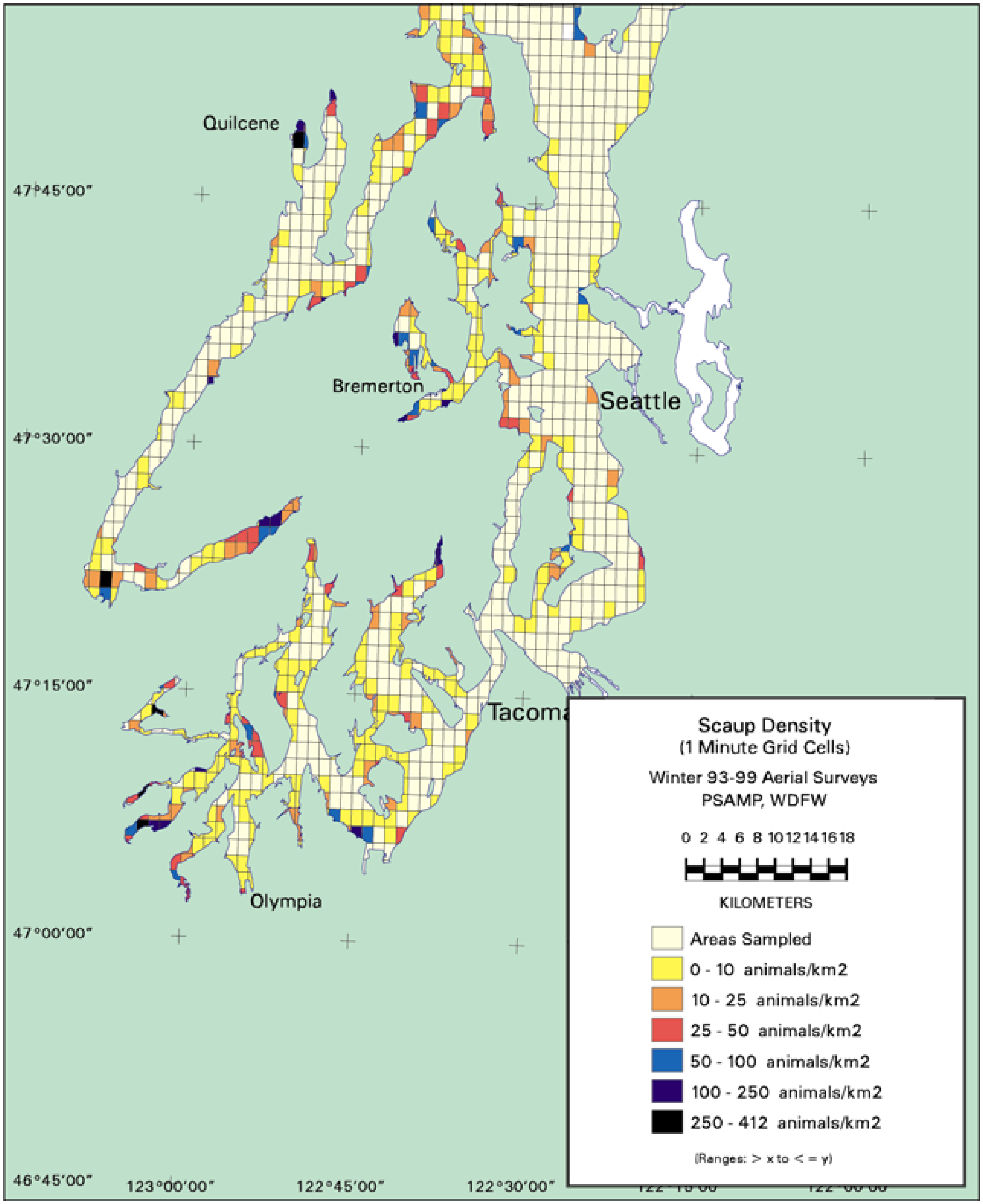


Figure 27. Mean Densities for Scaup (2 spp.) in Southern and Central Puget Sound Derived from Winter 1992-99 Aerial Surveys.

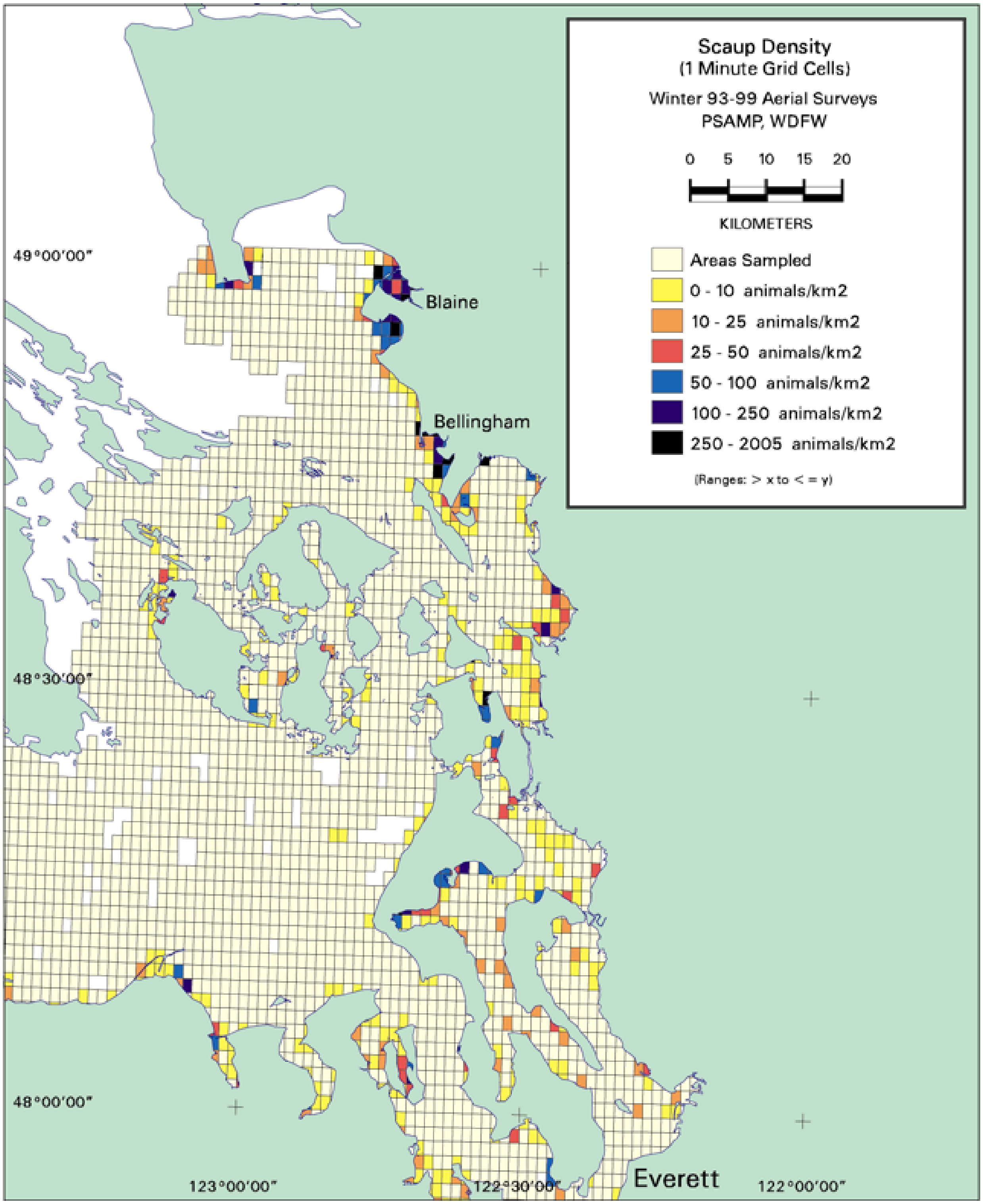


Figure 28. Mean Densities for Scaup (2 spp.) in Northern Greater Puget Sound Derived from Winter 1992-99 Aerial Surveys. .

Other species, comprising the remaining percentage of identified diving ducks observed (Table 7), are listed in decreasing order of abundance: the three merganser species (6.2%); ruddy duck (*Oxyura jamaicensis*) (2.5%); harlequin duck (1.2%); oldsquaw (*Clangula hyemalis*) (1.1%); and canvasback (*Aythya valisineria*) (0.5%). These species of diving ducks were seen each year with special distribution patterns, albeit in somewhat variable numbers. Mergansers are common throughout greater Puget Sound, usually in lower densities than other sea ducks (Figure 29). A large percentage of mergansers are unidentified to species on the aerial survey data, but this category is composed of mostly either common or red-breasted mergansers (*Mergus serrator*). During winter the red-breasted merganser was generally more numerous than the common. The hooded merganser (*Lophodytes cucullatus*) was the least abundant, and it exhibited a different distribution pattern (Figure 30), favoring the San Juan Islands and selected portions of south and central Puget Sound. Ruddy ducks were highly clumped with a patchy distribution (Figure 31) that favored southwestern Puget Sound, Penn Cove, Padilla Bay, and Drayton Harbor/Birch Bay vicinity. Canvasback exhibited a similar geographical pattern (Figure 32) to that noted for the ruddy duck, often clumping in sizeable single species flocks. Some years canvasback rafted in large flocks on lakes such as Samish Lake near Bellingham (Davison pers. comm.) and may not always have been present on the marine waters. Oldsquaw exhibited a much different habitat distribution pattern (Figure 33) and would be found in deeper nearshore waters, primarily in the eastern portions of the Strait of Juan de Fuca and Georgia Strait. Harlequin ducks, due to an almost linear and close association with the intertidal, were found along selected shorelines; three portions of greater Puget Sound have been examined in greater detail to come closer to mapping the actual location and densities (Figures 34-36). Kelp beds were also quite attractive to this species, such as those found along the south shore of the Strait of Juan de Fuca. The winter distribution of harlequin ducks differs from that of the summer in that more birds were widely dispersed throughout greater Puget Sound, but many of the same areas selected in summer still harbored the highest concentrations in winter.

Dabbling ducks comprised 50.5% of all waterfowl counted during 1992-99 winter surveys, with a range from 30.3% to 63.1% any one year. Of those dabbling ducks identified to species, four species comprised almost 100%: American wigeon (*Anas Americana*, 53.1%); mallard (39.3%); northern pintail (*A. acuta*, 5.5%); and teal, primarily green-winged teal (*A. crecca*, 1.8%). Gadwall (*A. strepera*) was also noted occasionally (0.2%). American wigeon was the most marine of these dabbling duck species and their abundance usually peaked in December before they moved inland and up river valleys.

Geese and swans comprised the remaining percentages of waterfowl (mean of 3.9%) observed on transect during the 1992-99 winter aerial transects. These species were most abundant on the marine shores during the colder winter 1992-93. For instance, that year 1,299 swans, both trumpeter swan (*Cygnus buccinator*) and tundra swans (*C. columbianus*), were seen (46% of western Washington populations at that time) while the total numbers ranged from 71 to 261 during the following six winters. Observations of geese followed a similar pattern where 10,733 were seen 1992-93 while other years somewhere between 1,300 and 2,400 would be counted on transects. Other WDFW surveys surveying other all marine and non-marine habitats focusing on geese species would find somewhere in the range of at least 70-80,000 geese any one year.

Table 7. Comparisons of other diving duck species counts obtained on transect during PSAMP winter aerial surveys, December-February 1992-99.

	Winter Survey Period						
Species	92-93	93-94	94-95	95-96	96-97	97-98	98-99
Total Mergansers	5,612	4,349	5,728	5,028	4,395	2,475	3,717
Common Merganser	48	118	706	471	308	267	1,470
Red-breasted Merganser	640	1,155	1,001	1,295	1,002	734	825
Hooded Merganser	313	161	119	311	135	60	98
Unid. Merganser	4,611	2,915	3,902	2,951	2,950	1,414	1,324
Ruddy Duck	2,261	2,840	1,639	2,156	1,825	938	919
Harlequin Duck	699	725	862	1,095	931	951	758
Oldsquaw	405	327	1,539	667	1,068	615	707
Canvasback	485	284	254	163	1,065	229	146
Unid. Diving Ducks	3,700	5,236	4,744	5,399	1,953	779	977

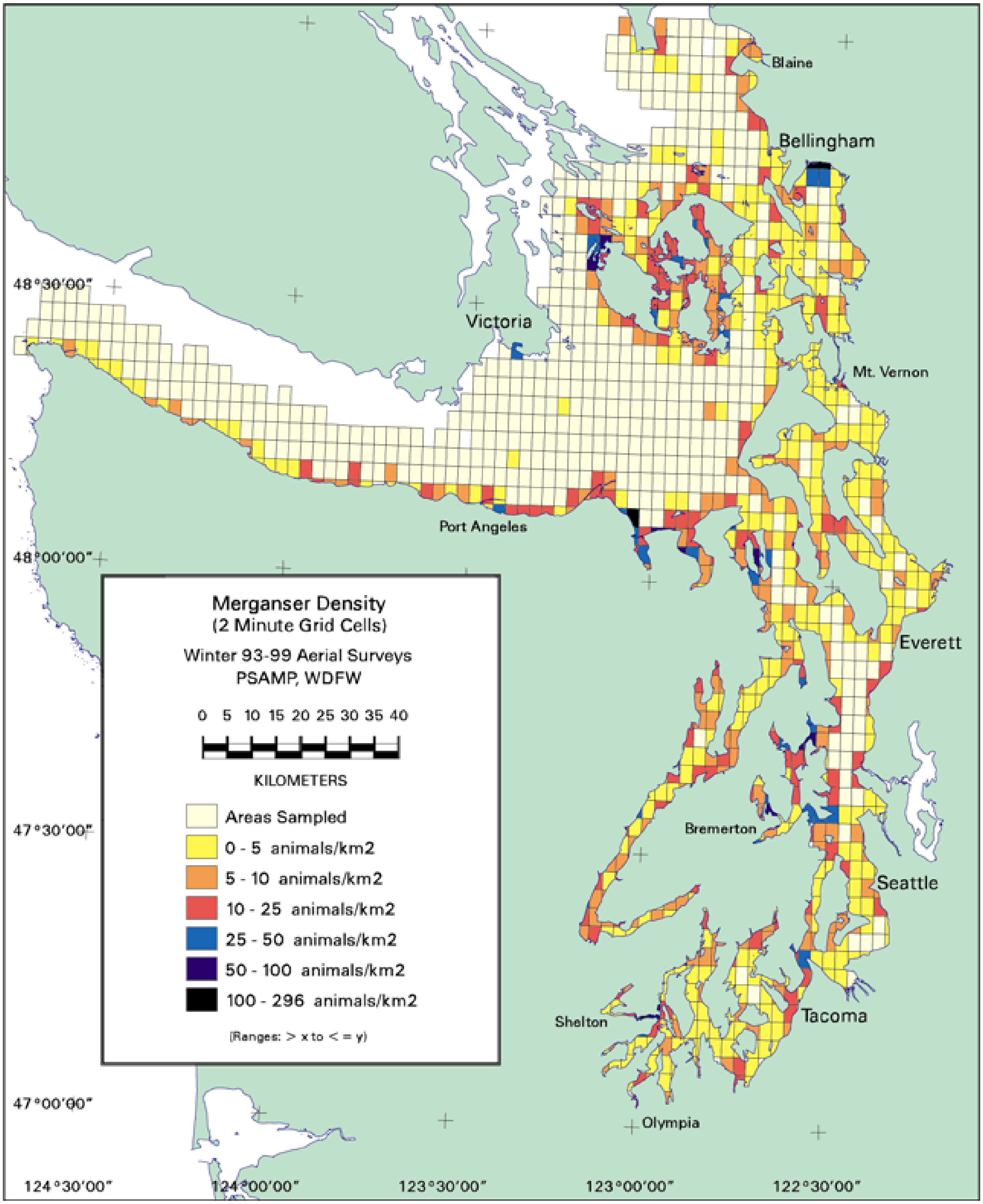


Figure 29. Mean Densities for Mergansers (3 spp.) in Greater Puget Sound Derived from Winter 1992-99 Aerial Surveys.

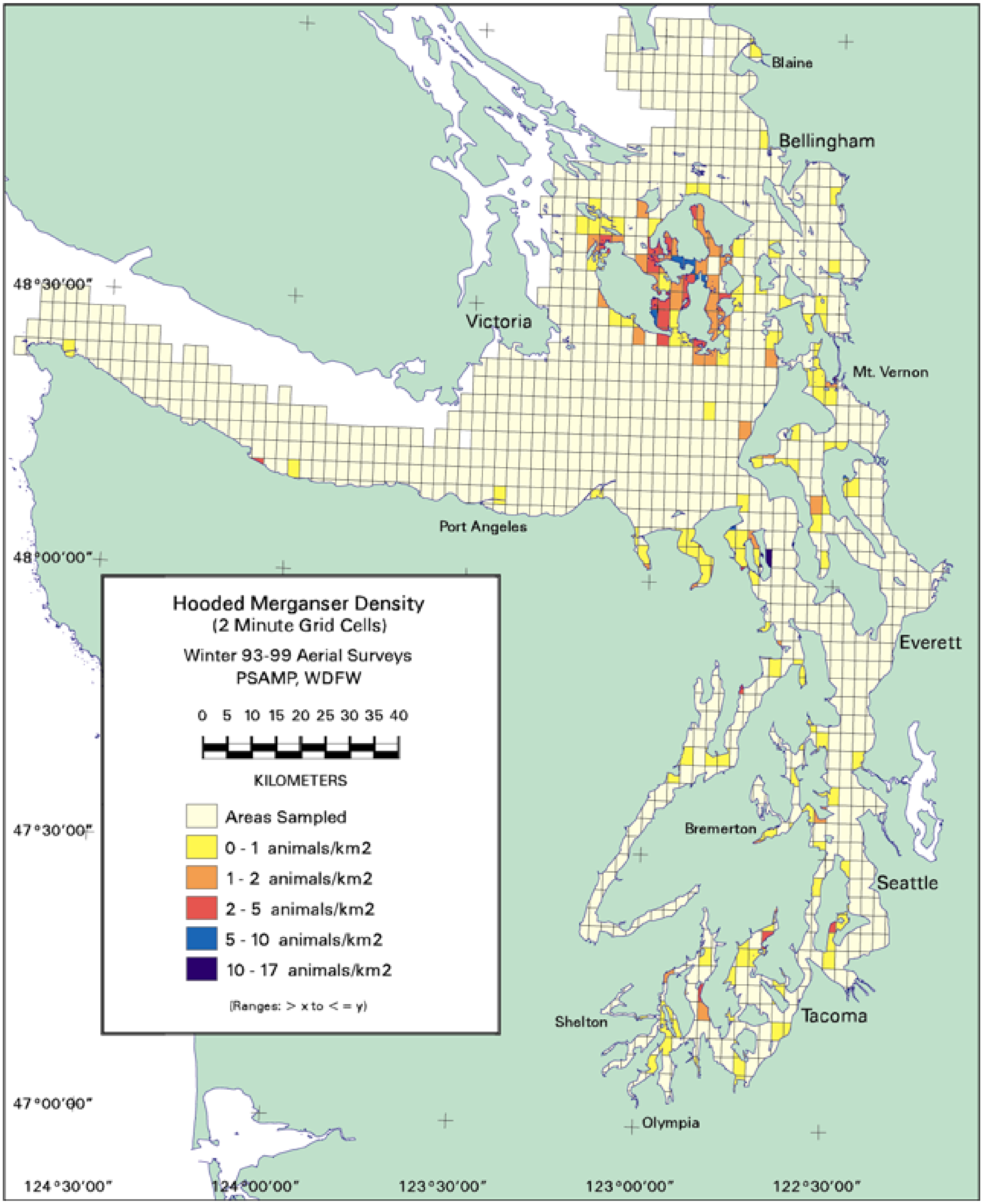


Figure 30. Mean Densities for Hooded Merganser in Greater Puget Sound Derived from Winter 1992-99 Aerial Surveys.

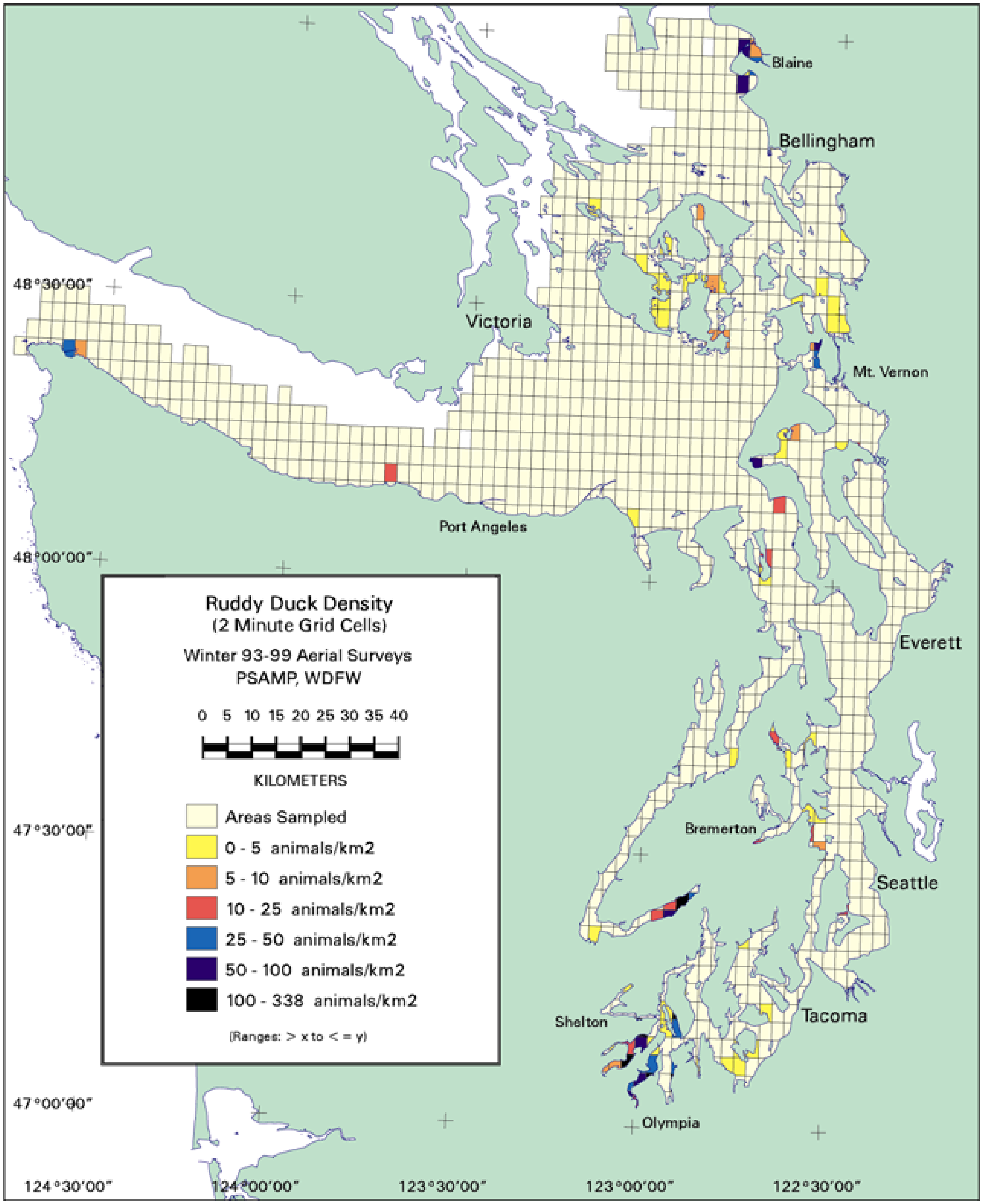


Figure 31. Mean Densities for Ruddy Duck in Greater Puget Sound Derived from Winter 1992-99 Aerial Surveys.

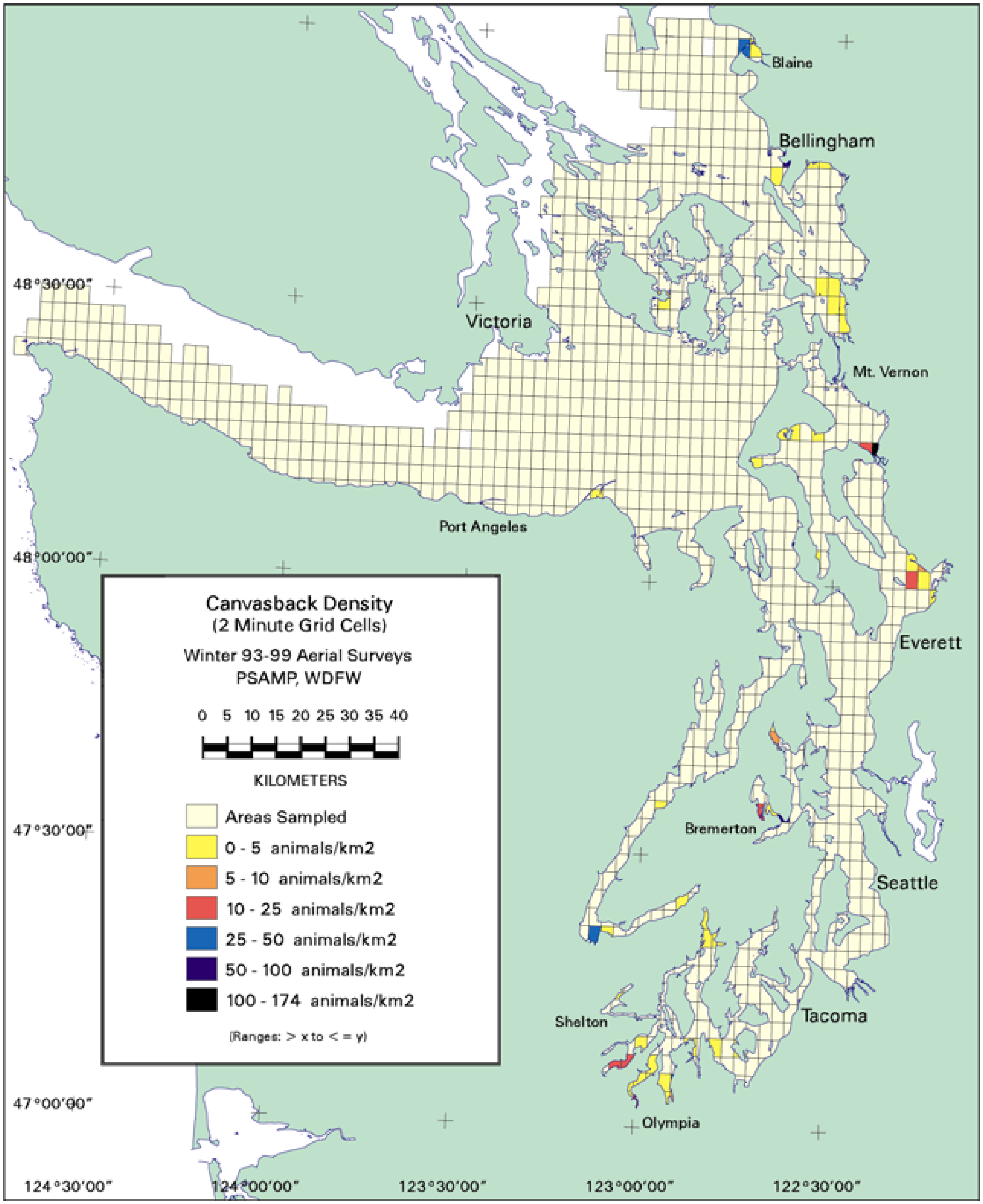


Figure 32. Mean Densities for Canvasback in Greater Puget Sound Derived from Winter 1992-99 Aerial Surveys.

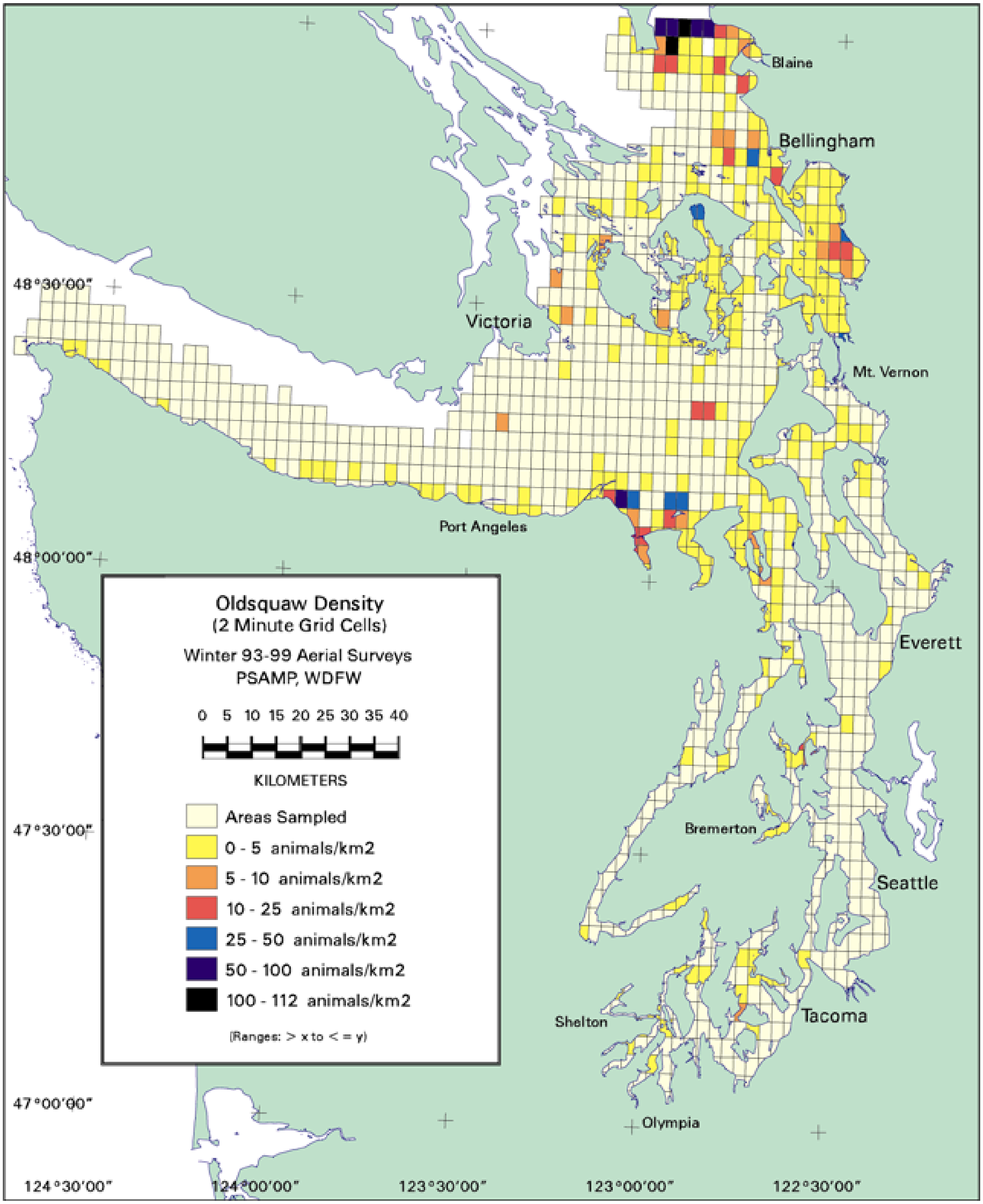


Figure 33. Mean Densities for Oldsquaw in Greater Puget Sound Derived from Winter 1992-99 Aerial Surveys.

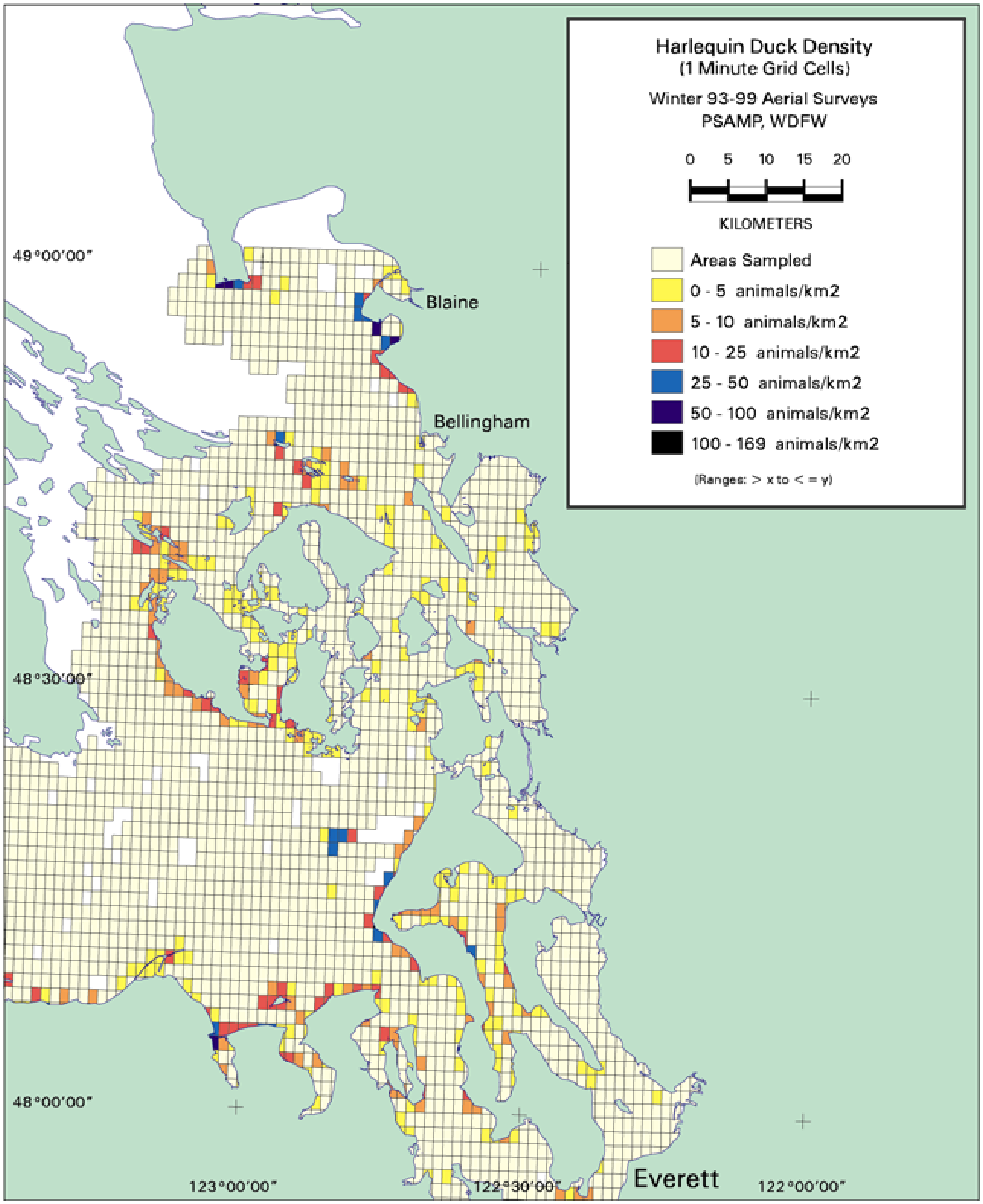


Figure 34. Mean Densities for Harlequin Duck in Northern Puget Sound Derived from Winter 1992-99 Aerial Surveys.

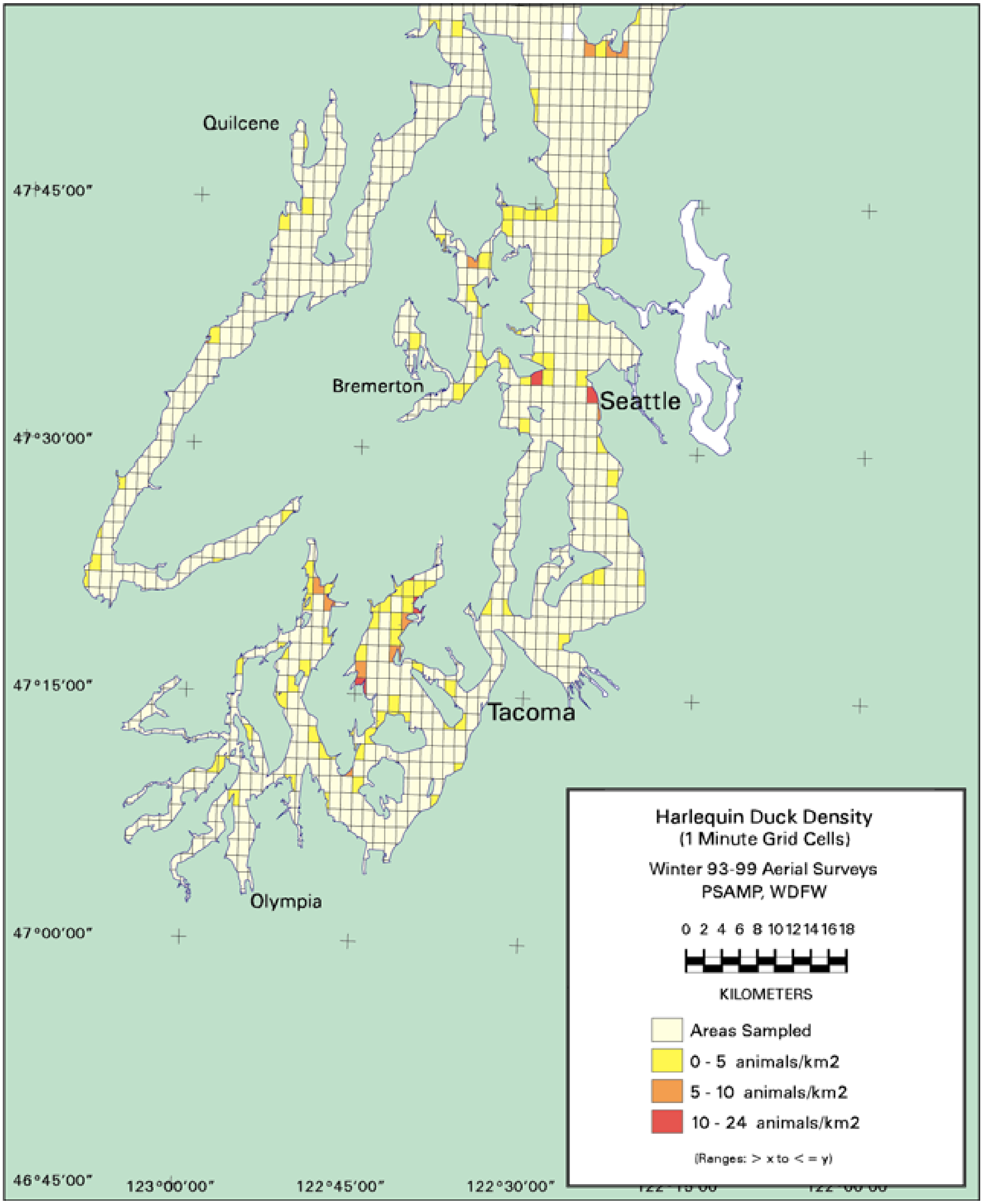


Figure 35. Mean Densities for Harlequin Duck in Southern and Central Puget Sound Derived from Winter 1992-99 Aerial Surveys.

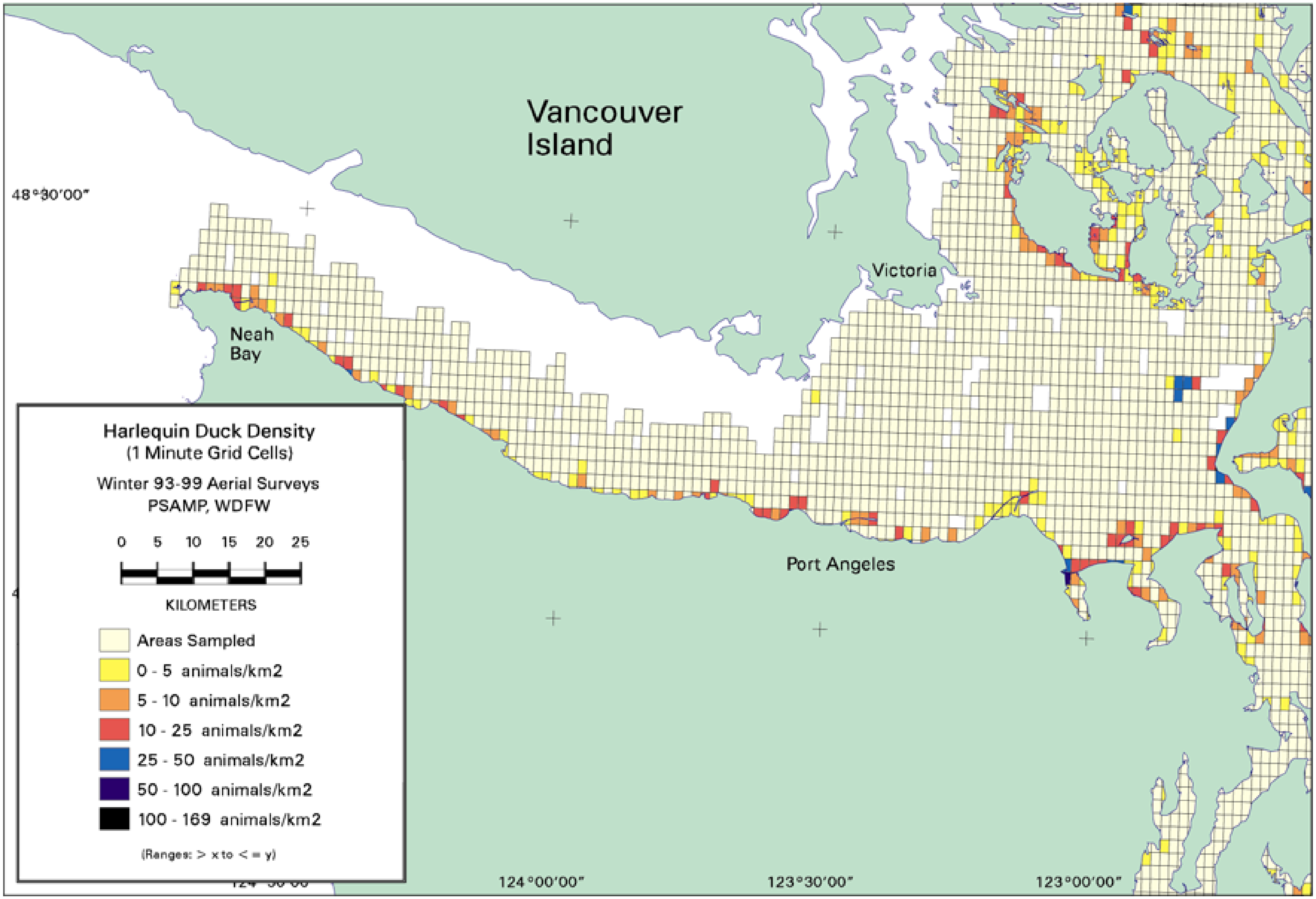


Figure 36. Mean Densities for Harlequin Duck in Strait of Juan de Fuca Derived from Winter 1992-99 Aerial Surveys.

Other surveys in Washington since 1970 (Kraege 1990; WDW unpub. data) have documented the following changes for wintering populations of dabbling and diving ducks, geese and swans. The population of dabbling ducks has varied from year to year. The overall trend was stable until the late 1980's when numbers increased 100-200%, possibly as a result of feeding programs and management actions. Diving duck estimates have also varied annually with a possible overall downward trend since 1978 (Kraege, 1990); however, the change in survey methods from plots to overall census for diving ducks in 1986 limits trend analysis with the midwinter database. Later discussion in this paper on trends will examine more appropriate comparisons of diving duck trends. Trumpeter swans have been increasing over the last 15 years in Washington, with numbers doubling in certain areas (Kraege, pers. comm.). Brant (*Branta bernicula*) population estimates were as low as 3,000 when hunting was closed in 1981. When hunting was reopened in Washington in 1987, the population was just above 14,000 and has ranged between 7,000 and 20,000 since then. Snow geese (*Chen caerulescens*) move back and forth between the Fraser River delta in British Columbia and the Skagit River delta in Washington during winter. The total population was estimated at 46,000 birds in 1999. The snow goose population at the Fraser River estuary has increased about three fold since the mid 1970's (S. Boyd, pers. comm.).

<u>Alcids</u>

The proportion of alcid species on winter surveys ranged between 0.5% and 2.4% during winter observations 1992-99, averaging 1.5% of all marine birds. The actual numbers are less for most of these species than those recorded during summer transects. Winter distribution patterns were also different from summer (July) in several respects, depending upon the species. Species composition in winter also changed from that seen during July, with the arrival of ancient murrelets (*Synthliboramphus antiquus*) and the departure of tufted puffins and most of the rhinoceros auklets. The five species commonly observed in portions of greater Puget Sound during winter are the following, listed by percentages of total numbers seen of species identified over the seven winters: common murre (72.2%), pigeon guillemot (11.3%), ancient murrelet (8.0%), marbled murrelet (5.7%), and rhinoceros auklet (2.8%)

Common murres were the predominant winter alcid species by far, ranging annually from 53.1% to 82.9% of alcids identified to species. Murres were sometimes seen along the southern shore of the western Strait of Juan de Fuca, but most of the time the majority of the murres concentrated in passes, straits, and features of the San Juan Islands, banks near Victoria on Vancouver Island, tidal/current features in Admiralty Inlet, banks near the southern shore of eastern Strait of Juan de Fuca, and the Pt. Roberts/Alden Banks vicinity (Figure 37). Certain smaller numbers were found in southern and central Puget Sound near Fox Island, Tacoma Narrows, and Possession Bar off the south end of Whidbey Island. Their mean annual offshore density ranged from 6.59 to 15.49 birds per km^2, but their densities would often be in the range of 50-455 birds per km^2 in the areas where flocks concentrated (Figure 37).

Pigeon guillemot densities decreased from those seen during summer surveys and also made more use of offshore banks and other regions, suggesting a general dispersion (Figure 38). The

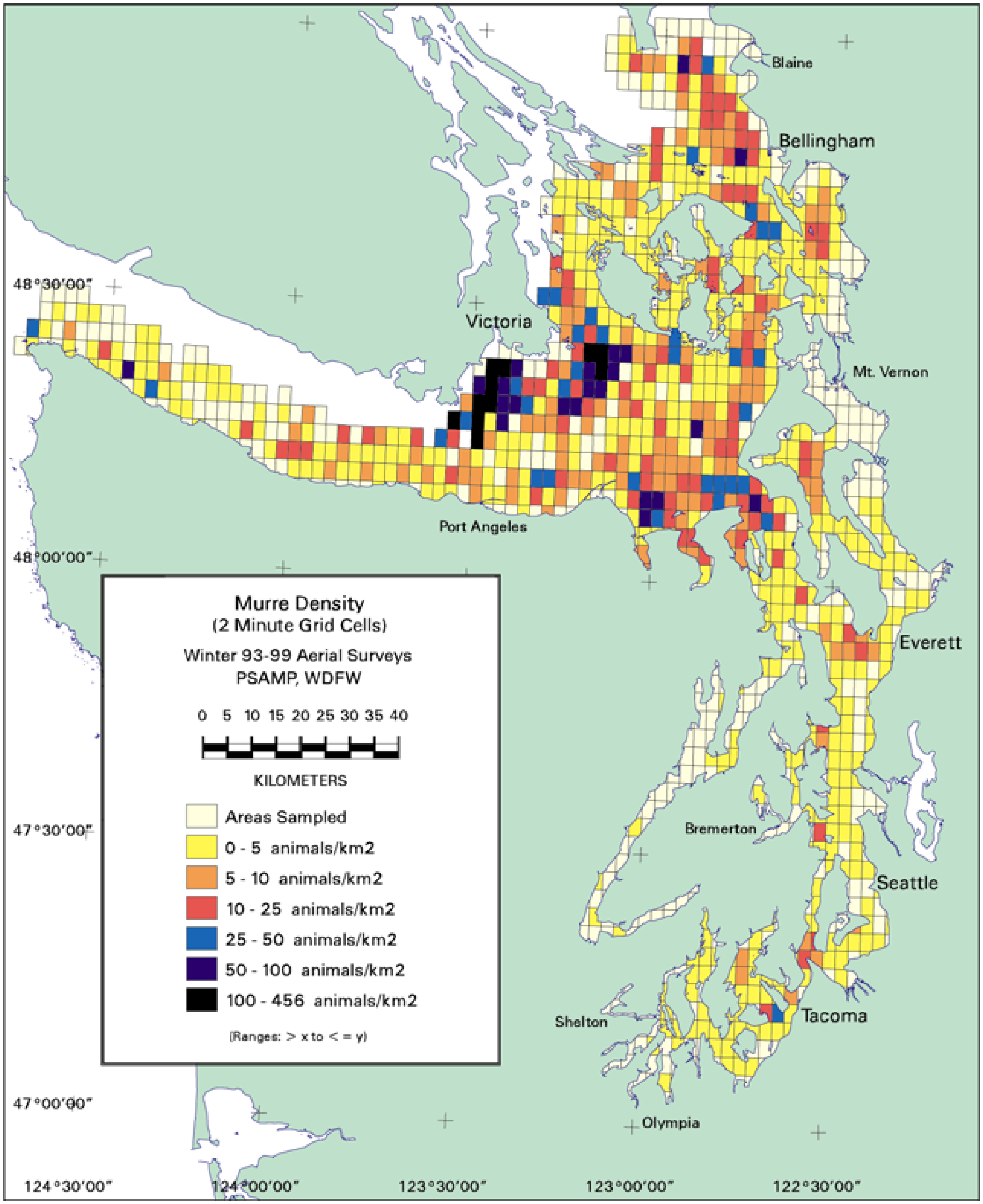


Figure 37. Mean Densities for Common Murres in Greater Puget Sound Derived from Winter 1992-99 Aerial Surveys.

