Abundance and Trend of Waterbirds on Alaska's Yukon-Kuskokwim Delta Coast based on 1988 to 2013 Aerial Surveys

Robert M. Platte and Robert A. Stehn,
Waterfowl Management Branch
Division of Migratory Bird Management
U.S. Fish and Wildlife Service
1011 East Tudor Road, Anchorage, Alaska 99503

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Abstract: We summarize 1988 to 2013 (no survey in 2011) aerial survey waterbird sightings that index the abundance and trend of populations in the Yukon-Kuskokwim delta coastal zone. The threatened spectacled eider (*Somateria fischeri*) population index for 2013 was 6,808 birds, the highest in the history of the survey. Traditionally, a visibility correction factor of 3.58 has been applied for spectacled eiders yielding a population estimate of 24,373 which was 106% above its 1988-2012 long-term average (LTA) size. However, we calculated a new estimate of visibility rate for spectacled eiders in 2010 using the ratio of the aerial index of indicated breeding birds to the estimated population of nests (Fischer et al. 2010). The ratio was 0.425 nests per aerial indicated pair or, expressed as the inverse, 2.351 birds per aerial index. Using this correction, the population estimate for spectacled eiders was 16,006 breeding birds.

In 2013, the three most numerous waterfowl species were northern pintail (*Anas acuta*) with a visibility-corrected estimate of 115,479 birds, greater scaup (*Aythya marila*) with 46,750 birds, and green-winged teal (*Anas crecca*) at 24,373 birds. The scaup index was the lowest in the history of the survey. The estimated population sizes for species of special interest were 7,343 common eiders (*Somateria mollissima*), 9,253 long-tailed ducks (*Clangula hyamelis*), 14,501 black scoters (*Melanitta nigra*), and 2,352 red-throated loons (*Gavia stellata*). The estimated numbers of common eiders and black scoters were above their LTAs. Numbers of the other duck species were substantially below their LTAs.

Of the non-waterfowl species in 2013, Sabine's gulls (*Xema sabini*) were most numerous with an estimated 50,352 birds (159% above LTA), followed by 38,689 glaucous gulls (*Larus hyperboreus*) (+1%) and 25,601 mew gulls (*Larus canus*) (+85%). The indices for both Sabines' gulls and mew gulls were the highest in the history of the survey. The estimated population of Arctic terns (*Sterna paradisaea*) was 20,993 (+3%). Pacific loons (*Gavia pacifica*) were estimated at 19,043 birds (+16%).

Long term trends based on log-linear regression showed significant population increases (p<0.10) for spectacled eider, common eider, greater scaup, red-breasted merganser (*Mergus serrator*), mew gull, Sabine's gull, and arctic tern. Populations declined for American wigeon (*Anas americana*), canvasback (*Aythya valisineria*), and jaegers (*Stercorarius spp.*).

Previous analysis showed a strong correlation between the thaw-degree-day index of spring warming temperatures and average cackling goose (*Branta hutchinsii minima*) clutch initiation date. We used this relationship to predict an appropriate start date for the 2013 survey consistent with average survey timing of the last several years. We began flights on 8 June, ten days after predicted average nest initiation of 29 May. Later examination of nesting data showed the average cackling goose initiation date was 2 June (Fischer et al. 2014). Therefore, the 2013 survey started 6 days after average nest initiation which is a few days earlier relative to survey timing in recent years. Due to logistical constraints several transects scattered throughout the survey area were unable to be flown in 2013.

We continued to compile individual geographic locations for sightings of 21 major species of waterbirds based on the aircraft global positioning system and now have over 145,000 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 of birds on the Yukon-Kuskokwim delta (YKD) coastal zone in western Alaska provide indices to population abundance, trend, and distribution for many species of breeding waterbirds. This information is 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. The survey was initiated in 1985 to monitor populations of Cackling and White-fronted geese that had shown substantial declines in fall counts. The initial YKD surveys were flown with a pilot/observer in the left front seat and an 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 on the YKD makes it too difficult for front seat observers to also observe and record other species of waterbirds. Therefore, in 1988, an additional observer in the right back 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 for monitoring the threatened population of spectacled eider and other species of concern including common eider, black scoter, long-tailed duck, and red-throated loon. The objective in this report is to present details on the survey methods, and summarize the population estimates and trends for all species recorded from 1988 to 2013 by the back seat observer. No survey data were collected in 2011 due to a shortage of personnel.

METHODS

Survey Design

We modified the survey area and transect design slightly in 2012 to omit areas surrounding villages from the survey excluding a total of 212.7 square kilometers. The survey area originally encompassed 12,832 km^2 of tundra wetlands from Norton Sound to Kuskokwim Bay, extending about 50 km inland from the west coast. The area was divided into 18 strata with generally homogeneous physiographic features visible on an unclassified LANDSAT image mosaic at 1:250,000 scale (Fig. 1). We used custom TrueBASIC programs and ArcGIS® (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 higher densities of geese and generally higher variances were allocated transects at 1.61 km spacing. Intervals were expanded to 3.22, 6.44, or 12.88 km spacing for strata with fewer geese. Flight distance in 2013 totaled about 1,978 km on 189 transects with a 200 m wide observed area of 396 km^2. The survey design has changed slightly over the years in the number and placement of transects. In 1998 we started a 4-year rotating panel of transects spaced at 1.6, 3.2, 6.4, or 12.8 km within the various strata. Intermediate transects were flown each year from 1998 to 2001, allowing 50% coverage of the habitat at the 1.6 km intervals by combining samples from four years. We began a second rotation of the same set of transects by replicating the same lines flown in 1998 again in 2002. In 2013, we flew the fourth year of the fourth replicate set of rotations by flying the same transects as in 2001, 2005, and 2009.

Data Collection

Survey methods followed the standard protocol for waterfowl breeding ground surveys in North America (USFWS and Canadian Wildlife Service 1987). For all surveys prior to 2012, a Cessna 206 amphibious aircraft was used. In 2012, a Quest Kodiak amphibious aircraft was used. In 2013 we used a Cessna 206 float plane. The aircraft was flown at 145-170 km per hour, 30-46 m 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, 1992-2013) to maintain the correct 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). Geographic point locations were interpolated based on the proportion of elapsed time between the start and end coordinates for each transect. Since 1998, the observer used a computerized data collection program called Survey Recording Program written by John Hodges (retired USFWS, Migratory Bird Management, Juneau, Alaska). This system consisted of a notebook computer connected to the aircraft's GPS receiver and a remote microphone/mouse. The observer voice recorded each transect number, transect start and end points, and bird sighted within the 200 m wide strip to the right side of the aircraft to the computer using the remote microphone/mouse (.WAV file format). The observer identified birds to species or species group and recorded group size as a single, pair, or number of birds in flocks. The mouse click for each sighting caused the latitude/longitude coordinates (WGS84 datum) from the GPS to be written to a computer file (.POS). We then used a computer transcription program to replay the .WAV format sound files, enter header information (year, month, day, observer initials, and transect number.), species and group size, and combine these with the geographic coordinates in the .POS position file to produce a final data file.

Leslie Slater was the observer in 1988 and Karen Bollinger observed in 1989 and 1990. Bob Platte has collected the data every year since 1991, except 2011 when he collected geese, swan, and crane sightings from the right front seat and there was no rear seat observer. We now have twenty-five years of counts on duck species. Observations on other waterbird species were added with jaegers recorded in 1989, and 1993 to 2013, loons counted beginning in 1989, and gulls and terns added in 1992.

Due to a variety of circumstances data discrepancies have occurred, but none have greatly altered the observations or data analysis on over 100 transects (not subdivided by strata) flown each year. In 1997, the back seat observer was unable to collect data on 13 transects north of the Askinuk Mountains, therefore, we duplicated the data from the 1996 survey for those transects. Twenty-three transects were not flown in 1999 causing population indices to be calculated with fewer transects in some strata. Because the survey is generally flown without covering every adjacent transect in sequence (some transects were skipped early in the survey and flown later to geographically spread the survey observation effort over time), the completed transects still sampled each stratum at systematic intervals and provided adequate data for analysis. 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, transect numbers 81 and 83 were inadvertently flown twice on different days and transects 82 and 84 were skipped. We included both replicates in the data analysis. In 2007, data were lost for transect 2, most of 15, and some of 16 due to computer malfunction. 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. In 2012, 4 transects (82, 96, 97, and 98) were truncated on the west ends from 0.3 – 1.6 miles due to fog along the coast. In 2013 several transects were not flown due to limited hours on the aircraft and logistics (transects 55, 59, 63, 72, 87, 100, 102-105, 107, and 109). The observer also lost data for Transect 56 and a small portion of the east end of Transect 67 due to computer problems.

The survey has been flown 1988 to 2013 (except no duck survey in 2011) within a maximum range of dates from 29 May to 24 June. The average annual dates ranged from 2 June to 16 June. The goal for timing the survey was to coincide with laying and early incubation of nesting geese because geese are the primary focus of the survey. Informal observations of nesting phenology obtained from biologists already at field camps were used to time the survey. Prior to 1993, the average survey date was 10 June or later, and surveys were of slightly longer duration, however in those years the timing of nesting was later as well. We considered that consistent survey timing relative to nesting would reduce variation in visibility rate linked to normal shifts in nesting behaviors such as constancy of nest attendance, departure of males in some species, and the flocking and departure of failed breeders. In 2010, we set an objective for beginning the survey each year at about 9 days after average clutch initiation for cackling geese, corresponding to survey timing in 2007-2009.

We examined ways to predict average clutch initiation date for cackling geese because nesting data from the present year are not available until after the aerial survey is completed. A nesting survey has been conducted each spring on a portion of the central coastal zone since 1982 (Fischer et al. 2013). Clutch initiation date has been determined each year by backdating from the stage of incubation indicated by egg floatation angle, adding a laying period equal to clutch size minus one, and averaging all nests found on plots searched by ground crews. The 1993-2011, 19-year average cackling goose clutch initiation date was 24 May (SD=+-4.1 days). This date would correspond to a start for the aerial survey on 2 June, nine days later.

However, the weather conditions in the current year also affect nesting phenology. We downloaded from the Weather Underground web site (http://www.wunderground.com/) all years of available Meteorological Terminal Air Report (METAR) temperature data for Bethel, Cape Romanzof, Emmonak, Hooper Bay, Mekoryuk, and St Marys. We found a good correlation between clutch initiation date and day-of-year (DOY = Julian date) when warming temperatures measured by thaw-degree-days (TDD) reached 25. Thaw-degree-days are the daily accumulation of degrees of daily mean temperature above 32F. The average anomaly, defined as the departure in days from the 1993-2012 average date at TDD >25, was calculated for 6 weather stations (Fig. 3) and showed a high correlation ($r = 0.77$) with clutch initiation date. In 2013, the 6-station average anomaly for TDD warming was -

0.90 days, later than the average date over all years and predicted clutch initiation was DOY = 149, May 29. The predicted survey start date was around 7 June. We began the survey on 8 June.

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).

Data Analysis

With unequal length transect units sampling each strata, we used a ratio estimator (Cochran 1977) to calculate the mean density of observations for each species. The stratum population index total (= density * stratum area) and variance were added across all 18 strata. Duck population indices were based on indicated total birds, 2 * (nsg + npr) + bflk, where nsg = number of single birds, npr = number of pairs, and bflk = number of birds in flocks. A flock was defined as a group of 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. For these species the aerial population index was the total birds sighted, nsg + 2*npr + bflk.

We plotted the species population index for each year as a column shaded to indicate single, indicated single, pair, and flock components. The standard error of the total population divided by the total was the coefficient of variation (CV). The average of all annual CVs provided a measure of survey precision. For nearly all species, the data analysis with 18 strata had a smaller CV compared to analysis using the minimum of only four sampling intensity strata.

Log-linear least squares regression determined the average slope of annual population indices across years. By exponentiation, we converted the log-linear slope to the rate of annual change or the population growth rate. Annual % change is the (growth rate-1)*100. The estimated standard error of growth rate is the residual mean square error in the log scale multiplied by the growth rate (Taylor series approximation, see Bart et al. 1998).

The residuals around the log-linear regression line provided another estimate related to the precision of the survey. The CV of the residuals after regression included components of both the regression model lack-of-fit error and the sampling error, and it was usually larger than the estimated sampling error CV based only on variation among transects within strata. We calculated a standardized measure of power to detect trend for each species using the approximate formula of Gerrodette (1987) that links sample size, slope, CV, and probabilities for Type 1 and Type 2 errors. The number of years needed to detect a slope significantly different from zero was calculated for each species. Under standard conditions (alpha set at 0.10, beta at 0.20, population change with a slope of 0.0341 equating to 50% change in 20 years), the expected number of data years necessary to show a significant slope provided a useful way to compare species. Each species had estimates using both observed sampling error CV and regression residual error CV. We also calculated the growth rates for each species using only the last 10 years of data.

RESULTS

Spring phenology and survey conditions

The Yukon Delta coast was colder than normal with ice and snow lingering in many locations during the spring of 2013. The predicted average Cackling goose clutch initiation date of 29 May based on thaw-degree-days was about 3 days earlier than 2 June, the date based on the 2013 nest plot data. Thus the aerial survey start should have been around 11 June to be consistent with previous years survey timing. This indicated that the 8 June aerial survey start date was a few days early relative to previous years timing and probably had little effect on population indices.

The 2013 survey transects (Fig. 2) were flown on a total of 6 survey days from June 8 to June 13. Weather conditions recorded during the 2013 survey at the village of Chevak, centered in the survey area, are given in Figure 4.

Satellite imagery indicated 2013 snowmelt began around the third week of May in part of the YKD and was not complete until about the first week of June along the coast (Fig. 5). The pattern of snowmelt progressed normally in a generally east to west direction from interior towards the coast. The date when the coastal zone became snow-free has varied by as much as 4 weeks (Fig. 6) based on 14 years of MODIS satellite data. The 2013 snowmelt was delayed compared to previous years but ended at a similar date.

Relative abundance and distribution

Number of birds sighted, the area observed, and the sampling effort in each strata provided the data to calculate total aerial population indices for each species. Indices for 2013, and where available, the visibility-corrected population estimates are tabulated (Table 1). The aerial population indices, with no correction for visibility bias, showed the relative contribution by group size category for all survey years (Figs. 7 to 25). Caution in interpretation is necessary for species with relatively low numbers of sightings such as canvasbacks and red-breasted mergansers because sampling error alone may cause the apparently large fluctuations in estimated population size. Additionally, logistical constraints in 2013 caused 12 transects to be unsampled possibly contributing to a slightly biased sample and thus an unknown effect on the population indices.

The spectacled eider population index of 6,808 indicated total birds for 2013 was the highest in the history of the survey. To convert the aerial indices 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). The spectacled eider population estimate of 24,373 birds was higher than the 2010 estimate and up 106% from the LTA. This estimate was calculated using a visibility correction factor of 3.58 which may be too large. If a new ratio of 2.35 is used, derived as twice the number of nests per indicated birds aerial index in the plot-sampled area of 716 km^2, the estimate would be 16,006 spectacled eiders. Pintails (186,986 birds), scaup (70,955), and green-winged teal (23,558) were the most numerous waterfowl species in 2013.

