Field Report - 24 May 2006

Monitoring Black Scoter populations in Alaska, 2005.

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Abstract

We completed a second year of aerial survey observations to monitor Black Scoter (*Melanitta nigra*) breeding populations in western Alaska tundra wetlands. The stratified survey design was based on analysis of intensive systematic surveys flown 1989-1997. We flew 8 survey days from 12-21 June 2004 and 11 survey days from 13-24 June 2005. For each year and observer, we estimated aerial detection rates with independent double-count observations made approximately every fourth transect. The visibility-corrected estimates of breeding populations after combining all 2004-05 data were 108,100 Black Scoter (standard error SE = 13,300), 198,900 (SE = 28,600) Greater Scaup (*Aythya marila*), and 42,200 (SE = 13,200) Long-tailed Duck (*Clangula hyemalis*). Compared to the similar surveys flown 15 to 7 years ago, estimated total population size indicated declines with average annual change at -3.1% for Scoter, -5.2% for Scaup, and -3.5% for Long-tailed duck. Other factors associated with flying the survey approximately 2 weeks later in the season were confounded with, and may account for, these apparent changes in population size.

Introduction

Our objective was to estimate annual population size of Black Scoters on 154,475 km^2 of breeding habitat in western Alaska. Visibility-corrected estimates of population size should have sufficient precision to detect a significant change, if it should occur, within a relatively short period. Monitoring becomes useful when it can rapidly detect population response to change such as a shift in hunting regulations, other management practices, or environmental conditions. We set a specific goal based on the standard recommended for monitoring landbirds (Bart et al. 2004). With 10 years of survey data, we wanted to verify any trend equivalent or greater than 3.41% average annual change in abundance (i.e. 50% change in 20 years, 29.3% change in 10 years) with a statistical significance level at $p<0.10$ and 80% power. According to an approximate formula for statistical power (Gerrodette 1987, eq. 20), an annual survey with a sampling error coefficient of variation (CV) of <12.5% would meet this goal.

The North American Waterfowl Breeding Pair and Habitat Survey (WBPHS) has sampled wetland habitat in 11 Alaskan strata with 5871 kilometers of transects flown between 15 May and 15 June every year since 1955. In the 4 tundra strata, observations from 1977-2005 indicate an increasing trend for Scaup, a decline for Long-tailed Duck, and a slight decline for Scoter (Conant and Groves 2005). Interpretation of these trend data can be questioned because the survey provides less than ideal timing for scoters, limited species identification, and restricted sample coverage. Recent discussion of problems caused by inadequate sampling design and unfounded assumptions of constant detection rate (Anderson 2001) focuses attention on the bias, precision, and scientific rigor of the WBPHS aerial survey in Alaska. In addition, since the design of the WBPHS survey, the results from more intensive aerial survey data have proven useful for managers to assess wildlife value on specific land parcels, to determine the size and trend of regional populations for subsistence co-management, and to provide localized bird density information to guide land-use and development permit decisions.

Methods

Survey Design

We based the survey design on analysis of observations from aerial surveys flown in 1989-97 to inventory the distribution of waterfowl in tundra wetlands of western Alaska. Transects were flown and observations recorded in late-May to mid-June for 2 or 4 years in each region (Table 1). Straight-line east-west transects crossed all wetland habitat at approximately 7.4 km systematic intervals. All species of large waterbirds sighted within 200 meters of the aircraft, including geese, swans, cranes, ducks, loons, gulls, jaegers, and terns, were recorded by a left-seat pilot observer and a right-seat observer. Transects were flown in float-equipped Cessna 206 or 185 aircraft at 30-46m altitude and 135-157 km/hr. The combined data set contained 46,344 sightings with species, group size, and geographic location. These data are summarized in various USFWS unpublished reports (http://www.r7.fws.gov/mbsp/mbm/waterfowl/surveys/ebpsare.htm) for Yukon Delta (Platte and Butler 1993), Bristol Bay (Platte and Butler 1995), Innoko (Platte 1996), and Selawik (Platte 1999).

These aerial surveys indexed the distribution and relative abundance of all species present. Observers made no special effort to concentrate attention on scoters, or to identify every scoter seen. Less experienced observers cannot reliably identify the species of scoter when they are at distance or under backlit conditions, and at times, definite identification is impossible. Of the species identified on these 4 tundra surveys, 93% were Black Scoter, 5% Surf Scoter (*Melanitta perspicillata*), and 2% White-winged Scoter (*Melanitta fusca*), but of all the scoters seen, 22% were not identified to species. In data analysis used to design the present survey, we combined all identified and unidentified scoters. The combined scoter species observed are hereafter simply referred to as Black Scoter (BLSC), the prevalent species of tundra wetlands.

The majority of scoter on the historic expanded surveys were seen as pairs (Table 2). Of all scoters observations, 68% were in pairs, 26% as singles, 5% in groups of 3-10, and 1% in flocks of more than 11 birds. For comparison, scaup observations were 54% pairs and 42% singles, and long-tailed duck were 38% pairs and 59% singles. The largest proportions of scoters in flocks (16% and 12%) were for the surveys in the Bristol Bay region flown at the earliest dates, 25-31 May.

The Innoko region had too few scoter to justify its inclusion in the standardized annual BLSC survey (Table 3). Black Scoters do not prefer the mixed boreal and boggy habitats of this region. In addition, the proportions of surf and white-winged scoter were relatively large in comparison to their proportions in more coastal tundra areas.

We have flown additional expanded inventory surveys. Observations from Yukon Flats (Platte and Butler 1992), Koyukuk and Kanuti (Platte 1999), Tanana-Kuskokwim (Platte 2003), Kenai-Susitna (USFWS MBM Anchorage unpubl. data), and the annual Arctic Coastal Plain (ACP) survey (Mallek et al. 2005) combine to provide statewide estimates for scoters, scaup, and long-tailed ducks (Table 3). Scoters species were not distinguished on the 1989-91 Yukon Flats surveys, however recent surveys flown in mid-June showed that 99% were white-winged scoter (Mallek 2005). The WBPHS surveys flown before 1 June on Yukon Flats reported higher proportions of surf scoter and in some years black scoter (Conant and Groves 2005). Although patterns are not understood, we assume that surveys flown earlier will in some years include birds still in migration and this influences population numbers, species composition, and group size. The area sampled in the current BLSC survey design includes 95% of all Black Scoter from all the expanded survey estimates flown statewide. This proportion is approximate because we have not sampled all the wetland areas (e.g. Gulkana, Copper River Delta) and we did not sample the many scattered lakes peripheral to the large contiguous wetland boundaries. Nevertheless, the small area and low densities at these locations ensure such errors are small for scoters.

The tundra areas sampled by the current BLSC survey also include all but a few thousand long-tailed ducks except for large population sampled by the ACP survey (Mallek et al 2004). Statewide, we estimate that 69% of both species of scaup, and 48% of the long-tailed ducks are included in the BLSC survey area (Table 3). Scaup species are combined in aerial observations because Lesser Scaup (*Aythya affinis*) cannot be distinguished from Greater Scaup. We assume that most Lesser Scaup nest in boreal and mixed northern forest habitats and are rare in tundra wetlands of western Alaska. Therefore, the current survey samples nearly all the Greater Scaup breeding populations outside of those sampled by the ACP survey on the North Slope.

We re-analyzed the historic expanded survey data from Bristol Bay, Yukon Delta, Seward Peninsula, and Selawik by combining all years, crews, and regions, as if they were flown in a single year. All 24,260 km of transects, that took a total of 49 days to fly, provided a systematic sample of 6.3% of the area. We plotted all scoter sightings and determined isopleths depicting the relative density. In each region, we reanalyzed the same data 4 times, once with no stratification, and three times using alternate stratification boundaries that followed a different contour line of density to delineate between relatively high density and relatively low density. Within each of the 4 regions, the stratification boundary that resulted in the smallest standard error (greatest precision) for the total estimated population in that region was adopted for the final design. We further smoothed boundaries, combined some polygons, and dropped other small isolated polygons.

The small patches of tundra wetland on the southern Seward Peninsula and on the Alaska Peninsula presented a practical problem. The combination of low sampling intensity, short transects, and remoteness from the remainder of the survey area make these transects very expensive to fly. Each area would require almost a full day's effort even though only a small part of that time would actually be on-transect observing birds. We designated these areas as separate strata and decided to sample them periodically, for example only every 4th year but at 4 times the intensity. The result was a design with 10 strata (Fig. 1) that was a practical combination of the best preliminary designs examined.

We decided to count only species of seaducks, Black Scoter, White-winged Scoter, Surf Scoter, Greater Scaup, and Long-tailed Duck. White-winged Scoter and Surf Scoter were identified when possible, but these are combined with Black Scoter for any comparisons with historic data. We analyzed any unidentified scoters as Black Scoter. Scaup and Long-tailed ducks were included primarily to gather information on possible misidentification of Black Scoters. We selected indicated total birds as the population index measure, which we calculated as twice number of singles, plus pairs, plus any birds seen in flocks. This measure is routinely used for most waterfowl species although there are no data in mid-June from tundra habitat that confirms that an observed single male scoter likely indicates an unseen female. Sex ratio of Black Scoter on nesting areas is assumed equal to 1:1.

The systematic transect lines were generated beginning at a random start point near the southwest corner of the maximum rectangular extent of the study area. The east-west transects are sections of great circle routes between 2 points of equal latitudes at each edge of the study area extent. The spacing between lines was set at about 30 km to achieve a maximum practical coverage that could be flown in about 7 days of flight time with about 400 km on transect flown per day. We divided this spacing by 4 to produce a rotating panel of equally spaced lines. Every fourth line was selected to be flown in a given year. To increase efficiency, peripheral areas will not be sampled every year but will instead be flown periodically at greater intensity to increase efficiency and reduce cost.

Survey Timing

Timing of the proposed survey was 15-30 June to monitor the distribution and trend for only the breeding component of the total population. Scoters appeared to have a relatively lengthy optimal period for observing pairs on breeding territories (Anderson, unpubl. data, Aropuk Lake timing survey 2002-03). We balanced 3 considerations in selecting the survey timing. The first factor was avoiding flocks of birds associated with spring migration and staging. Based on 14 black scoters marked with satellite transmitters in April 2003 at Nelson Lagoon (Sea Duck Joint Venture, J. Schamber, unpublished data), spring migration flights leaving the Alaska Peninsula began in early May (average10 May, range 27 April to 2 June, n=14 males). Although the captured birds in the marked sample were apparently adult-plumaged but non-breeding males, we assumed that timing of spring migration for breeding pairs moving from coastal waters along the Aleutians, Bristol Bay, South-central and South-east Alaska was similar. It appeared that birds progressively stage in marine coastal waters at Kvichak Bay, Hagemeister Straight, Chagvan Bay, Kuskokwim Bay, Etolin Straight, and Hazen Bay, until they are adjacent to breeding areas by mid-May. Movement into inland areas began as rivers and lakes become free of ice. Although not yet well documented, some flocks of scoters in spring migration use traditional concentration or resting areas on large rivers or lakes. This is observed on the Yukon-Kuskokwim Delta (YKD) near the Kuskokwim and Johnson Rivers near Bethel. These spring flocks may have a high proportion of non-paired first, second, or third year males. Perhaps such groups are more typical of white-winged scoter than for black scoter. In any case, survey timing should be delayed until after all flocked birds move through an area. Timing of flights probably differs among years due to ice conditions, but at least for the YKD, flocks typically have departed by about 7 June.

A second factor, which admittedly included some guesswork, involves trying to avoid the temporary movement of non-breeding birds to breeding areas. Of the 7 birds detected at inland locations, only one bird remained into summer, 6 June to 26 July, in an area near Becharof Lake (J. Schamber, unpubl. data). For the other 6 birds, the dates of arrival at various inland locations averaged 20 May but then departure occurred by 10 June, with a range between 11 May and 18 June. These males could not have successively bred because their departure was several weeks before egg-laying and incubation that typically begins about 1 July (P. Flint and J. Schamber, unpubl. data). The aerial breeding population survey should be delayed until after these non-breeding males depart from their brief "prospecting" visit to inland nesting areas. If the survey is conducted too early in some years, a variable fraction of observed birds could include these soon-to-depart non-breeding males. In 2003, a year with early nesting chronology on the YKD, the departure dates of the satellite-tagged birds moving back to nearby coastal marine waters occurred from 4-18 June. The objective for BLSC survey does not include monitoring the population of non-breeding birds that spend most of the year in marine waters (e.g. Kamishak Bay, Kvichak Bay, and Kuskokwim Bay).

A third factor to include in determining survey timing is to complete the survey before the incubation of eggs begins by about 1 July. Similar to male Spectacled Eider (*Somateria fischeri*), male Black Scoters depart from the nesting areas during early incubation, and the females become much less visible as they spend nearly all their time incubating eggs. This pattern of behavior is differs for male Long-tailed Ducks that remain on the nesting territories and are observed as singles during the incubation period, and for male Scaup that aggregate into small groups but tend to remain on nearby lakes. The degree of synchrony in the timing of Black Scoter nesting within and between areas is not well documented. As we learn more about the movements and behavior of non-breeding and breeding male Black Scoters in various areas and habitats, we can refine timing the survey. For now, between 15 and 30 June is reasonable.

The data collected in the Aropuk Lake area of YDNWR by Paul Anderson throughout June 2002 and 2003 are consistent with these observations. The 5 surveys flown 3-10 June averaged 16% more scoters (28% more sightings) observed than the average number seen on the other 9 days of surveys between 11-24 June. The largest source of variation in the number seen was attributable to day rather than transect, observer, seat, replicate, year, or week.

Flight procedures and data recording

We followed the standard aerial survey protocol used on the WBPHS and other surveys flown in Alaska (Larned et al. 2005, Mallek et al. 2004, Platte and Stehn 2005). Transects were flown at 30-45 m at 145-170 km/hr in a Cessna 206 aircraft on amphibious floats. A Global Positioning System receiver maintained accurate positions on a moving map display and a radar altimeter referenced altitude. The pilot observer recorded observations on the left side within 200 m of the aircraft's centerline. Departing from standard protocol, the second observer sat in the rear-seat and recorded birds within 200 m of the aircraft on the right side. The right-front seat was not used at any time.

The 2 observers independently voice-recorded their observations using a computer program (J. Hodges, USFWS Juneau) that simultaneously captures time and aircraft GPS coordinates. Using the data transcription part of this same program, each observer produces a data file including transect, date, time, geographic coordinates, species, group size, and descriptive notes for each observation. For the Izembek and Port Moller transects that were flown in a small 2-seat Supercub aircraft, the seat configuration and space restricted data collection equipment to the rear-seat observer, who simply recorded observations and waypoints on paper. Intercom voice communication from the front-seat pilot observer allowed the rear-seat observer to record both sets of observations. When observing on the same-side, this required complete honesty to keep the double-count observation data independent.