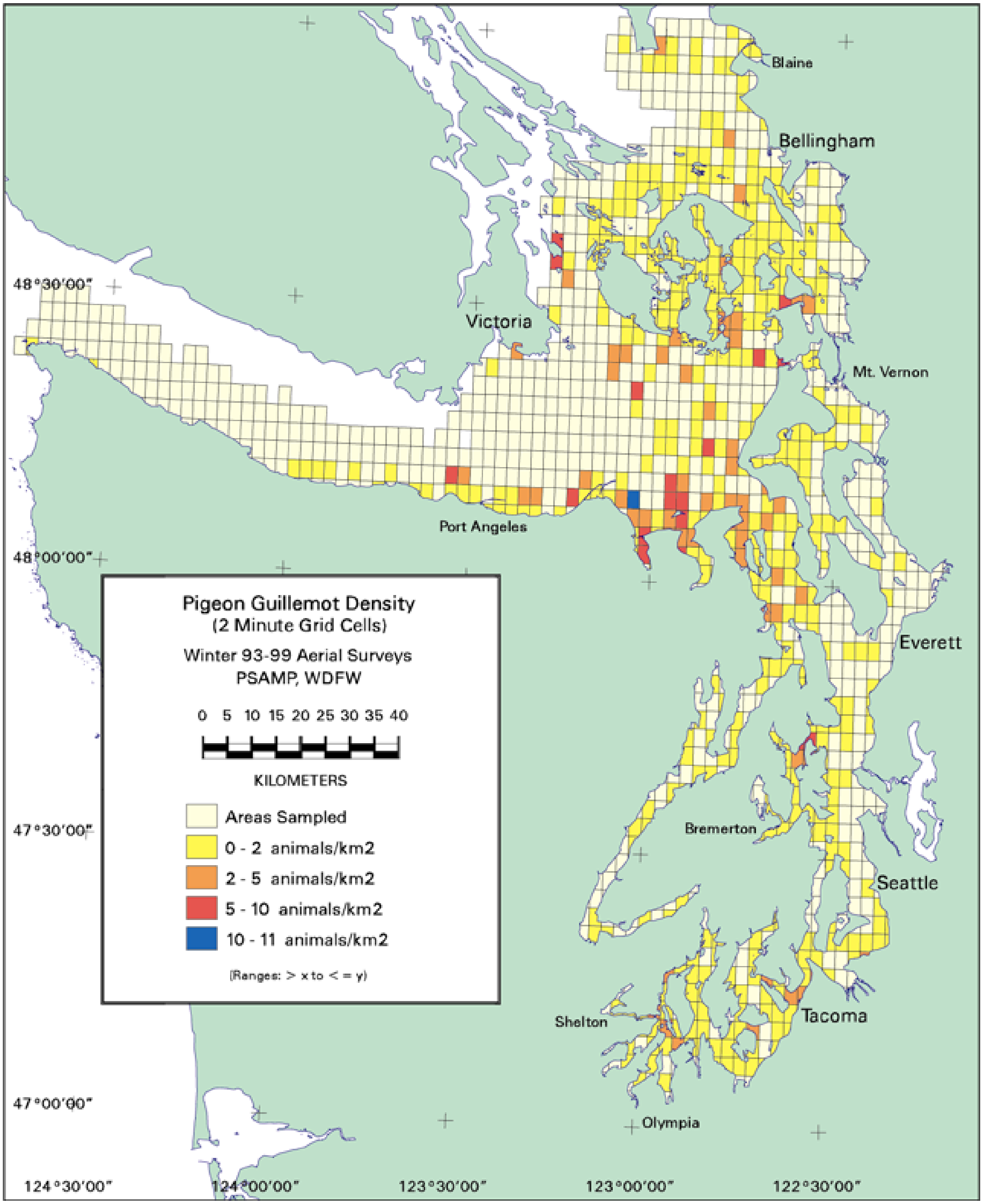


Figure 38. Mean Densities for Pigeon Guillemot in Greater Puget Sound Derived from Winter 1992-99 Aerial Surveys.

nearshore densities were still higher than those seen offshore and ranged annually from 0.26 to 1.16 birds per km^2. The eastern portion of Strait of Juan de Fuca and Admiralty Inlet still had higher densities than other portions of greater Puget Sound.

Rhinoceros auklets, the most numerous summer alcid, mostly leave the summer breeding grounds in the eastern Strait of Juan de Fuca and head towards the Pacific Ocean and continental shelf edges, but small numbers do winter in inland marine waters, with the southern portion of Puget Sound (Figure 39) attracting the majority.

Ancient murrelets enter the inner marine waters during winter and were often seen in flocks and highly clumped distribution patterns, primarily in offshore waters in the eastern Strait of Juan de Fuca, Haro Strait, and southern Georgia Straits near banks and tidal/current features (Figure 40). Their offshore mean density varied annually from 0.51 to 2.00 birds per km^2, but densities in the vicinities of the flocks ranged between 25 and 152 birds per km^2.

Marbled murrelet numbers increased from those seen in the summer, suggesting that murrelets migrate into portions of Puget Sound either during the fall or winter. This species continued to use nearshore areas utilized during the breeding season, but it was also seen in areas such as southern Hood Canal and some offshore banks where they were not observed much during the summer surveys (Figure 41). Nearshore and offshore mean densities were more similar than summer densities and the mean annual densities for both strata combined ranged from 0.07 to 0.35 birds per km^2.

Loons and Grebes

Loons and grebes accounted for 4.5% of the marine bird species observed 1992-99. Grebes accounted overall during the seven winters for 3.8% of all marine birds seen. Large and highly aggregated concentrations of western grebes (close to 35,000 seen on or near transects early in the decade) dominated this group numerically (Table 8).

The four grebe species identified from the aerials are listed in decreasing order of abundance among grebes: western grebe, 84.7%; horned grebe (*Podiceps auritus*), 10.9%; red-necked grebe (*P. grisegena*), 4.4%; and pied-billed grebe (*Podilymbus podiceps*), <0.01%. Although western grebes comprised a large percentage of all grebes identified to species, this may in part be an artifact due to aerial surveys underestimating the smaller-sized, dispersed grebe species, such as horned and perhaps red-necked grebes. The data on Table 8 also illustrate two other phenomena: 1) Observers improved their skills in identifying loons and grebes over time as both unidentified categories decreased. 2) The decreased emphasis of counting birds off transect after the first two years is seen, with exception of western grebes; and this change probably was influential in the increased identification on transect (i.e. horned grebes) rather than an actual increase. Each of the three main grebe species, captured in some degree by PSAMP aerial survey methodology, did demonstrate a consistently different density and distribution pattern over the seven years of winter surveys.

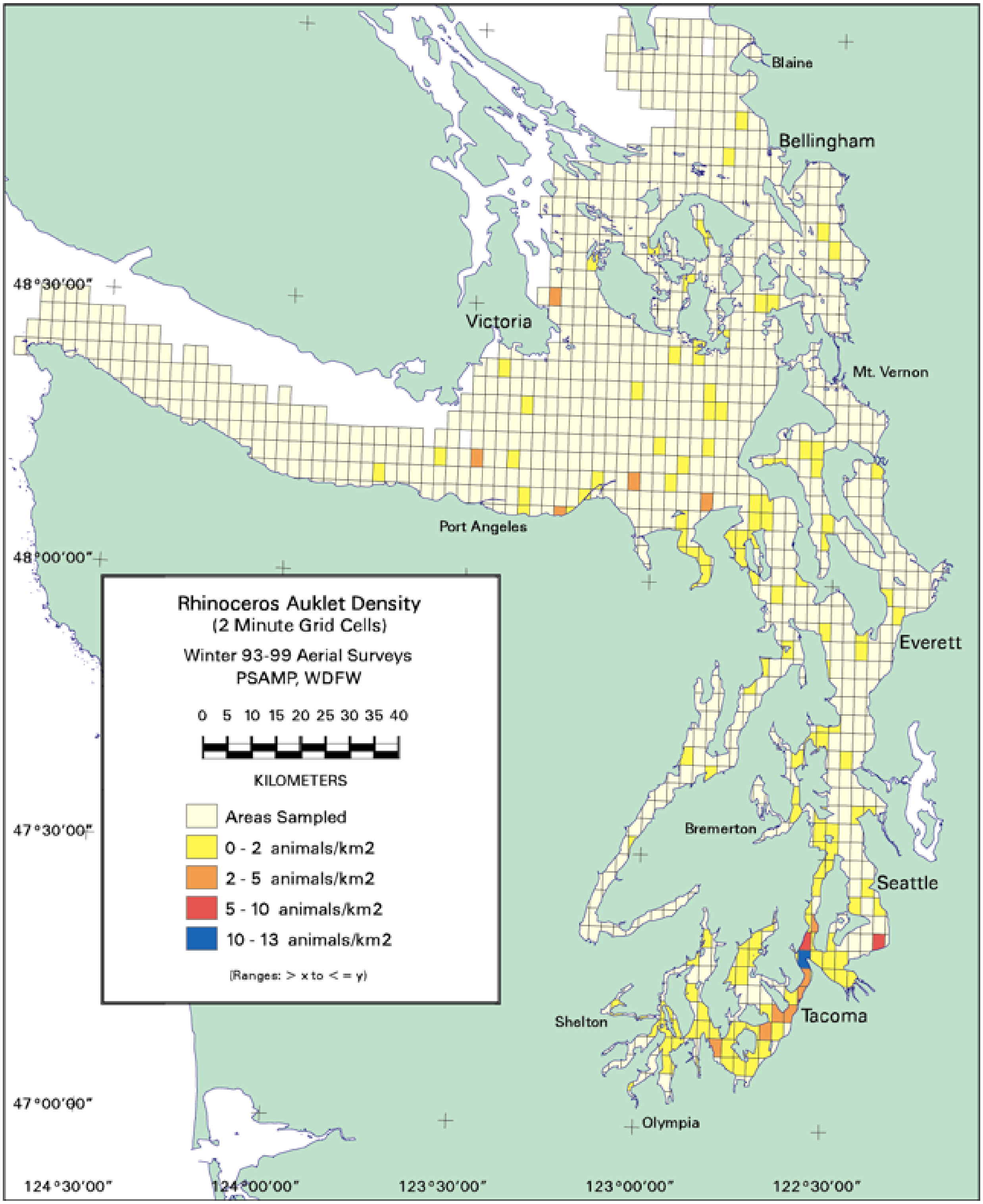


Figure 39. Mean Densities for Rhinoceros Auklets in Greater Puget Sound Derived from Winter 1992-99 Aerial Surveys.

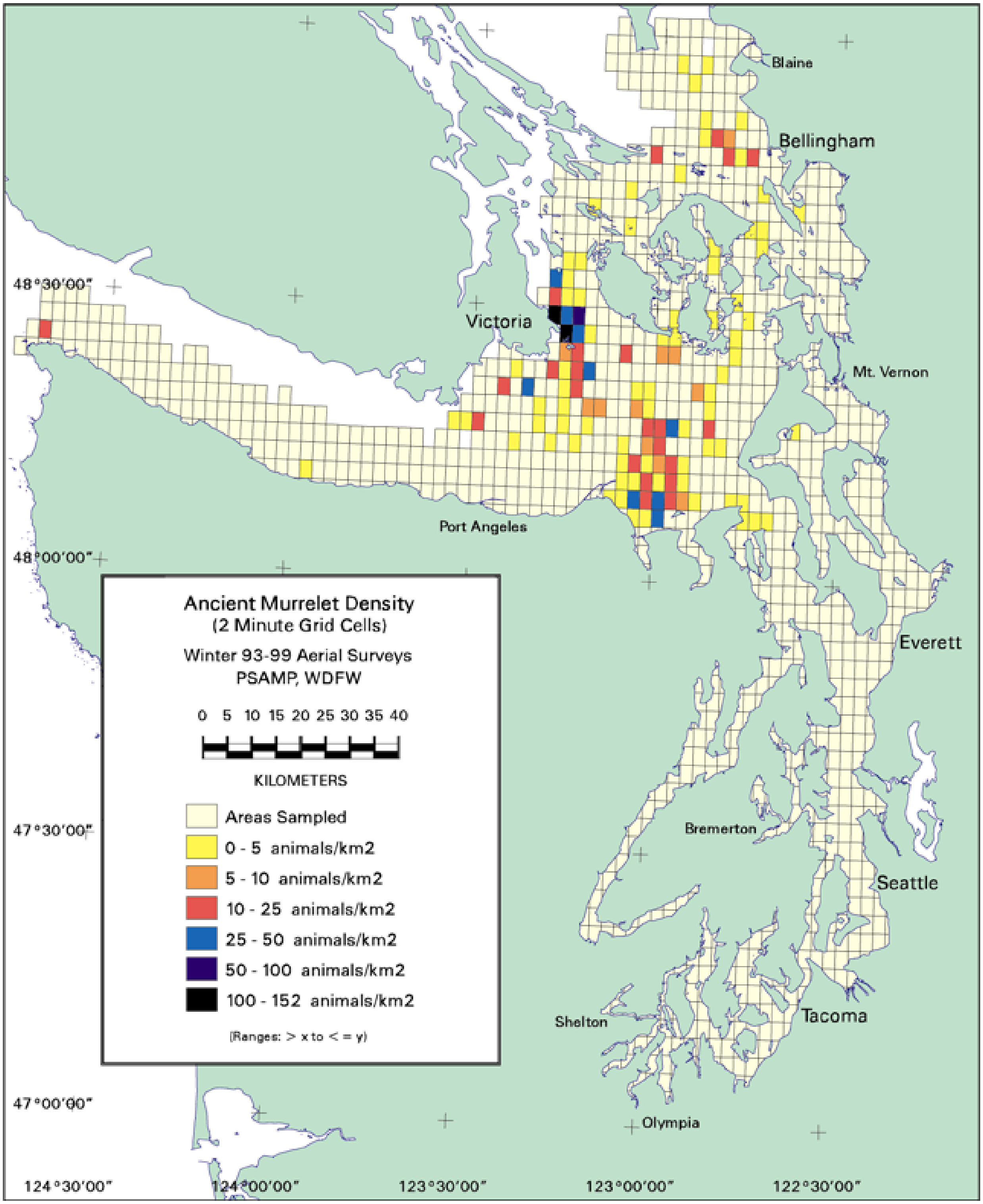


Figure 40. Mean Densities for Ancient Murrelets in Greater Puget Sound Derived from Winter 1992-99 Aerial Surveys.

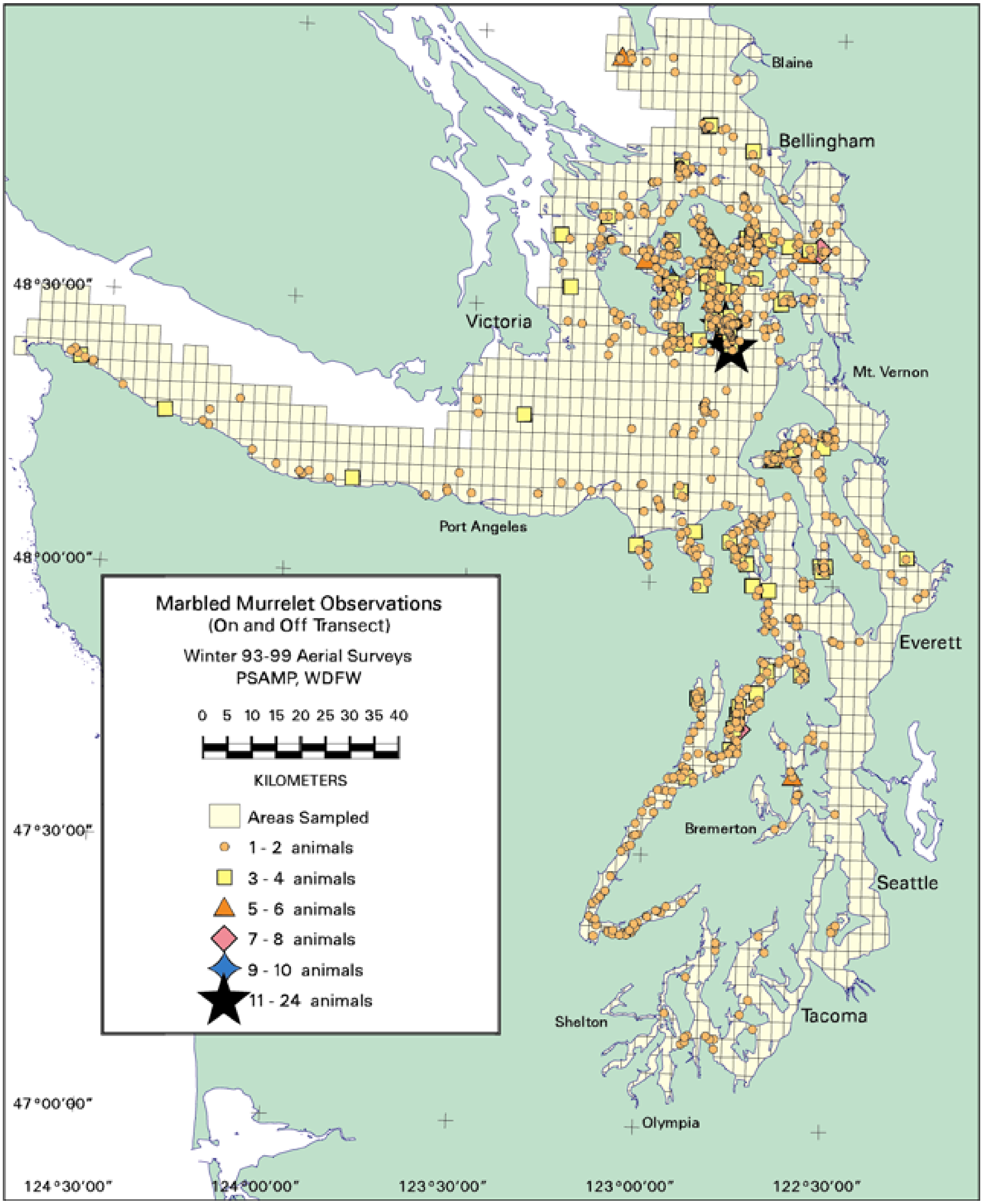


Figure 41. Observations of Marbled Murrelets in Greater Puget Sound Seen During Winter 1992-99 Aerial Surveys.

Table 8. Comparisons of grebe and loon species counts obtained during PSAMP winter aerial surveys, December-February 1992-99.

	Winter Survey Period[1]						
Species	92-93	93-94	94-95	95-96	96-97	97-98	98-99
Total Grebes	11,337 / 36,247	4,217 / 30,663	15,048 / 33,451	7,922 / 24,942	11,502 / 20,655	6,392 / 13,570	6,613 / 14,790
Western Grebe	10,485 / 34,898	3,313 / 14,446	14,150 / 32,272	6,927 / 23,272	10,057 / 19,179	4,909 / 12,020	4,713 / 12,854
Red-necked Grebe	232 / 411	327 / 417	274 / 306	396 / 566	450 / 458	428 / 464	700 / 732
Horned Grebe	280 / 329	270 / 299	337 / 369	386 / 425	922 / 928	1,053 / 1,084	1,196 / 1,200
Unid. Grebes	340 / 609	307 / 638	287 / 504	213 / 679	73 / 90	2 / 2	4 / 4
Total Loons	942 / 1,631	2,206 / 2,932	1,468 / 2,636	1,475 / 3,123	1,651 / 1,913	1,359 / 1,560	1,737 / 2,581
Common Loon	124 / 251	143 / 210	175 / 272	242 / 407	532 / 613	377 / 408	415 / 420
Red-throated Loon	283 / 351	484 / 623	302 / 533	577 / 772	555 / 572	588 / 723	728 / 778
Pacific Loon	84 / 153	273 / 371	307 / 585	458 / 1,473	449 / 583	356 / 385	577 / 1,366
Unid. Loon	451 / 876	1,306 / 1,728	684 / 1,246	198 / 471	115 / 145	38 / 44	17 / 17

Note: [1] Each year the count total is listed first by on-transect counts and then combined on- and off-transect counts.

Western grebes dispersed and foraged at night, but usually gathered during daylight hours of winters 1992-99 into sizeable flocks. These flocks frequented the same general areas of more protected bays or inlets each year rather than exposed waters such as those of the Strait of Juan de Fuca (Figures 42-43). Major concentration sites included Boundary Bay, Bellingham Bay, Penn Cove/Oak Harbor vicinity, Holmes Harbor and Saratoga Passage between Whidbey and Camano Islands, Everett/Port Susan areas, portions of Hood Canal, Port Townsend and Discovery Bay area, Port Orchard, Port Madison, and Yukon Harbor/Blake Island vicinity, Quartermaster Harbor/Tacoma Narrows, Fox Island/Carr Inlet, certain areas of Case Inlet, and the mouths of Dana and Pickering Passages. Many of these areas are also holding areas or near spawning areas for herring and other forage fish. Overall densities, combined for both nearshore and offshore waters because they were similar, ranged from 4.5 to 13.7 birds per km^2, but densities in the vicinities of the flocks fell between 50 and 1,343 birds per km^2.

Horned grebes, on the other hand, associated closely with shallower water near shorelines throughout greater Puget Sound (Figure 44). Air/boat comparisons have demonstrated that our aerial surveys miss many of this small species, perhaps by a factor of ten at worst, because they dive at the approach of any large flying object, whether it be an eagle or a plane. Hence the actual densities recorded by our surveys may be considerably greater at times. The observed densities for the nearshore habitat strata for this species, as recorded by the aerial surveys, ranged annually from 0.52 to 2.46 birds per km^2.

Red-necked grebes were equally distributed in low to moderate densities throughout greater Puget Sound, but they occurred in deeper waters that were just outside those frequented by horned grebes (Figure 45). This grebe species also appeared to tolerate or seek more exposed conditions. Their overall mean densities were the lowest of the three common marine grebe species, ranging from 0.15 to 0.84 birds per km^2 for offshore and nearshore strata combined. Their densities were higher in nearshore waters, ranging from 0.44 to 1.06 birds per km^2, making for some overlap with densities observed for horned grebes.

The three loon species identified from the aerial surveys constituted 0.7% of all marine birds surveyed winters 1992-99. The red-throated loon (*Gavia stellata*; 43.8%) was the most numerically abundant loon species identified, followed by the Pacific loon (*G. pacifica*; 31.2%) and the common loon (*G. immer*; 25.0%). Loons, which often dove upon the approach of the plane, are under represented in our aerial surveys, more so in the beginning years. Identification skills of loon species by survey crews improved after the first 2-3 years of survey effort.

Distribution and density patterns are different for the three loon species (Figures 46-48). Pacific loons gathered in the largest flocks, with the most clumped distribution of loons. Their densities were somewhat higher in more exposed deeper waters (annual mean densities for offshore waters ranged from 0.40 to 1.16 birds per km^2). Densities of Pacific loons near concentrations ranged from 10 to 88 birds per km^2. Red-throated loons, however, were more widespread with lower densities, but tended to favor the more protected inlets (mean annual densities for both strata of marine waters combined ranged from 0.34 to 1.20 birds per km^2). Common loons were found throughout the inner marine waters of Washington, but tended to be found in pairs or very small groups (mean annual densities ranging from 0.17 to 0.52 birds per km^2).

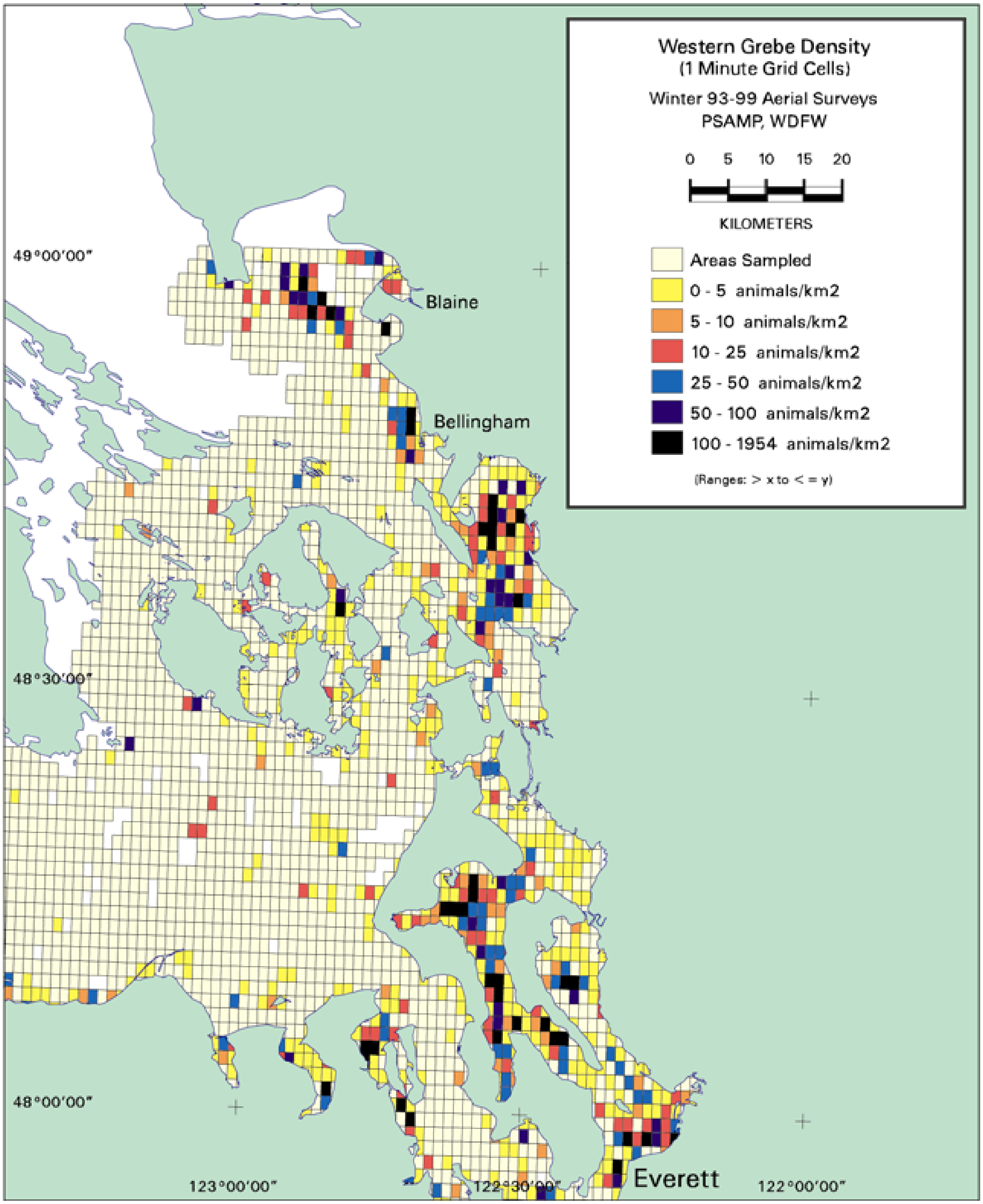


Figure 42. Mean Densities for Western Grebes in Northern Puget Sound Derived from Winter 1992-99 Aerial Surveys.

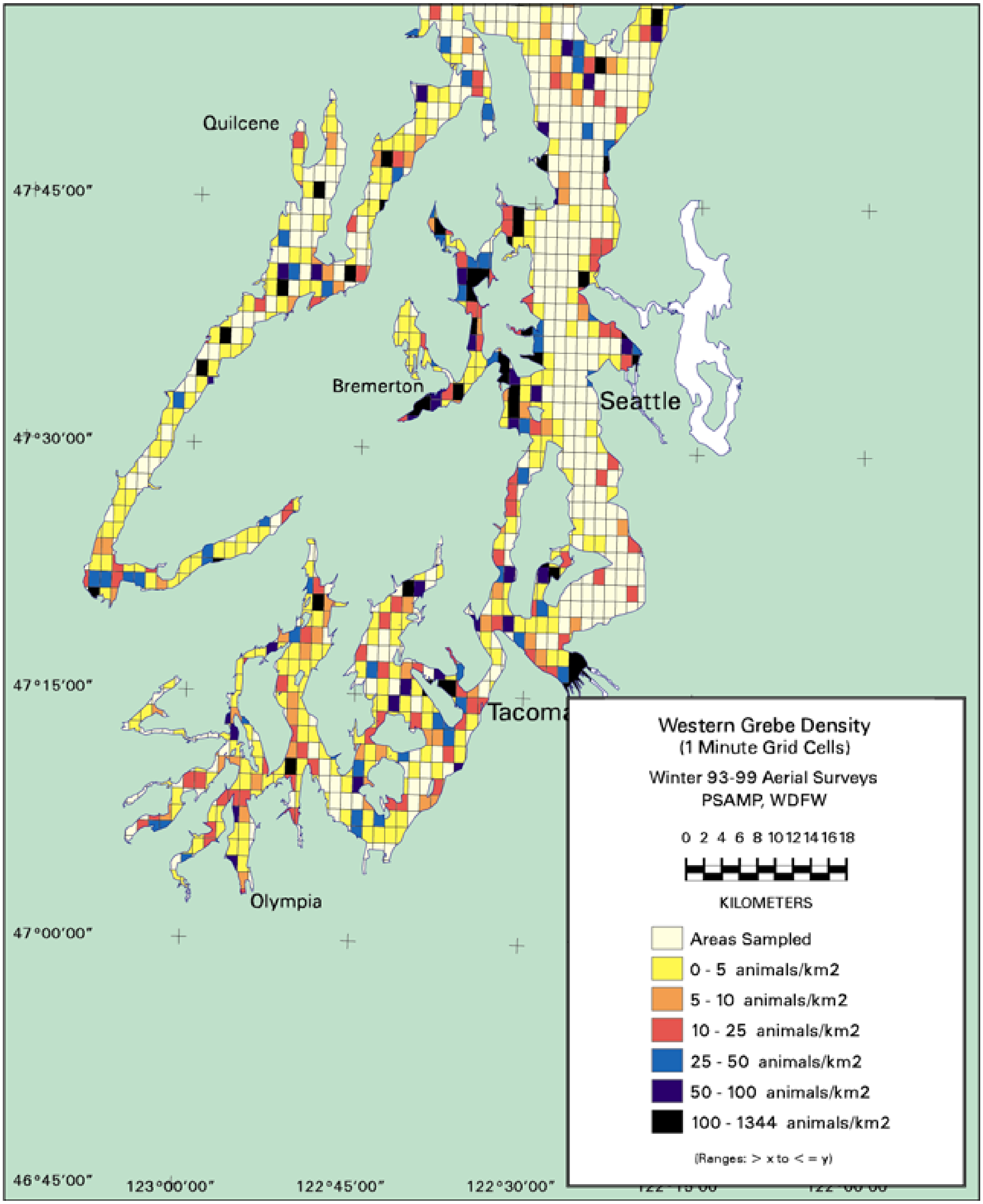


Figure 43. Mean Densities for Western Grebes in Southern and Central Puget Sound Derived from Winter 1992-99 Aerial Surveys.

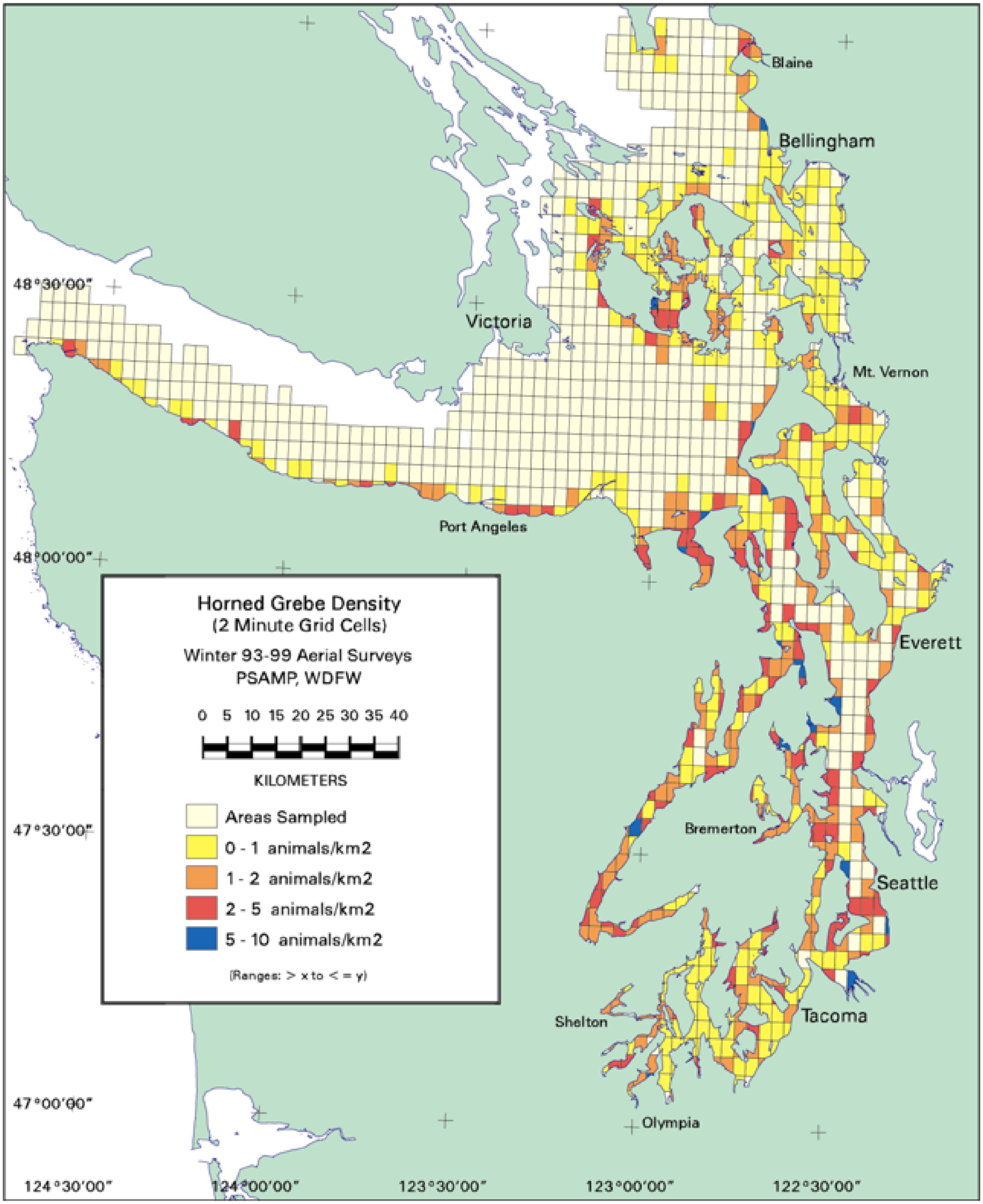


Figure 44. Mean Densities for Horned Grebes in Greater Puget Sound Derived from Winter 1992-99 Aerial Surveys.

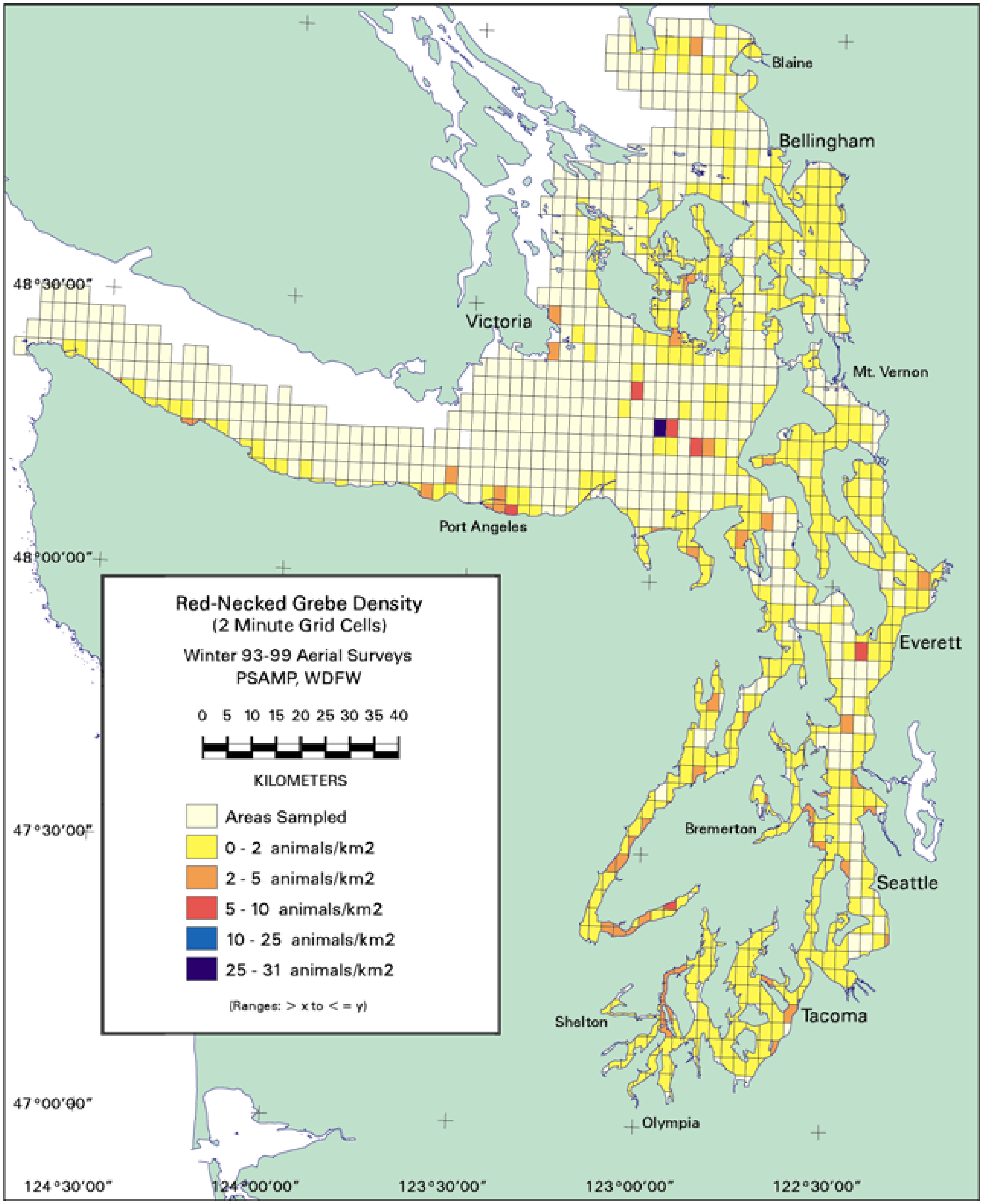


Figure 45. Mean Densities for Red-necked Grebes in Greater Puget Sound Derived from Winter 1992-99 Aerial Surveys.

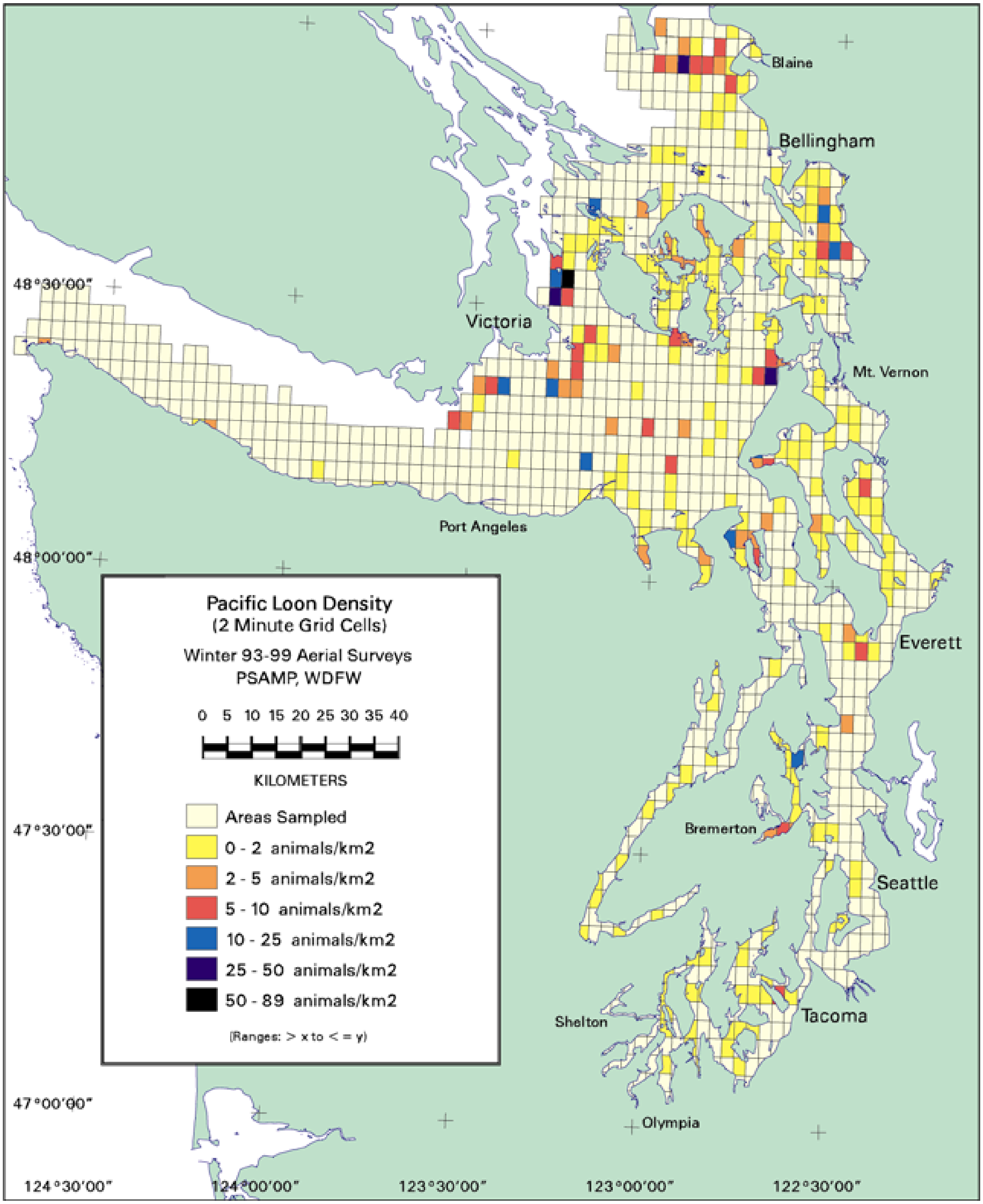


Figure 46. Mean Densities for Pacific Loons in Greater Puget Sound Derived from Winter 1992-99 Aerial Surveys.

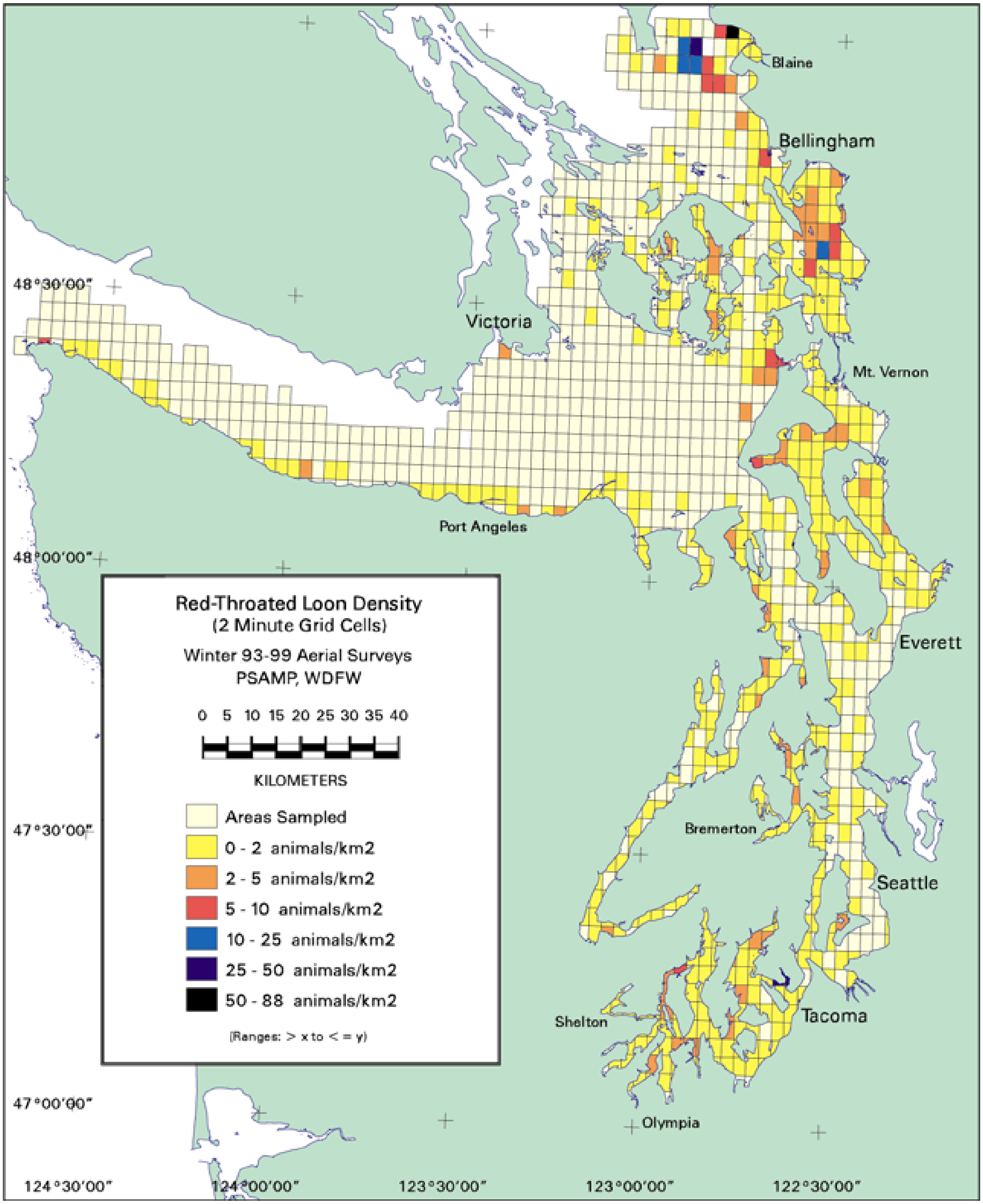


Figure 47. Mean Densities for Red-throated Loon in Greater Puget Sound Derived from Winter 1992-99 Aerial Surveys.

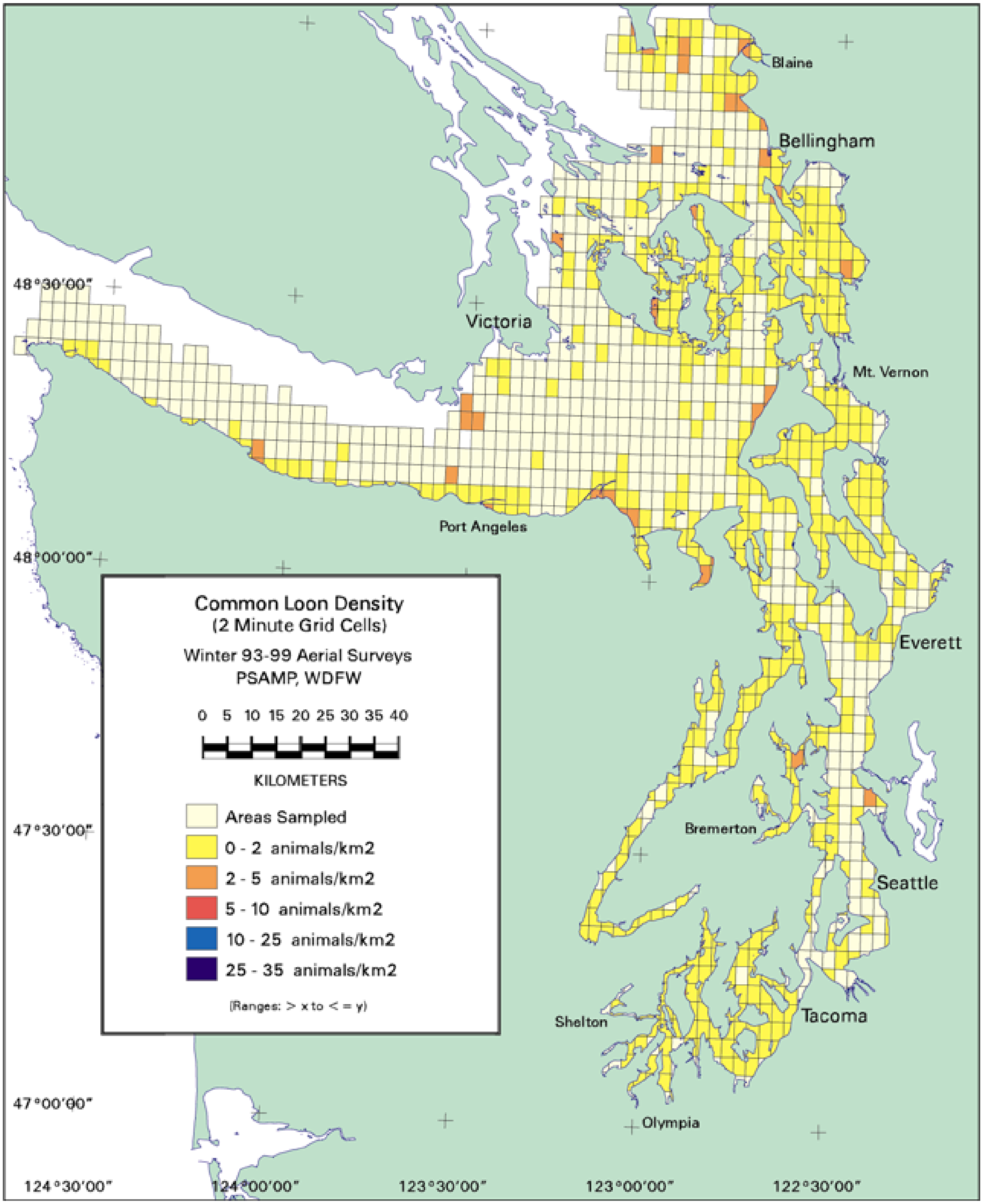


Figure 48. Mean Densities for Common Loon in Greater Puget Sound Derived from Winter 1992-99 Aerial Surveys.

Gulls

The proportion of gull species on winter surveys ranged annually from 10.5 to 14.0%, averaging 12.3% of all marine birds observed on winter transects during the 1992-99 period. Overall mean densities for both offshore and nearshore strata ranged from 17.54 to 34.99 birds per km^2, which is roughly only a third of that seen for gull species during the summer. Highest gull densities were seen near Victoria/Port Angeles area, the Tacoma Narrows vicinity, and along certain river deltas (Figure 49).

The species composition in winter differed significantly from that observed during the July surveys. Three species and two additional species groups were usually identified by our aerial survey methodology. The latter two categories were 1) unidentified gulls with black or darker wing tips and 2) any other unidentified gulls. Mew (*Larus canus*) and Thayer's (*L. thayeri*) gulls were the largest component of the first of these two groups. This group also included western gull (*L. occidentalis*), herring gull (*L. argentatus*), western X glaucous-winged intergrades, and ring-billed gulls. The remaining fifth category of other unidentified gulls was always the largest category of gulls, averaging 80% over the seven years. The 20% identified to one of the first four species groups contained the following: glaucous-winged gulls (48.8%), unidentified gulls with dark-tipped wings (22.1%), Bonaparte's gulls (16.9%), and mew gulls (12.2%). Glaucous-winged and mew gulls were usually the two most common gull species, sometimes constituting up to 75% of all gull species seen. Although not distinguished during PSAMP aerial surveys, Thayer's gulls were most likely the third most abundant gull species in Puget Sound during the winter (Wahl, pers. obs.). Of the other remaining gull species, Bonaparte's gulls were either common or not, depending upon the severity of the winter weather. Heermann's gulls were gone from Washington by our winter surveys while California gulls were present only in low numbers at that time. Ring-billed gulls were present, seen most commonly in fresh, brackish, or estuarine waters.