Estimates for spectacled eiders, common eiders, and black scoters were higher than the long-term averages (Table 2). Shovelers, long-tailed ducks, pintails, mallards, scaup, green-winged teal, red-breasted mergansers, and wigeon were below their LTAs. The northern shoveler population estimate was higher than 2012 but still substantially below the LTA. Sabine’s gulls, mew gulls, jaegers, Pacific loons, arctic terns, and glaucous gulls were above their LTAs whereas red-throated loons were below their LTA. However, the 2013 index for red-throated loons rebounded from the lowest in the history of the survey in 2012.

The geographic locations of over 145,000 sightings of 21 species of waterbirds have been collected in 25 years of surveys. Average location accuracy of the observations when the surveys were flown using LORAN for navigation was estimated as 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 are incorporated into a GIS database for potential use in research or management.

Population trends

Only American wigeon, canvasback, and jaegers showed consistent strong decreasing trends (Figs. 12, 16, and 21 and Table 3) over all years of the survey, however, this is mostly due to relatively few observations with varying group sizes. Increasing trends occurred for spectacled eider, common eider, greater scaup, red-breasted merganser, mew gull, Sabine’s gull, and arctic tern. Trends were significantly increasing over the last 10 years for spectacled eider, mew gull, Sabine’s gull, and arctic tern. Red-throated loon northern shoveler, greater scaup, long-tailed duck, black scoter, 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.

For spectacled eiders, the population growth rate from 1988 to 2012 for the aerial indicated total bird index was 1.068 (Fig. 7) The 2004-2013 growth rate of 1.079 was over 3 times higher than the nest population growth rate of 1.025 from the ground studies 2004-2013 (Fischer and Stehn 2013). However the overlap in the 90% confidence intervals for these estimated growth rates indicated no real difference.

DISCUSSION

Three different observers have collected data for this survey, although the same observer has collected 22 years of data. All observers were experienced at identifying and counting birds from aircraft, however especially for the less common species, a "learning curve" effect is likely 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 account for the relatively lower counts in the first years of this survey, however, because a single observer completed 22 years of surveys, 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 multi-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 back-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-back seat observer was 68%. 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.

Timing of snowmelt and warming temperatures can affect the breeding chronology of waterfowl (Batt et al. 1992) and this variation, in combination with differences in survey timing, may influence observed population indices. Different stages of nesting may correlate with changes in the flocking behavior, single:pair ratio, and tendency to hide or flush from the aircraft. To get the best population trend information, surveys should be timed consistently relative to nesting chronology. The intended survey timing was within the first half of incubation for nesting geese. Better prediction of nesting chronology by using the correlation with warming temperatures will help standardize timing, although 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 eider, the more visible male eiders depart from the breeding grounds returning to marine foraging habitat shortly after hens begin incubation. Depending on survey timing, a variable portion of the males may have already departed and thus are not available for observation. Late survey timing is expected to lower the population index for eiders. An example of possible timing effect occurred when both spring chronology and nesting were very early in 2004 yet the survey was flown close to average timing, possibly causing the eider index to be lower. Conversely, in 2006, the survey was flown earlier relative to average hatch date and this may have caused a larger population index for eiders that year. Earlier reports analyze and discuss these influences (Platte et al. 1999, Stehn et al. 2006). In this report, we include additional data on survey timing and nesting chronology, however further analysis remains necessary to best account for the confounding between timing, nesting, index ratios, and other changes in detection rate that may contribute to bias in trend from aerial population indices. When completed, this work will be reported separately. Similarly, further details and exploration of relationships among various measures of spring warming and timing of nest initiation, snowmelt, and river breakup will be presented in a separate report.

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 to expand the nest population to the entire YKD coast. The combined data provide unique and detailed information at two scales of geographic extent and intensity of coverage. Both are better than either one alone for monitoring the spectacled eider and other populations.

The aerial survey also provides information on many other species of interest, although caution in generalization is needed 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 had low sampling fractions and these species occur even further inland where we did not sample at all. For better information on seaduck species, we could expand coverage and add transects in inland areas. Because we base the survey aircraft from Bethel, much of this area must be crossed 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 would cause only a minimal decrease in precision for geese and eiders.

The geographic point locations of birds collected over the 25 years of this survey have been used for a number of purposes. Interpolated density polygons have been developed for most species as one method to show species distribution. These can be used as baseline to detect future changes in distribution due to such factors as alteration of habitat, disturbance, or climate change. Distribution information was essential in evaluation of YKD coastal zone areas for delineation as critical habitat for spectacled eiders. Relative density distribution maps have been used to illustrate and evaluate patterns of land ownership and impacts of potential land exchanges. 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.

Although originally justified and designed just to monitor geese, this survey has expanded to a multi-species effort to collect accurate data on distribution, trend, and abundance for all large waterbird species. This broader ecological or community-based approach not only provides information on these other species but it also provides essential data for understanding the population dynamics of geese. For example, depredation on goose nests and broods has been related to Glaucous gull population size and distribution. The multi-species data collection approach proactively provided five years of population data on spectacled eider even before there was direct support or recognition of the need to monitor eiders. This survey provides continuing annual data for USFWS focal species and species of special concern including common eider, black brant, emperor geese, black scoter, long-tailed duck, and red-throated loon.

The extensive coverage with the aerial transect survey allows an objective procedure for expansion of the ground-based sampling by nest plots. Conversely, the data from the more intensive plot sampling contributes to understanding the aerial observation process. We calculated index ratios between the aerial indices and the population of nests and evaluated confounding factors such as survey timing, observer experience, visibility rate, availability, nesting success, and nesting chronology. Although it was feasible to collect sufficient data on such factors for only certain species, these variables may influence all species and appropriate adjustments will improve the monitoring process.

A good example of linking aerial and ground sampling is the ongoing work on black brant that has used plot estimates of nesting density to validate that the aerial index accurately monitors nesting brant, indicates a shifting distribution of nesting birds, and shows stability in total number of brant nests (Stehn et al. 2011). Multi-species, multi-scale, designed sampling surveys also provide unique and important data essential to detect and quantify population level responses among species. For example, such data are needed to establish if Cackling geese are a buffer prey species key to increasing nest success for spectacled eider, common eider, and other ducks, or if numbers of cackling geese are beneficial to goslings in emperor geese and brant perhaps due to expansion of grazing-lawn habitat. Extensive, long-term, multi-species surveys provide the data to link population change to variation in species habitat, a key precursor for landscape-level conservation practices and management to preserve species abundance and diversity. The North American Waterfowl Breeding Pair and Habitat Survey also has some similar attributes and objectives, but it is designed for duck species and flyway-scale harvest management. As such, it does not need high statistical precision in both aerial and ground estimates, it does not directly estimate nests, and therefore cannot hope to resolve such issues as are mentioned above. To our knowledge, the YKD survey initiated in 1985 for geese, has grown to provide the longest duration, most precise, multi-species, multi-scale monitoring survey for nesting waterfowl and other waterbirds in North America.

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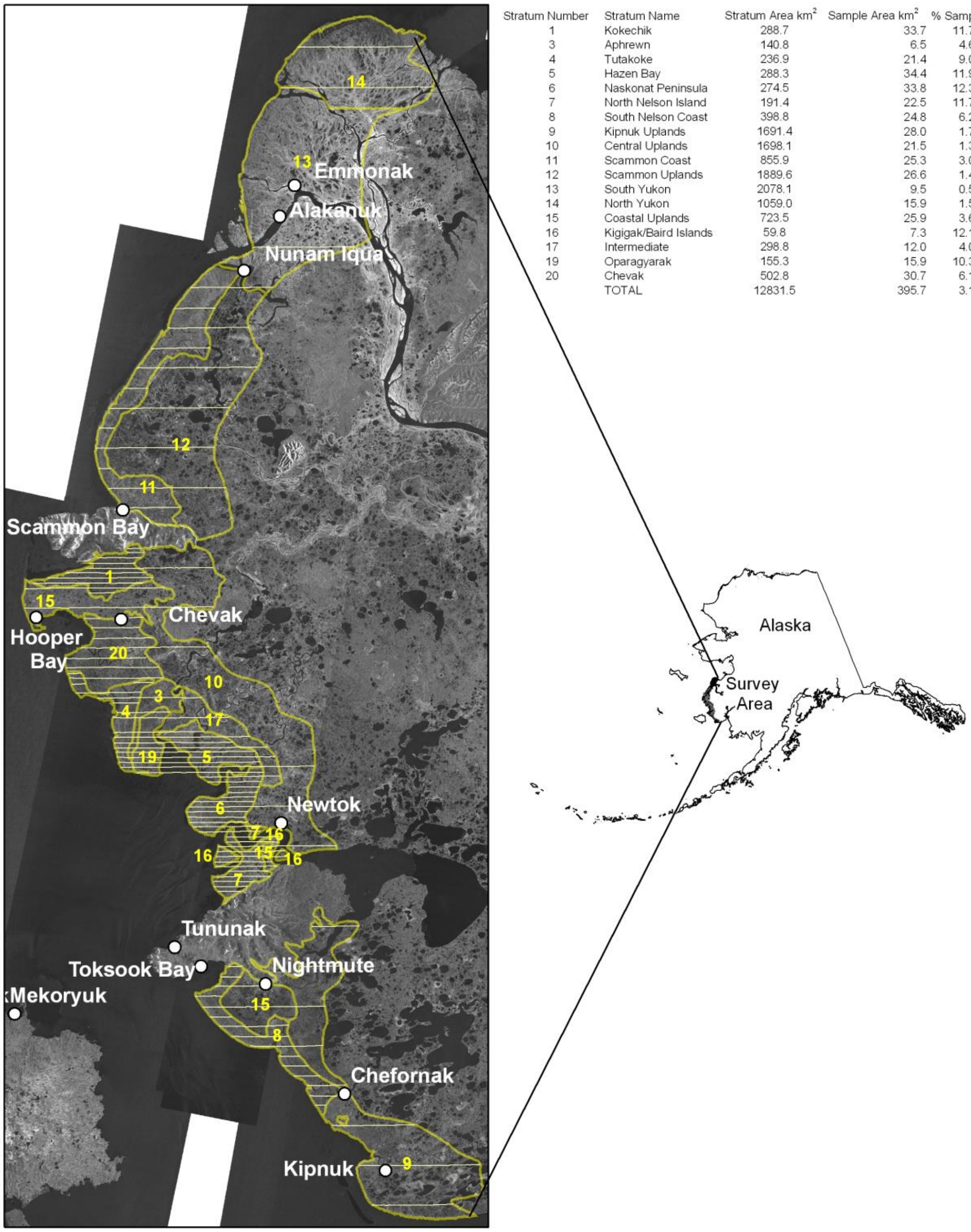


Stratum Number	Stratum Name	Stratum Area km^2	Sample Area km^2	% Sample
1	Kokechik	288.7	33.7	11.7%
3	Aphrewn	140.8	6.5	4.6%
4	Tutakoke	236.9	21.4	9.0%
5	Hazen Bay	288.3	34.4	11.9%
6	Naskonat Peninsula	274.5	33.8	12.3%
7	North Nelson Island	191.4	22.5	11.7%
8	South Nelson Coast	398.8	24.8	6.2%
9	Kipnuk Uplands	1691.4	28.0	1.7%
10	Central Uplands	1698.1	21.5	1.3%
11	Scammon Coast	855.9	25.3	3.0%
12	Scammon Uplands	1889.6	26.6	1.4%
13	South Yukon	2078.1	9.5	0.5%
14	North Yukon	1059.0	15.9	1.5%
15	Coastal Uplands	723.5	25.9	3.6%
16	Kigigak/Baird Islands	59.8	7.3	12.1%
17	Intermediate	298.8	12.0	4.0%
19	Oparagyarak	155.3	15.9	10.3%
20	Chevak	502.8	30.7	6.1%
	TOTAL	12831.5	395.7	3.1%

Figure 1. Transects and strata for aerial waterbird survey, June 8-13, 2013, 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. Due to logistical constraints, not all transects were flown in 2013.

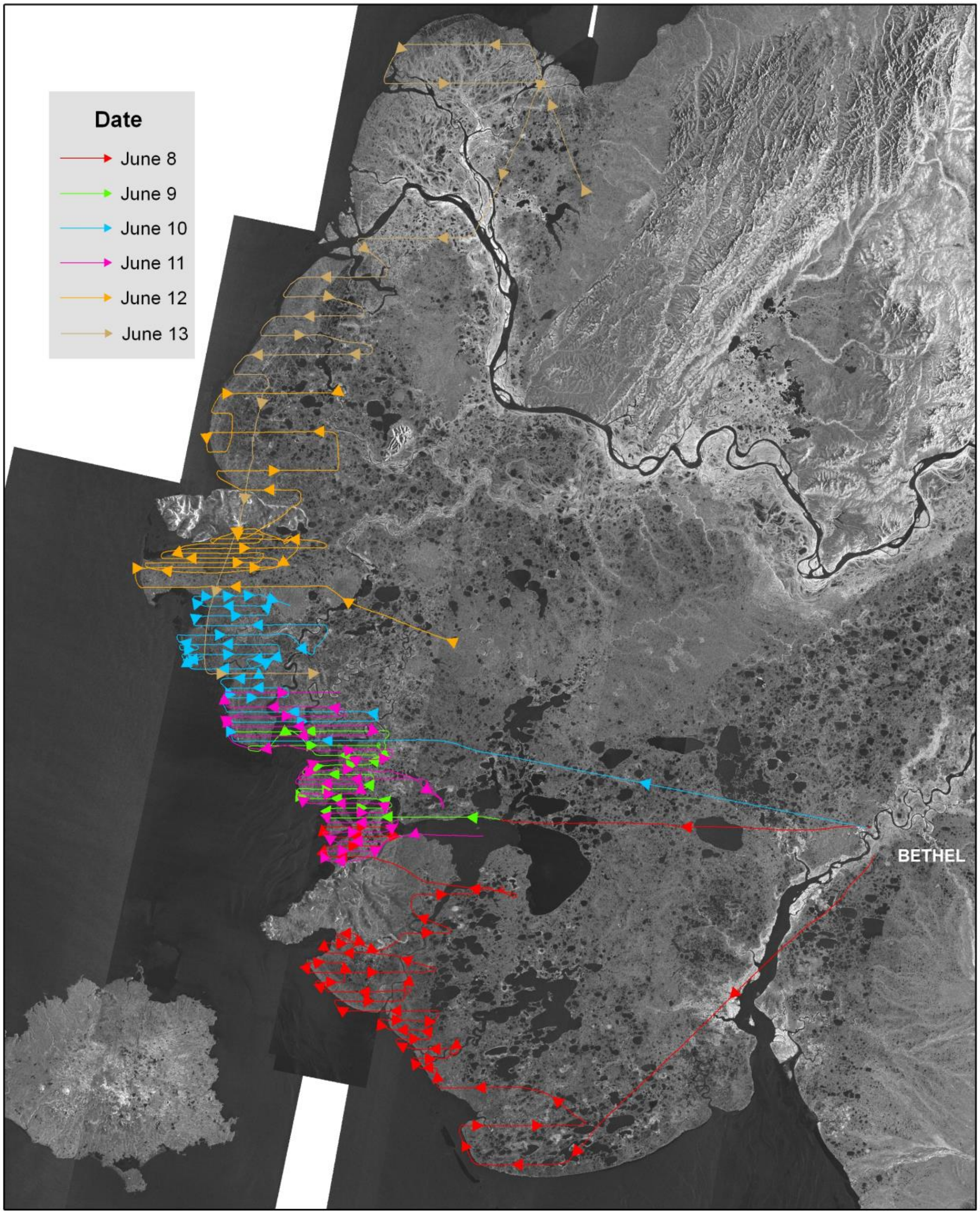


Figure 2. Transects color-coded by date flown in 2013 showing progression of survey by date. We skip every other transect in the 1-mile strata so as not to double-count flushing birds and to spread the sample temporally.

