Abundance and Trend of Waterbirds on Alaska's Yukon-Kuskokwim Delta Coast based on 1988 to 2008 Aerial Surveys

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Abstract: We summarized twenty-one years of aerial survey observations 1988 to 2008 that indexed abundance, trend, and distribution of waterbird nesting populations in the Yukon-Kuskokwim delta coastal zone. Analysis of previous year's data showed a strong correlation between thaw-degree days and average cackling goose (*Branta hutchinsii*) hatch dates. We used this relationship along with average survey timing to determine a start date for the 2008 survey consistent with timing of the last 7 years of surveys. In 2008, the coastal zone became snow-free around mid-May, similar to 2007. We started the 2008 survey on June 2 and finished on June 10, timing that was appropriate for the subsequent June 21 average cackling goose hatch date as determined by nest plot data (Fischer et al. 2008).

In 2008 the three most numerous waterfowl species were northern pintails (*Anas acuta*) with a visibility corrected estimate of 161,333 birds, greater scaup (*Aythya marila*) with 72,307 birds, and northern shovelers (*Anas clypeata*) at 28,880 birds. The estimated population sizes for special interest species were 20,453 threatened spectacled eiders (*Somateria fischeri*), 4,919 common eiders (*Somateria mollissima*) currently designated a focal species, 6,986 long-tailed ducks (*Clangula hyamelis*), 10,757 black scoters (*Melanitta nigra*), and 2,971 red-throated loons (*Gavia stellata*). The spectacled eider estimate was the highest in the history of the survey, 105% above the long term average (LTA) whereas the long-tailed duck estimate was the second lowest (42% below LTA). Jaegers (*Stercorarius spp.*) had the lowest population estimate in the history of the survey. All surveyed waterfowl species except for spectacled eider, common eider, northern pintail, and greater scaup had population estimates for 2008 below the long term averages.

Of the gull species in 2008, glaucous gulls (*Larus hyperboreus*) were most numerous with an estimated 37,463 birds (2% below LTA) followed by 28,019 (+69%) Sabine's gulls (*Xema sabini*) and 19,708 (+56%) mew gulls (*Larus canus*). The Sabine's gull and mew gull estimates were the highest for the history of the survey. The estimated population size for Arctic terns (*Sterna paradisaea*) was 24,144 (+26%). Pacific loons (*Gavia pacifica*) were estimated at 15,181 birds (-11%).

Population trends based on log-linear regression showed significant decline ($p<0.10$) only for American wigeon and canvasback. Significant increase occurred for greater scaup, spectacled eider, common eider, red-breasted merganser, Sabine's gull, mew gull, arctic tern, Pacific loon, and red-throated loon.

We continued to compile individual geographic locations for sightings of 21 major species of waterbirds and now have over 107,000 bird locations in a geographic information system useful for research and management.

Key words: aerial survey, Alaska, geographic information system, GIS, population index, *Somateria fischeri*, spectacled eider, trend, waterbird, waterfowl, Yukon-Kuskokwim delta.

Annual aerial survey observations on the Yukon-Kuskokwim delta (YKD) coastal zone in western Alaska provide population indices, trend, and distribution data for many species of breeding waterbirds that are used by the Pacific Flyway Council, the Alaska Migratory Bird Co-management Council, U.S. Fish and Wildlife Service (USFWS) refuge managers, and other biologists. This intensive aerial survey was initiated in 1985 to monitor populations of geese that had shown substantial declines in fall population counts in California. The initial YKD surveys were flown with a pilot/observer in the left front seat and an additional observer in the right front seat, each counting geese, swans, and cranes (Eldridge 2003). Data on these species are reported in July each year in the Pacific Flyway Data Book (USFWS, Portland, Oregon).

The high density of geese of the YKD made it too difficult for front seat observers to also observe and record all species of waterbirds. Therefore in 1988, an additional observer in the right rear seat began to monitor populations of other waterbird species. The objective for the back seat observer was to document the relative abundance, trend, and distribution of ducks, loons, grebes, gulls, terns, and jaegers. These survey data have become a primary source to monitor the threatened population of spectacled eider and other species of concern such as the common eider, black scoter, long-tailed duck, and red-throated loon,. The objective in this report is to summarize the population estimates and trends for all species recorded from 1988 to 2008 by the rear seat observer.

METHODS

Survey Design

The survey area included the coastal tundra from Norton Sound in the north to Kuskokwim Bay in the south, extending from the west coast to about 50 km inland, and encompassing 12,832 km^2. This area was divided into 18 strata by identifying areas of generally homogeneous physiographic features from an unclassified LANDSAT image mosaic at 1:250,000 scale (Fig. 1). We used a custom True BASIC program and ARC/INFO® (Environmental Systems Research Institute, Inc., Redlands, California) geographic information system (GIS) software to generate systematic transects from a random coordinate within the survey area. Transects were oriented east west along great circle routes. Strata with high variance, known to have higher numbers of waterfowl, were allocated more transects. Prior to 1998, annual flights totaled about 2,500 km on roughly 100 transects with an observed sample area of about 500 km^2. The survey design has changed slightly over the years in the number and placement of transects. We used 1.61 km transect spacing in the higher density areas, and in strata with fewer waterfowl, intervals of 3.22, 6.44, or 12.88 km. Since redesign of the survey in 1998, transects have been spaced at 1.60, 3.20, 6.40, or 12.80 km within the various strata, and we designed a 4-year rotating panel of transect coverage. A different set of transects was flown in each year, 1998-2001, such that we obtained 50% coverage of the habitat at the 1.60 km interval after combining transects (200m wide) from four years. In 2002, we began a second replicate of each set of transects by flying the same lines as in 1998. In 2008, we flew the same transects as in 2000 and 2004 completing the third year of the third 4-year rotation.

Data Collection

We flew the surveys generally within the first 2 weeks of June (Fig. 2) to coincide with egg-laying or early incubation stages for breeding geese, although prior to 1993, surveys extended for a longer period and nesting was late in some years. Historically, timing of surveys was based on informal, anecdotal information on spring phenology obtained from field camps. For 2008 we estimated our start date based on the relationship between thaw degree days (daily mean temperature – 32) and goose nesting chronology from previous ground surveys (Fischer et al. 2007). Meteorological Terminal Air Report (METAR) temperature data for Hooper Bay, Mekoryuk, Emmonak, and Bethel were downloaded from the Weather Underground (http://www.wunderground.com/). We used the day-of-year (DOY) when thaw degree days reached 33. We calculated annual deviations for each station from its own 1984-2007 average DOY at reaching this threshold. Averaging across stations provided a single annual value for the relative timing of spring warm-up whereas averaging across years provided a long-term mean. Deviation of the annual mean from the long-term mean was calculated for each year and regressed against mean cackling goose hatch date to provide an equation for predicting hatch date (Fig. 3). This resulted in a predicted cackling goose average hatch date of June 21, 2008. We calculated the average number of days before mean cackling goose hatch that we started the aerial survey over the last 7 years (2001-2007). The aerial survey has begun on average 19 days before mean cackling goose hatch. Therefore we obtained a target start date for the survey of June 2.

In addition to temperature data, we obtained satellite imagery data after the survey to determine the approximate timing of snowmelt over the survey area as a general indicator of timing of nest site availability. We obtained sequential 8-day mosaics (mid-April to June) of snow extent from the Terra satellite's Moderate Resolution Imaging Spectroradiometer (MODIS) sensor with a 500m grid cell resolution (Hall et al. 2008).

Survey methods followed the standard protocol established for waterfowl breeding ground surveys in North America (USFWS and Canadian Wildlife Service 1987). A Cessna 206 amphibious aircraft was flown at 145-170 km per hour, 30-46m of altitude, with wind speed <24 km per hour, ceilings >152 m, and visibility >16 km. The pilot used a LORAN (1985-1991) or global positioning system (GPS, 1992-2008) and reference to topographic maps to maintain a precise course while flying transects.

Data collection prior to 1998 used voice recording of observations to a cassette tape recorder running continuously while on transect (Butler et al. 1995). Since 1998, the observer used a computerized data collection program called Survey Recording Program written by John Hodges (USFWS, Migratory Bird Management, Juneau, Alaska). This system consisted of a notebook computer connected with the aircraft's GPS receiver, a remote microphone, and mouse. The observer voice recorded each transect number, transect start and stop points, and every bird sighted within the 200 m wide strip to the right side of the aircraft into a WAV format sound file using the remote microphone and mouse. The observer identified birds to species and recorded group size as a single, pair, or number of birds in flocks. Simultaneously, at the mouse click for each sighting, the latitude/longitude coordinates (WGS84 datum) were automatically downloaded from the aircraft GPS to a computer file. We then used a computer transcription program to replay the sound files, enter header information (e.g. year, month, day, observer initials, etc.), enter species and group size, and combine these with the geographic coordinates to produce a final data file. Leslie Slater was the observer in 1988, Karen Bollinger observed in 1989 and 1990, and Bob Platte has collected the data every year since 1991.

We have twenty-one years (1988 to 2008) of counts on ducks but data on other waterbird species were not complete for all years. Jaegers were recorded in 1989, then 1993 to 2008. We began counting loons in 1989, and gulls and terns in 1992. The back seat observer was unable to collect data on 13 transects north of the Askinuk Mountains in 1997, therefore we duplicated the data from the 1996 survey for those transects to include in the 1997 data set to make up for the missing transects. Twenty-three transects were not flown in 1999, and population indices were calculated with fewer transects in some strata. Because the survey was generally flown without covering every adjacent transect in sequence (e.g. some transects were skipped early in the survey and flown later to geographically spread the survey effort over time), the transects that were flown still sampled each stratum at reasonably systematical intervals. In 2001, the back seat observer was unable to fly 13 transects in the central coastal zone and 23 transects north of the Askinuk Mountains. For the missing northern transects, William Eldridge, the right front seat observer, was able to record observations for all species because of the relatively low density of geese, swans, and cranes north of the Askinuk Mountains. In 2003, eleven transects north of the Askinuk Mountains had no data due to a microphone malfunction. In 2004, two short transects in the Scammon Coast stratum and one transect crossing the South Yukon and North Yukon strata were skipped due to wind. In 2006, transects 81 and 83 were inadvertently flown twice on different days and transects 82 and 84 were inadvertently missed, however we still included all the data from these transects. Otherwise, all other transects were flown in 2006. In 2007, data was lost for all of Transect 2, most of Transect 15, and some of Transect 16 due to computer malfunction. Data for all other transects was collected in 2007. and In 2008, a 10.4 km section of Transect 74 in the eastern coastal upland stratum had no data recorded due to a computer malfunction however no major effect on results was expected. No other problems were encountered and all other transects were flown for 2008 in a progression similar to previous years as shown in Fig. 4.

Data Analysis

We calculated densities, population indices, and variability for each species using a ratio estimate (Cochran 1977). Duck population indices were based on indicated total birds: 2 * (S + P) + F, where S = number of single birds sighted, P = number of pairs sighted, and F = number of birds in flocks. A flock was defined as 5 or more ducks occurring together. A single male duck was assumed to represent a breeding pair because the nesting hen was usually not observable, and therefore a single male duck was doubled for all species except scaup. Scaup tend to have an unbalanced sex ratio with an excess of males in the population, therefore a single male scaup does not reliably indicate an unseen female. We did not double single birds for other waterbird species such as grebes, loons, terns, and gulls where the sexes are not obviously dimorphic and their population indices only included total birds sighted. Within each stratum, the sum of indicated total or observed total birds divided by the sum of sampled transect area estimated the average density. The variance of density was based on the variability among sampling units (transect sections) within each stratum. Density multiplied by stratum area calculated the population index. The sum of the population indices and sum of the variances for each of the 18 strata provided the total population index and variance for each year. For most species, the stratified analysis reduced the variance of the total population index in comparison to analysis using only the minimum four sampling intensity strata.

We plotted the species population index for each year as a column shaded to indicate single, pair, and flock components. The range shown with a vertical line indicated the 95% confidence interval (1.96 times the standard error) of the indicted total or total observed index. The standard error of the sample divided by its mean estimated the coefficient of variation (CV) of the annual population index. The average across all annual CVs provided a measure of average survey precision, the sampling error CV.

Log-linear least squares regression determined the average slope of annual population indices across years. Following exponentiation, the log-linear slope is the rate of annual change or the growth rate. Annual % change is the (growth rate-1)*100. The residuals around the log-linear regression provided another estimate of survey precision. The estimated standard error of growth rate is the residual mean square error from log-linear regression multiplied by the growth rate. The residual CV, that included both regression model lack-of-fit error and sampling error, was usually larger than the estimated sampling error CV. We calculated a standardized measure of the relative precision of the aerial survey for each species using the approximate formula of Gerrodette (1987) that links the sample size, slope, CV, and probabilities for Type 1 and Type 2 errors. With alpha set at 0.10 and beta at 0.20, assuming a population growth with a slope of 0.0341 (50% change over 20 years), and using the observed average sampling error CV, the minimum years to detect a slope significantly different from zero was calculated for each species. Growth rates were also calculated for all species using only the last 10 years of data.

Timing of snowmelt and temperature can affect the breeding chronology of waterfowl (Batt et al. 1992). This variation, possibly in combination with differences in survey timing, may have an influence on population indices. The number of spectacled eiders observed on the YKD aerial survey is strongly influenced by the survey timing relative to nesting chronology because male eiders depart to marine habitat as females begin incubation. In this report, we included the observed population indices and data on survey timing and nesting chronology, but a full analysis remains necessary to account for correlation between the two and the potential bias in the trend. When completed, this will be reported separately.

Similarly, any change in detection rate may introduce bias in the trend of observed population indices. From 1995 to 2002, the right-front seat observer, as well as the right-rear seat observer, recorded Spectacled and Common eiders, and using this independent double-count data, we calculated annual spectacled eider detection rates.

RESULTS

Survey conditions

The 2008 survey was flown from June 2 – 10 (Figs. 2 and 4), with no survey on June 5 due to weather, for a total of 8 survey days. Spring phenology in 2008 was advanced only 3 days from the long-term mean. Average temperature in Bethel rose above freezing on March 31st but cumulative thaw degree days began rising steadily after April 19th. Late May and early June temperatures were below normal for Bethel (Fig. 5). The average May 2008 temperature in Bethel was 42.3º F (Fig. 6). Based on surveys of nesting birds on a portion of the coastal zone (Fischer et al. 2008), average cackling goose hatch occurred on June 21, 2008, which matched the hatch date estimated from the thaw degree day data. Therefore, the 2008 survey was timed correctly relative to recent previous year's survey timing.

Correspondingly, satellite imagery indicated snowmelt began around the first week of April in the eastern portions of the refuge and was largely complete by the third week of May along the coast (Fig. 7). Pattern of snowmelt progressed normally in a generally east west direction from the interior of the refuge to the coast. Average break up date for the Kuskokwim River at Bethel is May 12th, for 2008 the break up date was May 13th. Breakup was complete on the Yukon River at Alakunuk by May 23th in 2008, which is also the average break up date for that location.

Weather conditions during the 2008 survey were mostly cool and partly cloudy with little precipitation however, scattered snow showers occurred on June 7 (Fig. 5). Snow showers have not been encountered on this aerial survey since 1992.

With 9 years of MODIS satellite data on snowmelt, the time when the coastal zone became snow-free has varied by as much as about 4 weeks (Fig. 8). Snowmelt in 2008 was similar to 2002, 2005, and 2007. In 2000 and 2001, the coastal zone was snow free by around the last week of May. Snow in the survey area had melted around the third week of May in 2002 and 2005. Early snowmelt occurred in 2003 by the second week of May and in 2004 by the first week of May. Spring in 2006 was relatively late compared to recent previous years with the coastal zone became snow-free around the third week of May.

Relative abundance

Number of birds sighted on each sampled transect and the sampling effort in each strata provided the data to calculate the aerial population indices expanded to the entire survey area (Figs 9 – 27), and the visibility-corrected population estimates for 2008 (Table 1). To convert the aerial index to estimated populations, we used the standard visibility correction factors determined by the ratio of helicopter to fixed-wing aircraft observations for tundra Alaska species (Conant et al. 2000). Pintails (161,333 birds), scaup (72,307), and shovelers (28,880) were the most numerous waterfowl species in 2008, similar to 2005, 2006, and 2007.

However, estimates for all waterfowl species except spectacled eider, common eider, pintail, and scaup were lower in 2008 from 2007 (Table 2). Pintails were 38% above the 2007 estimate and 6% above the LTA, possibly as a result of overflight from the prairies. Greater scaup were 14% above the 2007 estimate and 1% above the LTA. Shoveler estimates were 14% lower than in 2007 and 24% lower than the LTA. The spectacled eider population estimate of 20,453 birds was higher than the 2007 estimate and the highest for the history of the survey, up 105% from the LTA. Common eider estimates were up 9% from the previous year and 10% from the LTA. Black scoter estimates were down 8% from the previous year and 10% from the LTA. Long-tailed ducks were 30% below the 2007 estimate and 42% below the LTA. The red-throated loon estimate was substantially higher than in 2007 (+23%) and also 19% above the LTA.

The aerial population indices, with no correction for visibility bias, showed the relative abundance by group size category for all survey years (Figs. 9 - 27). Cautious interpretation is necessary for those species with relatively low numbers of sightings that can fluctuate greatly in estimated population size. For example, an observation of a single flock of 200 red-breasted mergansers in 2006 greatly influenced the population index and trend.

Population trends

American wigeon and canvasbacks showed a consistent strong decreasing trend (Figs. 15 and 20 and Table 3) over the course of the survey, however, for canvasbacks this is mostly due to relatively few observations of varying group sizes. Increasing trends occurred for greater scaup, spectacled eider, common eider, red-breasted merganser, Sabine’s gull, mew gull, arctic tern, Pacific loon, and red-throated loon. However, trends over the last 10 years were significantly increasing only for mallards. Canvasbacks, Pacific loons, and jaeger species showed significant declines over the past 10 years. The rest of the species showed relatively stable trends over the history of the survey and during the last 10 years.

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Spectacled eider trend

The population growth rate from 1988 to 2008 for the aerial indicated total bird index for spectacled eiders was 1.069 (Fig. 13). However, the most recent 10-year trend was 1.060. A more thorough analysis accounting for observer experience and survey timing yielded a 1993-2006 adjusted growth rate of 1.042 (Stehn et al. 2006). The growth rate from the nest populations estimated from ground studies during 1999-2008 was 1.046. There was overlap in the confidence intervals for these estimated growth rates indicating no real differences.

Relationship between aerial observations and nests

Birds observed along aerial transect samples provide an index to the actual population size. If visibility detection rate for each sighting of a single, pair, or flock of each species could be determined, the actual population size of birds could then be calculated from the aerial index results. Because the detection rates may vary over time or space, for example as influenced by weather conditions, observers, geographic area, and population density, the estimated trend as well as the size of the population has potential for bias. The magnitude of bias in the trend of the population index is the trend of the index ratio over the same period (Bart et al. 2004). The index ratio is defined as the survey result (the aerial observation index measure) divided by actual population size as determined by a more intensive or additional data (Bart et al. 1998, Bart et al. 2004). Of course, the remaining problem is to obtain a representative sample of the survey area with such additional data to determine the actual population.

We do not have any data that measured the actual birds present in 200 m strip indexed by the aerial observer. Nevertheless, we did have data on the population of nests for a portion of the aerial survey area. We calculated an index ratio between the aerial population index and the nest population size (after correction for nest detection rate) to examine the relationship between these two independent measures of different, but presumably closely related, populations. We expected a constant index ratio between aerial observations and nests. If a species nests strictly as monogamous pairs, if renesting is absent, and if immature or non-nesting birds are not observed at the time of the survey, we assumed that each nest should be associated with just two birds, the male and female of each pair, and therefore with 100% visibility, the expected index ratio would be 2.00. Eiders and loons approximate these nesting characteristics unlike most of the waterfowl species nesting on the YKD.

We used only the aerial transect observations and nests found on plots within the core eider area of 716 km^2 (Fischer et al. 2008). To ensure accurate correspondence between the aerial strata, sampling intensities, and the ground-sampled area, aerial survey data were analyzed with 27 strata (stratification design A2G). The aerial population index measure for eider and other ducks already included the doubling of single birds as an adjustment to compensate for unseen cryptic females on nests. Single birds are not doubled for loons, gulls, and terns. The index ratio related the indicated birds observed on the aerial survey to the estimated population of nests corrected for nest detection rate from the ground plots. This ratio differs from the actual index ratio for visibility rate of birds because:

1) some birds may be unavailable for sighting if they are outside the area at the time of survey due to temporary or seasonal departure of the males back to marine foraging areas,
2) the aerial index number already counted observed single males as two birds in an attempt to correct for unseen females on nests,
3) occasional single females are seen but by standard protocol, they are not recorded by

aerial observers, and

4) birds may be present that did not initiate a nest.

Figures 28-35 show the results of the comparison between the aerial and ground surveys for eiders, loons, gulls, and terns. The bottom figure shows nests estimates compared to aerial survey indices within the ground-sampled area and the ratio between the two measures. The top figure shows the aerial population index inside and outside the ground sampled area as well as the ratio between the two and a 7-year average ratio between the two. The middle figure summarizes the nesting population. For spectacled eiders, the average (1999-2008) ratio of birds indexed on the aerial survey per 2 times the corrected nests within the plot sampled area was about 47% whereas the ratio for common eiders and loons ranged from about 26%-29%. In contrast, gulls, terns, and combined duck species ratios ranged from about 71%-107%. The higher index ratios for ducks and terns certainly indicated that many non-nesting birds were present even though they were seen in singles and pairs. High index ratios for aerial indices that included flocked gulls certainly indicated many were non-breeders.

The number of indicated total spectacled eiders from the aerial survey in 2008 was 5,713 birds or 2,857 pairs, uncorrected for visibility bias. The 2008 spectacled eider nest estimate, corrected with a nest detection rate, and expanded for the entire coastal zone was 4,991 (Fischer et al. 2008). The ratio of aerial index indicated pairs to nests was 0.572 (= 2,857/4,991). In other words, if every observed bird (indicated total aerial index) is associated with half of a nest, the visibility rate is 5,713 birds per (4,991 nests x 2 birds/nest) which is 0.572 (57%). The visibility correction factor is the inverse, 1.75.

Distribution

The geographic locations of over 107,000 sightings of 21 species of waterbirds have been collected over the 21 years of this survey. Average location accuracy of the observations when the surveys were flown using LORAN for navigation was within 367 meters along transect compared to 214 meters when using the GPS (Butler et al. 1995). Locations from GPS in recent years are expected to be more accurate. These spatial data have been incorporated into a GIS database for research and management purposes.

DISCUSSION

Three different observers have collected data for this survey, although the same observer has collected the last 18 years data. All observers were experienced at identifying and counting birds from aircraft, however especially for the less common species, a "learning curve" effect is possible during the first 2 or 3 years for each observer and the first 5 years in this data set. Observers become more skilled over time resulting in increasingly more reliable information. As observers gain experience with a specific survey, we expect that improvements were possible in several aspects of aerial observations. First, accuracy of species identification improves with development of “search images” for each species seen in various distance, light, behavior, and habitat conditions. Second, skill in counting large flocks increases. Third, complete coverage of a 200 m strip width becomes less variable, both within a survey and between years, even though survey flights did include some training by flying over known-width marks or checking sight angles with an inclinometer. Fourth, with more practice, observers improve in their ability to quickly detect, identify, and record each observation and then mentally switch back to all possible search images over the full width of the transect. It is possible that less-experienced observers contributed relatively lower counts in the first years of this survey. Because a single observer completed the last 18 years of survey, the magnitude of possible bias in long-term trends becomes very small.

Some variation in detection rate occurs each day due to weather conditions, with higher wind speed and bright sun causing glare likely to be the most detrimental factors. The average of all conditions experienced over the 8-day survey is much less variable among years than are the day-to-day changes. We assumed no long-term trend in detection rate. Preliminary analysis of 8 years of double-count data where the front-seat observer independently recorded spectacled eiders showed little variation and no significant trend in the detection rate for the rear-seat observer (Platte, Eldridge, and Stehn, unpubl. data). The average spectacled eider detection rate for the 8 years of double-count data for the right-rear seat observer was 67.8%. A non-significant increase of 1.6% per year was noted, however based on this preliminary analysis, the small magnitude of change in detection rate strengthens the validity of the observed trend index for eiders and probably other species. However, a comparison of the aerial index of spectacled eiders to nests from ground plot surveys was 57%. Therefore the visibility correction factor for spectacled eiders may be closer to 1.75 rather than the 3.58 factor traditionally applied to eider population indices. Consequently the population estimate for spectacled eiders would be 9,988 instead of 20,453.