Shorebirds

Shorebirds were censused November to December period of 1992 and 1993 and December 1994 to early February 1995 period by PSAMP-funded surveys contracted to Cascadia Research Collective, specifically targeting winter resident shorebirds (Evenson, 1993; Evenson and Buchanan 1994 and 1995). The aerial and land-based survey techniques covered inland areas as well as marine shorelines. The shorebird totals from aerials and land-based counts fell in the range between approximately 52,000 and 72,000 shorebirds, representing 17-18 species. Skagit Bay, Port Susan, and Padilla Bay vicinities had the highest counts, with a range of 32-80% of the totals counted throughout greater Puget Sound. Dunlin (*Calidris alpina*) was the most abundant species comprising 91-96% of the shorebirds observed, followed by western sandpiper (*C. mauri*; ≤3%), sanderling (*C. alba*; 1%), killdeer (*Charadrius vociferus*; 1%), and black-bellied plover (*Pluvialis squatarola*; 1%). Dunlin and killdeer were the most widely distributed species, occurring at 33-34 and 25-36 sites respectively of the 48-49 sites surveyed, followed by black-bellied plover (18-19), greater yellowlegs (*Tringa melanocephala*) (11), sanderling (10-13), western sandpiper (8-18), and black turnstone (*Arenaria melanocephala*) (8-11).

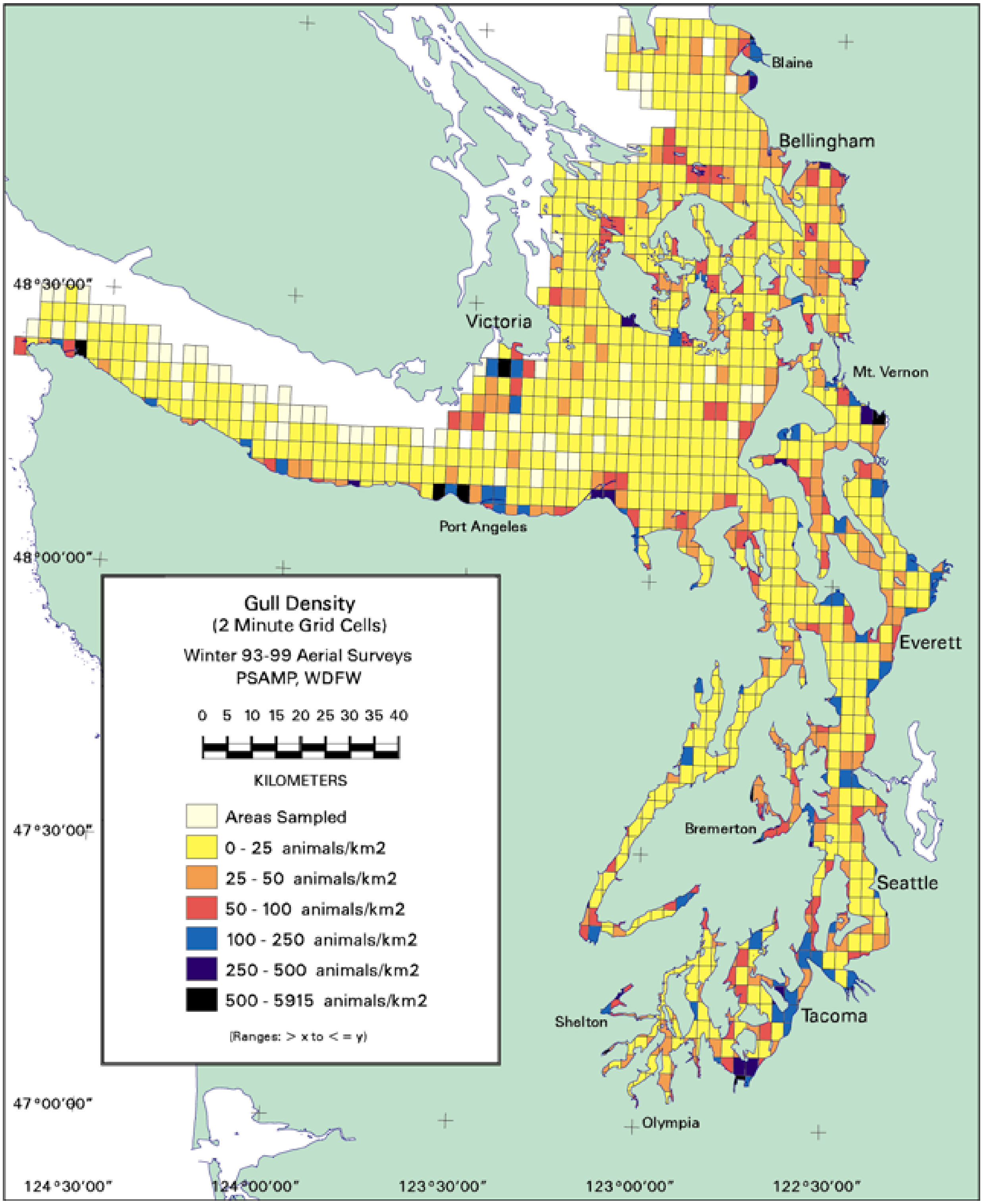


Figure 49. Mean Densities for Gull Species in Greater Puget Sound Derived from Winter 1992-99 Aerial Surveys.

The department's regular PSAMP winter aerial surveys were not designed specifically for shorebird surveys as the contracted Cascadia surveys were. The PSAMP flights did not survey feeding and roosting inland sites associated with nearby marine coastlines systematically within a limited time period like the Cascadia study did, nor did they consider tidal stage or other pertinent factors. Shorebirds were counted when transected by aerial surveys, and flock searches were not performed, so estimates are low. Observers were less trained in shorebird identification from the air and hence there were often large numbers listed in unidentified shorebird categories. Nevertheless, at least 11 species were often identified and the total counts each winter ranged from 11,243 to 73,068, with an annual mean over the seven years of 35,426. Dunlins were again, by far, the most abundant resident shorebird species (90^{th} percentile or more) on any of these surveys. Listed are some of the other species groups and the ranges of numbers seen any one winter: great blue herons (250-720), black-bellied plovers (24-309), black oystercatchers (0-68), surfbirds (0-75), turnstones (2-762), phalaropes (0-31), sanderlings (0-55), yellowlegs (0-14), killdeer and semi-palmated plovers (0-6). The numbers of great blue herons in winter is interesting in that this is somewhere between a third and half of the numbers seen along these shorelines during the summer. Wintering densities (Figure 50) are greatly reduced from those seen during summer (Figures 17-18). This reflects the general understanding that females and young leave the marine shores and move to streams and rivers during winter months while males may remain more on marine areas.

Cormorants

Three species of cormorants were observed again as during the summer, with the composition ranging annually from 0.9 to 2.3%, averaging 1.6%, of all marine birds observed on transect during the 1992-99 winter surveys. Double-crested cormorants comprised the vast majority (91% of the cormorants identified to species), with Brandt's and pelagic cormorants dividing up the remainder. It should be noted that double-crested cormorants are the easiest to identify on the aerial surveys and a large percentage of the other two species was included in the large unidentified cormorant category (74% of all cormorants seen were designated as unidentified cormorants).

The mean densities of all cormorants seen overall on transect varied from 2.34 to 3.71 birds per km^2 while the mean density in the nearshore strata, their preferred habitat, ranged from 6.46 to 10.32 birds per km^2. Winter counts of cormorants exceeded the numbers observed on the same transects during the summer and their winter distribution expanded into southern and central Puget Sound where they were scarce during summer, suggesting a migration influx (Figure 51). At least one cormorant banded in British Columbia was captured in an Indian gill net in winter near the Nisqually River in recent years (Grettenberger, pers. comm.). This all suggests that these winter numbers of cormorants were likely to include migrants from locations outside of greater Puget Sound such as interior portions of North America or coastal portions of British Columbia.

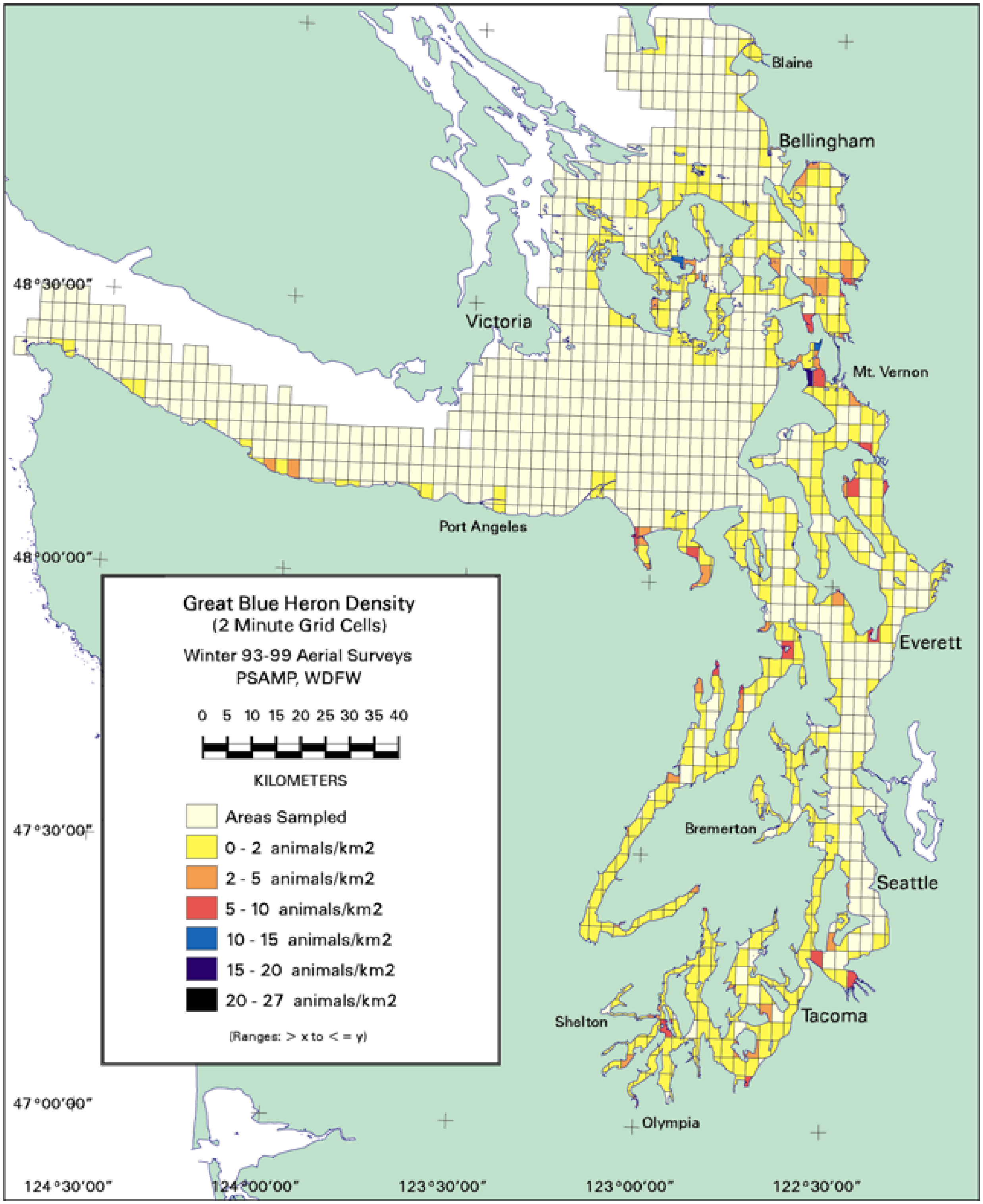


Figure 50. Mean Densities for Great Blue Herons in Greater Puget Sound Derived from Winter 1992-99 Aerial Surveys.

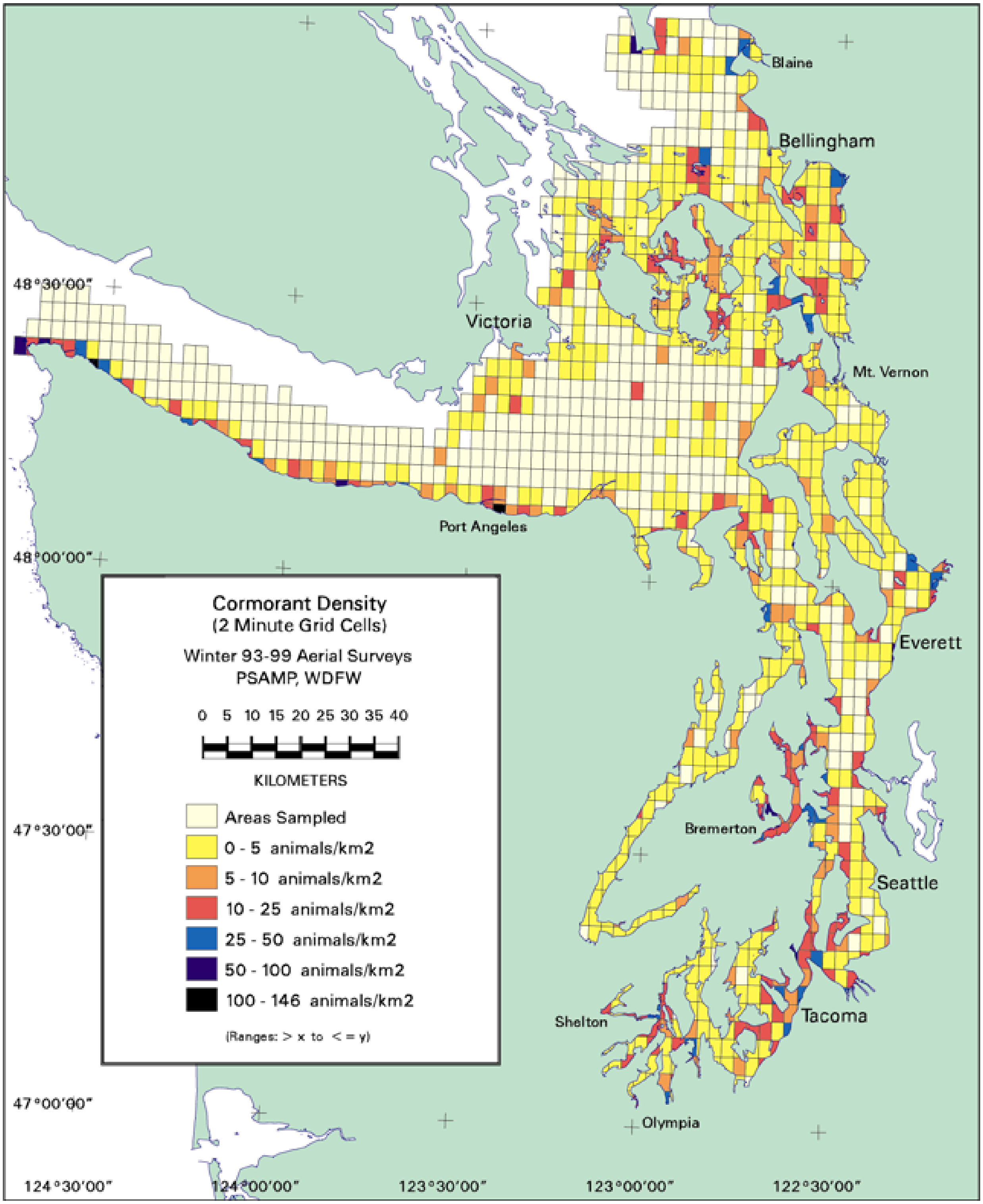


Figure 51. Mean Densities for Cormorants in Greater Puget Sound Derived from Winter 1992-99 Aerial Surveys.

3.2 Monitoring of Key Species and Associated Trends

A set of species was originally selected by the component implementation plan (Nysewander et al. 1993) using criteria related to 1) usage of or dependence upon marine waters of Puget Sound, 2) consistent peaks of abundance during our survey windows, 3) roles that they might play as indicators of environmental change, and 4) other concerns due to limited numbers or special vulnerability to human caused mortality. The monitoring methodologies used focused on determining trends that may be occurring related to marine bird numbers and their distribution in the inner marine waters of Washington State. Some species seem more appropriate for this task than others, given the methodologies and funding available. The following sections will evaluate what is presently known of trends during the 1992-99 periods as well as between this last decade and the marine bird numbers estimated by the 1978-79 MESA studies (Speich et al. 1981).

3.2.1 Summer

PSAMP Surveys

The original emphasis recommended for summer monitoring concentrated on five species when the PSAMP surveys started in July 1992: common murre, rhinoceros auklet, pigeon guillemot, harlequin duck, and marbled murrelet. The original contract that set up the survey design originally included the cormorant and gull species that breed in Puget Sound. However, it quickly became apparent that some type of ongoing water or land-based studies better monitored cormorants and gulls because PSAMP aerial survey data tended to include categories of numerous unidentified mixed gull or cormorant species. Some of the best sites to monitor cormorants were at their breeding colonies during summer, but concerns were raised that aerial surveys might disrupt their reproductive success. USFWS biologists at refuges and university research efforts were already conducting some type of monitoring at a few large colony sites on gull and cormorant species. The PSAMP monitoring program's goal was to not duplicate any ongoing monitoring, but complement what was already being implemented. In this light, PSAMP monitoring in summer chose to primarily concentrate either on marine bird distributions at sea, trends in numbers or indices at colonial breeding sites not covered in 1992-93, or indices of reproductive success of non-colonial species such as murrelets.

Common Murre

No murres breed in the inner marine waters of Washington State, but common murres often move into inner marine waters of Washington once they leave their breeding areas on the outer coasts of Washington and Oregon. Their arrival time can be quite variable, ranging from July to later in the fall, this arrival oftentimes seemingly related to the success or failure of breeding that year on the outer coasts. Total numbers or abundance were also highly variable as migrating murres might continue moving up the western coast of Vancouver Island, or might turn east into the Puget Sound and Georgia Straits regions. The PSAMP summer aerial surveys revealed that the July survey window is not ideal for monitoring this species because it only periodically captures whatever early movement might occur into our study area any one particular year, and there was no consistent presence of this species during July in our study area 1992-99.

Rhinoceros Auklet

Species breeding locally such as these should theoretically be less variable for the July survey window because both adults of this species are out on the water finding food for the chicks and most breeding birds are still distributed within 80 kilometers of breeding sites. Rhinoceros auklets generally finish attending their chicks by the middle of August and begin to leave for the outer coast and continental shelf waters where they primarily winter. Even though aerial surveys were discontinued in southern and central Puget Sound after 1996, this did not affect our monitoring effort for this species because they are not generally found in the discontinued survey area during summer. The general impression from the July PSAMP aerial surveys suggests that a relatively stable pattern of density indices occurred between 1992 and 1999, with only the slightest hint of decline towards the end of this period (Figure 52). Confidence limits are still somewhat high around these indices, which would have to be remedied by more replicates.

Pigeon Guillemot

Because pigeon guillemots are common and well distributed year-round residents throughout the inland marine waters of Washington, they appear to be an even better monitoring candidate for a breeding species of resident diving marine bird. The summer aerial surveys have recorded pigeon guillemot numbers in northern Puget Sound and Strait of Juan de Fuca 1992-99 while central and southern Puget Sound were only surveyed 1992-96 due to budget reduction and subsequent decisions. If we look at just the northern two areas including the Strait of Juan de Fuca to maximize the number of comparable years, the comparisons of guillemot annual density indices during the 1992-99 PSAMP surveys have not revealed any clear trend between years due to both the high confidence limits surrounding each density estimate and the differing mean densities seen each year (Figure 53).

The high confidence limits associated with the aerial survey method most likely reflect the ineffectiveness of this methodology for guillemots, as this method works best when birds are not moving geographically much during a diurnal period. Pigeon guillemots are known to disperse widely from nesting colonies after the early morning hours. Better estimates of guillemots could be obtained by 1) either increasing the aerial survey effort to reduce the high confidence limits, or 2) timing the aerial surveys at the same time of day for each area, or 3) conducting a series of censuses of breeding adults attending nesting colonies by boat at selected times of day during a limited span of days. The first two options are essentially not feasible or economical for such a large area in a limited time span, but the latter option became feasible through collaboration with different groups of interested scientists. The boat surveys at breeding colony sites are now considered the best options to pursue for future documentation of trends in this species, because they combine more replicates with less cost and standardized survey times.

Scientists from WDFW and USFWS began a three to five year effort in 1999 to monitor more effectively pigeon guillemot breeding populations in the inner marine waters of Washington State. PSAMP staff associated with WDFW and USFWS coordinated this survey effort, with participants from U.S. National Wildlife Refuges, the Whale Museum, and regional WDFW staff

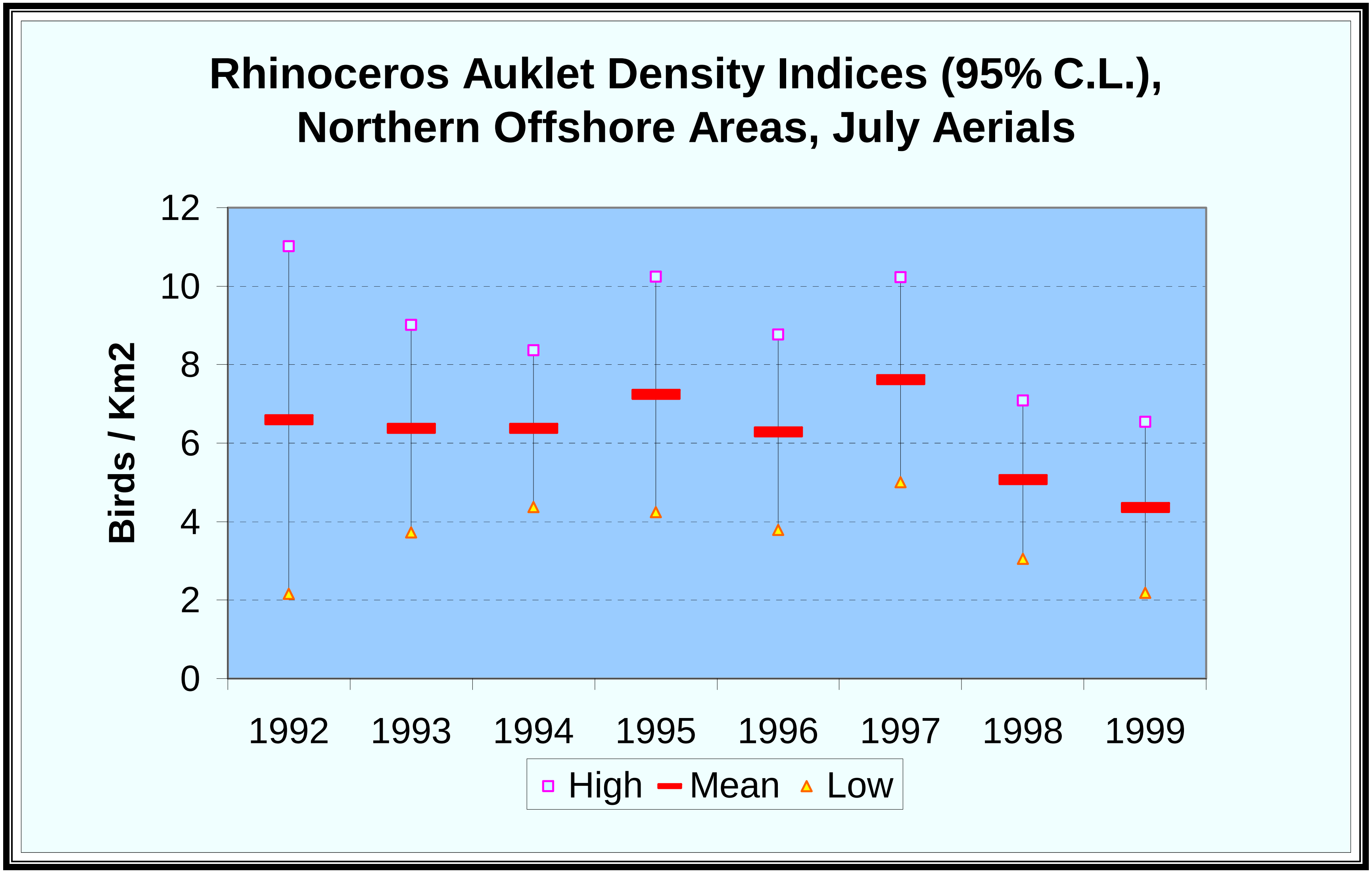


Figure 52. Density Indices Observed for Rhinoceros Auklets July 1992-99 in PSAMP Aerial Surveys in Offshore Strata in Northern Survey Areas.

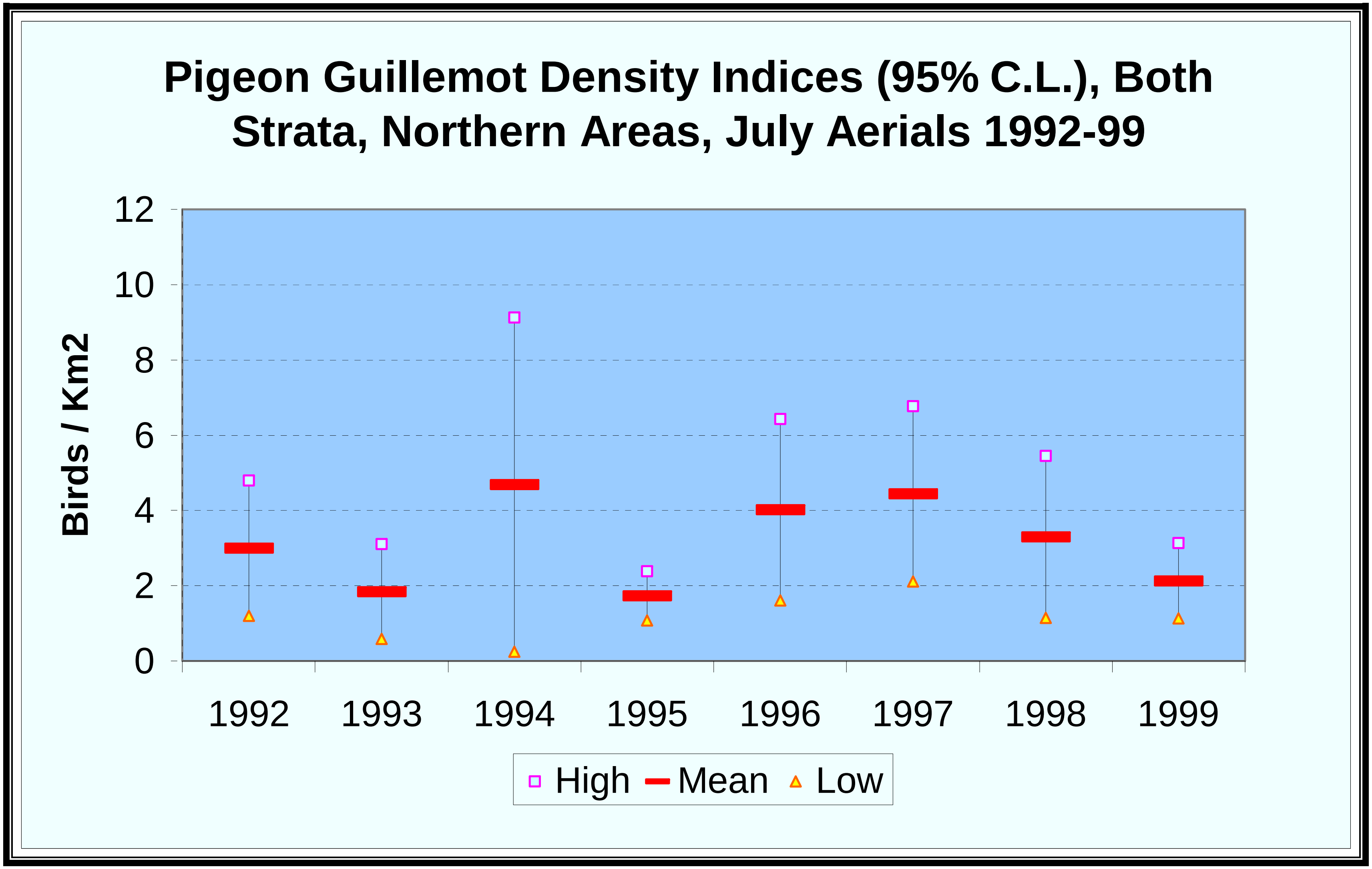


Figure 53. Density Indices for Pigeon Guillemots Observed on Both Strata, Northern Areas, During July PSAMP Aerial Surveys.

all assisting in conducting counts. The censuses were conducted primarily during May, and were limited to the first three hours after sunrise of any given day. Counts during May were conducted at all sites listed in the Catalog of Washington Seabird Colonies (Speich and Wahl, 1989), usually with two or more counts conducted on different days. This reduced the possibility of missing birds due to environmental factors and disturbance at each colony. Searches and censuses were also conducted at colony sites not listed in the historical colony catalog.

The results of the 1999 and 2000 surveys will be reported in more detail elsewhere (Evenson et al. 2001), but the general results so far are the following: The average total count of breeding guillemots during both years was approximately 11,000. Over 260 colonies not previously recorded were documented in addition to the 120 sites already listed in the colony catalog, adding over 50% to the total number of guillemots known. The importance of counting smaller colonies was apparent; 78% of the colonies had <= 25 birds, comprising 20% of all birds counted. The biggest colony gaps in the historical data were in the southern half of Puget Sound; there the number of sites jumped from 29 to 160, increasing the number of known breeding birds in the region during the 1999 surveys by more than 300%. By continuing this survey that combines standardized timing, methodology, replicates, and geographic coverage within each season, pigeon guillemot population trends will be documented better in the future.

Harlequin Duck

Harlequin ducks are distributed in such a linear fashion along certain shorelines such that counts rather than density indices appear to be more useful at this time for tracking this population. Although our surveys were stratified into low (offshore) and high (nearshore) densities, they are apparently not stratified enough to compensate for the highly aggregated distribution of the harlequin duck. The lack enough detail on stratification concerning the distribution of this species creates population estimates that are much higher than what actual population levels are felt to be. In fact, most of the summer and winter PSAMP counts of this species on aerial surveys are quite similar to past and ongoing survey counts conducted by other department staff in recent years (Schirato, pers. comm.). Hence, for the time being, the PSAMP counts rather than the population extrapolations are used for monitoring of harlequin ducks. The July counts (217-671) are useful primarily for pointing out where molting flocks of males are located (Figure 15) and where others will join them in August and early fall, before the harlequins disperse around the marine shorelines of the northwest. For these reasons, the counts of harlequins on winter aerial surveys are recommended as the more appropriate data to monitor over time for changes in status of a larger percentage of the harlequin duck population that utilizes our marine waters.

Other Species

Murrelets were initially considered a summer species to monitor until air/boat comparisons gave us a feel for the large and variable number of murrelets missed by the aerial survey methodology employed by our study design. Boat surveys were considered as a more desirable option and a special pilot project was conducted 1993-95, looking at adult/juvenile ratios in selected areas of greater Puget Sound. The results and recommendations are reported elsewhere (Stein and

Nysewander 1999). Conclusions from the pilot study resulted in the postponement of further monitoring until research efforts outside of PSAMP agreed upon recommendations for standardized monitoring methodologies to apply to this species.

An opportunity occurred in May 1999 to optimize field effort and look at breeding numbers of American black oystercatchers in the San Juan Island vicinity, during the same period in which the pigeon guillemot breeding surveys were being conducted. Nysewander (1977) had been involved with similar colony surveys in the 1973-75 period and was encouraged by USFWS and others to gather recent data for comparisons. The pigeon guillemot surveys concluded in the early morning, allowing crews in certain regions to conduct other surveys during the afternoon. Summaries and tabular databases related to breeding oystercatchers were created and distributed to federal and state resource management entities. In the process, Nysewander noticed that breeding colonies of glaucous-winged gulls appeared to have declined over the last 25 years in the San Juan Islands vicinity. A small subset of three islands was checked and numbers of breeding gulls were significantly less. It was uncertain if any increases at sites such as Protection Island and Smith Island might balance out these local decreases. Discussions with USFWS and university staff revealed a need to resurvey all these sites in a consistent way in the near future to determine what the actual status is regarding these breeding populations of gulls. This may be addressed in the summer of 2001. The possibility of declining numbers of breeding gulls may relate to a number of factors: less winter food options at dumps, more eagle predation, less forage fish available, or some other factor. This investigation provides another avenue for insight into the changes which marine bird populations have experienced the last 25 years.

Comparison with Summer Datasets Collected During the Last 20 Years

At first glance, the 1978-79 MESA studies offer a wealth of data to evaluate for comparisons over the last two decades. PSAMP and MESA efforts, however, differed in their emphasis, methods, and timing. PSAMP efforts have not tried to look at the monthly changes or status and have not utilized the variety of platforms used in the MESA studies. PSAMP efforts, on the other hand, have looked at certain areas (e.g. offshore waters) in more detail by aerial surveys and have datasets that extend over a 7-8 year period rather than just 2 years. Aerial surveys, in fact, were not utilized as extensively during the MESA studies as they have been during the 1992-99 PSAMP surveys. WDFW staff have looked in recent years at different ways to compare these data and have decided that it is most appropriate to compare density indices of wintering species, including pigeon guillemot, observed between selected aerial surveys of both MESA and PSAMP flights that were nearly identical in terms of area, timing, and actual location of transects.

The two species, rhinoceros auklets and pigeon guillemots, on which PSAMP focused their summer monitoring were not especially compatible with this approach featuring comparisons of similar aerial survey transects. Rhinoceros auklets tended to be found in deeper offshore waters and MESA studies did not conduct any aerial survey effort in this area. Pigeon guillemot movements throughout the day during summer, as mentioned earlier, confound data comparison gathered from summer aerial surveys because aerial surveys could not be feasibly standardized at so many different sites in terms of time of day over such a large area.

Another set of historical data exists regarding pigeon guillemots in Puget Sound, that of colony counts from June and July, conducted prior to 1983 (Speich and Wahl, 1989). Methods associated with data collected by Speich and Wahl (1989) were highly variable in terms of methods and time of month or day. Evenson et al. (1999 and 2001) discuss efforts to compare these earlier June counts with 1999 June counts. It is not likely that a reliable comparison between any historical summer data set (either the colony counts, or the MESA aerial surveys) and current efforts can be made. The only valid conclusion that might be made is if future colony censuses dipped below the historic colony census; it could then be assumed that there are indeed fewer birds, albeit without any understanding of the degree of decline. To better understand and assess pigeon guillemot trends in the future, it is best to continue with the standardized protocol applied to counts at colonies during May 1999 and 2000. These data are the most reliable, nearly all breeding birds are censused each year, and the protocol avoids the high confidence limits found using the aerial survey method.

3.2.2 Winter

PSAMP Surveys

Diving duck, grebe, loon, and alcid species comprise the primary monitoring focus for marine bird concentrations found in and most dependent upon the inner marine waters of Washington State during the December to February period. Density indices (displayed with 95% confidence limits) derived from aerial surveys will be the primary measurement by which interannual trends or changes are tracked.

Sea and Bay Ducks

1) Scoters

During the PSAMP monitoring effort during 1993-99, which included all of the inner marine waters of Washington, scoter densities were overall either relatively stable or still decreasing slowly (Figure 54). When comparing the survey area of the north (MESA study area) with the south, the densities in each area tend to mirror the other in terms of increases or decreases any one year except during the 1996-97 winter (Figure 55); that winter the scoter indices went down noticeably in the southern area while they remained stable in the northern part. During the next two winters, the scoter indices again mirrored each other at these new levels. This illustrated that changes can be different for different portions of Washington marine waters. But it raised the issue again whether scoters move to some other portion of their wintering range in different years. As Nysewander and Evenson discussed (1998), all other wintering areas on the west coast where data are available have had declining numbers over the last twenty years and do not suggest such a move. British Columbia marine waters, however, are the major gap in this winter monitoring of sea ducks and our monitoring efforts illustrate the need for a similar monitoring program in British Columbia. Recently a volunteer program has been set up in British

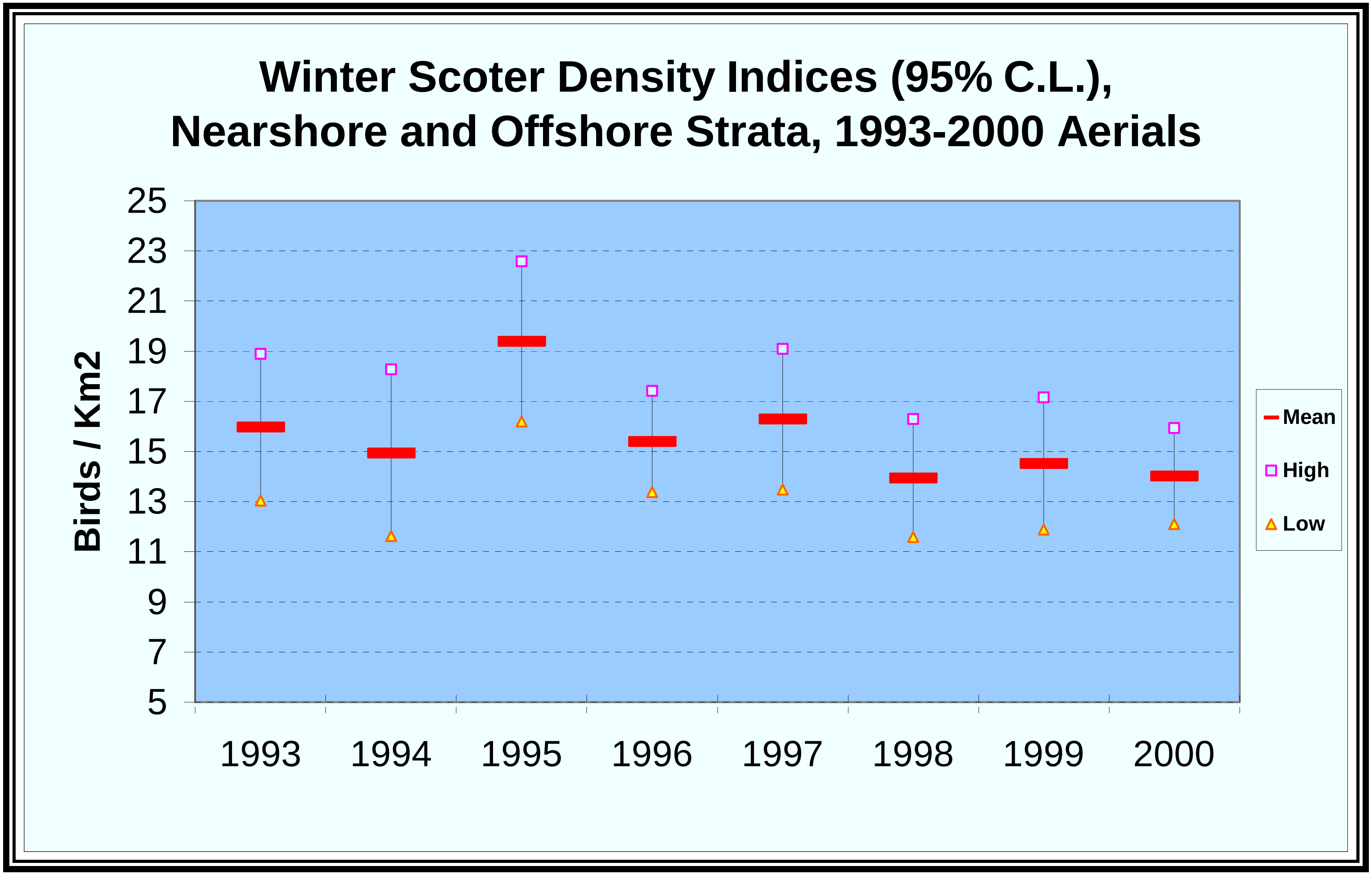


Figure 54. Density Indices Observed for All Scoters During 1993-2000 PSAMP Winter Aerial Surveys.

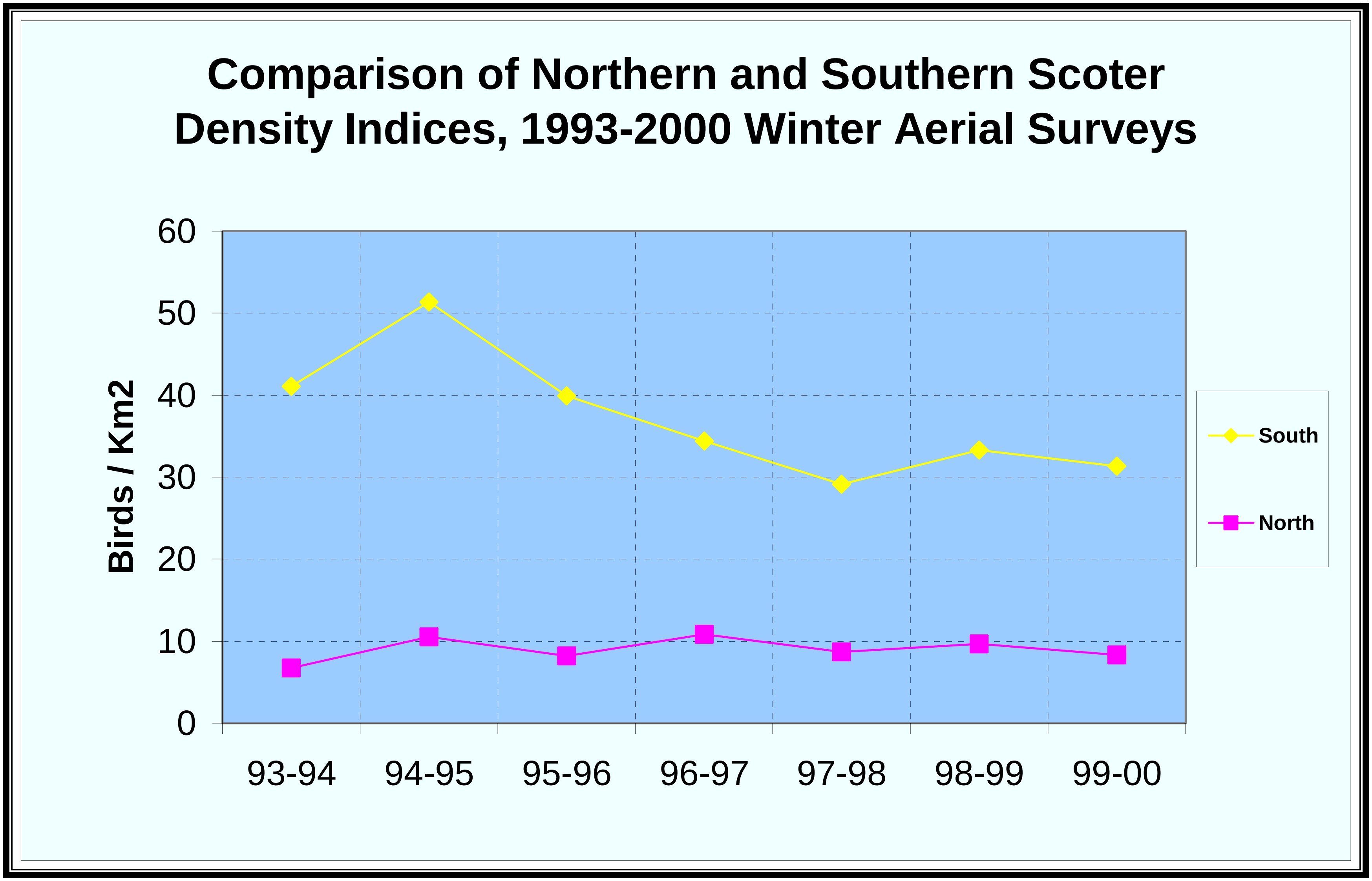


Figure 55. Comparison of Northern and Southern Scoter Density Indices, 1993-2000 PSAMP Winter Aerial Surveys.

Columbia, developed by Bird Studies Canada and Canadian Wildlife Service, to implement a province-wide, long-term monitoring program of coastal waterbirds in British Columbia. This will not help us evaluate trends over the last 20-25 years, but it will help inform marine bird scientists what levels of marine bird numbers utilize portions of nearby Canadian waters.

2) **Goldeneyes and Buffleheads**

Both identified and unidentified goldeneye species categories are combined for monitoring of trends, because a fairly large unidentified category of goldeneyes results from aerial survey methodology. Both goldeneye species and bufflehead are in the same *Bucephala* genus, and both their diet composition and habitat use show considerable overlap, even though there are differences (Hirsch 1980). Monitoring trends of density indices of both total goldeneyes (Figure 56) and bufflehead (Figure 57) are somewhat similar also, suggesting some type of slow decline during the 1992-99 period. There were occasional differences any one year when some different timing or annual variation of migration pattern was captured by our aerial surveys. For instance, unusual numbers, large flocks in the case of bufflehead, of these three *Bucephala* species were seen in the 1994-95 winter, but the trend of lowering density indices resumed in following years.

3) **Scaup**

The two scaup species are also combined using the aerial survey data, even though greater scaup probably make up the overwhelming percentage of these species present in the marine waters of western Washington. This species group tends to be highly clumped in its distribution, and density indices reflect this with larger confidence limits. Nevertheless, these indices suggest that these species remain at low densities overall in the study area in recent years (Figure 58).

4) **Harlequin Ducks**

As discussed for the summer observations related to this species, counts of harlequins are the more appropriate data to monitor until our survey data are restratified in the future in terms of more habitat and depth strata detail. Figure 59 depicts a relatively stable number of harlequins during the winters of 1993-99. Although the pattern is variable with no consistent decrease or increase in recent years, the low numbers and historical vulnerability of this species to events such as oil spills suggests that this species continue to be monitored closely in the future.

5) Other Diving Duck Species

Trends in other species of diving ducks (e.g. oldsquaw and mergansers) are hard to interpret considering only the PSAMP survey period. The oldsquaw numbers are fairly low and the merganser numbers seem quite variable during different years. However, when compared with 1978-79 MESA data, there are some interesting differences, which will be discussed later. Canvasback and ruddy ducks are present each year, but due to low abundance, patchy distribution, and variability in different years, no conclusions can be made regarding trends at this time. Canvasbacks sometimes move between larger fresh water lakes and marine waters, suggesting another monitoring design may be more appropriate for this species.

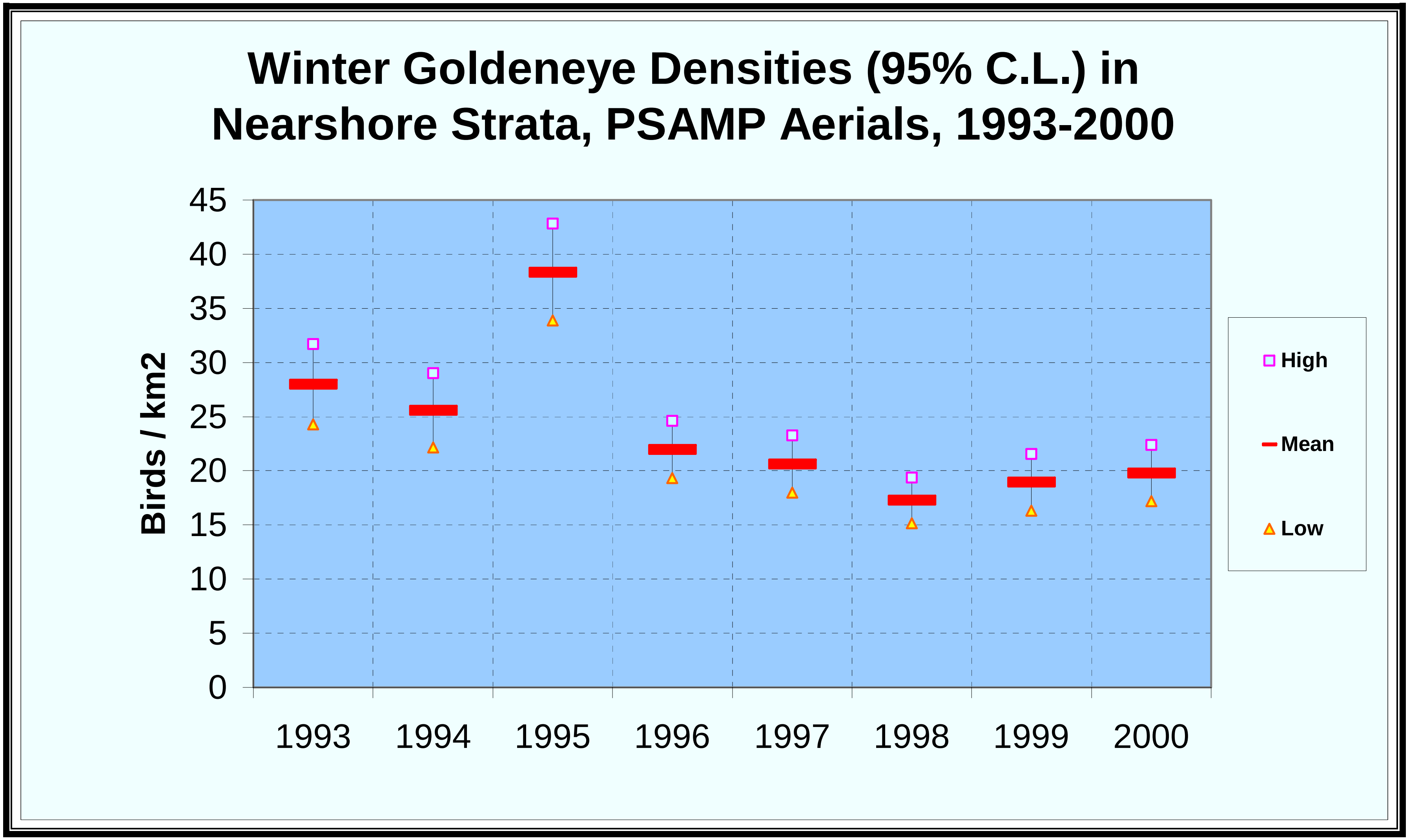


Figure 56. Winter Goldeneye Densities Observed During 1993-2000 PSAMP Winter Aerial Surveys in Nearshore Strata.