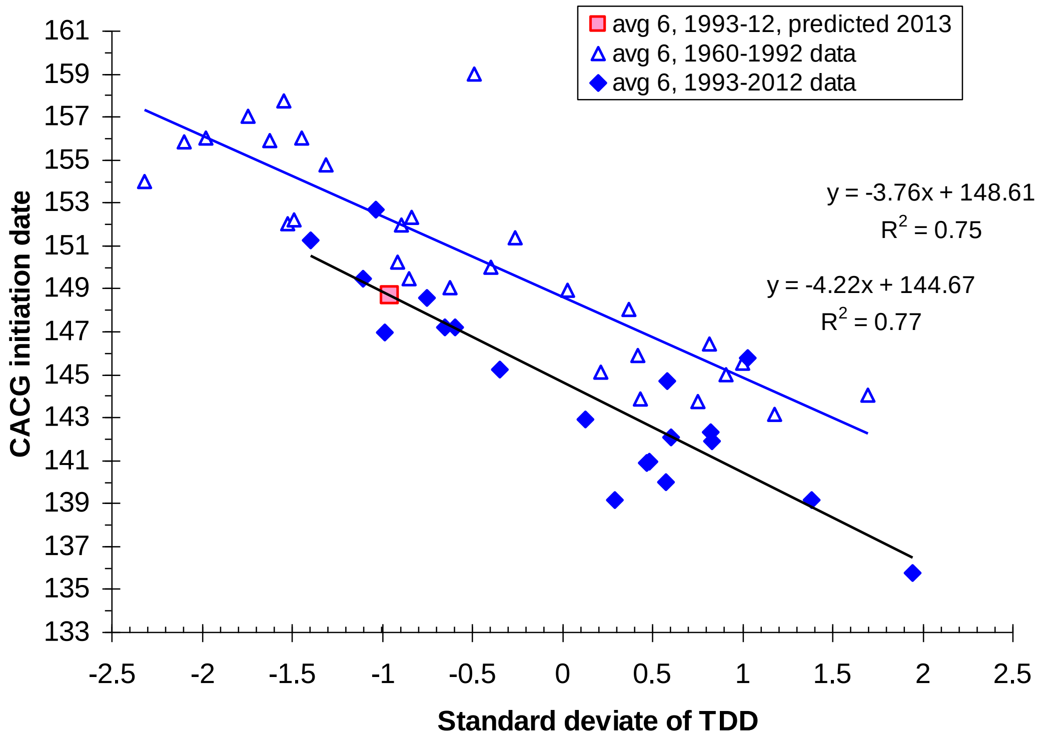


Figure 3. 2013 predicted cackling goose average clutch initiation date based on the linear regression relationship of the standard deviates from 6-station average date at thaw-degree-days>25 criterion. Analysis conducted on June 3, 2013 and predicted initiation on 29 May.

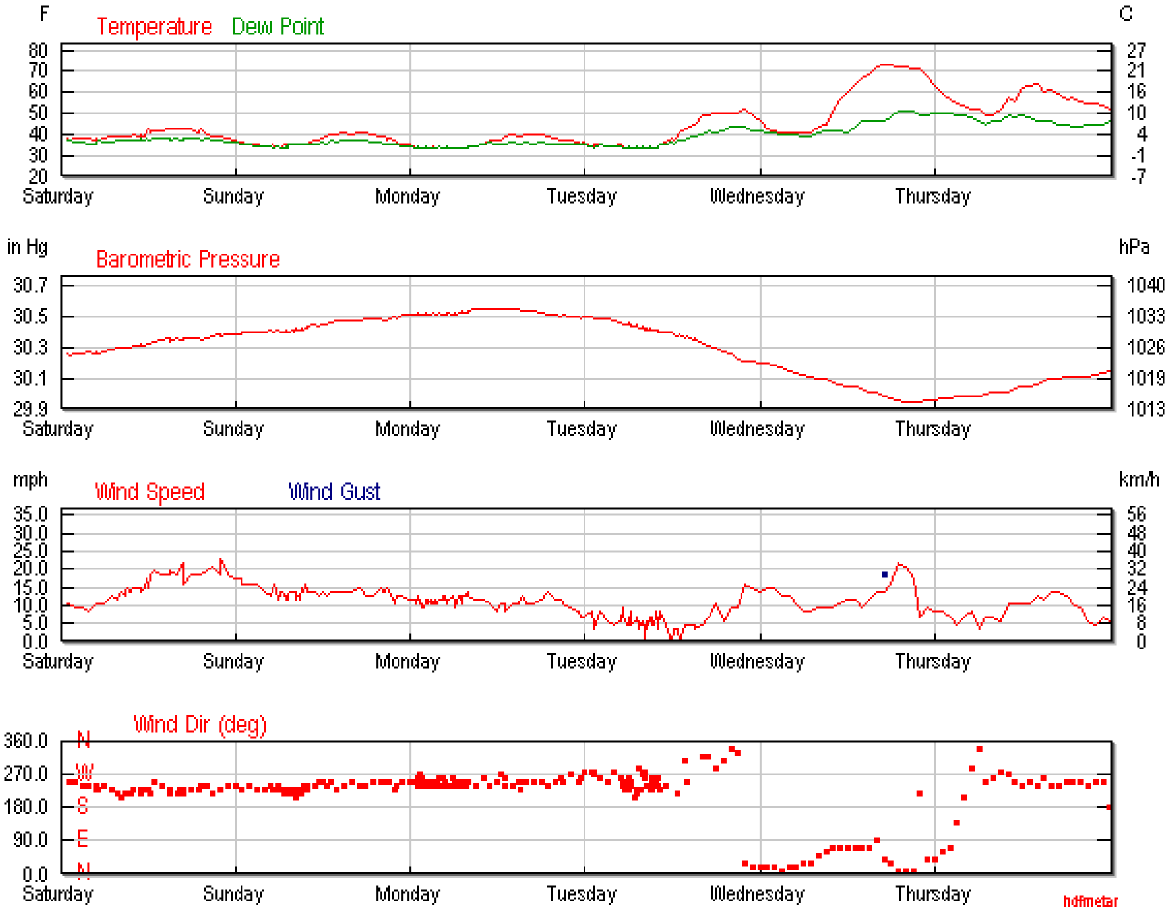


Figure 4. Weather data during the aerial survey, June 8-13, 2013 from Chevak in the central coastal zone (from http://www.wunderground.com/history/airport/PAVA/2013/6/10/CustomHistory.html).

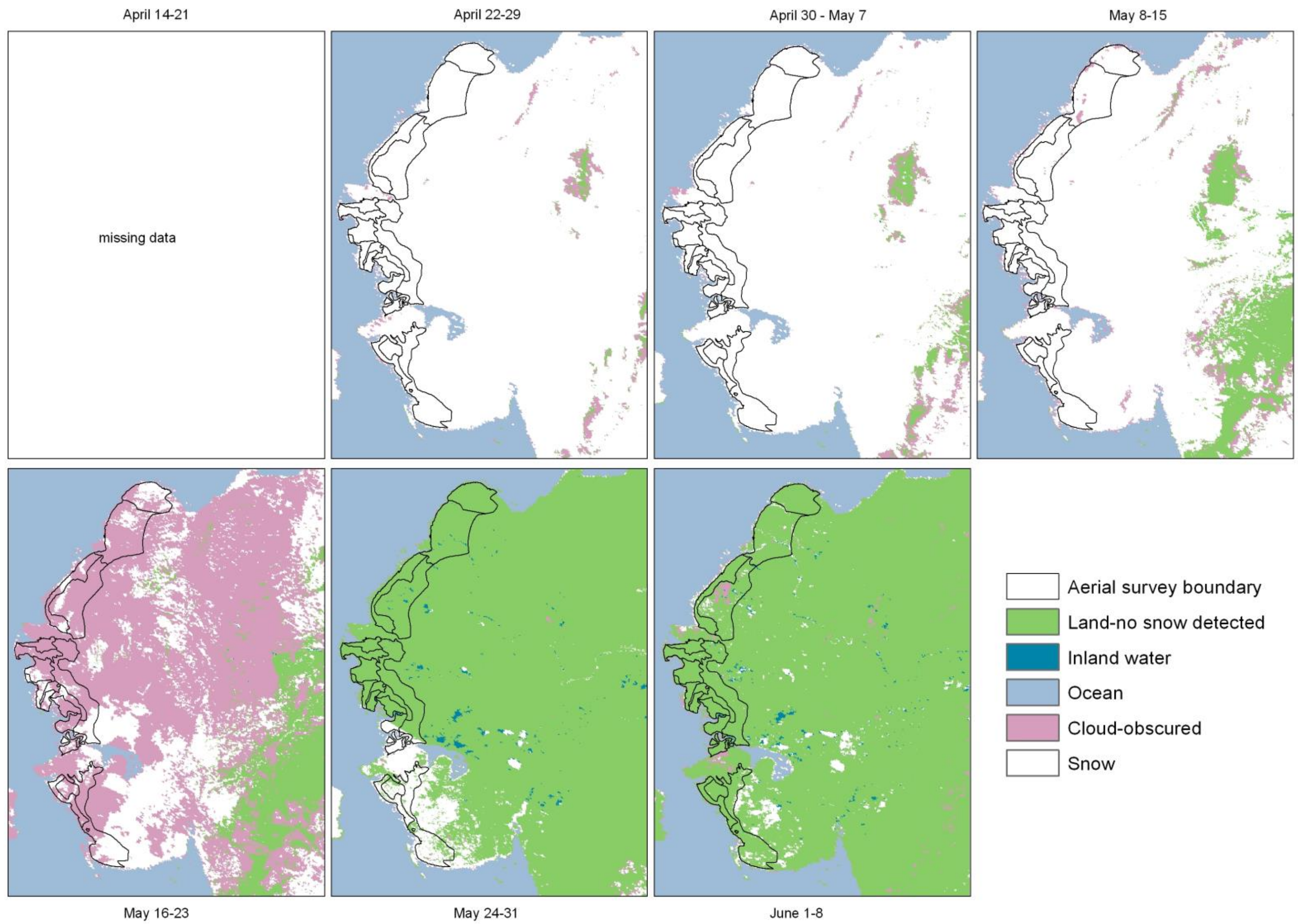


Figure 5. Snow melt chronology from Terra staellite MODIS 8-day composite maximum snow extent, 2013, Yukon Delta National Wildlife Refuge, Alaska. Data from Hall, D.K., G.A. Riggs, and V.V. Salomonson. 2013, updated daily. MODIS/Terra Snow Cover Daily L3 Global 500m Grid V005, April to June 2013. Boulder, CO, USA: National Snow and Ice Data Center. Digital media

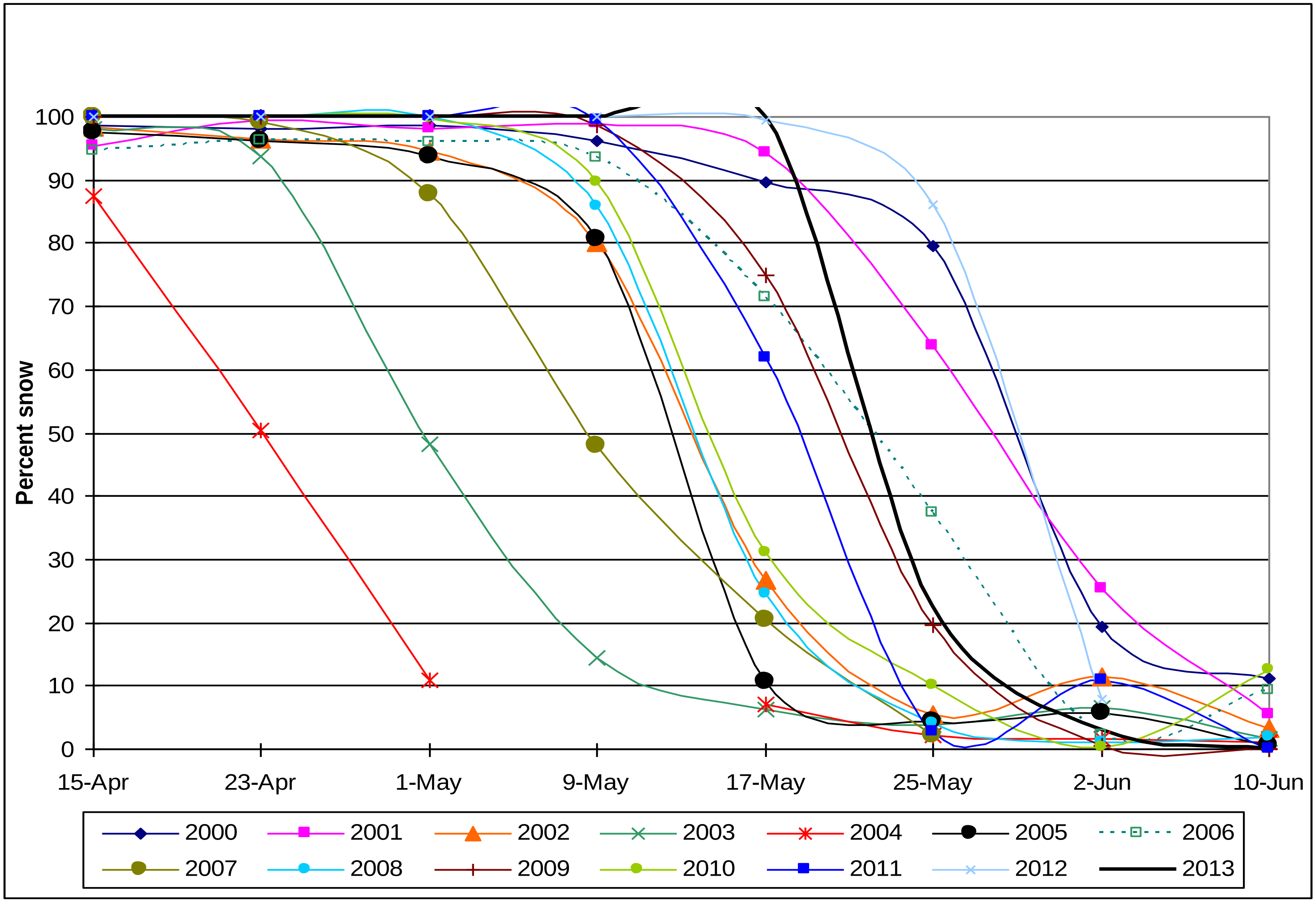
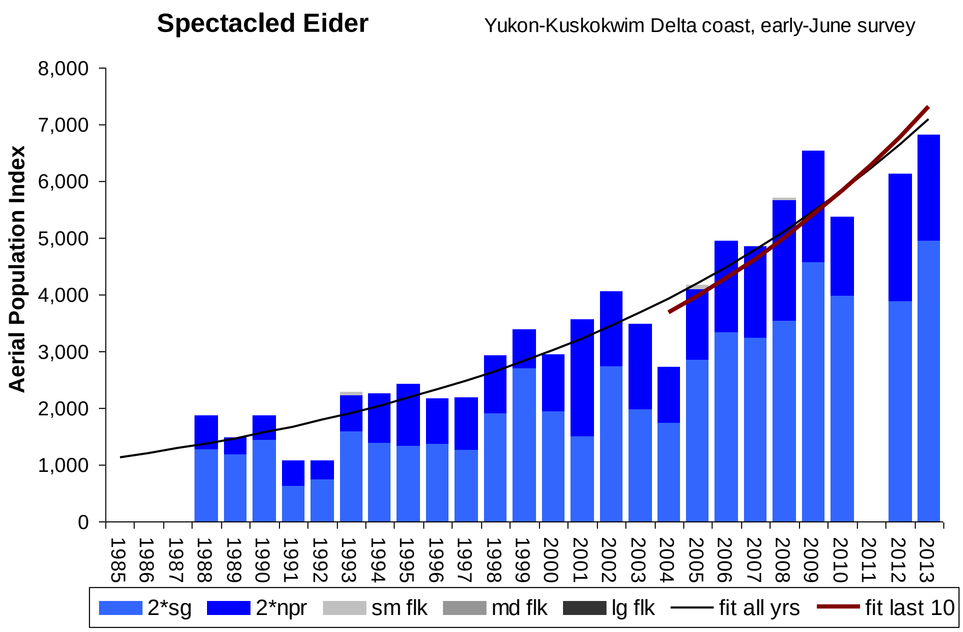