Seasonal timing of surveys was also a factor potentially affecting the number of observations and the trend. Behavior and the visibility of many species changes with the stage of incubation; therefore, to get the best trend information, the surveys should be timed consistently relative to nesting chronology. Different stages of nesting may correlate with changes in the flocking behavior, single:pair ratio, or tendency to flush from the aircraft. The intended survey timing was to fall within the first half of incubation for the average of nesting geese. Although the dates of earliest nests found were available from field camp observations, when we begin the aerial survey we do not know the degree of nesting synchrony and the average date of nest initiation, and we cannot always time our survey optimally. Weather, pilot flight hours, and aircraft mechanical problems can also have an influence. For most species both birds of a nesting pair remain in the nesting area, but for spectacled eiders, the much more visible males begin their departure from the breeding grounds shortly after the hens begin incubation, and depending on timing, the survey can miss a variable proportion of the males. If the survey timing was late relative to phenology, a greater proportion of spectacled eider males would have departed which results in a lower population index in that year (Platte et al. 1999). The discrepancy between population trends shown by the population of nests as measured by ground sampling (Fischer et al. 2006) and the trend of aerial population indices was analyzed more fully in 2006. Increased aerial counts were strongly correlated with a change to slightly earlier average survey timing beginning in 1998. When observer experience and survey date were added as variables in log-linear regression, the average growth rate changed from 1.067 to 1.042 and there was no significant difference in trends between the aerial and ground data (Stehn et al., 2006).

The number of spectacled eider pairs observed during the aerial survey in 2001 was the highest in the history of the survey. This may have been caused by increased visibility of the birds due to high fox predation on nests that year and/or late nesting chronology. Predation was also high in 2003 but nest initiation was relatively early. Predation may account for relatively higher numbers of pairs of spectacled eiders observed in 2003. Spring chronology and nesting was very early in 2004, however the survey was flown 1-7 June relatively closer to average timing, and that may have caused the index to be lower. In 2006, the survey was flown earlier relative to average hatch date that may have contributed to the larger population index for eiders.

The geographic locations of birds collected over the 21 years of this survey have been used for a number of purposes. Interpolated density polygons for most species have been developed to show species distribution and can be used as a baseline to detect any future changes in distribution due to such factors as climate change. Distribution information was included in evaluation of YKD coastal zone areas for inclusion as designated critical habitat for spectacled eiders. Relative density distribution maps help illustrate and evaluate impacts of potential land ownership exchange on waterbirds. Survey information was incorporated into the Birds of North America species account for Sabine's gulls. Loon information has contributed to the Loon Working Group for baseline monitoring and in plans for red-throated loon sampling. Population trends were used to compare with other information in a review of seaduck population status.

The survey was designed to monitor geese, however because the distribution of cackling geese largely coincided with that of the spectacled eider, the survey also was appropriate for monitoring spectacled eiders. For species such as scoter and scaup with relatively higher numbers farther inland, where the sampling is less intense, the allocation of sampling effort is not optimal.

RECOMMENDATIONS

Currently there are two survey efforts to monitor the spectacled eider population on the Yukon Delta, the coastal zone aerial survey and the ground plot sampling for nests. Because it is impractical for the nest plot survey to sample the entire coast, it is necessary to continue the aerial survey to gather data necessary to expand the nest population to the entire YKD coast. We believe these two surveys are highly complementary. Together they provide a unique combination of detailed information at two scales of geographic extent and intensity of coverage. Both are better than either one alone for monitoring the spectacled eider population.

The aerial survey also provides information on many other species of interest, although interpretation must be qualified if a significant part of the range of those species extends beyond the coastal zone. Long-tailed ducks, scoters, and scaup are abundant in the more inland strata that were not sampled as intensively, and even further inland, not sampled at all. For better information on these species, we could allocate more effort in this area. We should consider expanding coverage and adding transects in inland areas to obtain better information on seaducks. Because the survey aircraft is flown from Bethel, much of this area must be traversed anyway, just to reach the coast. With the considerable change in populations of some geese since the late 1980s, a re-examination of the allocation of sampling effort might reveal that a moderate decrease in the number of transects in the high-intensity strata may result in a minimal decrease in precision for geese and eiders.

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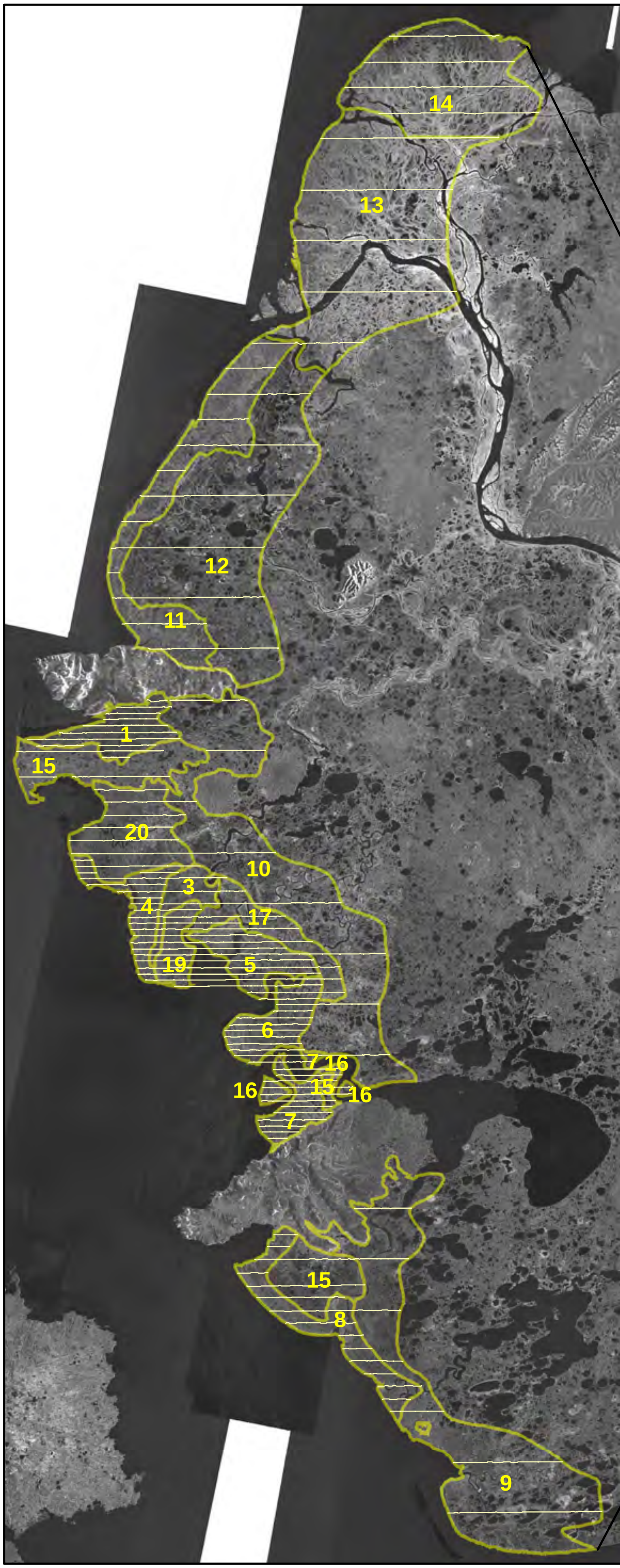


Stratum Number	Stratum Name	Survey Area km^2	Sample Area km^2	% Sample
1	Kokechik	288.7	35.4	12.3%
3	Aphrewn	140.8	10.9	7.8%
4	Tutakoke	236.9	29.6	12.5%
5	Hazen Bay	288.3	36.1	12.5%
6	Naskonat Peninsula	274.5	34.3	12.5%
7	North Nelson Island	191.4	23.2	12.1%
8	South Nelson Coast	398.8	23.9	6.0%
9	Kipnuk Uplands	1691.4	24.6	1.5%
10	Central Uplands	1698.1	25.5	1.5%
11	Scammon Coast	855.9	27.4	3.2%
12	Scammon Uplands	1889.6	29.0	1.5%
13	South Yukon	2078.1	34.8	1.7%
14	North Yukon	1059.0	29.3	2.8%
15	Coastal Uplands	723.5	27.5	3.8%
16	Kigigak/Baird Islands	59.8	7.2	12.1%
17	Intermediate	298.8	20.3	6.8%
19	Oparagyarak	155.3	19.7	12.7%
20	Chevak	502.8	32.0	6.4%
	TOTAL	12831.5	470.9	3.7%

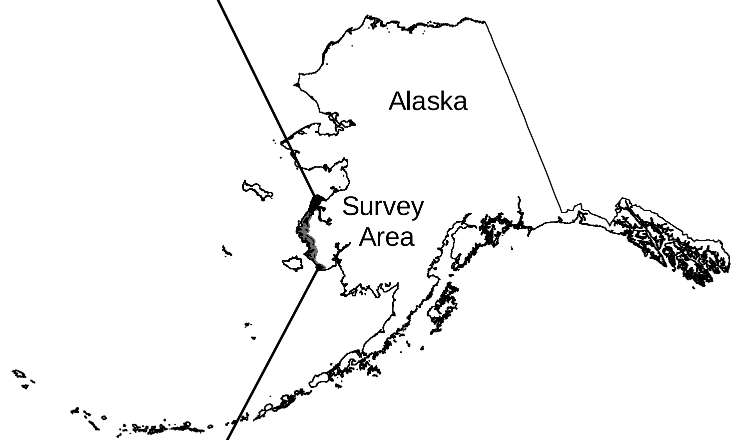


Fig. 1. Transects and strata for aerial waterbird survey, June 2 - June 10, 2008, Yukon Delta coastal zone, Alaska. Transects were spaced at 1-mile intervals in strata 1, 4, 5, 6, 7, 16, and 19, 2-mile intervals in strata 3, 8, 17, and 20, 4-mile intervals in strata 11, 14, and 15, and 8-mile intervals in strata 9, 10, 12, and 13.

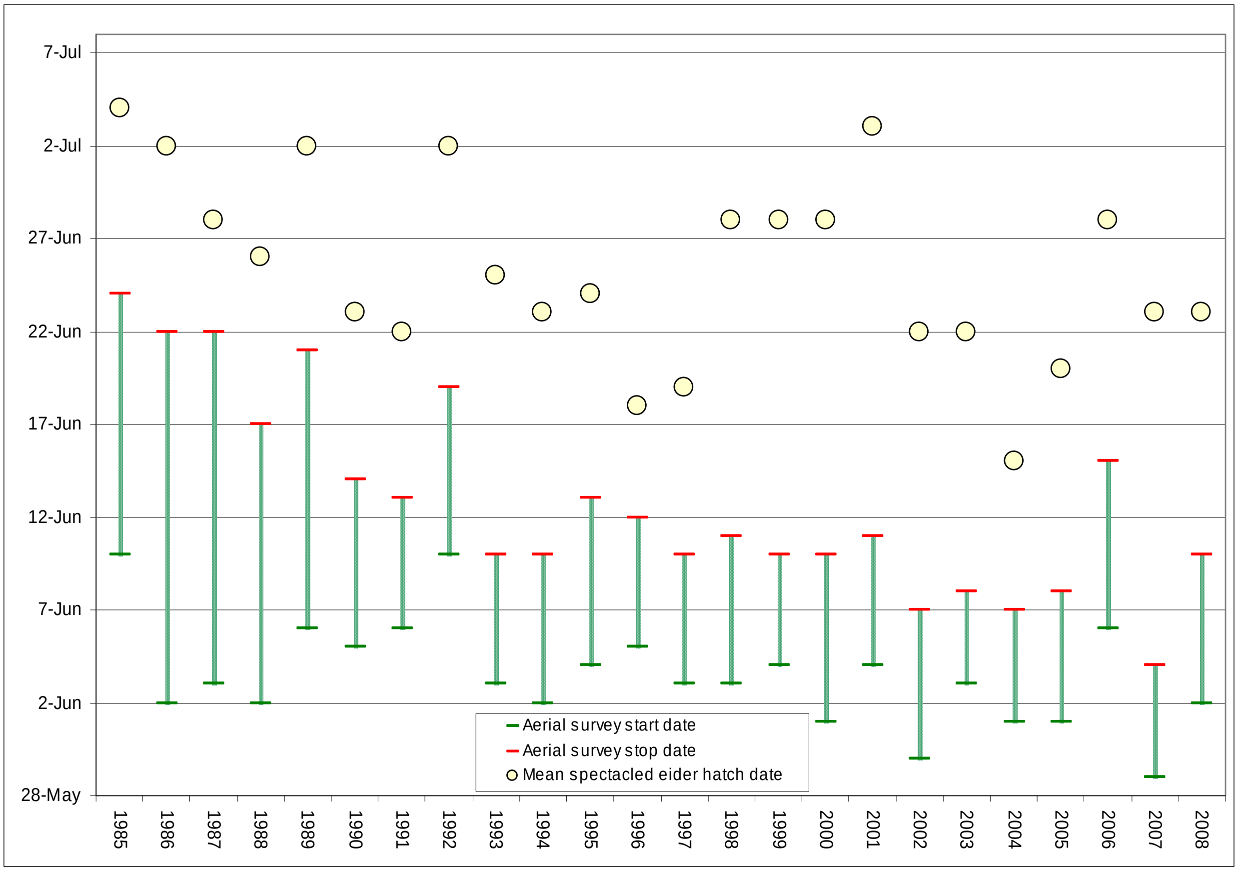
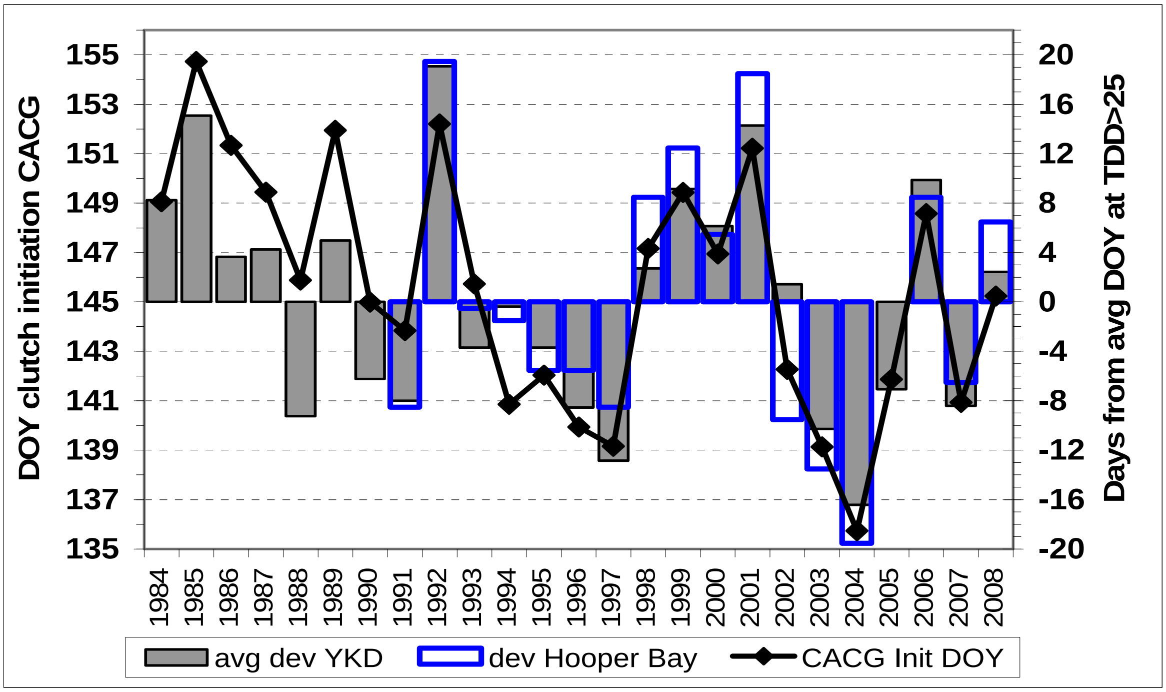


Fig. 2. Timing and duration of the coastal zone aerial survey in relation to average spectacled eider hatch date from ground surveys (Fischer et al. 2008), Yukon-Kuskokwim Delta, Alaska, 1985-2008.



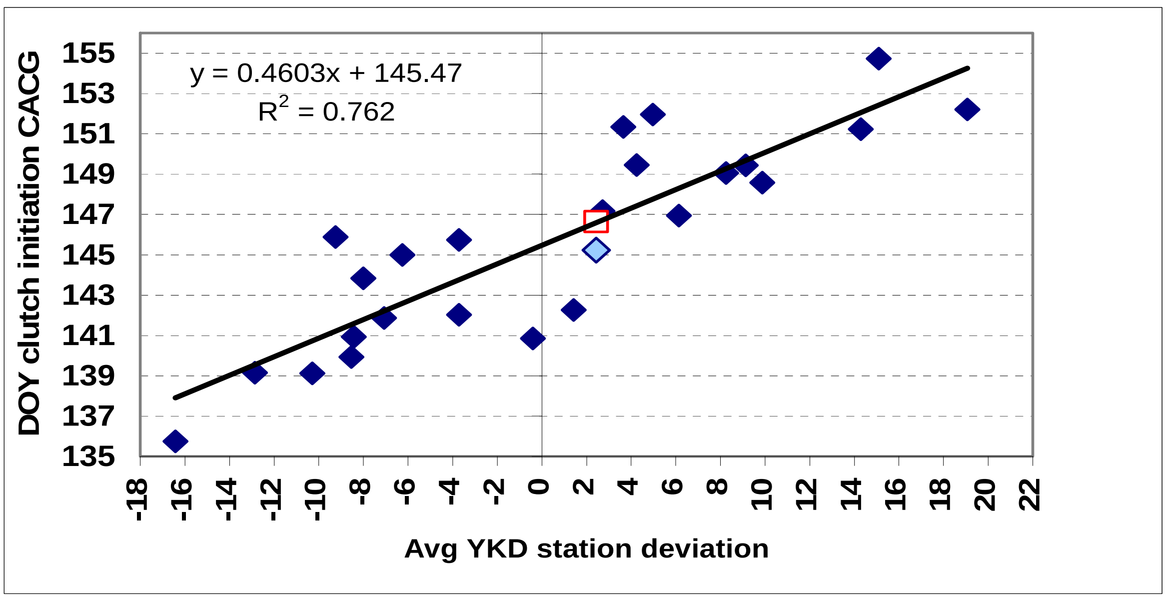


Figure 3. Top graph overlays a line showing the day-of-year (DOY or Julian date) of average clutch initiation date for Cackling Geese each year, and columns indicating the days before or after the average date when Thaw-degree-days (TDD) reached a threshold value of 25 at Hooper Bay. Also shown (grey columns) are the average of the annual deviations in days calculated for each of 7 weather stations on the YKD when TDD reached threshold values. The lower graph plots clutch initiation against average station deviation in days at TDD>threshold . The red box indicates the predicted 2008 CACG average initiation date compared to the light-blue diamond showing the observed initiation date.

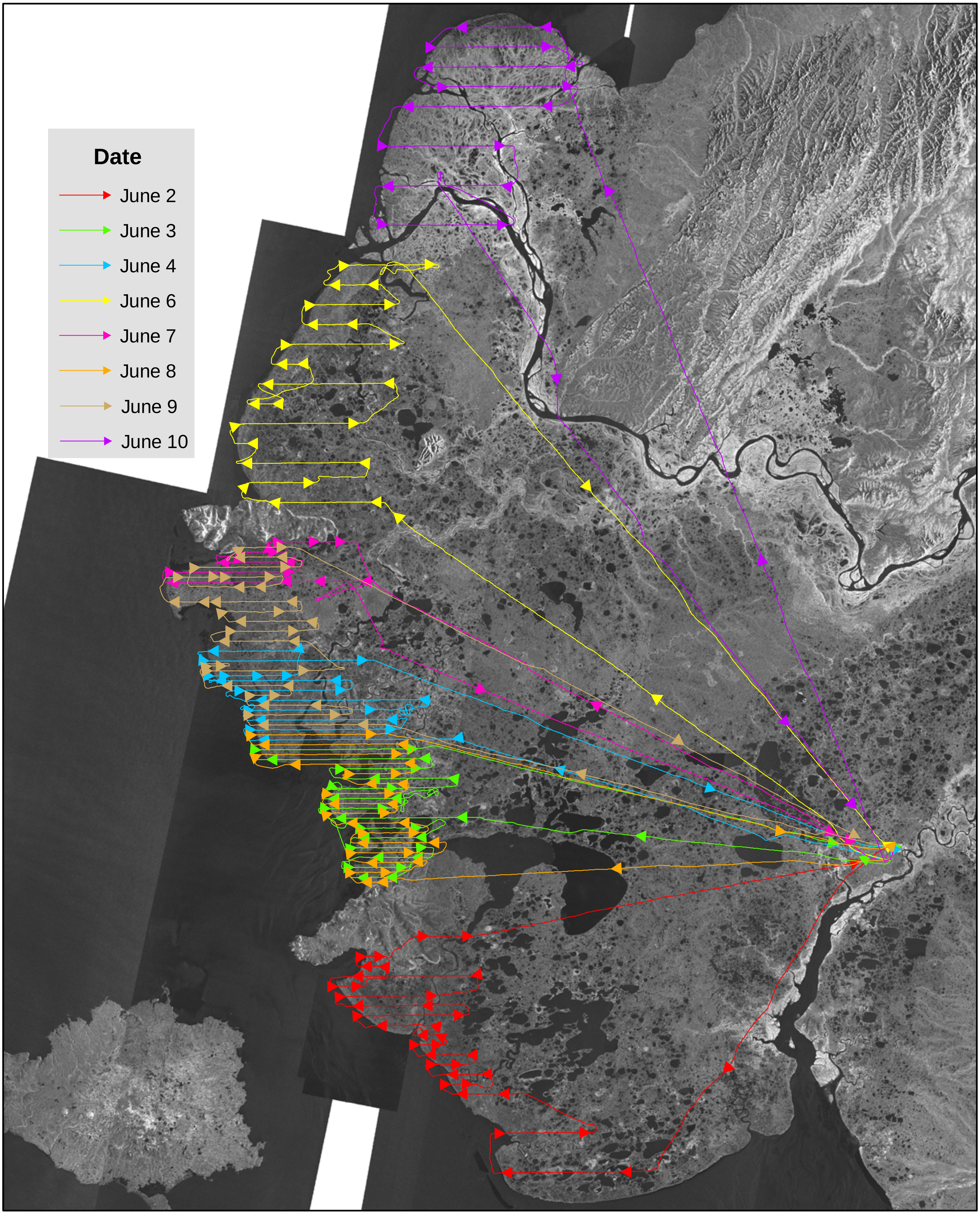


Fig. 4. Transects color-coded by date flown in 2008 showing typical progression of survey by date. We skip every other transect in 1-mile interval strata so as not to double count flushing birds and to spread the survey temporally.

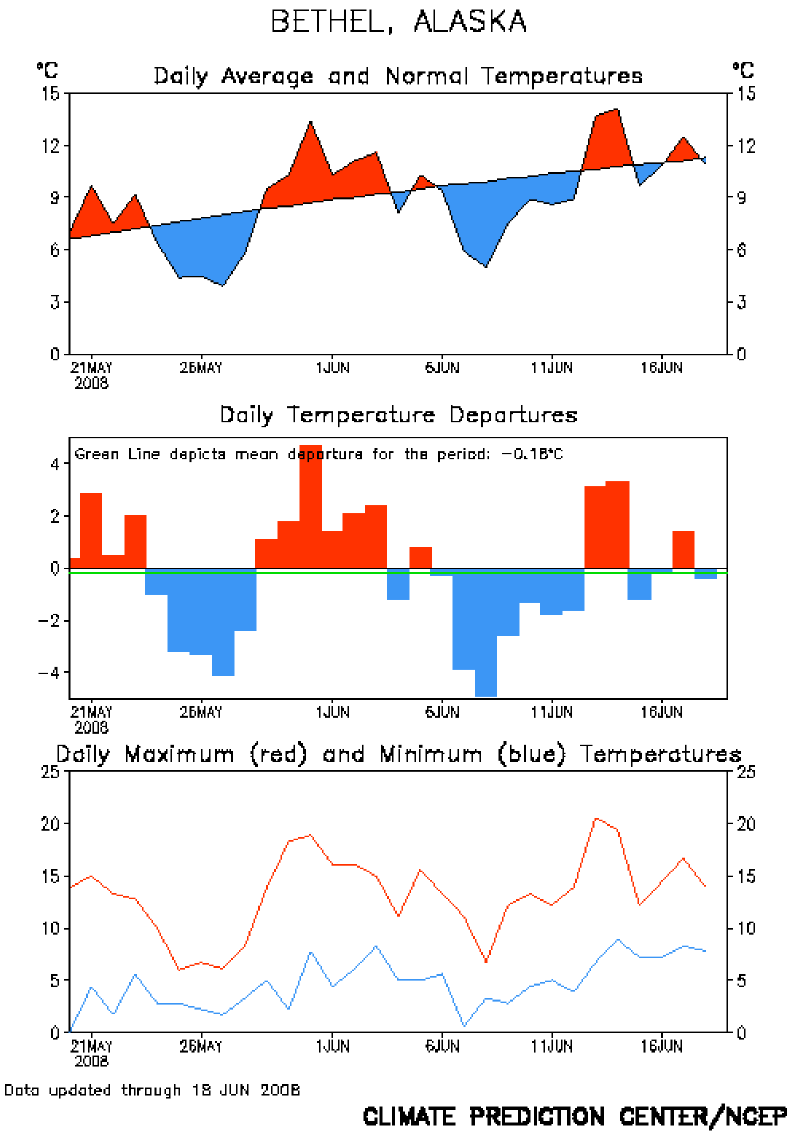


Fig. 5. Temperature information prior to and during the 2008 survey (June 2-10), from Bethel Airport, approximately 140km east of the survey area.