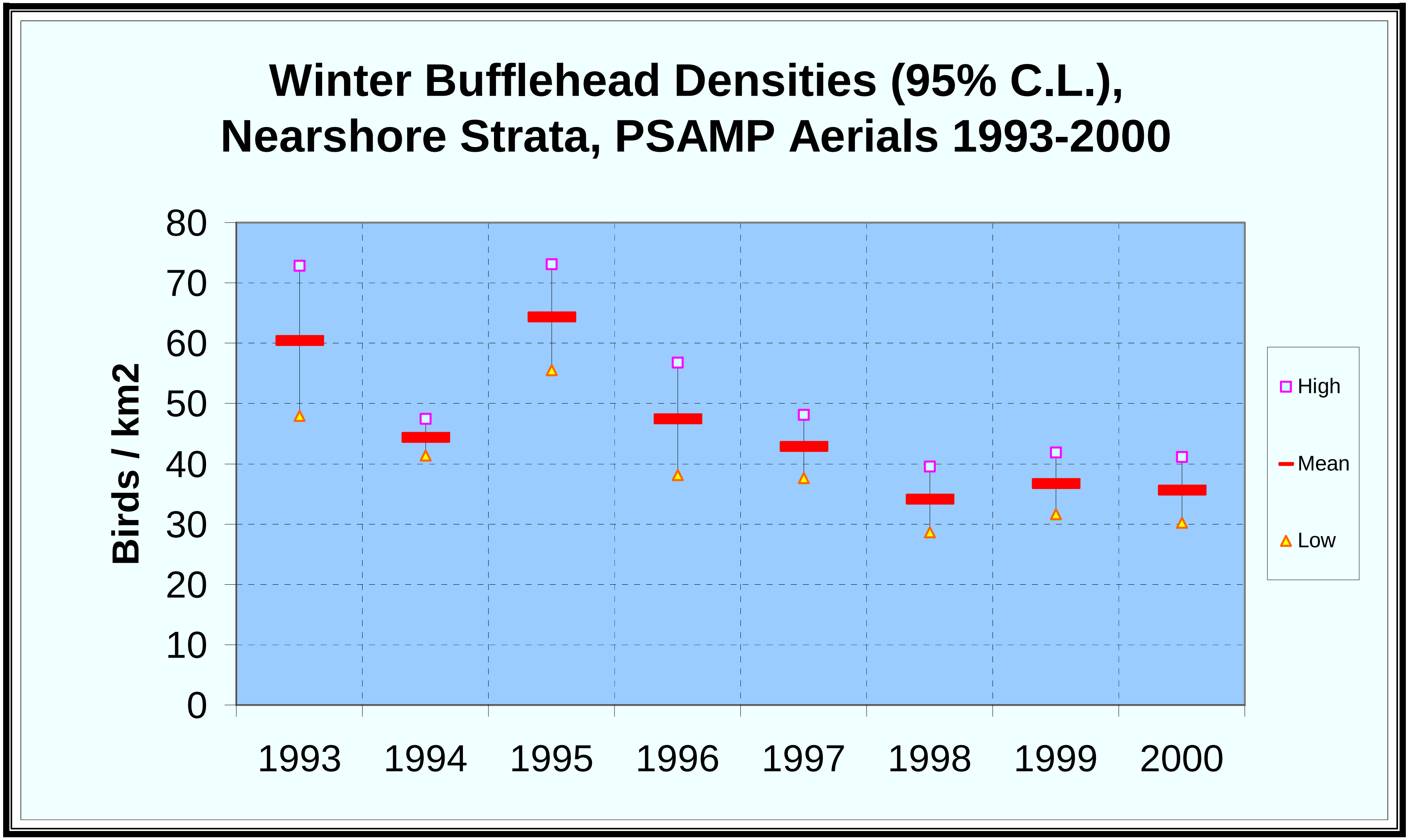


Figure 57. Winter Bufflehead Densities Observed During 1993-2000 PSAMP Winter Aerial Surveys in Nearshore Strata.

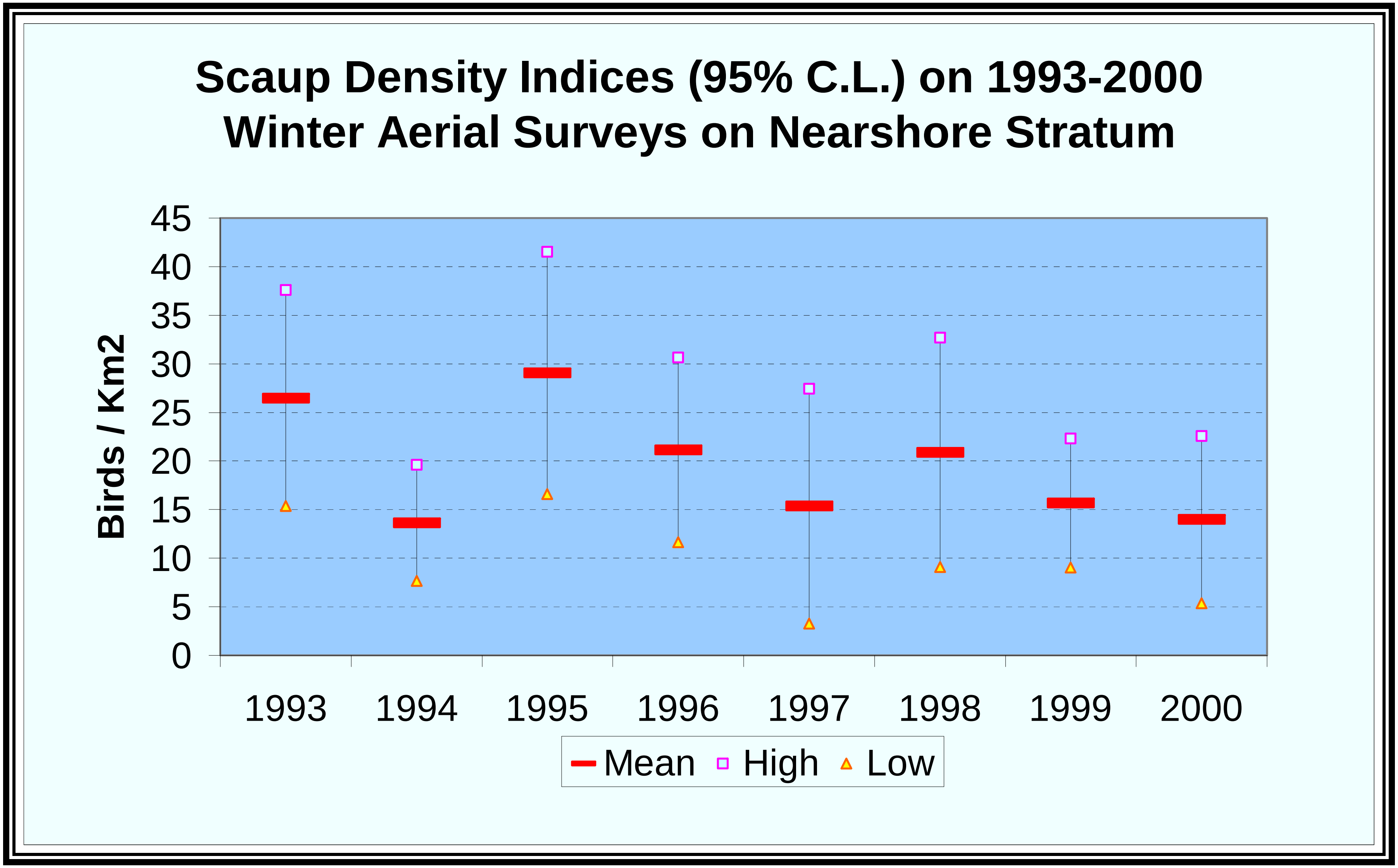


Figure 58. Scaup Densities Observed During 1993-2000 PSAMP Winter Aerial Surveys in Nearshore Strata.

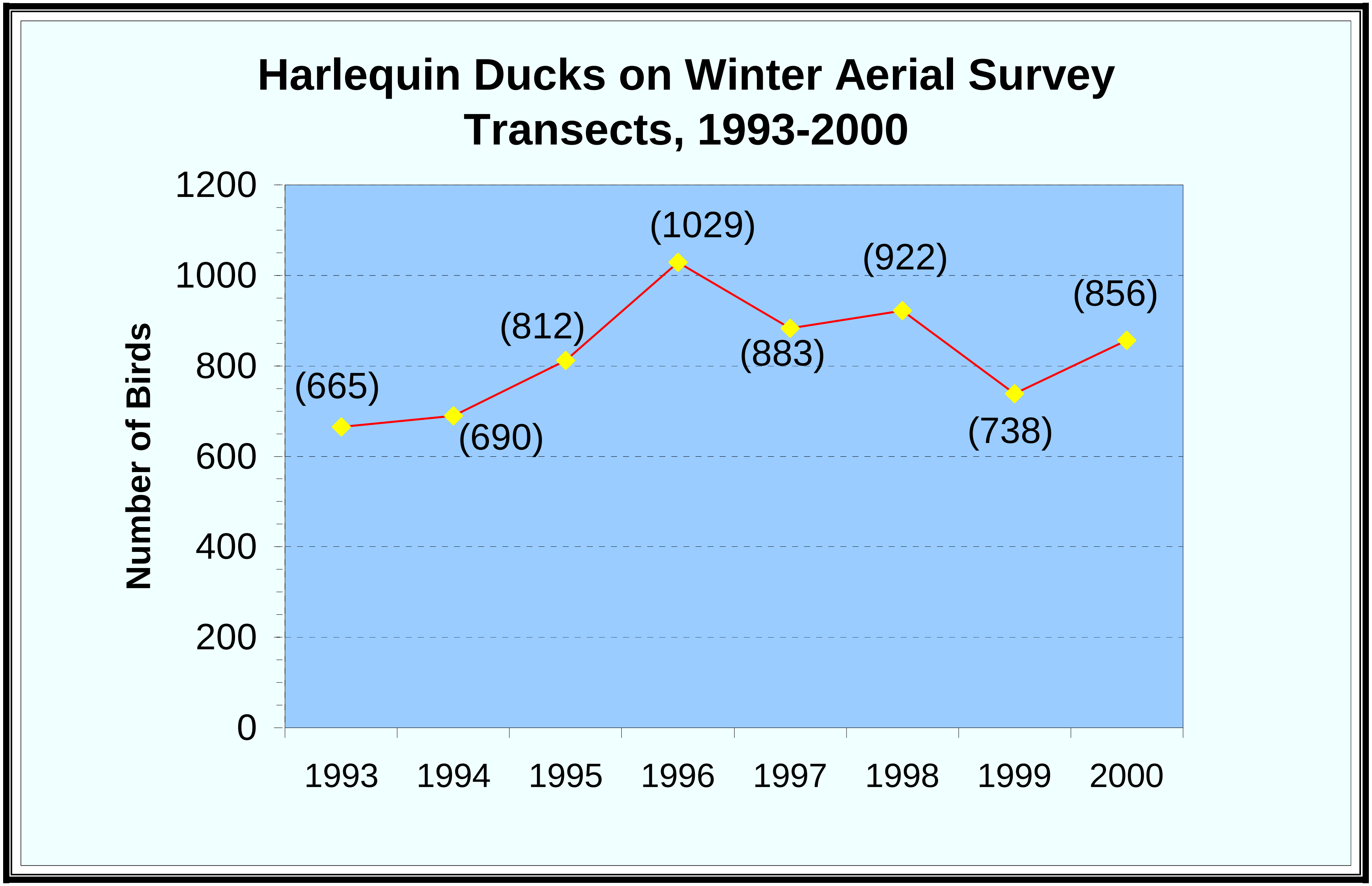


Figure 59. Harlequin Duck Counts Observed on 1993-2000 PSAMP Winter Aerial Survey Transects.

Alcids

1) Murres

The initial monitoring design assumed that there might be a consistent portion of the murre population that utilized the inner marine waters each year during winter surveys, but the 1993-2000 winter density indices show a highly variable pattern between years (Figure 60), with mean annual densities for the offshore waters (their preferred stratum) ranging from 6.59 $\pm$2.05 to 15.49 $\pm$4.84 birds per km^2. Murres may still be in the inner marine waters, but might be concentrated some years up in Georgia Straits or elsewhere. While there was consistent use of some areas, there was no consistent trend in numbers or densities upwards or downwards in our study area. Murres were not considered one of the best species to monitor as indices, given there were so many possible factors figuring into their annual variation.

2) Pigeon Guillemot

The numbers and densities of this species decrease from those observed during summer and also disperse from the concentrations seen during the summer. While they still favor shallower depths somewhat, they also favor passes, banks, and certain tidal currents and rips with the eastern portion of the Strait of Juan de Fuca being an area of higher densities (Figure 11). The decreases in numbers raise the hypothesis that these birds utilize some sort of migration and it is uncertain if they all remain in the state or disperse more widely. The lower densities seen the first two years may be related to either increased observer skill or differences related to changes in observer personnel. In any event, the density indices observed 1993-2000 show a fairly variable pattern for either the offshore or nearshore strata (Figure 61).

Grebes and Loons

1) Western Grebes

The highly aggregated concentrations that are typical of this species in the inner marine waters of Washington raise several different concerns. The mean density indices associated with these daytime flocks tend to have large confidence limits associated with them due to the clumped distribution. This suggests that more replicate surveys be conducted each year focusing on this species because survey intensity must increase with flock size to obtain the same level of accuracy (Gaston and Smith 1984). However, because these large concentrations of western grebes use both Washington and British Columbia marine waters in sizeable numbers, a change in numbers in one area might just mean that portions of the population were using the other nation's waters at that time. The degree to which winter feeding areas are used again each year by the same component of this species' population is unknown.

The daytime resting concentrations can be in either nearshore or offshore strata because they are primarily resting areas for this crepuscular or nocturnal feeder. The more detailed stratification of our survey data in the future may help in any future estimates of numbers. For now, the mean density indices (Figure 62) demonstrate the variation that occurs any one year when surveyed with

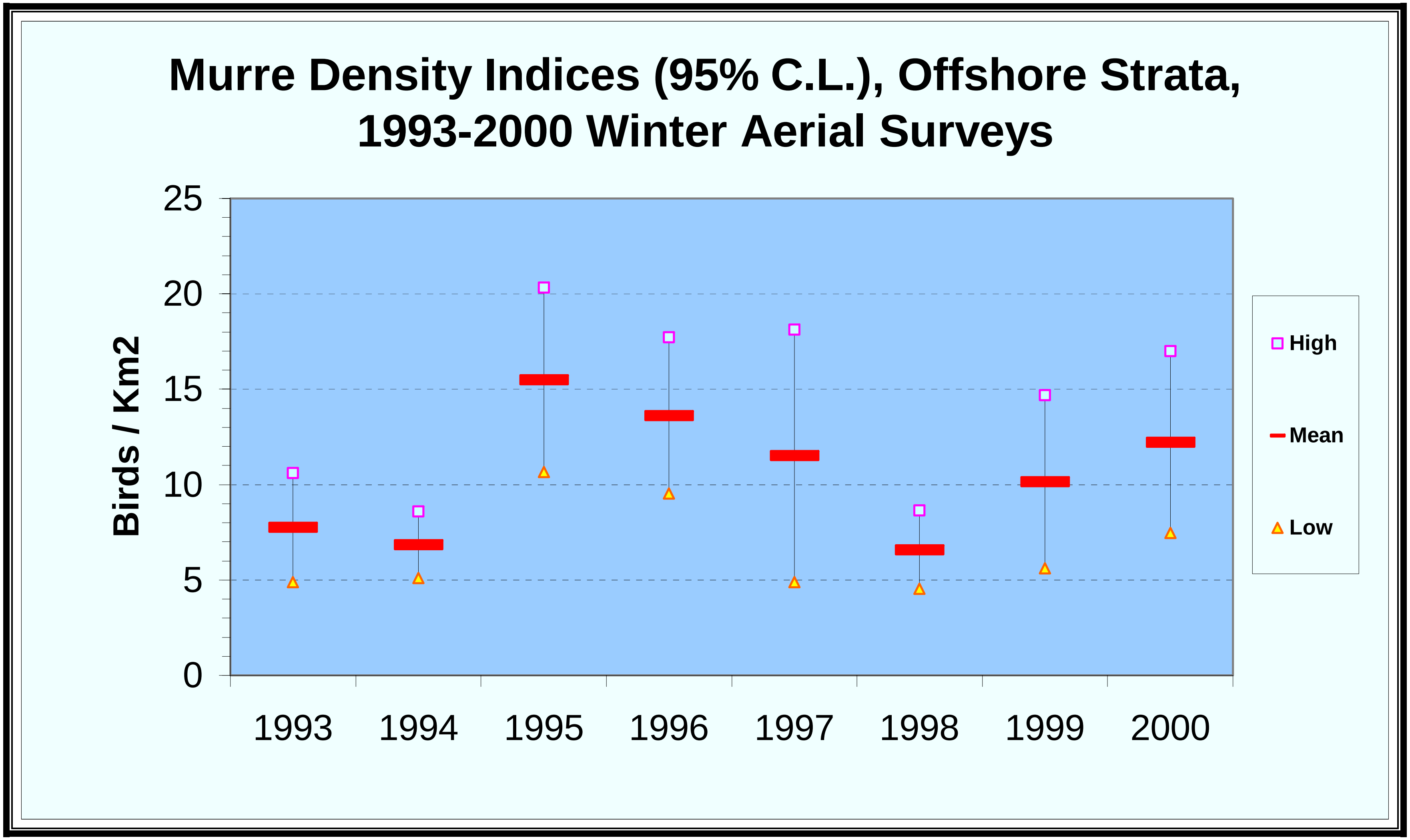
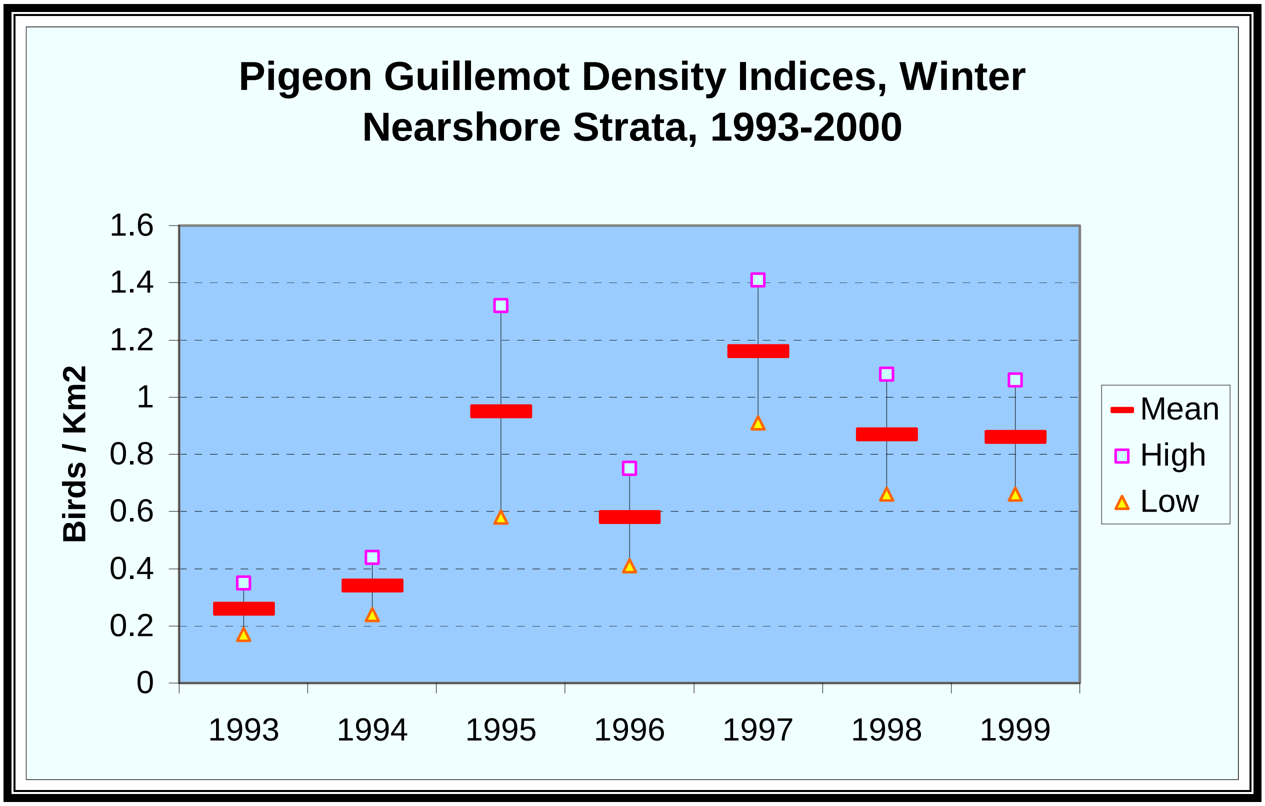


Figure 60. Murre Density Indices Observed During 1993-2000 PSAMP Winter Aerial Surveys in Offshore Strata.



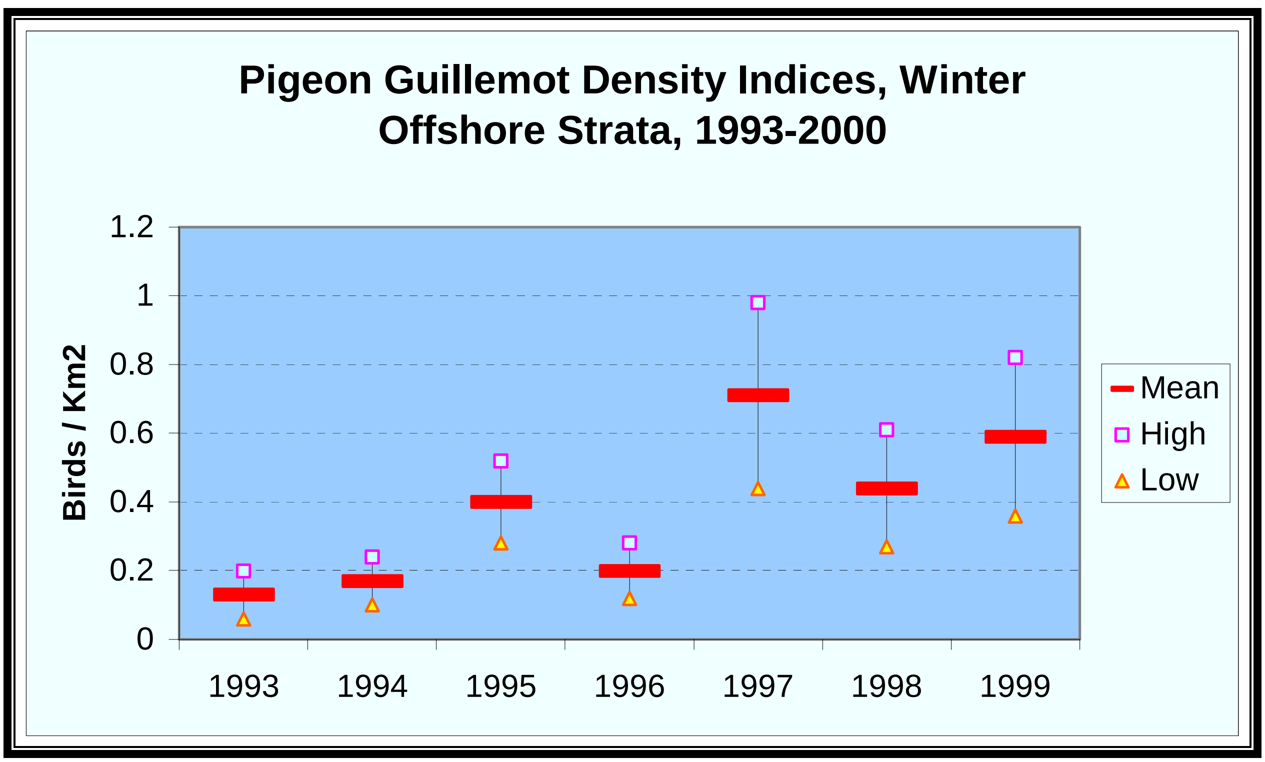


Figure 61. Pigeon Guillemot Density Indices Observed During 1993-2000 PSAMP Winter Aerial Surveys in Nearshore (<20m) and Offshore (>20m) Strata.

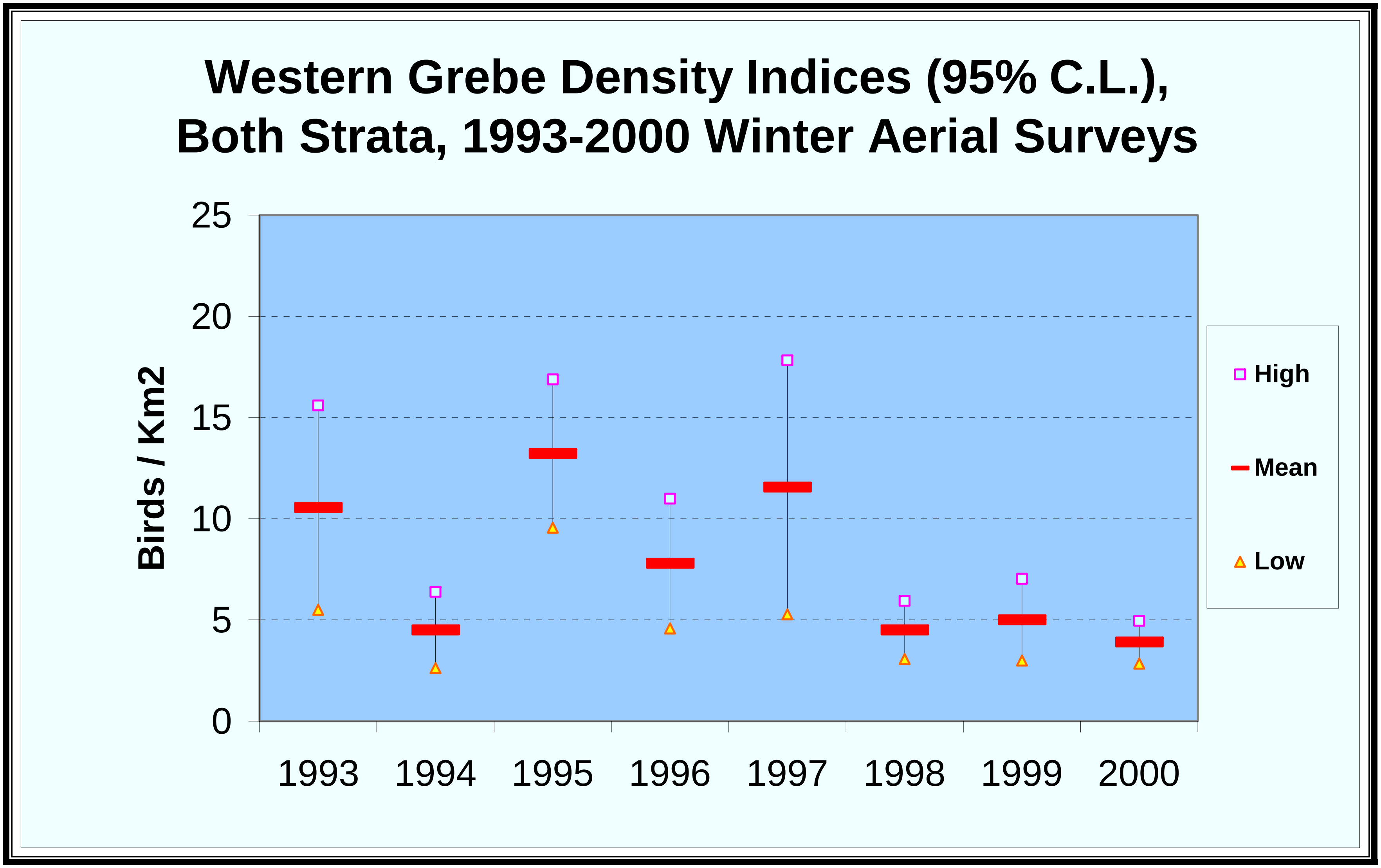


Figure 62. Western Grebe Density Indices Observed During 1993-2000 PSAMP Winter Aerial Surveys in Both Strata.

the present coverage and lack of replicates used by PSAMP aerial surveys.

Comparisons of northern and southern indices of western grebe density capture some decrease during any one-year period in any one area, but do not show a corresponding increase to occur in the northern area (Figure 63). The highly clumped distribution pattern of this species, combined with our present survey design, makes it impossible to make any conclusions about decreases for one year, because our survey of offshore waters might have missed the concentration of this species there that year. The comparison in the figure does suggest that movement between areas is likely not the reason for the decline.

2) Loons

If you combine the unknown loon categories with the identified species totals and assume that a similar ratio of missed birds has occurred each year, then there is some evidence that suggests that loon numbers have been increasing somewhat on marine waters this last decade (Table 8; Figure 64). Densities are still quite low and more years of monitoring will be required to make any conclusions. See the later discussion on comparisons with the MESA data for such a longer-term type of comparison, which incidentally shows a decline over the longer period of 20 years.

Other Species

Cormorants do migrate into inner marine waters of Washington State and Figure 65 illustrates the density indices observed in the nearshore strata for all cormorant species combined during the PSAMP aerial surveys 1993-2000 (Figure 65). There does not seem to be any clear trend during these recent years. See again the later discussion of comparisons with MESA data for a longer time period to compare.

Comparison with MESA Studies

The original contract design for the monitoring of marine birds by PSAMP included creation of a digital database which translated the MESA survey results, primarily density type data, into synthesis databases needed for comparison with recent monitoring. This was completed although certain labels of historical transects were not included in this creation. Staff have been able to determine the location of most of these transects through analyses of transect lengths and MESA sub regions where the transects occurred. This latter exercise finally allowed more specific comparisons in certain areas of nearly identical transects between the 1978-79 MESA and the 1992-99 PSAMP efforts.

Comparisons of PSAMP surveys with USFWS and WDFW efforts in more recent years will be examined briefly later in our discussion. However, the comparison of nearly identical MESA and PSAMP aerial transects offers, in our judgment, the best opportunity to look over the longest time period available (20 years) that was measured by relatively comparable survey methodologies. While the MESA efforts did not utilize aerial surveys to the extent that PSAMP efforts have, there is enough overlap geographically in appropriate areas to capture some picture of trends that have been occurring in western Washington marine waters for a number of species.

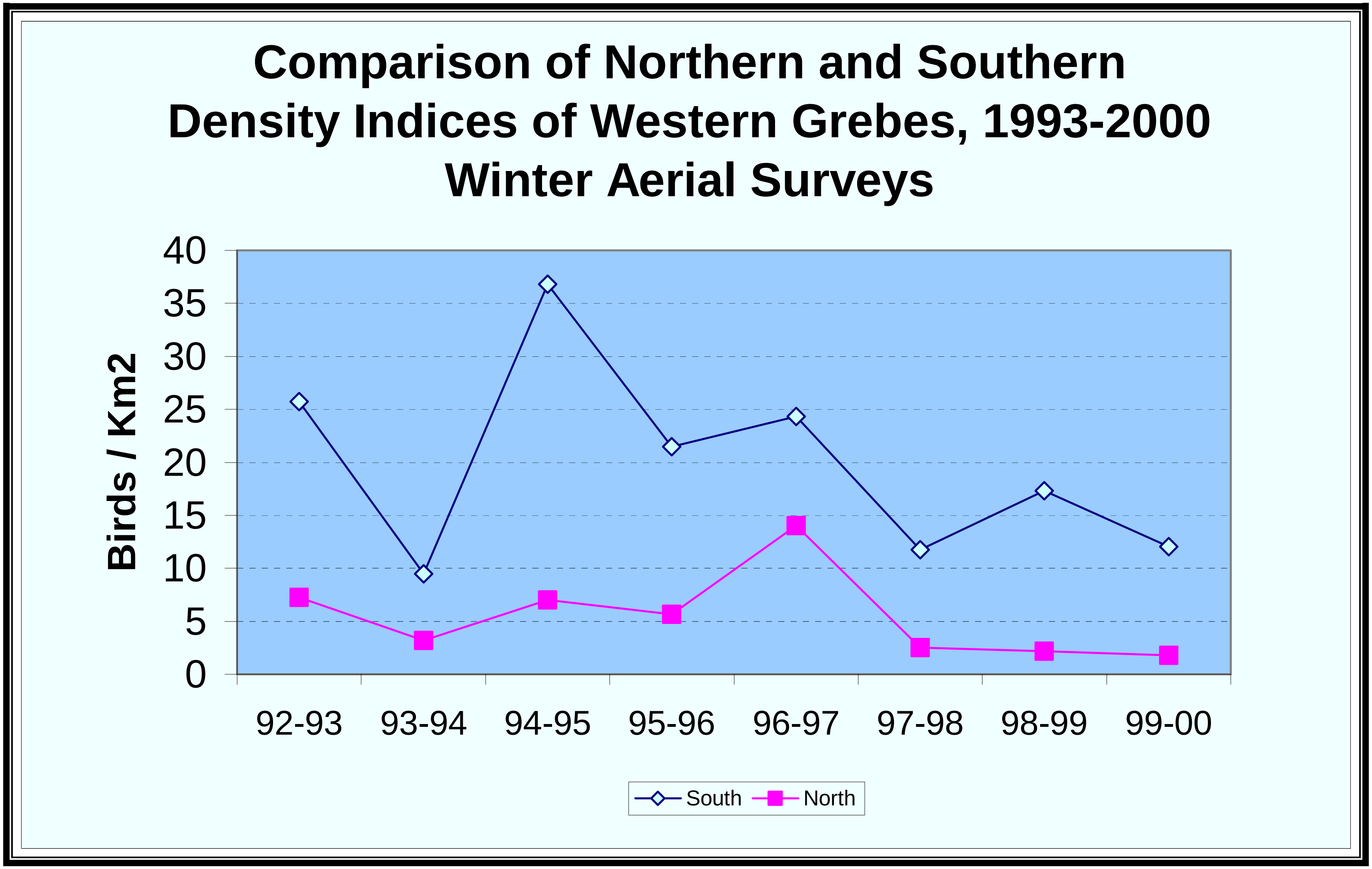


Figure 63. Comparison of Northern and Southern Density Indices Observed for Western Grebes, 1993-2000 PSAMP Winter Aerial Surveys.

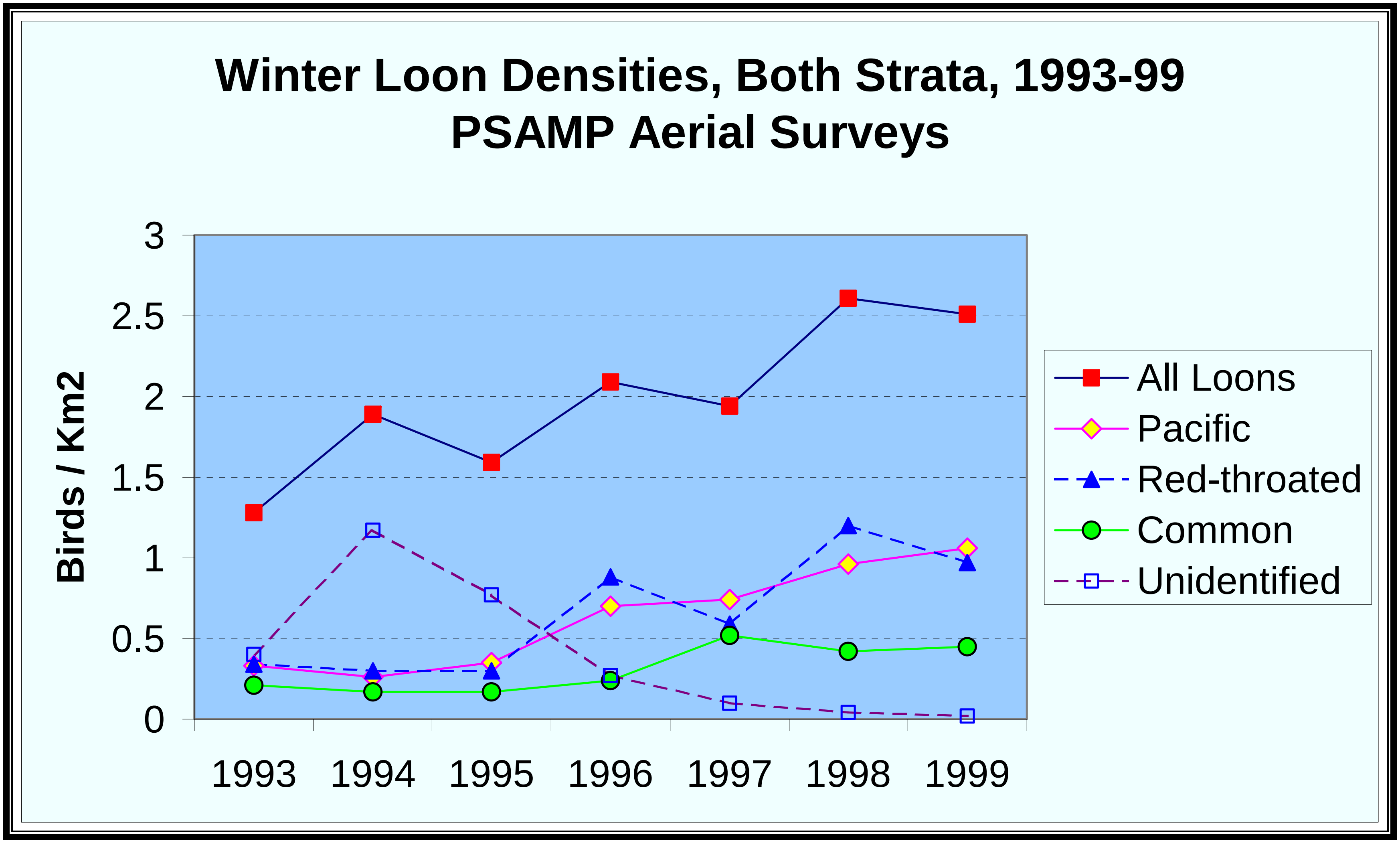


Figure 64. Annual Density Indices of Loons Seen During PSAMP Winter Aerial Surveys 1993-99. .

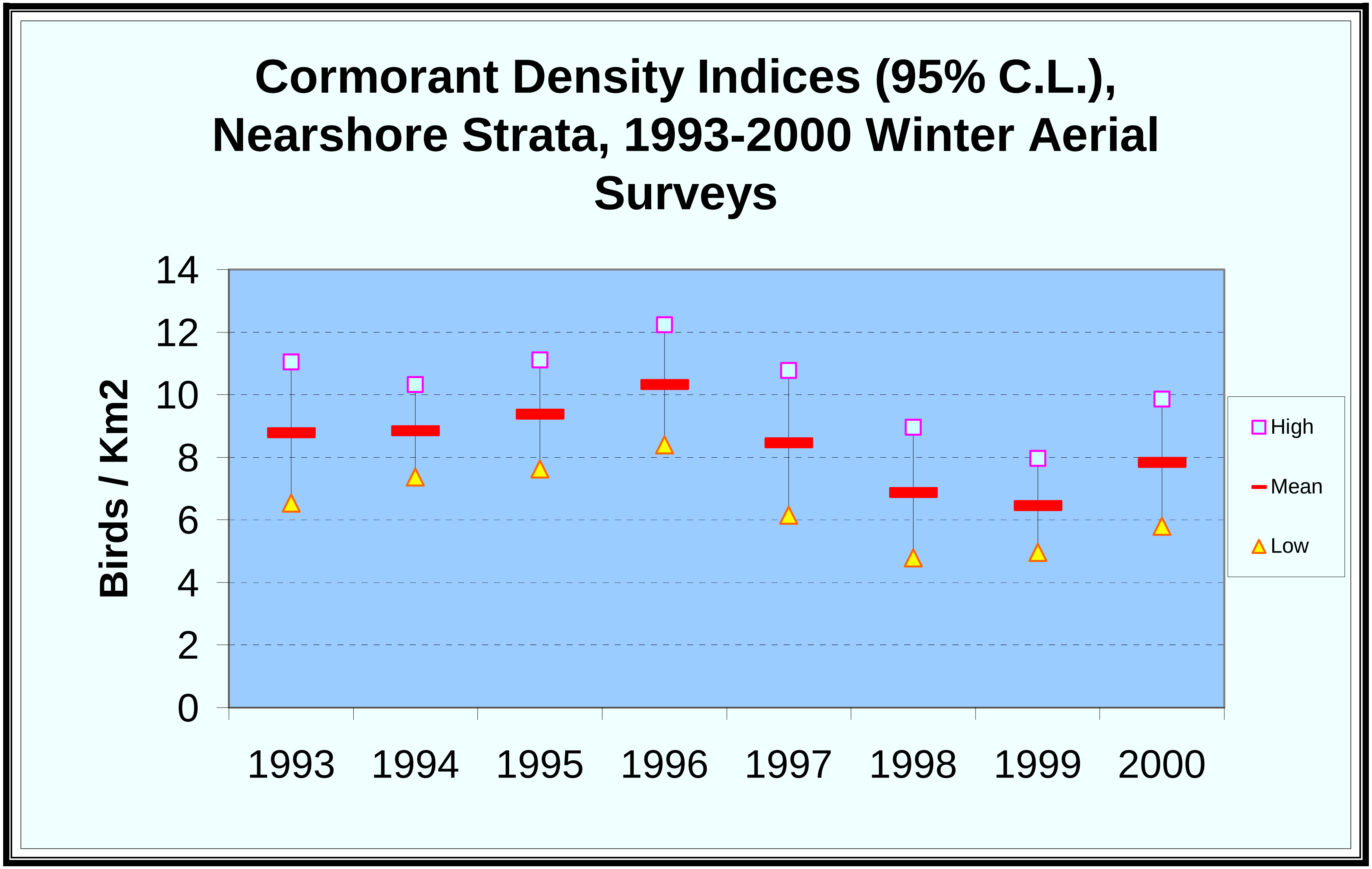


Figure 65. Density Indices Observed in Nearshore Strata for All Cormorant Species Combined During 1993-2000 PSAMP Winter Aerial Surveys.

The aerial surveys being compared here were conducted from generally two different types of planes: Cessna model without floats in MESA, and DeHaviland Beaver with floats in PSAMP. This means that the viewing area and angle is slightly different and the noise level is quite different. Each transect width was slightly different and the data have been weighted to account for this. The quieter Cessna might permit more of the small and more wary species (e.g. marbled murrelets, horned grebes) to be observed, but larger species should have been observed similarly with either plane. When funding exists, future comparisons of survey platforms can address what difference the different planes make in results. At present, we assume that the differences are not enough to mask the large types of decreases that are shown.

The comparisons of 54 transects shared by aerial surveys between 1978-79 and 1992-99 (Figure 66) differ from any earlier analyses (Nysewander and Evenson 1998) in that they include more species and compare only that part of the PSAMP survey effort which strictly mimicked the MESA transect effort. Data were combined into two periods: the 1978-79 MESA (N = 124), and 1992-1999 PSAMP (N = 414) or 1994-95 only in PSAMP (N = 52). Estimated mean densities were calculated for each period, weighting by sample unit areas. Differences between periods were tested by ANOVA. Table 9 compares the 1978-79 MESA densities with the mean densities combined for the entire PSAMP survey period 1992-99. Table 10 compares the MESA densities with just the one PSAMP winter survey (1994-95) where highest densities were recorded for most species during the seven years covered by PSAMP surveys. If the 1978-79 MESA densities were, by chance, one of the peaks of abundance during the normal interannual variation seen during any consecutive series of years, then comparison to another peak year (1994-95) is informative. This comparison reduces somewhat the degree of decrease, and more so the attached significance, because of larger confidence limits in the reduced set of PSAMP data, but this still does not eliminate most decreases. However, we have no information to suggest that 1978-79 was atypical. Therefore, most of the following discussion will be based upon the results derived from the comparison summarized by Table 9, which assumes that the MESA densities were likely average for that period.

Diving Ducks and Selected Other Waterfowl

Recent publications on status of sea and diving ducks have suggested that certain species have declined (Goudie et al. 1994; Henny et al. 1995) in certain portions of the Pacific Flyway. Nysewander and Evenson (1998) described different ways of evaluating how wintering scoter numbers had probably declined somewhere between 40-70% over the last 20 years in greater Puget Sound by 1998. The comparisons of data from nearly identical aerial transects in both MESA and PSAMP monitoring displayed in Table 9 and Figures 67-69 depict statistically significant decreases in densities for scoters ($P<0.001$, 57.0 % decrease), scaup ($P<0.001$, 72.3% decrease), and oldsquaw ($P<0.001$, 91.0% decrease) while showing significant increases for harlequins ($P<0.001$, 188.6% increase). The other three species of diving ducks examined did not have significance attached to their changes: goldeneyes ($P=0.211$, 22.6% decrease), bufflehead ($P=0.465$, 20.1% increase), and mergansers ($P=0.065$, 55.3% increase). In the latter case, it should be noted that merganser increases are close to being statistically significant. Even though black brant are notoriously wary of surveying airplanes, it was assumed that either aerial survey had a similar chance of still capturing some portion of brant present. The MESA/PSAMP comparisons suggest that brant densities declined ($P=0.03$, 66.3% decline).

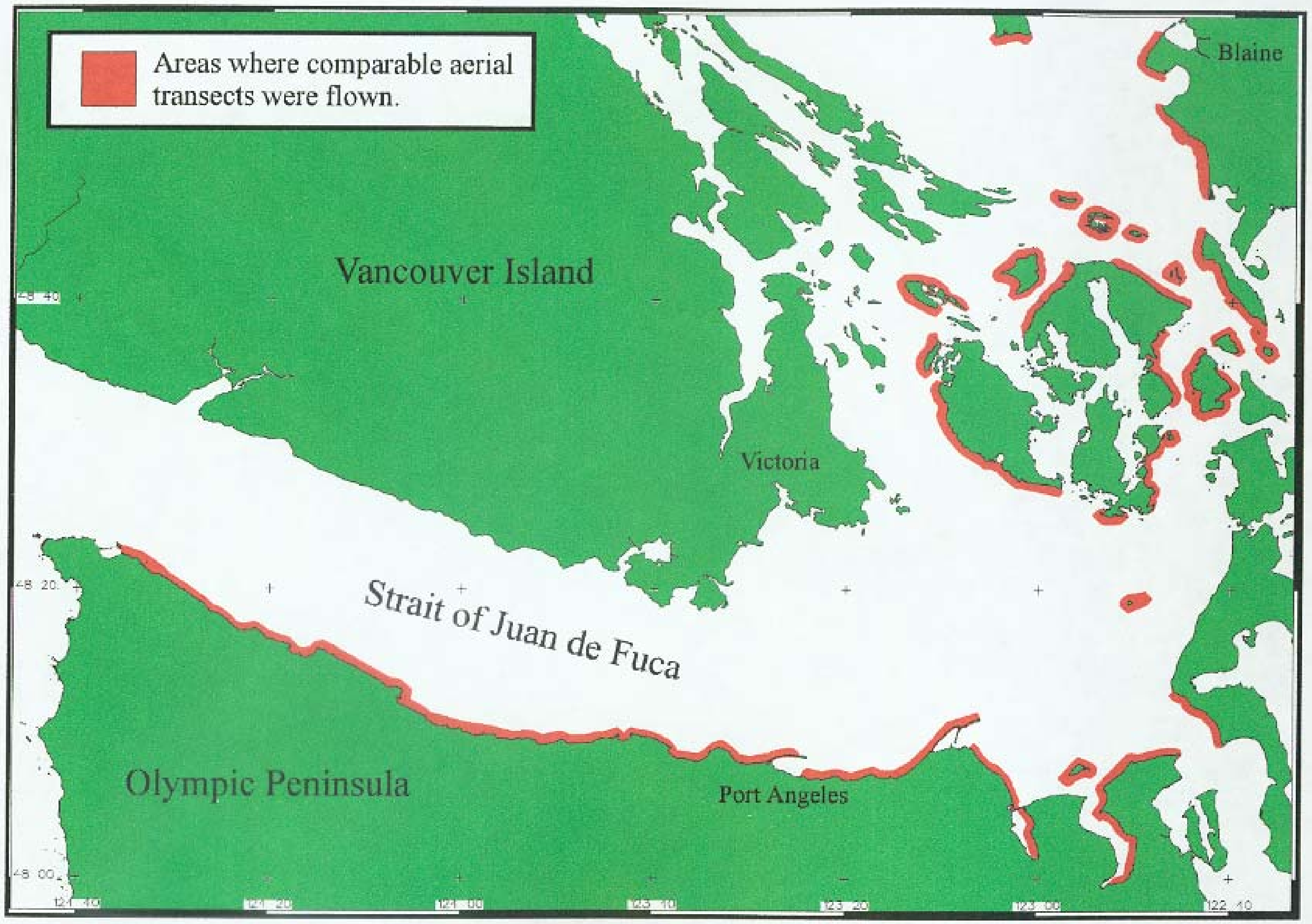


Figure 66. Transect Locations for Comparisons of Density Indices Derived from Aerial Surveys Conducted by Both MESA and PSAMP Efforts.

Table 9. Comparison of mean densities (birds/km^2) for selected wintering species derived from comparable 1978-79 MESA and 1992-99 PSAMP aerial track-lines.

Species	MESA Density (95% C. L.)	PSAMP Density (95% C. L.)	% Change	P Value (ANOVA)
Scoters	74.56 " 17.78	32.04 " 9.65	-57.0%	< 0.001
Scaup	27.34 " 7.83	7.57 " 4.25	-72.3%	< 0.001
Goldeneyes	18.29 " 5.70	14.15 " 3.09	-22.6%	0.211
Bufflehead	49.83 " 23.63	59.85 " 12.82	20.1%	0.465
Oldsquaw	13.79 " 4.85	1.24 " 2.63	-91.0%	< 0.001
Harlequin Duck	4.33 " 2.98	12.51 " 1.62	188.6%	< 0.001
Mergansers	8.01 " 4.13	12.45 " 2.24	55.3%	0.065
Black Brant	5.90 " 3.10	1.99 " 1.68	-66.3%	0.03
Western Grebe	22.19 " 4.01	1.07 " 2.18	-95.2%	< 0.001
Red-necked Grebe	4.31 " 0.79	0.48 " 0.43	-88.8%	< 0.001
Horned Grebe	10.07 " 1.50	1.77 " 0.81	-82.4%	< 0.001
Loons	7.99 " 1.74	1.67 " 0.94	-79.1%	< 0.001
Common Loon	2.28 " 0.41	0.82 " 0.22	-64.3%	< 0.001
Cormorants	17.61 " 4.21	8.29 " 2.29	-53.0%	<0.001
Double-crested Cormorant	4.97 " 1.58	1.90 " 0.86	-61.7%	0.001
Pigeon Guillemot	1.53 " 0.59	0.69 " 0.32	-55.2%	0.014
Marbled Murrelet	4.67 " 2.70	0.18 " 1.47	-96.3%	0.004
Gulls	133.97 " 77.35	75.71 " 41.98	-43.5%	0.195
Great Blue Heron	0.61 " 0.37	0.49 " 0.20	-18.8%	0.597
Bald Eagle	0.42 " 0.44	0.57 " 0.24	35.4%	0.56

Table 10. Comparison of mean densities (birds/km^2) for selected wintering species derived from comparable 1978-79 MESA and 1994-95 PSAMP aerial track-lines.