Figure 6. Percent snow cover for coastal zone survey area in spring from MODIS imagery (Hall et al. 2013) .



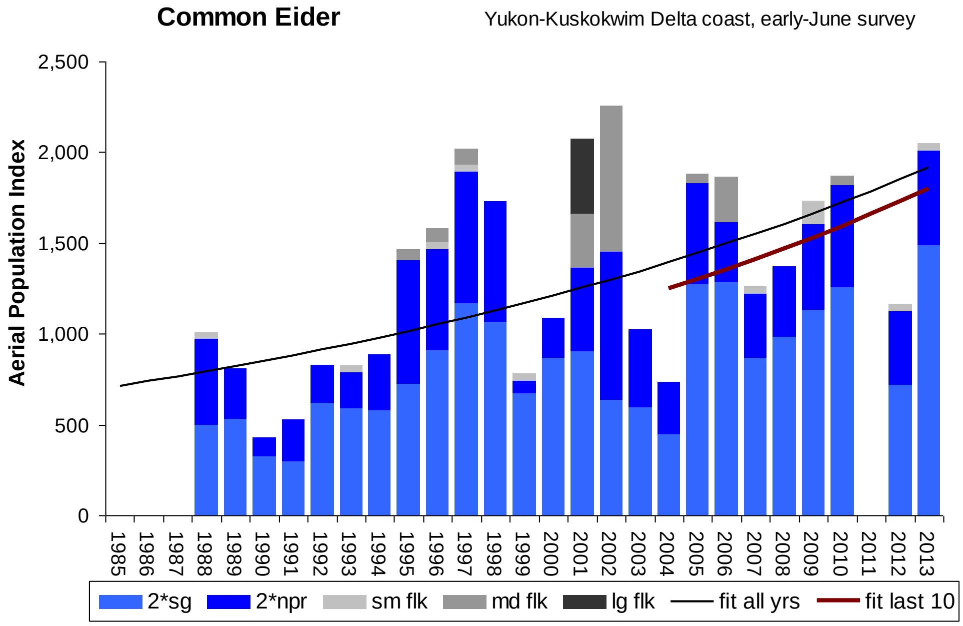
18 strata = 12,832 km² **Aerial index = Indicated Total birds**

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
2009	4568	1969	0	0	0	**6537**	527
2010	3976	1386	0	0	0	**5362**	527
2011							
2012	3892	2246	0	0	0	**6138**	504
2013	4936	1872	0	0	0	**6808**	576

obsvr= **right rear**

Aerial index: Indicated total	
n yrs =	25
average index =	**3452**
std dev =	1710
std error =	342
low 90%ci =	2889
high 90%ci =	4014
avg index last 10 yrs=	**5250**
std dev last 10 yrs=	1269
trend over all years :	
ln linear slope =	0.0657
SE ln slope =	0.0055
Growth Rate =	**1.068**
low 90%ci GR =	1.058
high 90%ci GR =	1.078
trend last 10 years :	
Growth Rate =	**1.079**
low 90%ci GR =	1.046
high 90%ci GR =	1.114
min yrs to detect -50%/20yr rate :	
regression resid CV =	0.203
avg sampling err CV =	0.127
w/ regression resid CV =	13.8
w/ sample error CV =	10.1

Figure 7. Population trend for Spectacled Eiders (*Somateria fischeri*) observed on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta. The indicated total aerial 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 or more. Average annual growth rate was calculated by log-linear regression. The power to detect a significant growth rate of -0.034, a 50% decline in 20 years, if it were to occur, used alpha set at *p*=0.10, beta set at *p*=0.20, and a coefficient of variation based on regression residuals or average annual sampling error.



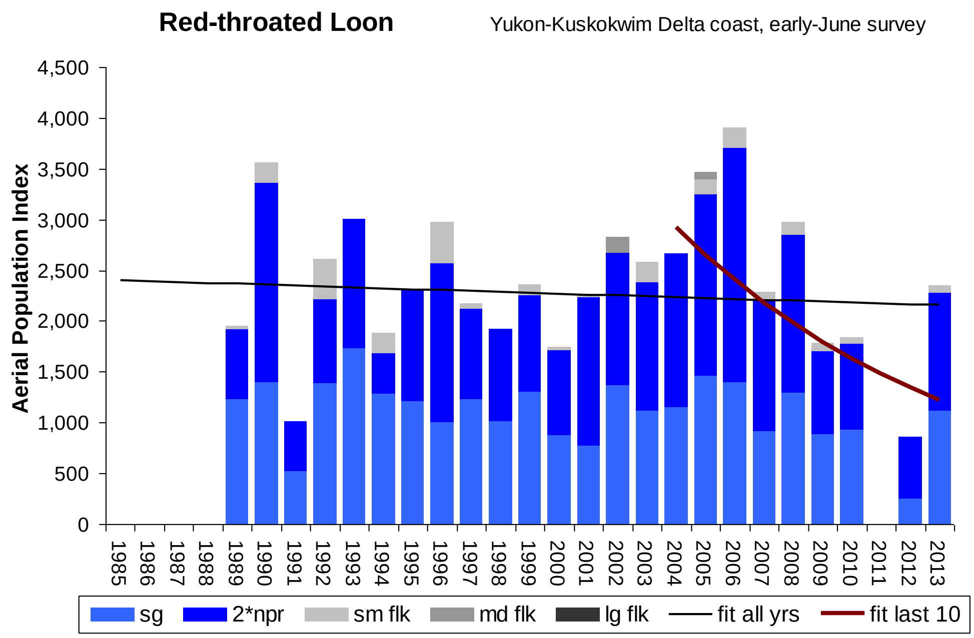
18 strata = 12,832 km² **Aerial index = Indicated Total birds**

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
2009	1131	474	122	0	0	**1728**	275
2010	1255	564	0	50	0	**1869**	464
2011							
2012	719	406	41	0	0	**1166**	211
2013	1485	524	43	0	0	**2051**	340

obsvr= **right rear**

Aerial index: Indicated total	
n yrs =	25
average index =	**1330**
std dev =	542
std error =	108
low 90%ci =	1152
high 90%ci =	1508
avg index last 10 yrs=	**1547**
std dev last 10 yrs=	435
trend over all years :	
ln linear slope =	0.0353
SE ln slope =	0.0103
Growth Rate =	**1.036**
low 90%ci GR =	1.018
high 90%ci GR =	1.054
trend last 10 years :	
Growth Rate =	**1.042**
low 90%ci GR =	0.979
high 90%ci GR =	1.108
min yrs to detect -50%/20yr rate :	
regression resid CV =	0.380
avg sampling err CV =	0.232
w/ regression resid CV =	20.9
w/ sample error CV =	15.0

Figure 8. Population trend for Common Eiders (*Somateria mollissima*) observed on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta. The indicated total aerial 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 or more. Average annual growth rate was calculated by log-linear regression. The power to detect a significant growth rate of -0.034, a 50% decline in 20 years, if it were to occur, used alpha set at p=0.10, beta set at p=0.20, and a coefficient of variation based on regression residuals or average annual sampling error.

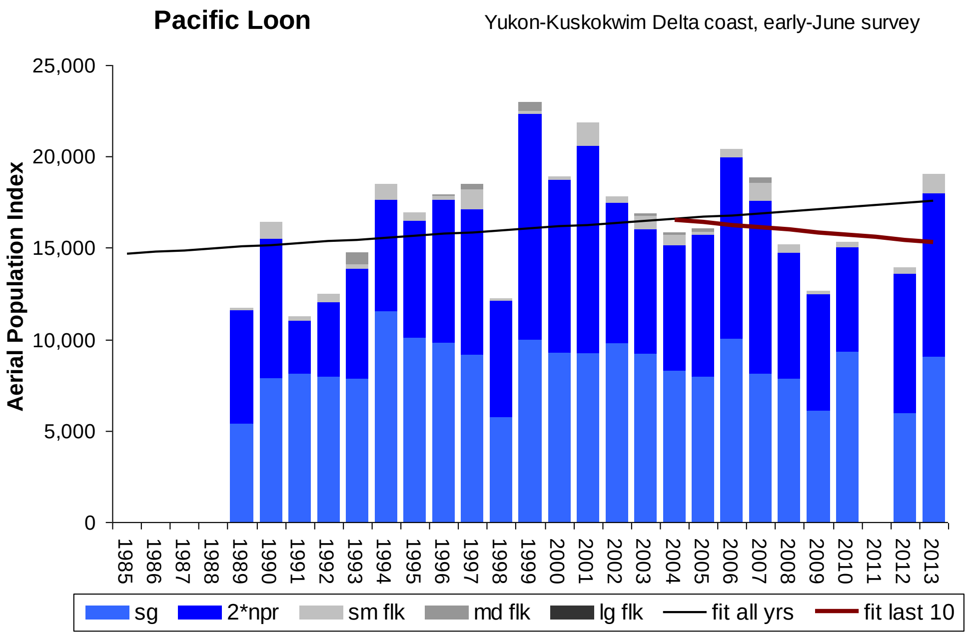


18 strata = 12,832 km² **Aerial index = Total birds** obsvr= **right rear**

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
2009	888	818	79	0	0	**1785**	247
2010	931	842	67	0	0	**1839**	260
2011							
2012	250	609	0	0	0	**860**	211
2013	1113	1162	76	0	0	**2352**	523

Aerial index: total birds	
n yrs =	24
average index =	**2386**
std dev =	732
std error =	149
low 90%ci =	2140
high 90%ci =	2632
avg index last 10 yrs=	**2458**
std dev last 10 yrs=	925
trend over all years :	
ln linear slope =	#####
SE ln slope =	0.0104
Growth Rate =	**0.996**
low 90%ci GR =	0.979
high 90%ci GR =	1.013
trend last 10 years :	
Growth Rate =	**0.907**
low 90%ci GR =	0.848
high 90%ci GR =	0.971
min yrs to detect -50%/20yr rate :	
regression resid CV =	0.360
avg sampling err CV =	0.166
w/ regression resid CV =	20.2
w/ sample error CV =	12.1

Figure 9. Population trend for Red-throated Loon (*Gavia stellata*) observed on aerial transects sampling 12,832 km^2 of the coastal Yukon-Kuskokwim Delta. The total aerial index is the sum of birds observed as singles, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31 or more. Average annual growth rate was calculated by log-linear regression. The power to detect a significant growth rate of -0.034, a 50% decline in 20 years, if it were to occur, used alpha set at *p*=0.10, beta set at *p*=0.20, and a coefficient of variation based on regression residuals or average annual sampling error.