Detection Bias

The index ratio is defined as the survey result divided by the parameter of interest (Bart et al. 1998, Bart et al. 2004). For aerial surveys, this ratio is the detection rate, the indicated total bird aerial population index divided by an estimate of actual size of the breeding population. The inverse of the index ratio is the visibility correction factor (VCF), a multiplicative factor used to convert the aerial index to an estimated population size. A practical method to estimate the index ratio (the number of birds seen per bird actually present within the transect strip) is a challenge for aerial surveys. For several uses of monitoring data, the magnitude of the index ratio may not be of concern. If the index ratio is essentially constant across geographic areas, the index count still provides a valid measure of relative density. If the index ratio is constant over time, trend of the indexed population still is a valid measure of trend for the actual population. On the other hand, serious bias (error) can result when spatial or temporal variation occurs in the index ratio (Anderson 2001). In Alaska, the WBPHS uses constant VCF adjustments, for example 1.167 based on aerial counts of scoters made from a helicopter versus fixed-wing platforms in tundra habitat (Smith 1995, analysis of B. Conant, C.P. Dau, and W.W. Larned, unpubl. data). This serves to rescale the population index to a numeric value with less bias for mean population size, but it does not address the potential problem of temporal change in the index ratio. Any long-term trend in the index ratio will bias the estimated population trend. Variability in the index ratio, even without a consistent trend, will decrease the precision (increase noise) of both the estimated mean population size and the estimated trend.

Because aerial survey observers do not detect all birds within the transect strip ("At 100 feet and 100 mph, no one sees 100% of anything."), expanding the density of observations to the total area still underestimates the population size. Detection rate varies because of change in: a) observers that have different inherent skill, b) observer ability improving with experience, c) aircraft type and window configuration, d) wind, sunlight, glare, and other weather-related factors, e) location of the bird in the habitat, and f) bird behavior influenced by date, time of day, stage of the nesting season, and g) seasonal chronology of vegetative growth. Our objective was to estimate average detection rate for each species, year, and observer. Although many factors affect visibility within each day (e.g. wind, glare, flight direction, fatigue, habitat), it is very difficult to obtain both detailed data on such covariates and enough observations to estimate detection rate for each set of conditions. Fortunately, this is not necessary. A reliable estimate of the average detection rate can be obtained if adequate and representative sampling is maintained throughout the entire survey period. Average detection rate is the appropriate correction for the average aerial index density of birds as calculated for each species, stratum, observer, and year.

We followed a procedure integrated with the standard survey to obtain detection rates. The required flight range, gross weight limitation, and fuel capacity of the available aircraft prevented using a third observer, therefore we sacrificed a portion of the observations of the right-seat observer to make double-counts on the left-side.

In the historic data, 1,465 transect sections covered 9,703.9 km^2 observed in sampling 154,285 km^2 of nesting habitat. The overall average density was 0.892 indicated scoters per km^2 (SE = 0.0356), or 0.446 pairs per km^2, or 2.24 km^2 per pair. Therefore, if evenly spread over the entire area, scoter pairs would average 5.6 km apart along the 400m wide strip transects. At 2.362 birds per km^2 in the highest density Seward Peninsula stratum, the linear spacing between pairs would still average 2.12 km or 51 seconds apart at a flight speed of 150 km/hour or 41.7 m/sec. Their sparse distribution made it feasible to obtain distinct matching of birds in the double-count transects based on their locations. We did not observe scoter or scaup to dive and they rarely flew in response to the aircraft, making detection and matching observations relatively easy in comparison with some other species.

We estimated visibility detection rate using independent double-counts (Seber 1973, Magnussen et al. 1978, Pollock and Kendall 1987, Graham and Bell 1989). On every fourth transect, the rear-seat observer sat behind the pilot instead of the usual position in the right-rear seat. Adjustment was made if the fourth transect was unusually short or in an area with no birds. In addition, on some days beginning in 2005, double-count observations were made on adjacent pairs of transects flown for each 4-pairs of transects due to the difficulty of switching seats without loosening the microphone, mouse, GPS, and power connections to the laptop computer. We estimated the detection rate for the pilot in the left-front seat and for the observer in the left-rear seat. We assumed that right-rear and left-rear seats have equivalent average visibility because the window and seat configuration are the same on either side.

The matching observations between the front and rear seats were determined by comparing the independently recorded data for geographic location, group size, species, observed location in the habitat, and notes of bird behavior. Added descriptive information on observations increased our confidence in the determination of matches. With accumulation of enough data over many years, these additional notes may also allow for subdivisions (e.g. singles vs. pairs, nearshore vs. open water, flock size) having more homogeneous sighting probability within each group, thus reducing the potential bias caused by heterogeneity in the estimate of average detection rate (Rivest et al. 1995). Observers recorded obvious categories of bird behavior (flying, swimming, standing), distance from aircraft in relation to the 200 m strip (near, mid, far, off), and habitat location (pond, lakeshore, river), as well as species and group size.

Population change

We used loglinear regression to calculate the average growth rate from the 1986-2005 WBPHS population data. The natural logarithm was taken of each population estimate with a minimum of 50 birds substituted for any stratum estimated at zero birds. Converting back from the log scale, annual growth rate is exponentiated from the linear least squares regression slope of log numbers, R = EXP(*lnslope*). Percent annual change is %chg = (R-1)/100. Standard error of the growth rate is SE_R = EXP(*lnslope*)**selnslope*, where *selnslope* is the standard error of the slope in the log scale. Standard error of the residuals following regression is SE_{resid} = EXP(*lnmean*)* (*lnresidmse*)$^{0.5}$, where *lnmean* is the mean and *lnresidmse* is the residual mean square error calculated in the log scale. The coefficient of variation of residuals following regression is CV_{resid} = SE_{resid} / mean = EXP(*lnmean*)* (*lnresidmse*)$^{0.5}$ / EXP(*lnmean*) = (*lnresidmse*)$^{0.5}$.

We also calculated average growth rate from the change between two population estimates. We used the ratio of the populations and the interval between two estimates of population to calculate the average annual growth rate from the expanded inventory survey estimate (corrected by standard tundra fixed-wing:helicopter detection rates) to the average 2004-2005 BLSC survey population estimate (corrected by visibility rates for each year, region, and observer). The growth rate is, $R = [N_2 / N_1]^{1/y}$, where N_t = population sizes at time 2 and time 1, respectively, and y = $year_2 - year_1$, the time interval in years. The estimated standard error of R (Taylor series approximation, Bart et al. 1998, eq 2.56) is $SE_R = (1/y)\, R^{(1/y)-1} \bullet [\ (N_2/N_1)^2 \bullet (cv_1^{\,2} + cv_2^{\,2})\ ]^{0.5}$, where the coefficient of variation is $cv_t = [var(N_t)]^{0.5} / N_t$, the standard error of estimated population mean divided by the mean for each time period.

Results

Observed birds

Aerial observations were made on 8 days between 12 and 21 June, 2004 and 11 days from 13 and 25 June, 2005. Total flight time was 54.3 hrs in 2004 and 54.2 hrs in 2005. Approximate flight cost each year (@ $126 /hr plus fuel @ $4 x 18 gal/hr) was just under $11,000. The time on transect actually making observations totaled 20.6 hours in 2004 and 22.6 hours in 2005, ranging between 0.2 and 5.3 hours per day (Table 4). In addition, we flew the intensively sampled areas near Izembek and Port Moller in approximately 6 (?) hrs. The sampled transects included 63 sections with 3,175 km in 2004, and 100 sections with 3,544 km in 2005 (Table 5). Good conditions for observations were typical (Table 6), except for marginal windy conditions on the last 6 transects flown near Izembek on June 14, 2005. Front and rear-seat double count observations were flown for 5.1 hours (25% of total observation time) on 16 transects in 2004, and for 2.9 hours (13% of total time) on 18 transects in 2005, plus on 6 of the 33 transects near Izembek for which exact flight time data were not available.

The pattern of observation density across the 8 strata was very similar to that shown by the historic data (Fig. 2). Most of the Black Scoters, 58% of the estimated total population index, were in 2 strata (Bristol Bay high, Yukon Delta high) that cover 30% of the area. Density averaged 0.91 and 0.85 birds observed per km^2, respectively. Densities were also high in other smaller areas on the Seward Peninsula (0.75 birds/km^2) and Selawik (0.63 birds/km^2). The area surveyed for the first time this year near Port Moller and Izembek Lagoon on the Alaska Peninsula had the highest average density (1.81 birds/km^2) with 12% of the total population on just 3% of the area.

We compared the average of front and rear-seat population indices for years 2004-2005 directly with the 1989-1997 aerial observation indices. The indicated total bird aerial index of Scoters declined from 137,007 to 79,770 birds, 58% of the earlier estimate (Table 8). Similarly, the aerial index for Scaup declined to 63% (Table 9) and Long-tailed ducks to 33% (Table 10) of historic numbers. The percent change was somewhat smaller for Yukon

Delta strata compared to other areas. We calculated these changes from aerial indices uncorrected for detection rate, therefore any departure from the assumption that visibility is constant would bias these results. The average percent annual change that could account for these observed changes in the aerial population indices were -4.3% for Scoters, -3.8% for Scaup, and -8.7% for Long-tailed duck (Tables 8, 9, 10).

Aerial Detection Rate

An objective was to derive an estimate of average detection rate applicable to the average survey conditions for each species, region, observer, and year. To ensure small bias in the mark-recapture estimator, the minimum sample size recommended is 6 matched observations (Rivest et al. 1995). In addition, the sum of the numbers recorded by the two independent observers should exceed the estimated population size (Seber 1973). Due to the low numbers of birds, many individual days had too few matching observations to obtain a useful mark-recapture estimate of population size for each species. We combined species to examine the average detection rate among as many individual days as possible (Fig. 3). A test of equality in visibility correction factors calculated for the 7 survey days with adequate data indicated significant heterogeneity ($p=0.049$, $df=6$, Rivest et al. 1995) among the estimated detection rates. Without the single day 13 June 2005, that represented data collected with a Supercub rather than a Cessna 206 aircraft, heterogeneity was not significant ($p=0.704$, $df=5$). We therefore combined days to assess differences among crews (Crew1 - Bristol Bay-YKD, 4 strata, Crew2 - Seward-Selawik, 5 strata, and Crew3 - AK Peninsula, 1 stratum) and between years for each species. No significant heterogeneity was found ($p=0.728$, $df=2$) for scoters but differences were greater for scaup ($p=0.005$, $df=3$) observations that showed lower detection in both regions in 2004 (Fig. 4). We did not have enough matching data to obtain reliable rates for long-tailed duck or white-winged scoter.

Pooling days for each crew, we calculated the average detection rates for front- and rear-seat observers for each species, region, and year (Table 7). With more data representing a greater variety of survey conditions and observers, we should be able to identify the most significant sources of variability, and be justified in pooling detection rate estimates that differ simply due to sampling error. For now, we decided to calculate a detection rate for each species, region, observer, and year. We combined the data over potential categories of group size, day, and density. If an inadequate number of matches (<6) occurred within a single year, we used the pooled data from both years to calculate the average detection rate for each species-region-observer (Table 7). Combining double-count data over years may not be justified and it should be avoided to obtain independent annual estimates of population size. Each survey crew should obtain enough double count data to have at least 6 matching observations for each species, year, and region. In 2004, Crew 2 missed this criterion for scoter, and in 2005, Crew 1 did not obtain enough matches for scoter and scaup. An adequate number of matched observations has yet to be reached for long-tailed duck.

To this point, we have presented only the "best estimate" from the matching data. Unfortunately, the analysis of these data includes a subjective element. After transcription, each observer has a data file that includes transect, date, time, geographic coordinates, species, group size, and descriptive notes for each observation. We then used a custom program to identify the matching observations by reading the two files and producing a single interleaved data set sequenced by time with all observations listed in two sets of columns. After a few trial runs, we found a distance criterion of 400m to be useful for separating most of the matching and non-matching observations. This distance is equivalent to about 9 seconds at 42 m/sec (150 km/hr) typical flight speed. We reviewed the sequenced output file using a range of criteria for determining matched observations. These included: 1) all data with matching species, group size, and less than 400m difference in location, as run by the computer program; 2) a reasonable judgment of matches using all recorded notes on location, behavior, group size, and with the exclusion of observations potentially beyond the 200m transect strip by one or both observers; 3) the most lenient interpretation of group size, location, behavior, and other notes thus maximizing the number of matches; and 4) the strictest matching criteria thus minimizing the number of matches. We selected the "best" detection rate as that calculated using matches determined by criterion 2, with the potential range of detection rates and their standard errors calculated by criteria 3 and 4.

The variation among these considerations is due to subjective decisions of how to categorize certain observations. For example, if one observer recorded a single plus a pair of scoters on a pond, and the other observer recorded 2 single scoters, this could be recorded at 2 matched observations if lenient, or 1 match and 2 unmatched observations, if strict. It remains possible that because neither ponds nor scoters are actually marked, these could represent 3 different sets of birds. We did not include such "worst possible case" non-matches because we think these are quite unlikely. When both observers record a sighting within a few seconds of each other, this contrasts strongly with previous minutes without seeing any birds. The method works only because sightings are sparse. This example also illustrates our consideration that the best analysis unit for the determination of detection rate was the sighting, i.e. the observation location. For example with lenient matching criteria, the observation of a single male is equivalent to an observed pair, or a flock of 6 is equivalent to a flock of 8, with each counting as one matched observation between front and rear-seat observers. Nevertheless, following standard aerial survey protocol, a pair plus a single male, even if on the same pond, are considered separate sightings, and therefore 3 birds are not considered equivalent to a pair. Group size is a descriptive identifier, similar to distance from the aircraft or bird behavior, and with strict matching criteria, we considered a single bird a different sighting than a pair. With lenient criteria, an observed single bird matched a pair unless it was distinct based on other notes. Single females are generally not recorded according to standard survey protocol, although we included female sightings (4 matched, 5 unmatched) to include as much data as possible to estimate detection rate.

The 2004 data set contained 149 observations including 26 lenient matches that we could also consider as 47 unmatched observations using strict criteria. In 2005, 140 observations included 12 matches that we could consider as 18 unmatched observations. We attribute the decrease from 17% to 9% in the frequency of such ambiguous matching observations, and the corresponding decrease in the range of possible detection rates (Fig. 5), to more consistent recording of additional notes on location and behavior of birds by both observers in 2005. We calculated asymmetric 90% confidence intervals of detection rates assuming log normal distribution (Chao 1989). We included the possible matching errors in the statistical confidence limits by using the highest 90% confidence interval of the detection rate calculated from the lenient matches and the lowest 90% confidence interval of the detection rate from the strict matches. We used this expanded 90% confidence range to calculate an approximate effective standard error for the best detection rate estimate with SE = 90% confidence maximum range / [2 x 1.6449] (Table 7).