Species	MESA Density (95% C. L.)	PSAMP Density (95% C. L.)	% Change	P Value (ANOVA)
Scoters	74.56 " 17.78	41.99 " 33.39	-43.7%	0.114
Scaup	27.34 " 7.83	12.14 " 22.25	-55.6%	0.267
Goldeneyes	18.29 " 5.70	32.42 " 11.44	77.3%	0.046
Bufflehead	49.83 " 23.63	102.56 " 46.32	105.8%	0.065
Oldsquaw	13.79 " 4.85	2.89 " 14.60	-79.1%	0.225
Harlequin Duck	4.33 " 2.98	10.45 " 2.70	141%	< 0.001
Mergansers	8.01 " 4.13	17.14 " 5.27	113.9%	0.005
Black Brant	5.90 " 3.10	2.40 " 7.49	-59.3%	0.446
Western Grebe	22.19 " 4.01	3.50 " 11.61	-84.2%	0.01
Red-necked Grebe	4.31 " 0.79	0.06 " 2.25	-98.5%	0.003
Horned Grebe	10.07 " 1.50	0.82 " 4.25	-91.9%	0.001
Loons	7.99 " 1.74	1.65 " 5.00	-79.3%	0.04
Common Loon	2.28 " 0.41	0.57 " 0.88	-87.8%	0.002
Cormorants	17.61 " 4.21	8.43 " 9.44	-52.1%	0.115
Double-crested Cormorant	4.97 " 1.58	3.47 " 3.40	-30.2%	0.472
Pigeon Guillemot	1.53 " 0.59	1.29 " 0.61	-16.1%	0.677
Marbled Murrelet	4.67 " 2.70	0.32 " 8.21	-93.2%	0.388
Gulls	133.97 " 77.35	83.74 " 133.69	-37.5%	0.54
Great Blue Heron	0.61 " 0.37	0.46 " 0.85	-24.4%	0.776
Bald Eagle	0.42 " 0.44	0.31 " 0.56	-26.8%	0.743

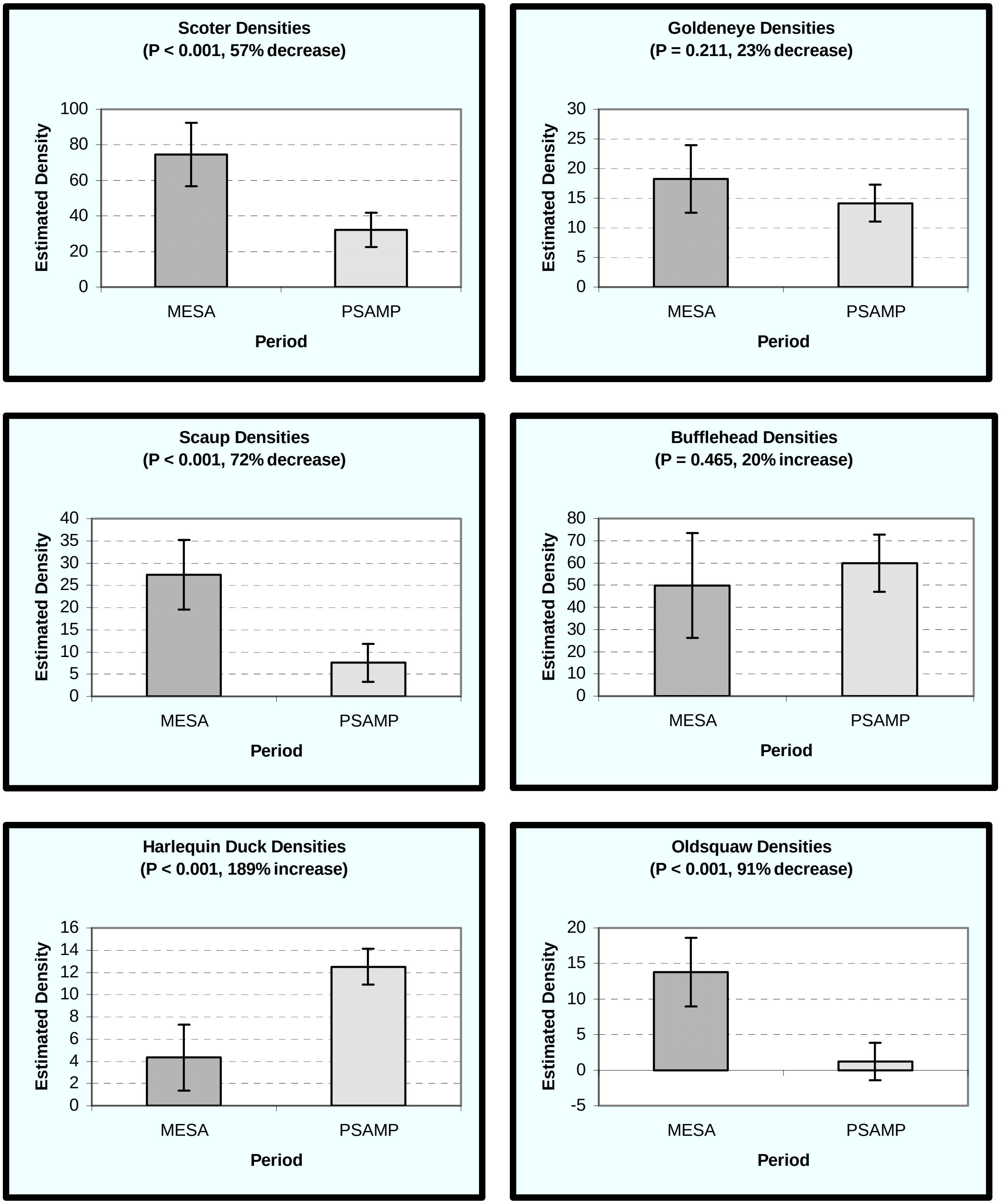


Figure 67. Changes in Density Indices (birds/km^2) of Selected Diving Duck Species Observed on Nearly Identical Transects Between the 1978-79 MESA and the 1992-99 PSAMP Aerial Surveys.

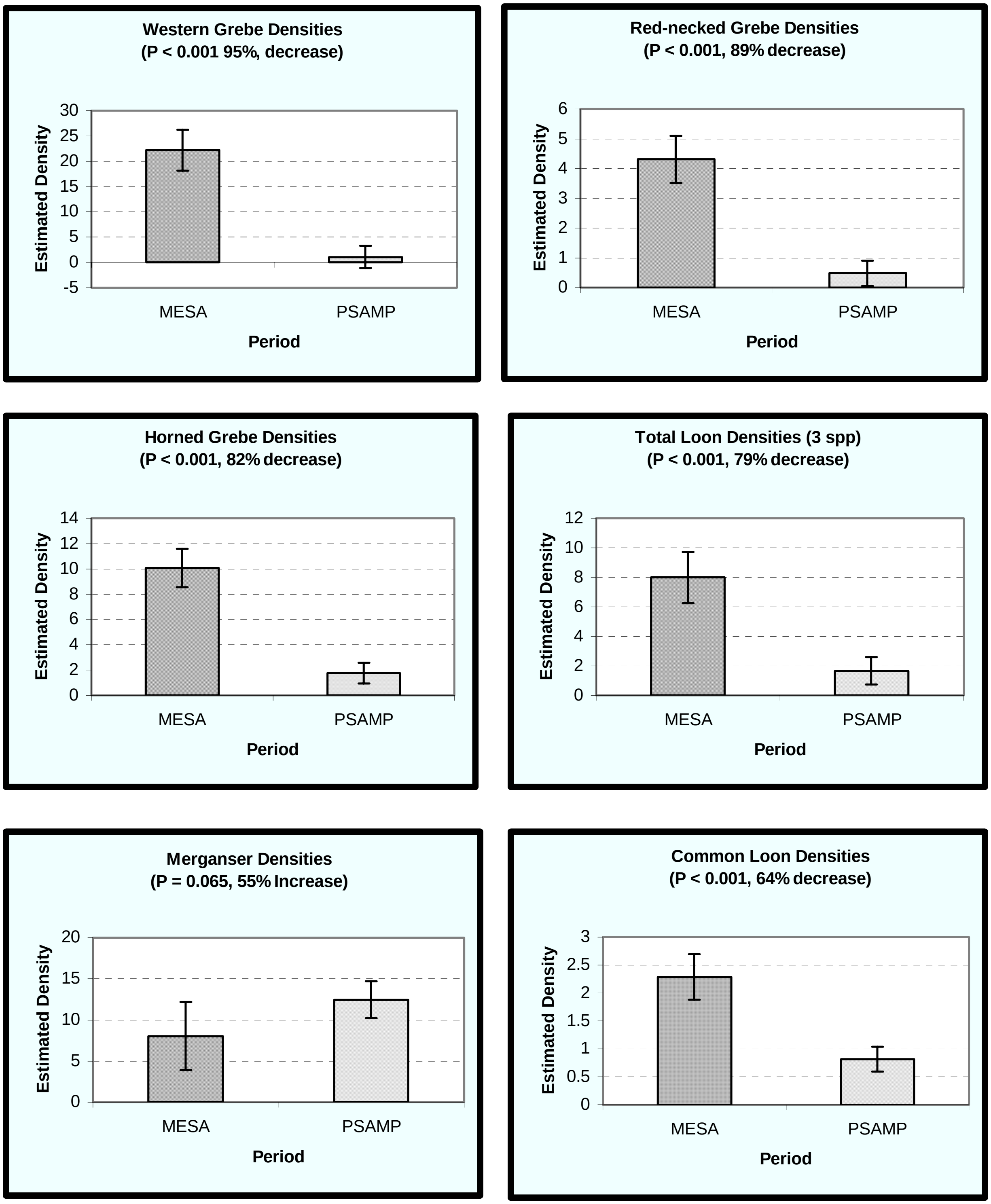


Figure 68. Changes in Density Indices (birds/km^2) of Grebe, Loon, and Merganser Species Observed on Nearly Identical Transects Between the 1978-79 MESA and the 1992-99 PSAMP Aerial Surveys.

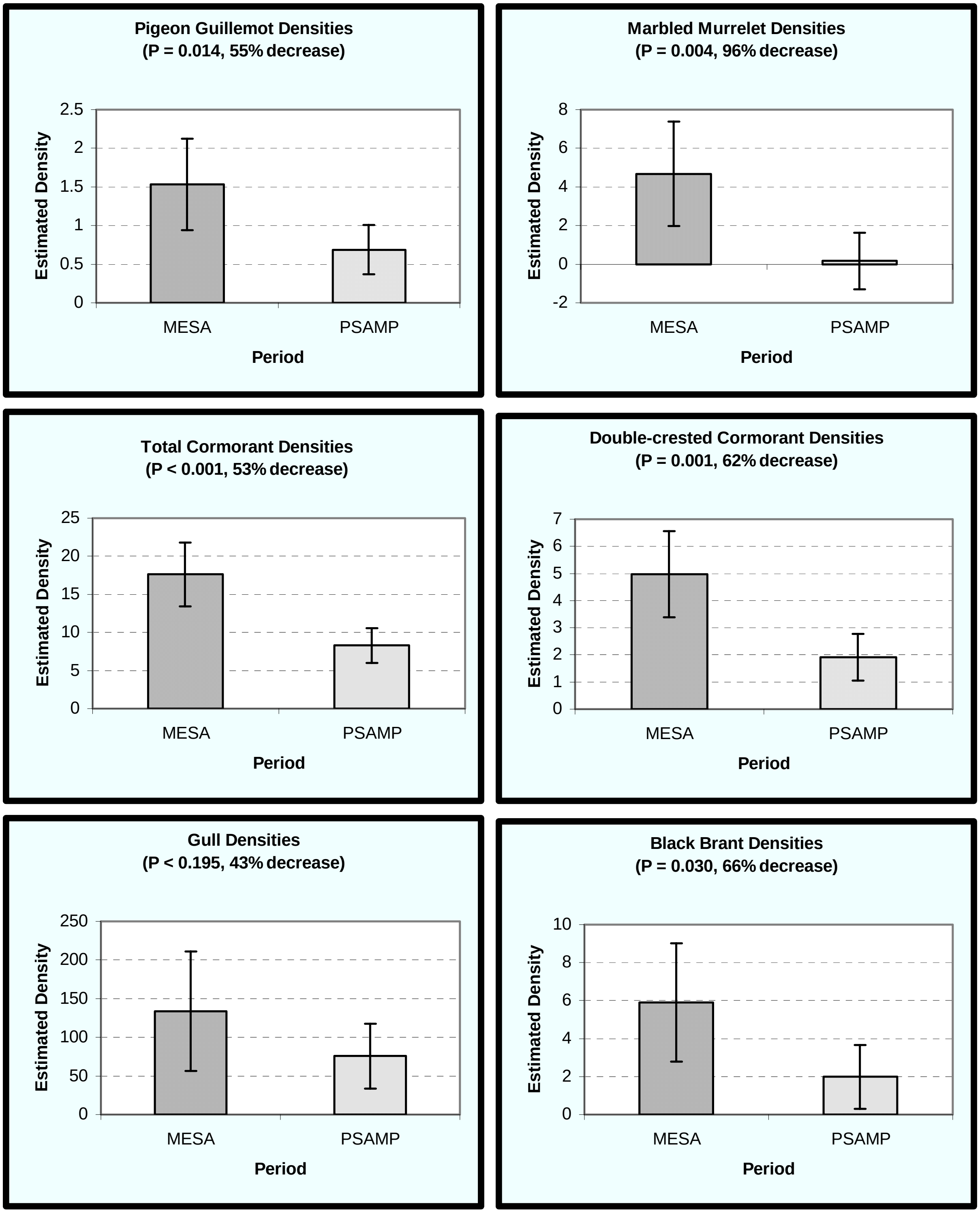


Figure 69. Changes in Density Indices (birds/km^2) of Alcid, Cormorant, Gull, and Other Species Observed on Nearly Identical Transects Between the 1978-79 MESA and the 1992-99 PSAMP Aerial Surveys.

Grebes and Loons

Western grebes appear to have declined even more so than diving duck species from levels seen twenty years ago. For instance, in greater Bellingham Bay the MESA studies (Wahl et al. 1981) reported 38,000 western grebes in that area while the PSAMP surveys have never seen, on and off transect combined, more than 5700 birds in that same area during the 1993-99 period. Their winter distribution in Washington is much more clumped than that seen for species such as scoters. As a result, a survey any one-year period might or might not catch some of these concentrations and thus create very large confidence limits. The PSAMP aerial survey design would need to be altered or boat surveys could be utilized to provide tighter confidence limits for monitoring of this species, increasing coverage intensity or number of replicates. Nevertheless, the comparison of density indices in Table 9 and Figure 68 still depicts a significant decline over the last 20 years for this species (P<0.001, 95% decrease). The southern area (south and central Puget Sound) has contained both higher densities and higher overall numbers of western grebes than those found to the north during the 1992-99 PSAMP surveys, but comparisons during this same period do not capture any exchange of numbers between these regions (see earlier Figure 63).

In fact, all the loon and grebe species examined have experienced marked decreases (Figure 68) in the MESA/PSAMP comparisons: red-necked grebe (P<0.001. 89% decrease), horned grebe ((P<0.001, 82% decrease), common loon (P<0.001, 64 % decrease), or all loons combined (P<0.001, 79% decrease). The aerial surveys almost certainly miss some of these species as they can often dive as the airplane approaches. These differences may modify the exact degree of decline recorded, but not the fact that actual declines in numbers and densities have occurred. The horned grebe is the only one of these species that the aerial surveys consistently underestimate considerably.

Alcids

Murres favor the offshore depth strata and passes of the inner marine waters of Washington State. The aerial transects that were comparable between MESA and PSAMP were all located in nearshore strata, thus eliminating murres from this particular comparison. Nevertheless, it should be mentioned that the Pacific and Yukon Region of Environment Canada reports Christmas Bird Count data for murres in the Strait of Georgia that demonstrates highly variable numbers but a possible declining trend between 1983 and 1997. (http://www.ecoinfo.ec.gc.ca/env_ind/region/seabird/seabird_e.cfm).

Comparisons are possible for both pigeon guillemots and marbled murrelets because they frequent nearshore depth strata in Washington State. Even though aerial surveys miss some of these, especially marbled murrelets, the comparisons of densities seen on aerial surveys in both MESA and PSAMP efforts suggest significant declines for these two species: pigeon guillemot (P=0.014, 55% decline) and marbled murrelet (P=0.004, 96% decrease). Later discussions on air/boat comparisons of these two species will suggest what proportion of these species is missed by aerial surveys. However, we are assuming that the two different aerial survey efforts are probably similar in their ratio of missed birds. This seems especially likely for pigeon guillemots because they are not as wary or cryptic as murrelets.

Cormorants

While wintering cormorant densities did not appear to change much during the PSAMP period (Figure 65), there have been significant decreases in densities between the MESA and PSAMP periods (Figure 69), both for identified double-crested cormorants (P=0.001, 62% decrease) and for all cormorants including the unidentified category (P<0.001, 53% decrease). It is unknown whether cormorants return to similar wintering areas each winter. There is some evidence from observations of banded birds that certain species such as gulls come back to the same wintering areas each winter and this characteristic may also apply to cormorants.

Other Species

The inner marine waters of Washington State contain many other resident marine bird species, such as numerous gulls. Comparisons of densities for selected species or species groups between MESA and PSAMP (Table 9 and Figure 69) depict large confidence limits for total gulls, great blue herons, and bald eagles. The decrease in gull densities comes closest to significance (P=0.195, 43.5% decrease). The densities of herons and eagles are most likely not very precise because the aerial surveys were not coordinated with tidal stages (in the case of herons), nor did the PSAMP effort encourage observers to raise their eyes from transects to include eagles that might have been ocurring in trees on shorelines.

Correlation of Density Indices Between Compared Transects and Total MESA Nearshore Transects

The nearly identical aerial survey transects used for comparison were not found in all of the MESA sub regions. In order to help evaluate whether these transects might be representative of what happened in the other portions of the MESA study area, we compared changes in annual winter density indices during 1992-99 for the same species on both the nearshore transects used for comparison and the total MESA nearshore transects. The results (Figures 70-72) suggested that changes on the transects used for comparison reflected the changes found throughout the total MESA area for the following species: scoters, goldeneyes, bufflehead, harlequin duck, black brant, total loons, common loon, red-necked grebe, horned grebe, mergansers, pigeon guillemot, and gulls. The following species or groups did not correlate as well between the two areas: scaup, oldsquaw, western grebe, marbled murrelet, total cormorants, or double-crested cormorants. Apparently some important habitat use area is either under or over represented in the subset of transects which were used for comparison for the latter species.

Review of these various comparisons suggests that the best chance to document any significant changes probably lies with continuing the PSAMP aerial surveys in a form that permits enough replicates and coverage to reduce confidence limits for selected key species. Up to now, the PSAMP surveys have taken all of the allotted time scheduled just to complete one pass of the

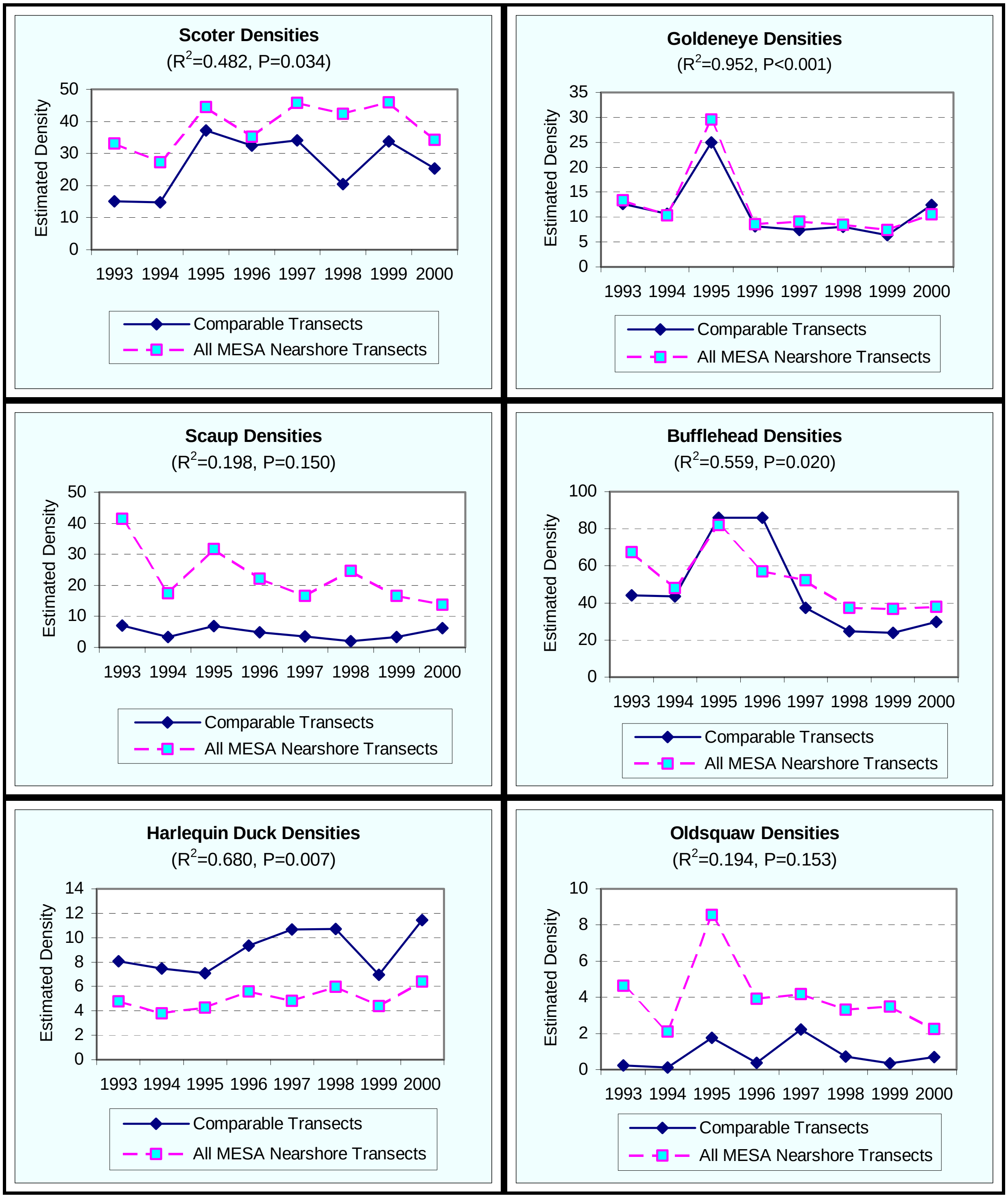


Figure 70. Density Indices of Selected Diving Ducks on Nearshore Transects Used for MESA/PSAMP Aerial Trends Compared With the Density Indices of Same Species Seen on All Nearshore Transects Conducted in MESA Area During PSAMP Aerial Surveys.

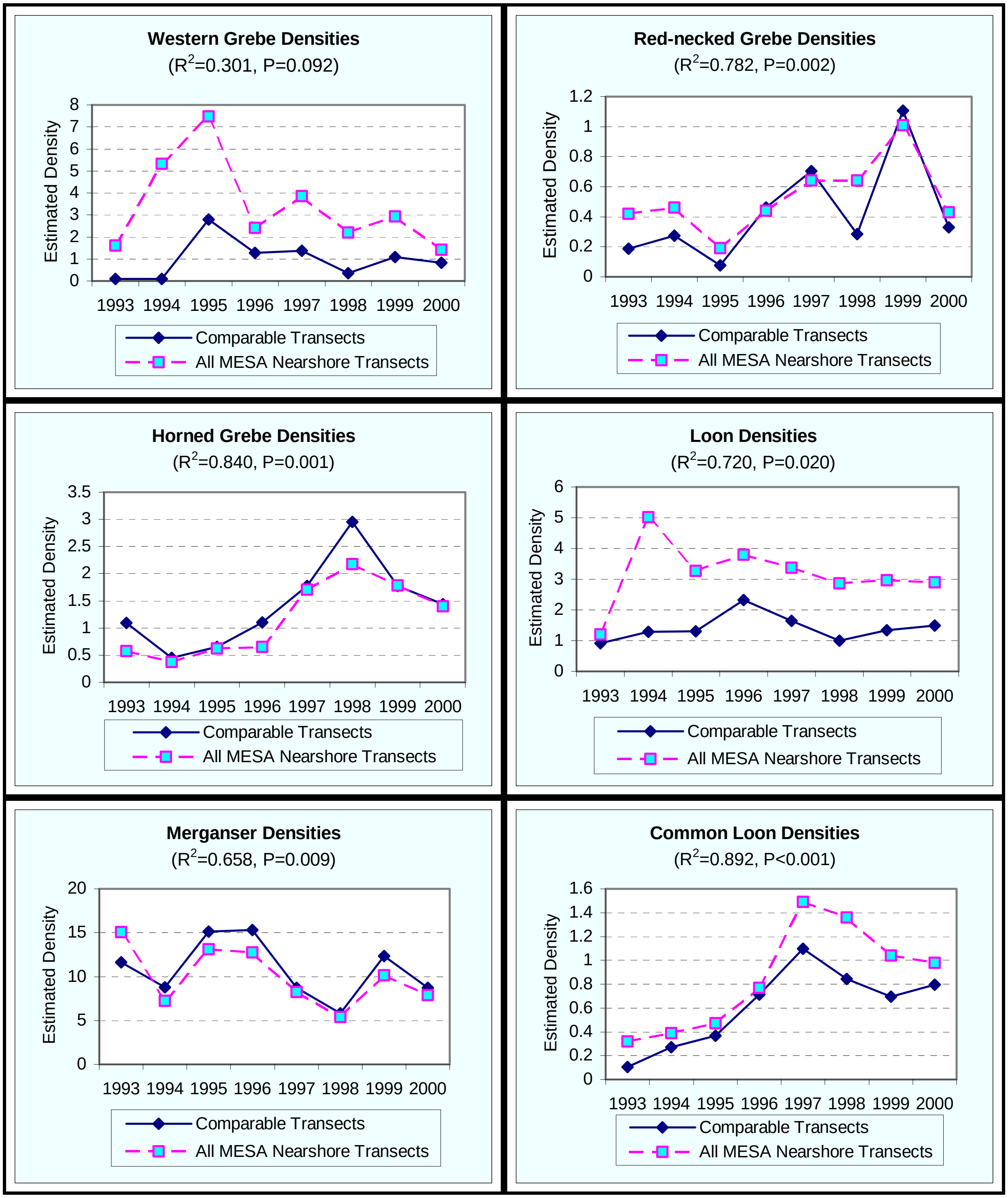


Figure 71. Density Indices of Grebe, Loon, and Merganser Species on Nearshore Transects Used for MESA/PSAMP Aerial Trends Compared With the Density Indices of Same Species Seen on All Nearshore Transects Conducted in MESA Area During PSAMP Aerial Surveys.

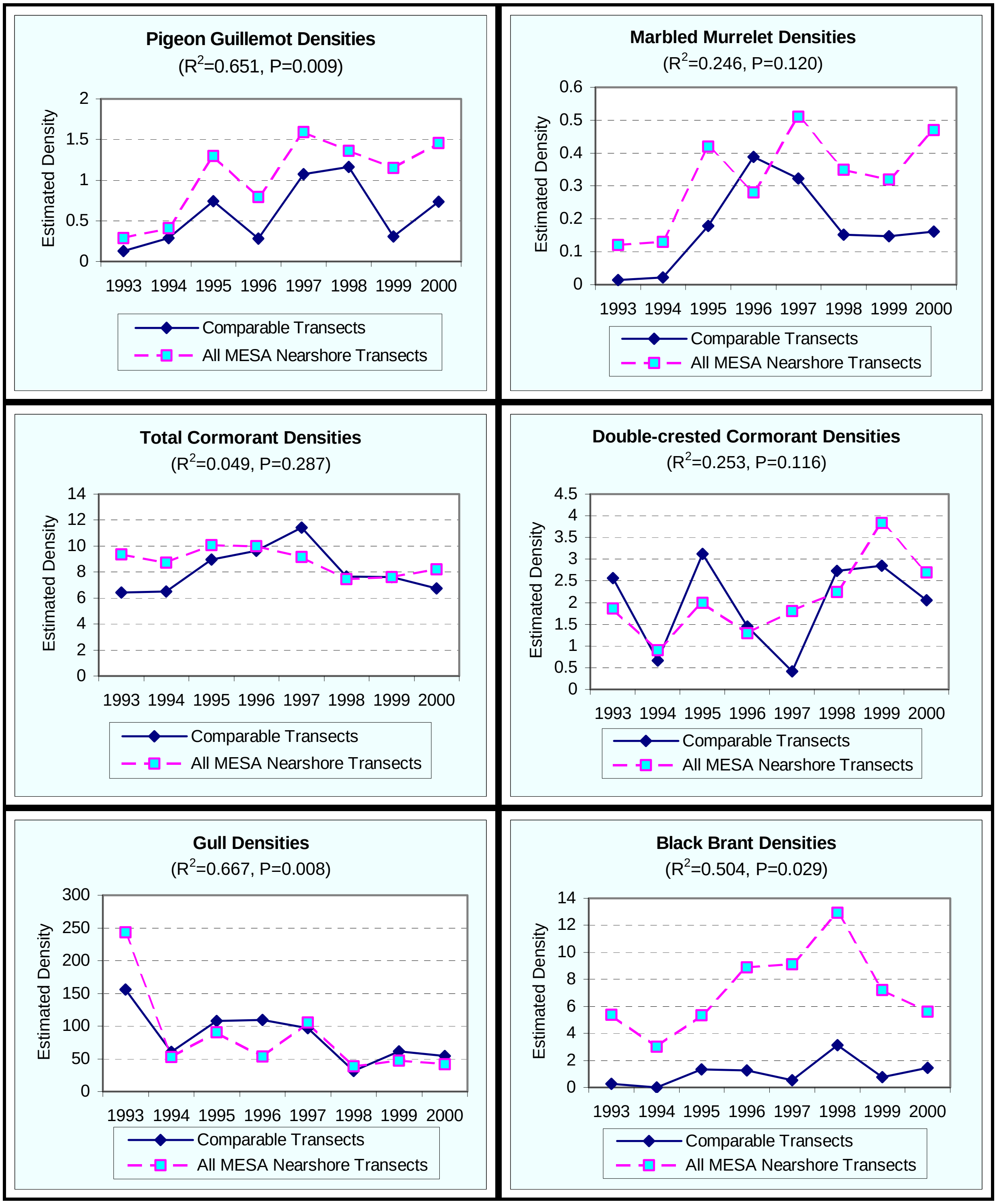


Figure 72. Density Indices of Alcid, Cormorant, Gull, and Other Species on Nearshore Transects Used for MESA/PSAMP Aerial Trends Compared With the Density Indices of Same Species Seen on All Nearshore Transects Conducted in MESA Area During PSAMP Aerial Surveys.

entire study area. The scope of geographic coverage utilized by PSAMP survey design has been very useful in evaluating theories about movement of bird populations. While replicates might reduce confidence limits, future efforts should review periodically what strategy or mix of overall coverage and replicates is best for future monitoring goals, given the limited funding available for this type of monitoring at this time.

3.2.3 Comparison of PSAMP and Two Other Aerial Survey Efforts During 1982-86 and 1992-93.

The historical comparison discussed above has focused on the 1978-79 MESA study area, which included the Strait of Juan de Fuca, San Juan Islands, and all inner marine waters north to the Canadian border. There are two other aerial survey efforts that occurred in southern or central Puget Sound during the 1982-92 period. The USFWS effort, compared here for the winter of 1992-93, used a much different aerial survey methodology, while the WDFW winter effort during 1982-86 used a methodology fairly similar to that used by PSAMP aerial surveys. PSAMP data are not compared extensively to these other data in this document, but selected examples were chosen to illustrate the options for comparison.

Comparison of PSAMP and USFWS Aerial Survey Data for Selected 1992-93 Winter Survey Areas.

Staff at the Nisqually National Wildlife Refuge conducted monthly aerial surveys of portions of South Puget Sound during the 1992-93 winter, as they had done in the previous years during the latter 1980's. In December 1992, the USFWS survey was flown (December 11-12) within a few days of the PSAMP aerial survey flown (December 15) in those same areas. The Nisqually Refuge staff, specifically Louise Vicencio and Mike McMinn, shared summaries of their monthly surveys with PSAMP and WDFW. Budgetary restraints did not allow them to do monthly surveys during the 1993-94 winter nor afterwards. The PSAMP and USFWS surveys of the same areas during the 1993-94 winter period differed in timing from each other by a month and hence are not so comparable. Budget restrictions led USFWS in following years to survey only the immediate area near their refuge lands and no other overlap of survey times and areas occurred thereafter.

The USFWS summaries used different geographical strata for summarizing their data than the MESA sub regions established by Speich and Wahl (1980, 1983) for southern and central Puget Sound, but data in at least four MESA sub regions were easily separated out for preliminary comparison of PSAMP and USFWS survey counts in 1992-93 (Table 11). The PSAMP surveys differed in methodology from that of USFWS in that minor shoreline indentations and bays were followed more closely by the PSAMP studies, thus creating longer transect lengths per any one sub-region than their type of survey created. On the other hand, the PSAMP counts listed are just those seen on transect while the USFWS counts were more of a total count in an area, which would include large concentrations noticed some distance from the plane. However, the overall pattern of survey coverage was generally similar with parallel flights along shorelines.

Table 11. Comparisons of Counts of Selected Winter Waterfowl and Grebe Species Observed During Winter Aerial Surveys 1992-93 Between the PSAMP[1] and USFWS[2] Efforts in Portions of Southern Puget Sound.

Species	Marine Bird Counts by MESA Sub Region											
	Henderson Inlet (MESA 1617)			Budd Inlet (MESA 1619)			Eld Inlet (MESA 1620)			Totten Inlet (MESA 1621)		
	USFWS		PSAMP	USFWS		PSAMP	USFWS		PSAMP	USFWS		PSAMP
	Dec.	Jan.	Dec.	Dec.	Jan.	Dec.	Dec.	Jan.	Dec.	Dec.	Jan.	Dec.
Mallard	25	445	32	2	90	2	251	270	155	122	200	182
Wigeon	22	50	325	22	0	30	0	103	3	0	0	145
Pintail	0	20	0	0	0	0	0	0	0	85	100	315
Scaups	0	0	16	10	10	8	110	55	144	430	20	185
Goldeneyes	130	27	298	453	185	854	134	126	164	60	75	70
Bufflehead	166	85	429	96	30	69	325	168	723	386	255	624
Scoters	196	200	982	873	225	1406	924	550	1009	622	325	382
Ruddy	0	0	0	560	965	329	725	395	802	180	40	138
Canvasback	0	0	0	87	40	30	30	40	0	65	25	64
Western Grebe	10	0	17	75	0	145	55	10	0	31	20	57

Notes:

1 PSAMP survey was done December 15, 1992 with track line following indentations of shoreline more closely than USFWS survey; hence most likely a longer transect length per any one sub region.

2 USFWS surveys were flown December 11-12, 1992 and January 6-7, 1993.

The inclusion of both December and January counts for the USFWS surveys (Table 11) illustrate the changes that might occur on a monthly basis within the same area and winter. The variation of numbers probably reflects the phenomenon of flocks moving from one area to another area not covered in this comparison, because the four areas listed in Table 11 are not contiguous with each other. This would be highly likely for those species concentrating in larger flocks such as western grebes. Other factors, such as surveys being done at different tidal levels and times, may also contribute to some of the variation recorded, especially for dabbling ducks.

The results of the comparison fall into three categories:

1) No consistent difference is noted between survey results for some species.
2) The difference is explainable for other species given the limits of the areas, sample size, and idiosyncrasies of a species (i.e. dabbling ducks not remaining on marine habitats).
3) The PSAMP surveys tended to count more scoters, goldeneyes, and buffleheads than the USFWS surveys.

It is unclear whether this latter difference relates to different observers, different methods, different numbers of birds present, or some combination thereof. Observers involved with the PSAMP survey did demonstrate some improvement with practice, but this involved lower numbers seen of some more cryptic species (e.g murrelets, harlequin ducks). At any rate, the comparison was reassuring at the time in that PSAMP surveys were not missing any important component of the avifauna present. However, because the USFWS counts could not be translated into densities, the data are not comparable because track lines or areas surveyed were actually different.

The comparison of PSAMP to USFWS data demonstrates the importance of comparable methodologies applied over a multiyear effort. All aerial surveys are likely to provide results that reflect relative indices rather than total counts. Only the counts obtained by the PSAMP transects were displayed in the table; however, the PSAMP transects only covered a proportion of the habitat found in an area. A population estimate could use these transect counts in combination with the total habitat area to arrive at a higher total population estimate, if the survey data were stratified appropriately. While these figures might be closer to an actual population estimate, they would likely not be comparable with past indices derived from different methodologies. It seems advisable to have an overlap of several years between any changes of methods so as to be able to evaluate what data differences are created by using different methods.

Limited Comparison of PSAMP and 1982-86 WDFW Aerial Survey Data For Southern Hood Canal (MESA Sub Region 1510).

Wahl and Speich (1983) initiated winter aerial censuses of marine birds in portions of southern and central Puget Sound and Hood Canal during the December 1982 to February 1983 period. WDFW personnel and Steve Speich then continued some of these winter surveys during the mid-1980's, while USFWS continued surveys in the south Sound utilizing the different methodology discussed earlier. Two historical databases were translated into digital format when the PSAMP marine bird component began in 1992: the 1978-79 MESA efforts (Wahl.dat) which we used in our earlier comparison, and a second digital database (known as Kraege.dat) that translated both the MESA and the 1982-86 density type data into a slightly different synthesis database. This latter database used the different species groups used for identifying marine birds on aerial surveys during the 1982-86 efforts. This database has not been analyzed much at this time, because it has less consistency, coverage, detail, or time period available for comparison. However, it does give us a glimpse into whether other portions of the inner marine waters of Washington State experienced trends similar to those seen in the MESA study area.

The aerial survey methodology used by the varied WDFW observers differed somewhat from PSAMP methodology in several ways:

1) Smaller Cessna airplanes without floats were used.
2) Bird identification extended only down to certain groups emphasizing waterfowl, with all other birds lumped into a few miscellaneous categories.
3) There was no consistent coverage of large areas over numerous years.
4) The width of survey transects and actual track lines varied somewhat, making it important to use density calculations for some degree of comparison.

Aerial survey data were recently compiled in response to public requests for the nearshore strata of one MESA sub region (1510S), which included all of lower Hood Canal from Lynch Cove near Belfair on the east end west to Union just east of the mouth of the Skokomish River in the Great Bend area. The bird concentrations right at the mouth of the Skokomish River were not included in this summary. Total bird densities were used to make comparisons with PSAMP data more valid. Winter aerial surveys utilizing a fairly similar aerial survey methodology were conducted here four times during 1982-86 and eight times during 1993-2000 (Table 12). Mean densities of all marine birds combined ranged from 1,291 to 2,329 / km^2 during 1982-86 while mean densities ranged from 175 to 469 / km^2 during 1993-2000. These results suggest that declines in marine bird numbers similar to those recorded for the MESA study areas have occurred in southern and central Puget Sound also.

3.3 Quality Assurance and Correction Factors of PSAMP Data

In the methods section of this report, we discussed the various types of errors and biases that enter into this type of survey and its entry into and manipulation by various computer databases and programs. This section will review our efforts to evaluate these and the efforts to either correct these or develop correction factors.

It is also known that different survey methodologies rarely measure total populations, but rather are partial counts of the total numbers of animals present. As a result, these survey results are usually characterized as indices. In addition, different species are observed in different proportions due to factors such as appearance (e.g. dark or light, small or large), behavior (e.g. dive or fly, wary or not), or type of survey methodology and platform (noise level and view angle). The PSAMP data are indices, but there will be continuing requests for total biomass and other population estimates, which should be adjusted, to account for these variables. Some of these correction factors are available in the literature for other regions with similar species. Ideally, most of these sources of error should be examined for each region and each species.

Table 12. Estimated Densities of All Marine Birds and Waterfowl Compared for Lower Hood Canal Near Shore Strata (MESA Sub Region 1510S), As Derived From Winter Aerial Survey Transects Conducted December-February of 1982-86 and 1992-2000.

Year, Month, Survey Team	Birds Counted on Transect	Area Surveyed on Transect (km2)	Mean Densities Observed
Dec.-Feb. 2000, PSAMP	1,464	6.873	213.01
Dec.-Feb. 1999, PSAMP	2,613	6.464	404.24
Dec.-Feb. 1998, PSAMP	1,275	7.289	174.92
Dec.-Feb. 1997, PSAMP	2,072	6.991	296.38
Dec.-Feb. 1996, PSAMP	3,033	6.553	464.24
Dec.-Feb. 1995, PSAMP	3,221	6.749	477.26
Dec.-Feb. 1994, PSAMP	2,871	6,555	437.99
Dec.-Feb. 1993, PSAMP	4,053	8.647	468.72
Jan. 1986, Kraege.dat	9,369	5.70	1,801.70
Jan. 1984, Kraege.dat	7,358	5.70	1,290.87
Feb. 1983, Kraege.dat	13,295	5.70	2,328.94
Dec. 1982, Kraege.dat	9,089	5.70	1,594.56

The following three limited exercises were conducted to examine what visual correction factors might be most appropriate for the PSAMP survey methodology utilized. Limited funding stopped this effort before it was finalized. Additional comparisons are needed for at least the winter period.

3.3.1 Comparison of Aerial and Boat Surveys

Summer Species of Concern

The first PSAMP effort to compare aerial and boat surveys occurred during the last week of July in 1993 immediately following the usual July aerial survey period. Windy weather conditions, equipment breakdown, training, and other work commitments permitted only two days of simultaneous surveys. During those two days, five nearshore transects extending 56.21 km in length, and 3 open water transects extending 30.10 km were run, averaging a mean length of 10.79 km per transect. MESA transects were used for the most part, with only two new open water transects created in order to concentrate on waters where less frequently occurring species (e.g. marbled murrelets) might be encountered. The airplane used a 100 m wide transect (50 m each side), while the boat observers covered a 200 m wide transect (100 m each side). The airplane observers used this width because it was similar to that used in the regular PSAMP aerials, and the computer programs that calculate density used this transect width in their calculations. The boat followed standard survey methodology for strip transects in use on the west coast at that time (Gould and Forsell 1989, Tasker et al. 1984, Conant et al. 1988). The wider transect for the boat survey is mandated because the boat is slower and the birds begin to move away from the boat as it approaches. For comparison, the boat survey data were divided by half because its transect area was twice that of the aerial surveys.

The goal was to essentially run the two types of surveys as nearly simultaneously as possible by starting both at the same time. Other similar studies in Alaska (Conant et al. 1988; Piatt et al. 1991) found that boats would drive birds from the survey route if they went first. In the Alaska survey targeting marbled murrelets (Piatt et al. 1991), they used transects no longer than 2 km in length. The MESA transects we used were much longer. This usually resulted in the passage of considerable time between the end of the aerial coverage of a particular transect and the end of the boat coverage of the same transect. This turned out to be a problem for surveys of species such as murres, auklets, and murrelets that followed certain moving tidal features (e.g. upwelling and rips), that would be associated with forage fish concentrations. If too much time passed before the boat arrived, the feeding flocks could move onto or away from transects before both surveys passed that area.

The results from the 1993 effort were highly variable and did not observe enough numbers even of easily identified species to make useful conclusions. These surveys did serve, however, as a pilot study, and thus helped formulate adjustments to methods and transects which were applied to more extensive comparisons conducted in 1994.

Four recommendations or options were suggested by the 1993 pilot study:

1) Shorten the transect lengths, perhaps as short as 2 km, and pick transects where shallow

water or rock hazards would not unduly slow down the boat surveys, so that both boat and aerial surveys complete the same transect within a shorter time period.

2) Attempt to run 3-7 replicates of each transect to compensate for anomalies.
3) Select transects that will increase the likelihood of encountering larger numbers of the key species of concern during summer surveys. These are primarily the four diving alcid species: common murre, rhinoceros auklet, pigeon guillemot, and marbled murrelet.
4) Widen the aerial survey transect width to a total of 200 m so as to minimize both counting and interpretation concerns. This could mean having the plane fly two track lines that are immediately adjacent to each other and parallel to the shoreline or having each observer double his width of observation. The first option might be difficult for the plane to do without overlapping certain areas. The second option compounds any error from observers missing small dark diving birds such as murrelets in the outer portion of their portion of the transect. Alternatively, the plane might fly the same transect twice, if disturbance is not critical.

The first three of these options were straightforward and were largely implemented in 1994. The fourth has several problems associated with it and in 1994 we chose to have the plane fly each transect twice to evaluate how this might affect observations.

The PSAMP survey team combined with different WDFW wildlife biologists during the September 12-26, 1994 period to conduct simultaneously by boat and fixed-wing aircraft one to five replicate surveys of 27 strip transects (Figure 73) for marine birds. These 27 transects ranged from 1.12 to 7.71 km in length individually, covered 106.21 km in total length. The air to boat ratios displayed in Table 13 are displayed as totals seen over the 75 runs of individual transects, which sampled 306.76 km in total length over six days, averaging 4.09 km in mean transect length conducted. At least 15 of the 27 transects were run three or more times on different days over that six day period, which resulted in sampling of 30.68 km^2 by airplane and 61.35 km^2 by boat.

Boat surveys were conducted from WDFW's 24-foot *R/V Harlequin* with one observer on each side of the vessel; observers searched for birds in a 90 degree arc from the transect line to abeam of the vessel; strip width was 200 m (100 m on each side of the vessel). Fixed-wing aircraft surveys were conducted in a De Havilland Beaver floatplane flying at an approximate height of 55 meters and speed of 160 km per hour; one observer on each side of the aircraft searched a strip width of 50 m for a total strip width of 100 m. Observers looked down from the aircraft at an angle between 33 and 58 degrees from a line parallel to the surface, thereby each scanning a strip 50 m in width; the area surveyed by both aircraft observers constituted a 100 m subset of the 200 m wide area surveyed by the boat observers. Observers recorded their observations into audiotapes that were later transcribed onto data sheet and entered in databases. All observers had extensive training and years of experience as aerial observers. The boat and aircraft began each transect at the same time and location. Because the aircraft finished each transect long before the boat completed the transect, the aircraft circled around and conducted a second run of the transect, beginning at the same location as its first run, and typically completed the second run at about the same time as the boat. All marine bird species were noted, but the diving marine birds were the key focus, specifically the four common diving alcid species.

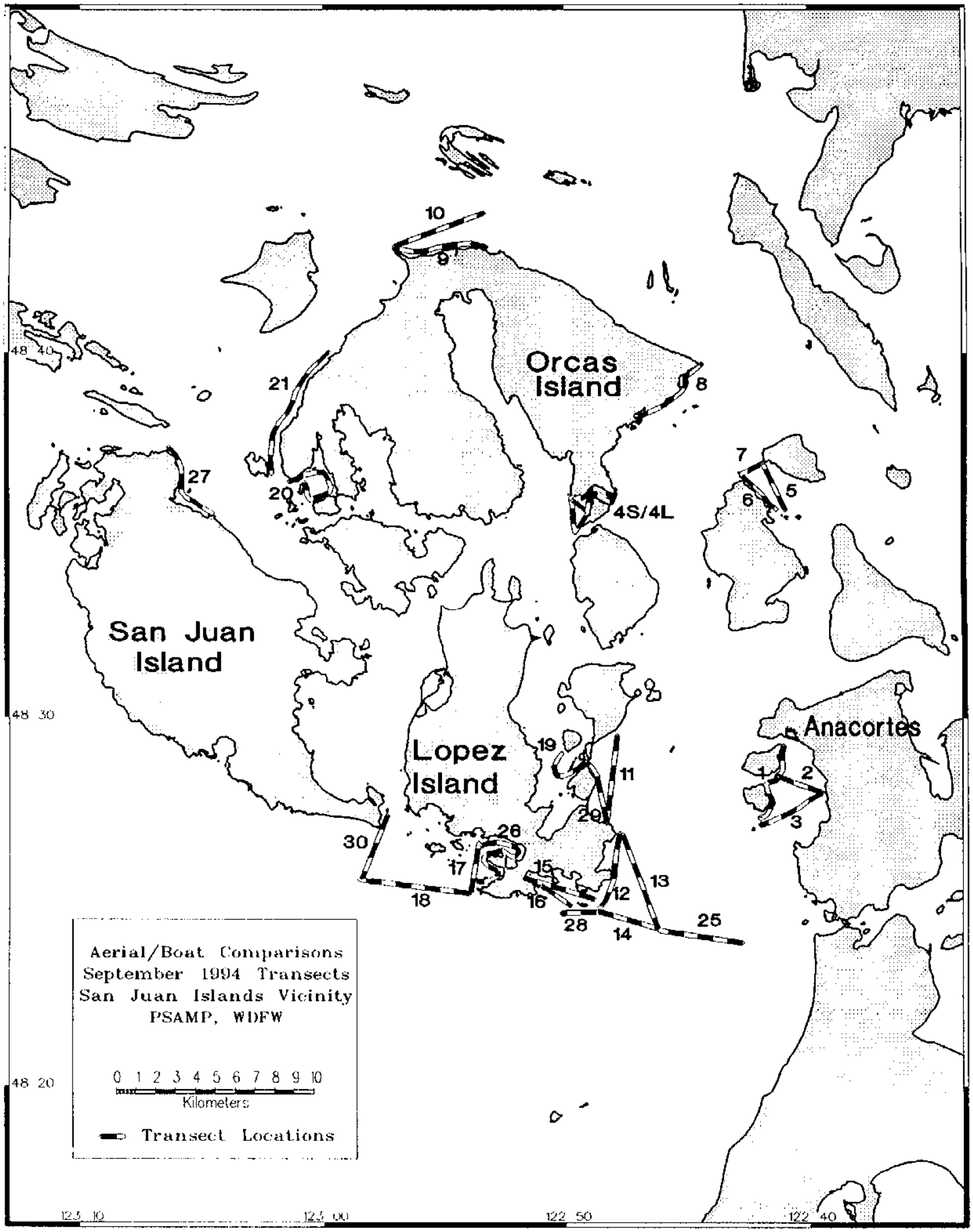


Figure 73. Map of San Juan Island vicinity, Washington, indicating the locations of transects used for surveying marine birds simultaneously from boats and aircraft in 1994.

Table 13. Comparison of Aerial and Boat Survey Counts of Selected Marine Bird Species, September 1994, San Juan Islands Area.