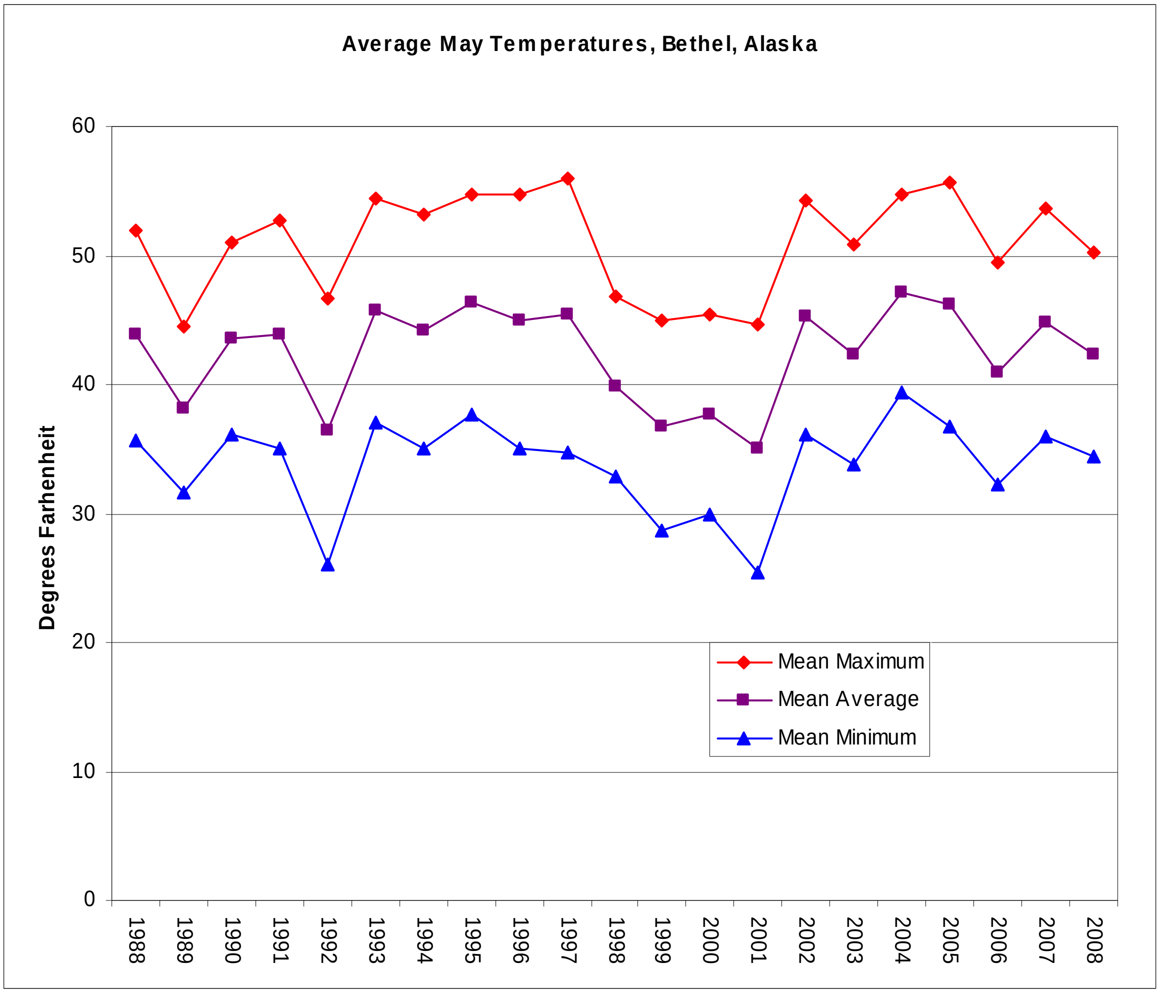


Fig. 6. Mean maximum, mean average, and mean minimum May temperatures from Bethel, Alaska, 1988 – 2008.

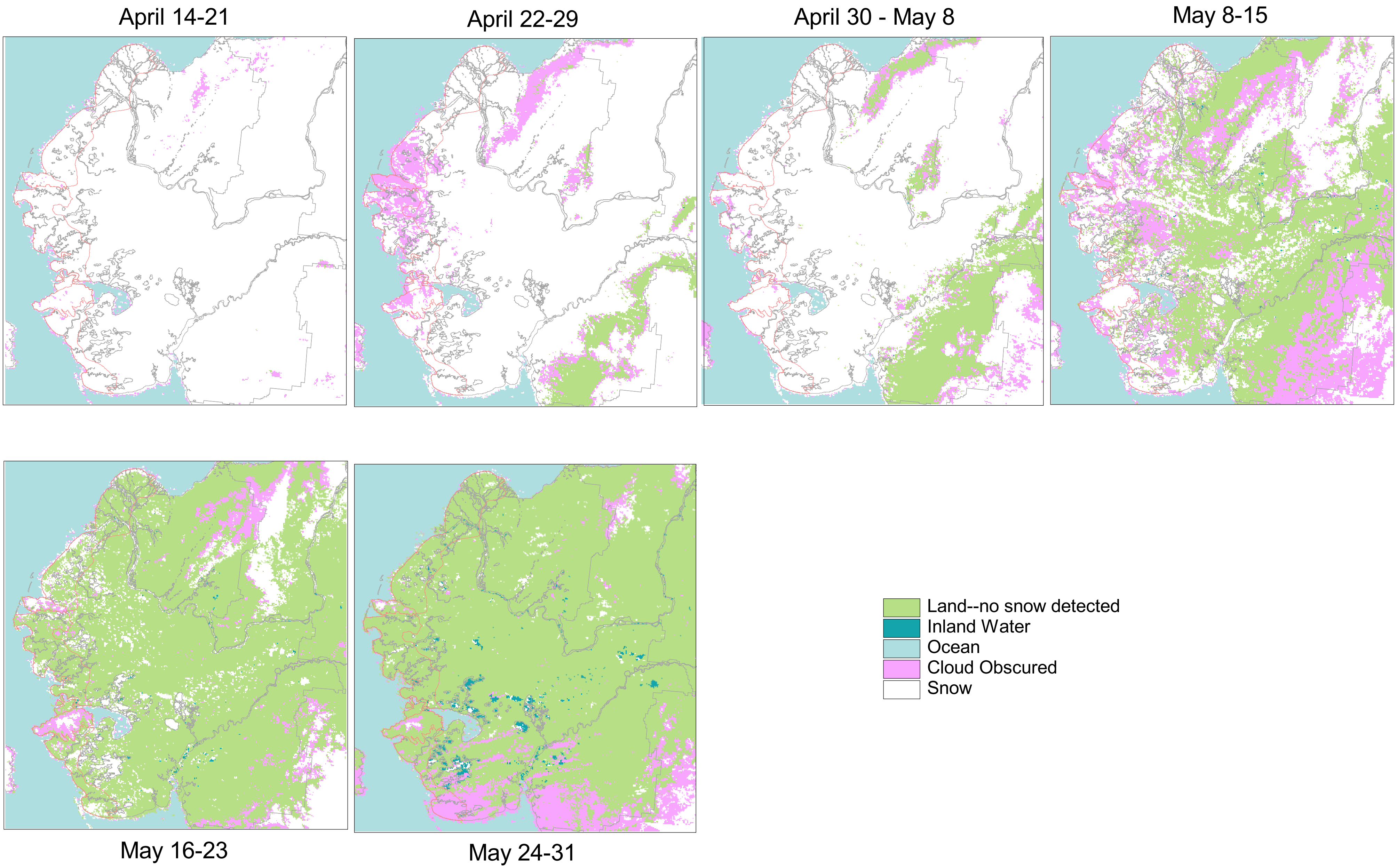


Fig. 7. Snow melt phenology from Terra satellite MODIS 8-day composite maximum snow extent, 2008, Yukon Delta National Wildlife Refuge, Alaska. (Coastal zone aerial survey boundary in red).

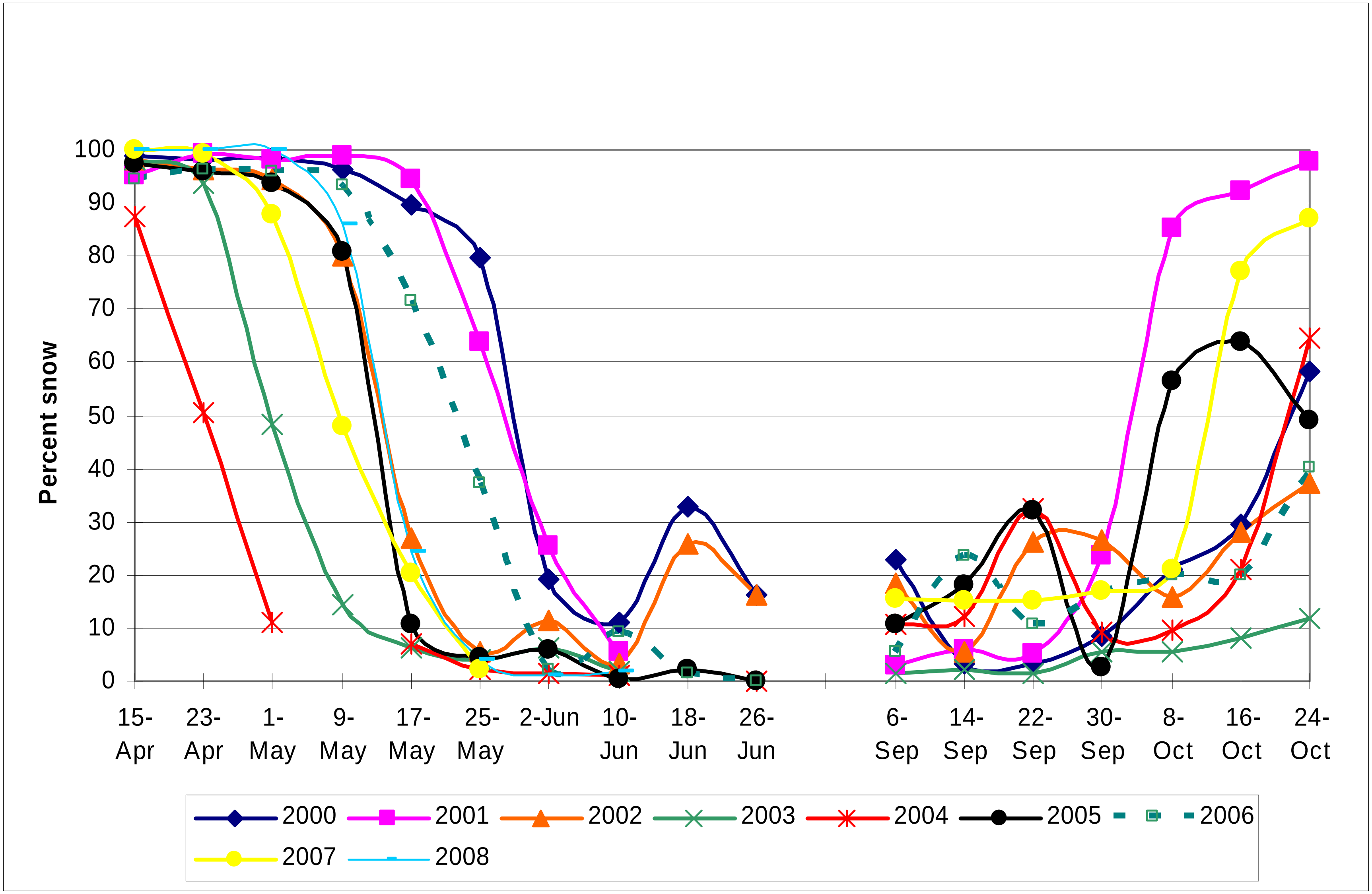
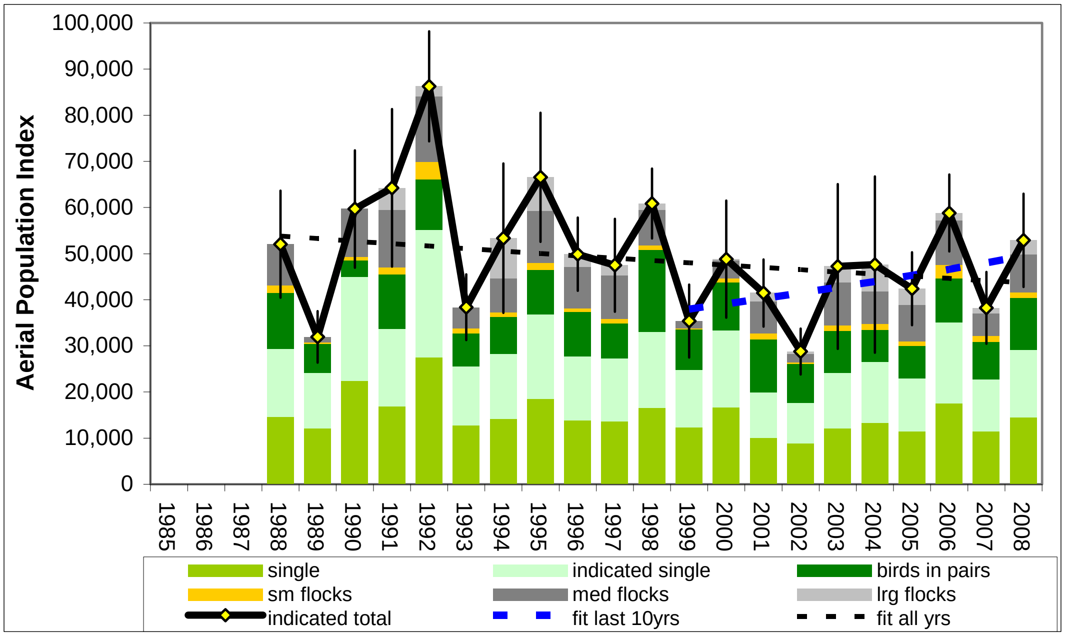


Fig. 8. Percent snow cover for coastal zone survey area in spring and early winter from MODIS imagery.

Northern Pintail

Yukon-Kuskokwim Delta coast, early-June survey



18 strata = 12,832 km²

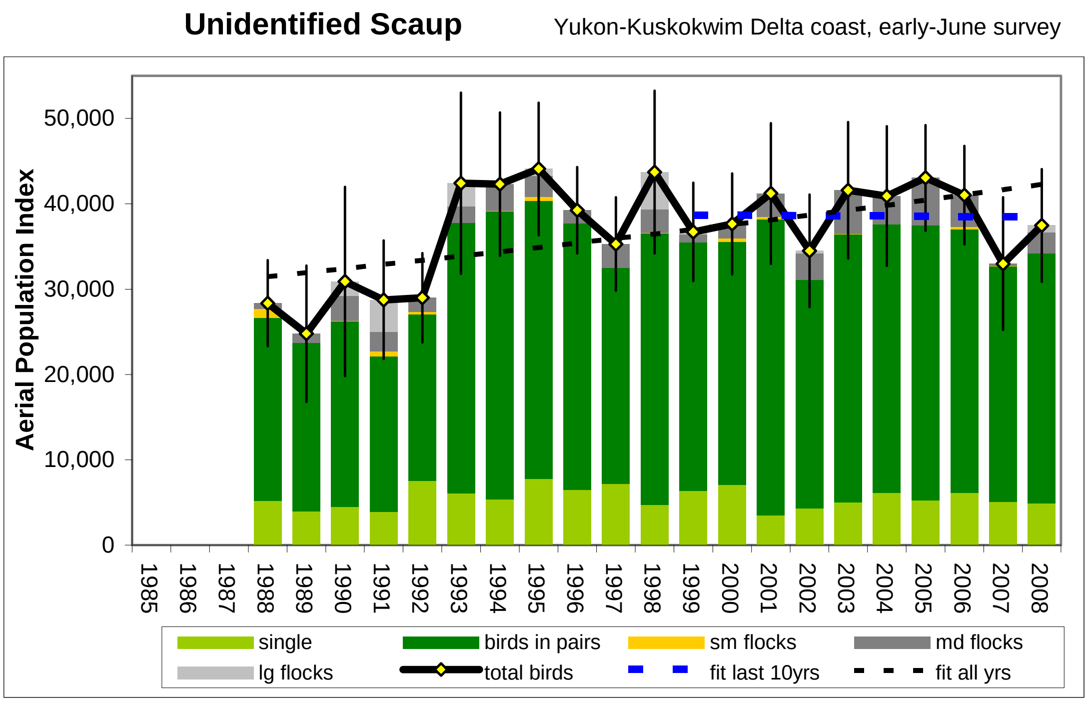
year	2*sg	2*npr	sm flk	md flk	lg flk	Index	StdErr
1985							
1986							
1987							
1988	29350	12109	1621	8972	0	**52052**	5916
1989	24168	6325	322	1148	0	**31962**	2842
1990	44941	3638	708	10377	0	**59663**	6490
1991	33658	11813	1486	12570	4724	**64250**	8719
1992	55085	11049	3819	14084	2235	**86272**	6082
1993	25554	7122	1167	4537	0	**38379**	3644
1994	28293	7989	1012	7361	8682	**53336**	8254
1995	36893	9571	1547	11223	7325	**66560**	7133
1996	27708	9591	876	8947	2726	**49847**	4055
1997	27284	7671	899	9386	2236	**47476**	5128
1998	33010	17789	1010	7686	1369	**60863**	3861
1999	24751	8775	288	1567	0	**35382**	4025
2000	33328	10489	852	3843	278	**48790**	6474
2001	19949	11493	1256	6888	1866	**41452**	3727
2002	17703	8322	444	1879	402	**28750**	2547
2003	24199	8980	1324	9220	3513	**47236**	9108
2004	26546	6870	1365	7043	5804	**47628**	9766
2005	22948	7081	935	7921	3474	**42360**	4037
2006	35063	9619	2898	9679	1538	**58797**	4245
2007	22749	8144	1227	4974	1136	**38230**	3978
2008	29119	11243	1225	8173	3137	**52896**	5159

NOPI

Aerial index: Indicated total

n yrs =	21
mean index =	**50104**
std dev =	13270
std error =	2896
low 90%ci =	44428
high 90%ci =	55780
trend over all years :	
ln linear slope =	-0.01
SE slope =	0.0094
Growth Rate =	**0.990**
low 90%ci GR =	0.975
high 90%ci GR =	1.005
most recent 10 years :	
Growth Rate =	**1.030**
low 90%ci GR =	0.993
high 90%ci GR =	1.068
regression resid CV =	0.260
avg sampling err CV =	0.110
min yrs to detect -50%/20yr rate :	
w/ regression resid CV =	16.2
w/ sample error CV =	9.2

Figure 9. Population trend for Northern Pintail (*Anas acuta*) observed by a rear-seat observer on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta in western Alaska. The indicated total birds population index is the sum of birds observed as singles, an equal number of unseen single birds, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31+, indicated by column divisions from bottom to top. Vertical lines indicate 95% confidence intervals based on sampling error calculated among transects. Stratification included 18 physiographic regions. Birds on nests are included in the index. Average annual growth rate is calculated by log-linear regression. Power calculations use alpha set at p=0.10, beta at p=0.20, and a coefficient of variation based on either regression residuals or sampling errors. The power of the survey to detect trend can be compared between species using the estimated minimum number of years of data needed to detect a significant annual rate of change of -0.034, a 50% decline in 20 years, if it were to occur.



18 strata = 12,832 km²

year	sg	2*npr	sm flk	md flk	lg flk	Index	StdErr
1985							
1986							
1987							
1988	5191	21435	1035	688	0	**28348**	2573
1989	3999	19673	0	1108	0	**24780**	4076
1990	4500	21698	72	2980	1644	**30895**	5652
1991	3900	18230	579	2304	3740	**28753**	3541
1992	7536	19475	339	1623	0	**28973**	2673
1993	6074	31655	0	1933	2735	**42398**	5421
1994	5330	33779	82	3113	0	**42304**	4289
1995	7782	32557	462	2428	854	**44084**	3965
1996	6500	31167	0	1590	0	**39256**	2581
1997	7180	25313	0	2788	0	**35280**	2791
1998	4746	31765	83	2777	4345	**43715**	4863
1999	6400	29075	0	936	301	**36712**	2934
2000	7059	28473	404	1695	0	**37631**	3018
2001	3526	34639	317	2730	0	**41211**	4203
2002	4333	26745	0	3123	280	**34481**	3371
2003	4993	31396	83	5113	0	**41585**	4078
2004	6134	31424	0	3351	0	**40909**	4170
2005	5270	32188	0	5586	0	**43044**	3154
2006	6144	30841	333	3697	0	**41015**	2946
2007	5047	27630	40	258	0	**32975**	3963
2008	4909	29336	0	2388	833	**37465**	3366

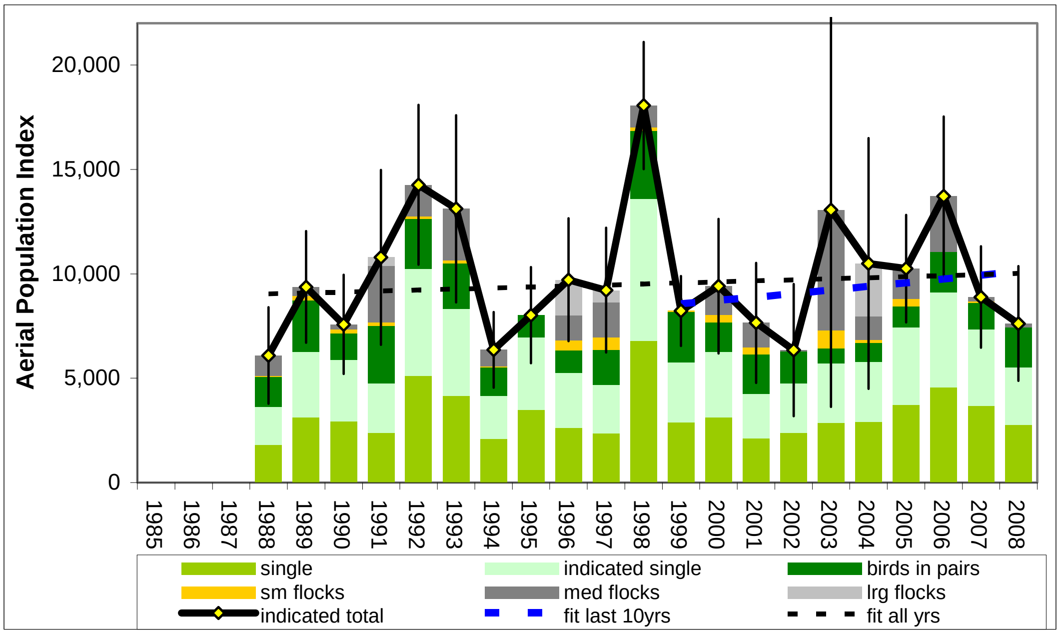
SCAU

Aerial index: Total birds

n yrs =	21
mean index =	**36944**
std dev =	5850
std error =	1277
low 90%ci =	34442
high 90%ci =	39445
trend over all years :	
ln linear slope =	0.0148
SE slope =	0.0053
Growth Rate =	**1.015**
low 90%ci GR =	1.006
high 90%ci GR =	1.024
most recent 10 years :	
Growth Rate =	**0.999**
low 90%ci GR =	0.982
high 90%ci GR =	1.016
regression resid CV =	0.146
avg sampling err CV =	0.102
min yrs to detect -50%/20yr rate :	
w/ regression resid CV =	11.1
w/ sample error CV =	8.7

Figure 10. Population trend for Unidentified Scaup, predominantly Greater Scaup (*Aythya marila*), observed by a rear-seat observer on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta in western Alaska. The indicated total birds population index is the sum of birds observed as singles, an equal number of unseen single birds, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31+, indicated by column divisions from bottom to top. Vertical lines indicate 95% confidence intervals based on sampling error calculated among transects. Stratification included 18 physiographic regions. Birds on nests are included in the index. Average annual growth rate is calculated by log-linear regression. Power calculations use alpha set at p=0.10, beta at p=0.20, and a coefficient of variation based on either regression residuals or sampling errors. The power of the survey to detect trend can be compared between species using the estimated minimum number of years of data needed to detect a significant annual rate of change of -0.034, a 50% decline in 20 years, if it were to occur.

