Abundance and Trend of Waterbirds on Alaska's Yukon-Kuskokwim Delta Coast based on 1988 to 2012 Aerial Surveys

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Abstract: We summarize 1988 to 2012 (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 2012 was 6,138 birds. Traditionally, a visibility correction factor of 3.58 has been applied for spectacled eiders yielding a population estimate of 21,974 which was 85% 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 (minimum of 2 birds per nest) per aerial index. Using this correction, the population estimate for spectacled eiders was 14,442 breeding birds.

In 2012 the three most numerous waterfowl species were northern pintail (*Anas acuta*) with a visibility-corrected estimate of 186,986 birds, greater scaup (*Aythya marila*) with 70,955 birds, and green-winged teal (*Anas crecca*) at 23,558 birds. The estimated population sizes for species of special interest were 4,174 common eiders (*Somateria mollissima*), 8,963 long-tailed ducks (*Clangula hyamelis*), 10,408 black scoters (*Melanitta nigra*), and 860 red-throated loons (*Gavia stellata*). The estimated number of pintails was 23% above the LTA. Numbers of long-tailed ducks, northern shovelers, red-breasted mergansers, and red-throated loons were substantially below their LTAs.

Of the non-waterfowl species in 2012, glaucous gulls (*Larus hyperboreus*) were most numerous with an estimated 40,744 birds (7%above LTA), followed by 36,224 (+86%) Sabine's gulls and 22,700 (+64%) mew gulls. The estimated population of Arctic terns was 29,427 (+45%). Pacific loons (*Gavia pacifica*) were estimated at 13,946 birds (-15%).

Twenty-five year trends based on log-linear regression showed significant population increases (p<0.10) for greater scaup, spectacled eider, common eider, red-breasted merganser (*Mergus serrator*), Sabine's gull (*Xema sabini*), mew gull (*Larus canus*), and arctic tern (*Sterna paradisaea*). 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 2012 survey consistent with average survey timing of the last several years. We began flights on June 3, nine days after predicted average nest initiation of 27 May. Later examination of nesting data showed the average cackling goose initiation date was 2 June (Fischer et al. 2013). Therefore, the 2012 survey started about 7 days earlier in timing relative to average nest initiation compared to recent years.

We continued to compile individual geographic locations for sightings of 21 major species of waterbirds and now have over 139,000 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 all 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 2012 by the back seat observer. No survey data were collected in 2011 due to a shortage of personnel.

METHODS

Survey Design

We modified the 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 2012 totaled about 2,230 km on 221 transects with a 200 m wide observed area of 466 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 observations 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 2012, we flew the third year of the fourth replicate set of 4-year rotations by flying the same transects as in 2000, 2004, and 2008.

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. 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, 1992-2012) 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-four years of counts on duck species. Observations on other waterbird species were added with jaegers recorded in 1989, and 1993 to 2012, 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 all transects were flown in a progression similar to previous years, (Fig. 2), however 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.

The survey has been flown 1988 to 2012 (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 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, 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 1993-2011 average date at TDD >25, was calculated for 5 weather stations (Fig.3) and showed a high correlation (r = 0.80) with clutch initiation date. In 2012, the 5-station average anomaly for TDD warming was -1.054 days, later than the average date over all years and predicted clutch initiation was DOY = 148.5, May 28. The predicted survey start date was around June 6.

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 2012. The predicted average Cackling goose clutch initiation date of 28 May was about 3 days earlier than 2 June, the actual date based on the 2012 nest plot data. This indicated that the 3 June aerial survey start date was about a week early relative to nesting phenology and may have affected the population indices for some species.

The 2012 survey transects (Fig. 2) were flown on a total of 8 survey days from June 3 to June 14, with no survey flights on June 7, 8, 9, and 12 due to bad weather. Weather conditions recorded during the 2012 survey at the village of Chevak, centered in the survey area, are given in Figure 4.

Satellite imagery indicated 2012 snowmelt began around the second week of April in part of the YKD and was not complete until about the first week of June along the coast (Fig. 5). We did observe remnant snow patches in much of the sampled coastal area during the survey period. 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 13 years of MODIS satellite data. The 2012 snowmelt was the most delayed of any year in this data set.