Species	Ratios (Air: Boat) of Species Counted (Derived from All Transects Combined)	
	Transect Type and Width	
	100 m wide Aerial [Run 1]: Boat/2 (# birds counted each)	200 m wide[1] Aerial [Run 1 + 2] : Boat (# birds counted each)
Pigeon Guillemot	0.335 (139 / 415)	0.304 (252 / 830)
Marbled Murrelet	0.396 (452 / 1140.5)	0.365 (833 / 2281)
Common Murre	0.468 (673 / 1438)	0.469 (1349 / 2876)
Rhinoceros Auklet	0.394 (55 / 139.5)	0.344 (96 / 279)
Total Alcids (incl. unknown alcid spp)	0.433 (1358 / 3138)	0.414 (2599 / 6276)
Total Scoters	0.463 (157 / 339)	0.417 (283 / 678)
Total Grebes	0.159[2] (9 / 56.5)	0.115[2] (13 / 113)
Total Loons (mostly Common Loon)	0.774 (12 / 15.5)	0.581 (18 / 31)
Total Gulls	0.843 (1761 / 2090)	0.783 (3273 / 4180)
Total Cormorants	0.691[2] (321 / 464.5)	0.563[2] (523 / 929)

Notes:

[1] This width simulated for aerial surveys by combining Run 1 and 2 of the aerial census per transect.

[2] These ratios possibly questionable either to low numbers seen or inclusion of roosting flocks.

Research scientists at WDFW, USFWS, and USFS were interested in these essentially simultaneous transects, especially in relationship to the marbled murrelet data derived from these comparisons. Data were shared and a manuscript was prepared (Thompson et al., in review), which evaluates how murrelet survey data collected from fixed-wing aircraft can be combined with data collected from boats. It also addresses if a visibility correction factor (VCF) for data collected from aircraft can be sufficiently consistent to serve as a usable correction for the reduced visibility of murrelets from aircraft relative to boats. In the case of murrelets, three different methods to estimate ratios (VCF) and measures of their variance were examined: the unweighted mean, mean weighted by transect length, and the overall ratio known as the combined ratio estimator (Cochran 1977:165 as described in Prenzlow and Lovvorn 1996). The VCF values ranged from 0.396 to 0.473, with the smallest coefficient of variation (CV) of 6.0% associated with the Cochran method. The three methods for estimating VCF's yielded similar results (less than 20 % difference), but the CV's of the weighted and unweighted VCF's (95.9% and 93.0%) were more than tenfold the CV of the combined ratio estimator. Smith (1995) argues that VCF's can be used if they meet at least one of the following two criteria: 1) the CV of the VCF is $\leq$ 20%, or 2) the sum of the air counts and the sum of the ground counts each total at least 40. The first criterion is violated by the weighted and unweighted means, but the second criterion is satisfied by all methods for estimating VCF's. Statisticians and other reviewers are still evaluating the manuscript and merits of each method of analysis at this time.

Nevertheless, the preliminary findings suggest that large white or black species (e.g. cormorants, gulls, common loon) are not underestimated much by summer aerial surveys run under good viewing conditions (air to boat VCF's range from 0.691 to 0.843) and that diving species such as alcids have air to boat survey ratios that range from 0.335 to 0.468, depending upon the species. While the sample size is not large, note that scoters had a VCF of 0.463. This will be useful to remember during our later discussion of winter VCF values that should be used for winter diving duck species.

Winter Species of Concern

Sea and Bay Ducks in Lower Hood Canal February-March 1994-95

Simultaneous comparisons of aerial and boat surveys of winter waterfowl conducted during February and March of 1982-84 in northern portion of southeast Alaska (Conant et al. 1988) found about half as many ducks recorded from the air as from the ground or water. The waterfowl species they compared are essentially the major marine waterfowl species that winter in greater Puget Sound. The results of the Alaskan comparative air and boat surveys are similar to those found in comparisons conducted along marine shorelines in New Hampshire and Massachusetts (Stott and Olson 1972), and British Columbia (Savard 1982). The 1982-84 Alaska study came up with these VCF for the following species: mallards, 0.48; all dabbling ducks combined, 0.47; scoters, 0.57; goldeneyes 0.61; mergansers, 0.54; harlequin ducks, 0.33; bufflehead, 0.28; scaup, 0.33; all waterfowl combined, 0.50.

Because budgets were limited and a large pool of experienced observers was not available for winter work, the PSAMP marine bird component tried an experiment and began a limited series of sequential rather than simultaneous boat and air comparisons for winter species during late February and early March 1994 in the lower end of Hood Canal. Winter weather conditions deteriorated in the study area in February immediately after we completed 16 days of regular overall surveys in December and January. Finally, starting on 24 February and ending on March 8, four surveys were conducted comparing air and boat surveys in the southern portion of Hood Canal. Three of the four days had constant good weather throughout both types of surveys, whereas winds came up the other day, raising doubts about the comparability of that day's data. Similarly, following the next winter aerial survey period, four more survey days of sequential surveys were conducted February 21-24, 1995 over the same transect route. The primary species emphasis was on diving duck and certain grebe species that are likely to be under counted by aerial surveys.

Unlike the summer comparisons where bird movement was a critical factor, the winter sea duck species in this study area were confined by the end of a long inlet ringed by hills and their movements did not appear to carry them out of our study area. Many of the diving duck species tended to be distributed nearshore in a linear fashion except in the Lynch Cove area. The survey transects focused on the nearshore (< 20 m) strata. Hence, one type of survey (i.e. boat) would start at Union just east of the Great Bend area and follow the southern shoreline east to Lynch Cove and back along the northern shoreline until Musqueti Point was reached (Figure 74). Then the other survey type (aerials) would be conducted following the same track line. For the same reasons discussed under the summer/fall simultaneous comparisons, the aerial survey transect looked at 50 m on each side for a total width of 100 m while the boat survey looked at 100 m on each side for a total of 200 m. The aerial survey portion would normally take 23 to 24 minutes to cover the 51.24 km of shoreline sampled while the boat survey would take just a little over two hours to cover the same track line.

There were two additional complications to this approach. The eastern third of this route traveled through Lynch Cove and the shallow depths there were not just confined to shore but extended all the way across the inlet (Figure 74). There were often many birds in the Lynch Cove area, and it was possible that aerial surveys on one side might double count the same birds on the other side when the plane returned on the opposite side, because flocks would move as the plane surveyed. There was also a tendency for birds to flee before the approaching boat, possibly resulting in the boat missing some birds. The boat survey utilized a slight modification in its survey techniques, in that the boat would stop just before reaching the larger bird concentrations, the observers would count the birds ahead in the transect, and then the boat would veer out into deeper water and then back into shore beyond the bird concentrations to minimize driving them ahead of the boat down the shoreline.

Results are summarized for the major species or species groups seen (Table 14). The seven days of surveys appear to capture a highly variable ratio of air to boat observations on different days (Table 14). These comparisons recorded transect ratios ranging from 0.524 to 1.352 for most of the more common diving duck species and 0.108 to 0.891 for horned grebes. The numbers of other species observed (such as western grebes and loons) were too few in this study area to provide much information on correction factors for these species.

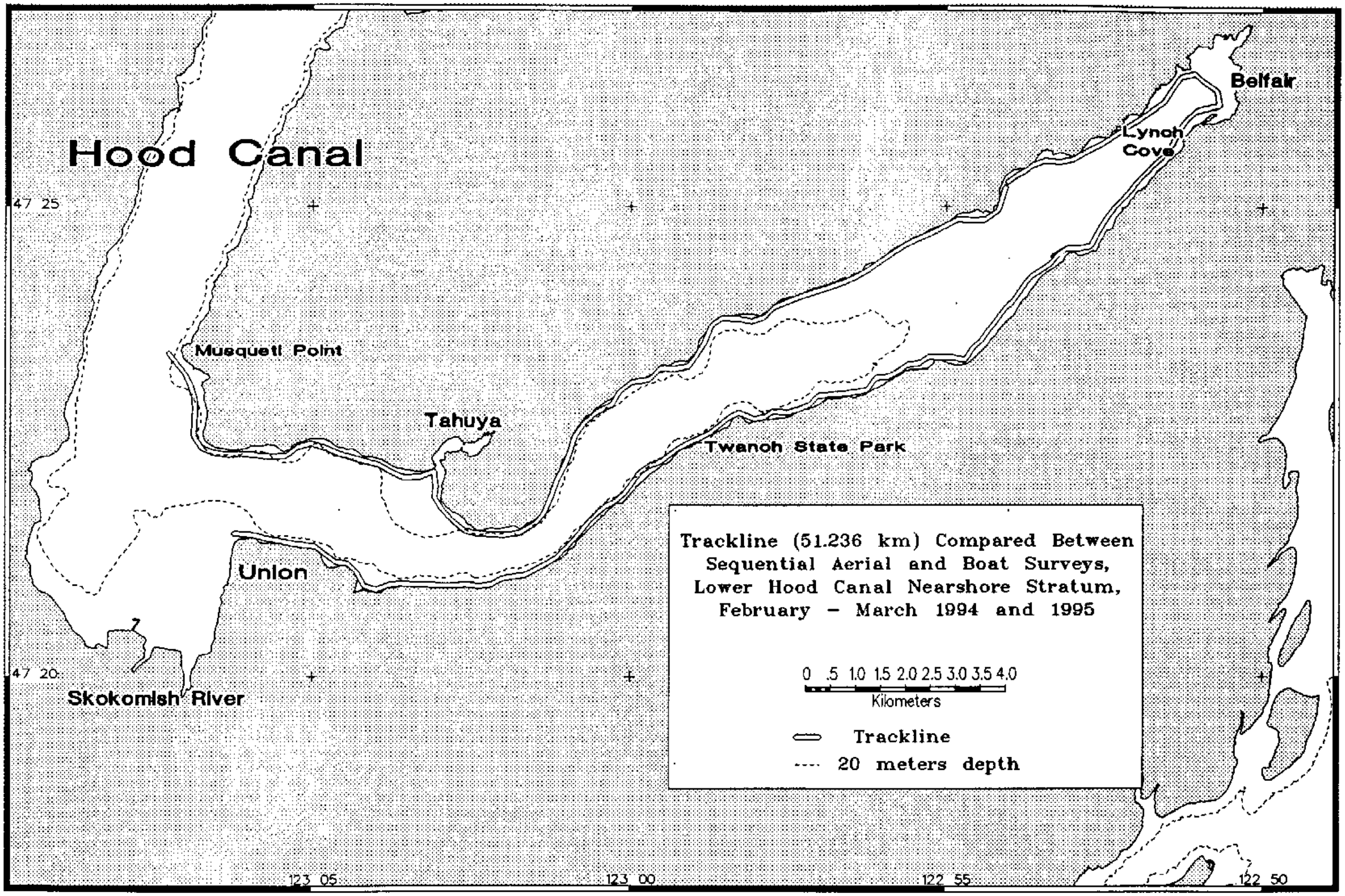


Figure 74. Survey track lines used for sequential comparisons in lower Hood Canal, February-March 1994 and 1995.

Table 14. Comparison of Sequential Aerial and Boat Survey Counts of Selected Winter Marine Bird Species, February-March 1994 and 1995, Southern Hood Canal.

	Air to Boat Ratios of Species Seen on Transect (51.24 km) Conducted By Each Method Each Day (Aerial counts : Boat counts/2)							
Species	Feb. 24, 1994	March 7, 1994	March 8, 1994	Feb. 21, 1995	Feb. 22, 1995	Feb. 23, 1995	Feb. 24, 1995	Transect (n=7) Means (S.E.)
Bufflehead	0.760 (135:177.5)	0.830 (286:344.5)	0.969 (285:294)	1.390 (238:171)	1.167 (195:167)	1.200 (96:80)	0.981 (80:81.5)	1.042 (0.084)
Total Scoters	0.761 (648:850.5)	1.336 (773:578.5)	1.172 (966:824)	1.129 (745:659.5)	0.940 (675:718)	1.180 (631:534.5)	1.260 (517:410)	1.111 (0.075)
Total Goldeneyes	0.524 (260:496)	0.989 (502:507.5)	1.174 (536:456.5)	1.352 (985:728.5)	0.950 (697:733.5)	1.255 (870:693)	0.736 (474:644)	0.997 (0.111)
Total Scaup	0.869 (50:57.5)	0.964 (151:156.5)	1.888 (153:81)	1.404 (217:154.5)	1.095 (143:130.5)	1.500 (135:90)	1.212 (120:99)	1.276 (0.133)
Horned Grebes	0.108 (5:46)	0.246 (19:77)	0.407 (32:78.5)	0.891 (78:87.5)	0.402 (42:104.5)	0.887 (67:75.5)	0.336 (18:53.5)	0.468 (0.115)

The results in the 1994-95 Hood Canal sequential comparisons are surprising, in that they appear considerably higher than the ratios seen for winter sea duck species in southeast Alaska (Conant et al. 1988) and elsewhere. The Alaskan surveys utilized a DeHavilland turbine Beaver on floats and flew their surveys at 100 feet above the water while the PSAMP surveys used a De Havilland piston Beaver on floats and flew their surveys at 200 feet above the water surface, the minimum altitude allowed by federal regulation in our study area in Washington State. The De Havilland turbine Beaver is much quieter than the piston version. Both surveys used very experienced observers, although the PSAMP program in Washington was undergoing a transition where newer observers were gradually being integrated into the surveys about this time. However, neither newer nor more experienced PSAMP observers demonstrated any more consistent trend in ratios observed than the other group did.

The results are counterintuitive and suspect for several reasons: 1) A third project biologist sits up front with the pilot and monitors the computer/mapping program. Both this person and the pilot frequently notice a number of sea ducks and other marine birds ahead which dive as the plane approaches, suggesting that some percentage of the birds present must be missed by the aerial surveys because the two main observers view from the bubble windows on each side of the plane and do not see as far forward as the two people up front. 2) None of the simultaneous aerial and boat comparisons noted in the literature found such high ratios. 3) The PSAMP simultaneous comparisons done September 1994 did observe some scoters on transects and recorded an aerial/boat ratio of 0.463.

The highly variable ratio seen on different days suggests that some changes are necessary to make a sequential methodology work better, if it were deemed worthwhile to pursue this type of survey method. It might be best to avoid shallow areas like Lynch Cove where large numbers and bird movement may compromise results. Other factors such as more replicates, different transect size, and survey during a less extended period of time might be helpful. For the present, until further data are gathered or replication occurs, we still recommend using the visibility correction factors of 0.5 for diving ducks documented by the more extensive and simultaneous comparisons cited. We do not recommend sequential comparisons at this time for determination of VCF, but would urge other approaches such as simultaneous flights or the third method PSAMP staff used in Port Orchard in February-March 1997.

Grebes and Loons in Port Orchard February-March 1997

Additional winter boat surveys were conducted during February and March 1997 to address at least three objectives:

1) Reduce confidence limits around indices of certain species that are highly clumped in distribution such as the western grebe.
2) Compare how aerial and boat surveys each characterize species numbers and distribution in the same area.
3) Evaluate how differences in sample unit size (1 or 2 km^2) might affect indices and confidence limits.

The highly clumped diurnal distribution of resting flocks of western grebes is problematic for our present aerial survey scheme because this type of distribution mandates more coverage and more replicates than our present design provides, if tighter confidence limits are to be obtained. These 1997 boat surveys resulted in a series of random replicates of boat surveys and the indices that they generated offered a comparison with the indices that the 1997 winter aerial survey had generated for that same area---thus giving us another possible VCF for some of these species. Most of the results from the 1997 winter boat surveys will be contained in a future, more detailed analysis and report, but some brief description of methods and certain results have been extracted here because of their pertinence to the discussion of appropriate visibility correction factors to use in relation to PSAMP aerial survey data.

A survey area, the greater Port Orchard marine area (Figure 75), was selected that would contain sizable concentrations of western grebes and that could be completely surveyed by boat in one or two days. The focus was not on shoreline, but on the more protected open waters and passes. The key species addressed were loons, grebes, and pigeon guillemots. The study area was stratified into 9 blocks, comprising a total area of 108.84 km^2. A random sampling scheme and start points were devised within each survey block to allow for nearly all areas within a survey block to have an equal chance of being surveyed. A computer program then randomly selected the start position and direction of travel for each given block for each day. The goal was to complete 10 replicates for each block during the February-early March survey period, before migration might begin to move birds out of the study area. The following 12 survey days were needed to get 5-7 replicates (Figure 76), with weather delaying some surveys until mid March: February 18-21, 24-25, 27-28 and March 11-14. This strategy still worked for the grebes and pigeon guillemot, but the different loon species appeared to be moving around or migrating, with different concentrations than those seen during the earlier aerial surveys. The replicates completed covered a total of 680.92 km of track lines, examining a survey area of 136 km^2.

The 24-foot Almar vessel, WDFW's *R/V Harlequin*, which is equipped with raised observer platforms on the aft deck, was used for surveys. Speed of the boat during survey was maintained at approximately 10 knots. The survey crew was comprised of four people: boat operator, computer operator/navigator, and two observers; one looking to starboard and the other to port with each focusing on a strip that extended out to 100 meters from their respective side of the vessel. Surveys were terminated if wind exceeded Beaufort 3. Data logging software (DLOG) was used to log survey track lines, depth, distance from shore, and sightings data, the latter reported to the computer operator through headphones from the observers. These sightings also included wind level, observer glare, and location of sightings on or off of the survey track line. If large flocks were encountered, the boat would either slow down, or stop, to get accurate flock size estimates. The boat crew each determined estimates making one or more counts of the flock size, then comparing counts and agreeing on a number most likely representing the actual flock size. Efforts were also made to get total flock counts of western grebes for each block, for those flocks that were not close or visible to the survey track line. From past aerial surveys it was known where the large flocks usually rested, and if transect lines did not pass those flocks, on a given survey, we would break from transect to get an "off" transect count of those flocks.

These 1997 boat surveys captured more bird sightings per these individual areas than the 1997 aerial surveys did, confirming our suspicions that air to boat ratios should usually be less than 1. Besides having an effect upon confidence limits and estimates, the survey data had many

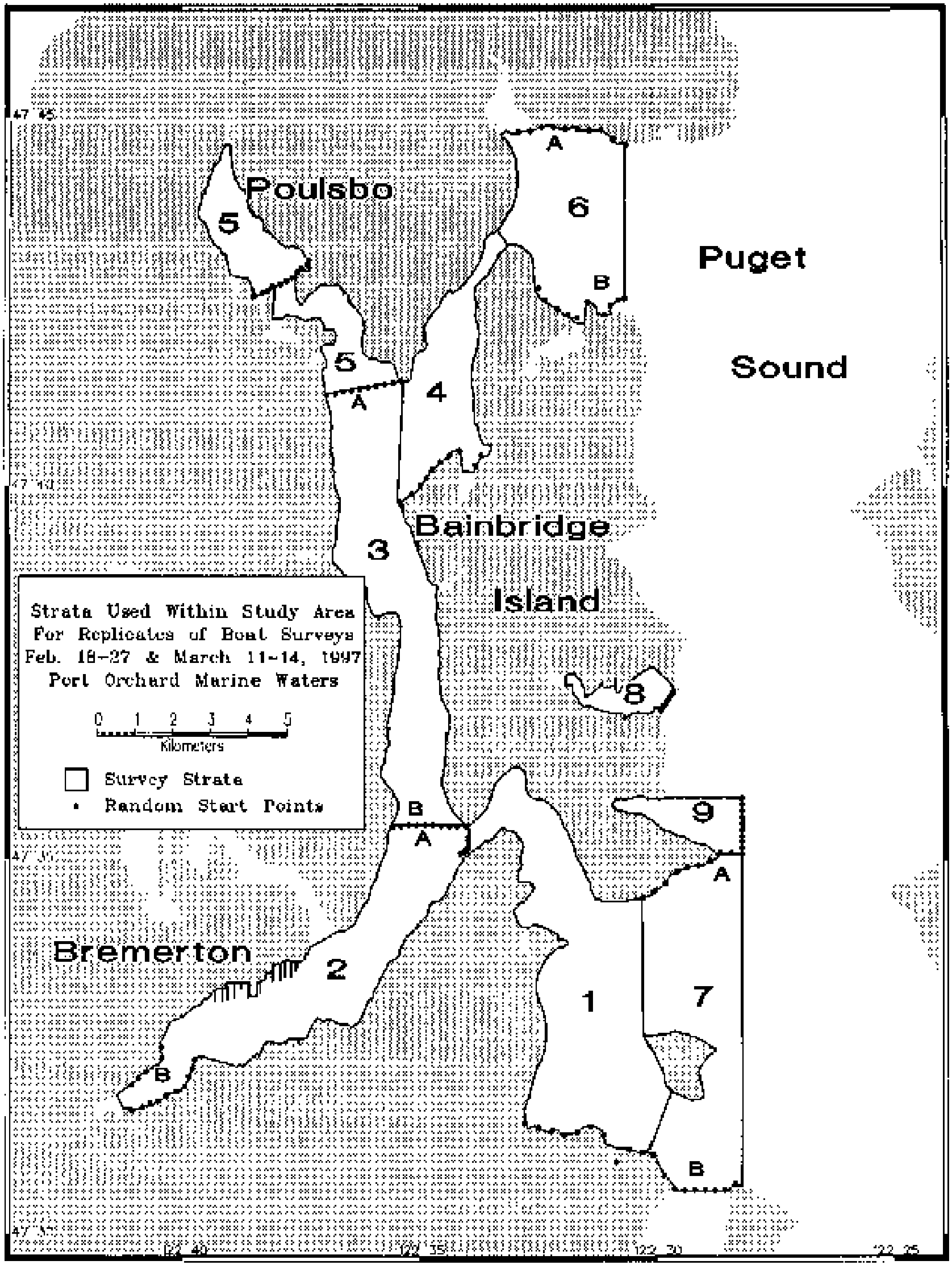


Figure 75. The study area and blocks used for replicate boat surveys of grebes and loons, February - March 1997 in greater Port Orchard marine waters.

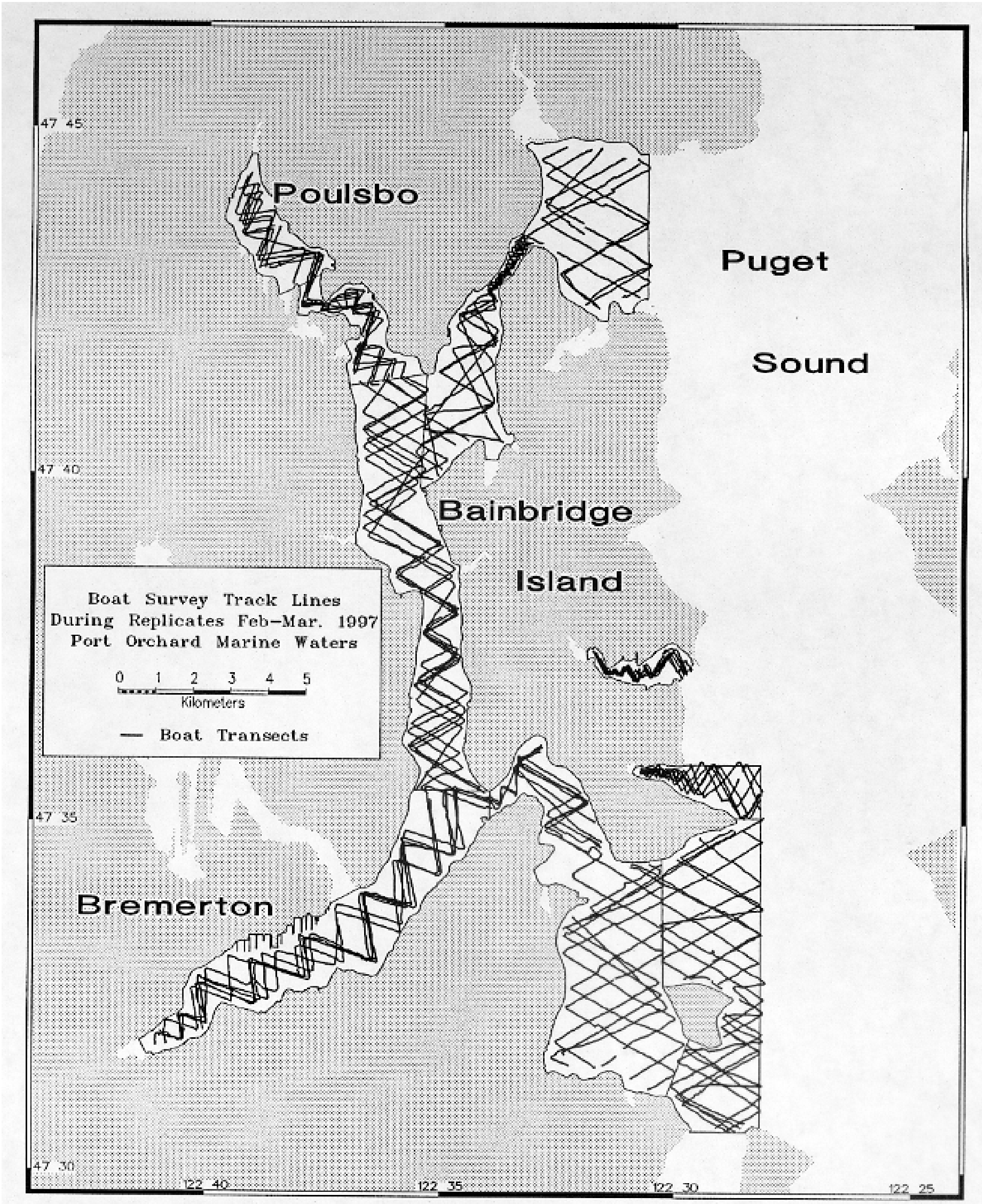


Figure 76. Track lines covered by random surveys during replicates of boat surveys focusing on loons and grebes, February – March 1997 in greater Port Orchard marine waters.

other advantages such as mapping species distribution by more detailed depth strata and geographic or hydrographic features. The distribution of western grebe observations (Figure 77) was interesting in that it suggested that aerial surveys combined over several years had captured essentially the same pattern. The distribution of pigeon guillemot (Figure 78) was very illustrative of how this species favors passes, banks, and certain hydrographic features. However, as mentioned earlier, only a few selected results will be listed and discussed at this time (Table 15 and 16), with three topics being the key focus of these limited results and discussion:

1) Values for VCF's were generated for three grebe species and the wintering pigeon guillemot, but movement into or out of the study by loon species between the aerial surveys and the boat surveys prevented the development of similar comparisons for loons (Table 15). VCF values were calculated for the following species: western grebe, 0.468; red-necked grebe, 0.167; horned grebe, 0.157; and pigeon guillemot, 0.345. Even though the pigeon guillemots were in a different winter plumage, the value for winter VCF (0.345) was quite similar to the summer VCF ratio (0.335) calculated from the simultaneous comparisons run in September 1994.
2) Confidence limits were improved for a number of species, especially that of grebes, for which the limits declined from 49.16% associated with aerial surveys (ratio of 95% C.L. to population estimate) to 34.90% for boat surveys, using the 1-km^2 sample unit size that has been used for aerial survey data analysis. Improvements in confidence occurred most noticeably with species exhibiting a highly clumped distribution. Confidence limits of horned grebes, for instance, did not differ much from 17.29% to 17.49%, using the same sample unit size and pooling of all blocks. Actual estimates of any of the species tended to be cumulatively higher because boat surveys recorded actual larger numbers of each species to insert into calculations.
3) The use of the smaller sample unit size of 1 km^2 usually resulted in tighter confidence limits for most species (Table 16), suggesting that our data analysis software in use now is satisfactory, because all the indices used for comparison in this report are now based on the 1-km^2 size of sample unit. Confidence limits were just a little better for those species concentrated in large flocks when using the 2-km^2-sample unit size, but the improvement was slight and probably does not justify treating a few species differently in analysis at this time.

3.3.2 Examination of Error Levels Associated with Survey Treatment and Analysis Done by Contracted Computer Programs

Six different categories of errors were described earlier that enter into the databases created by the PSAMP surveys. Some of these errors can be reduced by different proofing methods as described, but other errors are or were by-products of limitations of digitization accuracy, selective availability in the past of GPS signals by the Department of Defense creating inaccuracies, computer software decisions at junctures of habitat types, and survey design limitations for certain species. It became important to know what percentage of error was involved to evaluate what might need to or can be done to keep the error levels within acceptable limits.

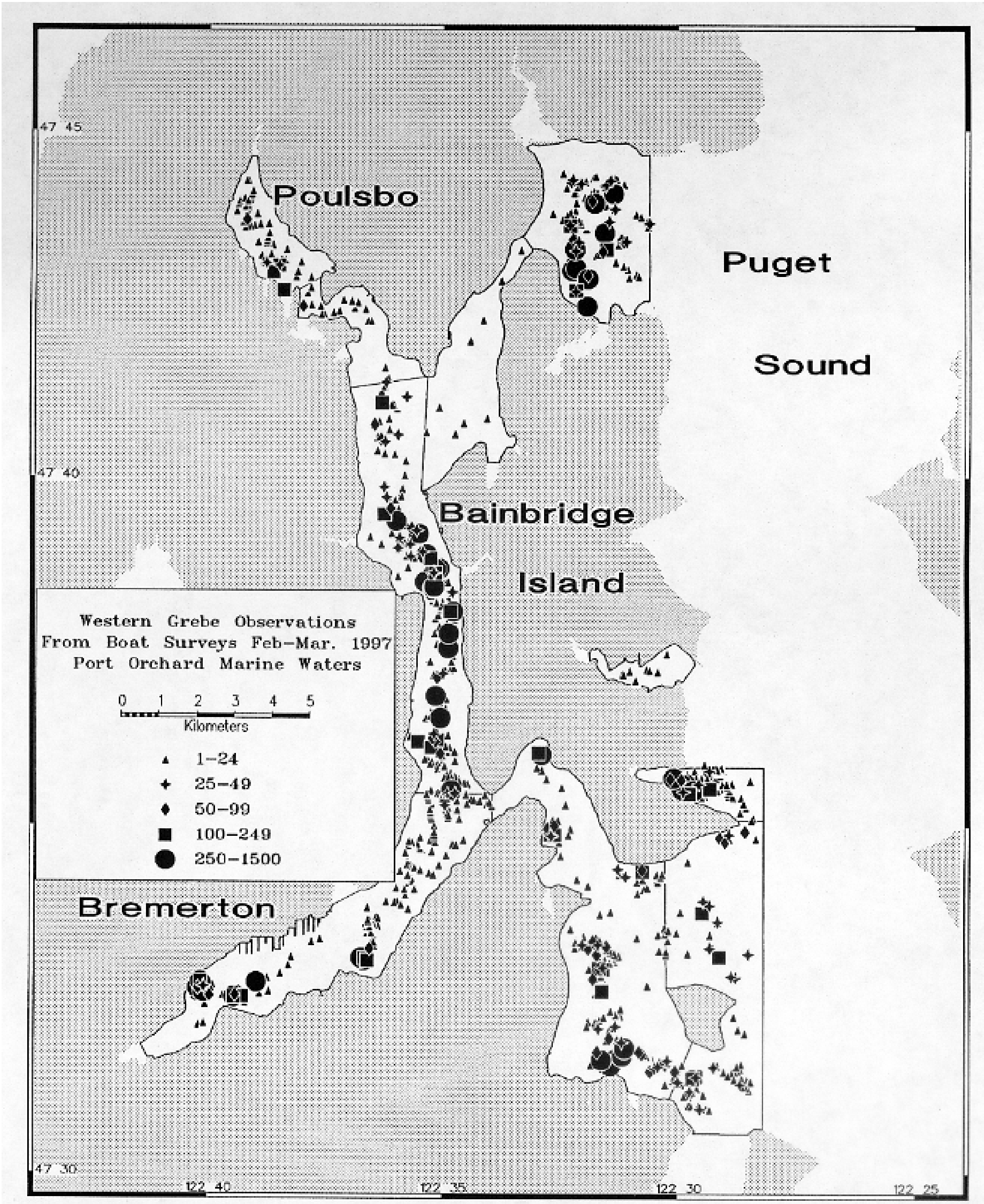


Figure 77. The distribution of western grebe observations recorded by replicates of boat surveys in central Puget Sound, February - March 1997.

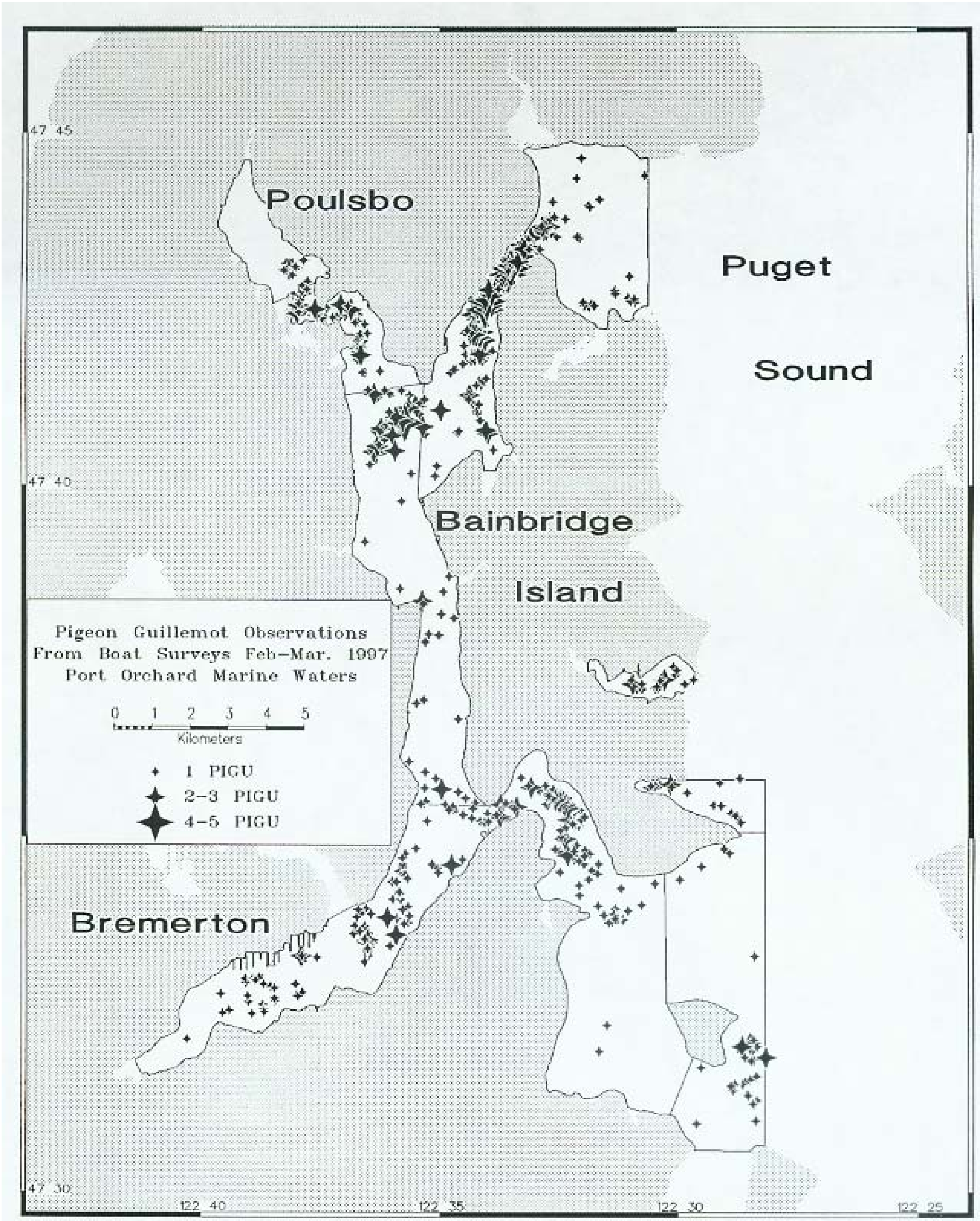


Figure 78. Distribution of pigeon guillemot observations recorded by replicates of boat surveys in central Puget Sound, February - March 1997.

Table 15. Visibility Correction Factors Suggested by Comparisons of Population Indices of Selected Marine Bird Species Derived From Either Boat or Aerial Surveys Within the Central Puget Sound Study Area During 1996-97 Winter Period[1].

SPECIES	POPULATION INDICES		PLATFORM RATIOS
	AERIAL	BOAT	AERIAL:BOAT
Western Grebe	6,760.0	14,437.1	0.468
Horned Grebe	257.9	1,642.1	0.157
Red-necked Grebe	184.1	1,104.8	0.167
Common Loon[2]	172.7	109.8	1.573[2]
Red-throated Loon[2]	127.4	82.1	1.551[2]
Pacific Loon[2]	136.1	794.5	0.171[2]
All Loon Species[2]	467.7	986.4	0.494[2]
Pigeon Guillemot	215.5	625.5	0.345

Notes:

[1] Boat surveys were conducted during February and early March 1997 while the aerials were conducted during December 1996 and January 1997.

[2] The ratios of loons are listed, but are not accurate for two reasons: migration out (red-throated loon) or into (pacific loon) the area between times of boat and aerial surveys. Loons also demonstrated a fairly strong behavioral avoidance of the boat survey, which differed from the behavior exhibited by the grebes and guillemot.

Table 16. Comparison of Population Indices Derived by Sampling Unit Size (1 km^2 or 2 km^2) and by Stratification (pooled or stratified by block) of Survey Data Collected February-March 1997, Greater Port Orchard Marine Waters.

Species	WEGR	HOGR	RNGR	PIGU	RTLO	PALO	COLO	UNLO	LOON
1 KM^2 STRATIFIED BY BLOCK									
Pop. Index	14,241	1,631	1,111	695	81	739	106	12	937
95% C.L.	4,548	249	152	142	24	264	25	7	264
C.L./Pop.	31.9%	15.3%	13.6%	20.4%	28.8%	35.7%	23.4%	61.5%	28.1%
2 KM^2 STRATIFIED BY BLOCK									
Pop. Index	14,315	1,659	1,154	710	85	806	115	13	1,018
95% C.L.	4,357	553	232	200	29	269	42	6	304
C.L./Pop.	30.4%	33.1%	20.1%	28.1%	34.3%	33.3%	36.9%	46.0%	29.9%
1 KM^2 ALL BLOCKS POOLED									
Pop. Index	13,928	1,888	1,176	721	91	802	113	11	1,016
95% C.L.	4,861	330	174	189	30	290	31	7	304
C.L./Pop.	34.9%	17.5%	14.8%	26.2%	33.0%	36.2%	27.1%	62.6%	29.9%
2 KM^2 ALL BLOCKS POOLED									
Pop. Index	14,738	2,094	1,232	659	101	819	113	13	1,045
95% C.L.	4,719	434	169	179	38	342	42	7	368
C.L./Pop.	32.0%	20.7%	13.7%	27.2%	37.7%	41.8%	37.2%	55.6%	35.2%

Note: Acronyms representing each specs:
WEGR = western grebe, HOGR = horned grebe, RNGR = red-necked grebe, PIGU = pigeon guillemot, RTLO = red-throated loon; PALO = pacific loon; COLO = common loon; UNLO = unidentified loon; and LOON = all loon categories combined.

Certain major modifications might have to be considered, provided that money and time were available, if the level of errors appeared too high. The survey method appears to produce useful products judging from the products produced and inquiries for maps and summaries. The following are some of the options that could be considered:

1) A higher degree of accuracy could be digitized into base maps and data files used by computer software for summary and analysis.
2) Computer software for analysis could be changed or rewritten to compensate for problem areas.
3) Either a base station or real time differential corrections could be utilized to make GPS locations even more accurate provided new differential GPS equipment were purchased that would allow this process. Now that the Department of Defense has deactivated their creation of errors in GPS signals, this is only a problem that pertains to our earlier years of data.
4) Survey strata could be restratified to compensate for certain species distributions not covered appropriately by the present survey design.

In recent years PSAMP staff have made corrections in the first two categories, especially after conducting the review of data in the 1993 survey databases described below. We are now planning work on the fourth category of re-stratification of survey data once the new detailed bathymetry is entered into CAMRIS polygons. The following description summarizes some of the process by which we came to realize that our software analysis programs needed correction and modification.

Three marine bird species were specifically examined in the databases created by the 1993 summer PSAMP aerial survey to determine what range of error was involved: marbled murrelet, common murre, and harlequin duck. These types of examination require a rather time-consuming task of comparing species totals in two types of databases: the interpolated database containing all observations and the database created by SYNPOL software to translate the on-transect counts into MESA areas so that PSMAP and PSPOP programs might analyze the data. The next step, equally time consuming, involved locating the differences uniquely, which then allowed us to look back into the original raw counts or transcriptions and evaluate what kind of mistake had occurred. This latter option was done mostly on the murrelet data and to a lesser degree on the murre data.

The marbled murrelet was chosen to be examined in more detail for several reasons: 1) A smaller set of sightings or observations made it more feasible to check in greater detail between actual observations and those in the databases; 2) This species often frequented nearshore habitat which might have larger error levels; 3) We were also especially concerned about accuracy of murrelet data because it was possibly needed for gill net mortality monitoring issues current at that time. Murres were selected as a common species that inhabited open waters and would be less likely to have sightings mistakenly located on land by GPS inaccuracies, hence ignored, than species found mostly along shorelines. We could then separate out so-called mystery errors that related most likely to software decisions when data were examined by different programs such as SYNPOL. The much larger set of observations for murres (n=4,642) required different methods for comparison than the manual methods used on the murrelets (n=203), using the CAMRIS mapping and measurement options. Harlequin duck data were examined similarly to murre data.

The CAMRIS mapping system was used to break apart and display data from the interpolated raw counts into "on" transect and "off" transect categories. The overlay in CAMRIS depicting the "on" transect data were compared with the overlays depicting the nearshore and offshore components of the MESA regions or types of marine water habitat presently used. The logic function of CAMRIS was then able to create three categories: 1) nearshore data, 2) offshore data, and 3) a "neither" category. The "neither" category of data were then examined on maps and in databases. The following sources of error were determined from this examination as well as from earlier similar exercises on porpoise data gathered by our surveys:

1) Lack of sufficient GPS input to create a latitude and longitude designation;
2) Sighting of birds in Canadian waters outside of our MESA sub regions;
3) Mistaken location records mapping the sightings way inland, which was created by the earlier version of GPSLOG data logging software (replaced by improved DLOG program in 1996) when the computer battery went down in the middle of a survey [We learned that navigator could correct this later by inserting "off" records in the database before transects are resumed];
4) Periodic location of sightings just barely on land when flying along coastlines, due to distortions caused by the government's selective availability of GPS signals;
5) Data entry or transcription errors;
6) Mystery types of omissions most likely related to software decisions whether to include data in or out of a MESA sub region (Ford pers. comm.).

In time, PSAMP staff learned that they could correct several of these mistakes through several different processes that are now in effect. We used a different data logging system as well as newer GPS equipment and antennas. We increased buffers on maps to make sure data observations would not be as easily thrown out by some abnormal GPS reading caused by use of non-differential GPS equipment. Error checking programs and procedures were constructed and used to check for and correct many of the above errors. Yet it still was pertinent to estimate what percentage of the data from these earlier surveys was not used.

Out of 210 marbled murrelets seen July 1993 on the aerial surveys, 107 were off transect and 103 were on transect in the raw counts. The SYNPOL program only used 88 of the 103 seen on transect. Ten of these related to the computer battery lapse mentioned above (#3). The remainder appeared to be mistakenly mapped just barely on land because of the GPS error limits (#4). Initially, these meant that 15.5% of data for murrelets were in error, but if the ten mistakes related to computer operator error are discounted as unusual because not documented as occurring elsewhere, the error level is 5.8%.

Out of 4,642 murres seen July 1993, 2,289 were considered as on transect. The SYNPOL program used 2,218 of these. Of the 71 bird difference, 16 related to sightings occurring in Canadian waters outside of MESA sub regions, 3 related to bad latitude and longitude readings (contain zero for one of them), and 52 are mysteries related to computer software decisions (#6) about lumping data into sub regions. The overall error level for data on this species was much better than that of the murrelets, with 3.1% overall and 2.3% just for the software interpretations.

Harlequin duck data were examined for both 1993 summer and the 1992-93 winter surveys. The summer data contained a total of 617 harlequins seen both on and off transects, with 613 seen on transect. PSMAP used 560 of these in its analysis, leaving out 53. The puzzling aspect here is that a comparison by CAMRIS of sightings mapped on land suggested that 90 were located on land. PSMAP apparently utilized some of these in its calculations. The winter data contained a total of 734 harlequins seen on and off transects, with 699 seen on transect. PSMAP used 697 of these in its calculations, with a difference of only 2, while the CAMRIS mapping exercise suggested that 128 were located on land. If we just look at PSMAP's use of the data, the error level varied between <1% and 8.6% for this species.

The errors in the first few years of surveys do not appear to affect a very large percentage of the data for most species. These checks on data quality led to some recommendation for corrections of software programs that have minimized the error level in later surveys. We no longer use SYNPOL and rarely PSMAP, but use PARADOX-based programs, which were designed to analyze our data more accurately. These programs have been used the last 4-5 years, but the documentation is still not completed. Now that WDFW is gradually switching to ACCESS as our agency database, it will be important to translate these PARADOX programs to continue the improved data analyses. Documentation of either PARADOX or ACCESS software needs to be completed while present staff familiar with these is still available.

4. SUMMARIES OF OTHER PROGRAM TASKS AND PRODUCTS

Although the focus of this decade report has been primarily oriented towards the marine bird surveys and associated comparisons or adjustments, other tasks and products were addressed during the 1992-99 period by this project either through contracts or cooperative efforts with other department and interagency staff.

4.1 Creation of Synthesized Historical Databases

ECI delivered the sets of synthesized historical databases to our program during the spring of 1993, although they did provide selected output from these at earlier times. These earlier databases included only the aerial, ferry, and small boat surveys conducted during the MESA studies (Wahl et al. 1981), guided by the desire to include only data that could be strictly related to a finite area in a short period of time to be able to calculate densities. When examining certain data for species such as murrelets, and through conversations with Wahl about MESA studies, we realized that this process left out certain areas and species because the first three methods did not cover all areas. Hence, in 1993 we contracted with Dennis Heinemann, who created the original databases for ECI, to add point count data to the synthesized historical database. This was delivered in 1993 along with new versions of the PSMAP and other similar programs because Heinemann discovered some mistakes in the original programs.

Additional boat surveys of marine birds were done the summer of 1987 in the MESA study areas (Dzinbal and Leschner 1987). These were not part of the computerized historical database initially created. It was decided to contract with Heinemann in 1993 to create a separate database for these surveys compatible with the same computer programs in use at that time, PSMAP and SYNPOL. Some of these were delivered August-September 1993 and the others came in 1994.

4.2 Creation of Improved Digital Bathymetric Database for Puget Sound

The original contract that set up the survey design and products included digital products that contained overlays displaying land and two strata of marine waters, <20 m and > 20 m in depth. It became clear eventually that we could use increased detail and accuracy in both the land and water overlays. The WRDS section of Wildlife Management in WDFW provided us with improved, more detailed databases on shoreline contours during 1995-96. CAMRIS had certain limits to numbers of vertices per any one polygon and it took considerable PSAMP staff efforts to translate the large polygons of the detailed shoreline into many smaller polygons that would work with our study area and software programs.

It was a more difficult process finding similar improvement for the digital data on bathymetry. Neither NOAA, USGS, nor any other entity was able to provide us any complete database in this aspect. A decision was made to contract out the creation of such a database. This contract combined the efforts of ECI, WDFW's WRDS section, and British Columbia government sources to create both a raster and vector version of improved depth data for all the marine waters of Washington State. ECI completed their part in 1998 and WRDS staff, with input from British Columbia, completed their part in 1999. This database was shared with Washington Department of Natural Resources (DNR) and they now share this statewide, we are told.

Because the raster files were quite large, certain vectors were created for certain depth strata, with the 10m, 20m, 40m, 60m, and 100m vectors being most useful for the inner marine waters. PSAMP staff began a process to convert these into polygons that could be displayed and used with our software. This process is not complete, but Figures 79 and 80 illustrate what we eventually hope to do for any part of our study area. We are interested in re-stratifying our survey data from two to at least five depth strata eventually, and this improved bathymetry was essential to begin addressing this task. Our survey data are oriented around density indices that might be compared relatively from year to year for trends. However, requests also are made to use these data for making estimates of biomass and populations. The observations of western grebes (Figure 79) and their distribution in different depth strata illustrate how use of just two strata would probably misrepresent a species like western grebes while the use of a greater number of strata would reduce some of the likely errors that might arise from extrapolations based on only two strata. The use of more strata will make it less likely that some bird densities will be extrapolated to include some other area where that density is not appropriate.

4.3 Winter Resident Shorebird Survey

WDFW, the USFWS, and Point Reyes Bird Observatory contracted with Cascadia Research Collective (Cascadia) during the 1992-93 winter period to identify wetlands of regional and national significance for shorebirds based on the number of shorebirds using them, and to

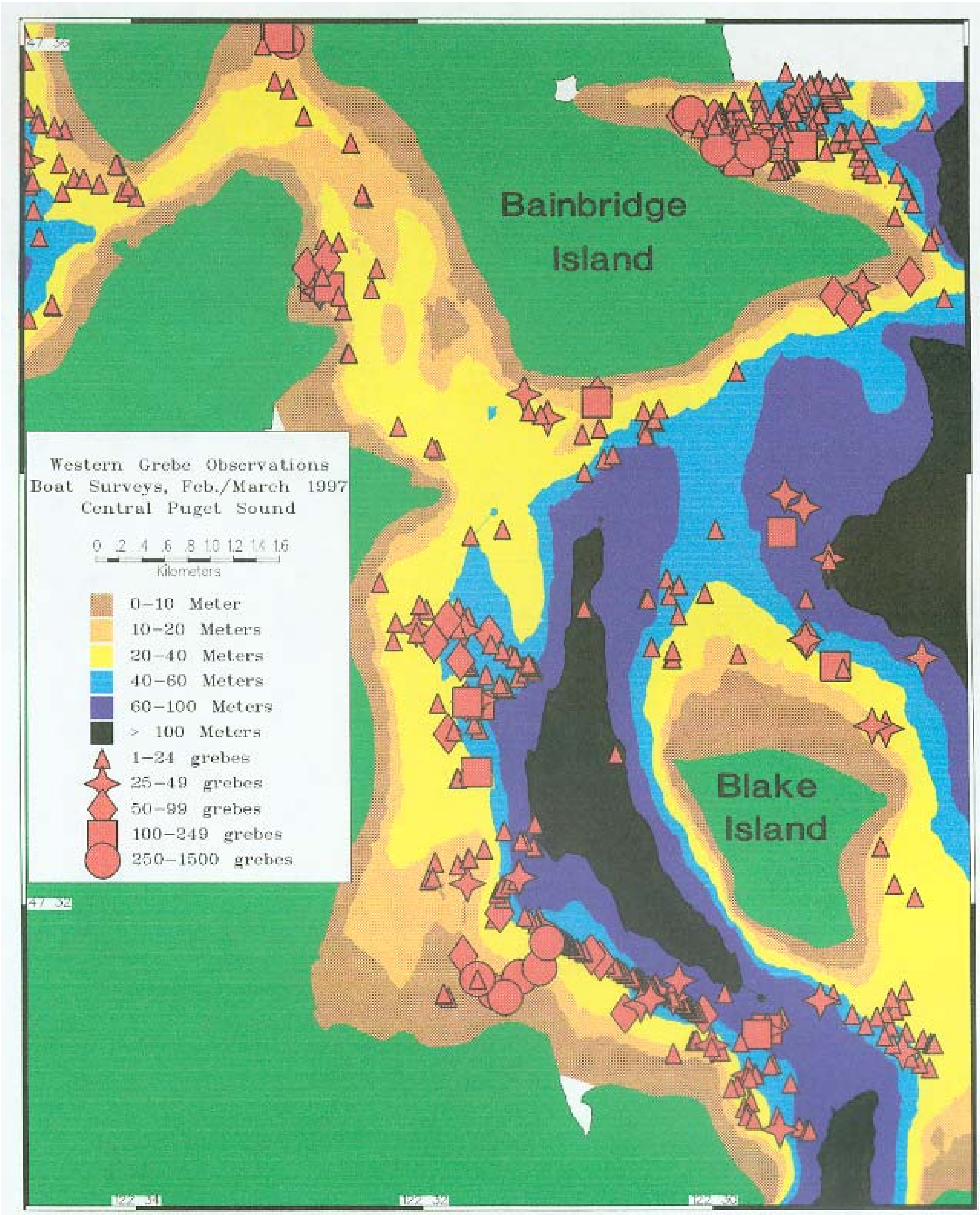


Figure 79. Distributions of western grebe observations among more detailed bathymetry strata in central Puget Sound, derived from replicate boat surveys, February/March 1997.