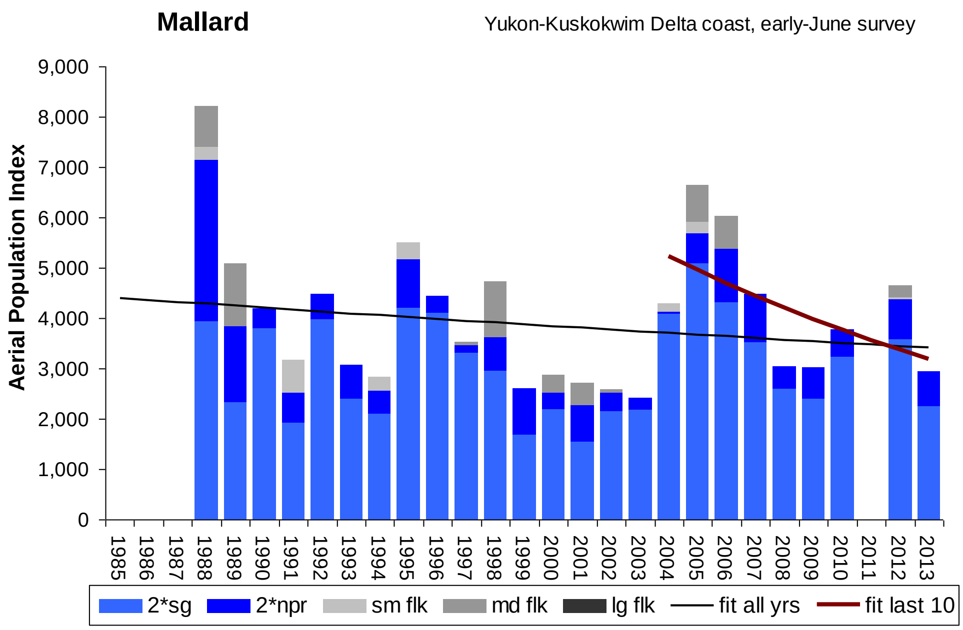
18 strata = 12,832 km² **Aerial index = Total birds**

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
2009	6107	6371	142	0	0	**12620**	939
2010	9364	5642	280	0	0	**15286**	1317
2011							
2012	5954	7600	392	0	0	**13946**	1311
2013	9026	8980	1037	0	0	**19043**	1609

obsvr= **right rear**

Aerial index: total birds	
n yrs =	24
average index =	**16513**
std dev =	3152
std error =	643
low 90%ci =	15455
high 90%ci =	17571
avg index last 10 yrs=	**16351**
std dev last 10 yrs=	2559
trend over all years :	
ln linear slope =	0.0064
SE ln slope =	0.0056
Growth Rate =	**1.006**
low 90%ci GR =	0.997
high 90%ci GR =	1.016
trend last 10 years :	
Growth Rate =	**0.992**
low 90%ci GR =	0.961
high 90%ci GR =	1.023
min yrs to detect -50%/20yr rate :	
regression resid CV =	0.194
avg sampling err CV =	0.089
w/ regression resid CV =	13.4
w/ sample error CV =	8.0

Figure 10. Population trend for Pacific Loon (*Gavia pacifica*) observed on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta. The total aerial index is the sum of birds observed as singles, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31 or more. Average annual growth rate was calculated by log-linear regression. The power to detect a significant growth rate of -0.034, a 50% decline in 20 years, if it were to occur, used alpha set at *p*=0.10, beta set at *p*=0.20, and a coefficient of variation based on regression residuals or average annual sampling error.



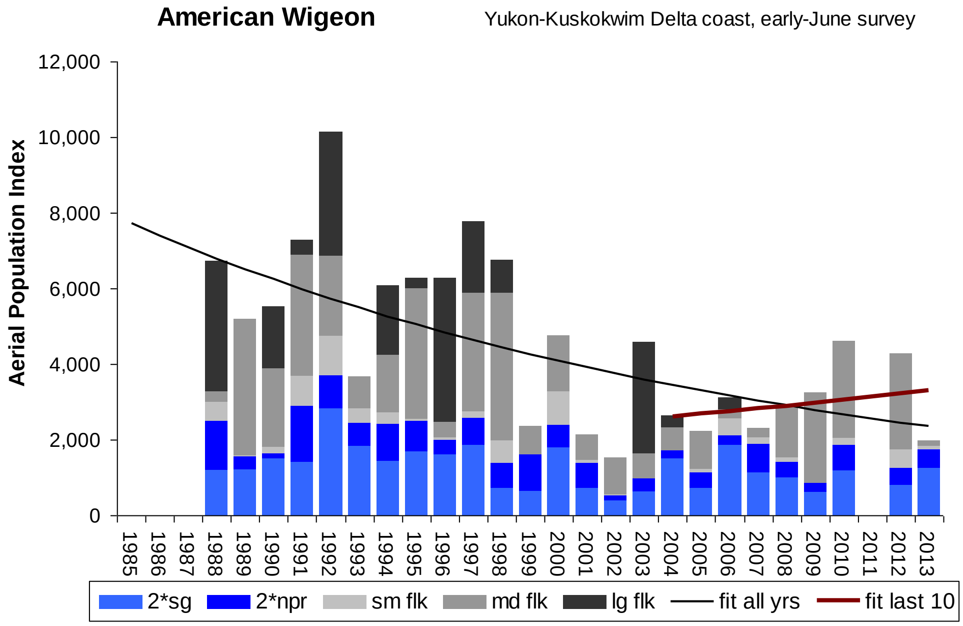
18 strata = 12,832 km² **Aerial index = Indicated Total birds**

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
2009	2386	641	0	0	0	**3028**	740
2010	3231	545	0	0	0	**3776**	688
2011							
2012	3592	780	41	231	0	**4644**	1073
2013	2257	674	0	0	0	**2931**	697

obsvr= **right rear**

Aerial index: Indicated total	
n yrs =	25
average index =	**4049**
std dev =	1435
std error =	287
low 90%ci =	3577
high 90%ci =	4521
avg index last 10 yrs=	**4317**
std dev last 10 yrs=	1319
trend over all years :	
ln linear slope =	-0.0091
SE ln slope =	0.0089
Growth Rate =	**0.991**
low 90%ci GR =	0.977
high 90%ci GR =	1.006
trend last 10 years :	
Growth Rate =	**0.946**
low 90%ci GR =	0.901
high 90%ci GR =	0.994
min yrs to detect -50%/20yr rate :	
regression resid CV =	0.326
avg sampling err CV =	0.218
w/ regression resid CV =	18.9
w/ sample error CV =	14.5

Figure 11. Population trend for Mallard (*Anas platyrhynchos*) observed on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta. The indicated total aerial 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 or more. Average annual growth rate was calculated by log-linear regression. The power to detect a significant growth rate of -0.034, a 50% decline in 20 years, if it were to occur, used alpha set at p=0.10, beta set at p=0.20, and a coefficient of variation based on regression residuals or average annual sampling error.



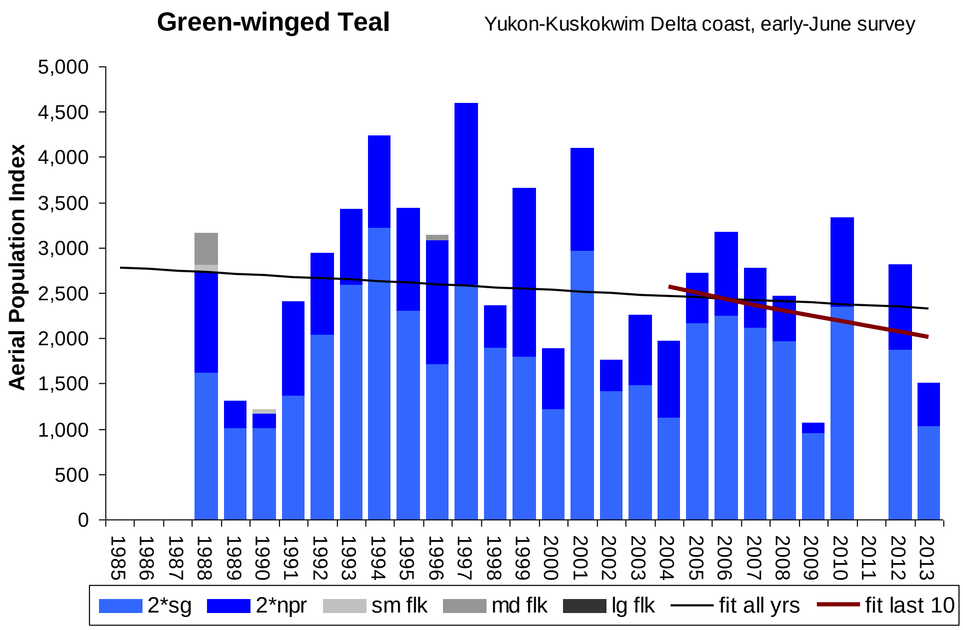
18 strata = 12,832 km² **Aerial index = Indicated Total birds**

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
2009	616	247	0	2375	0	**3238**	1124
2010	1203	650	190	2575	0	**4619**	1513
2011							
2012	814	440	495	2520	0	**4268**	1941
2013	1242	521	82	122	0	**1966**	508

obsvr= **right rear**

Aerial index: Indicated total	
n yrs =	25
average index =	**4573**
std dev =	2202
std error =	440
low 90%ci =	3849
high 90%ci =	5297
avg index last 10 yrs=	**3030**
std dev last 10 yrs=	907
trend over all years :	
ln linear slope =	-0.0424
SE ln slope =	0.0110
Growth Rate =	**0.958**
low 90%ci GR =	0.941
high 90%ci GR =	0.976
trend last 10 years :	
Growth Rate =	**1.026**
low 90%ci GR =	0.970
high 90%ci GR =	1.085
min yrs to detect -50%/20yr rate :	
regression resid CV =	0.403
avg sampling err CV =	0.364
w/ regression resid CV =	21.8
w/ sample error CV =	20.3

Figure 12. Population trend for American Wigeon (*Anas americana*) observed on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta. The indicated total aerial 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 or more. Average annual growth rate was calculated by log-linear regression. The power to detect a significant growth rate of -0.034, a 50% decline in 20 years, if it were to occur, used alpha set at p=0.10, beta set at p=0.20, and a coefficient of variation based on regression residuals or average annual sampling error.



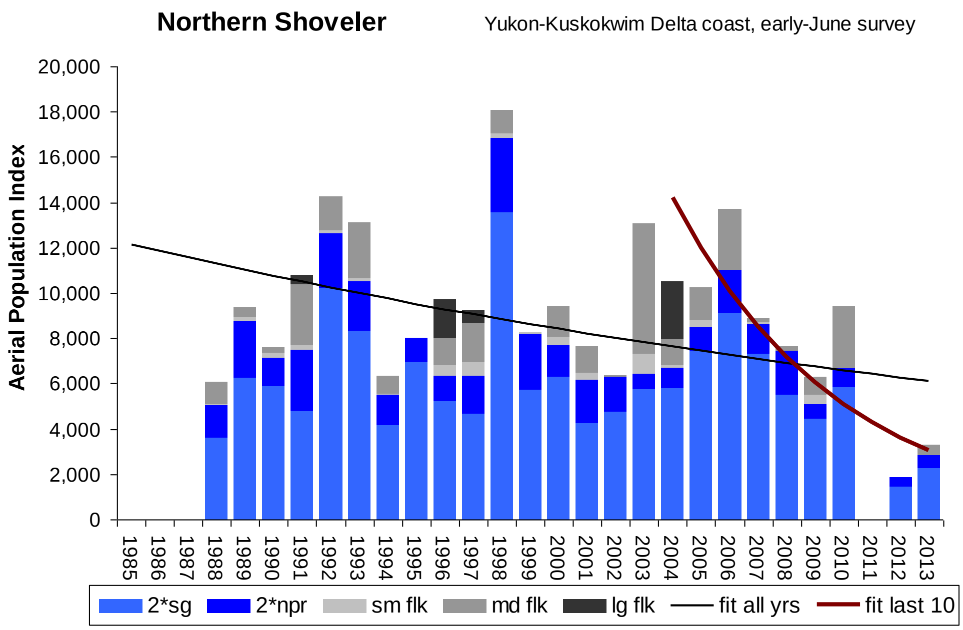
18 strata = 12,832 km² **Aerial index = Indicated Total birds**

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
2009	945	117	0	0	0	**1061**	287
2010	2353	975	0	0	0	**3328**	620
2011							
2012	1880	937	0	0	0	**2818**	686
2013	1025	480	0	0	0	**1505**	460

obsvr= **right rear**

Aerial index: Indicated total	
n yrs =	25
average index =	**2708**
std dev =	953
std error =	191
low 90%ci =	2395
high 90%ci =	3022
avg index last 10 yrs=	**2423**
std dev last 10 yrs=	763
trend over all years :	
ln linear slope =	-0.0063
SE ln slope =	0.0109
Growth Rate =	**0.994**
low 90%ci GR =	0.976
high 90%ci GR =	1.012
trend last 10 years :	
Growth Rate =	**0.973**
low 90%ci GR =	0.903
high 90%ci GR =	1.049
min yrs to detect -50%/20yr rate :	
regression resid CV =	0.401
avg sampling err CV =	0.229
w/ regression resid CV =	21.7
w/ sample error CV =	14.9

Figure 13. Population trend for Green-winged Teal (A*nas crecca*)observed on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta. The indicated total aerial 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 or more. Average annual growth rate was calculated by log-linear regression. The power to detect a significant growth rate of -0.034, a 50% decline in 20 years, if it were to occur, used alpha set at *p*=0.10, beta set at *p*=0.20, and a coefficient of variation based on regression residuals or average annual sampling error.



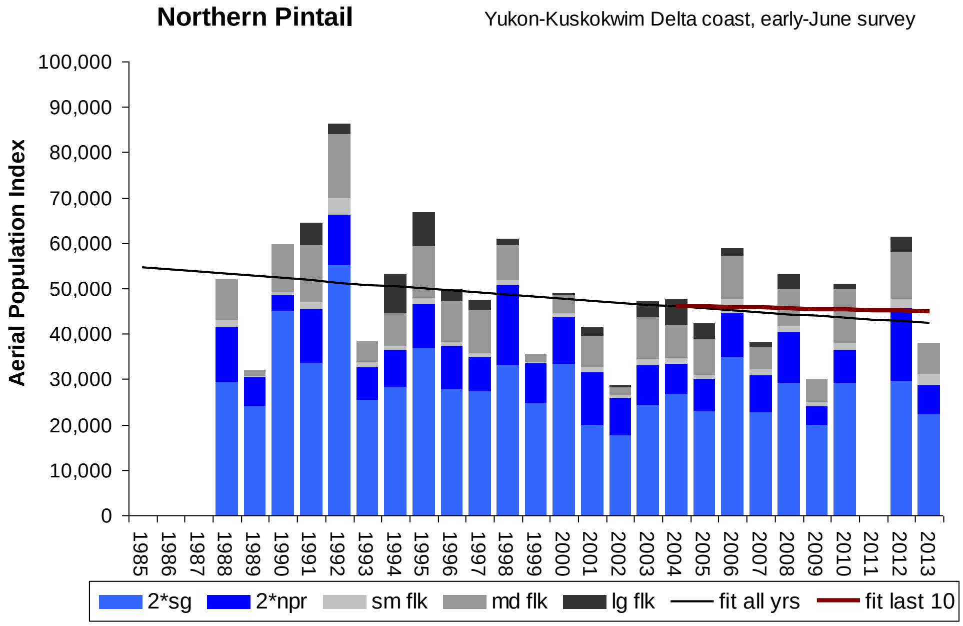
18 strata = 12,832 km² **Aerial index = Indicated Total birds**

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
2009	4421	675	433	747	0	**6277**	1032
2010	5814	856	0	2716	0	**9386**	1808
2011							
2012	1445	422	0	0	0	**1867**	495
2013	2259	565	0	466	0	**3289**	598

obsvr= **right rear**

Aerial index: Indicated total	
n yrs =	25
average index =	**9161**
std dev =	3497
std error =	699
low 90%ci =	8010
high 90%ci =	10311
avg index last 10 yrs=	**7976**
std dev last 10 yrs=	3700
trend over all years :	
ln linear slope =	-0.0245
SE ln slope =	0.0120
Growth Rate =	**0.976**
low 90%ci GR =	0.957
high 90%ci GR =	0.995
trend last 10 years :	
Growth Rate =	**0.843**
low 90%ci GR =	0.784
high 90%ci GR =	0.907
min yrs to detect -50%/20yr rate :	
regression resid CV =	0.439
avg sampling err CV =	0.180
w/ regression resid CV =	23.0
w/ sample error CV =	12.7

Figure 14. Population trend for Northern Shoveler (*Anas clypeata*) observed on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta. The indicated total aerial 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 or more. Average annual growth rate was calculated by log-linear regression. The power to detect a significant growth rate of -0.034, a 50% decline in 20 years, if it were to occur, used alpha set at p=0.10, beta set at p=0.20, and a coefficient of variation based on regression residuals or average annual sampling error.