Several results have emerged from the analysis of these double-count survey data. Over the range of weather encountered on surveys, conditions on individual days did not significantly change the detection rate (Fig. 3). The average detection rates tended to vary among observers, regions, and years (Fig. 4). For example, detection rates were higher in 2005 particularly for Scaup. The average estimated Black Scoter detection rate based on the front and rear-seat double-count technique was 0.750 (SE=0.102). This was lower than 0.857 (SE=0.077) based on the ratio of fixed-wing:helicopter observations (Smith 1995). The average detection rate for Scaup was 0.673 (SE=0.079) and higher than 0.517 (SE=0.057) from the fixed-wing:helicopter ratio. Long-tailed Duck and White-winged Scoter were rare and probably less visible, however we did not collect enough data to provide valid estimates of detection rates. For Long-tailed Duck we used a tentative estimate of 0.25 (SE=0.138) compared to the historic helicopter ratio of 0.536 (SE=0.083). The front-seat pilot observer averaged slightly lower in detection rates than the rear-seat observer (Fig 4).

Visibility-corrected population estimates

The 1989 to1997 expanded survey observations have no direct year-, survey-, or observer-specific measure of detection rate. In comparison with the current BLSC survey, observers on the earlier surveys recorded more waterbird species that could potentially reduce the average visibility rate. In general, the pilots on the earlier survey had more years of survey experience, but the right-seat observers had less experience, compared to the pilots and observers on the recent survey. In combination, this probably had little influence on average detection rate. The timing of the historic surveys averaged 8 days earlier for Yukon Delta and Seward Peninsula, 10 days earlier for Selawik, and 18 days earlier for Bristol Bay regions compared to the recent BLSC survey (Table 1 vs. Table 4).

For aerial detection rate on the WBPHS survey and expanded survey we used the ratio of number of birds observed from fixed-wing aircraft compared to a helicopter aerial survey platform. These data were collected on the Yukon Delta in 1989-1991. The average ratio and its standard error (Smith 1995) is an estimate of average detection rate assuming that the observer in the helicopter detected 100% of the birds present. Although 100% is an unlikely assumption, the visibility rate should be very high in a slow-flying noisy helicopter with its unrestricted front window for observations. The fixed-wing:helicopter ratios (Smith 1995) were used as average detection rate for all observers, strata, and years of the expanded survey data.

To estimate population size, the aerial index from the BLSC survey for each species, observer, stratum, and year was divided by the detection rate for that species, observer, region, and year. The variance of this ratio includes both the sampling error of the index and the error in the detection rate (Bart 1998, p272; Williams et al. 2002, p244). We calculated the population estimate for each stratum as the average of the visibility corrected populations from the 2 observers, with variance calculated as the sum of variances / 2. The total population was the sum of the individual stratum populations over the 10 strata. The total variance was the sum of the strata variances. The 2005 population estimates for strata 9 (lower AK Peninsula) and 10 (Seward Peninsula edge) were duplicated to 2004, because these areas were not flown in 2004. We also calculated the average population for 2004-05 by pooling all transects and observations for each observer as if they had been flown at a single time. Similarly, we pooled all the double-count data across years to estimate average detection rate. We used the 2004-2005 combined year estimates and the similar combined-year expanded survey estimate to determine population change ratio and calculate average growth rate.

The visibility-corrected population estimates were compared for the expanded, 2004, and 2005 surveys for each strata (Figs. 6, 7, 8). The average annual growth rates that could account for the change in population size were calculated and shown for each species and stratum (Figs. 6, 7, 8 and Tables 8, 9, 10). Nearly every stratum showed declining populations for all three species, and the rates of decline were slightly less for the Yukon Delta. The historic expanded survey did not sample the area on the Alaska Peninsula nearest to Izembek and Port Moller, and the population estimate was based on density expanded from transects sampled near Port Heiden.

The 2004-05 total population sizes estimated were 108,100 (SE=13,300) Black Scoter, 198,900 (SE=28,600) Greater Scaup, and 42,200 (SE=13,200) Long-tailed Duck. For scoters, the current population estimate was 68% of the population 12 years ago. Annual change of -3.1% could account for this change over 12 years. Scaup were at 53% of their earlier population with an equivalent annual rate of change of -5.2%. Long-tailed ducks are at 63% of their earlier population, equivalent to -3.5% annual change.

The average sampling error CVs of the 2004 and 2005 single year visibility-corrected population sizes were 15% for Scoter, 18% for Scaup, and 39% for Long-tailed Duck. Based on the approximate formula for power analysis in determining trend (Gerrodette 1987), we did not reach our goal of obtaining a CV of 12.5%. Instead of 10 years, for each species respectively, expectation becomes that 12, 13, or 22 years of data would be required to obtain statistical significance at $p<0.10$ with 80% power for a -3.4% average annual change.

Comparison with Waterfowl Breeding Pair and Habitat Survey data

The WBPHS data from the last 20 years (1986 to 2005) in the Alaska strata were downloaded from the USFWS Division of Migratory Bird Management website (http://www.fws.gov/birddata/databases/mas/maydb.html). These data, along with the Arctic Coastal Plain survey data 1986-2005 (Mallek et al. 2004), provide a statewide perspective on the relative numbers of scoter, scaup, and long-tailed duck (Table 11).

The tundra strata 8, 9, 10, and 11 of the WBPHS are similar in location but smaller in area compared to the 4 similar regions (Bristol Bay, Yukon Delta, Seward Peninsula, and Selawik) defined by the current BLSC survey. The boundaries of the BLSC survey, and the expanded inventory survey from which it was derived, included the full extent of contiguous wetland habitat in each region (Table 12). Nevertheless, because the increase in area was due to inclusion of peripheral areas with very low waterfowl density, a comparison of total population sizes among surveys is more accurate without a proportionate adjustment for area.

For each stratum and for combined tundra strata, we plotted the population estimates for each species and year based on the WPBHS, expanded survey, 2004, and 2005 BLSC survey observations (Figs. 9, 10, 11). Vertical lines show the within-year estimates of sampling error, indicated by 90% confidence intervals. The 20-year average WBPHS estimated populations for all 3 species were larger than the average population sizes based on the average of expanded survey and the BLSC survey data (Table 13). The 60% larger estimate for Black Scoter and the 48% larger population estimate for Long-tailed Duck were true in spite of the 31% smaller total area and higher detection rates (i.e. less expansion for incomplete visibility) used with the long-term WBPHS data. For Scaup, the average WBPHS detection rate was lower (Table 7) which caused a 30% larger expansion from the aerial index number, but this did not account for the 58% greater Scaup population estimated by the WBPHS data (Table 13).

We also compared average trends using the visibility-corrected population estimates for each species (Table 14). Loglinear regression provided an estimate of the average growth rate from the 1986-2005 WBPHS data. We used the ratio of populations and the interval in years between the two estimates of population to calculate the average annual growth rate between the expanded inventory survey estimate (corrected by standard tundra fixed-wing:helicopter detection rates) and the pooled 2004-2005 BLSC survey population estimate (corrected by visibility rates for each year, region, and observer). For 11 of the 12 comparisons of estimated growth rates (3 species in 4 regions), the WBPHS data indicated higher growth rates (Fig. 12). Significant differences between the trends (t-test, $p<.01$) were indicated for 7 of the 12 comparisons (Table 14). The difference between the populations estimated by the current BLSC survey and the expanded surveys flown on average 12 years earlier, showed declining trends for all 3 species in all 4 regions (Table 14). The Black Scoter average annual growth rate was 0.969, -3.1% annual change. This was 0.024 below and significantly different from, the growth rate of 0.993 calculated from the last 20-years of WBPHS data. For Greater Scaup, the survey indicated average annual growth was 0.948, and 0.080 below the WBPHS estimate of 1.028. For Long-tailed Duck, average annual growth rate was 0.965, and 0.018 below the WBPHS estimate of 0.982.

Discussion

Survey design and data collection methods

We now have 2 years of observations and another 2 years will complete a full panel of the designed systematic transects. The observed locations indicate that the stratification boundaries have been highly accurate in separating high- and low-density habitat. The precision of the estimated population size is adequate for scoter and scaup, however it should be improved if possible. The current intensity and extent of this survey makes it relatively difficult to complete and expensive to fly. After completion of 4 years of data, we will re-examine the sampling design. We may choose to restrict monitoring to 60-80% of the geographic extent of the Black Scoter population rather than >95% coverage included by the current boundaries. We also may consider reallocation of the sampling intensity among strata to maintain precision while further decreasing flight time and cost.

The high density of scoters observed in 2005 on the Alaska Peninsula near Izembek and Port Moller was an unexpected and intriguing observation. This wetland area of 4,200 km^2 is not very large, 3% of the total survey area. The presence of flocks (groups of pairs on a single lake) and White-winged Scoters also distinguished this area from the other tundra wetlands surveyed. A series of questions arise. Perhaps this population of about 1,500 Black Scoters is a distinct population segment. This southernmost breeding area is close to marine wintering habitat along the Alaska Peninsula and Aleutian Islands therefore these birds could be local migrants. The presence of flocks may indicate that nesting chronology is late compared to more northern areas or that many non-breeders are using these lakes. The survey and data recording methods also were somewhat different. The least experienced surveyors (KS, KR) recorded the highest detection rates while flying in a Supercub aircraft with a slower flight speed. Transect width, possible non-independence of observations, survey timing, species identification, and precise coverage of transects are possible questions that will be resolved with additional surveys, improved data collection techniques, and more observations.

On the double-count transects flown in 2005, we were able to improve data recording and standardize the categories used to describe observations relative to distance from the aircraft (near, mid, far), location in the habitat (pond, nearshore, land), and behavior (swimming, flying, standing) of the observed birds. This reduced the ambiguity in matching some of the observations, and in comparison to 2004, this narrowed the range of detection rate estimates when calculated with best- and worst-case assumptions for matching. Further observer training and practice should provide even better data. If accurate data on covariates could be collected for every observation, which may not be feasible, then more detailed mark-recapture data analysis models could be used.

Even with adjustment for detection rate, other factors may bias the aerial observation index as a measure of breeding population size. Differences among years in coverage, closure, and surplus birds (Bart et al. 2004) can also present problems. Breeding bird populations may vary in age structure, propensity to nest, chronology of nest initiation, tendency for non-breeders to linger in nesting areas, or behavioral response to aircraft disturbance. Some of these changes may relate to visibility and if so, the annual estimate of average detection rate should make the appropriate adjustment. Other changes do not relate to visibility. Of particular concern are any changes that may bias the double-count estimate of detection rate, such as differences between observers in effective transect strip width, or a tendency to misidentify certain species. Adherence to standard survey protocols and adequate observer training remain critical components of aerial survey. The number of birds and the operational definition of the breeding population also remain tied to assumptions defined by standard protocol. The doubling of observed singles, applicable for Scoter and Long-tailed Ducks but not for Scaup, is an approximate adjustment for assumptions of surplus birds and detection rates. Our estimates of average detection rate so far do not include consideration of group size; each sighting is a single unit for determination of detection rate. Group size may be an important factor but this would interact with standard aerial survey protocol definitions of indicated breeding population size that also incorporates group size. A visibility data model for a breeding waterfowl population, one that includes sighting of non-independent individuals that are dimorphic in appearance and behavior, may be necessary to clarify these issues of detection rate and protocol-specified measures for the indicated number of breeding birds.

Differences among surveys

To best determine population size and trend, this report analyzed and compared data from 3 different surveys, one survey repeated every year, and the other 2 surveys flown in consecutive pairs of years averaging 12 years apart. The WBPHS collected data in a very consistent manner. Every year from 1986 to 2005, transects, seasonal timing, turbine Beaver aircraft, and pilot-observer were the same, and the observer changed only infrequently. In comparison, several different pilots flew the 1989-1997 expanded inventory surveys in Cessna 206 or 185 aircraft. Although all pilots were highly experienced, observer experience was more variable. Timing averaged a few days later in the season. For both of these surveys all waterfowl species were counted and the standard fixed-wing:helicopter visibility ratio constants were the only estimate of average detection rates.

The WBPHS transects were not a systematic or random sample from a defined area of wetland habitat. Instead, the transects were subjectively drawn in representative waterfowl habitat with starting locations established at adequate geographic reference points and with transect length truncated into fixed-length segments. In contrast, the expanded inventory survey used systematic transects that extended completely across all contiguous wetland habitat including peripheral habitat of lower quality. The current BLSC survey design mirrored the expanded survey. Transects were strictly systematic although a few transects have been skipped due to time or fuel constraints. Compared to other surveys, the pilot and observers had fewer years of survey experience, nevertheless they were particularly well-trained and experienced observers for scoter and scaup in tundra habitat because they had completed 2-years of replicated surveys near Aropuk Lake that were flown to establish the best timing for this survey.

Another difference is that we flew the current BLSC survey 8-18 days later than the expanded surveys. The earlier seasonal chronology for nesting in recent years may also add to the effective difference in survey timing. Comparing years with surveys, geese on the Yukon Delta coast hatched an average of 8 days earlier in 2004-2005 than in 1989-1995 (Fischer et al. 2005). We presume that scoter, scaup, and long-tailed ducks show this same earlier pattern, and that earlier spring timing holds for Bristol Bay, Seward Peninsula, and Selawik regions. The later survey timing of the 2004-2005 BLSC surveys correlates with lower indicated populations for all three species compared to the WBPHS survey and to the expanded 1989-1997 surveys.