Northern Shoveler Yukon-Kuskokwim Delta coast, early-June survey



18 strata = 12,832 km²

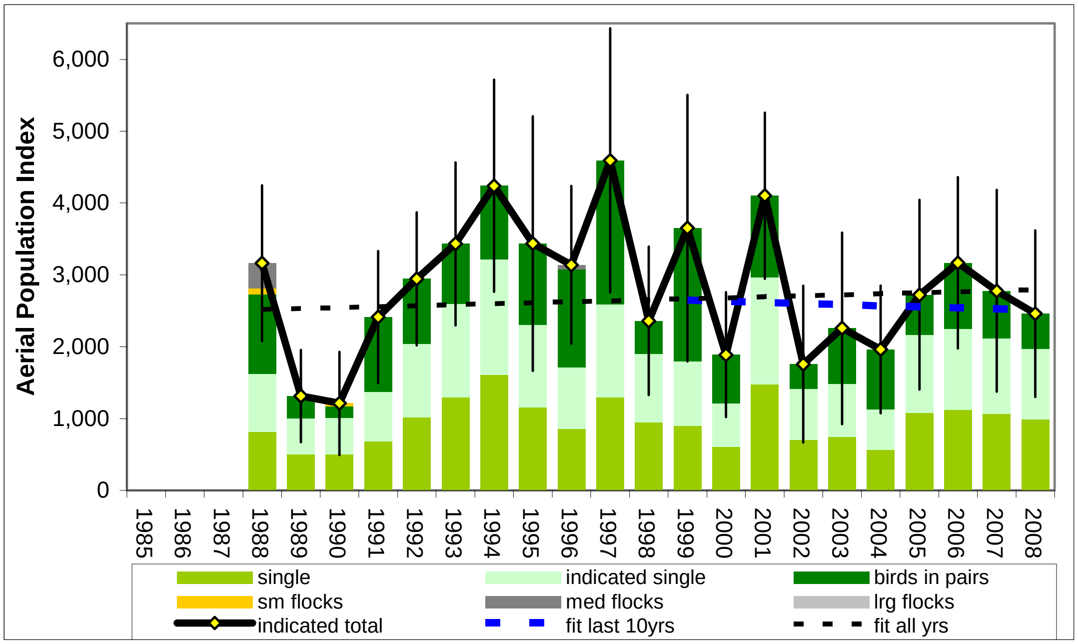
year	2*sg	2*npr	sm flk	md flk	lg flk	Index	StdErr
1985							
1986							
1987							
1988	3620	1442	42	982	0	**6085**	1180
1989	6250	2485	205	434	0	**9374**	1363
1990	5883	1260	205	226	0	**7574**	1210
1991	4755	2739	184	2704	410	**10791**	2136
1992	10233	2389	138	1502	0	**14263**	1951
1993	8326	2164	164	2458	0	**13112**	2286
1994	4162	1357	42	797	0	**6358**	927
1995	6952	1066	0	0	0	**8018**	1174
1996	5249	1078	480	1205	1703	**9716**	1504
1997	4695	1653	602	1693	571	**9213**	1525
1998	13586	3270	166	1038	0	**18060**	1551
1999	5755	2418	48	0	0	**8221**	853
2000	6273	1396	373	1367	0	**9409**	1644
2001	4252	1888	320	1190	0	**7650**	1464
2002	4753	1541	0	48	0	**6342**	1614
2003	5721	704	869	5762	0	**13056**	4810
2004	5776	927	119	1146	2527	**10495**	3061
2005	7447	1007	348	1443	0	**10245**	1310
2006	9112	1929	0	2673	0	**13713**	1951
2007	7329	1277	81	200	0	**8887**	1239
2008	5522	1911	0	187	0	**7620**	1403

NSHO

Aerial index: Indicated total	
n yrs =	21
mean index =	**9914**
std dev =	3046
std error =	665
low 90%ci =	8612
high 90%ci =	11217
trend over all years :	
ln linear slope =	0.0051
SE slope =	0.0106
Growth Rate =	**1.005**
low 90%ci GR =	0.988
high 90%ci GR =	1.023
most recent 10 years :	
Growth Rate =	**1.019**
low 90%ci GR =	0.973
high 90%ci GR =	1.066
regression resid CV =	0.295
avg sampling err CV =	0.175
min yrs to detect -50%/20yr rate :	
w/ regression resid CV =	17.7
w/ sample error CV =	12.5

Figure 11. Population trend for Northern Shoveler (*Anas clypeata*) observed by a rear-seat observer on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta in western Alaska. The indicated total birds population index is the sum of birds observed as singles, an equal number of unseen single birds, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31+, indicated by column divisions from bottom to top. Vertical lines indicate 95% confidence intervals based on sampling error calculated among transects. Stratification included 18 physiographic regions. Birds on nests are included in the index. Average annual growth rate is calculated by log-linear regression. Power calculations use alpha set at p=0.10, beta at p=0.20, and a coefficient of variation based on either regression residuals or sampling errors. The power of the survey to detect trend can be compared between species using the estimated minimum number of years of data needed to detect a significant annual rate of change of -0.034, a 50% decline in 20 years, if it were to occur.

Green-winged Teal Yukon-Kuskokwim Delta coast, early-June survey



18 strata = 12,832 km²

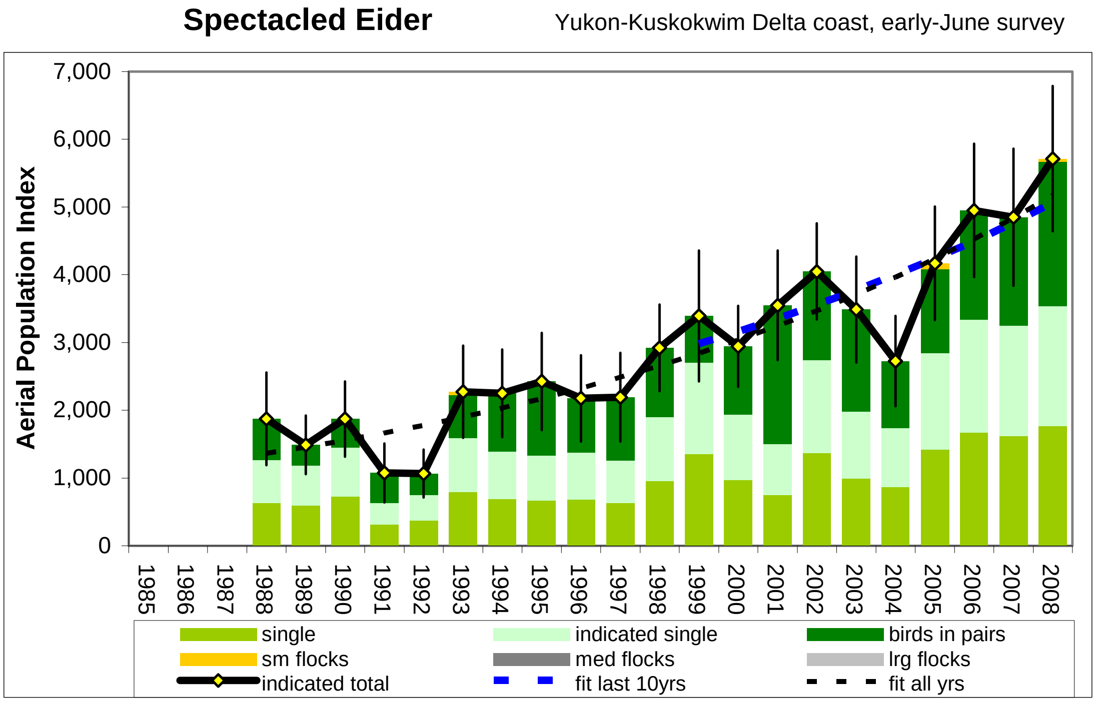
year	2*sg	2*npr	sm flk	md flk	lg flk	Index	StdErr
1985							
1986							
1987							
1988	1623	1105	82	354	0	**3163**	554
1989	1002	312	0	0	0	**1313**	328
1990	1007	164	41	0	0	**1212**	367
1991	1370	1042	0	0	0	**2412**	470
1992	2037	908	0	0	0	**2945**	472
1993	2595	836	0	0	0	**3431**	579
1994	3216	1023	0	0	0	**4240**	754
1995	2308	1128	0	0	0	**3436**	904
1996	1709	1371	0	59	0	**3140**	560
1997	2589	2003	0	0	0	**4592**	938
1998	1898	462	0	0	0	**2360**	528
1999	1798	1853	0	0	0	**3652**	946
2000	1211	678	0	0	0	**1889**	444
2001	2960	1142	0	0	0	**4102**	590
2002	1410	347	0	0	0	**1758**	557
2003	1483	775	0	0	0	**2258**	680
2004	1127	836	0	0	0	**1963**	453
2005	2166	557	0	0	0	**2722**	674
2006	2244	924	0	0	0	**3168**	608
2007	2119	658	0	0	0	**2778**	717
2008	1970	491	0	0	0	**2460**	590

AGWT

Aerial index: Indicated total

n yrs =	21
mean index =	**2809**
std dev =	923
std error =	201
low 90%ci =	2415
high 90%ci =	3204
trend over all years :	
ln linear slope =	0.0052
SE slope =	0.0132
Growth Rate =	**1.005**
low 90%ci GR =	0.984
high 90%ci GR =	1.027
most recent 10 years :	
Growth Rate =	**0.994**
low 90%ci GR =	0.941
high 90%ci GR =	1.050
regression resid CV =	0.368
avg sampling err CV =	0.225
min yrs to detect -50%/20yr rate :	
w/ regression resid CV =	20.5
w/ sample error CV =	14.7

Figure 12. Population trend for Green-winged Teal (A*nas crecca*) observed by a rear-seat observer on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta in western Alaska. The indicated total birds population index is the sum of birds observed as singles, an equal number of unseen single birds, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31+, indicated by column divisions from bottom to top. Vertical lines indicate 95% confidence intervals based on sampling error calculated among transects. Stratification included 18 physiographic regions. Birds on nests are included in the index. Average annual growth rate is calculated by log-linear regression. Power calculations use alpha set at p=0.10, beta at p=0.20, and a coefficient of variation based on either regression residuals or sampling errors. The power of the survey to detect trend can be compared between species using the estimated minimum number of years of data needed to detect a significant annual rate of change of -0.034, a 50% decline in 20 years, if it were to occur.



18 strata = 12,832 km²

year	2*sg	2*npr	sm flk	md flk	lg flk	Index	StdErr
1985							
1986							
1987							
1988	1272	603	0	0	0	**1874**	349
1989	1187	303	0	0	0	**1490**	222
1990	1451	421	0	0	0	**1872**	284
1991	629	446	0	0	0	**1075**	222
1992	747	319	0	0	0	**1066**	180
1993	1589	640	42	0	0	**2272**	347
1994	1387	865	0	0	0	**2252**	331
1995	1334	1092	0	0	0	**2426**	366
1996	1373	803	0	0	0	**2176**	324
1997	1262	930	0	0	0	**2192**	334
1998	1907	1014	0	0	0	**2921**	326
1999	2703	690	0	0	0	**3393**	493
2000	1937	1008	0	0	0	**2945**	305
2001	1500	2048	0	0	0	**3549**	413
2002	2739	1310	0	0	0	**4049**	362
2003	1985	1502	0	0	0	**3487**	399
2004	1737	991	0	0	0	**2728**	340
2005	2843	1244	83	0	0	**4170**	429
2006	3340	1609	0	0	0	**4949**	501
2007	3248	1601	0	0	0	**4849**	516
2008	3534	2139	39	0	0	**5713**	548

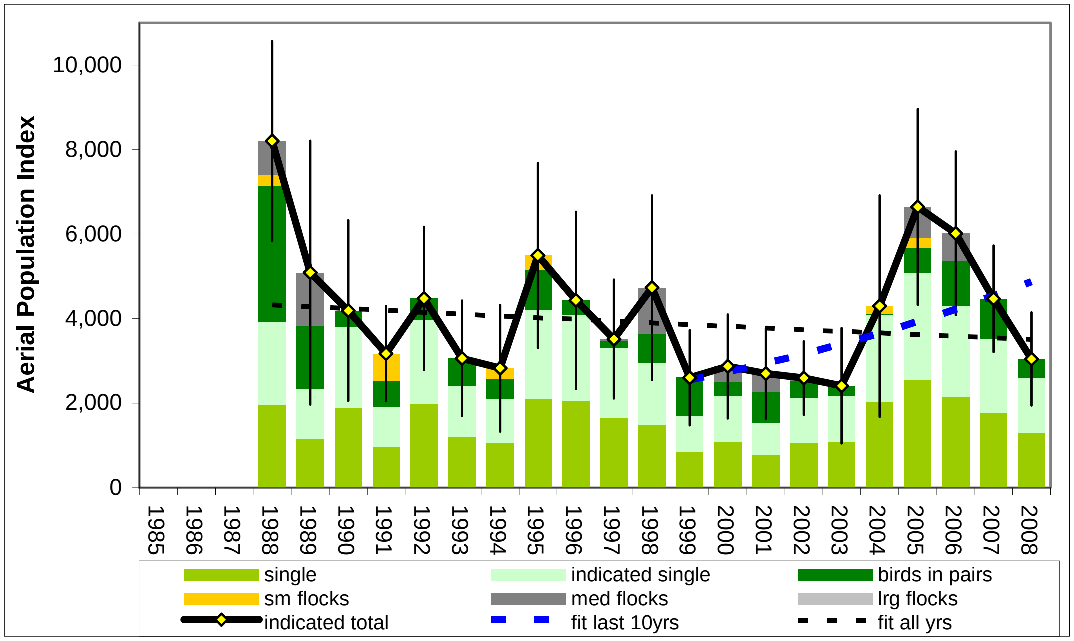
SPEI

Aerial index: Indicated total

n yrs =	21
mean index =	**2926**
std dev =	1279
std error =	279
low 90%ci =	2379
high 90%ci =	3473
trend over all years :	
ln linear slope =	0.0667
SE slope =	0.0078
Growth Rate =	**1.069**
low 90%ci GR =	1.055
high 90%ci GR =	1.083
most recent 10 years :	
Growth Rate =	**1.060**
low 90%ci GR =	1.029
high 90%ci GR =	1.093
regression resid CV =	0.218
avg sampling err CV =	0.135
min yrs to detect -50%/20yr rate :	
w/ regression resid CV =	14.4
w/ sample error CV =	10.5

Figure 13. Population trend for Spectacled Eiders (*Somateria fischeri*) observed by a rear-seat observer on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta in western Alaska. The indicated total birds population index is the sum of birds observed as singles, an equal number of unseen single birds, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31+, indicated by column divisions from bottom to top. Vertical lines indicate 95% confidence intervals based on sampling error calculated among transects. Stratification included 18 physiographic regions. Birds on nests are included in the index. Average annual growth rate is calculated by log-linear regression. Power calculations use alpha set at p=0.10, beta at p=0.20, and a coefficient of variation based on either regression residuals or sampling errors. The power of the survey to detect trend can be compared between species using the estimated minimum number of years of data needed to detect a significant annual rate of change of -0.034, a 50% decline in 20 years, if it were to occur.

Mallard Yukon-Kuskokwim Delta coast, early-June survey



18 strata = 12,832 km²

year	2*sg	2*npr	sm flk	md flk	lg flk	Index	StdErr
1985							
1986							
1987							
1988	3936	3200	266	800	0	**8202**	1205
1989	2334	1498	0	1258	0	**5090**	1593
1990	3790	401	0	0	0	**4191**	1091
1991	1907	615	649	0	0	**3171**	574
1992	3976	501	0	0	0	**4477**	867
1993	2403	658	0	0	0	**3061**	698
1994	2111	453	262	0	0	**2827**	767
1995	4214	946	337	0	0	**5496**	1117
1996	4098	334	0	0	0	**4432**	1070
1997	3313	153	0	50	0	**3517**	719
1998	2965	671	0	1096	0	**4731**	1113
1999	1697	904	0	0	0	**2602**	573
2000	2179	335	0	356	0	**2870**	628
2001	1538	723	0	441	0	**2702**	547
2002	2136	384	0	74	0	**2593**	444
2003	2179	233	0	0	0	**2412**	697
2004	4083	32	181	0	0	**4296**	1337
2005	5085	598	232	727	0	**6642**	1182
2006	4304	1069	0	647	0	**6020**	988
2007	3518	951	0	0	0	**4470**	642
2008	2607	441	0	0	0	**3047**	562

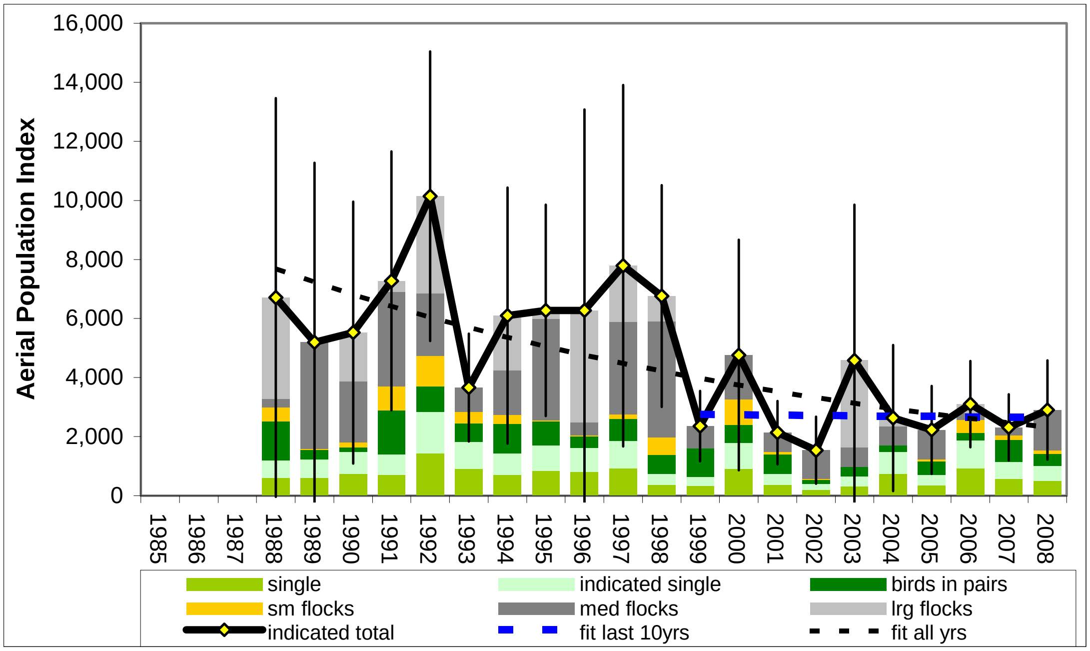
MALL

Aerial index: Indicated total

n yrs =	21
mean index =	**4136**
std dev =	1526
std error =	333
low 90%ci =	3483
high 90%ci =	4788
trend over all years :	
ln linear slope =	-0.01
SE slope =	0.0125
Growth Rate =	**0.990**
low 90%ci GR =	0.969
high 90%ci GR =	1.010
most recent 10 years :	
Growth Rate =	**1.075**
low 90%ci GR =	1.015
high 90%ci GR =	1.139
regression resid CV =	0.348
avg sampling err CV =	0.217
min yrs to detect -50%/20yr rate :	
w/ regression resid CV =	19.7
w/ sample error CV =	14.4

Figure 14. Population trend for Mallard (*Anas platyrhynchos*) observed by a rear-seat observer on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta in western Alaska. The indicated total birds population index is the sum of birds observed as singles, an equal number of unseen single birds, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31+, indicated by column divisions from bottom to top. Vertical lines indicate 95% confidence intervals based on sampling error calculated among transects. Stratification included 18 physiographic regions. Birds on nests are included in the index. Average annual growth rate is calculated by log-linear regression. Power calculations use alpha set at p=0.10, beta at p=0.20, and a coefficient of variation based on either regression residuals or sampling errors. The power of the survey to detect trend can be compared between species using the estimated minimum number of years of data needed to detect a significant annual rate of change of -0.034, a 50% decline in 20 years, if it were to occur.

American Wigeon Yukon-Kuskokwim Delta coast, early-June survey



18 strata = 12,832 km²

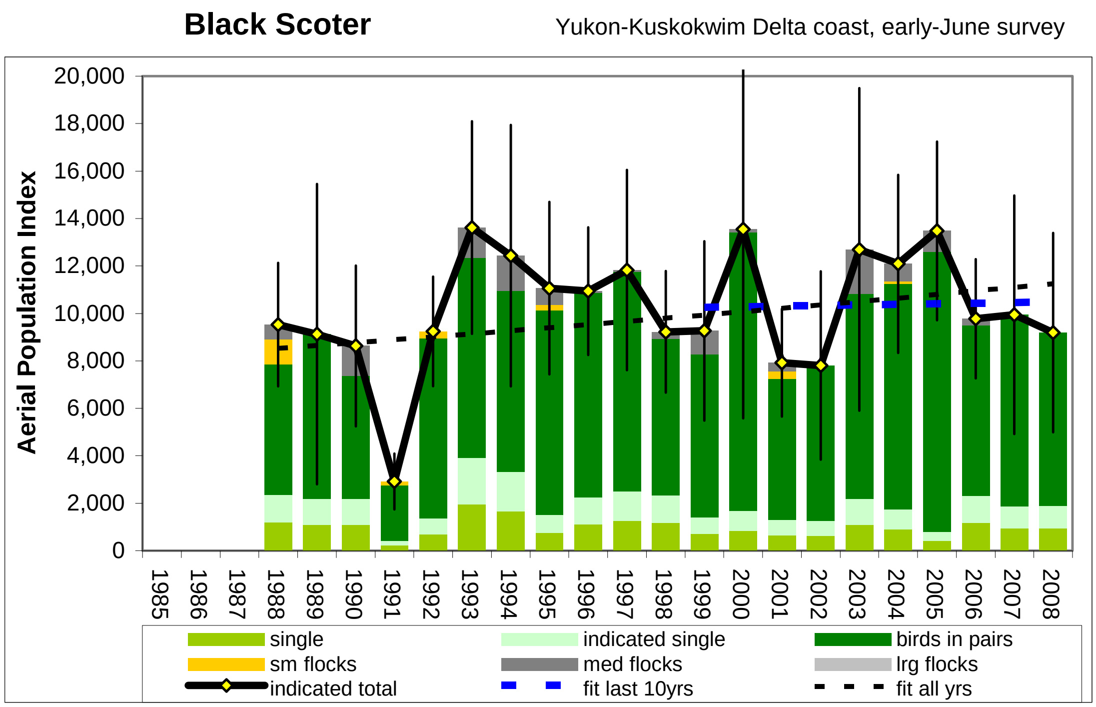
year	2*sg	2*npr	sm flk	md flk	lg flk	Index	StdErr
1985							
1986							
1987							
1988	1201	1311	480	297	3419	**6709**	3445
1989	1229	318	41	3605	0	**5192**	3102
1990	1493	141	171	2075	1644	**5524**	2261
1991	1403	1493	794	3211	369	**7270**	2235
1992	2841	864	1032	2111	3293	**10141**	2503
1993	1830	624	382	823	0	**3658**	932
1994	1431	995	305	1516	1850	**6096**	2211
1995	1702	803	42	3442	285	**6275**	1825
1996	1619	384	42	432	3794	**6271**	3470
1997	1854	743	163	3124	1907	**7790**	3121
1998	732	644	599	3924	862	**6761**	1916
1999	640	970	0	744	0	**2354**	606
2000	1798	592	877	1496	0	**4763**	1992
2001	733	666	80	653	0	**2133**	548
2002	401	125	40	973	0	**1540**	581
2003	649	331	0	648	2955	**4583**	2690
2004	1488	224	0	634	283	**2629**	1261
2005	712	436	82	995	0	**2225**	758
2006	1862	261	437	254	290	**3104**	746
2007	1137	755	162	258	0	**2312**	571
2008	1009	406	120	1371	0	**2906**	856

AMWI

Aerial index: Indicated total

n yrs =	21
mean index =	**4773**
std dev =	2311
std error =	504
low 90%ci =	3785
high 90%ci =	5762
trend over all years :	
ln linear slope =	-0.06
SE slope =	0.0138
Growth Rate =	**0.942**
low 90%ci GR =	0.921
high 90%ci GR =	0.964
most recent 10 years :	
Growth Rate =	**0.996**
low 90%ci GR =	0.932
high 90%ci GR =	1.064
regression resid CV =	0.383
avg sampling err CV =	0.368
min yrs to detect -50%/20yr rate :	
w/ regression resid CV =	21.0
w/ sample error CV =	20.5

Figure 15. Population trend for American Wigeon (*Anas americana*) observed by a rear-seat observer on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta in western Alaska. The indicated total birds population index is the sum of birds observed as singles, an equal number of unseen single birds, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31+, indicated by column divisions from bottom to top. Vertical lines indicate 95% confidence intervals based on sampling error calculated among transects. Stratification included 18 physiographic regions. Birds on nests are included in the index. Average annual growth rate is calculated by log-linear regression. Power calculations use alpha set at p=0.10, beta at p=0.20, and a coefficient of variation based on either regression residuals or sampling errors. The power of the survey to detect trend can be compared between species using the estimated minimum number of years of data needed to detect a significant annual rate of change of -0.034, a 50% decline in 20 years, if it were to occur.