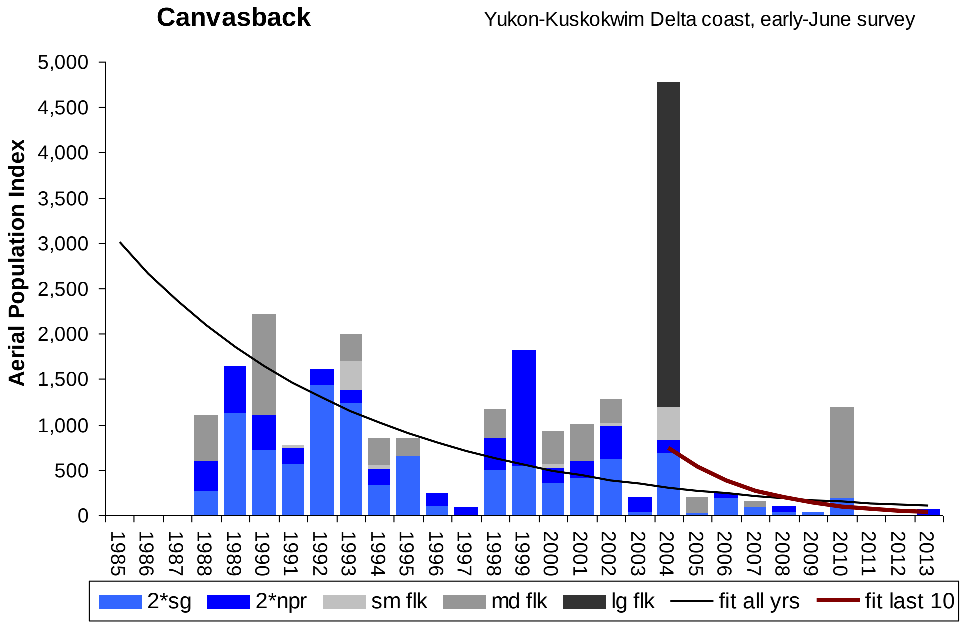
18 strata = 12,832 km² **Aerial index = Indicated Total birds**

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
2009	19829	4293	889	4838	0	**29849**	2901
2010	29079	7333	1484	11957	1029	**50880**	5962
2011							
2012	29526	16091	2158	10295	3237	**61307**	11225
2013	22184	6505	2311	6861	0	**37862**	3923

obsvr= **right rear**

Aerial index: Indicated total	
n yrs =	25
average index =	**49283**
std dev =	13215
std error =	2643
low 90%ci =	44935
high 90%ci =	53631
avg index last 10 yrs=	**46645**
std dev last 10 yrs=	10423
trend over all years :	
ln linear slope =	-0.0091
SE ln slope =	0.0072
Growth Rate =	**0.991**
low 90%ci GR =	0.979
high 90%ci GR =	1.003
trend last 10 years :	
Growth Rate =	**0.997**
low 90%ci GR =	0.951
high 90%ci GR =	1.045
min yrs to detect -50%/20yr rate :	
regression resid CV =	0.264
avg sampling err CV =	0.113
w/ regression resid CV =	16.4
w/ sample error CV =	9.3

Figure 15. Population trend for Northern Pintail (*Anas acuta*) observed on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta. The indicated total aerial 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 or more. Average annual growth rate was calculated by log-linear regression. The power to detect a significant growth rate of -0.034, a 50% decline in 20 years, if it were to occur, used alpha set at *p*=0.10, beta set at *p*=0.20, and a coefficient of variation based on regression residuals or average annual sampling error.



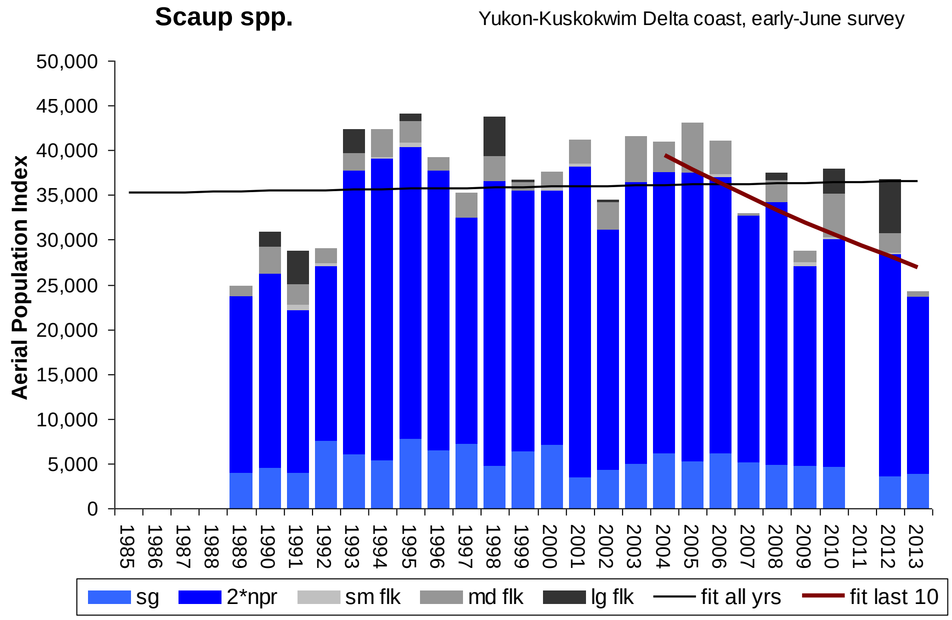
18 strata = 12,832 km² **Aerial index = Indicated Total birds**

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
2009	34	0	0	0	0	**34**	37
2010	187	0	0	1001	0	**1187**	966
2011							
2012	0	0	0	0	0	**20**	0
2013	0	68	0	0	0	**68**	68

obsvr= **right rear**

Aerial index: Indicated total	
n yrs =	25
average index =	**981**
std dev =	1039
std error =	208
low 90%ci =	639
high 90%ci =	1323
avg index last 10 yrs=	**752**
std dev last 10 yrs=	1550
trend over all years :	
ln linear slope =	-0.1208
SE ln slope =	0.0310
Growth Rate =	**0.886**
low 90%ci GR =	0.842
high 90%ci GR =	0.933
trend last 10 years :	
Growth Rate =	**0.714**
low 90%ci GR =	0.542
high 90%ci GR =	0.941
min yrs to detect -50%/20yr rate :	
regression resid CV =	1.142
avg sampling err CV =	0.594
w/ regression resid CV =	43.5
w/ sample error CV =	28.2

Figure 16. Population trend for Canvasback (*Aythya valisineria*) observed on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta. The indicated total aerial 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 or more. Average annual growth rate was calculated by log-linear regression. The power to detect a significant growth rate of -0.034, a 50% decline in 20 years, if it were to occur, used alpha set at *p*=0.10, beta set at *p*=0.20, and a coefficient of variation based on regression residuals or average annual sampling error.

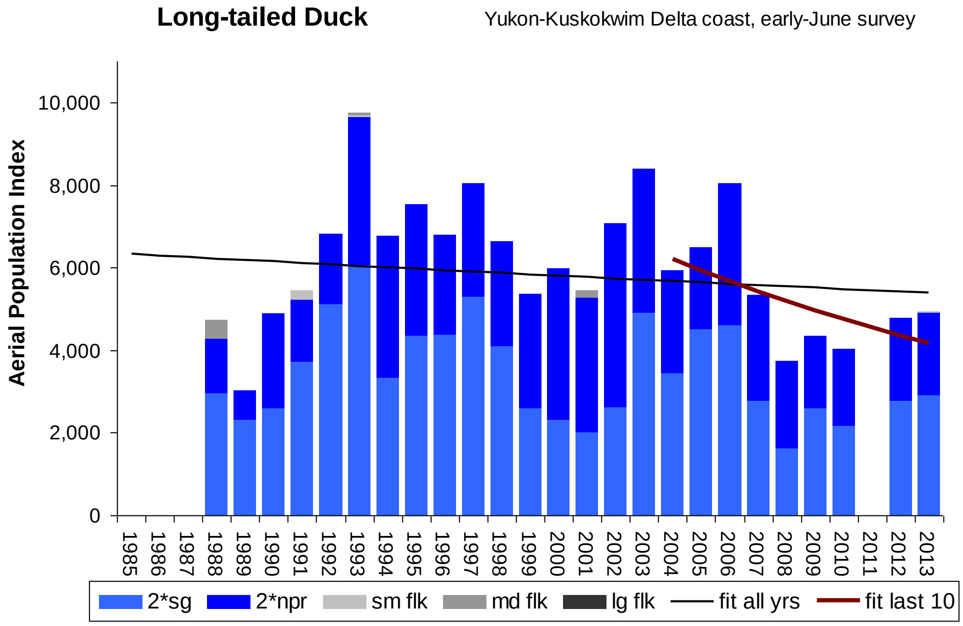


18 strata = 12,832 km² **Aerial index = Total birds** obsvr= **right rear**

year	**sg**	**2*npr**	**sm flk**	**md flk**	**lg flk**	Index	StdErr
1985							
1986							
1987							
1988							
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
2009	4705	22321	443	1345	0	**28814**	2607
2010	4608	25493	160	4928	2712	**37902**	4635
2011							
2012	3566	24855	82	2226	6036	**36764**	5451
2013	3802	19807	80	533	0	**24223**	2375

Aerial index: total birds	
n yrs =	24
average index =	**36465**
std dev =	6021
std error =	1229
low 90%ci =	34444
high 90%ci =	38487
avg index last 10 yrs=	**35901**
std dev last 10 yrs=	6171
trend over all years :	
ln linear slope =	0.0013
SE ln slope =	0.0053
Growth Rate =	**1.001**
low 90%ci GR =	0.993
high 90%ci GR =	1.010
trend last 10 years :	
Growth Rate =	**0.959**
low 90%ci GR =	0.933
high 90%ci GR =	0.985
min yrs to detect -50%/20yr rate :	
regression resid CV =	0.182
avg sampling err CV =	0.104
w/ regression resid CV =	12.8
w/ sample error CV =	8.8

Figure 17. Population trend for Unidentified Scaup, predominantly Greater Scaup (*Aythya marila*), observed on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta. The total aerial index is the sum of birds observed as singles, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31 or more. Average annual growth rate was calculated by log-linear regression. The power to detect a significant growth rate of -0.034, a 50% decline in 20 years, if it were to occur, used alpha set at p=0.10, beta set at p=0.20, and a coefficient of variation based on regression residuals or average annual sampling error.



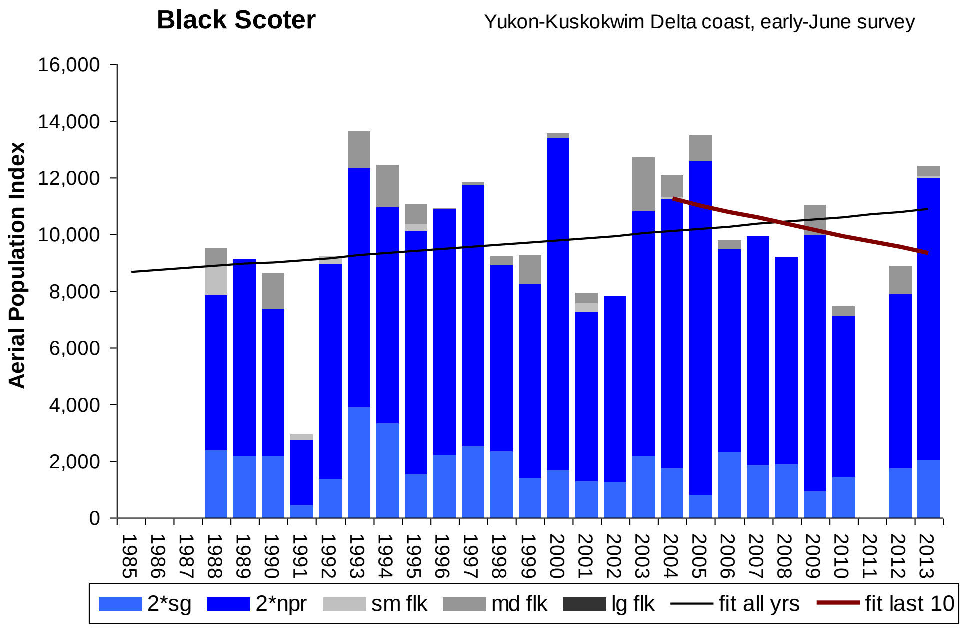
18 strata = 12,832 km² **Aerial index = Indicated Total birds**

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
2009	2601	1750	0	0	0	**4351**	824
2010	2163	1849	0	0	0	**4012**	567
2011							
2012	2783	2010	0	0	0	**4793**	823
2013	2891	2032	26	0	0	**4948**	545

obsvr= **right rear**

Aerial index: Indicated total	
n yrs =	25
average index =	**6015**
std dev =	1606
std error =	321
low 90%ci =	5486
high 90%ci =	6543
avg index last 10 yrs=	**5292**
std dev last 10 yrs=	1356
trend over all years :	
ln linear slope =	-0.0058
SE ln slope =	0.0076
Growth Rate =	**0.994**
low 90%ci GR =	0.982
high 90%ci GR =	1.007
trend last 10 years :	
Growth Rate =	**0.957**
low 90%ci GR =	0.919
high 90%ci GR =	0.997
min yrs to detect -50%/20yr rate :	
regression resid CV =	0.279
avg sampling err CV =	0.146
w/ regression resid CV =	17.0
w/ sample error CV =	11.1

Figure 18. Population trend for Long-tailed Duck (*Clangula hyemalis*) observed on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta. The indicated total aerial 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 or more. Average annual growth rate was calculated by log-linear regression. The power to detect a significant growth rate of -0.034, a 50% decline in 20 years, if it were to occur, used alpha set at *p*=0.10, beta set at *p*=0.20, and a coefficient of variation based on regression residuals or average annual sampling error.