We documented numerous significant differences in both population size and trend based on the various monitoring surveys. Nevertheless, without adequate objective data, we can only speculate and suggest alternative explanations. These include:

a) Because the historic data has no survey-specific estimate of detection rate, we cannot exclude the possibility that detection rates have changed. The constancy of survey protocols, conditions, and observer experience argues for relatively small differences in detection rate.

b) The larger population sizes estimated by the WBPHS observations likely reflects bias caused by transect placement in areas with higher than average density. Compared to the 1989-1997 expanded surveys, the averaged WBPHS population for the same range of years showed 29% more scoter, 14% more scaup, and 16% more long-tailed ducks. The smaller area of expansion and perhaps a greater detection rate from the turbine Beaver aircraft also contributed influences in opposite directions to these differences in the total population estimates. If the WBPHS transects are not a valid sample, as perhaps indicated by bias in average density, they could also provide an unrepresentative estimate of population trend.

c) Compared to the current BLSC survey, the WBPHS in recent years (1998-2005) has estimated 101% more scoter, 160% more scaup, and 75% more long-tailed ducks. Again, relative to the current BLSC survey, the expanded surveys 12 years ago (1989-1997) estimated 48% more scoter, 90% more scaup, and 55% more long-tailed ducks. A component of these differences is the incorporation into the current BLSC survey of detection rates specific to species, year, observer, and region (Table 7). The average effect of detection rate expansion (i.e. the aerial index increased to estimate the population) was to increase the scoters seen by a conversion of 1.355 rather than 1.167, 16% larger than previously used. For scaup, the conversion factor was 17% smaller, and for long-tailed ducks, conversion was 98% larger. Thus, for scoter and scaup, the effects of potential error or change in detection rates are relatively small compared to population change. For long-tailed ducks, the potential population decline would even be larger if our estimated detection rate is too low.

d) Another difference is the later seasonal timing of the current BLSC survey compared to both the WBPHS and the expanded surveys. Two anecdotal pieces of evidence support a hypothesis that the lower number of scoters estimated by the later-flown BLSC survey may be a more accurate measure of breeding population size. The replicate timing surveys flown near Aropuk Lake in 2002 and 2003 (P. Anderson, USFWS unpubl. data) indicated 28% more scoter and 2% more scaup sightings on transects flown 10 June or earlier (n = 5 days). Given the variability among transects and days, these differences were not statistically significant compared to observations on the same transects flown later (n = 9 days). In addition, telemetry data (J. Schamber, unpubl. data) has indicted that some males are temporary visitors to inland breeding areas for the first two weeks in June before they return to marine foraging habitat. The pattern and size of the population component involved in these temporary movements remains poorly documented. Therefore, the 32% decline in numbers of scoters from the 1989-1997 expanded surveys to the 2004-2005 BLSC surveys may include departure of non-breeding scoters (surplus birds) before the later-flown survey. We do not have adequate data to separate the amount of change due to survey timing versus change in population size. The BLSC survey, flown as designed during nest initiation and laying, has the potential to provide an unbiased estimate of population size and trend not confounded by surplus birds.

e) The later timing of surveys could also result in missing some portion of male scoters due to their departure at the start of incubation from breeding areas to return to marine foraging habitat. The exact timing of this behavior and degree of synchrony in breeding is not well documented for black scoters. Male scaup also leave incubating females although they generally form into small groups staying in the general area where they would still be visible on aerial surveys. Male long-tailed ducks remain with the females for much of incubation. Behavior and timing of movements of failed breeders of all 3 species are unknown.

f) The late seasonal timing of the BLSC survey may not provide useful data for long-tailed ducks because they initiate nests earlier than scoter. Our survey probably coincided with mid- to late incubation when males, as well as the females, often may be hidden and secretive. We had too few sightings to derive a valid detection rate, although we tentatively estimated detection at 0.25, less than half of the standard fixed-wing:helicopter ratio. Birds that do not flush from nests hidden in vegetation essentially disappear from the detectable population.

g) The rear-seat observer on the YKD coastal goose aerial survey has recorded ducks, loons, and gulls each year 1988-2005 (Platte and Stehn 2005). This survey was flown in early June and sampled 12,832 km^2, 8% of the 154,475 km^2 sampled by the BLSC survey. The observed long-term growth rates were 1.024 for Black Scoter, 1.023 for Scaup, and 1.019 for Long-tailed Duck, all indicating increasing populations. The sizes of the aerial indices on the YKD coast for these species were 10,295 scoter, 36,909 scaup, and 6,397 long-tailed duck. Not corrected for visibility, these indices represented 13%, 30%, and 56%, respectively, of the total uncorrected aerial indices from the entire BLSC survey area. The relative concentration of scaup and long-tailed ducks on the YKD coast was notable, although the 2-week difference in survey timing and possible difference in visibility rates confounded interpretation.

Conclusions and recommendations

1. Comparing aerial population indices from the current BLSC survey and the similar expanded inventory surveys flown on average 12 years ago, the growth rates that could account for the observed changes in indices were -4.3% annual change for scoter, -3.8% for scaup, and -8.7% for long-tailed duck. Following the adjustment for detection rate to the extent that available data allowed, the current scoter population was estimated as 68% of that observed 12 years ago, equivalent to a -3.1% annual change. Scaup were at 53% of their earlier population (-5.2% change/yr) and long-tailed ducks were at 63% of their earlier population (-3.5% change/yr). Later survey timing was confounded with the change in years. Associated differences in detection rates, movements of surplus birds, and change in behavior may account for some or all of the apparent population declines.
2. The front- and rear-seat double count observations provided a useful method to estimate specific detection rates for each species, year, observer, and region. More consistent recording of notes on location and behavior of birds by both observers in 2005 provided better information to resolve ambiguous matches and resulted in tighter confidence intervals on detection rate. We recommend continued or somewhat increased investment in the double count method to ensure that adequate data are available. Each survey crew should obtain enough double count data to have at least 6 matching observations for each species, year, and region. We have not yet quantified the relative cost and contribution of the double-count transects to the overall accuracy of the population estimate. We must examine covariance between the front- and rear-seat and verify the appropriate variance for detection adjusted combined estimates.
3. The pooled detection rate was 0.750 (SE=0.102) for scoter, which is lower than 0.857 (SE=0.077) based on the ratio of fixed-wing:helicopter observations (Smith 1995). The average detection rate for scaup was 0.673 (SE=0.079), higher than 0.517 (SE=0.057) from the fixed-wing:helicopter ratio. Long-tailed ducks were seldom seen and we used an optimistic estimate of 0.250 (SE=0.138) for detection rate compared to the standard 0.536 (SE=0.083).
4. The population estimate of 108,100 breeding Black Scoter was more accurate than the larger estimates determined by the earlier-flown expanded survey or the WBPHS surveys. Apparently, the later survey timing allows for the departure of non-breeding surplus birds from the breeding areas.
5. The current survey adequately monitors the breeding population of Black Scoter. An unbiased and precise estimate of population trend will become available by continuation of the survey.

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Table 1. Survey dates, observers, number of sightings, and birds observed for Scoters, Scaup, and Long-tailed ducks on each year of the expanded inventory surveys.

				number of sightings						number of birds observed					
Year	Dates flown	Pilot(s)	Observer(s)	BLSC	SCOT	SUSC	WWSC	SCAU	LTDU	BLSC	SCOT	SUSC	WWSC	SCAU	LTDU
Yukon Delta															
1989	10-13 June	rjk, wib	bg, wde	285	228			654	88	560	464			1289	129
1990	11-15 June	rjk, wib	Awb, wde	206	231	16	3	757	114	394	458	30	4	1219	153
1991	6-11 June	Jih	Fg	232	185			714	161	448	423			1318	218
1992	11,13-15 June	Jih	pjh	389	2	2	1	709	125	670	4	3	1	1402	182
Bristol Bay															
1993	28-31 May	rjk,wib,wwl	awb,rmp,grb	246	81	12	25	555	33	784	185	18	63	1441	48
1994	25-28 May	rjk,wib,wwl	awb,rmp,grb	335	2	15	6	530	38	970	46	36	8	1268	68
Innoko															
1994	1,2,4,5 June	jih		19	29	21		159		36	65	41		274	
1995	30-31 May, 1 June	wwl	awb	4		8	9	184	1	6		15	13	332	2
Seward Peninsula															
1992	13-18 June	wwl	grb	123	54		8	296	133	388	170		33	877	250
1993	9-11,13-16 June	jih	jgk	362	13	14		629	298	718	20	18		1326	507
Selawik															
1996	18-21 June	wwl	grb	215		10	1	915	75	370		23	2	1692	111
1997	4-8 June	jih	awb	274		52	1	918	161	564		131	2	1742	251
Total				2690	825	150	54	7020	1227	5908	1835	315	126	14180	1919

Table 2. Group size of Scoter, Scaup, and Long-tailed duck sightings in each region and year on the expanded surveys.

		All Scoters (BLSC, SUSC, WWSC, SCOT)				Scaup (SCAU)				Long-tailed Duck (LTDU)			
Region	year	single	pair	flock 3-10	flock 11+	single	pair	flock 3-10	flock 11+	single	pair	flock 3-10	Flock 11+
Yukon Delta	1989	131	356	23	3	209	421	18	6	47	41	0	0
Yukon Delta	1990	130	299	26	1	447	284	21	5	78	35	1	0
Yukon Delta	1991	80	328	6	3	217	489	3	5	108	52	1	0
Yukon Delta	1992	117	276	1	0	347	336	16	10	78	45	2	0
Bristol Bay	1993	63	241	45	15	159	350	30	16	18	15	0	0
Bristol Bay	1994	79	235	29	15	158	342	16	14	16	21	1	0
Innoko	1994	22	43	4	0	88	66	4	1	0	0	0	0
Innoko	1995	8	13	0	0	73	105	6	0	0	1	0	0
Seward Penn	1992	36	116	25	8	78	194	17	7	65	58	8	2
Seward Penn	1993	109	266	10	4	277	333	5	14	163	122	11	2
Selawik	1996	77	146	3	0	512	362	26	15	42	32	1	0
Selawik	1997	110	204	8	5	382	500	25	11	110	45	5	1
		962	2523	180	54	2947	3782	187	104	725	467	30	5

Table 3. Average aerial population indices without correction for visibility for Scoters, Scaup, and Long-tailed ducks in Alaska. All data from the expanded inventory surveys and the 1986-2005 average from the Arctic Coastal Plain survey are tabulated to show the proportions of the statewide population indices for each species that were sampled by the current tundra BLSC survey.

Wetland region	Km^2	Year(s)	BLSC	WWSC	SUSC	SCAU	LTDU
Tundra wetlands sampled by the BLSC survey:							
Bristol Bay	49,890	1993-94	46,104	1,689	1,360	96,241	5,258
Yukon-Kuskokwim Delta	72,117	1989-92	85,679	181	882	198,508	35,184
Seward Peninsula	14,845	1992-93	13,920	318	299	18,962	9,890
Selawik-Noatak	15,234	1996-97	10,094	0	1,797	31,911	4,815
Boreal, mixed, and Arctic Coastal Plain wetlands not sampled by the BLSC survey:							
Innoko, Yukon R., Kaiyuh	16,522	1994-95	2,411	357	1,363	20,383	73
Koyukuk, Kanuti	19,478	1996-97	3,246	488	1,824	24,669	972
Yukon Flats	18,771	1989-91	0 ?	30,912	0 ?	59,194	844
Tanana-Kuskokwim	52,797	2001-02	171	5,188	2,731	27,099	1,223
Kenai-Susitna	18,526	2003	0	0	849	2,772	0
Arctic Coastal Plain	61,645	1986-05	3,134	2,708	222	18,365	55,815
Total Expanded Inventory surveys	339,825		164,759	41,841	11,327	498,104	114,074
Black Scoter survey area (design 154,475 km^2)	152,086		155,797	2,188	4,338	345,622	55,147
% of statewide total sampled by the BLSC survey	44.8%		94.6%	5.2%	38.3%	69.4%	48.3%

Table 4. Total birds observed on the 2004 and 2005 Black Scoter survey transects tabulated by region, observer team, and day. The survey effort was indicated by the flight hours on transect observing and flight hours between lines including refueling and rest breaks, but this does not include the flight hours each day needed to reach the first transect or to return from the last.

Date	observers	N trans	Online flight hours	Total hours between lines	stratum	BLSC	GRSC	LTDU	SUSC	USCO	WWSC	BLSCH	GRSCH
12-Jun-04	PDA,FJB	10	2.6	4.7	BB	82	139	2	2	7	5	3	0
14-Jun-04	PDA,FJB	12	2.5	2.9	BB	62	46	1	0	0	0	0	0
15-Jun-04	PDA,FJB	3	0.2	0.7	BB	5	7	0	0	0	0	2	0
16-Jun-04	PDA,FJB	6	4.0	0.9	YKD	149	318	16	2	0	6	3	1
17-Jun-04	PDA,FJB	6	4.8	2.4	YKD	171	273	29	0	0	8	18	0
18-Jun-04	PDA,FJB	5	2.2	0.9	YKD	104	155	5	0	0	0	8	0
19-Jun-04	PDA,TLM	11	2.0	3.0	Sew P	88	66	27	0	0	0	0	0
21-Jun-04	PDA,TLM	10	2.3	1.7	Selawik	81	197	0	0	0	0	4	0
2004 Total		63	20.6	17.3		742	1201	80	4	7	19	38	1
13-Jun-05	KR,KS	13	na	na	AK pen	411	195	0	0	0	31	13	0
14-Jun-05	KR,KS	6	na	na	AK pen	12	12	0	0	0	0	0	0
15-Jun-05	PDA,FJB	15	2.1	2.2	AK pen	38	60	2	0	0	0	0	0
16-Jun-05	PDA,FJB	12	2.2	6.2	BB	131	136	0	0	0	0	0	0
17-Jun-05	PDA,FJB	2	0.3	0.1	BB	8	6	0	0	0	0	0	0
18-Jun-05	PDA,FJB	12	4.0	6.2	BB	80	144	17	11	0	0	5	0
20-Jun-05	PDA,FJB	6	5.3	3.8	YKD	161	260	17	0	0	1	7	0
21-Jun-05	PDA,FJB	3	2.9	0.5	YKD	87	397	10	1	0	0	1	0
22-Jun-05	PDA,FJB	3	1.2	0.4	YKD	7	16	1	0	0	0	0	0
23-Jun-05	PDA,TLM	9	1.7	3.8	Selawik	23	90	1	0	0	0	1	0
24-Jun-05	PDA,TLM	19	2.9	6.0	Sew P	104	111	19	0	0	0	1	0
2005 Total		100	22.6	29.1		1062	1427	67	12	0	32	28	0

Table 5. Sampling effort in each of the 10 survey strata measured by number of transects and square kilometers observed for the expanded inventory surveys flown in 1989-1997 and for the recent BLSC survey flown in 2004 and 2005.

				pilot-observer (lf)		right- or rear-seat observer (rf,lr,rr)	
Year	str	Stratum	Stratum km^2	n trans	trans km^2	n trans	trans km^2
93-94	9	AK peninsula	4214.1	16	50.4	16	50.1
93-94	2	BB low	34394.7	316	888.5	317	888.4
93-94	1	BB high	13877.6	125	374.4	125	373.9
89-92	3	YKD high	31642.3	46	941.4	46	940.6
89-92	4	YKD low	40387.9	92	1199.1	92	1197.5
92-93	10	SewP edge	4681.7	98	179.2	98	178.2
92-93	6	SewP low	5983.1	78	203.0	78	203.4
92-93	5	SewP high	4233.8	65	150.0	64	150.3
96-97	7	Selawik high	4907.0	108	305.1	108	304.1
96-97	8	Selawik low	10152.8	226	571.4	225	575.6
			154475.0	1170	4862.5	1169	4862.1
2004	9	AK peninsula	4214.1	0			
	2	BB low	34394.7	22	56.3	18	56.4
	1	BB high	13877.6	11	108.1	11	108.6
	3	YKD high	31642.3	13	251.8	13	249.9
	4	YKD low	40387.9	13	93.2	14	92.8
	10	SewP edge	4681.7	0			
	6	SewP low	5983.1	6	24.8	4	24.7
	5	SewP high	4233.8	8	34.2	8	34.1
	7	Selawik high	4907.0	6	40.0	7	40.2
	8	Selawik low	10152.8	7	26.9	7	26.6
			154475.0	86	635.3	82	633.3
2005	9	AK peninsula	4214.1	33	136.8	33	136.9
	2	BB low	34394.7	14	53.0	12	46.8
	1	BB high	13877.6	14	114.2	13	102.6
	3	YKD high	31642.3	12	191.3	7	148.3
	4	YKD low	40387.9	13	128.7	9	79.6
	10	SewP edge	4681.7	9	21.1	9	21.2
	6	SewP low	5983.1	7	27.7	6	27.2
	5	SewP high	4233.8	6	35.9	6	36.3
	7	Selawik high	4907.0	5	43.7	5	43.8
	8	Selawik low	10152.8	7	12.7	7	9.7
			154475.0	120	765.1	107	652.4

Table 6. Survey conditions noted at various times during aerial survey transect observations.