18 strata = 12,832 km²

year	2*sg	2*npr	sm flk	md flk	lg flk	Index	StdErr
1985							
1986							
1987							
1988	2364	5493	1052	623	0	**9531**	1329
1989	2187	6937	0	0	0	**9124**	3225
1990	2171	5193	0	1267	0	**8631**	1729
1991	432	2319	165	0	0	**2915**	599
1992	1379	7575	286	0	0	**9240**	1179
1993	3903	8441	0	1270	0	**13614**	2285
1994	3317	7629	0	1482	0	**12427**	2810
1995	1516	8607	231	702	0	**11057**	1855
1996	2236	8639	0	59	0	**10934**	1374
1997	2505	9240	0	81	0	**11826**	2150
1998	2332	6599	0	291	0	**9221**	1308
1999	1414	6850	0	999	0	**9264**	1928
2000	1667	11732	0	142	0	**13542**	4062
2001	1297	5945	321	355	0	**7917**	1155
2002	1257	6547	0	0	0	**7804**	2025
2003	2179	8645	0	1868	0	**12692**	3468
2004	1751	9500	84	756	0	**12090**	1913
2005	797	11790	0	888	0	**13475**	1922
2006	2325	7159	0	290	0	**9775**	1281
2007	1855	8089	0	0	0	**9943**	2564
2008	1893	7300	0	0	0	**9194**	2144

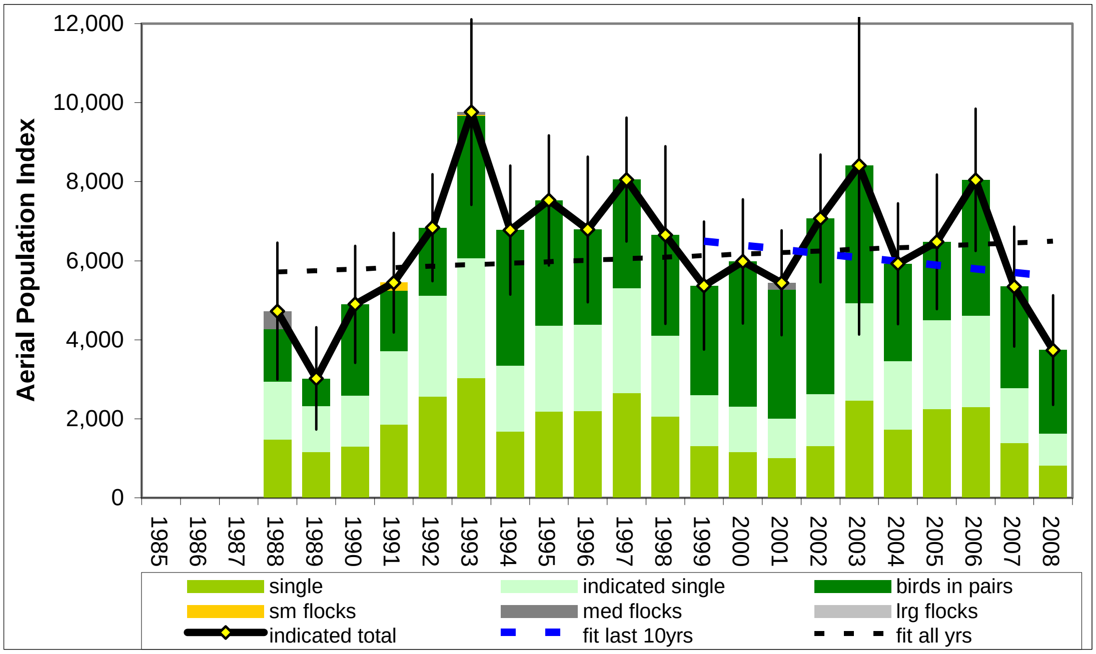
BLSC

Aerial index: Indicated total

n yrs =	21
mean index =	**10201**
std dev =	2493
std error =	544
low 90%ci =	9135
high 90%ci =	11267
trend over all years :	
ln linear slope =	0.0139
SE slope =	0.0117
Growth Rate =	**1.014**
low 90%ci GR =	0.995
high 90%ci GR =	1.034
most recent 10 years :	
Growth Rate =	**1.003**
low 90%ci GR =	0.963
high 90%ci GR =	1.043
regression resid CV =	0.324
avg sampling err CV =	0.197
min yrs to detect -50%/20yr rate :	
w/ regression resid CV =	18.8
w/ sample error CV =	13.5

Figure 16. Population trend for Black Scoter (*Melanitta nigra*) observed by a rear-seat observer on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta in western Alaska. The indicated total birds population index is the sum of birds observed as singles, an equal number of unseen single birds, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31+, indicated by column divisions from bottom to top. Vertical lines indicate 95% confidence intervals based on sampling error calculated among transects. Stratification included 18 physiographic regions. Birds on nests are included in the index. Average annual growth rate is calculated by log-linear regression. Power calculations use alpha set at p=0.10, beta at p=0.20, and a coefficient of variation based on either regression residuals or sampling errors. The power of the survey to detect trend can be compared between species using the estimated minimum number of years of data needed to detect a significant annual rate of change of -0.034, a 50% decline in 20 years, if it were to occur.

Long-tailed Duck Yukon-Kuskokwim Delta coast, early-June survey



18 strata = 12,832 km²

year	2*sg	2*npr	sm flk	md flk	lg flk	Index	StdErr
1985							
1986							
1987							
1988	2941	1331	0	451	0	**4723**	882
1989	2316	704	0	0	0	**3019**	660
1990	2592	2305	0	0	0	**4897**	757
1991	3720	1513	211	0	0	**5443**	643
1992	5121	1713	0	0	0	**6834**	690
1993	6062	3598	42	58	0	**9759**	1199
1994	3343	3433	0	0	0	**6776**	833
1995	4364	3161	0	0	0	**7525**	838
1996	4388	2401	0	0	0	**6789**	939
1997	5306	2747	0	0	0	**8053**	801
1998	4099	2550	0	0	0	**6650**	1148
1999	2607	2762	0	0	0	**5370**	827
2000	2311	3671	0	0	0	**5982**	801
2001	2003	3267	0	169	0	**5439**	675
2002	2622	4445	0	0	0	**7068**	825
2003	4927	3483	0	0	0	**8409**	2181
2004	3450	2474	0	0	0	**5924**	779
2005	4502	1979	0	0	0	**6482**	869
2006	4604	3441	0	0	0	**8044**	917
2007	2774	2567	0	0	0	**5340**	773
2008	1626	2112	0	0	0	**3736**	708

LTDU

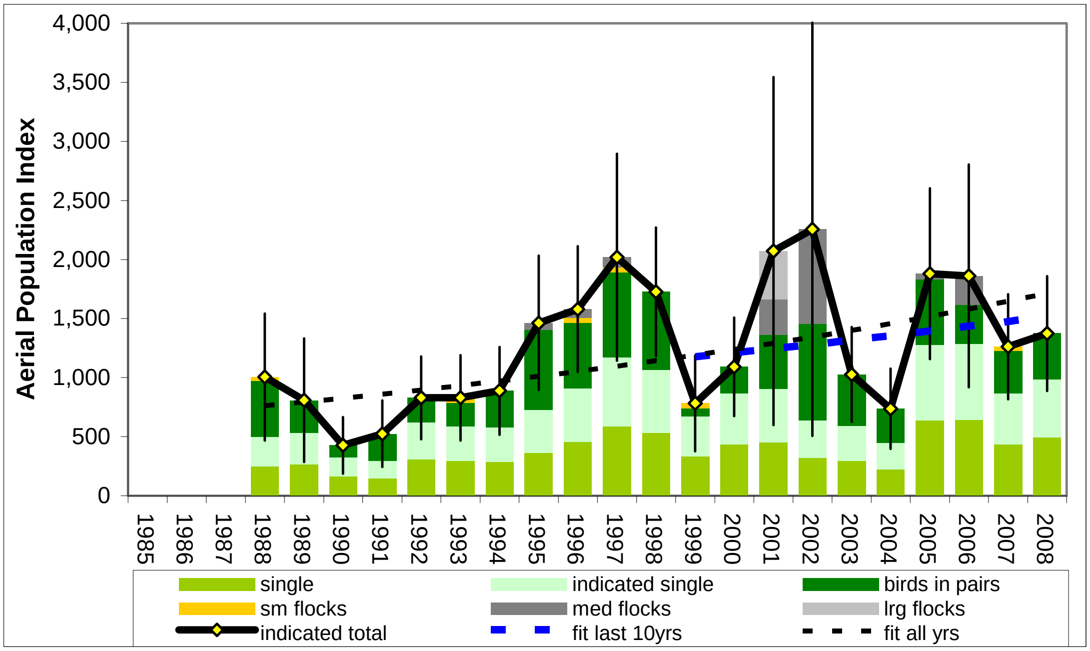
<u>Aerial index: Indicated total</u>

n yrs =	21
mean index =	**6298**
std dev =	1594
std error =	348
low 90%ci =	5616
high 90%ci =	6980
<u>trend over all years :</u>	
ln linear slope =	0.0064
SE slope =	0.0100
Growth Rate =	**1.006**
low 90%ci GR =	0.990
high 90%ci GR =	1.023
<u>most recent 10 years :</u>	
Growth Rate =	**0.984**
low 90%ci GR =	0.941
high 90%ci GR =	1.028
regression resid CV =	0.278
avg sampling err CV =	0.145
<u>min yrs to detect -50%/20yr rate :</u>	
w/ regression resid CV =	17.0
w/ sample error CV =	11.0

Figure 17. Population trend for Long-tailed Duck (*Clangula hyemalis*) observed by a rear-seat observer on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta in western Alaska. The indicated total birds population index is the sum of birds observed as singles, an equal number of unseen single birds, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31+, indicated by column divisions from bottom to top. Vertical lines indicate 95% confidence intervals based on sampling error calculated among transects. Stratification included 18 physiographic regions. Birds on nests are included in the index. Average annual growth rate is calculated by log-linear regression. Power calculations use alpha set at p=0.10, beta at p=0.20, and a coefficient of variation based on either regression residuals or sampling errors. The power of the survey to detect trend can be compared between species using the estimated minimum number of years of data needed to detect a significant annual rate of change of -0.034, a 50% decline in 20 years, if it were to occur.

Common Eider

Yukon-Kuskokwim Delta coast, early-June survey



18 strata = 12,832 km²

year	2*sg	2*npr	sm flk	md flk	lg flk	Index	StdErr
1985							
1986							
1987							
1988	497	476	33	0	0	**1005**	275
1989	530	280	0	0	0	**810**	267
1990	325	103	0	0	0	**428**	122
1991	293	232	0	0	0	**525**	143
1992	619	209	0	0	0	**829**	180
1993	588	198	42	0	0	**829**	184
1994	577	311	0	0	0	**888**	190
1995	725	680	0	58	0	**1463**	291
1996	910	555	41	74	0	**1580**	272
1997	1172	721	42	85	0	**2019**	447
1998	1065	663	0	0	0	**1728**	278
1999	670	69	43	0	0	**783**	207
2000	869	222	0	0	0	**1091**	213
2001	905	459	0	297	410	**2070**	751
2002	637	818	0	801	0	**2255**	893
2003	594	432	0	0	0	**1026**	205
2004	447	289	0	0	0	**736**	174
2005	1275	554	0	51	0	**1880**	369
2006	1287	327	0	248	0	**1861**	481
2007	869	354	39	0	0	**1261**	227
2008	985	389	0	0	0	**1374**	248

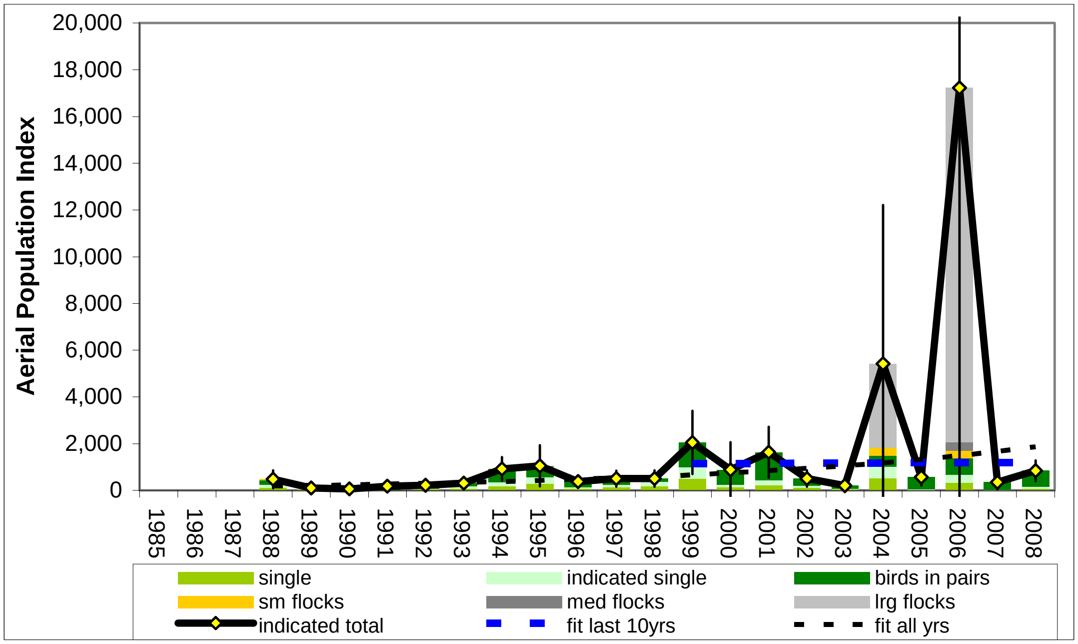
COEI

Aerial index: Indicated total

n yrs =	21
mean index =	**1259**
std dev =	545
std error =	119
low 90%ci =	1026
high 90%ci =	1492
trend over all years :	
ln linear slope =	0.0406
SE slope =	0.0145
Growth Rate =	**1.041**
low 90%ci GR =	1.017
high 90%ci GR =	1.067
most recent 10 years :	
Growth Rate =	**1.029**
low 90%ci GR =	0.954
high 90%ci GR =	1.109
regression resid CV =	0.402
avg sampling err CV =	0.240
min yrs to detect -50%/20yr rate :	
w/ regression resid CV =	21.7
w/ sample error CV =	15.4

Figure 18. Population trend for Common Eider (*Somateria mollissima*) observed by a rear-seat observer on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta in western Alaska. The indicated total birds population index is the sum of birds observed as singles, an equal number of unseen single birds, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31+, indicated by column divisions from bottom to top. Vertical lines indicate 95% confidence intervals based on sampling error calculated among transects. Stratification included 18 physiographic regions. Birds on nests are included in the index. Average annual growth rate is calculated by log-linear regression. Power calculations use alpha set at p=0.10, beta at p=0.20, and a coefficient of variation based on either regression residuals or sampling errors. The power of the survey to detect trend can be compared between species using the estimated minimum number of years of data needed to detect a significant annual rate of change of -0.034, a 50% decline in 20 years, if it were to occur.

Red-breasted Merganser Yukon-Kuskokwim Delta coast, early-June survey



18 strata = 12,832 km^2

year	2*sg	2*npr	sm flk	md flk	lg flk	Index	StdErr
1985							
1986							
1987							
1988	236	197	41	0	0	**473**	195
1989	104	0	0	0	0	**104**	73
1990	0	66	0	0	0	**67**	68
1991	18	164	0	0	0	**182**	100
1992	74	152	0	0	0	**226**	78
1993	164	146	0	0	0	**310**	131
1994	344	572	0	0	0	**917**	257
1995	576	344	0	127	0	**1047**	450
1996	140	239	0	0	0	**380**	120
1997	251	166	0	83	0	**500**	175
1998	358	145	0	0	0	**503**	180
1999	981	1072	0	0	0	**2052**	690
2000	249	636	0	0	0	**885**	600
2001	447	1184	0	0	0	**1630**	555
2002	206	297	0	0	0	**504**	180
2003	79	130	0	0	0	**209**	143
2004	1018	454	361	0	3581	**5414**	3466
2005	34	540	0	0	0	**574**	188
2006	667	715	304	365	15178	**17227**	12937
2007	35	310	0	0	0	**344**	155
2008	155	684	0	0	0	**838**	228

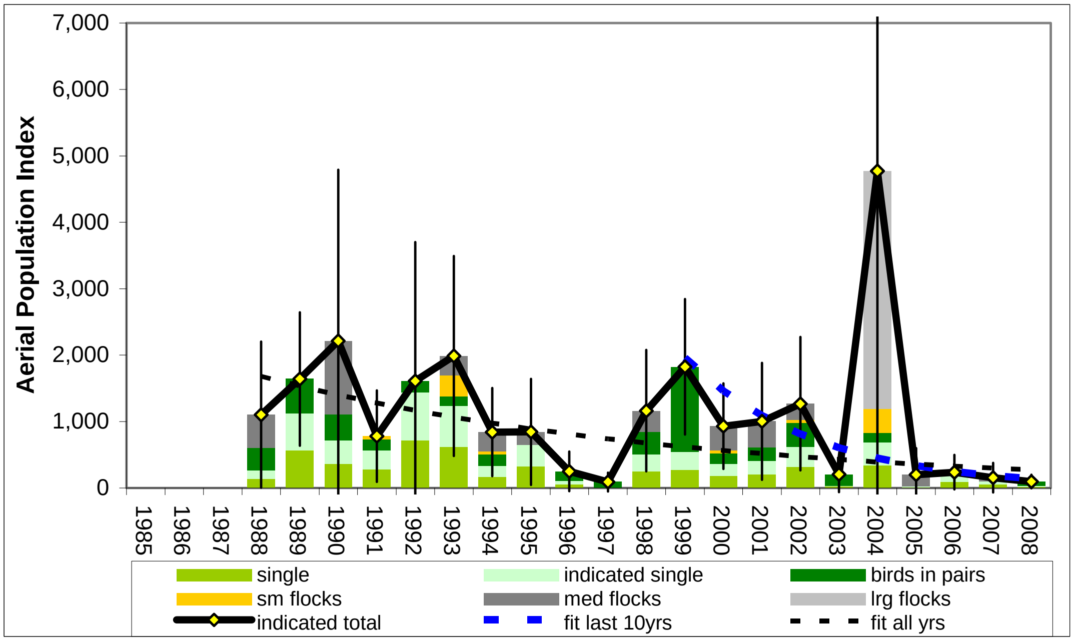
RBME

Aerial index: Indicated total

n yrs =	21
mean index =	**1638**
std dev =	3754
std error =	819
low 90%ci =	32
high 90%ci =	3243
trend over all years :	
ln linear slope =	0.1144
SE slope =	0.0386
Growth Rate =	**1.121**
low 90%ci GR =	1.052
high 90%ci GR =	1.195
most recent 10 years :	
Growth Rate =	**1.005**
low 90%ci GR =	0.778
high 90%ci GR =	1.297
regression resid CV =	1.073
avg sampling err CV =	0.477
min yrs to detect -50%/20yr rate :	
w/ regression resid CV =	41.8
w/ sample error CV =	24.3

Figure 19. Population trend for Red-breasted Merganser (*Mergus serrator*) observed by a rear-seat observer on aerial transects sampling 12,832 km^2 of the coastal Yukon-Kuskokwim Delta in western Alaska. The indicated total birds population index is the sum of birds observed as singles, an equal number of unseen single birds, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31+, indicated by column divisions from bottom to top. Vertical lines indicate 95% confidence intervals based on sampling error calculated among transects. Stratification included 18 physiographic regions. Birds on nests are included in the index. Average annual growth rate is calculated by log-linear regression. Power calculations use alpha set at p=0.10, beta at p=0.20, and a coefficient of variation based on either regression residuals or sampling errors. The power of the survey to detect trend can be compared between species using the estimated minimum number of years of data needed to detect a significant annual rate of change of -0.034, a 50% decline in 20 years, if it were to occur.

Canvasback Yukon-Kuskokwim Delta coast, early-June survey



18 strata = 12,832 km²

year	2*sg	2*npr	sm flk	md flk	lg flk	Index	StdErr
1985							
1986							
1987							
1988	268	333	0	502	0	**1103**	561
1989	1124	517	0	0	0	**1641**	512
1990	719	386	0	1111	0	**2215**	1314
1991	567	169	46	0	0	**781**	352
1992	1437	172	0	0	0	**1609**	1066
1993	1237	136	325	289	0	**1988**	768
1994	332	178	42	289	0	**841**	340
1995	649	0	0	194	0	**843**	408
1996	104	144	0	0	0	**249**	153
1997	0	89	0	0	0	**89**	73
1998	503	341	0	320	0	**1164**	466
1999	546	1276	0	0	0	**1823**	521
2000	363	159	40	369	0	**931**	329
2001	407	199	0	397	0	**1002**	449
2002	623	356	41	248	0	**1268**	513
2003	33	169	0	0	0	**202**	136
2004	684	144	361	0	3581	**4771**	3447
2005	18	0	0	184	0	**202**	203
2006	184	53	0	0	0	**238**	134
2007	98	0	0	57	0	**155**	113
2008	31	66	0	0	0	**97**	51

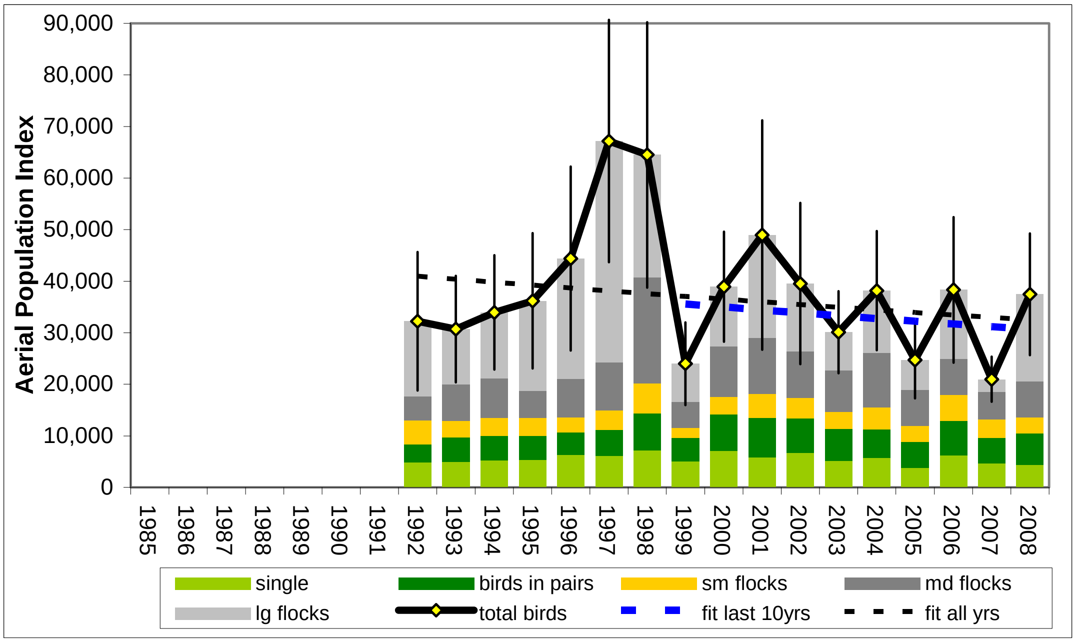
CANV

Aerial index: Indicated total

n yrs =	21
mean index =	**1105**
std dev =	1070
std error =	233
low 90%ci =	648
high 90%ci =	1563
trend over all years :	
ln linear slope =	-0.091
SE slope =	0.0360
Growth Rate =	**0.913**
low 90%ci GR =	0.861
high 90%ci GR =	0.969
most recent 10 years :	
Growth Rate =	**0.745**
low 90%ci GR =	0.625
high 90%ci GR =	0.889
regression resid CV =	0.999
avg sampling err CV =	0.541
min yrs to detect -50%/20yr rate :	
w/ regression resid CV =	39.8
w/ sample error CV =	26.5

Figure 20. Population trend for Canvasback (*Aythya valisineria*) observed by a rear-seat observer on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta in western Alaska. The indicated total birds population index is the sum of birds observed as singles, an equal number of unseen single birds, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31+, indicated by column divisions from bottom to top. Vertical lines indicate 95% confidence intervals based on sampling error calculated among transects. Stratification included 18 physiographic regions. Birds on nests are included in the index. Average annual growth rate is calculated by log-linear regression. Power calculations use alpha set at p=0.10, beta at p=0.20, and a coefficient of variation based on either regression residuals or sampling errors. The power of the survey to detect trend can be compared between species using the estimated minimum number of years of data needed to detect a significant annual rate of change of -0.034, a 50% decline in 20 years, if it were to occur.