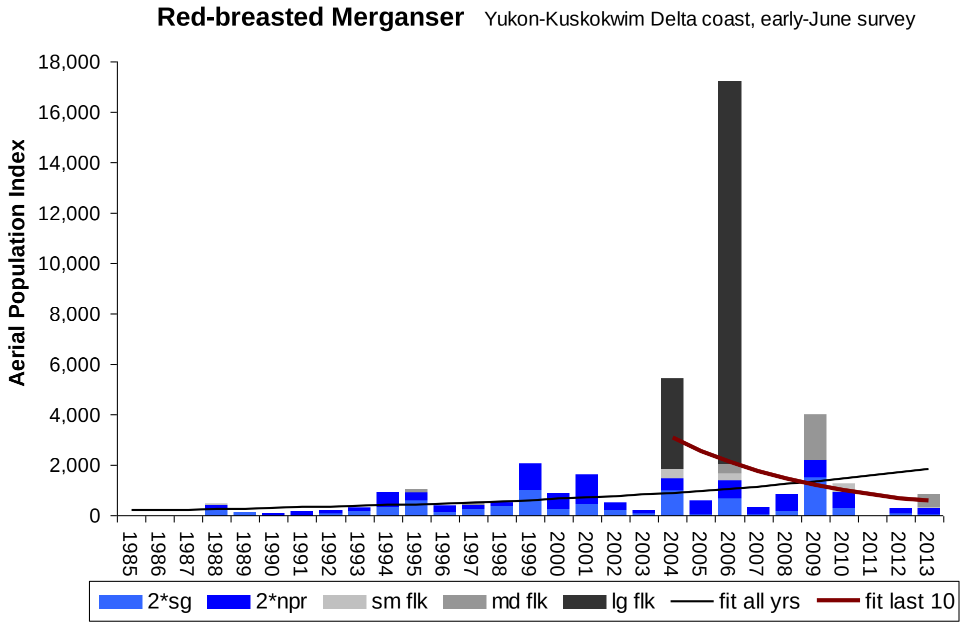
18 strata = 12,832 km² **Aerial index = Indicated Total birds**

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
2009	915	9037	0	1086	0	**11038**	2370
2010	1449	5656	0	346	0	**7450**	1140
2011							
2012	1732	6148	0	1017	0	**8896**	1740
2013	2043	9942	55	355	0	**12394**	1776

obsvr= **right rear**

Aerial index: Indicated total	
n yrs =	25
average index =	**10160**
std dev =	2407
std error =	481
low 90%ci =	9368
high 90%ci =	10952
avg index last 10 yrs=	**10473**
std dev last 10 yrs=	1926
trend over all years :	
ln linear slope =	0.0081
SE ln slope =	0.0084
Growth Rate =	**1.008**
low 90%ci GR =	0.994
high 90%ci GR =	1.022
trend last 10 years :	
Growth Rate =	**0.980**
low 90%ci GR =	0.945
high 90%ci GR =	1.015
min yrs to detect -50%/20yr rate :	
regression resid CV =	0.310
avg sampling err CV =	0.194
w/ regression resid CV =	18.3
w/ sample error CV =	13.4

Figure 19. Population trend for Black Scoter (*Melanitta nigra*) observed on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta. The indicated total aerial 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 or more. Average annual growth rate was calculated by log-linear regression. The power to detect a significant growth rate of -0.034, a 50% decline in 20 years, if it were to occur, used alpha set at p=0.10, beta set at p=0.20, and a coefficient of variation based on regression residuals or average annual sampling error.



18 strata = 12,832 km² **Aerial index = Indicated Total birds**

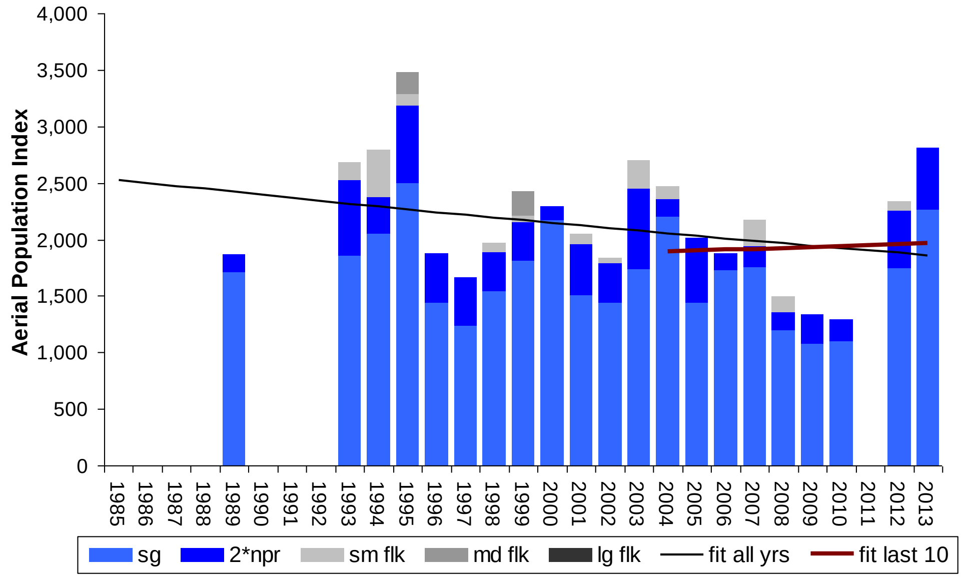
year	**2*sg**	**2*npr**	**sm flk**	**md flk**	**lg flk**	**Index**	StdErr
1985							
1986							
1987							
1988	236	197	41	0	0	**473**	195
1989	104	0	0	0	0	**104**	73
1990	0	66	0	0	0	**67**	68
1991	18	164	0	0	0	**182**	100
1992	74	152	0	0	0	**226**	78
1993	164	146	0	0	0	**310**	131
1994	344	572	0	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
2009	1500	719	0	1784	0	**4003**	1982
2010	282	643	306	0	0	**1231**	385
2011							
2012	86	222	0	0	0	**308**	117
2013	34	277	43	476	0	**830**	463

obsvr= **right rear**

Aerial index: Indicated total	
n yrs =	25
average index =	**1630**
std dev =	3476
std error =	695
low 90%ci =	487
high 90%ci =	2774
avg index last 10 yrs=	**3419**
std dev last 10 yrs=	5481
trend over all years :	
ln linear slope =	0.0807
SE ln slope =	0.0298
Growth Rate =	**1.084**
low 90%ci GR =	1.032
high 90%ci GR =	1.139
trend last 10 years :	
Growth Rate =	**0.828**
low 90%ci GR =	0.646
high 90%ci GR =	1.063
min yrs to detect -50%/20yr rate :	
regression resid CV =	1.097
avg sampling err CV =	0.471
w/ regression resid CV =	42.4
w/ sample error CV =	24.1

Figure 20. Population trend for Red-breasted Merganser (*Mergus serrator*) observed on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta. The indicated total aerial 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 or more. Average annual growth rate was calculated by log-linear regression. The power to detect a significant growth rate of -0.034, a 50% decline in 20 years, if it were to occur, used alpha set at p=0.10, beta set at p=0.20, and a coefficient of variation based on regression residuals or average annual sampling error.

Jaeger spp Yukon-Kuskokwim Delta coast, early-June survey



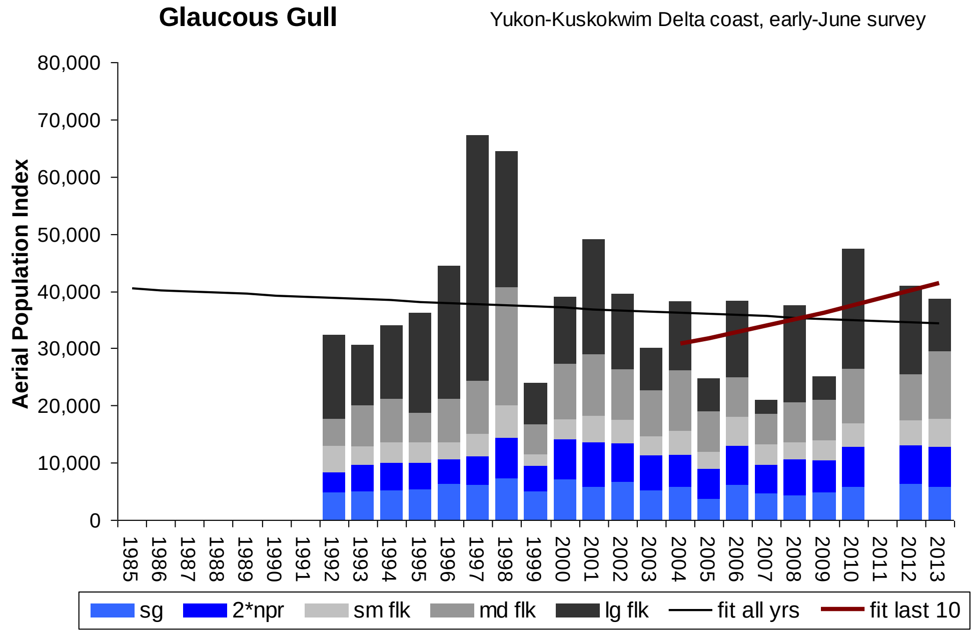
18 strata = 12,832 km² **Aerial index = Total birds**

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
2009	1079	256	0	0	0	**1335**	262
2010	1093	194	0	0	0	**1287**	215
2011							
2012	1747	511	79	0	0	**2337**	352
2013	2262	553	0	0	0	**2815**	526

obsvr= **right rear**

Aerial index: total birds	
n yrs =	21
average index =	**2163**
std dev =	543
std error =	118
low 90%ci =	1968
high 90%ci =	2358
avg index last 10 yrs=	**1978**
std dev last 10 yrs=	530
trend over all years :	
ln linear slope =	#####
SE ln slope =	0.0084
Growth Rate =	**0.989**
low 90%ci GR =	0.975
high 90%ci GR =	1.003
trend last 10 years :	
Growth Rate =	**1.004**
low 90%ci GR =	0.949
high 90%ci GR =	1.062
min yrs to detect -50%/20yr rate :	
regression resid CV =	0.250
avg sampling err CV =	0.174
w/ regression resid CV =	15.8
w/ sample error CV =	12.4

Figure 21. Population trend for Jaeger spp (*Stercorarius parasiticus*, *S. longicauda*, *S. pomarinus*) observed on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta. The total aerial index is the sum of birds observed as singles, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31 or more. Average annual growth rate was calculated by log-linear regression. The power to detect a significant growth rate of -0.034, a 50% decline in 20 years, if it were to occur, used alpha set at *p*=0.10, beta set at *p*=0.20, and a coefficient of variation based on regression residuals or average annual sampling error.



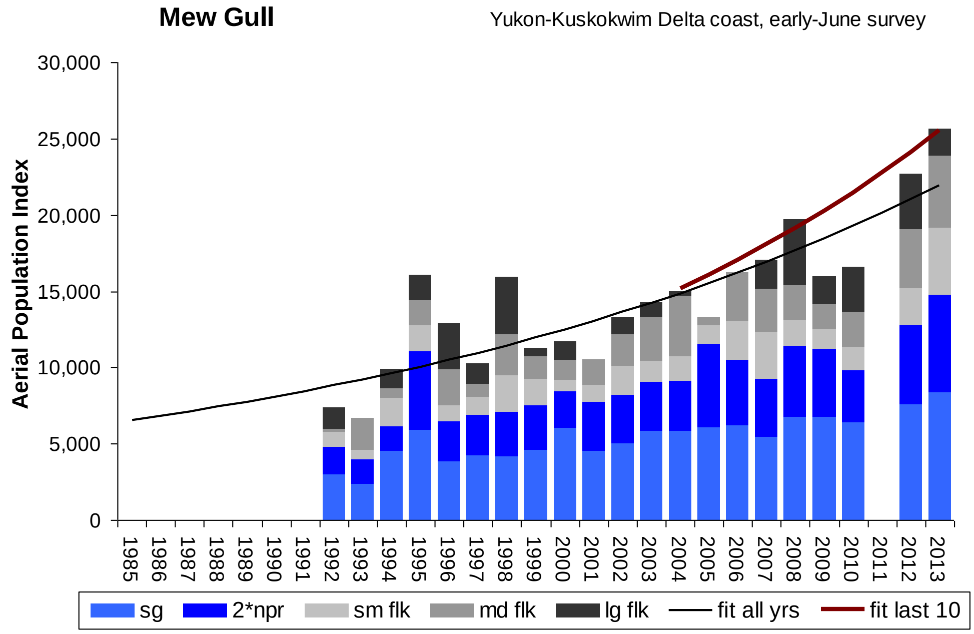
18 strata = 12,832 km² **Aerial index = Total birds**

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
2009	4782	5600	3470	7096	4164	**25111**	4390
2010	5727	7102	4080	9484	20939	**47334**	9182
2011							
2012	6267	6691	4476	8008	15303	**40744**	5462
2013	5714	7066	4810	11870	9229	**38689**	5917

obsvr= **right rear**

Aerial index: total birds	
n yrs =	21
average index =	**38195**
std dev =	11854
std error =	2587
low 90%ci =	33940
high 90%ci =	42450
avg index last 10 yrs=	**34611**
std dev last 10 yrs=	8838
trend over all years :	
ln linear slope =	#####
SE ln slope =	0.0107
Growth Rate =	**0.994**
low 90%ci GR =	0.977
high 90%ci GR =	1.012
trend last 10 years :	
Growth Rate =	**1.034**
low 90%ci GR =	0.981
high 90%ci GR =	1.089
min yrs to detect -50%/20yr rate :	
regression resid CV =	0.304
avg sampling err CV =	0.172
w/ regression resid CV =	18.0
w/ sample error CV =	12.4

Figure 22. Population trend for Glaucous Gull (*Larus hyperboreus)* observed on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta. The total aerial index is the sum of birds observed as singles, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31 or more. Average annual growth rate was calculated by log-linear regression. The power to detect a significant growth rate of -0.034, a 50% decline in 20 years, if it were to occur, used alpha set at p=0.10, beta set at p=0.20, and a coefficient of variation based on regression residuals or average annual sampling error.