Year	June date	Sky	Wind speed (kts)
2004	12	Overcast, broken, clear	
	14	Overcast, broken, clear	Calm, light, 5-10
	15	Overcast	7-8
	16	Overcast, cirrus	3, 5, 6
	17	Overcast, broken	Calm, light, 0,6,3,11
	18	Overcast	3-6
	19	Overcast	Calm, 3-5
	21	Clear, broken	Calm
2005	13	Glare	
	14	Glare	Windy, bumpy flight, streaks on lakes
	15	Clear	5
	16	Clear	5
	17	Overcast	8-10
	18	Overcast	6, 10, 12, 20
	20	Overcast, broken,	Calm, 3,4,5,8,10
	21	Scattered, broken	5, 8
	22	Scattered, overcast	Calm, 6, 8
	24	Overcast, broken, clear	Calm, 3
	25	Clear, scattered	3,4,5

Table 7. Numbers of unmatched and matched observations recorded by front and rear-seat observers on double-count transects and the estimated detection probabilities for sightings of each species, crew, and year. The effective standard errors were calculated from the highest and lowest 90% confidence range using the most lenient and the strictest matching criteria. Included for comparison are the detection rates used for the WBPHS data based on the fixed-wing:helicopter ratio of observations made on Alaska tundra habitat (Smith 1995). The data and estimates in italics were not used due to inadequate sample size for matched observations. Instead, we used the combined year estimates for each species and crew.

Species	Crew	Year	Front observer only	Rear observer only	Both obsvrs	Det Prob1	Det Prob2	Avg. detection rate	effective SE Pr1	effective SE Pr2	Effective SE avgPr
BLSC	C1	2004	6	8	26	0.766	0.8138	0.7899	0.1219	0.1345	0.1345
BLSC	*C1*	*2005*	*4*	*4*	*4*	*0.5263*	*0.5263*	*0.5263*	*0.115*	*0.115*	*0.1150*
BLSC	C1	2004/05	10	12	30	0.7159	0.7517	0.7338	0.1137	0.1231	0.1231
BLSC	*C2*	*2004*	*1*	*10*	*4*	*0.2941*	*0.8235*	*0.5588*	*0.0759*	*0.1501*	*0.2630*
BLSC	C2	2005	3	2	11	0.8485	0.7879	0.8182	0.1015	0.0955	0.1133
BLSC	C2	2004/05	4	12	15	0.5588	0.7941	0.6765	0.0973	0.1103	0.1673
BLSC	C3	2005	4	11	32	0.7448	0.8897	0.8172	0.0337	0.0391	0.0786
Combined	All	2004/05	18	35	77	0.688	0.8111	0.7496	0.0677	0.0752	0.1024
BLSC		1989/91	Fixed-wing:helicopter					0.857			0.0771
SCAU	C1	2004	21	17	32	0.6558	0.6063	0.631	0.1031	0.097	0.1103
SCAU	*C1*	*2005*	*4*	*6*	*2*	*0.3*	*0.4*	*0.35*	*0.0987*	*0.1316*	*0.1407*
SCAU	C1	2004/05	25	23	34	0.5994	0.5791	0.5893	0.0986	0.0969	0.1005
SCAU	C2	2004	7	9	10	0.5358	0.5989	0.5673	0.1057	0.107	0.1267
SCAU	C2	2005	2	3	15	0.8344	0.8834	0.8589	0.1078	0.0929	0.1229
SCAU	C2	2004/05	9	12	25	0.6779	0.7377	0.7078	0.0979	0.0901	0.1167
SCAU	C3	2005	3	3	18	0.8581	0.8581	0.8581	0.0296	0.0296	0.0296
Combined	All	2004/05	37	38	77	0.6705	0.6764	0.6734	0.0749	0.0709	0.0787
SCAU		1989/91	Fixed-wing:helicopter					0.517			0.0569
LTDU	*C1*	*2004*	*1*	*1*	*0*	*0.3333*	*0.3333*	*0.3333*	*0.0996*	*0.0996*	*0.0996*
LTDU	*C2*	*2004*	*0*	*2*	*0*	*0*	*1*	*0.5*	*0*	*0*	*0.3040*
LTDU	*C2*	*2005*	*4*	*5*	*0*	*0.1379*	*0.1724*	*0.1552*	*0.1101*	*0.1376*	*0.1415*
combined lenient	All	2004/05	4	7	1	0.1923	0.3077	0.25	0.0821	0.1314	0.1377
LTDU		1989/91	Fixed-wing:helicopter					0.536			0.0828

Table 8. Estimated population index and corrected population size for Black Scoter in each of 10 survey strata sampled by expanded surveys flown 1989-1997 and the BLSC survey in 2004-05.

Sppn	Strata	Avg year	Avg index	SE index	Avg year	Avg index	SE index	Growth Rate	SE GR
BLSC	AK pen	1993.5	1300.5	869.5	2004.5	7620.0	2737.7	1.174	0.410
BLSC	BB low	1993.5	13879.0	2301.9	2004.5	6297.5	3649.5	0.931	0.025
BLSC	BB high	1993.5	27737.5	3772.1	2004.5	12565.0	3231.2	0.931	0.012
BLSC	YKD high	1990.5	46169.0	3366.8	2004.5	26769.0	3762.6	0.962	0.007
BLSC	YKD low	1990.5	18452.0	1645.3	2004.5	12423.5	2651.0	0.972	0.011
BLSC	SewP edge	1992.5	4677.0	1231.8	2004.5	2426.5	2480.6	0.947	0.045
BLSC	SewP low	1992.5	3107.5	676.8	2004.5	2699.0	2116.2	0.988	0.059
BLSC	SewP high	1992.5	10025.5	3321.4	2004.5	3164.0	836.1	0.908	0.011
BLSC	Selwk high	1996.5	6767.0	817.0	2004.5	3098.5	999.8	0.907	0.019
BLSC	Selwk low	1996.5	4891.5	962.1	2004.5	2706.5	1835.8	0.929	0.048
	Total		137006.5	6994.7		79769.5	8254.7	0.957	0.005

Sppn	Strata	Avg year	Estimated Population	SE Pop	Avg year	Estimated Population	SE Pop	Growth Rate	SE GR
BLSC	AK pen	1993.5	1517.7	1024.0	2004.5	9356.0	3257.0	1.180	0.432
BLSC	BB low	1993.5	16196.8	3069.3	2004.5	8419.2	5177.4	0.942	0.030
BLSC	BB high	1993.5	32369.7	5309.1	2004.5	17071.8	5194.6	0.943	0.016
BLSC	YKD high	1990.5	53879.2	6242.3	2004.5	36436.3	7809.2	0.972	0.012
BLSC	YKD low	1990.5	21533.5	2731.8	2004.5	16823.0	4568.5	0.983	0.017
BLSC	SewP edge	1992.5	5458.1	1519.1	2004.5	3290.2	3256.0	0.959	0.051
BLSC	SewP low	1992.5	3626.5	861.2	2004.5	3912.8	2868.8	1.006	0.069
BLSC	SewP high	1992.5	11699.8	4016.4	2004.5	4561.4	1375.8	0.925	0.015
BLSC	Selwk high	1996.5	7897.1	1190.1	2004.5	4274.8	1522.9	0.926	0.026
BLSC	Selwk low	1996.5	5708.4	1239.0	2004.5	3952.5	2771.6	0.955	0.063
	Total		159886.6	10354.6		108098.0	13303.3	0.969	0.008

Table 9. Estimated population index and corrected population size for Greater Scaup in each of 10 survey strata sampled by expanded surveys flown 1989-1997 and the BLSC survey in 2004-05.

Sppn	Strata	Avg year	Avg index	SE index	Avg year	Avg index	SE index	Growth Rate	SE GR
SCAU	AK pen	1993.5	7583.0	3378.8	2004.5	4079.5	1044.9	0.945	0.025
SCAU	BB low	1993.5	22976.5	3883.2	2004.5	7239.5	3558.8	0.900	0.015
SCAU	BB high	1993.5	23865.0	4181.6	2004.5	10127.0	3151.7	0.925	0.014
SCAU	YKD high	1990.5	48120.5	4057.3	2004.5	48497.0	7724.0	1.001	0.013
SCAU	YKD low	1990.5	39806.0	3397.0	2004.5	26380.5	7430.8	0.971	0.014
SCAU	SewP edge	1992.5	9899.5	2359.3	2004.5	3420.5	1618.6	0.915	0.015
SCAU	SewP low	1992.5	2562.5	623.8	2004.5	2174.0	691.2	0.986	0.028
SCAU	SewP high	1992.5	6951.5	1514.7	2004.5	3226.5	774.2	0.938	0.012
SCAU	Selwk high	1996.5	16186.0	1521.3	2004.5	6579.0	1659.4	0.894	0.013
SCAU	Selwk low	1996.5	17732.0	3373.0	2004.5	11397.5	8476.4	0.946	0.061
	Total		195682.5	9691.4		123121.0	14726.5	0.962	0.007

Sppn	Strata	Avg year	Estimated Population	SE Pop	Avg year	Estimated Population	SE Pop	Growth Rate	SE GR
SCAU	AK pen	1993.5	14657.9	6734.1	2004.5	4754.3	1229.3	0.903	0.015
SCAU	BB low	1993.5	44413.6	8959.6	2004.5	12243.4	6301.9	0.889	0.014
SCAU	BB high	1993.5	46131.0	9545.2	2004.5	17165.9	6022.7	0.914	0.014
SCAU	YKD high	1990.5	93016.9	12888.9	2004.5	82499.7	19147.2	0.991	0.017
SCAU	YKD low	1990.5	76945.0	10718.2	2004.5	44915.1	14791.5	0.962	0.015
SCAU	SewP edge	1992.5	19135.7	5031.4	2004.5	4729.2	2319.5	0.890	0.011
SCAU	SewP low	1992.5	4953.3	1324.1	2004.5	3131.1	1111.7	0.962	0.023
SCAU	SewP high	1992.5	13437.2	3279.6	2004.5	4565.2	1254.4	0.914	0.010
SCAU	Selwk high	1996.5	31287.5	4557.9	2004.5	9208.8	2631.8	0.858	0.012
SCAU	Selwk low	1996.5	34276.0	7542.7	2004.5	15664.2	11731.0	0.907	0.044
	Total		378254.3	24763.4		198876.9	28559.3	0.948	0.007

Table 10. Estimated population index and corrected population size for Long-tailed Duck in each of 10 survey strata sampled by expanded surveys flown 1989-1997 and the BLSC survey in 2004-05.

Sppn	Strata	Avg year	Avg index	SE index	Avg year	Avg index	SE index	Growth Rate	SE GR
LTDU	AK pen	1993.5	0	0	2004.5	31.0	44.5		
LTDU	BB low	1993.5	1820	418	2004.5	667.0	794.1	0.913	0.040
LTDU	BB high	1993.5	1039	436	2004.5	128.0	128.0	0.827	0.012
LTDU	YKD high	1990.5	8406	1173	2004.5	4142.5	929.5	0.951	0.009
LTDU	YKD low	1990.5	8189	1085	2004.5	3669.0	1707.7	0.944	0.015
LTDU	SP edge	1992.5	3118	685	2004.5	0.0	0.0	0.000	0.000
LTDU	SP low	1992.5	3960	921	2004.5	1382.5	1200.8	0.916	0.026
LTDU	SP high	1992.5	3878	900	2004.5	1325.5	619.9	0.914	0.015
LTDU	Selwk high	1996.5	2441	534	2004.5	58.5	85.6	0.627	0.004
LTDU	Selwk low	1996.5	2239	388	2004.5	0.0	0.0	0.000	0.000
	Total		35089	2341		11404.0	2502.5	0.913	0.006

Sppn	Strata	Avg year	Estimated Population	SE Pop	Avg year	Estimated Population	SE Pop	Growth Rate	SE GR
LTDU	AK pen	1993.5	0.0	0.0	2004.5	161.2	251.3		
LTDU	BB low	1993.5	3397.0	941.4	2004.5	2167.8	2893.7	0.960	0.079
LTDU	BB high	1993.5	1938.9	871.2	2004.5	537.9	597.4	0.890	0.030
LTDU	YKD high	1990.5	15694.0	3330.3	2004.5	15342.9	7737.1	0.998	0.038
LTDU	YKD low	1990.5	15288.9	3154.7	2004.5	14053.7	8540.7	0.994	0.042
LTDU	SP edge	1992.5	5820.4	1562.9	2004.5	0.0	0.0	0.000	0.000
LTDU	SP low	1992.5	7393.3	2069.8	2004.5	4715.4	4676.5	0.963	0.055
LTDU	SP high	1992.5	7240.2	2021.2	2004.5	5015.7	3204.7	0.970	0.040
LTDU	Selwk high	1996.5	4557.3	1224.5	2004.5	190.1	300.8	0.672	0.008
LTDU	Selwk low	1996.5	4180.2	971.0	2004.5	0.0	0.0	0.000	0.000
	Total		65510.2	5995.2		42184.7	13184.5	0.965	0.017

Table 11. Alaskan statewide 20-year averages for estimated populations of Scoter spp., Scaup spp., and Long-tailed Ducks 1986-2005 based on aerial survey estimates from WBPHS transects in 12 strata and the Arctic Coastal Plain aerial surveys. Standard tundra visibility correction factors (Scoter = 1.167, Scaup = 1.933, Long-tailed Duck = 1.867, Smith 1995) were used to convert observed indicated total bird aerial indices to population size. In the 4 tundra strata, Scoter spp. are primarily Black Scoter and Scaup spp. are primarily Greater Scaup.