Glaucous Gull Yukon-Kuskokwim Delta coast, early-June survey



18 strata = 12,832 km²

year	sg	2*npr	sm flk	md flk	lg flk	Index	StdErr
1985							
1986							
1987							
1988							
1989							
1990							
1991							
1992	4881	3480	4619	4636	14606	**32221**	6858
1993	4938	4726	3215	7136	10672	**30688**	5275
1994	5243	4790	3438	7730	12746	**33947**	5663
1995	5336	4633	3529	5284	17400	**36183**	6691
1996	6283	4384	2918	7501	23299	**44384**	9110
1997	6170	4960	3858	9273	42928	**67188**	12002
1998	7180	7177	5775	20544	23815	**64493**	13138
1999	5101	4442	2005	5080	7363	**23992**	4084
2000	7082	7043	3433	9804	11572	**38934**	5455
2001	5798	7728	4629	10835	19960	**48950**	11358
2002	6697	6648	4028	9070	13080	**39524**	7978
2003	5148	6158	3400	7936	7452	**30094**	4064
2004	5734	5503	4332	10518	12072	**38158**	5892
2005	3733	5161	3032	6950	5819	**24694**	3800
2006	6194	6732	5056	6918	13421	**38321**	7207
2007	4641	4923	3627	5372	2420	**20984**	2226
2008	4329	6194	3043	6974	16923	**37463**	6024

GLGU

<u>Aerial index: Total birds</u>

n yrs = 17
mean index = **38248**
std dev = 12622
std error = 3061
low 90%ci = 32248
high 90%ci = 44248

<u>trend over all years :</u>

ln linear slope = -0.015
SE slope = 0.0155
Growth Rate = **0.986**
low 90%ci GR = 0.961
high 90%ci GR = 1.011

<u>most recent 10 years :</u>

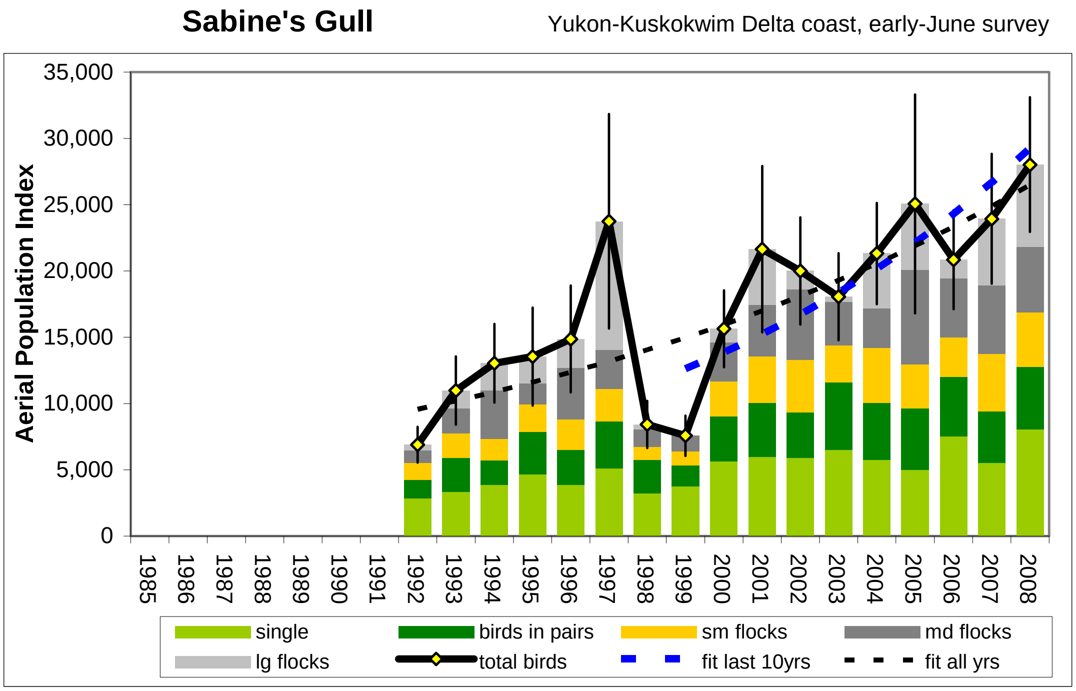
Growth Rate = **0.984**
low 90%ci GR = 0.934
high 90%ci GR = 1.036

regression resid CV = 0.314
avg sampling err CV = 0.175

<u>min yrs to detect -50%/20yr rate :</u>

w/ regression resid CV = 18.4
w/ sample error CV = 12.5

Figure 21. Population trend for Glaucous Gull (*Larus hyperboreus)* observed by a rear-seat observer on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta in western Alaska. The total observed bird population index is the sum of birds observed as singles, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31+, indicated by column divisions from bottom to top. Vertical lines indicate 95% confidence intervals based on sampling error calculated among transects. Stratification included 18 physiographic regions. Birds on nests are included in the index. Average annual growth rate is calculated by log-linear regression. Power calculations use alpha set at p=0.10, beta at p=0.20, and a coefficient of variation based on either regression residuals or sampling errors. The power of the survey to detect trend can be compared between species using the estimated minimum number of years of data needed to detect a significant annual rate of change of -0.034, a 50% decline in 20 years, if it were to occur.



18 strata = 12,832 km^2

year	sg	2*npr	sm flk	md flk	lg flk	Index	StdErr
1985							
1986							
1987							
1988							
1989							
1990							
1991							
1992	2847	1404	1288	914	440	**6893**	688
1993	3327	2560	1872	1888	1340	**10986**	1318
1994	3847	1859	1626	3652	2052	**13036**	1511
1995	4651	3212	2071	1600	2011	**13544**	1887
1996	3863	2622	2317	3899	2172	**14874**	2060
1997	5108	3532	2482	2933	9699	**23754**	4125
1998	3218	2503	1009	1329	369	**8426**	909
1999	3741	1594	1073	1162	0	**7570**	778
2000	5642	3404	2635	2926	1032	**15638**	1484
2001	5975	4100	3467	3887	4206	**21635**	3204
2002	5901	3416	3982	5318	1388	**20005**	2064
2003	6514	5051	2837	3250	406	**18058**	1681
2004	5753	4326	4122	2972	4144	**21317**	1952
2005	4984	4653	3320	7107	4998	**25061**	4213
2006	7524	4500	2997	4419	1413	**20853**	1902
2007	5534	3867	4343	5163	5030	**23936**	2497
2008	8053	4707	4107	4968	6184	**28019**	2594

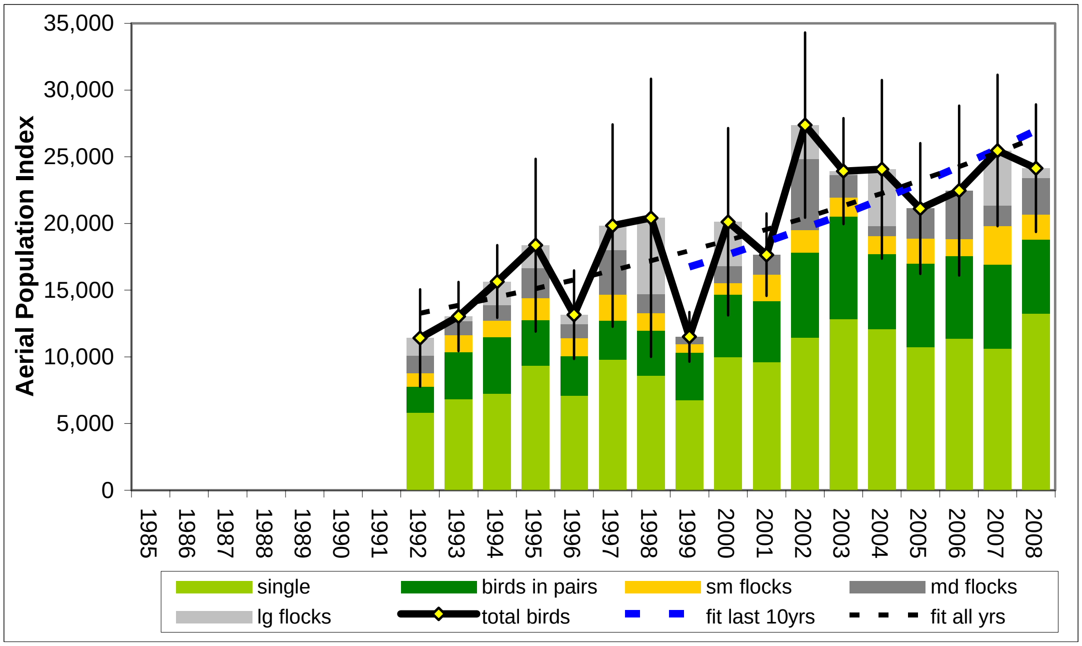
SAGU

Aerial index: Total birds

n yrs =	17
mean index =	**17271**
std dev =	6513
std error =	1580
low 90%ci =	14175
high 90%ci =	20367
trend over all years :	
ln linear slope =	0.0636
SE slope =	0.0151
Growth Rate =	**1.066**
low 90%ci GR =	1.040
high 90%ci GR =	1.092
most recent 10 years :	
Growth Rate =	**1.098**
low 90%ci GR =	1.050
high 90%ci GR =	1.148
regression resid CV =	0.304
avg sampling err CV =	0.117
min yrs to detect -50%/20yr rate :	
w/ regression resid CV =	18.0
w/ sample error CV =	9.5

Figure 22. Population trend for Sabine's Gull (*Xema sabini)* observed by a rear-seat observer on aerial transects sampling 12,832 km^2 of the coastal Yukon-Kuskokwim Delta in western Alaska. The total observed bird population index is the sum of birds observed as singles, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31+, indicated by column divisions from bottom to top. Vertical lines indicate 95% confidence intervals based on sampling error calculated among transects. Stratification included 18 physiographic regions. Birds on nests are included in the index. Average annual growth rate is calculated by log-linear regression. Power calculations use alpha set at p=0.10, beta at p=0.20, and a coefficient of variation based on either regression residuals or sampling errors. The power of the survey to detect trend can be compared between species using the estimated minimum number of years of data needed to detect a significant annual rate of change of -0.034, a 50% decline in 20 years, if it were to occur.

Arctic Tern Yukon-Kuskokwim Delta coast, early-June survey



18 strata = 12,832 km²

year	sg	2*npr	sm flk	md flk	lg flk	Index	StdErr
1985							
1986							
1987							
1988							
1989							
1990							
1991							
1992	5816	1937	1022	1311	1329	**11414**	1865
1993	6820	3517	1302	1022	370	**13031**	1319
1994	7226	4241	1220	1208	1754	**15648**	1391
1995	9347	3424	1644	2246	1711	**18372**	3301
1996	7133	2922	1361	1037	708	**13161**	1696
1997	9802	2935	1924	3346	1841	**19848**	3866
1998	8585	3347	1347	1418	5716	**20413**	5317
1999	6757	3547	645	547	0	**11497**	952
2000	10000	4680	845	1277	3318	**20120**	3584
2001	9592	4581	1994	1493	0	**17659**	1577
2002	11437	6372	1711	5324	2528	**27372**	3536
2003	12840	7694	1441	1677	285	**23937**	2027
2004	12085	5611	1371	718	4271	**24055**	3418
2005	10723	6276	1862	2259	0	**21121**	2505
2006	11392	6144	1290	3645	0	**22471**	3248
2007	10635	6286	2903	1545	4098	**25467**	2895
2008	13239	5519	1921	2716	749	**24144**	2443

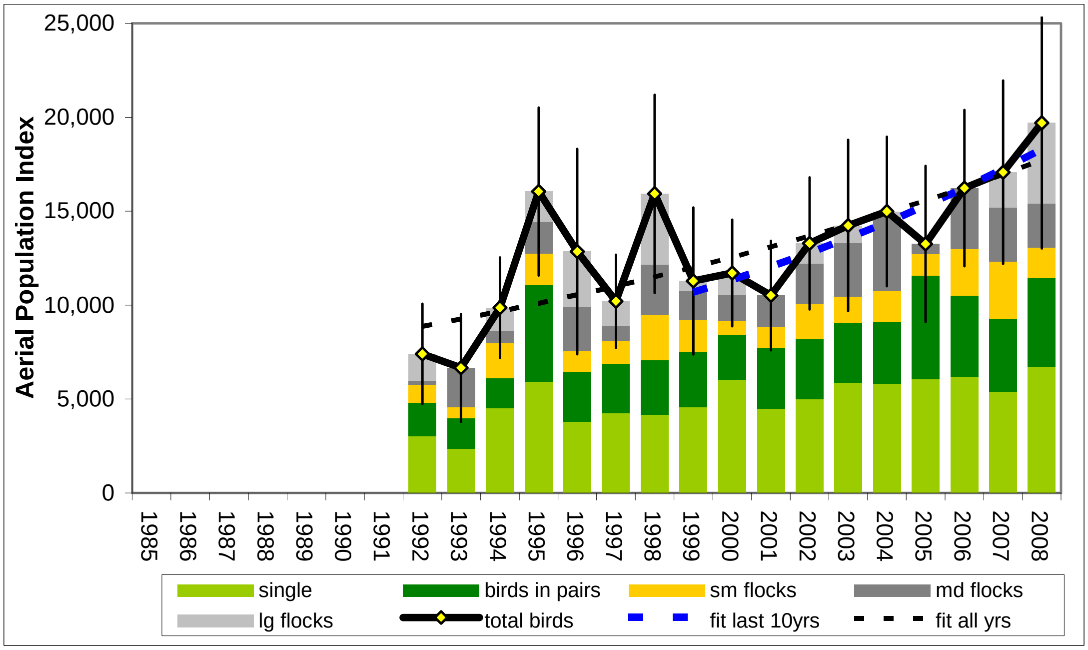
ARTE

Aerial index: Total birds

n yrs =	17
mean index =	**19396**
std dev =	5020
std error =	1217
low 90%ci =	17010
high 90%ci =	21782
trend over all years :	
ln linear slope =	0.043
SE slope =	0.0091
Growth Rate =	**1.044**
low 90%ci GR =	1.028
high 90%ci GR =	1.060
most recent 10 years :	
Growth Rate =	**1.055**
low 90%ci GR =	1.017
high 90%ci GR =	1.094
regression resid CV =	0.185
avg sampling err CV =	0.135
min yrs to detect -50%/20yr rate :	
w/ regression resid CV =	12.9
w/ sample error CV =	10.5

Figure 23. Population trend for Arctic Tern (*Sterna paradisaea)* observed by a rear-seat observer on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta in western Alaska. The total observed bird population index is the sum of birds observed as singles, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31+, indicated by column divisions from bottom to top. Vertical lines indicate 95% confidence intervals based on sampling error calculated among transects. Stratification included 18 physiographic regions. Birds on nests are included in the index. Average annual growth rate is calculated by log-linear regression. Power calculations use alpha set at p=0.10, beta at p=0.20, and a coefficient of variation based on either regression residuals or sampling errors. The power of the survey to detect trend can be compared between species using the estimated minimum number of years of data needed to detect a significant annual rate of change of -0.034, a 50% decline in 20 years, if it were to occur.

Mew Gull Yukon-Kuskokwim Delta coast, early-June survey



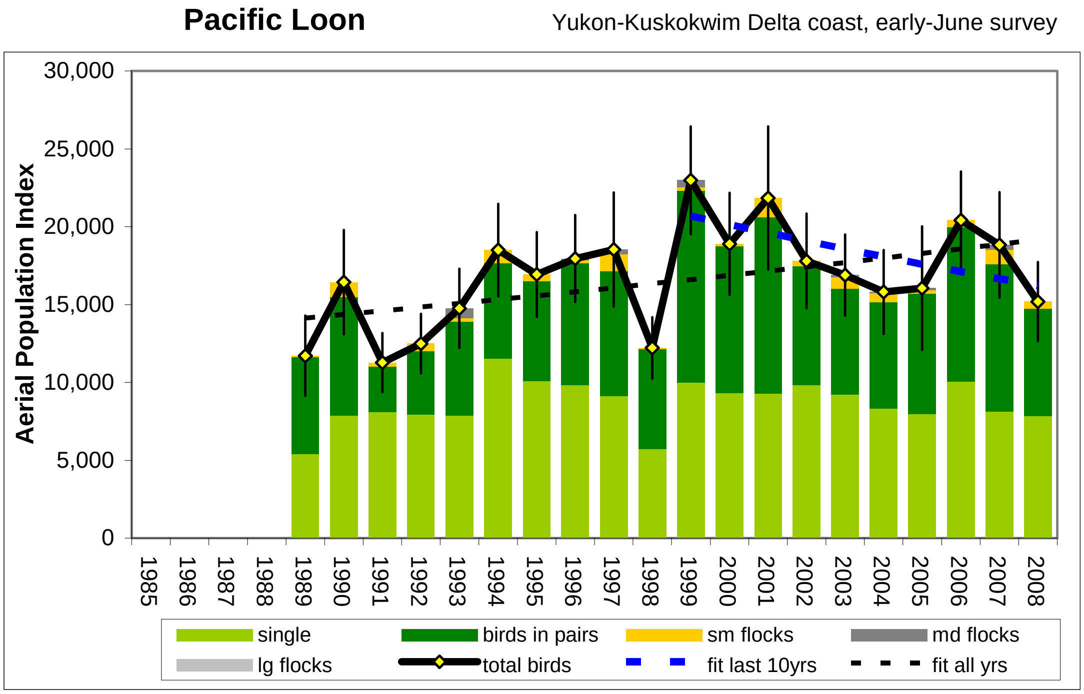
18 strata = 12,832 km^2

year	sg	2*npr	sm flk	md flk	lg flk	Index	StdErr
1985							
1986							
1987							
1988							
1989							
1990							
1991							
1992	3025	1792	934	238	1422	**7411**	1359
1993	2349	1634	591	2088	0	**6663**	1459
1994	4494	1626	1870	669	1207	**9866**	1368
1995	5915	5145	1695	1653	1642	**16051**	2279
1996	3806	2651	1093	2333	2966	**12849**	2785
1997	4232	2655	1188	815	1324	**10213**	1266
1998	4157	2915	2403	2698	3752	**15926**	2691
1999	4588	2928	1720	1488	560	**11284**	1997
2000	6041	2391	724	1385	1164	**11704**	1449
2001	4499	3251	1074	1687	0	**10512**	1487
2002	4997	3193	1869	2156	1068	**13283**	1795
2003	5857	3208	1392	2851	937	**14244**	2323
2004	5819	3267	1650	3963	285	**14984**	2030
2005	6082	5497	1130	554	0	**13262**	2122
2006	6180	4321	2487	3244	0	**16232**	2121
2007	5404	3864	3038	2888	1888	**17082**	2487
2008	6723	4703	1626	2337	4318	**19708**	3416

MEGU

Aerial index: Total birds	
n yrs =	17
mean index =	**13016**
std dev =	3495
std error =	848
low 90%ci =	11355
high 90%ci =	14677
trend over all years :	
ln linear slope =	0.0432
SE slope =	0.0099
Growth Rate =	**1.044**
low 90%ci GR =	1.027
high 90%ci GR =	1.061
most recent 10 years :	
Growth Rate =	**1.062**
low 90%ci GR =	1.046
high 90%ci GR =	1.078
regression resid CV =	0.200
avg sampling err CV =	0.158
min yrs to detect -50%/20yr rate :	
w/ regression resid CV =	13.6
w/ sample error CV =	11.6

Figure 24. Population trend for Mew Gull (*Larus canus)* observed by a rear-seat observer on aerial transects sampling 12,832 km^2 of the coastal Yukon-Kuskokwim Delta in western Alaska. The total observed bird population index is the sum of birds observed as singles, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31+, indicated by column divisions from bottom to top. Vertical lines indicate 95% confidence intervals based on sampling error calculated among transects. Stratification included 18 physiographic regions. Birds on nests are included in the index. Average annual growth rate is calculated by log-linear regression. Power calculations use alpha set at p=0.10, beta at p=0.20, and a coefficient of variation based on either regression residuals or sampling errors. The power of the survey to detect trend can be compared between species using the estimated minimum number of years of data needed to detect a significant annual rate of change of -0.034, a 50% decline in 20 years, if it were to occur.



18 strata = 12,832 km²

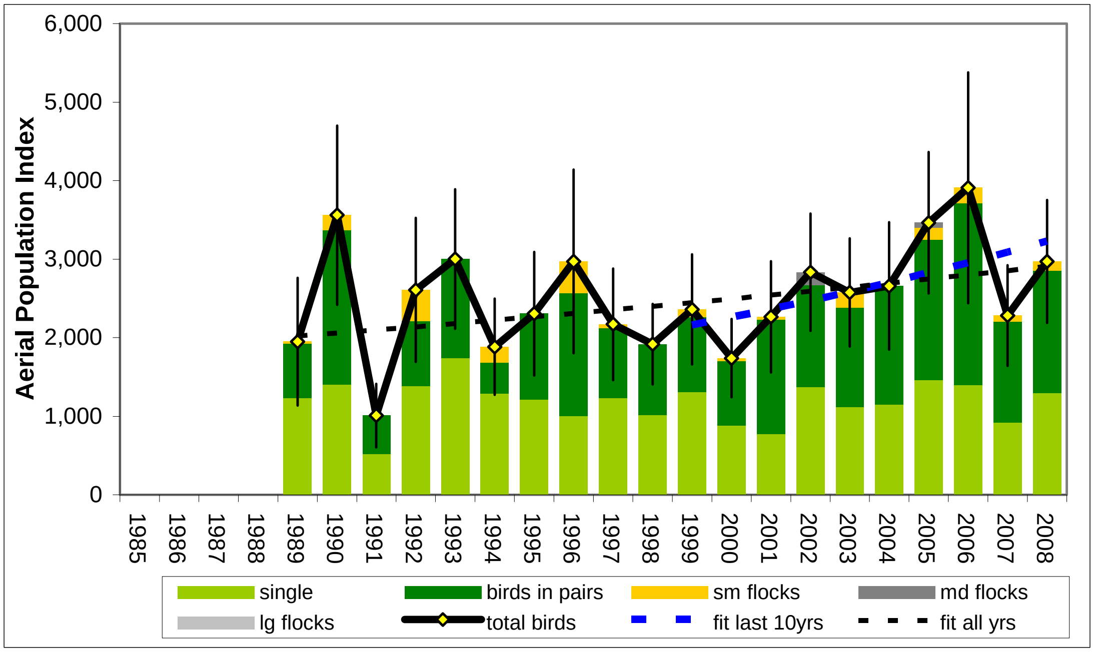
year	sg	2*npr	sm flk	md flk	lg flk	Index	StdErr
1985							
1986							
1987							
1988							
1989	5408	6215	90	0	0	**11712**	1317
1990	7861	7628	943	0	0	**16432**	1710
1991	8096	2928	257	0	0	**11281**	969
1992	7925	4069	500	0	0	**12495**	979
1993	7849	6037	222	652	0	**14759**	1298
1994	11527	6104	855	0	0	**18485**	1517
1995	10088	6402	440	0	0	**16929**	1389
1996	9808	7820	220	98	0	**17945**	1427
1997	9148	7986	1088	301	0	**18523**	1871
1998	5728	6403	82	0	0	**12212**	1004
1999	10004	12304	219	443	0	**22970**	1770
2000	9295	9445	151	0	0	**18891**	1673
2001	9248	11366	1229	0	0	**21842**	2346
2002	9826	7628	337	0	0	**17792**	1553
2003	9224	6779	751	133	0	**16886**	1331
2004	8313	6837	568	88	0	**15807**	1373
2005	7938	7774	192	148	0	**16052**	2029
2006	10045	9908	451	0	0	**20403**	1606
2007	8148	9429	957	292	0	**18825**	1731
2008	7832	6877	471	0	0	**15181**	1299

PALO

Aerial index: Total birds	
n yrs =	20
mean index =	**16771**
std dev =	3224
std error =	721
low 90%ci =	15358
high 90%ci =	18184
trend over all years :	
ln linear slope =	0.0161
SE slope =	0.0070
Growth Rate =	**1.016**
low 90%ci GR =	1.005
high 90%ci GR =	1.028
most recent 10 years :	
Growth Rate =	**0.973**
low 90%ci GR =	0.952
high 90%ci GR =	0.995
regression resid CV =	0.181
avg sampling err CV =	0.090
min yrs to detect -50%/20yr rate :	
w/ regression resid CV =	12.8
w/ sample error CV =	8.0

Figure 25. Population trend for Pacific Loon (*Gavia pacifica*) observed by a rear-seat observer on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta in western Alaska. The total observed bird population index is the sum of birds observed as singles, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31+, indicated by column divisions from bottom to top. Vertical lines indicate 95% confidence intervals based on sampling error calculated among transects. Stratification included 18 physiographic regions. Birds on nests are included in the index. Average annual growth rate is calculated by log-linear regression. Power calculations use alpha set at p=0.10, beta at p=0.20, and a coefficient of variation based on either regression residuals or sampling errors. The power of the survey to detect trend can be compared between species using the estimated minimum number of years of data needed to detect a significant annual rate of change of -0.034, a 50% decline in 20 years, if it were to occur.