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 2012, and where available, the visibility-corrected population estimates are tabulated (Table 1). To convert the aerial index to estimated populations, we used the standard visibility correction factors determined by the ratio of helicopter to fixed-wing aircraft observations for tundra Alaska species (Conant et al. 2000). Pintails (186,986 birds), scaup (70,955), and green-winged teal (23,558) were the most numerous waterfowl species in 2012. The spectacled eider population estimate of 21,974 birds was lhigher than the 2010 estimate and up 85% 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 14,424 spectacled eiders (see discussion below).

Estimates for spectacled eiders, northern pintails, mallards, and green-winged teal, were higher than the long-term averages. Wigeon, common eiders, black scoters, long-tailed ducks, shovelers, and red-breasted mergansers were below their LTAs (Table 2). Sabine’s gull, mew gull, arctic tern, and jaeger populations were above their LTAs whereas glaucous gull, Pacific loon, and red-throated loon were below their LTAs.

The estimate for red-throated loons was the lowest in the history of the survey. Low numbers of red-throated loons may have been due to the abundance of ice in shallow wetlands along the coast and the late spring breakup. The northern shoveler population index was also at the lowest population size in the history of the survey.

The aerial population indices, with no correction for visibility bias, showed the relative contribution by group size category for all survey years (Figs. 9 to 27). 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.

The geographic locations of over 139,000 sightings of 21 species of waterbirds have been collected in 24 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 a consistent strong decreasing trend (Figs. 12, 17, and 25 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. 11) The 2003-2012 growth rate of 1.085 was higher than the nest population growth rate of 1.058 from the ground studies 2003-2012 (Fischer and Stehn 2013). The overlap in the 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 21 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 21 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 24 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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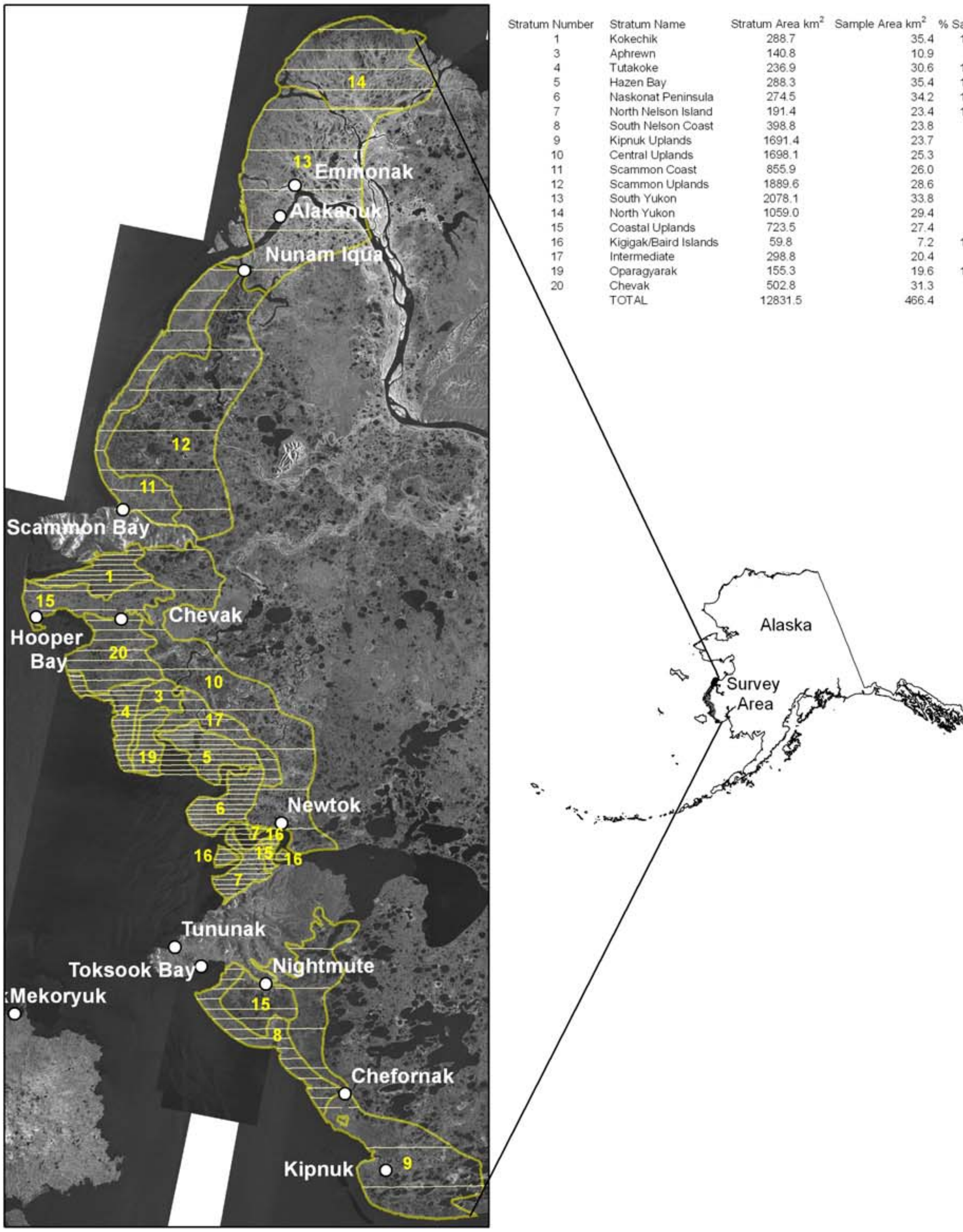