Stratum	Str#	Stratum area sq. miles	Area km^2	Linear mi flown /yr	Linear km /yr	N trans	N segs	Obsvrd area km^2 /yr	Scoter spp.	Scaup spp.	Long-tailed duck
Kenai-Susitna	1	2,200	5,698	160	257.5	6	10	103.0	2,188	6,273	131
Nelchina	2	3,900	10,101	208	334.7	10	13	133.9	7,191	37,960	642
Tanana-Kuskokwim	3	9,300	24,087	528	849.7	18	33	339.9	22,074	92,251	2,131
Yukon Flats	4	10,800	27,972	320	515.0	12	20	206.0	36,705	222,438	4,408
Innoko	5	3,400	8,806	176	283.2	7	11	113.3	4,343	16,527	477
Koyukuk	6	4,100	10,619	320	515.0	10	20	206.0	5,165	25,571	831
Copper River Delta	7	400	1,036	80	128.7	7	10	51.5	87	4,606	17
Old Crow	12	1,970	5,102	144	231.7	3	8	92.7	59,722	81,817	10,741
Boreal & mixed northern forest strata		36,070	93,420	1936	3115.7	73	125	1246.3	137,476	487,443	19,379
Bristol Bay	8	9,900	25,641	368	592.2	11	23	236.9	79,288	93,340	9,804
Yukon Delta	9	26,600	68,893	1040	1673.7	8	65	669.5	102,247	258,808	47,001
Seward Peninsula	10	3,850	9,971	112	180.2	4	7	72.1	17,513	33,854	14,392
Kotzebue Sound	11	5,350	13,856	192	309.0	7	12	123.6	14,913	70,330	8,344
Tundra wetlands strata		45,700	118,361	1712	2755	30	107	1102.1	213,961	456,332	79,541
Arctic Coastal Plain		23,801	61,645	803	1293		93	517.1	10,237	35,500	104,207
All strata		105,571	273,426	4451	7164	103	325	2865.5	361,674	979,274	203,127

Table 12. Comparisons of stratum sizes and sampled transect areas in the annual WBPHS survey, the expanded inventory surveys flown 1989-1997, and the 2004-05 BLSC survey. Although the expanded and BLSC surveys cover more habitat, this difference is due to the inclusion of peripheral wetlands with low densities of waterfowl.

BLSC survey region	Region area km^2	WBPHS stratum area km^2	BLSC region % larger than WBPHS stratum	Transect km2 observed each year of WBPHS	Transect km2 observed in 2 yrs of expanded surveys	Transect km2 observed in 2 yrs of BLSC survey
Bristol Bay	52,486	25,641	105%	592.2	2,625.7	919.7
Yukon Delta	72,030	68,893	5%	1,673.7	4,278.6	1,235.6
Seward Peninsula	14,899	9,971	49%	180.2	1,064.1	287.1
Selawik	15,060	13,856	9%	309.0	1,756.2	243.6
Total tundra wetlands:	154,475	118,361	31%	2,755.1	9,724.6	2,686.0

Table 13. Comparison within each region of average visibility-corrected population size for Scoter, Scaup, and Long-tailed Duck based on the 20-year average of WBPHS transects and the average of the 2-year expanded surveys and 2-years of BLSC surveys.

BLSC survey region	Average WBPHS population (A)	Std Error 20-yr avg WBPHS population	Average expanded & BLSC survey population (B)	Std Error 4-yr expanded & BLSC survey population	Difference (A – B)	% difference (A – B) / B	Prob. t-test (df=4, H_o: difference =0
Black Scoter							
Bristol Bay	79288	4074	42466	7178	36822	87%	0.011
Yukon Delta	102247	4743	64336	8009	37911	59%	0.015
Seward Peninsula	17513	1512	16274	4467	1238	8%	0.806
Selawik	14913	935	10916	2545	3997	37%	0.214
Total tundra wetlands:	213961	8281	133992	11920	79968	60%	0.005
Greater Scaup							
Bristol Bay	93340	6351	69683	12129	23657	34%	0.159
Yukon Delta	258808	13568	148688	20814	110119	74%	0.011
Seward Peninsula	33854	1950	24976	4797	8878	36%	0.162
Selawik	70330	6276	45218	10541	25112	56%	0.110
Total tundra wetlands:	456332	21470	288566	26729	167766	58%	0.008
Long-tailed Duck							
Bristol Bay	9804	1328	4101	2285	5703	139%	0.097
Yukon Delta	47001	2488	30190	8771	16811	56%	0.139
Seward Peninsula	14392	1663	15093	4634	-700	-5%	0.894
Selawik	8344	739	4464	1125	3880	87%	0.045
Total tundra wetlands:	79541	3709	53847	10241	25694	48%	0.078

Table 14. Comparison within each region for Scoter, Scaup, and Long-tailed Duck of average annual growth rates of visibility-corrected population size based on the 20-year trend from WBPHS transects and the interval and ratio of populations estimated for the 2-year BLSC surveys and the 2-year expanded surveys.

BLSC survey region	Average WBPHS population trend (A)	Std Error 20-year WBPHS trend	Growth rate expanded & BLSC surveys (B)	Std Error of growth rate expanded & BLSC surveys	Difference (A – B)	Prob. t-test (df=20, H_o: difference =0
Black Scoter						
Bristol Bay	0.9902	0.0086	0.9676	0.0171	0.0227	0.249
Yukon Delta	0.9941	0.0089	0.9755	0.0099	0.0186	0.177
Seward Peninsula	0.9785	0.0195	0.9537	0.0217	0.0248	0.405
Selawik	1.0082	0.0117	0.9391	0.0323	0.0691	0.058
Total tundra wetlands:	0.9930	0.0069	0.9687	0.0079	0.0243	0.031
Greater Scaup						
Bristol Bay	1.0318	0.0104	0.9028	0.0095	0.1290	0.000
Yukon Delta	1.0321	0.0068	0.9796	0.0117	0.0524	0.001
Seward Peninsula	0.9929	0.0107	0.9120	0.0085	0.0809	0.000
Selawik	1.0135	0.0129	0.8859	0.0265	0.1276	0.000
Total tundra wetlands:	1.0275	0.0066	0.9475	0.0073	0.0800	0.000
Long-tailed Duck						
Bristol Bay	0.9477	0.0232	0.9451	0.0546	0.0027	0.965
Yukon Delta	0.9797	0.0073	0.9963	0.0285	-0.0166	0.579
Seward Peninsula	0.9991	0.0161	0.9400	0.0254	0.0591	0.063
Selawik	0.9861	0.0181	0.6197	0.0066	0.3664	0.000
Total tundra wetlands:	0.9820	0.0064	0.9649	0.0176	0.0171	0.372

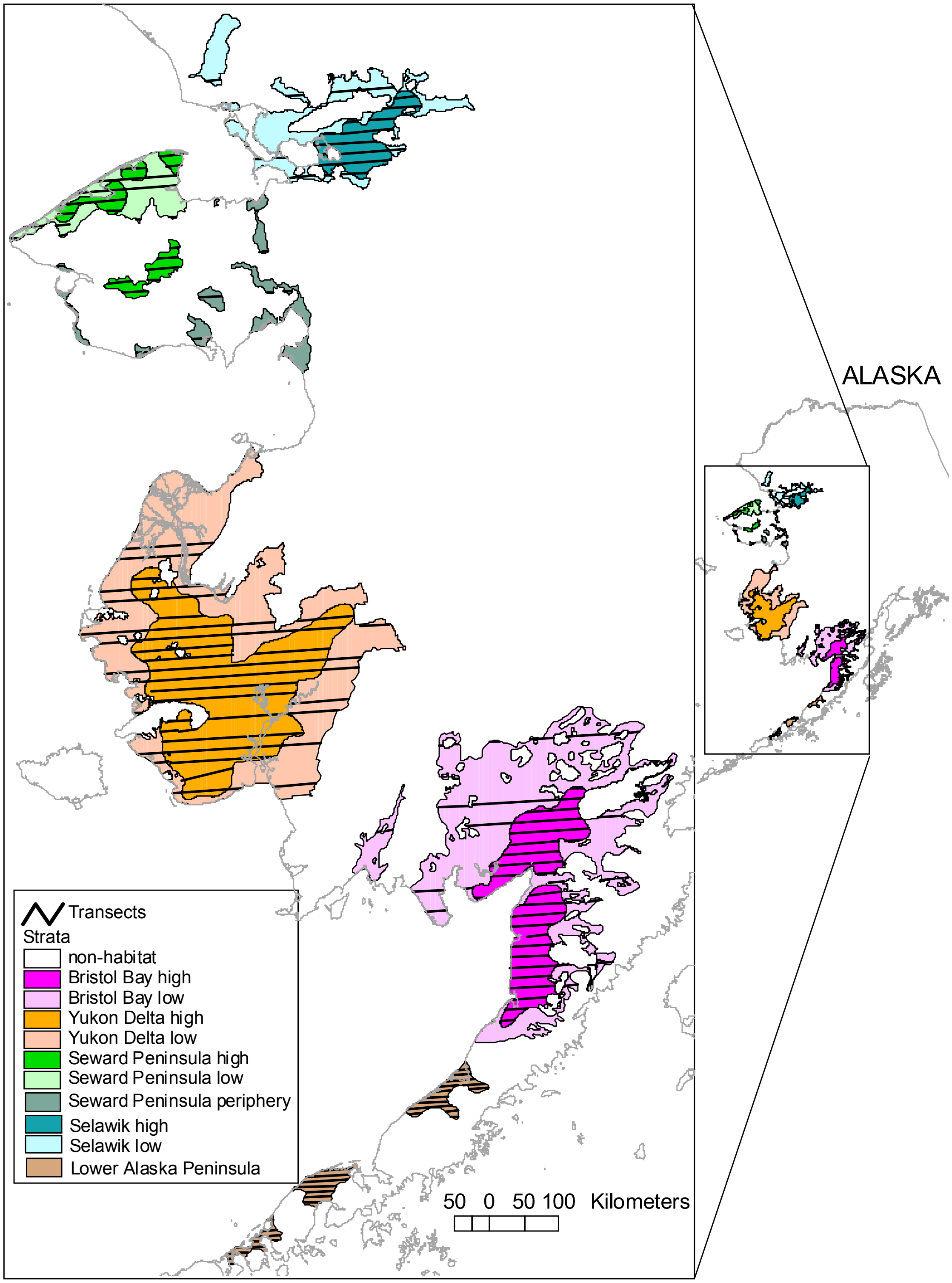


Figure 1. Location of 2004 and 2005 transects flown to sample 10 tundra wetland strata in western Alaska established to monitor the Black Scoter breeding population.

Figure 2. Location of all Black Scoter sightings in the 2004-05 surveys.

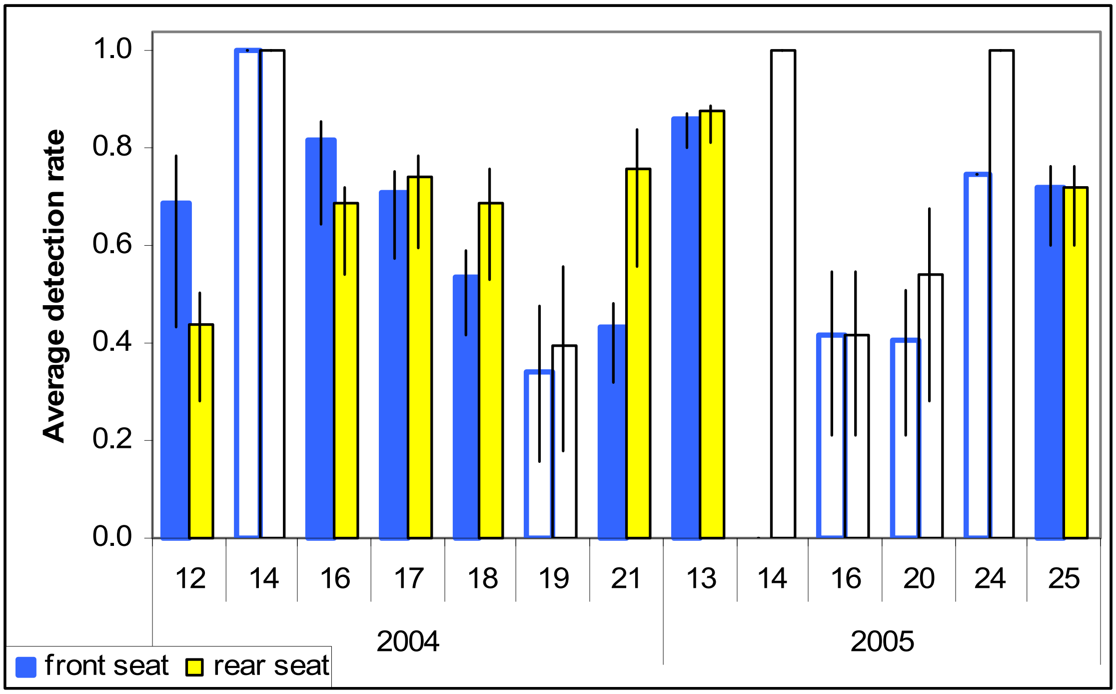


Figure 3. Average aerial detection rates for specific dates in June 2004 and June 2005 surveys calculated after combining Scoter, Scaup, and Long-tailed ducks. Vertical lines indicate 95% confidence intervals. The unfilled columns indicate estimates based on samples with fewer than 6 matched observations.

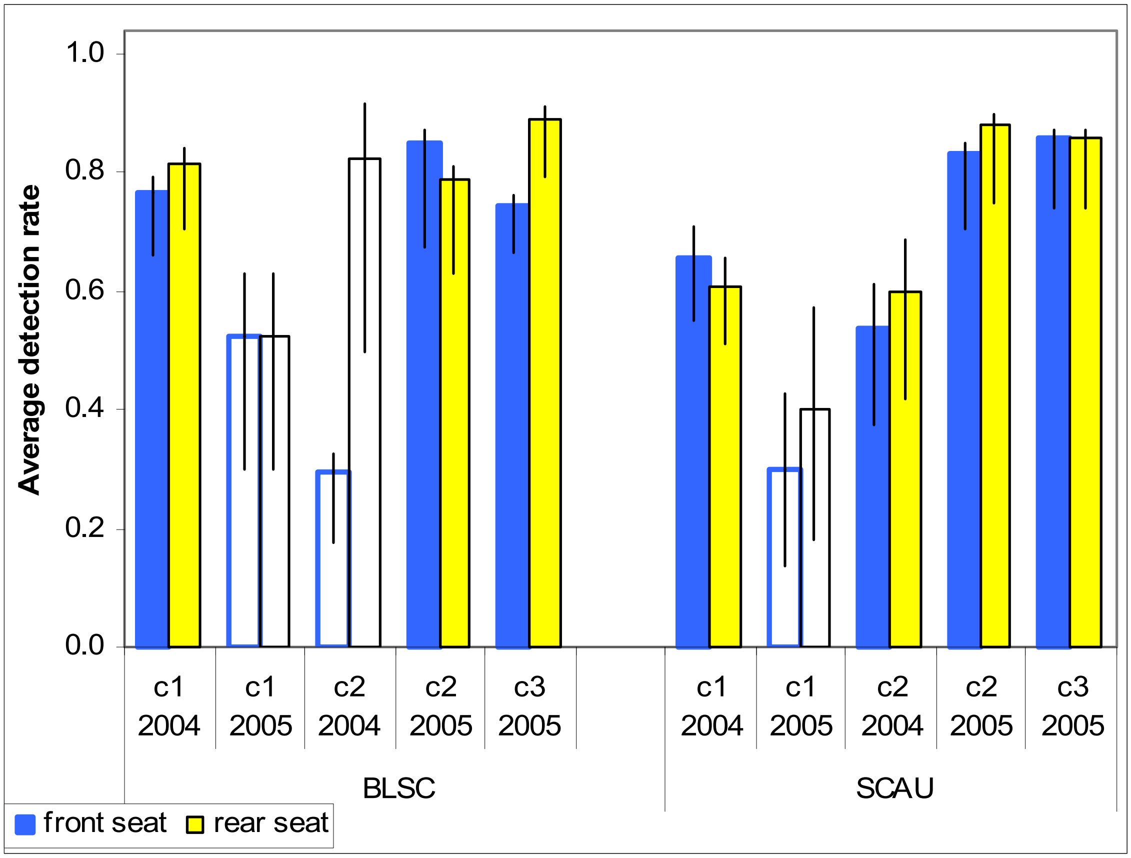


Figure 4. Average aerial detection rates for each survey crew (c1 = PDA,FJB, c2 = PDA,TLM, c3 = KR,KS) for Black Scoter and Greater Scaup observations calculated with all survey days combined. Vertical lines indicate 95% confidence intervals. The unshaded columns indicate estimates based on samples with fewer than 6 matched observations.