Red-throated Loon Yukon-Kuskokwim Delta coast, early-June survey



18 strata = 12,832 km²

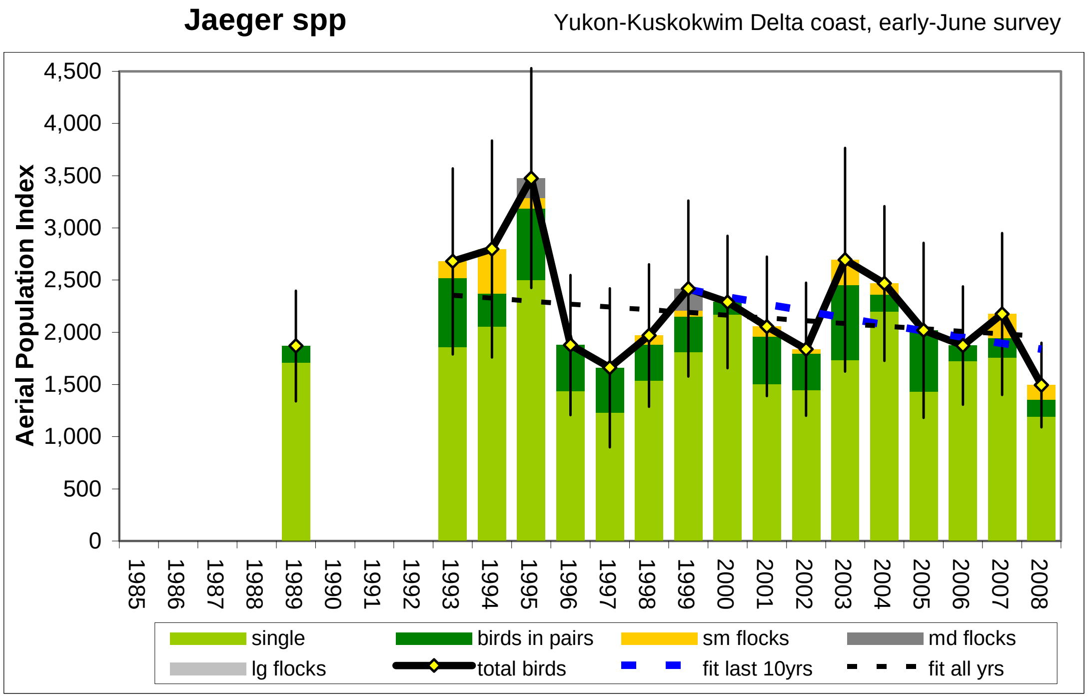
year	sg	2*npr	sm flk	md flk	lg flk	Index	StdErr
1985							
1986							
1987							
1988							
1989	1231	693	26	0	0	**1949**	415
1990	1400	1967	194	0	0	**3560**	582
1991	522	486	0	0	0	**1008**	207
1992	1385	825	398	0	0	**2608**	469
1993	1737	1266	0	0	0	**3002**	452
1994	1288	394	202	0	0	**1884**	312
1995	1212	1092	0	0	0	**2304**	402
1996	1008	1560	404	0	0	**2972**	597
1997	1227	893	51	0	0	**2171**	363
1998	1014	904	0	0	0	**1919**	262
1999	1307	953	100	0	0	**2360**	358
2000	879	828	32	0	0	**1739**	254
2001	775	1456	34	0	0	**2265**	362
2002	1369	1302	0	163	0	**2834**	381
2003	1117	1264	194	0	0	**2575**	352
2004	1150	1509	0	0	0	**2659**	415
2005	1461	1785	151	65	0	**3462**	459
2006	1399	2311	200	0	0	**3909**	750
2007	921	1280	81	0	0	**2282**	328
2008	1295	1555	122	0	0	**2971**	399

RTLO

Aerial index: Total birds

n yrs =	20
mean index =	**2522**
std dev =	687
std error =	154
low 90%ci =	2220
high 90%ci =	2823
trend over all years :	
ln linear slope =	0.0192
SE slope =	0.0112
Growth Rate =	**1.019**
low 90%ci GR =	1.001
high 90%ci GR =	1.038
most recent 10 years :	
Growth Rate =	**1.045**
low 90%ci GR =	1.009
high 90%ci GR =	1.084
regression resid CV =	0.288
avg sampling err CV =	0.162
min yrs to detect -50%/20yr rate :	
w/ regression resid CV =	17.4
w/ sample error CV =	11.9

Figure 26. Population trend for Red-throated Loon (*Gavia stellata*) observed by a rear-seat observer on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta in western Alaska. The total observed bird population index is the sum of birds observed as singles, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31+, indicated by column divisions from bottom to top. Vertical lines indicate 95% confidence intervals based on sampling error calculated among transects. Stratification included 18 physiographic regions. Birds on nests are included in the index. Average annual growth rate is calculated by log-linear regression. Power calculations use alpha set at p=0.10, beta at p=0.20, and a coefficient of variation based on either regression residuals or sampling errors. The power of the survey to detect trend can be compared between species using the estimated minimum number of years of data needed to detect a significant annual rate of change of -0.034, a 50% decline in 20 years, if it were to occur.



18 strata = 12,832 km²

year	sg	2*npr	sm flk	md flk	lg flk	Index	StdErr
1985							
1986							
1987							
1988							
1989	1708	161	0	0	0	**1869**	271
1990							
1991							
1992							
1993	1857	663	159	0	0	**2679**	455
1994	2055	316	426	0	0	**2797**	530
1995	2498	690	97	192	0	**3477**	536
1996	1438	440	0	0	0	**1878**	342
1997	1231	429	0	0	0	**1660**	388
1998	1539	342	87	0	0	**1968**	348
1999	1812	338	58	211	0	**2419**	430
2000	2170	120	0	0	0	**2290**	324
2001	1505	453	97	0	0	**2055**	341
2002	1443	353	42	0	0	**1838**	325
2003	1732	718	246	0	0	**2696**	547
2004	2198	162	109	0	0	**2468**	378
2005	1434	585	0	0	0	**2018**	428
2006	1726	146	0	0	0	**1872**	289
2007	1754	190	231	0	0	**2176**	396
2008	1193	160	141	0	0	**1494**	207

JAEG

Aerial index: Total birds	
n yrs =	17
mean index =	**2215**
std dev =	496
std error =	120
low 90%ci =	1979
high 90%ci =	2451
trend over all years :	
ln linear slope =	-0.012
SE slope =	0.0097
Growth Rate =	**0.988**
low 90%ci GR =	0.972
high 90%ci GR =	1.004
most recent 10 years :	
Growth Rate =	**0.970**
low 90%ci GR =	0.944
high 90%ci GR =	0.998
regression resid CV =	0.210
avg sampling err CV =	0.174
min yrs to detect -50%/20yr rate :	
w/ regression resid CV =	14.1
w/ sample error CV =	12.4

Figure 27. Population trend for Jaeger spp (*Stercorarius parasiticus, S. longicauda, S. pomarinus*) observed by a rear-seat observer on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta in western Alaska. The total observed bird population index is the sum of birds observed as singles, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31+, indicated by column divisions from bottom to top. Vertical lines indicate 95% confidence intervals based on sampling error calculated among transects. Stratification included 18 physiographic regions. Birds on nests are included in the index. Average annual growth rate is calculated by log-linear regression. Power calculations use alpha set at p=0.10, beta at p=0.20, and a coefficient of variation based on either regression residuals or sampling errors. The power of the survey to detect trend can be compared between species using the estimated minimum number of years of data needed to detect a significant annual rate of change of -0.034, a 50% decline in 20 years, if it were to occur.

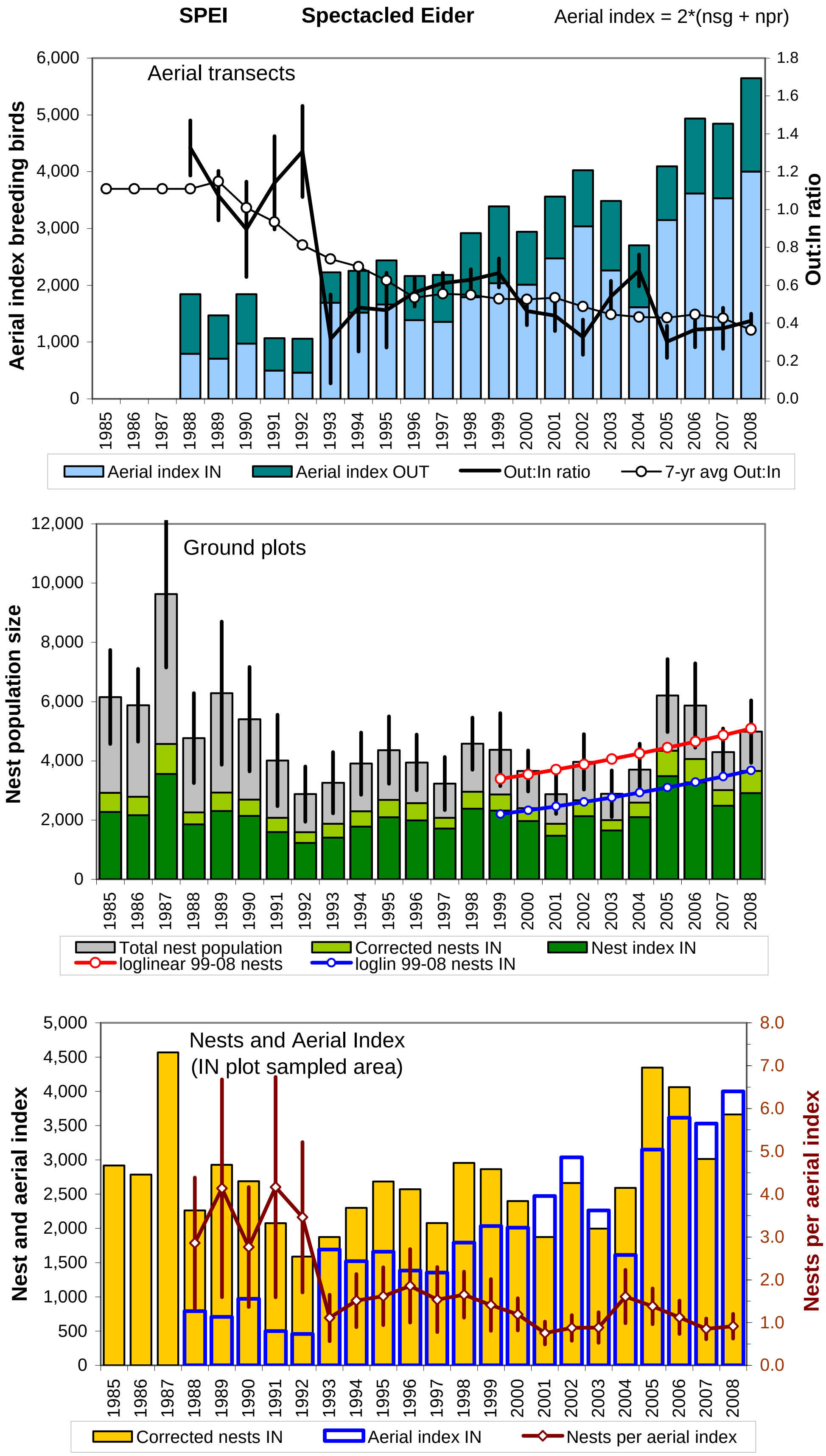


Fig. 28. Comparison of aerial survey indices with ground plot survey nest indices for spectacled eiders.

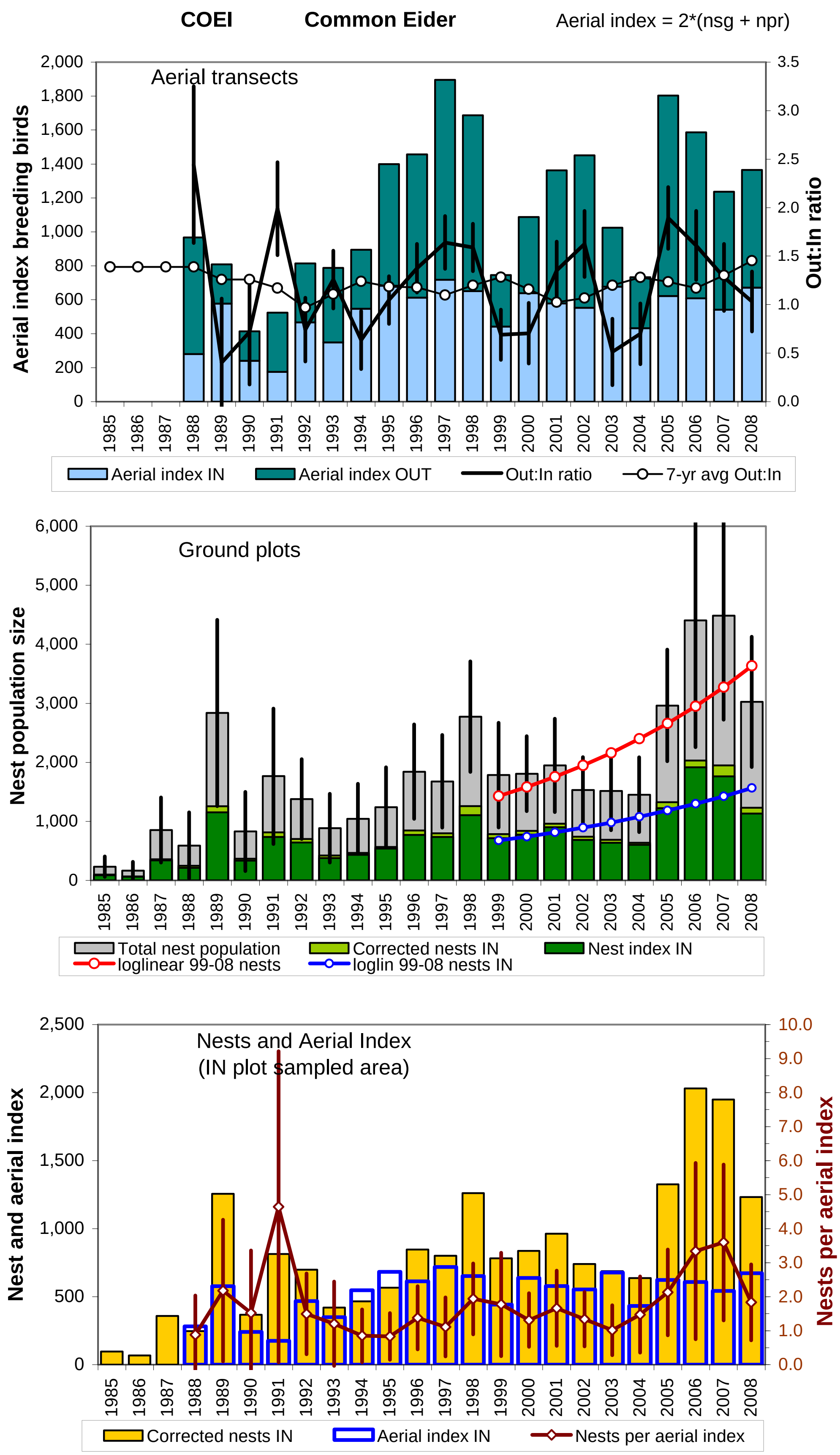


Fig. 29. Comparison of aerial survey indices with ground plot survey nest indices for common eiders.

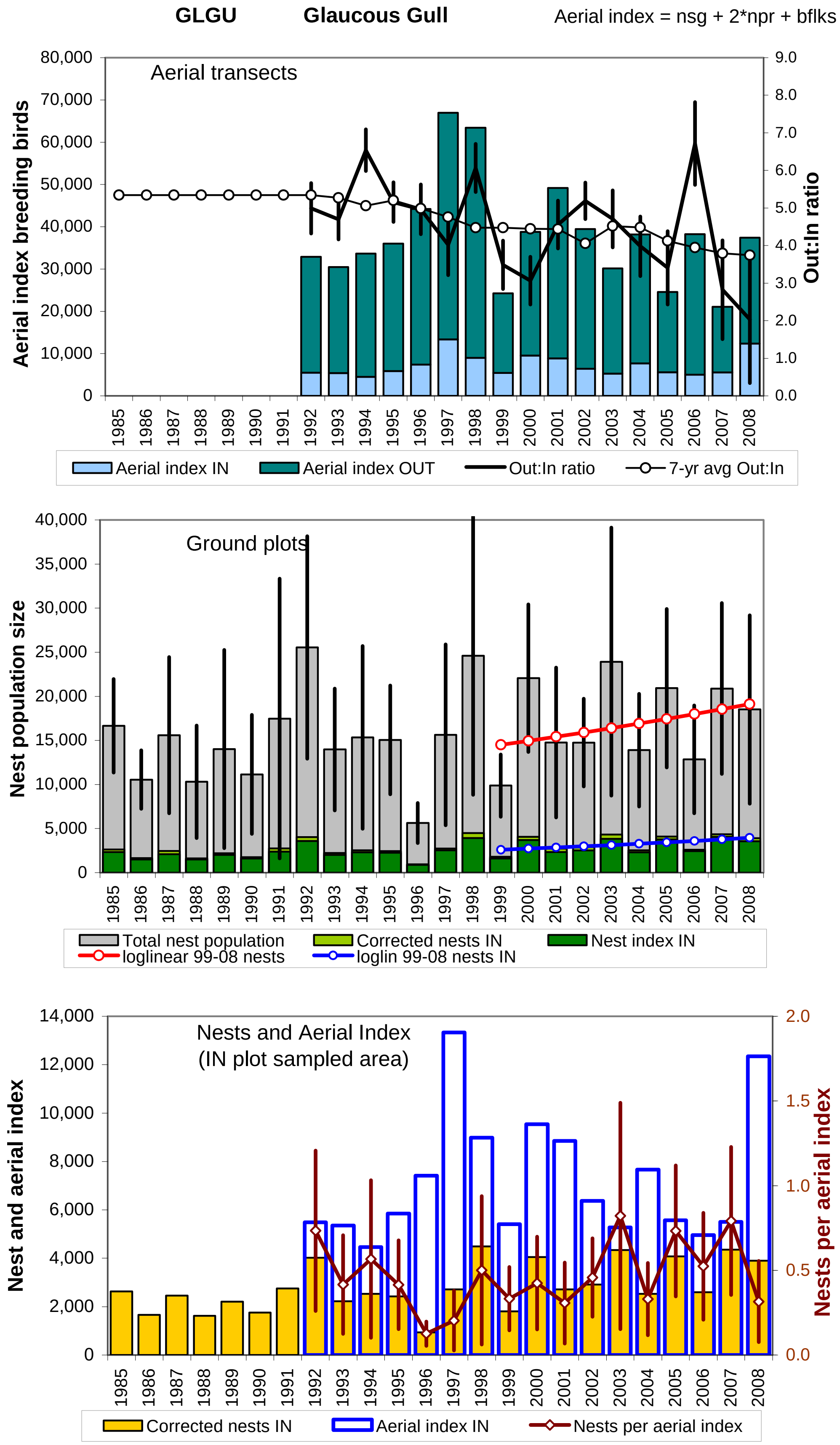


Fig. 30. Comparison of aerial survey indices with ground plot survey nest indices for glaucous gulls.

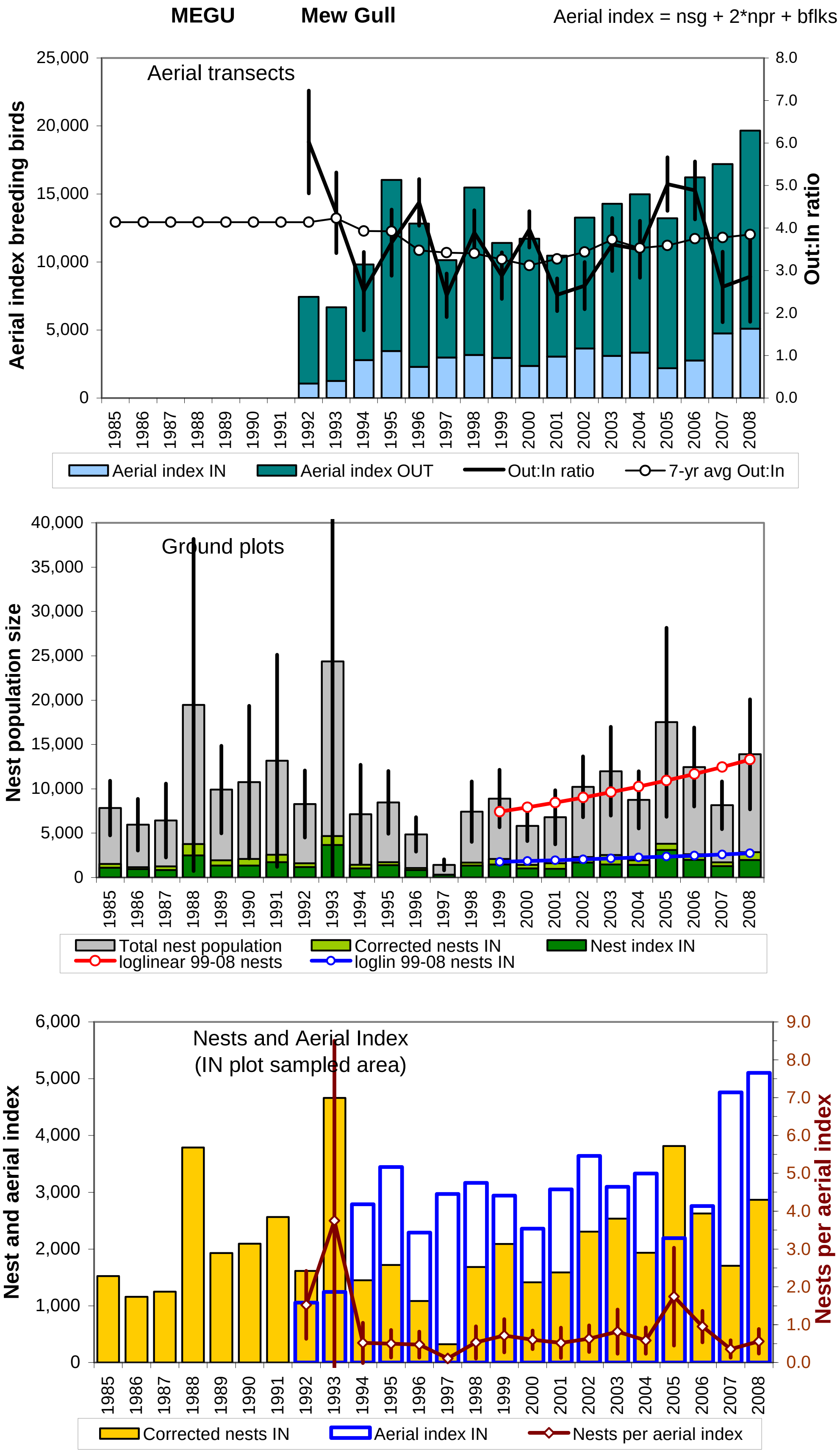


Fig. 31. Comparison of aerial survey indices with ground plot survey nest indices for mew gulls.