Stratum Number	Stratum Name	Stratum Area km²	Sample Area km²	% Sample
1	Kokechik	288.7	35.4	12.2%
3	Aphrewn	140.8	10.9	7.7%
4	Tutakoke	236.9	30.6	12.9%
5	Hazen Bay	288.3	35.4	12.3%
6	Naskonat Peninsula	274.5	34.2	12.5%
7	North Nelson Island	191.4	23.4	12.2%
8	South Nelson Coast	398.8	23.8	6.0%
9	Kipnuk Uplands	1691.4	23.7	1.4%
10	Central Uplands	1698.1	25.3	1.5%
11	Scammon Coast	855.9	26.0	3.0%
12	Scammon Uplands	1889.6	28.6	1.5%
13	South Yukon	2078.1	33.8	1.6%
14	North Yukon	1059.0	29.4	2.8%
15	Coastal Uplands	723.5	27.4	3.8%
16	Kigigak/Baird Islands	59.8	7.2	12.1%
17	Intermediate	298.8	20.4	6.8%
19	Oparagyarak	155.3	19.6	12.6%
20	Chevak	502.8	31.3	6.2%
	TOTAL	12831.5	466.4	3.6%

Figure 1. Transects and strata for aerial waterbird survey, June 3-14, 2012, 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.