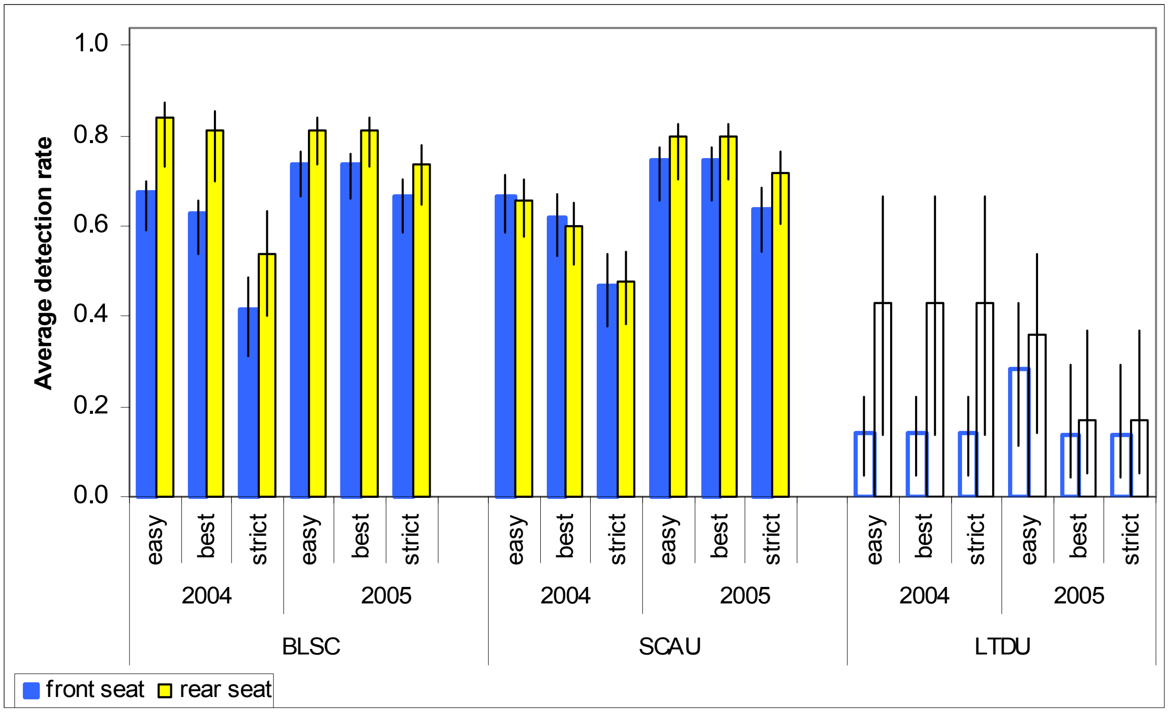


Figure 5. Average aerial detection rates for each species based on independent front- and rear-seat double-count observations using lenient, best, and strictest criteria for matching observations. All days and survey crews were combined. Vertical lines indicate 95% confidence intervals. The empty columns indicate estimates based on samples with fewer than 6 matched observations.

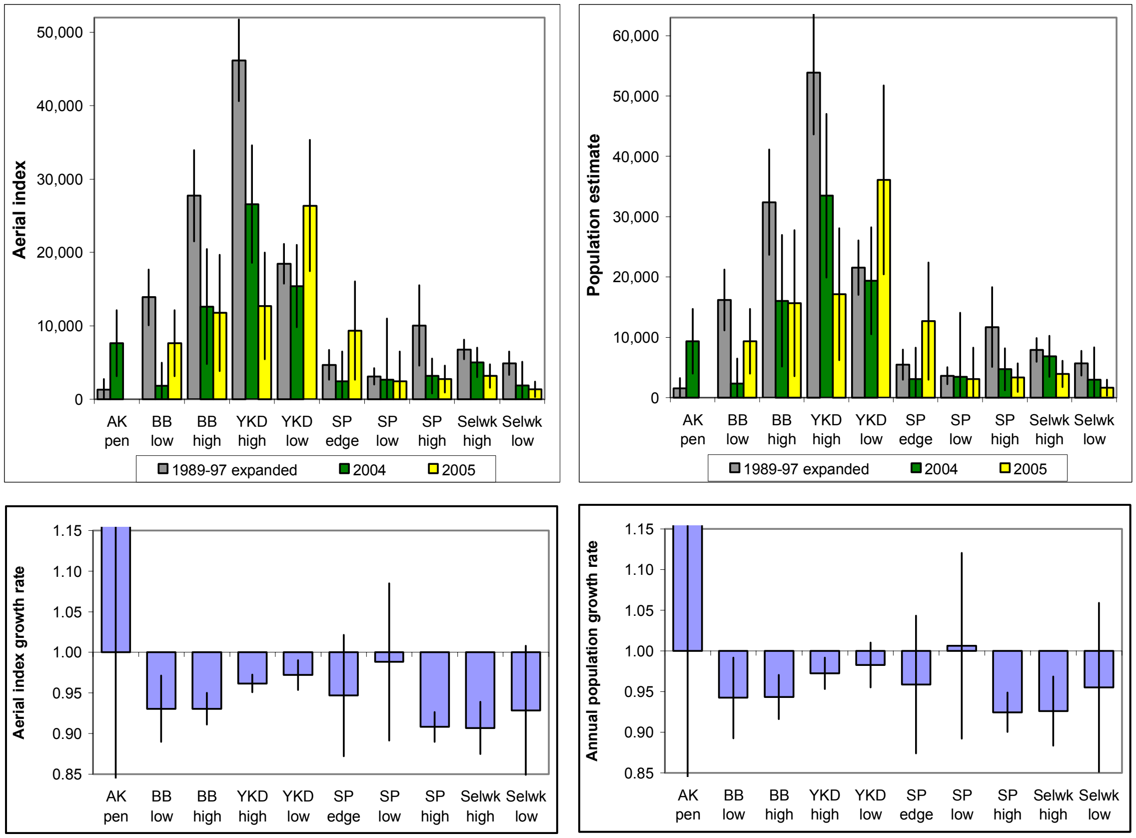


Figure 6. Aerial indices and population estimates corrected for detection-rate of Black Scoters on 10 strata in western Alaskan wetland tundra comparing 1989-1997 expanded survey observations with the 2004 and 2005 BLSC survey observations.

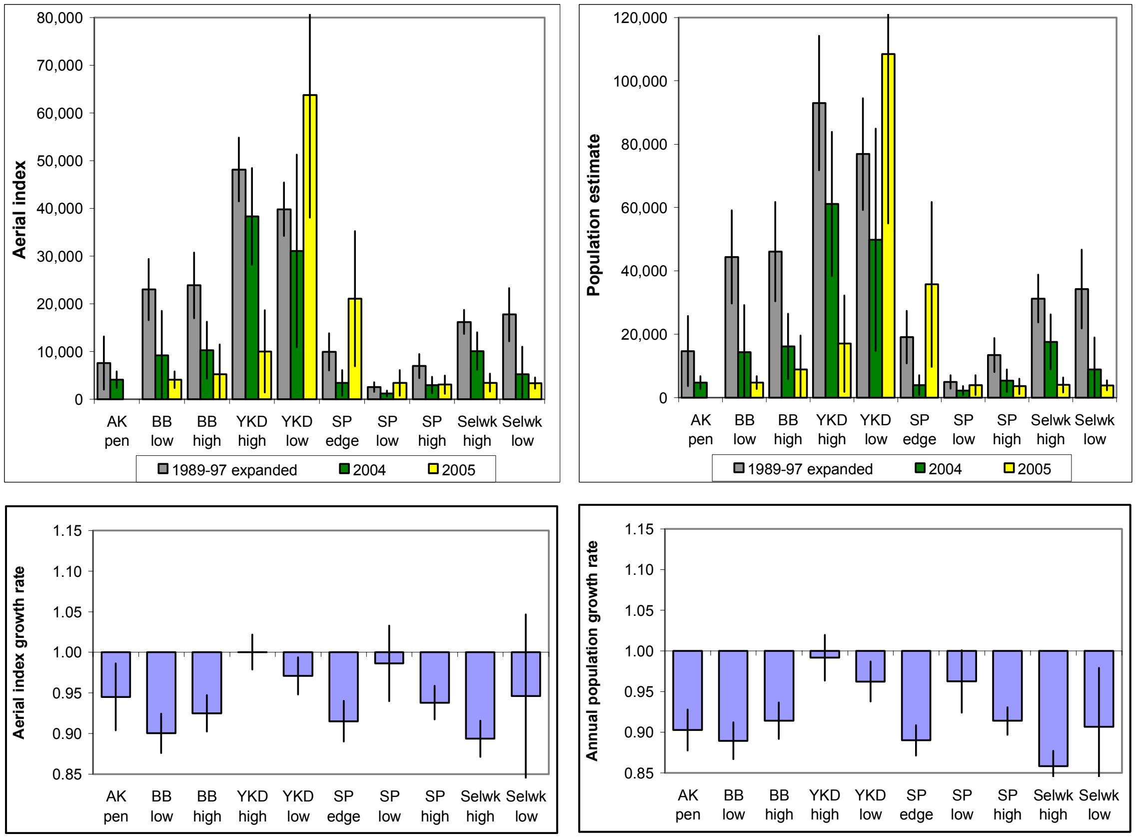


Figure 7. Aerial indices and population estimates corrected for detection-rate of Greater Scaup on 10 strata in western Alaskan wetland tundra comparing 1989-1997 expanded survey observations with the 2004 and 2005 BLSC survey observations.

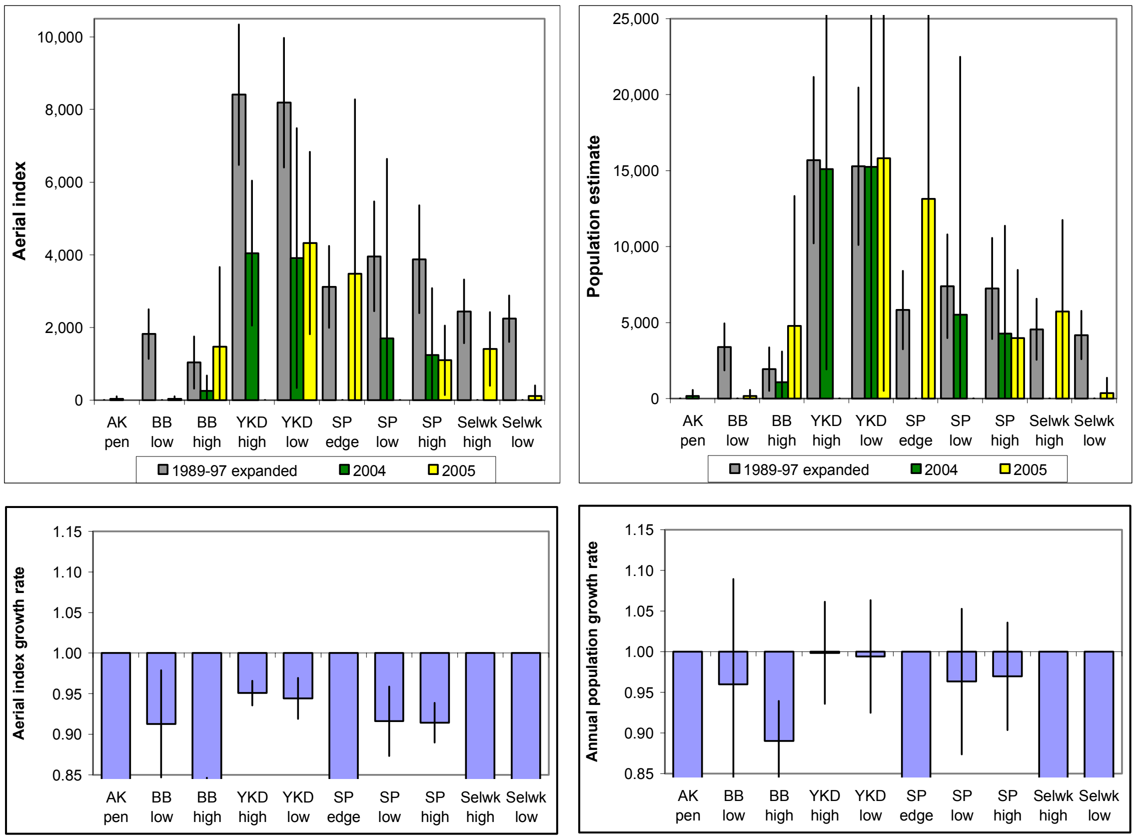


Figure 8. Aerial indices and population estimates corrected for detection-rate of Long-tailed Duck on 10 strata in western Alaskan wetland tundra comparing 1989-1997 expanded survey observations with the 2004 and 2005 BLSC survey observations.