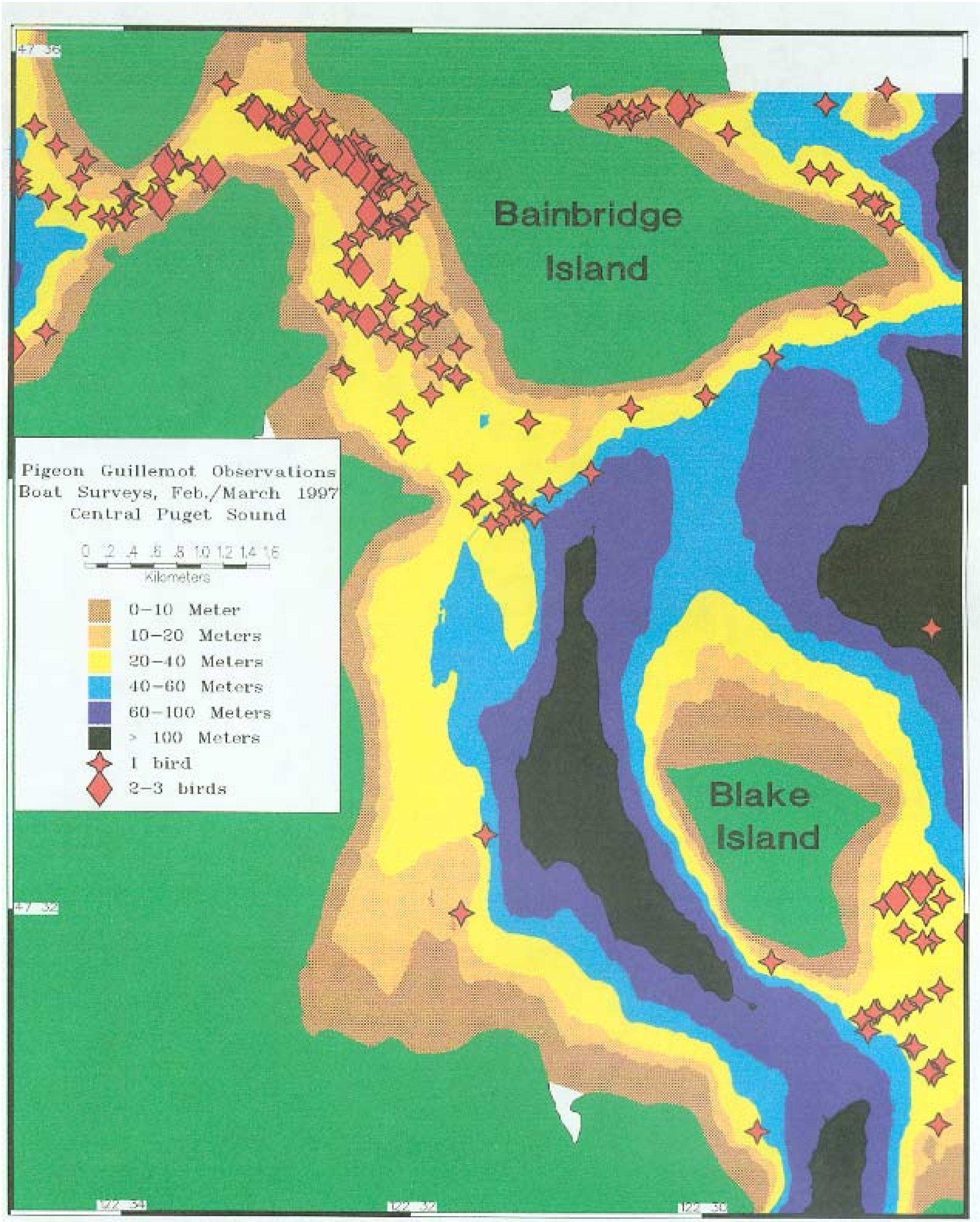


Figure 80. Distributions of pigeon guillemot observations among more detailed bathymetry strata in central Puget Sound, from replicate boat surveys, February/March 1997.

identify important wintering areas based on shorebird abundance and species diversity. Cascadia has been organizing shorebird counts in western Washington for the Pacific Flyway Project since the winter of 1990-91, utilizing a number of volunteers.

PSAMP assisted the 1992-93 winter survey effort by a contract enabling Cascadia to fly aerial surveys in conjunction with their ground surveys and to prepare a report summarizing all the results and comparisons. These aerial flights allowed them to cover areas not reachable by land surveys and evaluated how aerial and land-based surveys compared. The report on the 1992-93 winter surveys was received March 1993 (Evenson 1993). This effort was funded again through contracts during the 1993-94 and the 1994-95 winters. Reports were received by June 1995 (Evenson and Buchanan 1994 and 1995). Copies were distributed to the PSWQA steering committee at that time and copies are available to others upon request.

The overall results were mentioned earlier in section 3.1.2 on page 78 describing the overview of species distribution and abundance by season. There were several areas in the northern portion of greater Puget Sound where a large disparity occurred between the aerial and ground-based counts. Movements of flocks between sites in this northern area were suspected. Because they were unable to adequately track movements of flocks among sites, the authors were reluctant to derive cumulative counts for greater Puget Sound. Despite this reluctance, the authors feel that it is clear that the wintering dunlin population regularly exceeds 50,000 shorebirds and that it is the predominant wintering shorebird species in this region. By contrast, only two other species, the black-bellied plover and western sandpiper, had survey count totals that exceeded 500 birds.

Although it is likely that the most important sites have been identified, there is a distinct possibility that other potential monitoring sites have been missed. The authors believed this was likely because counts were only conducted once or twice each year and there was no means to account for movement among sites. In light of this, they recommended three actions: 1) Count additional winter counts each year. 2) Begin investigation of factors related to movements of shorebirds among sites. 3) Begin intensive monitoring at sites (e.g. Totten Inlet) where movement effects were not documented, thus developing a baseline data set that will be more likely to capture trends over time.

4.4 Adult-Juvenile Ratios of Marbled Murrelets On Inner Marine Waters of Washington

Most breeding marine bird species in Washington reside on national wildlife refuges and therefore have some monitoring program in place. PSAMP objectives originally called for monitoring of reproductive success for selected marine birds and mammals. Marbled murrelets are a marine bird species of concern in Washington State, and their reproductive success can not be measured very well at their dispersed nests in forests, because so few are located. A pilot study began in August 1993 and continued each August through 1995 to determine if reproductive success might be monitored from boat surveys when the juvenile murrelet first shows up on the marine waters, still looking different from adult plumages for a brief time. This pilot study was funded entirely by WDFW and was a cooperative project between PSAMP and regional staff of the department. Janet Stein, in collaboration with Ruth Milner, coordinated the project out of the Region 4 office. PSAMP staff, along with volunteers from the Oil Spill

Response team and staff from both Region 4 and 6, composed the major components of crew that conducted the surveys. Survey results were summarized each year (Stein 1994 and Stein and Nysewander 1995) with a final report distributed in 1999 (Stein and Nysewander 1999) that included recommendations for further research needed to refine this monitoring methodology.

This pilot study continued for three years to verify that the higher proportion of juveniles seen in 1993 was also seen other years in this same area. There was considerable interest by both USFWS and members of the Marbled Murrelet Recovery Team in obtaining these estimates, which were to be used in the demographic analyses being prepared for this species at that time. When this pilot study started in 1993, none of the many research efforts underway were focusing on at-sea distribution of murrelets in the inner marine waters of Washington State. At least five or more efforts have started work on at-sea murrelet issues in Washington since then. This is largely a function of this species' threatened status and its connections to old growth forest. However, the PSAMP pilot study was successful in several different ways and may have helped focus some of this effort on the inner marine waters. The survey results suggested that higher productivity rates (9.3% in 1993, 7.8% in 1994, and 7.9% in 1995) occurred in this area than recorded elsewhere. This survey also documented how distribution of juvenile marbled murrelets can be quite different between years, a factor that would have considerable impact on what kind of monitoring design would be satisfactory.

The PSAMP surveys occurred during the first two weeks of August. Some 53 of the 110 strip transects surveyed in 1993 had also been surveyed during May and June, either in 1987 (Dzinbal and Leschner 1987) or 1989 (Young, unpubl. data). A total of 985 Marbled Murrelets were counted along these transects during the historical studies, in comparison to 492 counted during the 1993 work. The difference in time of year, with juveniles present and some of the adults possibly still on or commuting to the nest in August, makes comparisons of these data meaningless. We originally intended to redo these transects in May and June to evaluate trends, but this was not done. The latest emphasis on line transects rather than strip transects for murrelet surveys may not be supportive of trying to compare these data sets.

Several issues brought about the end of the PSAMP pilot study and suspended implementation of any long term monitoring by PSAMP on this species. 1) The wildlife component of PSAMP encountered budgetary restraints in 1995-96 and acted upon suggestions of other research efforts to rely upon them to monitor murrelets in this study area. 2) The series of potential problems encountered by the methodology used in this pilot study suggested that further research would be needed before some standardized monitoring protocol would be adopted, which went beyond the PSAMP mandate. 3) While the inner marine waters of Puget Sound may be important for marbled murrelets, it is not so clear that marbled murrelets will serve as one of an appropriate set of species that would monitor the overall health of Puget Sound waters. Other species with more numerous and wider spread distribution appear more appropriate for this PSAMP objective.

4.5 Harbor Seal Census

PSAMP staff first started assisting Steve Jeffries (WDFW) and Harriet Huber (NMFS) with aerial survey and photography of harbor seal numbers at haul out sites in August 1993. Huber and Jeffries were in the midst of surveying all haul out sites for harbor seals throughout Puget Sound, a survey effort that extended over a larger time frame than just the August surveys and which started before the PSAMP program initiated the bird and mammal component. Staff time was needed for performing counts from photographs taken during the surveys in 1993; hence PSAMP funded the hiring of temporary help to complete this stage of the survey. PSAMP staff continued to help with different phases of this survey and analysis through 1996. After this time, budgetary restrictions led to a decision to alternate funding focus in different years between topics with the highest priority that year.

The survey data were and is still entered and archived with the National Marine Mammal Lab (NMML) office in Seattle, a part of NMFS. Huber continued coordinating the archiving and management of this survey data and all other seal data collected, even that funded by PSAMP and other state mammal programs. Until recently these data were in RBASE, but it is now being translated into ACCESS. This database was not made available to PSAMP or WDFW staff and the only copy or access was at Sand Point. There was some concern voiced by NMML staff over database integrity if they did not limit access and control. Discussions and negotiations have continued intermittently to address this and we believe that a copy of the ACCESS database will eventually be made available to WDFW staff in the Marine Mammal Investigations Office in Lakewood and hopefully to WRDS section in WDFW in the Olympia office.

This survey data contributed to creations of such products as an atlas of seal and sea lion haulout sites in Washington (Jeffries et al. 2000). However, limited staffing mixed with numerous tasks meant that analyses and reporting of other survey results such as trends did not get addressed very quickly. In 1997 the PSAMP component in WDFW funded George Divoky to assist Huber and Jeffries and produce such a report. A draft (Jeffries et al. 1998) complete with figures displaying trends in different sub regions of greater Puget Sound was received February 1998. These data and graphics have been used in various PSAMP, WDFW, and NMFS reports and presentations since then, but the report was not finalized and distributed. It is my understanding that this report is presently being assimilated with the seal data gathered for the last two years and is being incorporated into other NMML documents or publications. Posters at the 2001 Puget Sound Research Conference have displayed the latest set of graphs capturing the longer period of time (Jeffries et al. 2001). One of the advantages of delaying this report is that all of the remaining portions of the harbor seal population in Washington State have now displayed a leveling off of the population growth seen in the last 20 years. Earlier drafts seemed to suggest that this was happening within a few portions of the seal population, but this trend has clearly occurred throughout the state.

Current databases and reports illustrate some of the challenges PSAMP has encountered in meshing with the research relationships in place in Washington State when the bird and mammal component started in 1992. This component has not been able to devote large amounts of funding for marine mammal work alone; however, funding and staffing that was provided did enable some essential work to be done. However, this did not translate into the type of reports or recognition for which PSAT had hoped. Now that NMFS is a more active part of PSAT with representation on the PSAMP Management Committee, this may change in the future. It should be noted that the NMFS presence on PSAMP committees comes from the Montlake Office in

Seattle (fisheries emphasis) while the marine mammal work comes out of the NMFS Sand Point office.

4.6 Harbor Seal Contaminant and Disease Monitoring

PSAMP supported the capture, radio tagging, and biopsy of harbor seal females and pups at the seal haul out sites at Gertrude and Eagle Islands in southern Puget Sound, river mouths in Hood Canal, Minor and Smith Islands, and Boundary Bay/Fraser River sites throughout the 1992-99 period, through periodic funding and frequent participation of PSAMP staff assisting regularly as components of the seal capture team. All of this work is proceeding as described in the project implementation plan, with one notable change. Most of the historical contaminant examinations were previously made on harbor seal neonates collected dead at known pupping locations. Both NMML and the Marine Mammal Investigations at WDFW decided to also start biopsy of live harbor seal pups in addition and compare these results with those determined by the examination of dead neonates picked up on a regular basis. Some of the live pups biopsied lived into the fall and then died, with the carcasses collected for analysis. Although the sample size may not be large, it provides an opportunity to compare contaminant levels by both methods and transition into the preferred methodology that focuses primarily on condition of living mothers and pups.

PSAT gave additional funding in recent years to address some of the historical comparisons of contaminant sampling that were needed and facilitate the collaboration and production of reports between WDFW and NMML efforts, and those done by other research scientists (e.g. Peter Ross at the Institute of Ocean Sciences in Sydney, British Columbia and work in Washington done by John Calambokidis of Cascadia Research Collective in Olympia). A final report was distributed on temporal trends in contaminants in Puget Sound harbor seals in December 1999 (Calambokidis et al. 1999). The results reported indicate that there was clear decline in PCB and DDT concentrations in harbor seals between the 1970s and 1980s but that this decline has slowed and become less pronounced in the 1990s. Given that 1) the long-lived persistence of these contaminants and the fact that high concentrations in some areas such as Puget Sound will likely remain for years to come, and given that 2) these concentrations are in the range of those shown to cause immune response in other studies, harbor seals in this region may be at risk for some time to come.

Screening for diseases has also been accomplished by examining blood samples collected during the process of capturing and handling seals. Distemper and leptospirosis were not documented, but nearly a fourth of the samples (n=200) had positive or suspect titres (Huber et al. 1996) for *Brucella abortus*, documenting clearly for the first time that brucellosis is present in harbor seals in Washington State. A poster at the recent 2001 Puget Sound Research Conference (Lambourn et al. 2001) summarized the latest findings on this effort.

All of the above activities have resulted in varied presentations, papers, and reports at scientific meetings (e.g. Puget Sound Research Conferences [Ross et al. 1998] and Canadian Marine Mammal Conference [Jeffries 1998]). Additional manuscripts are being prepared and more information will be available at a later date. If information were needed sooner for PSAT or PSAMP needs, either Steve Jeffries (206-589-7235) or Harriet Huber (206-526-6433) would be the primary sources for this information.

4.7 Harbor Seal Life History and Reproductive Success

The seal captures served numerous purposes beside evaluations of contaminant levels and presence of diseases. One of the primary reasons for the captures was the effort to mark and follow known-age components of the female and pup portion of the harbor seal population in selected areas. Intensive and systematic observations could examine some of these haulout sites and eventually be able to answer questions about recruitment, natality, and survival of harbor seals in south Puget Sound. Life history theory predicts that parameters such as survival, recruitment, and female reproductive success differ between an increasing population and a stable population. However, an adequate time series of life history data were not available to undertake such an analysis for harbor seals in Washington State.

Permanent marking of harbor seals in south Puget Sound began in 1993. A total of 165 harbor seals were branded by the end of 1995 and 34% were of known age (Huber et al. 1996). During the pupping season, approximately 500 seals use Gertrude Island where about 110 pups are born each year, while Eagle Island had approximately 100 seals with 10 pups born per year. Resightings of brands and tags were 85% in 1993, 71% in 1994, and 60% in 1995 for the Gertrude Island seals. Two females tagged as subadults in 1993 gave birth for the first time in 1996. At least 3 tagged seals have given birth every year since 1993 and 75% of the branded females which gave birth in 1995 also gave birth in 1996. It appears that some of the needed information is beginning to be collected. Having spent this much effort marking these seals, it is important to keep these observations continuing. For this reason, even though few PSAMP funds have been available for supporting marine mammal work, what funds were found recently have been devoted to staff time associated with continuing these observations. Capture and marking of seals has continued from 1996 through 2000, but no report has been made available summarizing present knowledge. The capture and observation data are presently being entered into an ACCESS database (Lambourn, personal communication).

4.8 Resident Gray Whale Monitoring and Identification

Cascadia Research Collective (Cascadia) was granted a PSAMP contract in 1992 to gather baseline information on gray whales in Puget Sound that would help assess their exposure to contaminants. A report summarizing the 1992 work was received January 1993 (Calambokidis and Evenson 1993). Far fewer sightings of gray whales were reported in 1992 than in previous years, particularly in central and southern Puget Sound. The only portion of Puget Sound where regular sightings were received was the Port Susan/Saratoga Pass region. All gray whales identified consisted of four individuals and all of these individuals had been identified in this region in one or more past years. No gray whale deaths were reported in the inland marine waters of Washington during spring and summer of 1992. The 1992 period, as well as 1993, may have been unusual in that ENSO changed the normal patterns or timing of movements for many species.

In 1993, Cascadia continued the research conducted in 1992 and expanded their work in two areas: 1) Surveys were expanded to extend their geographic coverage to all marine waters of Washington State. 2) They would prepare a publication containing a summary of their findings and a photographic catalog of identified gray whales that reside in rather than migrate past Washington and British Columbia waters during the spring and early summer. The 1993 work was funded jointly by PSAMP and Marine Mammals Investigations of WDFW, with the PSAMP funding supporting just that work that fell within the inner marine waters of the state. The photographic atlas and publication would be produced and funded with the assistance of WDFW's staff in the information and education departments. Production of this publication was completed by June 30, 1994 (Calambokidis et al. 1994). The surveys between 1991 and 1993 documented photographically 53 individual gray whales in Washington waters with 17 seen in more than one year either in Washington or nearby British Columbia waters during the spring and early summer. One identified whale stayed at least 112 days, with the average minimum stay being 47 days. Two different patterns appeared to be emerging from these observations for gray whales in Washington. Gray whale use of Port Susan/Whidbey Island area and the outer coast of Washington was characterized by a high rate of return year after year and feeding on known high prey densities, with little mortality of identified whales. Gray whale use of the more southern portions of Puget Sound was characterized by high mortality of identified animals, no returns in multiple years, with no use of any clear prey base identified.

Cascadia has continued monitoring resident gray whales and continues to maintain and upgrade this photographic archive.   John Calambokidis can be contacted at Cascadia Research Collective (206-943-7325) for the latest publications, copies, or status of this database.

4.9 Creation of MAPSYS Software (ARC/Unix) and Bird/Mammal Map Products

The original survey design and contract that was the basis for implementing the PSAMP aerial surveys also included a PC-based computer GIS system (CAMRIS). The survey data were translated into DBASE or FOXPRO format (later translated into PARADOX) with map products derived from CAMRIS. This system has been and continues to be very useful for various individual tasks and map products. Survey data were also provided in ASCII text format to Don Kraege, who would run programs to extract the data needed for national midwinter waterfowl inventories.

It soon became clear from public requests that we needed some additional mapping system that would semi-automatically provide a suite of standardized, yet flexible map products that might meet public requests related to these surveys. Both PSAMP and WDFW also desired that the data be archived in some agency corporate database, which would increase the likelihood that it would still be available in the future for trend analyses. WDFW has corporate databases that are based upon ARC/INFO software and Unix hardware. A decision was made to put the PSAMP aerial survey data into the ARC environment. An additional program called MAPSYS was developed by Don Saul at WDFW to allow users to access the ARC dataset of aerial surveys through Unix by a series of choices on menus and choose what kind of data would be selected and how it would be displayed on one of 8 standard maps. The user can choose between a number of options to customize their map such as the following: summer or winter surveys, one year or several years combined, one species or several combined, densities or observations or transects, on or off transects or combined, how survey effort would be displayed, what size paper to use for map, and the particular scale and number of levels of the different data to illustrate.

Many of the density maps included in this report were created and printed through this MAPSYS process. Even though these aerial surveys were designed primarily for survey of marine birds, all bird and mammal species recognized are recorded and entered into the database. Surveys for marine mammals and birds tend to require different conditions for maximum utility. Birds, for instance, show up better on cloudy overcast days while marine mammals are seen more clearly in the water when the day is sunny and clear. So the mammal data included in the PSAMP aerial survey database is not ideal for tracking trends, but the complete coverage pattern and the series of yearly surveys does record some interesting patterns of marine mammal distribution. For this reason, 12 maps have been included in the appendices summarizing observations (or densities in the case of seals) seen 1992-99 during either summer or winter survey window for the following marine mammal species or groups: harbor seals, all sea lions combined, harbor porpoise, Dall porpoise, unidentified porpoise, sea otters, and orca whales.

Because the aerial survey area on nearshore transects includes those animals seen up to the high tide line, the summer surveys capture some portion of the seal haul out areas where pupping occurs; the seal density maps capture the tendency towards summer concentrations and the wider dispersal in winter. Only the waters off the greater Seattle waterfront seem to display reduced use by seals compared to that seen elsewhere throughout the inner marine waters of Washington State. In contrast, sea lion distribution increased noticeably in winter and tended to concentrate, in a few areas in the Strait of Juan de Fuca (e.g. Race Rocks and the reefs off the south end of Cattle Pass), also concentrating especially along urban shorelines and river mouth areas in southern and central Puget Sound. The summer and winter observations of harbor porpoise are interesting in that some individuals have been seen in southern and central Puget Sound, but most concentrations used either the Strait of Juan de Fuca and the offshore banks common in its eastern portion, the northern entrance of Admiralty Inlet, the major passes and banks in the San Juan Islands, or northern waters up to Boundary Bay. There does seem to be somewhat of a different pattern between summer and winter for harbor porpoise. Dall porpoise, however, differed in that they were not as widely distributed as the harbor porpoise, but favored certain areas considerably (e.g. Haro Straits and the central portion of the Strait of Juan de Fuca). Dall porpoise also entered the southern and central Puget Sound in larger numbers during winter reaching up into Saratoga Passage and down even south of the Narrows near Tacoma. Our winter aerial surveys have captured the expanding movement of sea otters further east into the Strait of Juan de Fuca periodically. Observations of orca whales do not occur very frequently from our surveys, but they are picked up in the summer around the two larger passes of the San Juan Islands, Haro and Rosario Straits. In winter, the few sightings of orcas recorded either fell between the south end of Whidbey Island and Tacoma or out the western portion of the Strait of Juan de Fuca.

5. DISCUSSION

It has been recommended that aerial surveys use the same observers, plane, time of year, survey procedures, and large numbers of surveys and replicates (Gaston and Smith, 1984; Martinson and Kaczynski, 1967). Comparisons of the MESA and PSAMP data run into some problems here as several of these categories were different, but the ongoing PSAMP aerial surveys have consistently followed this strategy to this date and cover a larger percentage of the study area (15-18% for nearshore and 3-6% for offshore) than most aerial surveys have (<5%).

The presence of PSAMP aerial transects in all portions of Puget Sound nearshore and offshore waters has yielded maps that characterize spatial and seasonal patterns of abundance, thus meeting some PSAMP goals. The detail into which the data can be displayed also appears useful for a number of management concerns that include oil spills and gill net mortality. The monitoring of trends or determination of significant change has been a more difficult task however. This type of monitoring would be most successful if a series of continuing annual data are gathered. This effort, depending upon the species chosen for focus, might also require increasing the number of replicate surveys in order to reduce the confidence limit around each estimate. There has been tension between the overall coverage, the need for replicates, the limited budget, and the limited number of days available for survey. Replicates appear most likely to be implemented in some smaller focus area on selected species.

The PSALLOC program that came with the project's original package of survey analysis software was used to evaluate how the standard error would be affected by replicates. The areas to replicate and the number of replicates needed depends upon which species or group of species are selected, how many species are combined, the flocking proclivity of the species under consideration, and the number of different habitats preferred by these species. In general, the more significance given to the above factors, the more replicates and longer cumulative amounts of transects that will be needed. In 1993, use of the PSALLOC software on the surveys completed until that time suggested that the following replicates that might be needed.

When loons, western grebe, eight species of diving ducks, and two alcids (marbled murrelet and common murre) are selected from the 1992-93 winter data set, the PSALLOC analysis recommended that replicates be flown additionally in four MESA sub-regions to reduce the overall standard error 32.8%. This would have translated into 1,453 km more of transects, roughly half of the total shoreline found in Puget Sound. The MESA sub-regions selected were 1401S-1406S and 1401D-1406D (nearshore and offshore habitats of Whidbey, Camano, and Skagit area) and 601S-607S and 601D-607D (nearshore and offshore habitats of Whatcom County).

On the other hand, even selecting only a few species will sometimes still require a number of replicates if flock size is large. Gaston and Smith (1984) demonstrated that survey intensity must increase with flock size to maintain the same level of accuracy. In the case of murres, the PSALLOC program indicated that the standard error would be reduced by 14.5% if 1,441 km of transects were flown in the offshore portions of MESA regions 6 (Whatcom County), 8 (Haro

Strait), and 16 (all of south Puget Sound).

In either case, it seems unlikely that very many replicates will ever be accomplished, given the limits of budgets and desired geographic coverage. This suggests a twofold approach to aerial survey and monitoring:

1) Continue to count all species in survey transects to obtain overall distribution patterns and relative abundance that is needed by management issues. Continue this effort annually in at least the winter survey period. If something catastrophic occurs to any one species, the change will be noticed. If this type of data collection occurs over a long enough period of time, the normal cycles of variation will likely become known and a decline may be separated from these.

2) Use only a few suitable species for attempts to monitor more subtle degrees of change. This is probably required if only portions of a large area were to be sampled. Goldeneye and bufflehead ducks might be species that work best in this regard because they tend to be more uniformly distributed and the confidence limits have been consistently tight for them in the PSAMP survey data. Rhinoceros auklets in summer are other possible species that might qualify for this type of monitoring focus by aerial surveys.

Statistical analysis of changes in population size of marine birds is discussed in detail in the implementation plan pertinent to this task (Nysewander et al. 1993, pp. 42-45). Population size estimates of marine birds typically have large within-survey variances because of patchy spatial distributions, large within-year variances because of seasonality, and large among-year variances because of yearly variation in migratory patterns. The non-parametric tests for trend analysis recommended by the original study design contract suggested that 5-20 years of survey data would be needed for analysis if there were to be a reasonable chance of recognizing significant changes of any gradual nature. This is especially valid for comparisons with the historical database and its large confidence limits, caused in part by different survey platforms, observers, timing of surveys, and survey methodology. Dr. John Skalski, with the School of Fisheries at the University of Washington at Seattle, reviewed in 1997 the project design and formulas used in statistical analyses of PSAMP aerial survey data. He suggested a few changes in the basic formula being used and supported the use of ANOVA and two sample type of tests. His changes have been incorporated into the PARADOX programs that summarize data and prepare confidence limits associated with these data. The appendices will include a section on the sample units and the formulas used.

Calculation of densities for just the two strata, <20 m and > 20 m, and then using these to calculate population estimates for certain species, have indicated to us that the survey strata need to be increased from two to at least five or six different depth strata, if we wish to use the relative density indices for some type of biomass calculation or estimate of total population. The new bathymetry database offers us this opportunity. Project personnel are working to create the GIS polygons that will allow this better stratification and analyses of data. The project would then like to revisit all past survey observations and associated GPS location data and run them again through our analysis software calculating density indices using these new strata. This is somewhat time consuming, but the end product promises to be more useful and likely more realistic.

One of the other factors to consider that might help reduce the variability involved with monitoring of these marine species is the study of how certain tidal features (e.g. upwelling or rip currents) may concentrate or attract species at certain tidal stages. This would be especially important if surveys did not cover the total area being covered now and were concentrating only on certain areas because of budget restrictions or lack of time. Although this was mentioned in the implementation plan (Nysewander et al. 1993), it has not been possible to implement this with the demands on time and personnel that the other component tasks are making at this time.

Briggs et al. (1985a, 1985b), Savard (1982), and Stott and Olson (1972) discuss the many variables with which aerial surveys and observers must contend. The PSAMP aerial surveys attempt to minimize these by only surveying when certain conditions exist (i.e. enough visibility with sufficient lighting, no wind above Beaufort 4 or 18 mph), training observers, using the same observers, and limiting length of survey periods just to mention a few. Differences between observers have not been considered a serious problem, but we have not attempted to quantify this at this time. Some aerial survey programs such as those used by U. S. Fish and Wildlife Service (USFWS) in Alaska minimize this problem by making pay level high enough and job positions attractive so that little turnover occurs. It seems unlikely that WDFW will be able to follow this same approach and hence further thought may be needed to minimize this variable or address how we wish to quantify it.

Funding levels have never increased for this component since its inception other than for cost of living or inflation type adjustments, even though there has been general recognition that the project was not staffed sufficiently in the beginning to tackle the extent of tasks assigned. One position was added even though no additional funding was given and the accomplishments recorded by this report owe much to this improved staffing effort. Nevertheless, one aspect or another of this component has been postponed or neglected because of this funding deficiency. The marine mammal tasks have received consistent support from PSAMP survey staff for seal captures and other tasks, but the actual funding other than staff time has been minimal. It seems appropriate for one person to be funded full time for marine mammal work by PSAMP if funding were available, but recent budget enhancement proposals did not meet with success. We have participated in prioritization exercises, but this still pits the bird task and the marine mammal task competing against each other for limited funds. This will likely not change until the bird and mammal component are funded on a level more comparable with that given to the other PSAMP components.

6. CONCLUSIONS AND RECOMMENDATIONS

The PSAMP aerial surveys of marine birds that started in 1992 were the first, of which we were aware, that attempted to combine the frequent positions provided by GPS with such large concentrations of birds near shorelines. The mapping options for displaying data provided by this methodology are highly useful for managers who work with marine bird resources. The survey method is challenging for the observers and there is an abundance of tedious data entry and transcriptions that are needed before the computer displays and maps are available. Nevertheless, the results appear to justify the process. The following are recommendations to consider if our present monitoring focus will continue.

1. Modifications of computer software or survey databases:

A) Finish re-stratification of bathymetry data into the needed polygons used by PSAMP software analyses, incorporate these into ACCESS analysis programs, and then retreat all past surveys to come up with new density indices and population estimates.
B) Document the present PARADOX software being used; specifically putting down the specific steps personnel go through in converting observations to databases used.
C) Enhance the indices production software (ACCESS) to provide capability to produce summaries for smaller areas (e.g. sub regions).
D) Set up a schedule for translating all PARADOX software programs in use (data entry, correction, summary, and analyses) into ACCESS programs using Visual Basic.
E) Make a field for databases that is unique; so when mapped in CAMRIS, we can identify more easily specific records that need correction.
F) Create some limits in the INTERP or comparable ACCESS program that would prevent wrong latitude and longitude from being attached to sightings when computer batteries go down or electrical connections fail.

2. Modification of survey options and accuracy:

A) Examine options in software to choose width of aerial transects (either 50 m or 100 m) in software programs so that transects may be more comparable upon occasion with transects run by boats which must use the 100 m width.
B) Develop techniques for using either real time differential corrections or base station adjustment of GPS data to improve accuracy because our surveys are as close to land as the range of error associated with the non-differential GPS in use at this time. This may not be necessary now that Department of Defense has ceased the irregular corruption of GPS signals.

3. Survey methodologies and focus:

A) New technology was suggested that would allow data to be entered into computer databases by voice or from tape directly. The technology that does this reportedly had an unacceptable level of error a few years ago (Conant pers. comm.). It is projected that the error level will be, or is now reduced to an acceptable level. The technology should be considered for future use, as this would speed up the data entry process. This delay in data entry makes it difficult to submit our winter survey data as quickly as needed.

B) Research tape recorders to see if something might be available to record the time automatically, which would eliminate the observer from having to for the observer to look away from the survey transect to his watch.

C) Implement more boat surveys (similar to that used in Port Orchard marine waters in February-March 1997) to focus on specific species, areas, and objectives, especially for winter species exhibiting declines. This might mean better confidence limits for species such as western grebes, or a better understanding of what percentage of diving ducks (i.e. inconspicuous females) might be missed by aerial surveys.

D) Continue at least some effort in each season, with the replicate colony surveys of pigeon guillemots being most appropriate for the summer window.

E) Maintain some key focus effort related to marine mammals, the most appropriate at this time appearing to be both the life history and reproductive success derived from the seal marking/captures, or the food habits of harbor seals.

4. Distribution of data and products to satisfy requests:

A) Continue to encourage WRDS section of WDFW to assist in making maps and reports accessible to the public, either through FTP, Internet downloads, or printed map products.

A) Translate reports into PDF formats so that they will be made available for access on the web, similar to those that other agency PSAMP components have provided. Use PSAMP funds allotted to WRDS to support this activity.

B) Further streamline the process by which the public accesses map products from MAPSYS, so that less project staff time is consumed each year meeting these requests. Perhaps the MAPSYS software should be renamed something such as BIRDS or some other name, which would engender quicker recognition of what data it provides.

C) Decide what mix of other activities such as talks, slide presentations, and publications should continue to be included in public outreach.

5. Staffing and funding recommendations:

A) Continue to encourage supervisors, department administrators, and PSAT staff to support increased funding and staffing levels for both the bird and mammal components of PSAMP in order that it be comparably funded and capable of complementing the other more fully funded PSAMP components.

B) Encourage the increased pay and status of aerial survey crew to maintain continuity over time as other programs of similar survey scope have done.

C) Get agreement and funding for a more stable marine mammal portion of the component without discontinuing or jeopardizing the bird monitoring surveys.

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APPENDICES

APPENDIX A. Estimating Sea Bird Abundance from Strip-Transect Data by John Skalski

APPENDIX B. Three Examples of Aerial Survey Track Lines during 1994-1999 Periods

- B.1. Typical Summer Track Line For 1993-96 After Changes from First Year Coverage, As Exemplified by 1995 Routes
- B.2. Typical Summer Track Lines for 1997-99 After Budget Cuts, Exemplified by 1999 Routes
- B.3. Typical Winter Track Lines for 1994-99, Exemplified by 1999 Routes

APPENDIX C. Maps Displaying Incidental Observation Data For Varied Marine Mammals, Derived from PSAMP Aerial Surveys 1993-1999.

- C.1. Mean Densities of Harbor Seals During July Aerial Surveys 1993-99
- C.2. Mean Densities of Harbor Seals During Winter Aerial Surveys 1993-99
- C.3. Sea Lion Observations During Winter Aerial Surveys 1993-99
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- C.11. Orca Observations During July Aerial Surveys 1993-99
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APPENDIX A. Estimating Sea Bird Abundance from Strip-Transect Data by John Skalski

Estimating Sea Bird Abundance from Strip-Transect Data

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Estimates of bird abundance and densities are desired for specific strata as well as across a composite of strata. The purpose here is to estimate these parameters and their associated variances. The following values are defined:

n_{ij} = count of a given species on the jth segment ($j = 1,\ldots,m_i$) in the ith stratum ($i = 1,\ldots,L$);
m_i = number of segments sampled in the ith stratum ($i = 1,\ldots,L$);
M_i = number of possible segments in the ith stratum ($i = 1,\ldots,L$);
L = number of strata over which estimation is desired;
l_{ij} = length of the jth segment ($j = 1,\ldots,m_i$) in the ith stratum ($i = 1,\ldots,L$);
w_{ij} = width of the jth segment ($j = 1,\ldots,m_i$) in the ith stratum ($i = 1,\ldots,L$);
a_{ij} = $l_{ij} \bullet w_{ij}$ = area of the jth segment ($j = 1,\ldots,m_i$) in the ith stratum ($i = 1,\ldots,L$);
$d_{ij} = \frac{n_{ij}}{a_{ij}}$ = density of a species in the jth segment ($j = 1,\ldots,m_i$) in the ith stratum ($i = 1,\ldots,L$);
A_i = area size of the ith stratum ($i = 1,\ldots,L$);
$A = \sum_{i=1}^{L} A_i$ = area across all strata of interest;
N_i = bird abundance in ith stratum ($i = 1,\ldots,L$);
N = total bird abundance across all strata of interest;
D_i = bird density in the ith stratum ($i = 1,\ldots,L$);
D = overall bird density across all strata of interest.

1) PARAMETER ESTIMATES WITHIN A STRATUM

Density in the ith Stratum $\left(\hat{D}_i\right)$

An estimate of D_i would be based on the ratio estimator

$$\hat{D}_i = \frac{\sum_{j=1}^{m_i} n_{ij}}{\sum_{j=1}^{m_i} a_{ij}} \quad (1)$$

The density estimator has an approximate variance of

$$Var(\hat{D}_i) = \frac{\left(1 - \frac{\sum_{j=1}^{m_i} a_{ij}}{A_i}\right)}{m_i(\overline{A}_i)^2} \frac{\sum_{j=1}^{M_i}(n_{ij} - D_i a_{ij})^2}{(M_i - 1)}$$

where

$$\overline{a}_i = \frac{\sum_{j=1}^{M_i} a_{ij}}{M_i}$$

This variance can be estimated by the formula

$$Var(\hat{D}_i) = \frac{\left(1 - \frac{\sum_{j=1}^{m_i} a_{ij}}{A_i}\right)}{m_i(\overline{a}_i)^2} \frac{\sum_{j=1}^{m_i}(n_{ij} - \hat{D}_i a_{ij})^2}{(m_i - 1)}$$

$$= \frac{\left(1 - \frac{\sum_{j=1}^{m_i} a_{ij}}{A_i}\right)}{m_i(\overline{a}_i)^2} \frac{\sum_{j=1}^{m_i} n_{ij}{}^2 - 2\hat{D}_i \sum_{j=1}^{m_i} n_{ij} a_{ij} + \hat{D}^2 \sum_{j=2}^{m_i} a_{ij}{}^2}{(m_i - 1)}$$

(2)

and where

$$\overline{a}_i = \frac{\sum_{j=1}^{m_i} a_{ij}}{m_i}$$

Equation (2) can be found in Cochran (1977: p.33). Variance estimator (2) is generally computationally the easiest approach to calculating the variance of $\hat{D}_i$. The standard error of $\hat{D}_i$ would then be

$$\hat{S}E(\hat{D}_i) = \sqrt{V\hat{a}r(\hat{D}_i)}$$

and a $(1 - \propto)$ 100% confidence interval computed as

$$\hat{D}_i \pm Z_{\frac{\propto}{2}} \bullet SE(\hat{D}_i) .$$

[The following paragraph and formula were not in the original Skalski feedback, but resulted from later discussions related to our particular survey type]

The two variations of equation (2) above include a finite population correction (fpc), which is used for correction when surveys sample less than 20-30% of the area of a stratum and where animals do not move between areas during survey. If you sample more or there is movement, then this correction is not used. The overall aerial surveys were not likely independent of movement between areas; hence the variance for PSAMP aerial survey data was calculated by the following formula:

$$Var(\hat{D}_i) = \frac{\sum_{j=1}^{m_i}(n_{ij} - \hat{D}_i a_{ij})^2}{m_i(\bar{a}_i)^2(m_i - 1)}$$

Abundance in the ith Stratum $\left(\hat{N}_i\right)$

Abundance $\left(\hat{N}_i\right)$ for the *i*th stratum is by definition

$$N_i = A_i \bullet D_i \,.$$

Hence the abundance estimator for the *i*th stratum would be

$$\hat{N}_i = A_i \bullet \hat{D}_i \,. \qquad (3)$$

The estimated variance for $\hat{N}_i$ follows immediately to be

$$V\hat{a}r\left(\hat{N}_i\right) = V\hat{a}r\left(A \bullet \hat{D}_i\right) = A_i^2 V\hat{a}r\left(\hat{D}_i\right) \qquad (4)$$

with associated standard error

$$\hat{S}E\left(\hat{N}_i\right) = A_i \bullet \hat{S}E\left(\hat{D}_i\right).$$

2)PARAMETER ESTIMATES ACROSS STRATA

Consider now the case where inferences are to be made across *L* strata purposefully selected because of some interest. The following formula naturally follows from the theory of stratified random sampling (Cochran 1977: 89-111).

3)

4)Density across Strata $\left(\hat{D}_i\right)$

The density across strata is defined as

$$D = \frac{\sum_{i=1}^{L} A_i D_i}{\sum_{i=1}^{L} A_i}$$

$$D = \frac{\sum_{i=1}^{L} N_i}{\sum_{i=1}^{L} A_i} = \frac{N}{A}$$

Using this definition of overall density *D*, the density estimator can then be expressed as

$$\hat{D} = \frac{\sum_{i=1}^{L} A_i \hat{D}_i}{\sum_{i=1}^{L} A_i} = \frac{\sum_{i=1}^{L} A_i \hat{D}_i}{A}$$

$$\hat{D} = \sum_{i=1}^{L} W_i \hat{D}_i$$

(5)

where the strata weights are defined as

$$W_i = \frac{A_i}{\sum_{i=1}^{L} A_i} = \frac{A_i}{A}.$$

The variance of $\hat{D}$ follows from the independent sampling within each stratum where

$$V\hat{a}r\left(\hat{D}\right) = \sum_{i=1}^{L} W_i^{\,2} V\hat{a}r\left(\hat{D}_i\right)$$

or

$$V\hat{a}r\left(\hat{D}\right) = \sum_{i=1}^{L}\left[\left(\frac{A_i}{A}\right)^2 V\hat{a}r\left(\hat{D}_i\right)\right]$$

(6)

Abundance across Strata $\left(\hat{N}\right)$

By definition, total abundance across strata is

$$N = \sum_{i=1}^{L} N_i = \sum_{i=1}^{L} A_i D_i$$

which leads to the estimator

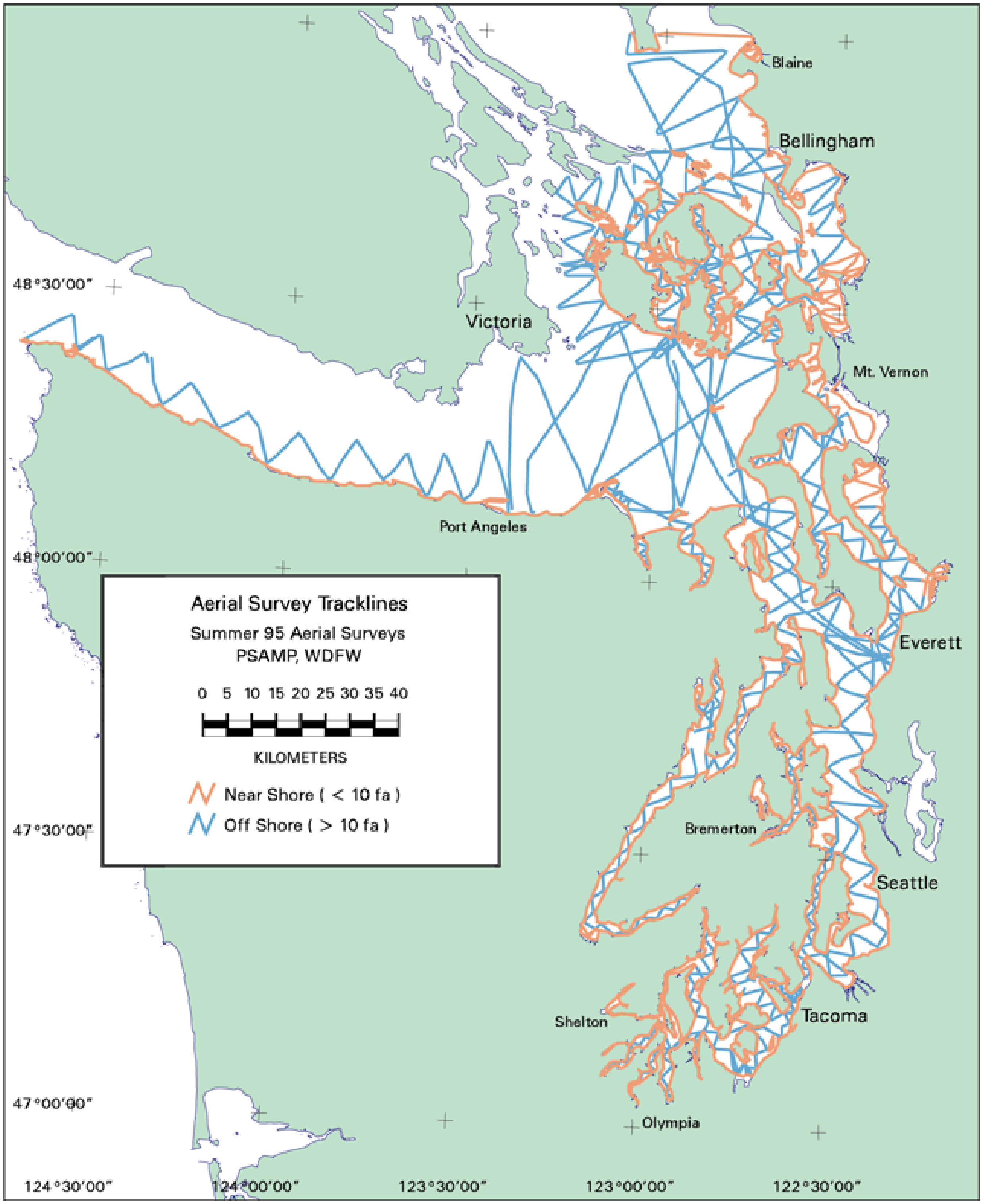
$$\hat{N} = \sum_{i=1}^{L} A_i D_i$$

(7)

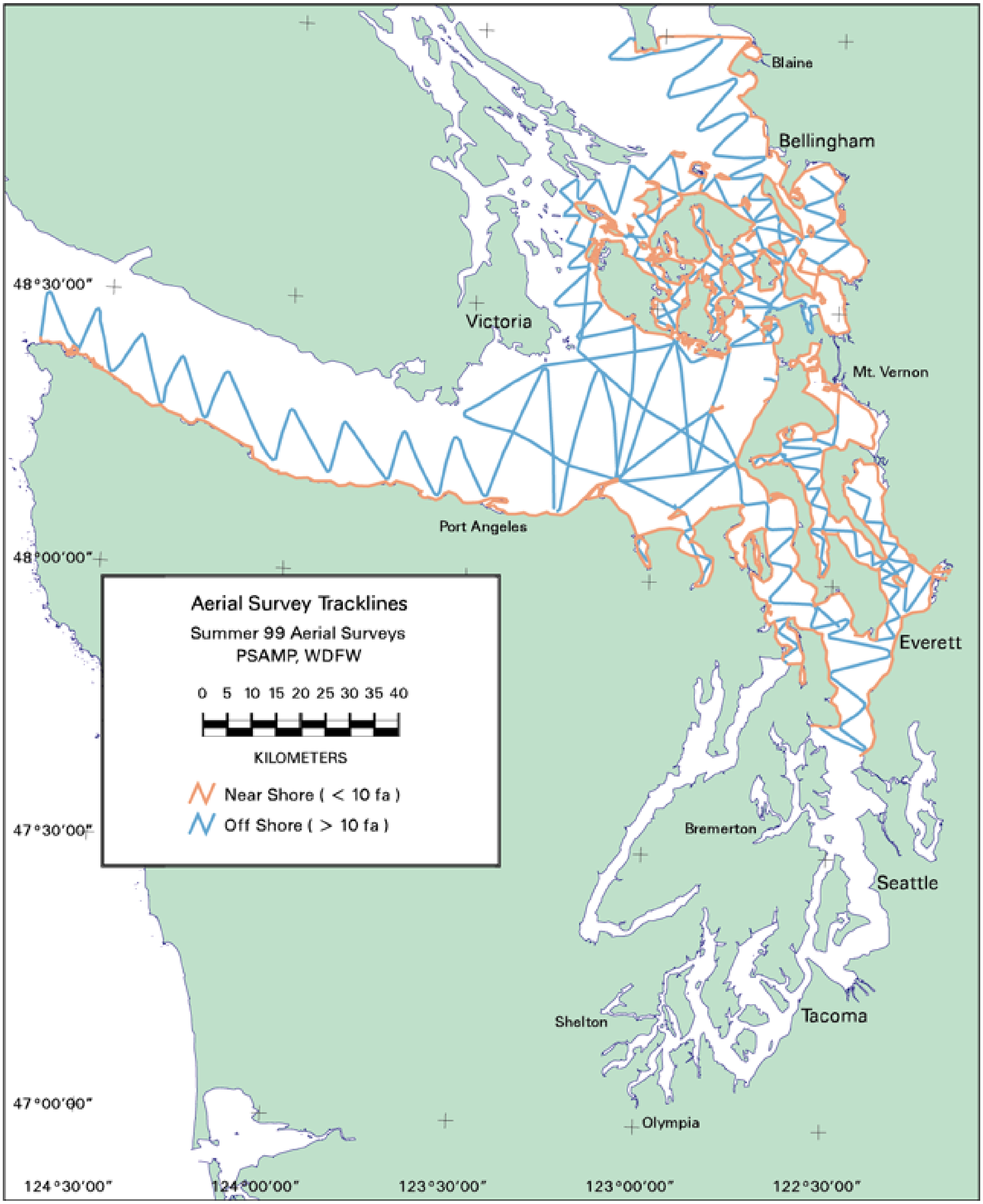
with variance

$$V\hat{a}r\left(\hat{N}\right) = \sum_{i=1}^{L}\left[A_i^{\,2} V\hat{a}r\left(\hat{D}_i\right)\right].$$