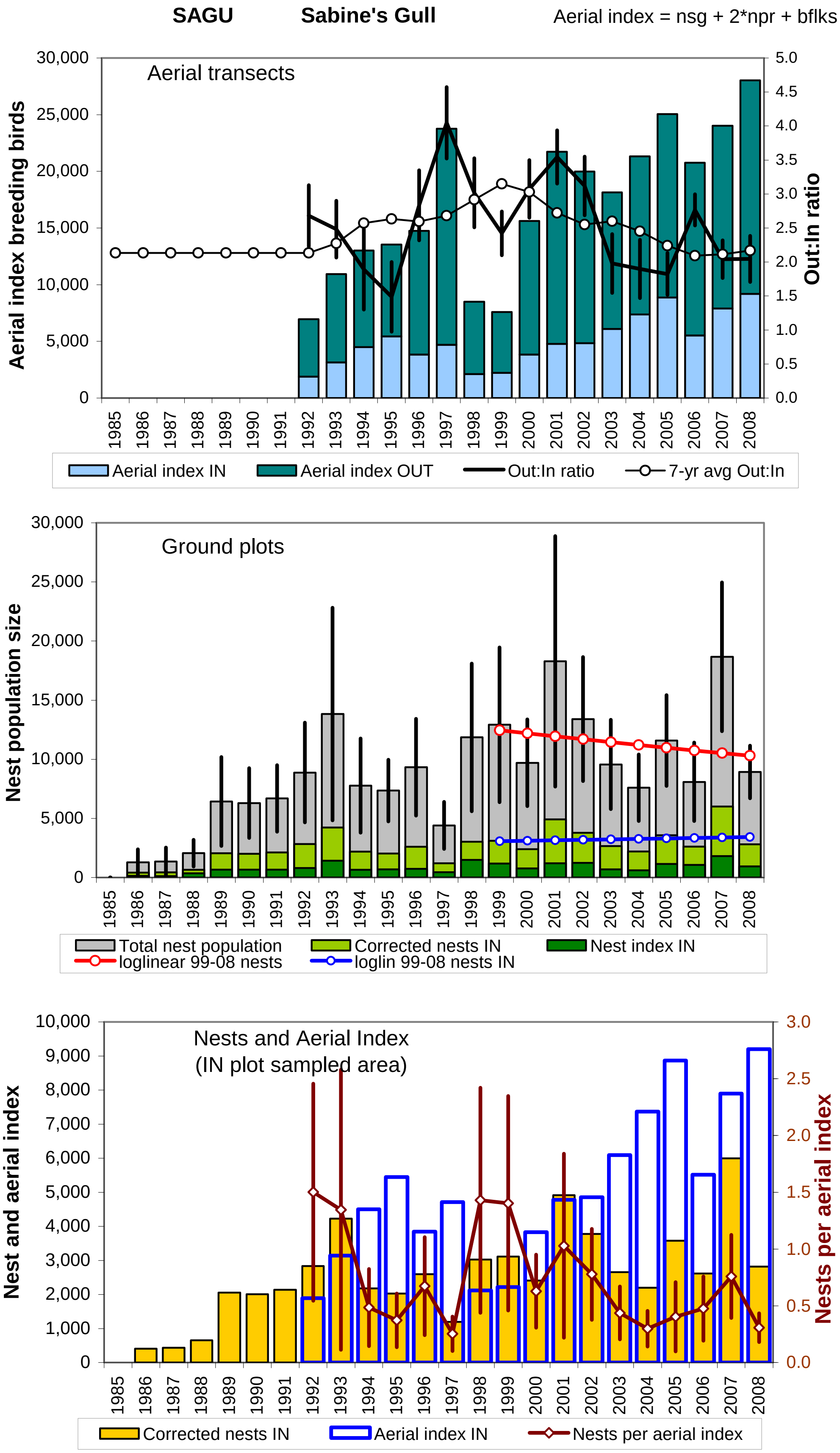


Fig. 32. Comparison of aerial survey indices with ground plot survey nest indices for Sabine's gulls.

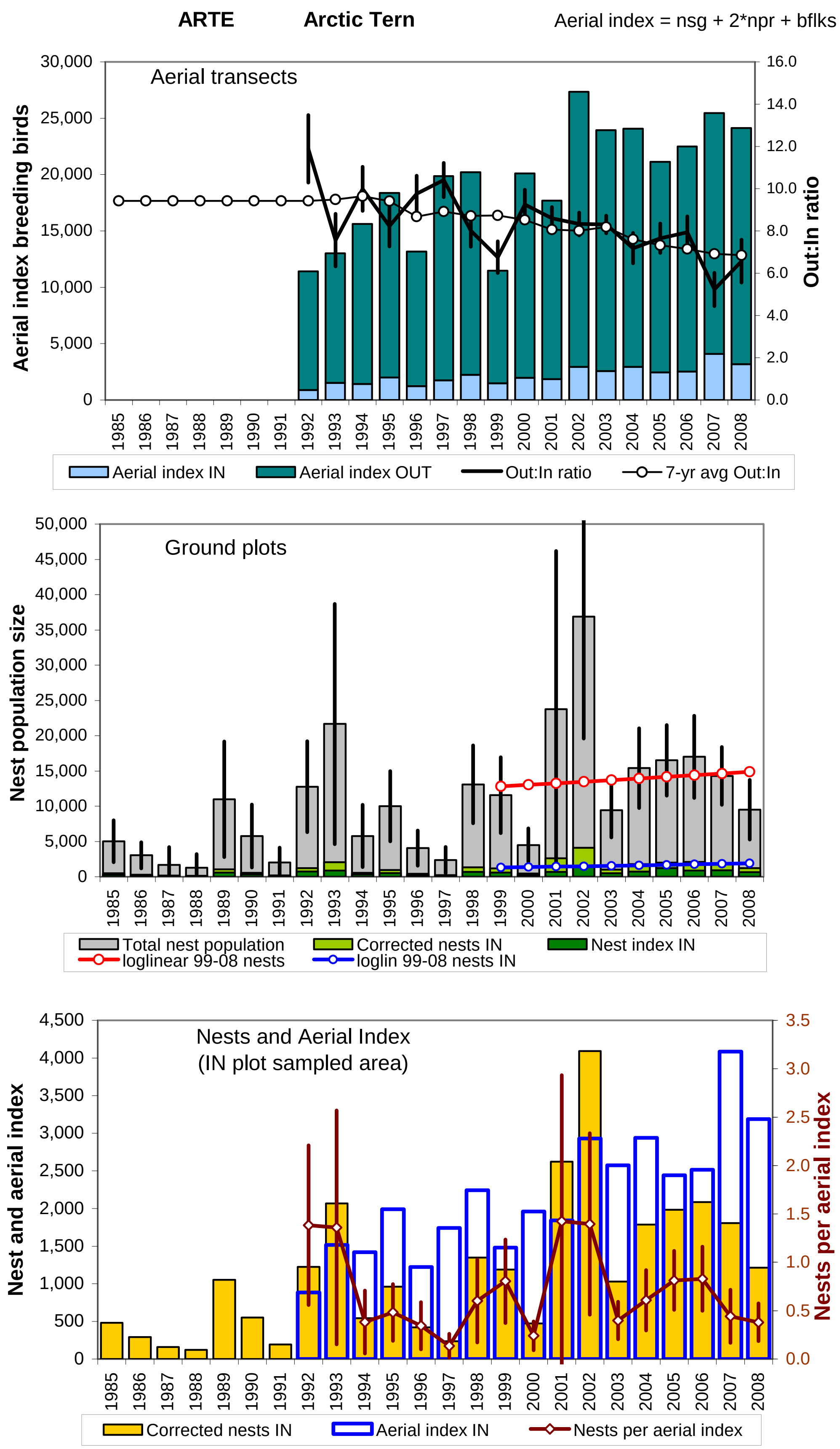


Fig. 33. Comparison of aerial survey indices with ground plot survey nest indices for arctic terns.

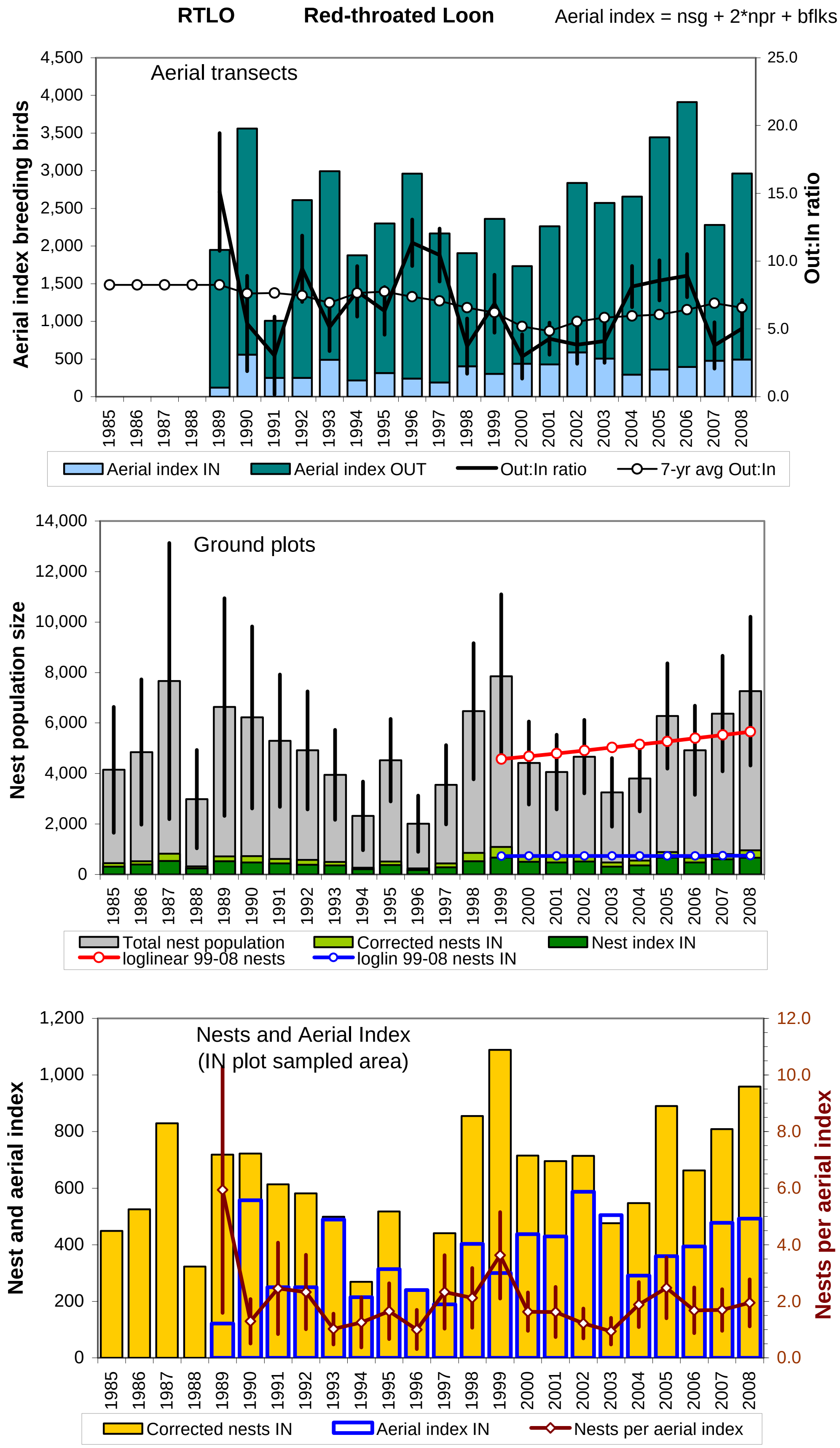


Fig. 34. Comparison of aerial survey indices with ground plot survey nest indices for red-throated loons.

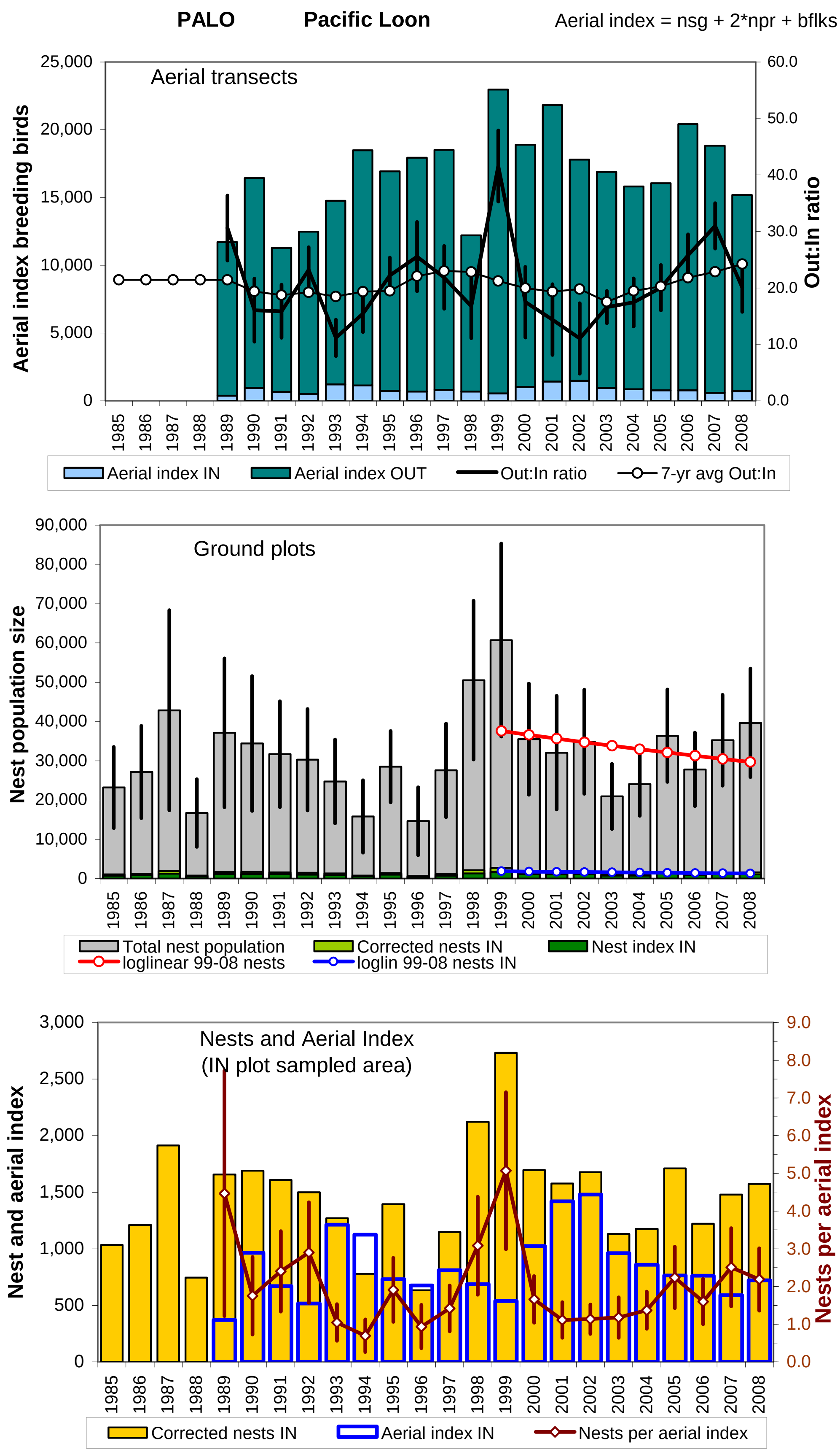


Fig. 35. Comparison of aerial survey indices with ground plot survey nest indices for Pacific loons.

Table 1. Number of birds sighted by category and expanded numbers for waterbirds counted by the right-rear-seat observer on the June 2008 Yukon Delta Coastal Zone aerial survey, Alaska. Species sorted in order of decreasing population estimates for ducks, then for other species. Survey area = 12,831.5 km^2 and sampled area = 470.9 km^2. Number of transects (n) = 222. Density was calculated using 18 strata and therefore is not simply the indicated total divided by the sampled area.

Species	No. of single birds sighted	No. of pairs sighted	No. of grouped birds sighted[a]	Indicated total birds[b]	Sample density Birds/km^2	Population index (No. of birds)	Standard error	Visibility correction factor	Population estimate (No. of birds)
Northern pintail	888	329	1,233	3,667	4.122	52,896	5,159	3.05	**161,333**
Greater scaup	151	514	169	1,348	2.920	37,465	3,366	1.93	**72,307**
Northern shoveler	85	36	6	248	0.594	7,620	1,403	3.79	**28,880**
American green-winged teal	29	9	0	76	0.192	2,460	590	8.36	**20,566**
Spectacled eider	214	118	5	669	0.445	5,713	548	3.58	**20,453**
Mallard	53	9	0	124	0.237	3,047	562	4.01	**12,218**
American wigeon	23	10	105	171	0.226	2,906	856	3.84	**11,159**
Black scoter	24	104	0	256	0.717	9,194	2,144	1.17	**10,757**
Long-tailed duck	36	52	0	176	0.291	3,736	708	1.87	**6,986**
Common eider	55	22	5	159	0.107	1,374	248	3.58	**4,919**
Red-breasted merganser	6	19	0	50	0.027	838	228	1.27	**1064**
Canvasback	1	3	0	8	0.008	97	51	2.43	**236**
Glaucous gull	348	205	2,309	3,067	2.920	**37,463**	6,024	unknown	n/a
Sabine's gull	747	243	1,617	2,850	2.184	**28,019**	2,594	unknown	n/a
Arctic tern	727	188	296	1,399	1.882	**24,144**	2,443	unknown	n/a
Mew gull	421	146	905	1,618	1.536	**19,708**	3,416	unknown	n/a
Pacific loon	338	117	31	603	1.183	**15,181**	1,299	unknown	n/a
Red-throated loon	70	43	12	168	0.232	**2,971**	399	unknown	n/a
Jaeger species	49	8	7	72	0.116	**1,494**	207	unknown	n/a

[a] For ducks, groups are 5 or more birds, for other species, groups are 3 or more birds per sighting.
[b] For ducks, Indicated total birds = 2 * (singles + pairs) + birds in groups, for other species, observed totals = singles + (2 * pairs) + birds in groups.

[c]Greater scaup single drakes are not doubled, scaup number is observed total.

Table 2. Change in population estimates from 2007 and from the long-term average, sorted in decreasing order of percent change from long-term average for waterfowl, then other species.

Species	Population estimate 2007	Population estimate 2008	Change between 2007 and 2008	Long term (1988-2007) average population estimate	Change between 2008 and long term average
Spectacled eider	17,359	20,453	18%	9,977	105%
Common eider	4,514	4,919	9%	4,486	10%
Northern pintail	116,602	161,333	38%	152,390	6%
Greater scaup	63,642	72,307	14%	71,250	1%
Black scoter	11,633	10,757	-8%	11,994	-10%
Green-winged teal	23,216	20,566	-11%	23,634	-13%
Northern shoveler	33,682	28,880	-14%	38,010	-24%
Mallard	17,925	12,218	-32%	16,802	-27%
American wigeon	8,878	11,159	26%	18,685	-40%
Long-tailed duck	9,986	6,986	-30%	12,017	-42%
Red-breasted merganser	437	1,064	143%	2,130	-50%
Canvasback	377	236	-37%	2,809	-92%
Sabine's gull	23,936	28,019	15%	16,600	69%
Mew gull	17,082	19,708	13%	12,598	56%
Arctic tern	25,467	24,144	-5%	19,099	26%
Red-throated loon	2,282	2,971	23%	2,498	19%
Glaucuos gull	20,984	37,463	44%	38,297	-2%
Pacific loon	18,825	15,181	-24%	16,963	-11%
Jaeger spp.	2,176	1,494	-46%	2,260	-34%

Table 3. Summary of trends for waterbird species counted by the right-rear-seat observer on the Yukon-Kuskokwim Delta coastal zone aerial survey Alaska. Ducks have been counted since 1988. Other species have been added to the survey as indicated. Geographic stratification into 18 regions represents a balance determined by sampling intensity, similar physiographic areas, and reasonable gains in precision for most of the species. Green-shaded cells indicate growth rates significantly above 1.0 and yellow-shaded cells indicate significantly declining trends.

Fig. #	Species	No of yrs	Average pop. Index	Std dev pop. Index	Log-linear slope	SE slope	Growth Rate	Low 90%CI GR	High 90%CI GR	CV regress. Resids.	CV sampling error	Yrs. to detect change w/ regress. Resid. CV	Yrs. to detect change w/ sample error CV	Growth rate last 10 yrs.	Low 90%CI GR last 10 yrs.	High 90%CI GR last 10 yrs.
9	Northern pintail	21	**50104**	13270	-0.0104	0.0094	**0.990**	0.975	1.005	0.260	0.110	16.2	9.2	**1.030**	0.993	1.068
10	Greater scaup	21	**36944**	5850	0.0148	0.0053	**1.015**	1.006	1.024	0.146	0.102	11.1	8.7	**0.999**	0.982	1.016
11	Northern Shoveler	21	**9914**	3046	0.0051	0.0106	**1.005**	0.988	1.023	0.295	0.175	17.7	12.5	**1.019**	0.973	1.066
12	Green-winged teal	21	**2809**	923	0.0052	0.0132	**1.005**	0.984	1.027	0.368	0.225	20.5	14.7	**0.994**	0.941	1.050
13	Spectacled eider	21	**2926**	1279	0.0667	0.0078	**1.069**	1.055	1.083	0.218	0.135	14.4	10.5	**1.060**	1.029	1.093
14	Mallard	21	**4136**	1526	-0.0105	0.0125	**0.990**	0.969	1.010	0.348	0.217	19.7	14.4	**1.075**	1.015	1.139
15	American wigeon	21	**4773**	2311	-0.0597	0.0138	**0.942**	0.921	0.964	0.383	0.368	21.0	20.5	**0.996**	0.932	1.064
16	Black scoter	21	**10201**	2493	0.0139	0.0117	**1.0140**	0.9950	1.0340	0.324	0.197	18.8	13.5	**1.0030**	0.9630	1.0430
17	Long-tailed duck	21	**6298**	1594	0.0064	0.0100	**1.006**	0.990	1.023	0.278	0.145	17.0	11.0	**0.984**	0.941	1.028
18	Common eider	21	**1259**	545	0.0406	0.0145	**1.041**	1.017	1.067	0.402	0.240	21.7	15.4	**1.029**	0.954	1.109
19	Red-breasted merganser	21	**1638**	3754	0.1144	0.0386	**1.1210**	**1.0520**	1.1950	1.073	0.477	41.8	24.3	**1.0050**	0.7780	1.2970
20	Canvasback	21	**1105**	1070	-0.0909	0.0360	**0.913**	0.861	0.969	0.999	0.541	39.8	26.5	**0.745**	0.625	0.889
21	Glaucous gull	17	**38248**	12622	-0.0145	0.0155	**0.986**	0.961	1.011	0.314	0.175	18.4	12.5	**0.984**	0.934	1.036
22	Sabine's gull	17	**17271**	6513	0.0636	0.0151	**1.066**	1.040	1.092	0.304	0.117	18.0	9.5	**1.098**	1.050	1.148
23	Arctic tern	17	**19396**	5020	0.0430	0.0091	**1.044**	1.028	1.060	0.185	0.135	12.9	10.5	**1.055**	1.017	1.094
24	Mew gull	17	**13016**	3495	0.0432	0.0099	**1.044**	1.027	1.061	0.200	0.158	13.6	11.6	**1.062**	1.046	1.078
25	Pacific loon	20	**16771**	3224	0.0161	0.0070	**1.016**	1.005	1.028	0.181	0.090	12.8	8.0	**0.973**	0.952	0.995
26	Red-throated loon	20	**2522**	687	0.0192	0.0112	**1.019**	1.001	1.038	0.288	0.162	17.4	11.9	**1.045**	1.009	1.084
27	Jaeger spp.	17	**2215**	496	-0.0122	0.0097	**0.988**	0.972	1.004	0.210	0.174	14.1	12.4	**0.970**	0.944	0.998