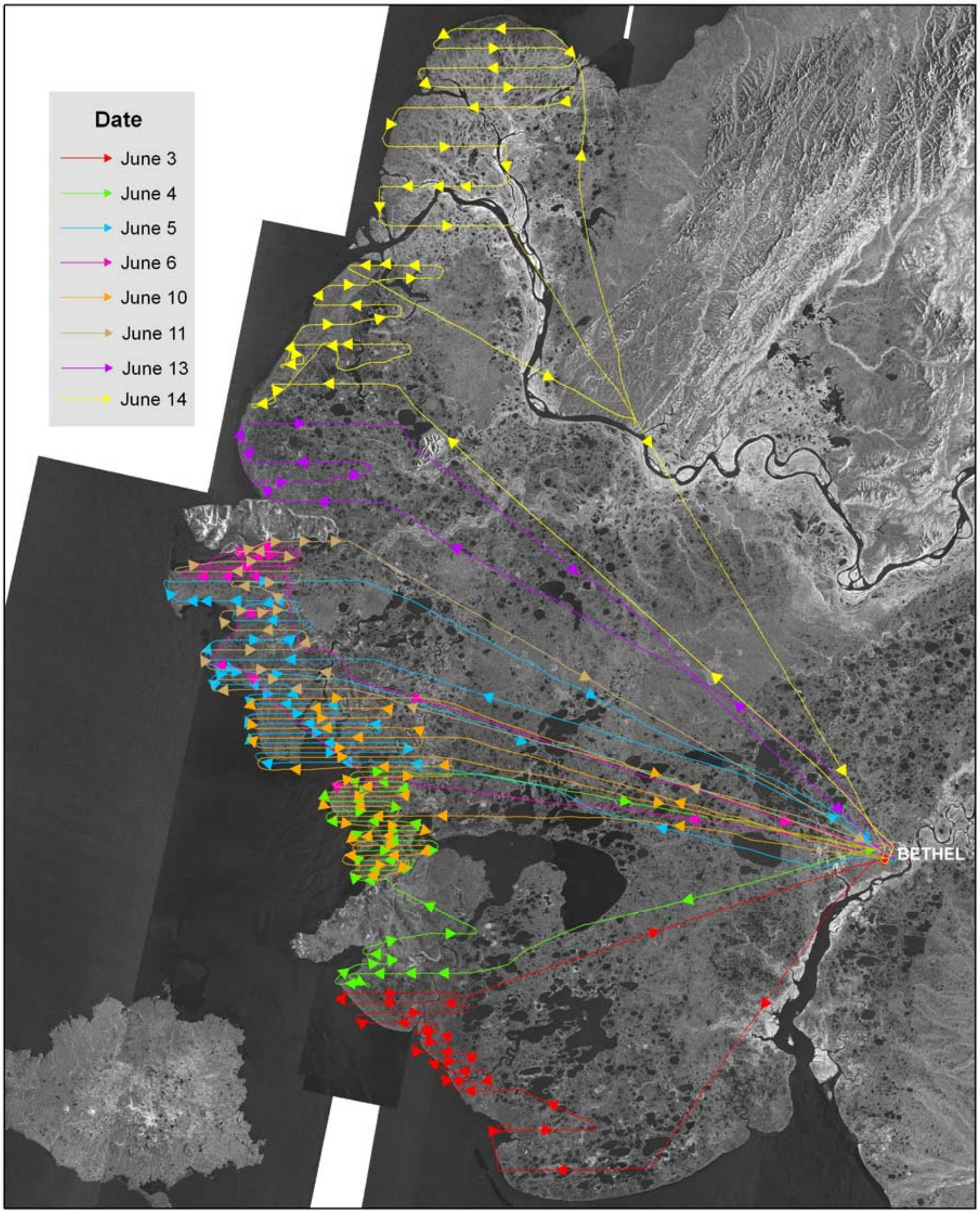


Figure 2. Transects color-coded by date flown in 2012 showing progression of survey by date. We skip every other transect in the 1-mile strata so as not to double-count flushing birds and to spread the survey temporally.