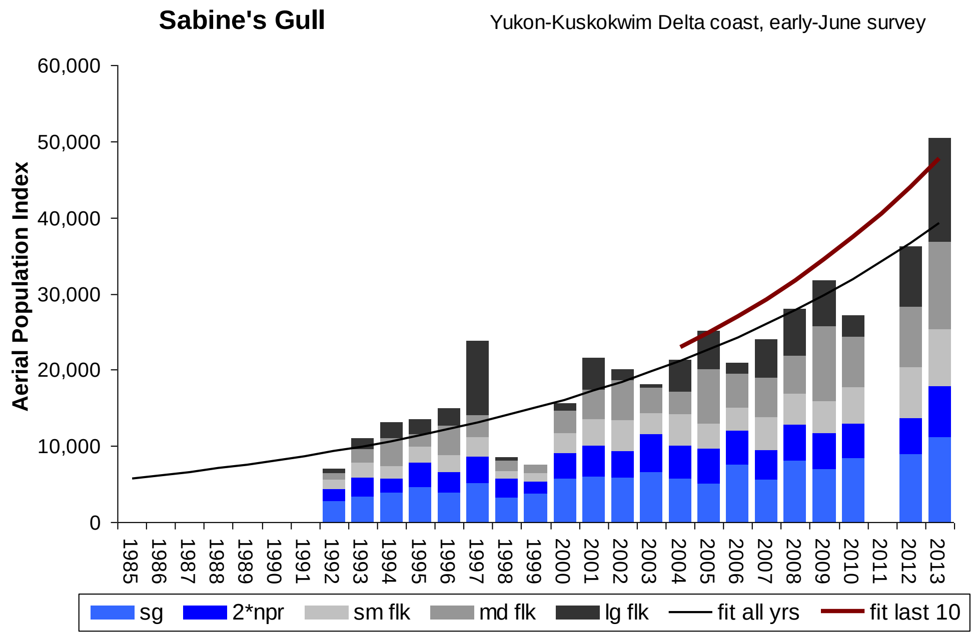
18 strata = 12,832 km² **Aerial index = Total birds**

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
2009	6735	4496	1304	1562	1861	**15959**	2014
2010	6424	3425	1496	2305	2894	**16544**	3601
2011							
2012	7561	5214	2415	3888	3622	**22700**	3063
2013	8338	6418	4399	4700	1746	**25601**	3340

obsvr= **right rear**

Aerial index: total birds	
n yrs =	21
average index =	**14385**
std dev =	4633
std error =	1011
low 90%ci =	12721
high 90%ci =	16048
avg index last 10 yrs=	**18008**
std dev last 10 yrs=	3946
trend over all years :	
ln linear slope =	0.0434
SE ln slope =	0.0066
Growth Rate =	**1.044**
low 90%ci GR =	1.033
high 90%ci GR =	1.056
trend last 10 years :	
Growth Rate =	**1.059**
low 90%ci GR =	1.036
high 90%ci GR =	1.083
min yrs to detect -50%/20yr rate :	
regression resid CV =	0.189
avg sampling err CV =	0.157
w/ regression resid CV =	13.1
w/ sample error CV =	11.6

Figure 23. Population trend for Mew Gull (*Larus canus)* observed on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta. The total aerial index is the sum of birds observed as singles, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31 or more. Average annual growth rate was calculated by log-linear regression. The power to detect a significant growth rate of -0.034, a 50% decline in 20 years, if it were to occur, used alpha set at *p*=0.10, beta set at *p*=0.20, and a coefficient of variation based on regression residuals or average annual sampling error.



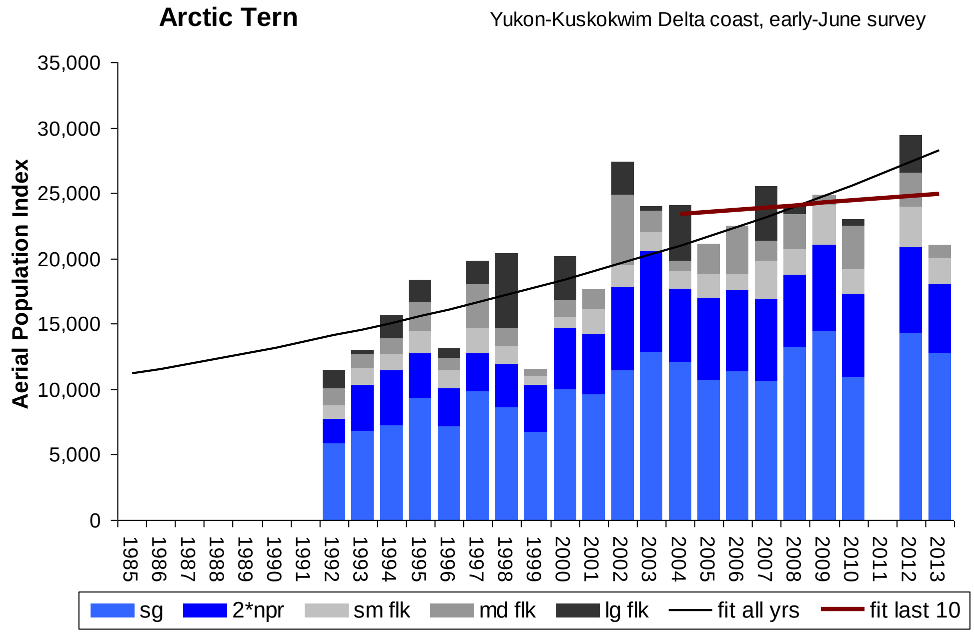
18 strata = 12,832 km² — **Aerial index = Total birds**

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
2009	7025	4688	4227	9753	6067	**31760**	5004
2010	8299	4579	4839	6576	2812	**27104**	2335
2011							
2012	8912	4718	6650	8004	7939	**36224**	3722
2013	11106	6746	7504	11458	13539	**50352**	8748

obsvr= **right rear**

Aerial index: total birds	
n yrs =	21
average index =	**20907**
std dev =	10395
std error =	2268
low 90%ci =	17175
high 90%ci =	24638
avg index last 10 yrs=	**29403**
std dev last 10 yrs=	9256
trend over all years :	
ln linear slope =	0.0687
SE ln slope =	0.0098
Growth Rate =	**1.071**
low 90%ci GR =	1.054
high 90%ci GR =	1.089
trend last 10 years :	
Growth Rate =	**1.085**
low 90%ci GR =	1.059
high 90%ci GR =	1.112
min yrs to detect -50%/20yr rate :	
regression resid CV =	0.280
avg sampling err CV =	0.119
w/ regression resid CV =	17.1
w/ sample error CV =	9.7

Figure 24. Population trend for Sabine's Gull (*Xema sabini)* observed on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta. The total aerial index is the sum of birds observed as singles, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31 or more. Average annual growth rate was calculated by log-linear regression. The power to detect a significant growth rate of -0.034, a 50% decline in 20 years, if it were to occur, used alpha set at p=0.10, beta set at p=0.20, and a coefficient of variation based on regression residuals or average annual sampling error.



18 strata = 12,832 km² — **Aerial index = Total birds**

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
2009	14446	6595	3108	681	0	**24829**	1798
2010	10926	6350	1877	3307	499	**22958**	2624
2011							
2012	14274	6562	3116	2627	2849	**29427**	2964
2013	12735	5285	2055	917	0	**20993**	1722

obsvr= **right rear**

Aerial index: total birds	
n yrs =	21
average index =	**20378**
std dev =	5140
std error =	1122
low 90%ci =	18533
high 90%ci =	22223
avg index last 10 yrs=	**23941**
std dev last 10 yrs=	2575
trend over all years :	
ln linear slope =	0.0331
SE ln slope =	0.0066
Growth Rate =	**1.034**
low 90%ci GR =	1.023
high 90%ci GR =	1.045
trend last 10 years :	
Growth Rate =	**1.007**
low 90%ci GR =	0.987
high 90%ci GR =	1.028
min yrs to detect -50%/20yr rate :	
regression resid CV =	0.187
avg sampling err CV =	0.127
w/ regression resid CV =	13.0
w/ sample error CV =	10.1

Figure 25. Population trend for Arctic Tern (*Sterna paradisaea)* observed on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta. The total aerial index is the sum of birds observed as singles, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31 or more. Average annual growth rate was calculated by log-linear regression. The power to detect a significant growth rate of -0.034, a 50% decline in 20 years, if it were to occur, used alpha set at *p*=0.10, beta set at *p*=0.20, and a coefficient of variation based on regression residuals or average annual sampling error.

Table 1. Number of birds sighted by category and expanded numbers for waterbirds counted by the right-rear-seat observer on the June 2013 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 = 395.6 km^2. Number of transects (n) = 189. 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	469	106	417	1,567	2.95	37,862	3,923	3.05	**115,479**
Greater scaup	122	334	44	834	1.89	24,223	2,375	1.93	**46,750**
Spectacled eider	253	95	0	696	0.53	6,808	576	3.58	**24,373**
Black scoter	28	129	33	347	0.97	12,394	1,776	1.17	**14,501**
American green-winged teal	7	6	0	26	0.12	1,505	460	8.36	**12,582**
Northern shoveler	30	7	7	81	0.26	3,289	598	3.79	**12,465**
Mallard	29	8	0	74	0.23	2,931	697	4.01	**11,753**
Long-tailed duck	50	37	3	177	0.39	4,948	545	1.87	**9,253**
American wigeon	10	4	20	48	0.15	1,966	508	3.84	**7,549**
Common eider	85	33	5	241	0.16	2,051	340	3.58	**7,343**
Red-breasted merganser	2	5	11	25	0.02	830	463	1.27	**1,054**
Canvasback	0	1	0	2	0.01	68	68	2	**165**
Sabine's gull	953	271	2,214	3,709	3.92	**50,352**	8,748	unknown	n/a
Glaucous gull	396	216	2,095	2,923	3.02	**38,689**	5,917	unknown	n/a
Mew gull	478	191	793	1,653	2.00	**25,601**	3,340	unknown	n/a
Arctic tern	631	143	159	1,076	1.64	**20,993**	1,722	unknown	n/a
Pacific loon	353	143	30	669	1.48	**19,043**	1,609	unknown	n/a
Jaeger species	69	6	0	81	0.22	**2,815**	526	unknown	n/a
Red-throated loon	59	34	12	139	0.18	**2,352**	523	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 2012 and from the long-term average (1988-2012), sorted in decreasing order of percent change from long-term average, first for waterfowl and then for other species.

Species	Population estimate 2012	Population estimate 2013	Change between 2012 and 2013	Long term (1988-2012) average population estimate	Change between 2013 and long term average
Spectacled eider	21,974	24,373	11%	11,857	106%
Common eider	4,174	7,343	76%	4,654	58%
Black scoter	10,408	14,501	39%	11,778	23%
Long-tailed duck	8,963	9,253	3%	11,330	-18%
Northern pintail	186,986	115,479	-38%	151,765	-24%
Mallard	18,622	11,753	-37%	16,425	-28%
Greater scaup	70,955	46,750	-34%	70,709	-34%
Green-winged teal	23,558	12,582	-47%	23,057	-45%
Red-breasted merganser	391	1,054	169%	2,113	-50%
American wigeon	16,389	7,549	-54%	17,979	-58%
Northern shoveler	7,076	12,465	76%	35,645	-65%
Canvasback	0	165		2,476	-93%
Sabine's gull	36,224	50,352	39%	19,435	159%
Mew gull	22,700	25,601	13%	13,824	85%
Jaeger spp.	2,337	2,815	20%	2,131	32%
Pacific loon	13,946	19,043	37%	16,403	16%
Arctic tern	29,427	20,993	-29%	20,347	3%
Glaucous gull	40,744	38,689	-5%	38,170	1%
Red-throated loon	860	2,352	173%	2,388	-2%

Table 3. Summary of trends for waterbird species counted by the right-back-seat observer on the Yukon-Kuskokwim Delta coastal zone aerial survey Alaska. Ducks have been counted from 1988 to 2013(except no survey in 2011). 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.

species name	Sppn	Meas	N yrs	Mean	Std dev	Log-linear slope	SE slope	**Growth Rate**	Low 90% CI GR	High 90% CI GR	**GR last 10 yrs**	Low 90% CI 10 yr	High 90% CI 10 yr	Regress. resid CV	Sampling error CV	N yrs w/ resid CV	N yrs w/ sampling err CV
1988-2013																	
Spectacled Eider	SPEI	ind.total	25	**3452**	1710	0.0657	0.0055	**1.068**	1.058	1.078	**1.079**	1.046	1.114	0.203	0.127	13.8	10.1
Common Eider	COEI	ind.total	25	**1330**	542	0.0353	0.0103	**1.036**	1.018	1.054	**1.042**	0.979	1.108	0.380	0.232	20.9	15.0
Red-throated Loon	RTLO	total	24	**2386**	732	-0.0038	0.0104	**0.996**	0.979	1.013	**0.907**	0.848	0.971	0.360	0.166	20.2	12.1
Pacific Loon	PALO	total	24	**16513**	3152	0.0064	0.0056	**1.006**	0.997	1.016	**0.992**	0.961	1.023	0.194	0.089	13.4	8.0
Mallard	MALL	ind.total	25	**4049**	1435	-0.0091	0.0089	**0.991**	0.977	1.006	**0.946**	0.901	0.994	0.326	0.218	18.9	14.5
American Wigeon	AMWI	ind.total	25	**4573**	2202	-0.0424	0.0110	**0.958**	0.941	0.976	**1.026**	0.970	1.085	0.403	0.364	21.8	20.3
Green-winged Teal	AGWT	ind.total	25	**2708**	953	-0.0063	0.0109	**0.994**	0.976	1.012	**0.973**	0.903	1.049	0.401	0.229	21.7	14.9
Northern Shoveler	NSHO	ind.total	25	**9161**	3497	-0.0245	0.0120	**0.976**	0.957	0.995	**0.843**	0.784	0.907	0.439	0.180	23.0	12.7
Northern Pintail	NOPI	ind.total	25	**49283**	13215	-0.0091	0.0072	**0.991**	0.979	1.003	**0.997**	0.951	1.045	0.264	0.113	16.4	9.3
Canvasback	CANV	ind.total	25	**981**	1039	-0.1208	0.0310	**0.886**	0.842	0.933	**0.714**	0.542	0.941	1.142	0.594	43.5	28.2
Scaup spp.	SCAU	total	24	**36465**	6021	0.0013	0.0053	**1.001**	0.993	1.010	**0.959**	0.933	0.985	0.182	0.104	12.8	8.8
Long-tailed Duck	LTDU	ind.total	25	**6015**	1606	-0.0058	0.0076	**0.994**	0.982	1.007	**0.957**	0.919	0.997	0.279	0.146	17.0	11.1
Black Scoter	BLSC	ind.total	25	**10160**	2407	0.0081	0.0084	**1.008**	0.994	1.022	**0.980**	0.945	1.015	0.310	0.194	18.3	13.4
Red-breasted Merganser	RBME	ind.total	25	**1630**	3476	0.0807	0.0298	**1.084**	1.032	1.139	**0.828**	0.646	1.063	1.097	0.471	42.4	24.1
Jaeger spp	JAEG	total	21	**2163**	543	-0.0110	0.0084	**0.989**	0.975	1.003	**1.004**	0.949	1.062	0.250	0.174	15.8	12.4
Glaucous Gull	GLGU	total	21	**38195**	11854	-0.0058	0.0107	**0.994**	0.977	1.012	**1.034**	0.981	1.089	0.304	0.172	18.0	12.4
Mew Gull	MEGU	total	21	**14385**	4633	0.0434	0.0066	**1.044**	1.033	1.056	**1.059**	1.036	1.083	0.189	0.157	13.1	11.6
Sabine's Gull	SAGU	total	21	**20907**	10395	0.0687	0.0098	**1.071**	1.054	1.089	**1.085**	1.059	1.112	0.280	0.119	17.1	9.7
Arctic Tern	ARTE	total	21	**20378**	5140	0.0331	0.0066	**1.034**	1.023	1.045	**1.007**	0.987	1.028	0.187	0.127	13.0	10.1