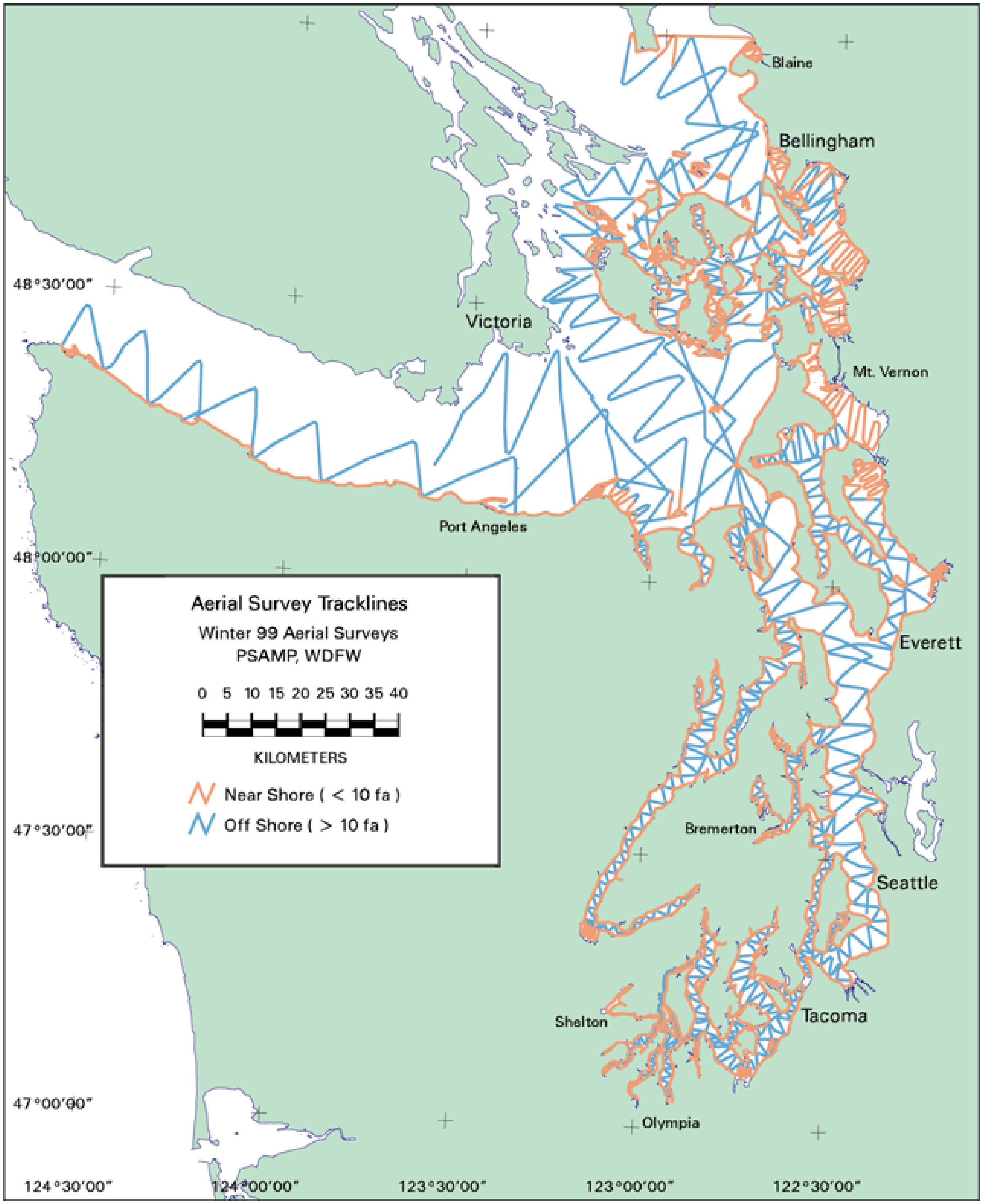
(8)



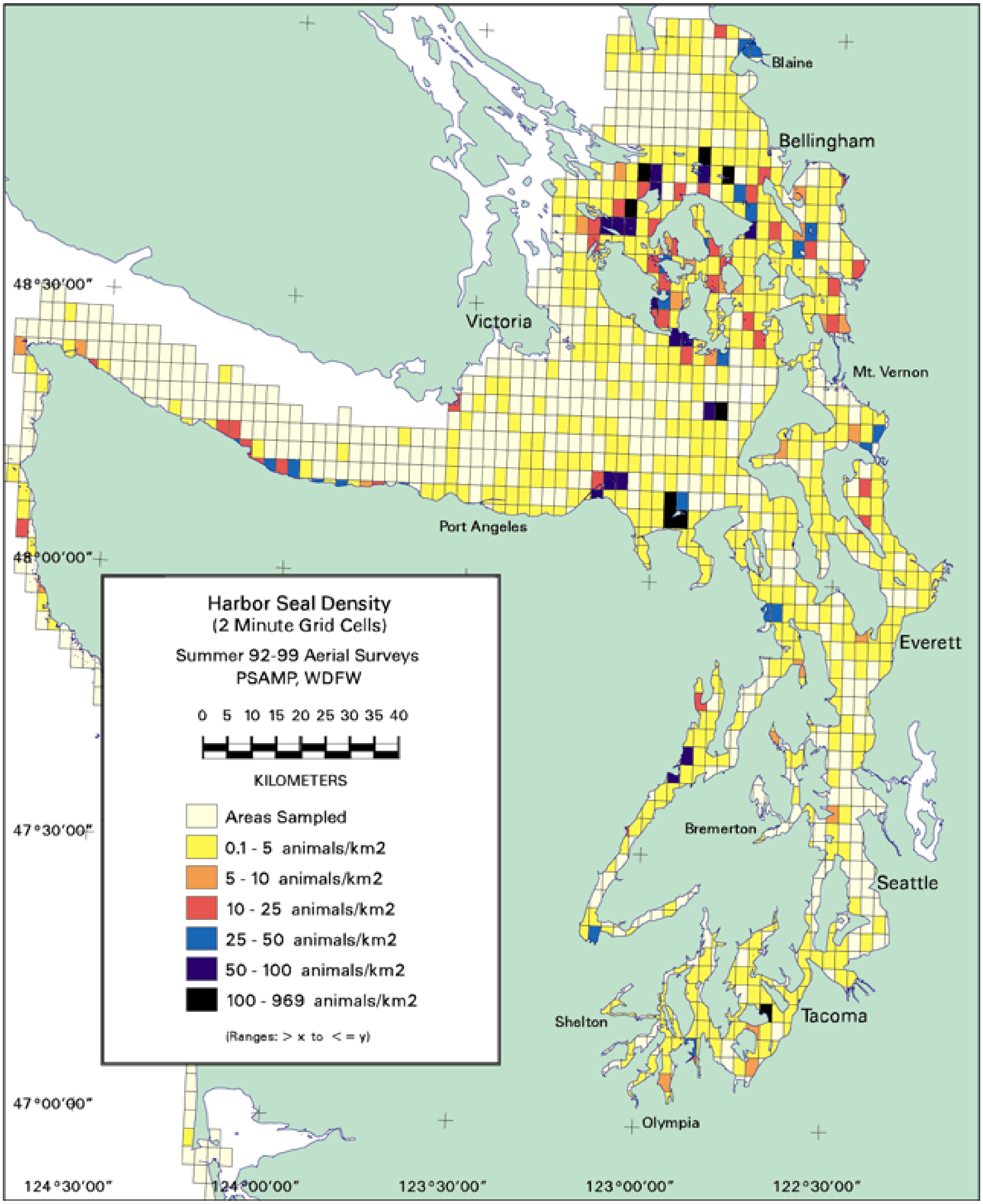
B.1. Typical Summer Track Line For 1993-96 After Changes from First Year Coverage, As Exemplified by 1995 Routes



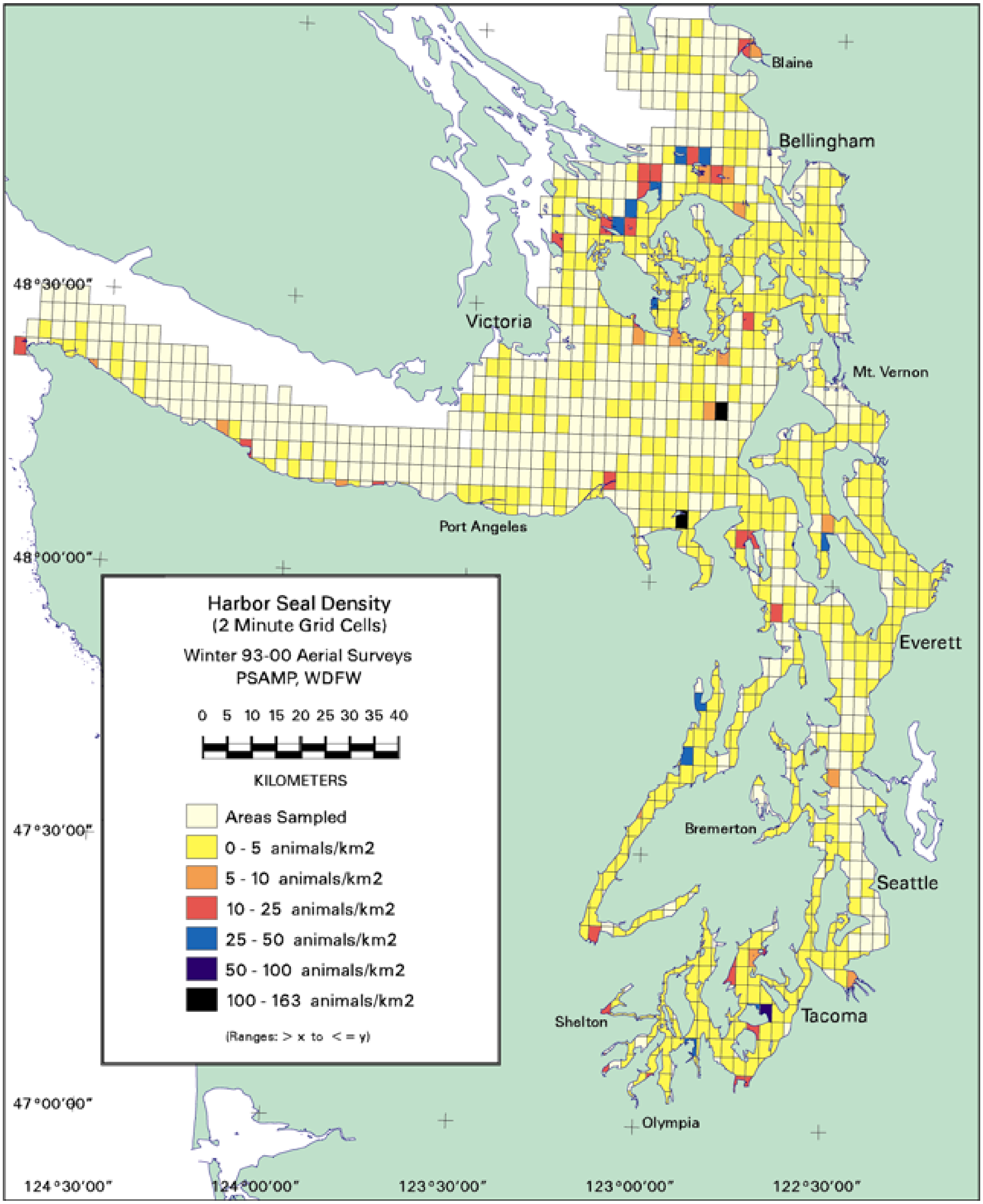
B.2. Typical Summer Track Lines for 1997-99 After Budget Cuts, Exemplified by 1999 Routes



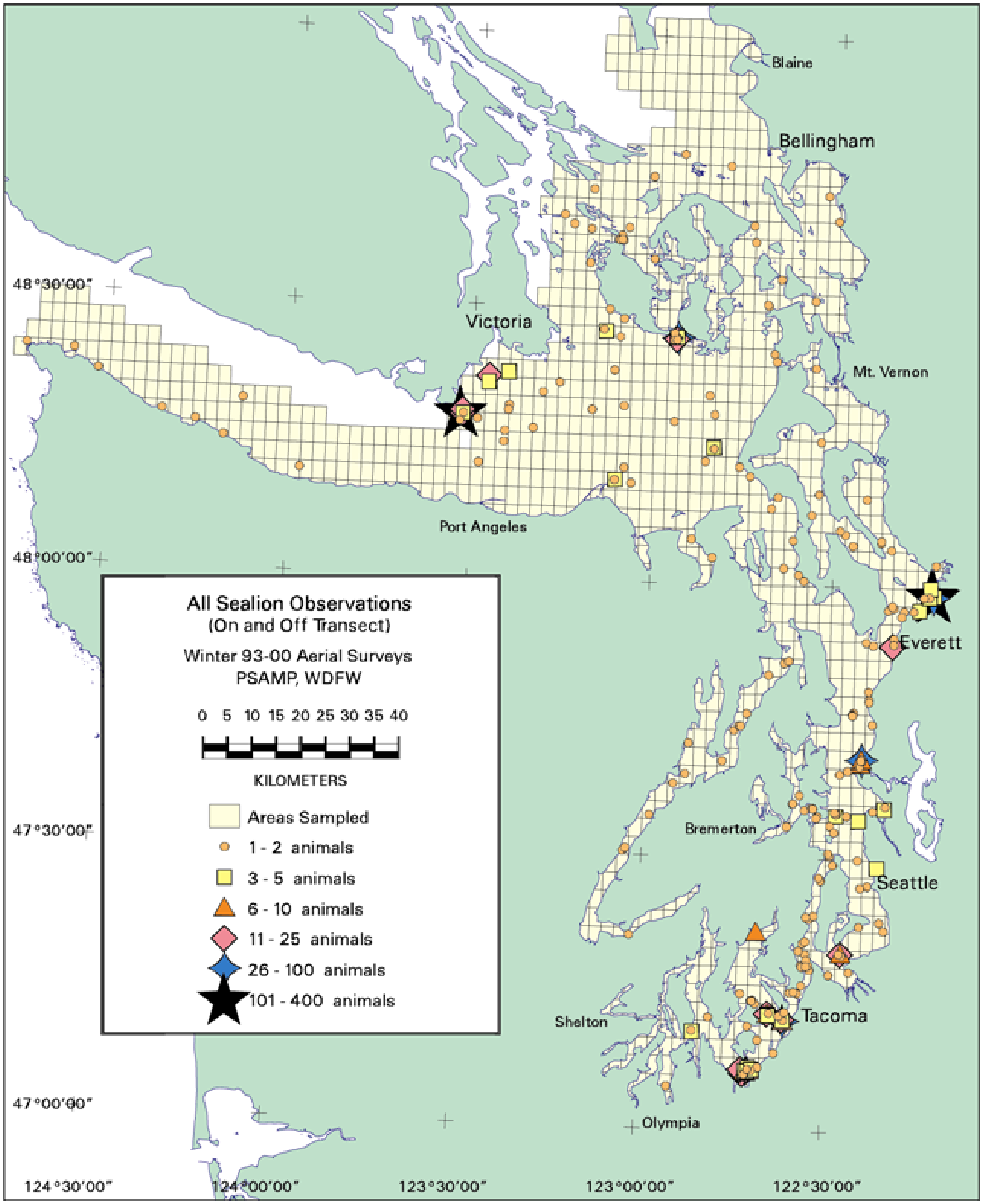
B.3. Typical Winter Track Lines for 1994-99, Exemplified by 1999 Routes



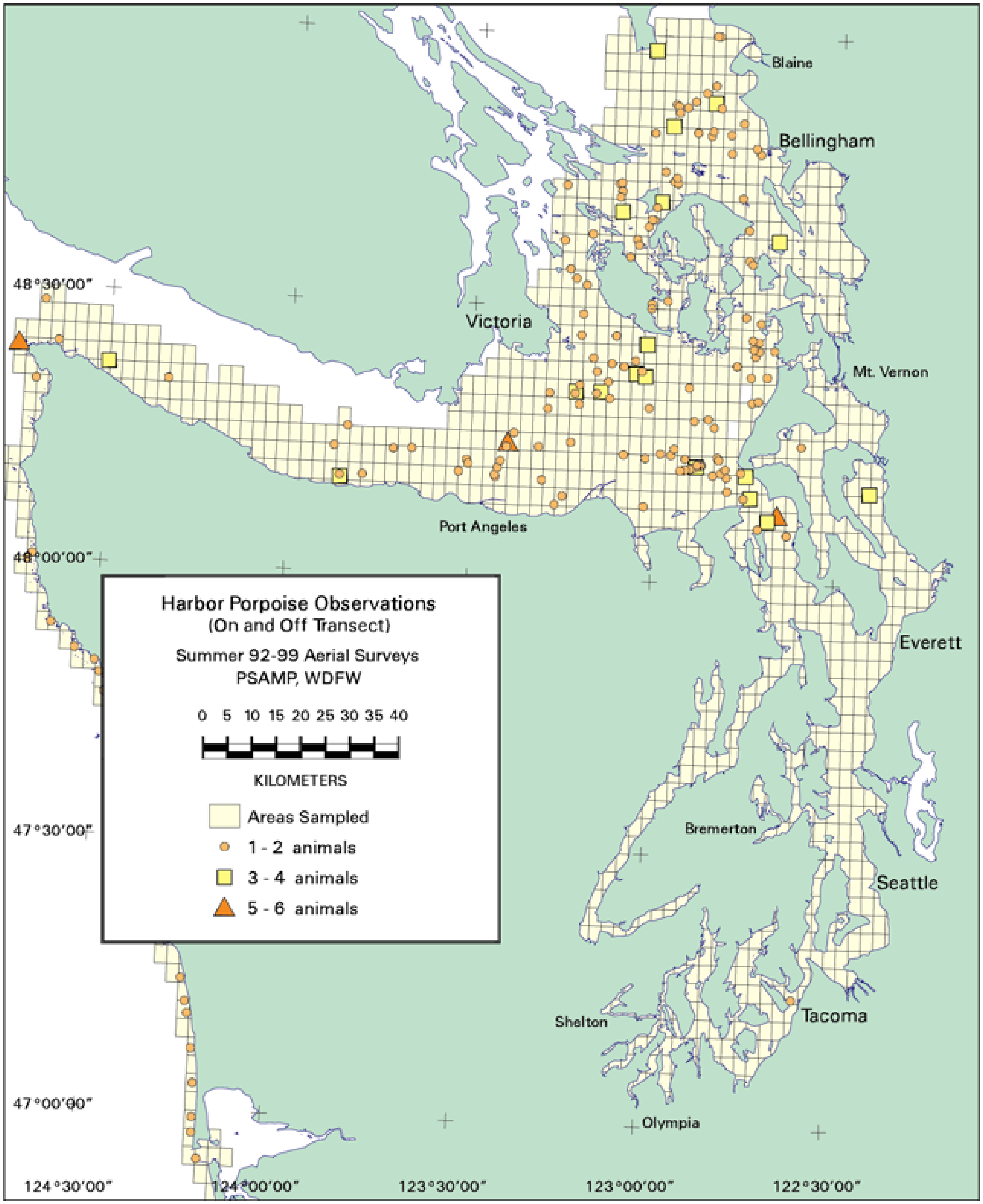
C.1. Mean Densities of Harbor Seals During July Aerial Surveys 1992-2000



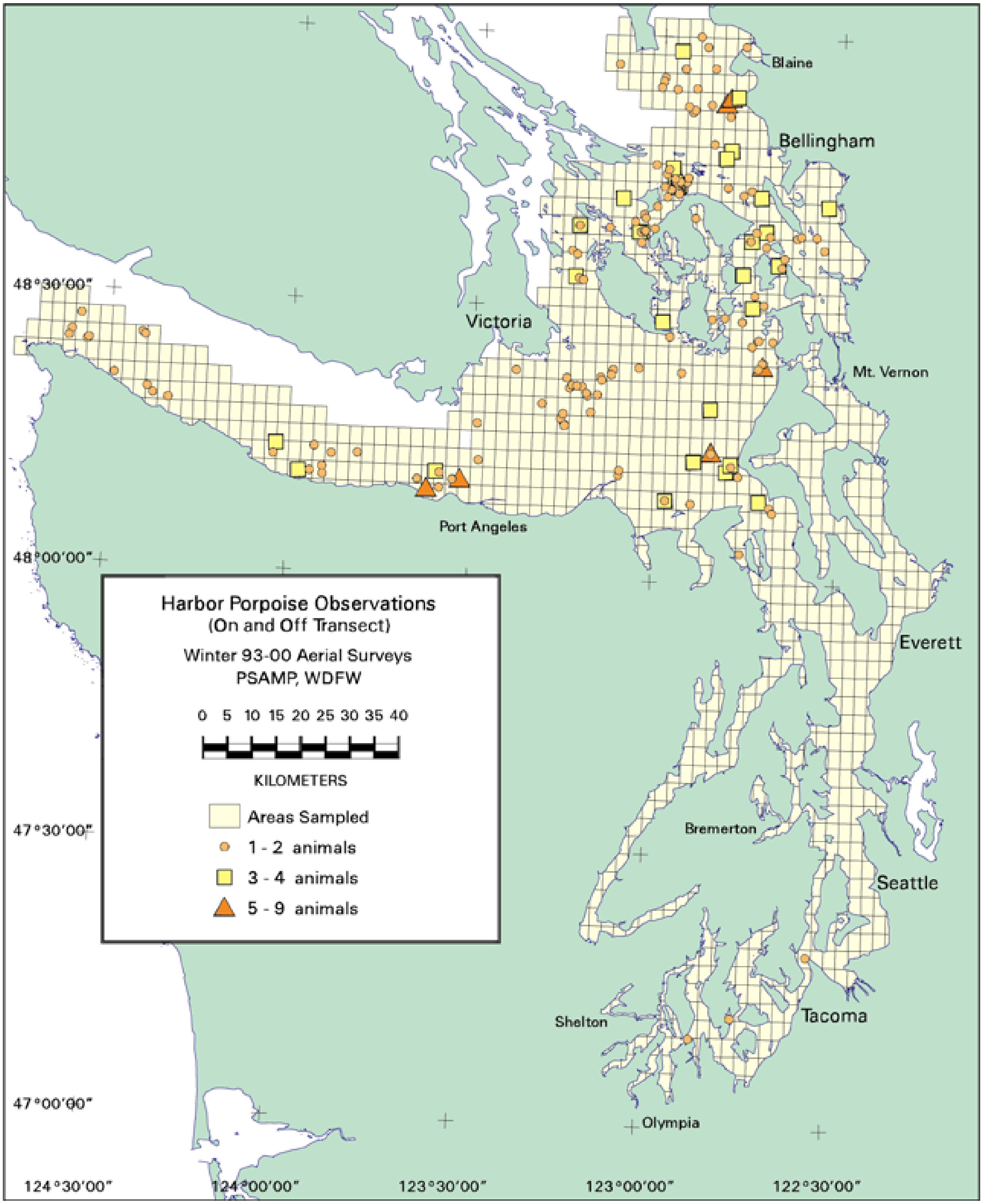
C.2. Mean Densities of Harbor Seals During Winter Aerial Surveys 1993-2000



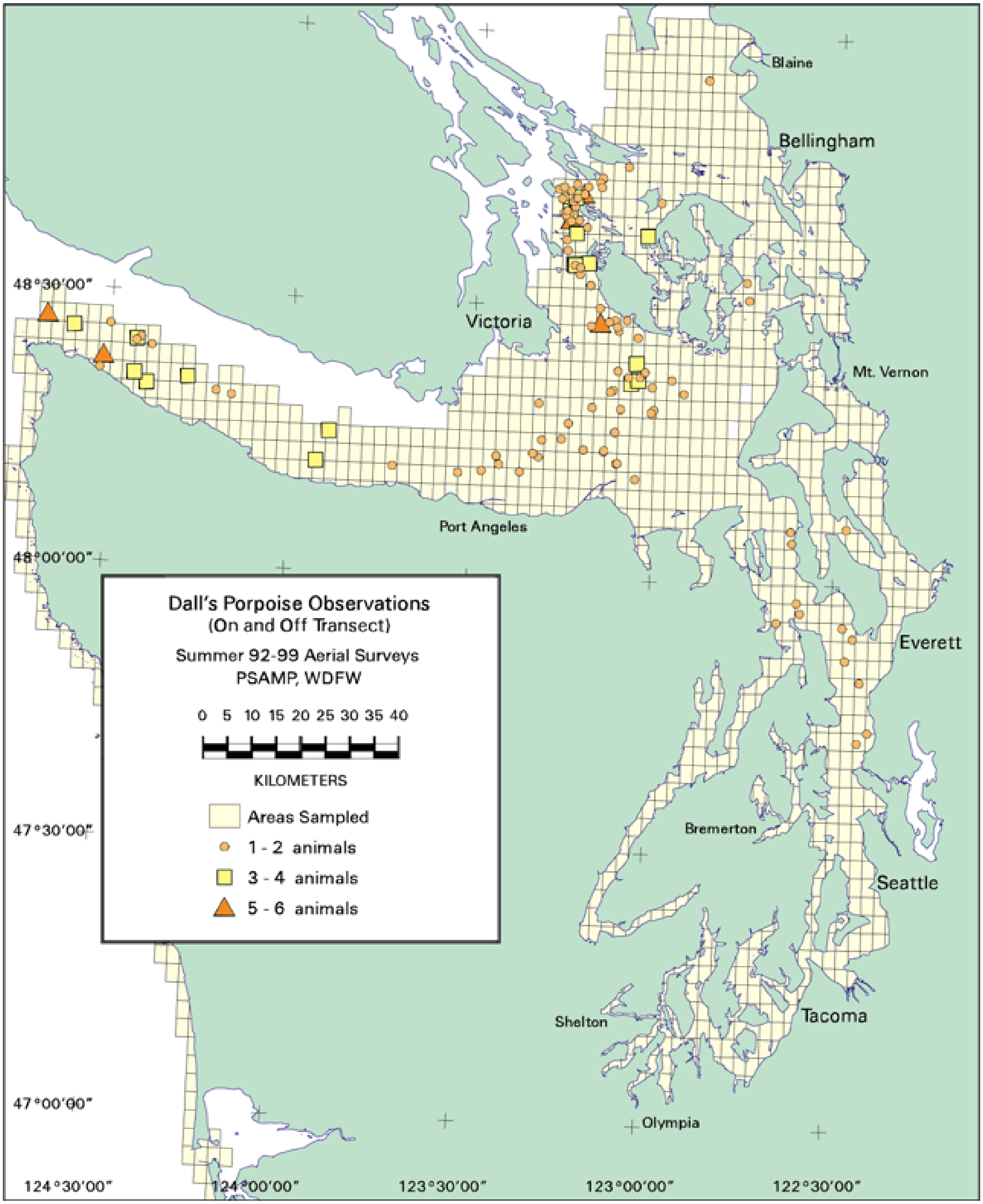
C.3. Sea Lion Observations During Winter Aerial Surveys 1993-2000



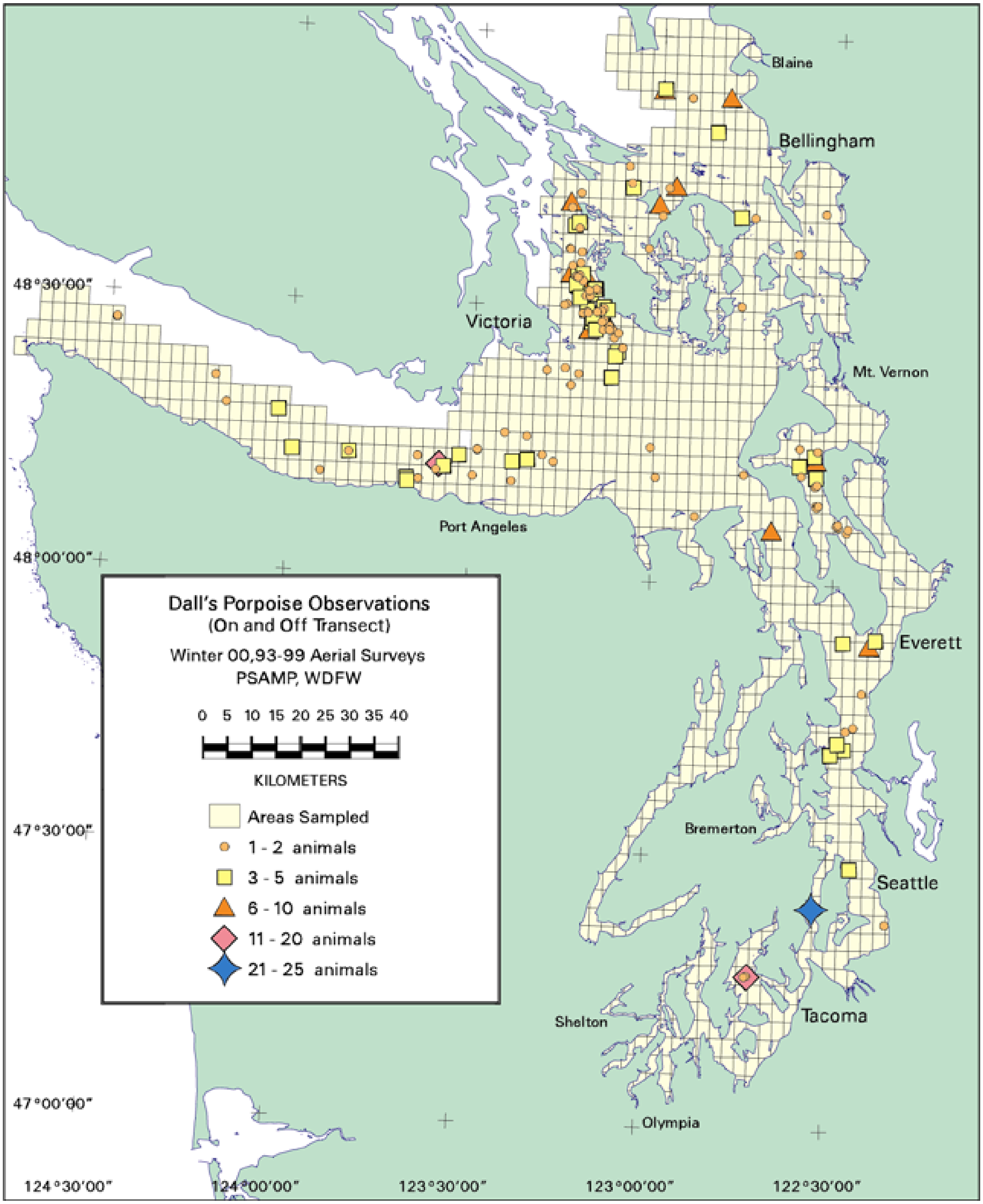
C.4. Harbor Porpoise Observations During July Aerial Surveys 1992-99



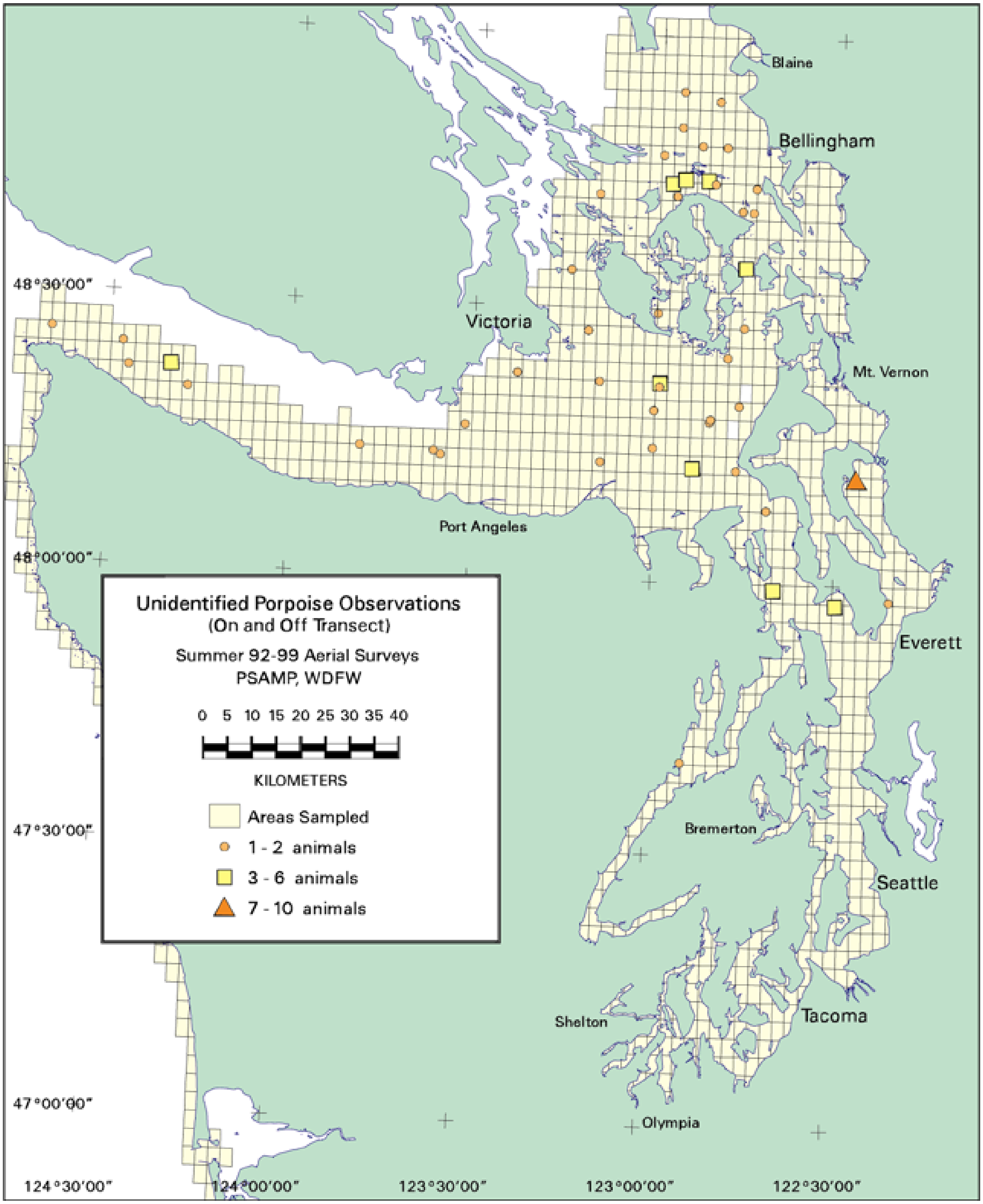
C.5. Harbor Porpoise Observations During Winter Aerial Surveys 1993-99



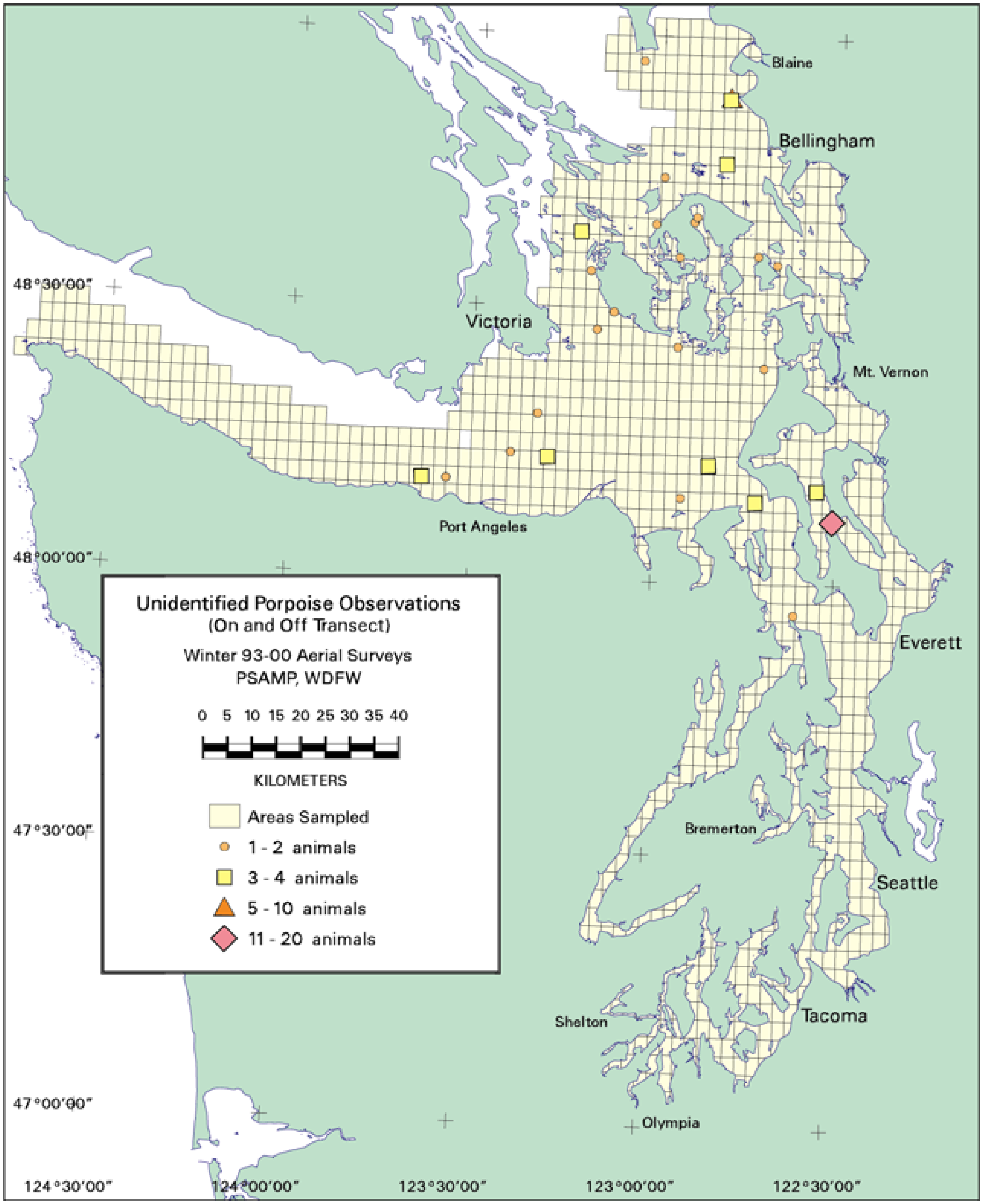
C.6. Dall Porpoise Observations During July Aerial Surveys 1993-99



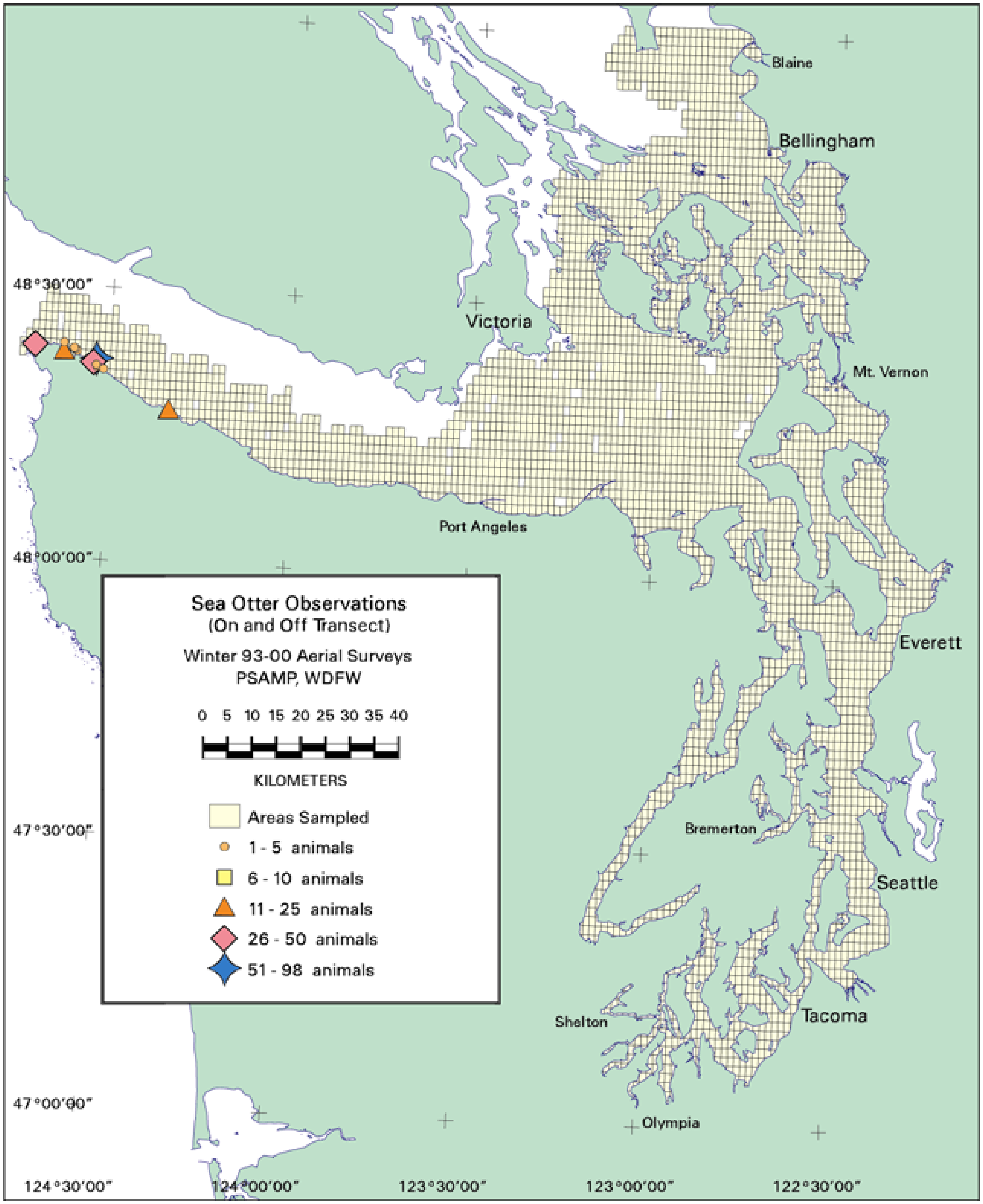
C.7. Dall Porpoise Observations During Winter Aerial Surveys 1993-99



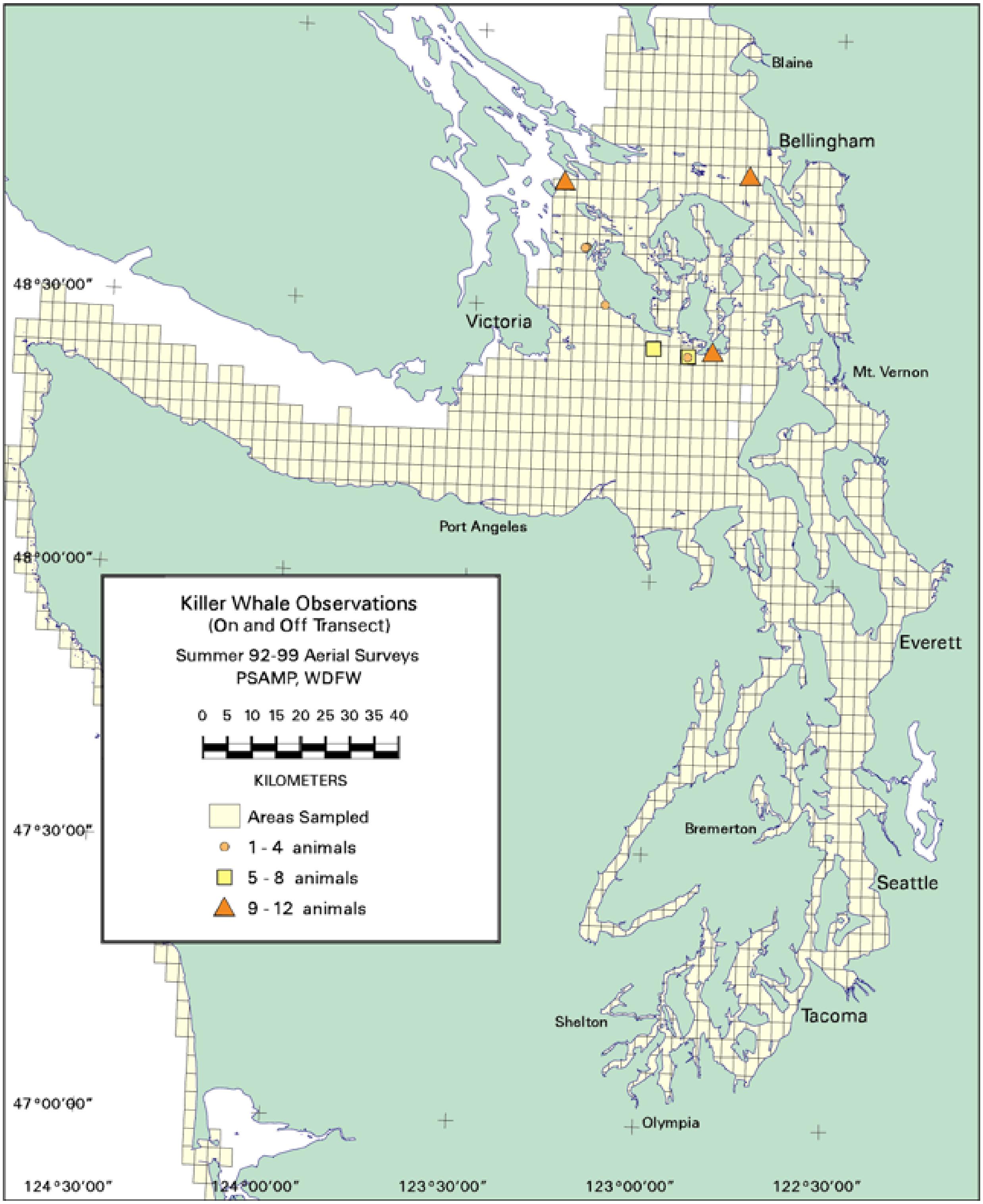
C.8. Unidentified Porpoise Observations During July Aerial Surveys 1993-99



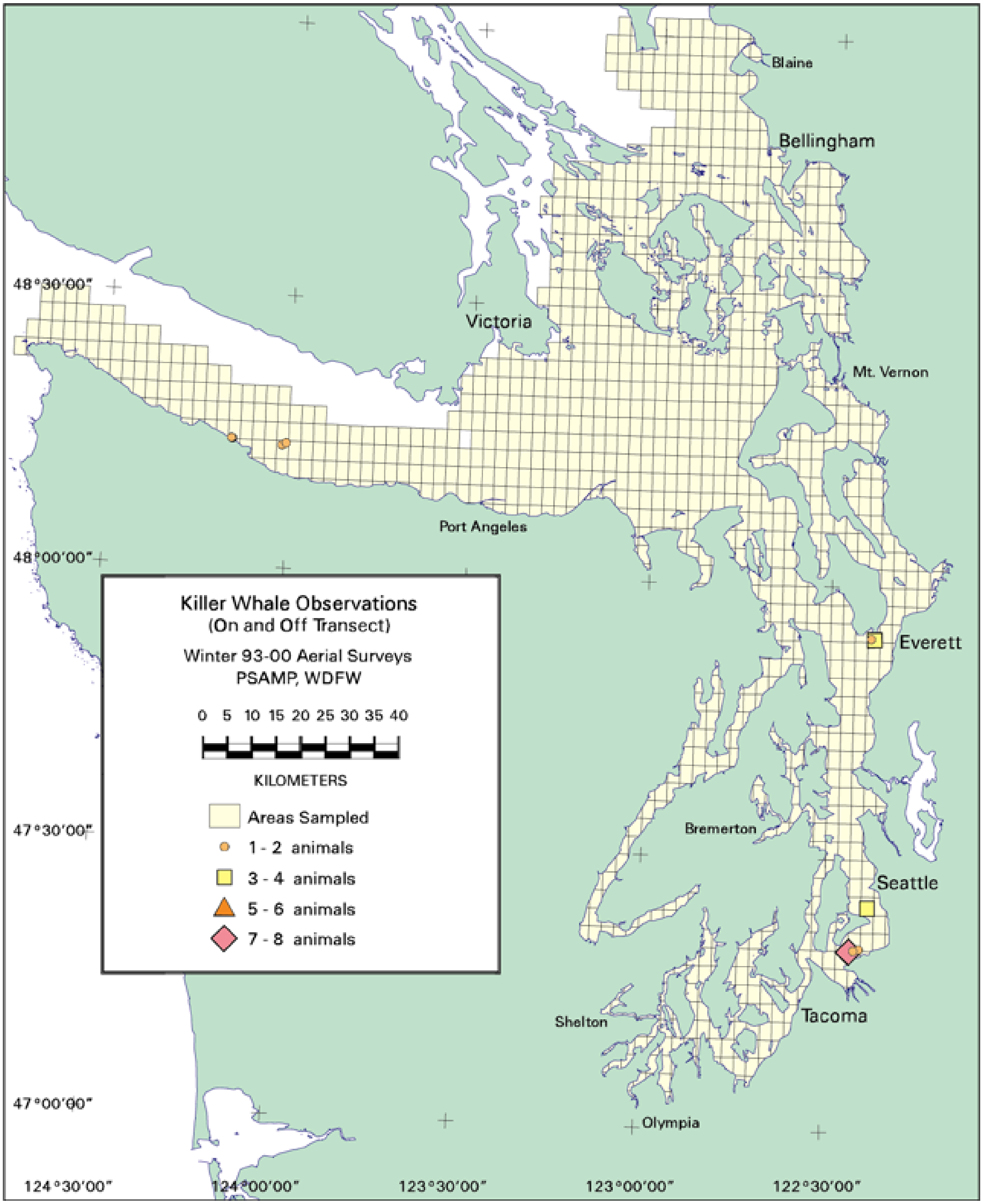
C.9. Unidentified Porpoise Observations During Winter Aerial Surveys 1993-99



C.10. Sea Otter Observations During Winter Aerial Surveys 1993-99



C.11. Orca Observations During July Aerial Surveys 1993-99



C.12. Orca Observations During Winter Aerial Surveys 1993-99