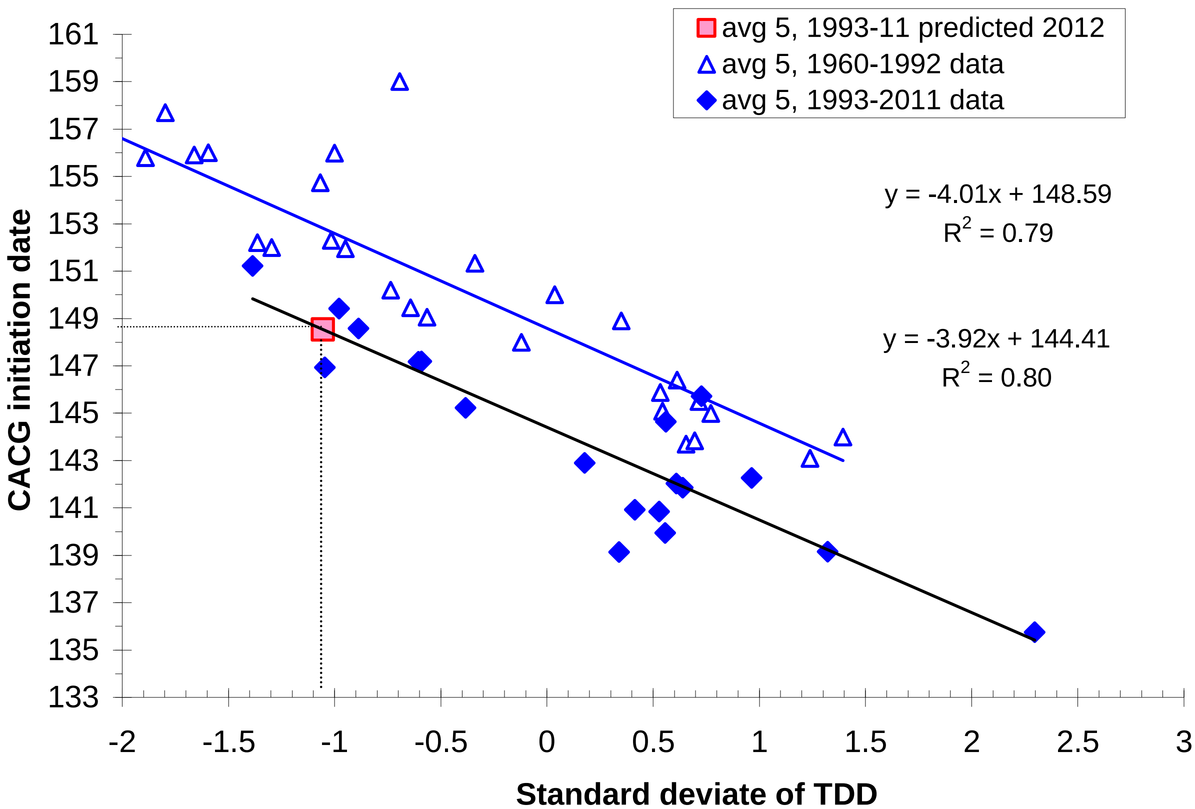


Figure 3. 2012 predicted cackling goose average clutch initiation date based on the linear regression relationship of the standard deviates from 5-station average date at TDD>25 criterion. Analysis conducted on May 28, 2012 and predicted initiation on May 26 or 27.