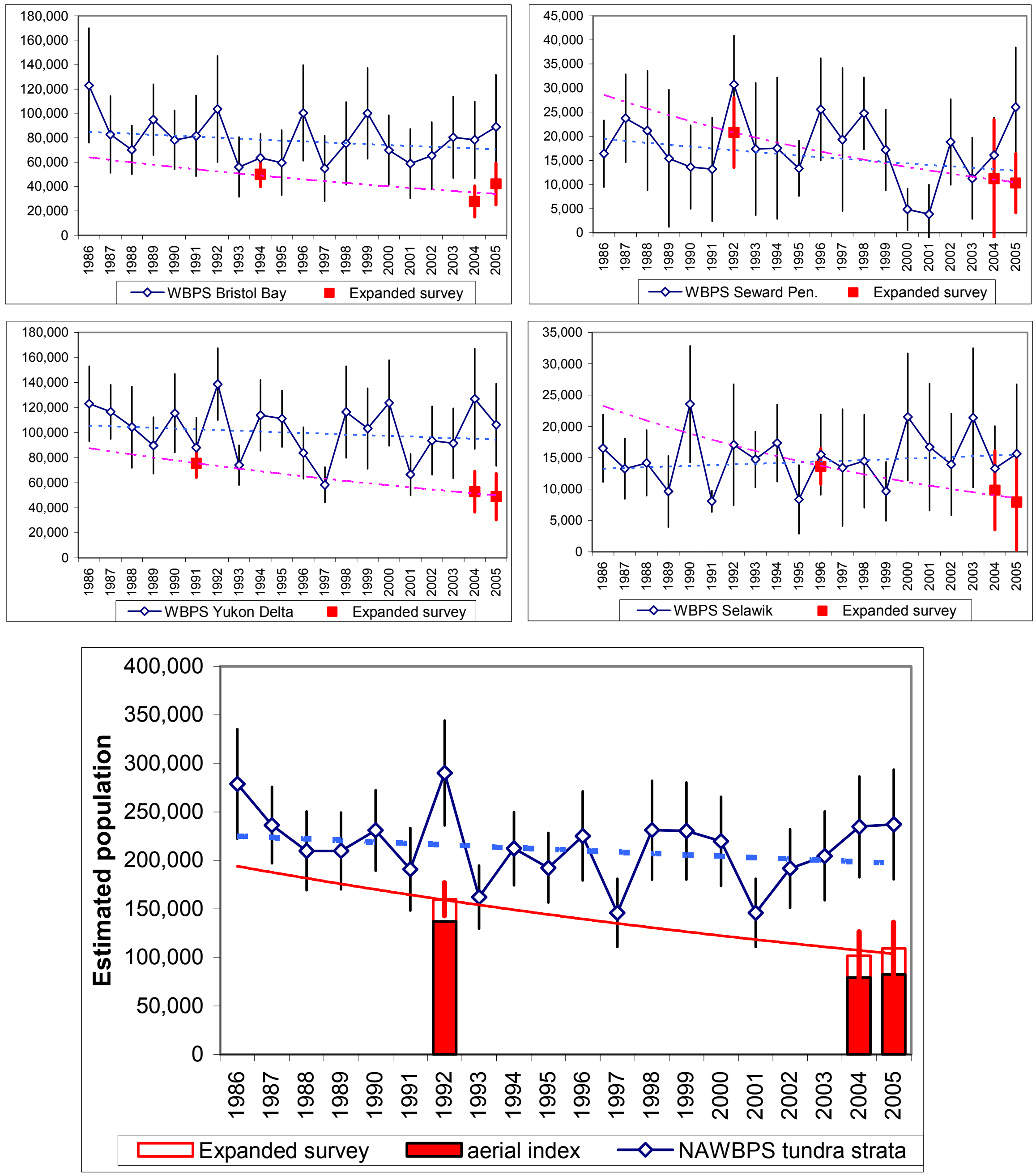


Figure 9. Comparison of visibility corrected population estimates for Black Scoters in each of 4 western Alaska tundra wetland regions as measured by the N.A. Waterfowl Breeding Pair Survey, the Expanded Inventory survey, and the first 2 years of the Black Scoter survey.

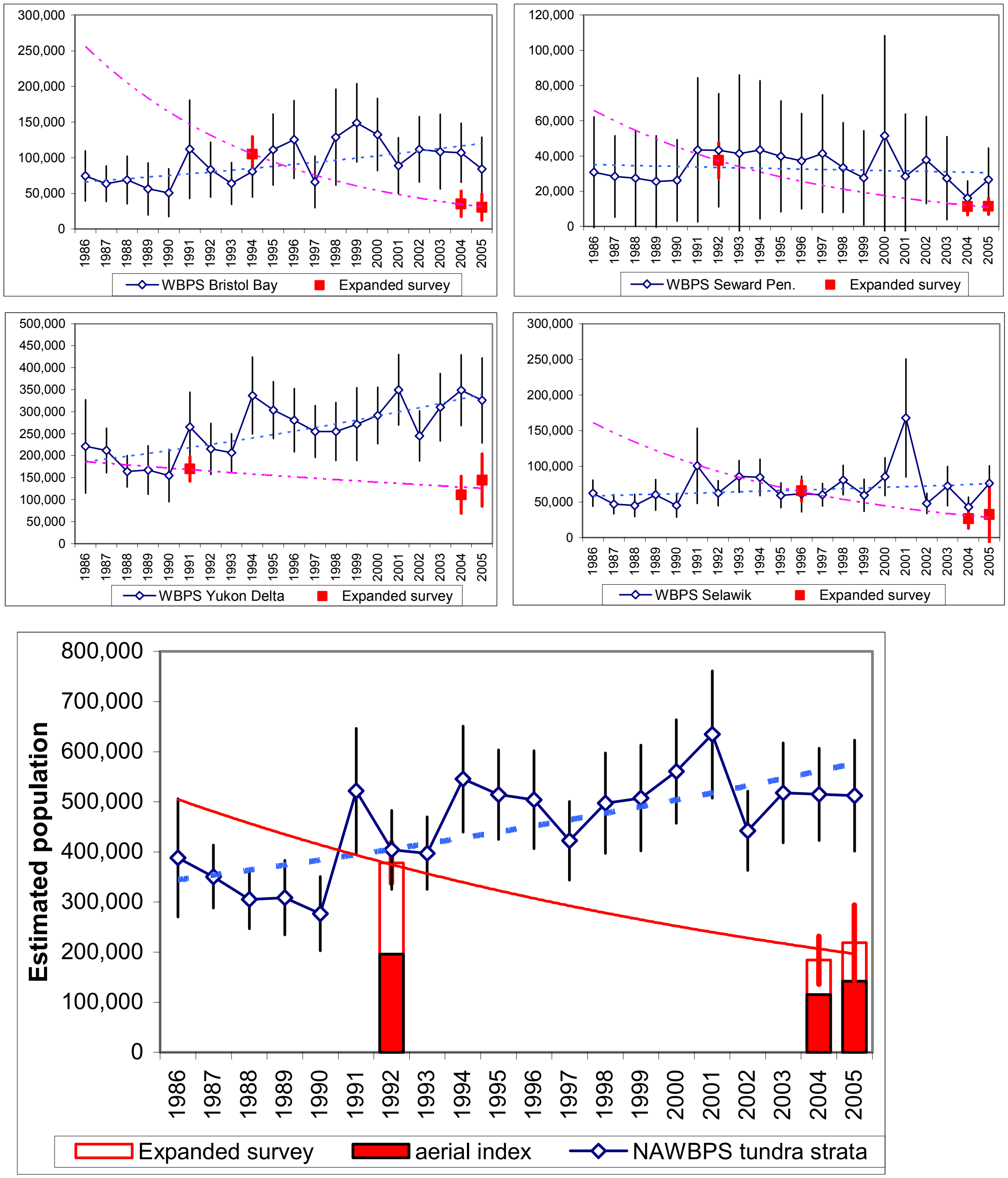


Figure 10. Comparison of visibility corrected population estimates for Scaup in each of 4 western Alaska tundra wetland regions as measured by the N.A. Waterfowl Breeding Pair Survey, the Expanded Inventory survey, and the first 2 years of the Black Scoter survey.

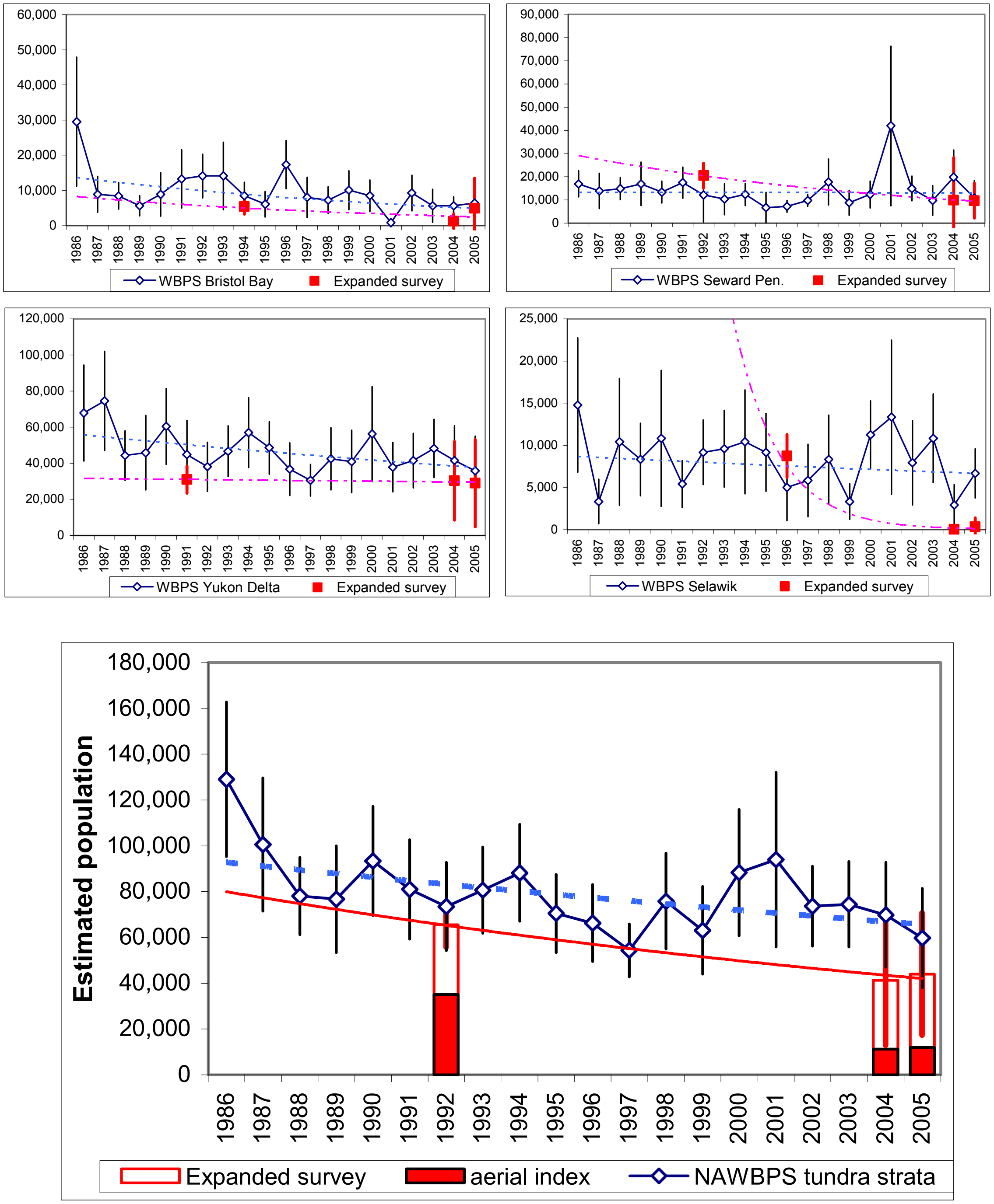
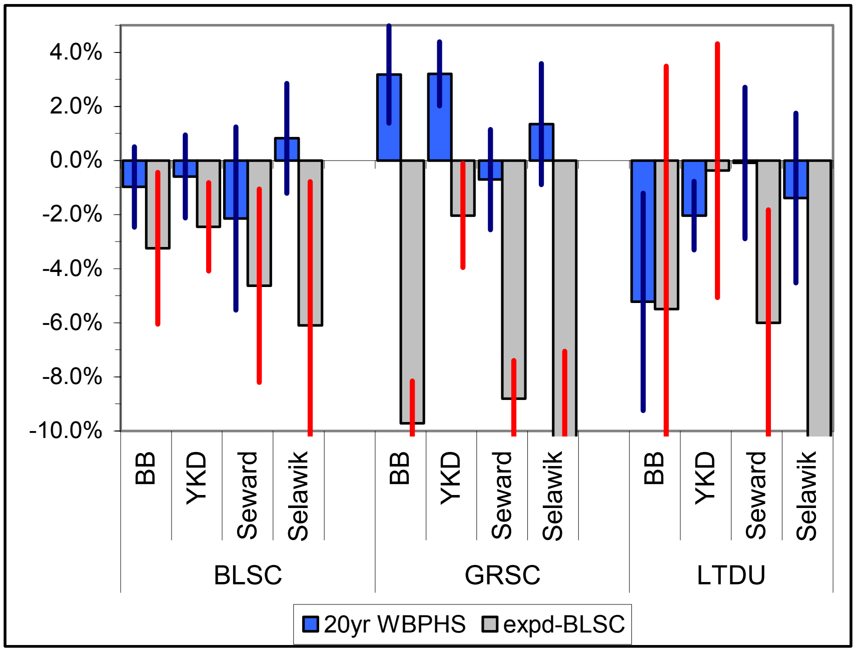


Figure 11. Comparison of visibility corrected population estimates for Long-tailed Duck in each of 4 western Alaska tundra wetland regions as measured by the N.A. Waterfowl Breeding Pair Survey, the Expanded Inventory survey, and the first 2 years of the Black Scoter survey.



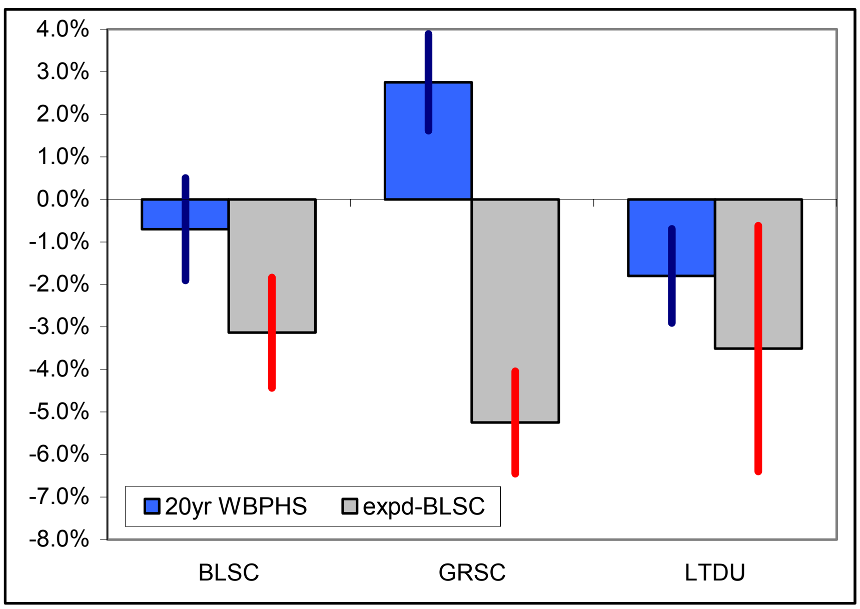


Figure 12. Comparison of estimated population growth rates (% average annual change) for visibility-corrected population estimates from Black Scoter (BLSC), Greater Scaup (GRSC) and Long-tailed Duck (LTDU) observations as measured by 1986-2005 Waterfowl Breeding Pair Habitat Survey data, or the ratio of change between the expanded inventory survey and the first 2 years of the Black Scoter survey. The top graph shows estimates in each of 4 western Alaska tundra wetland regions and the lower graph shows the combined estimates for all tundra regions. Vertical lines indicate 90% confidence intervals around the estimated growth rates.