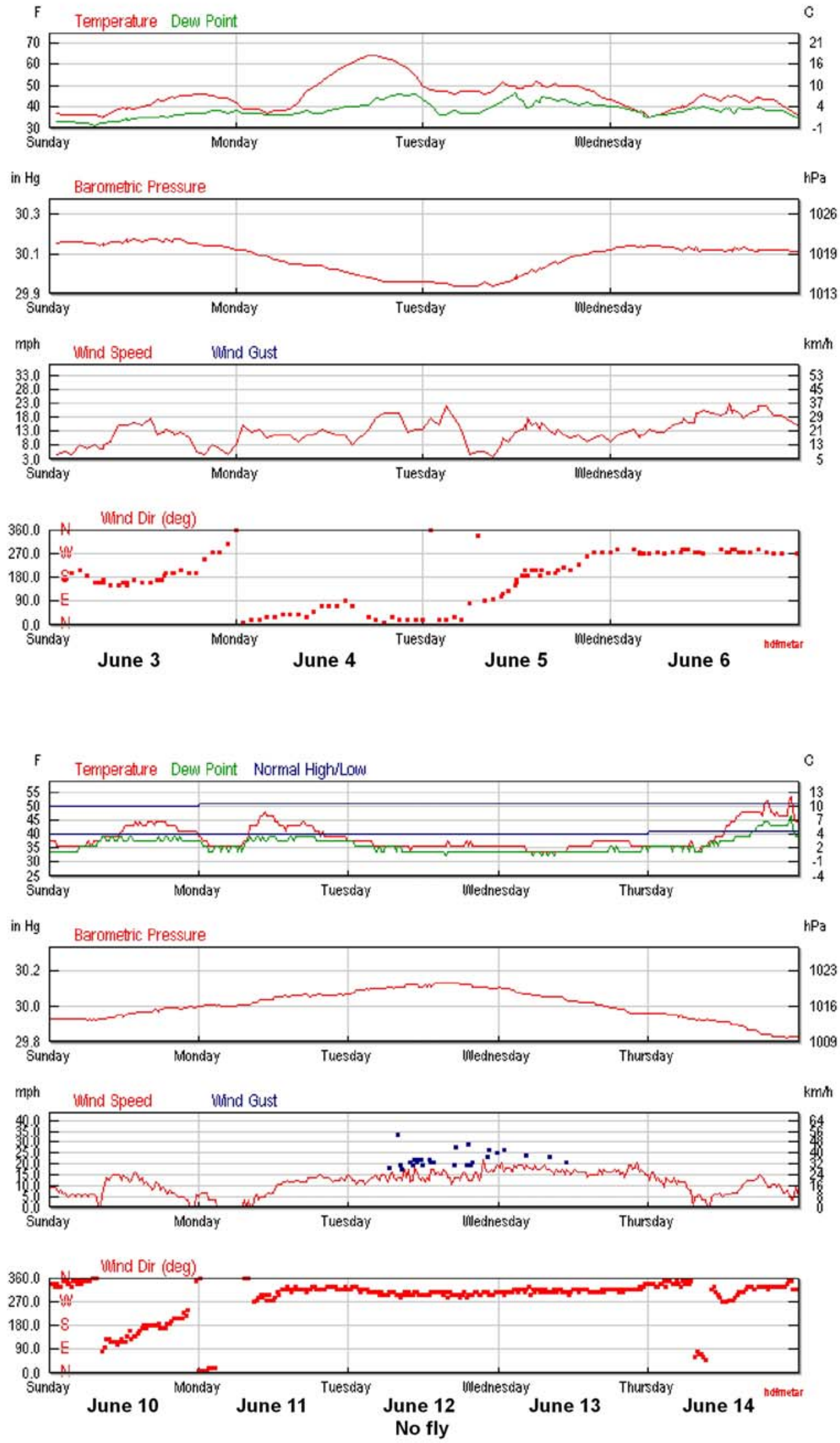


Figure 4. Weather data during the aerial survey, June 3-14, 2012 from Chevak in the central coastal zone (from http://www.wunderground.com/history/airport/PAVA/2012/6/10/CustomHistory.html).

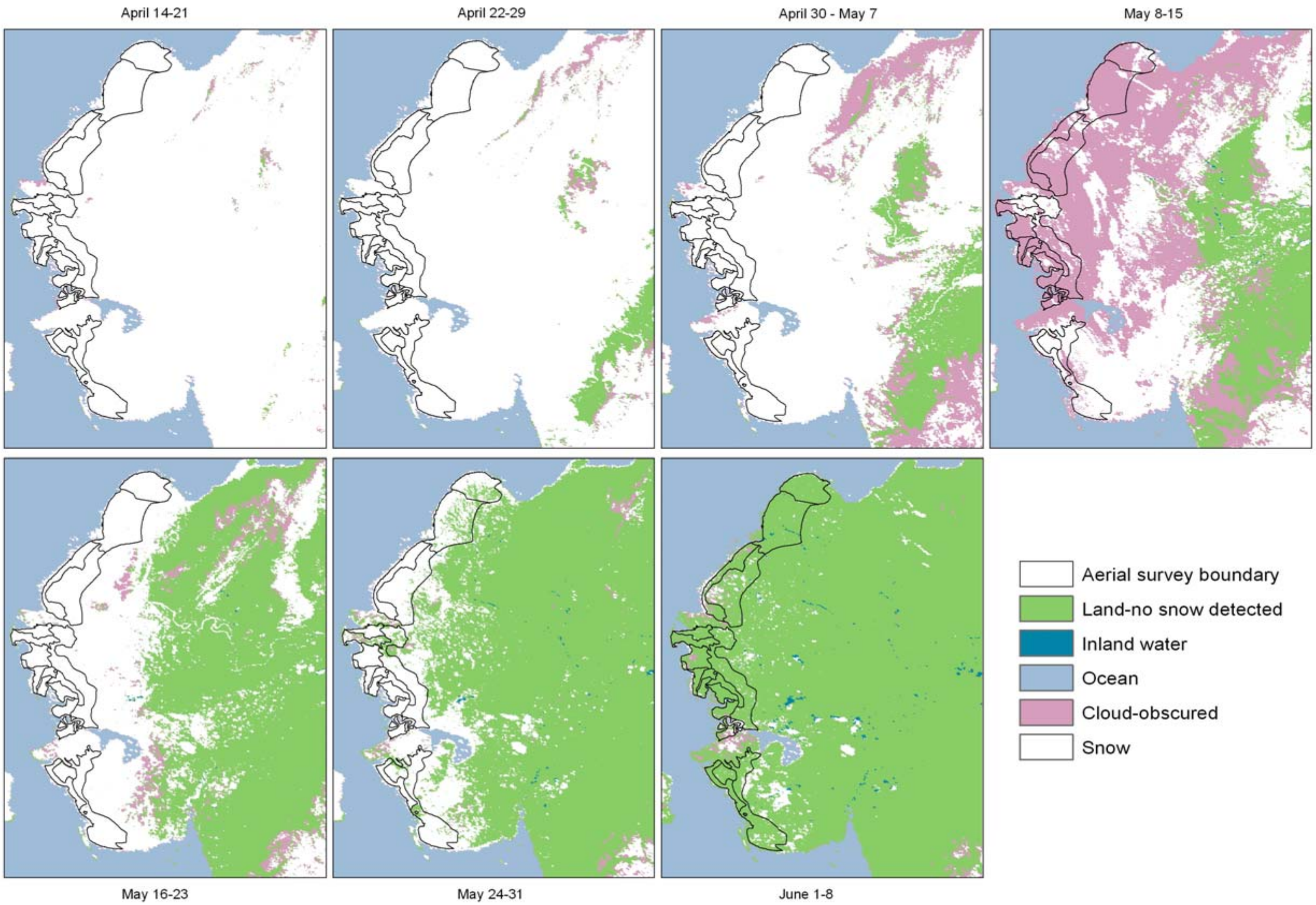


Figure 5. Snow melt chronology from Terra staellite MODIS 8-day composite maximum snow extent, 2012, Yukon Delta National Wildlife Refuge, Alaska.

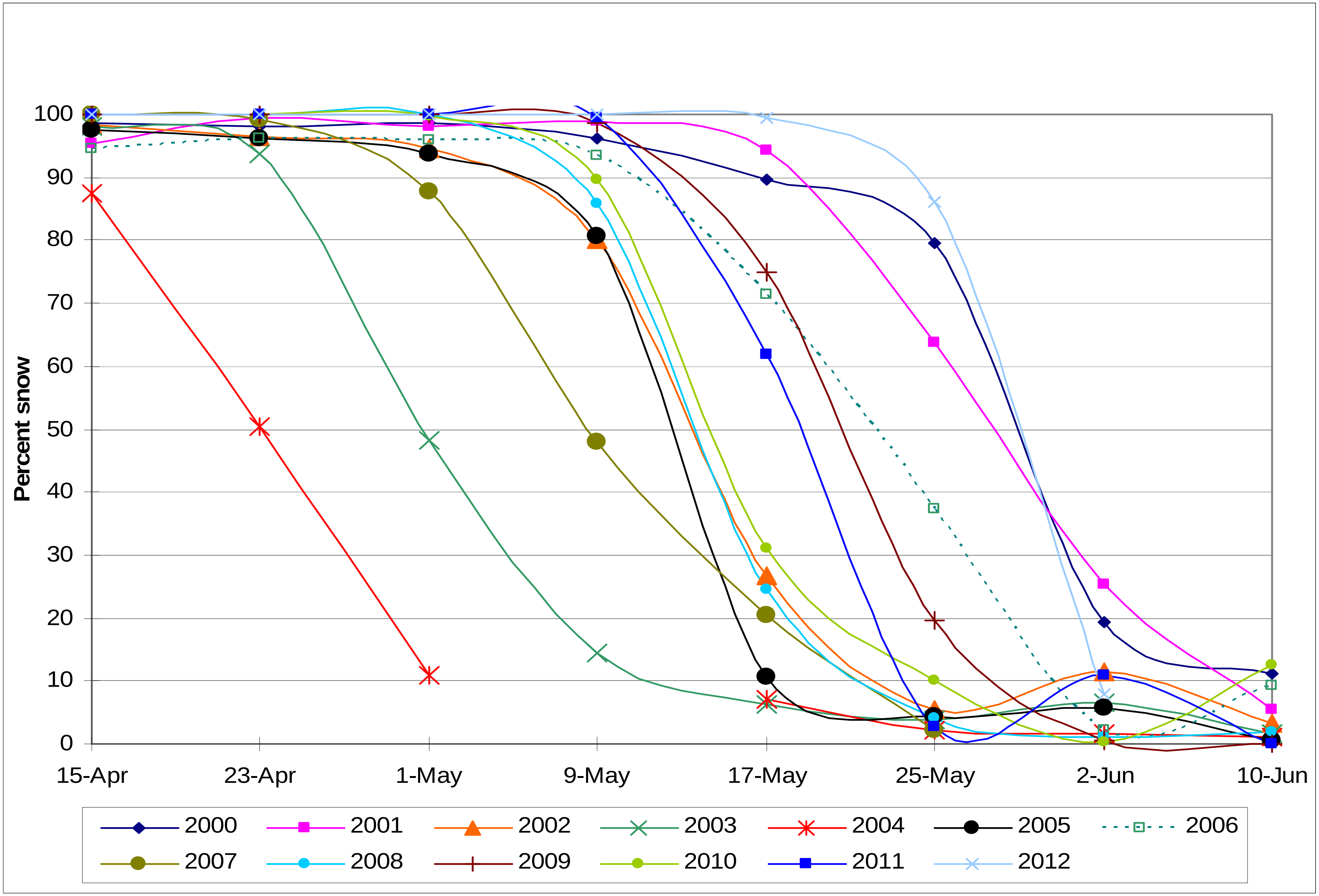
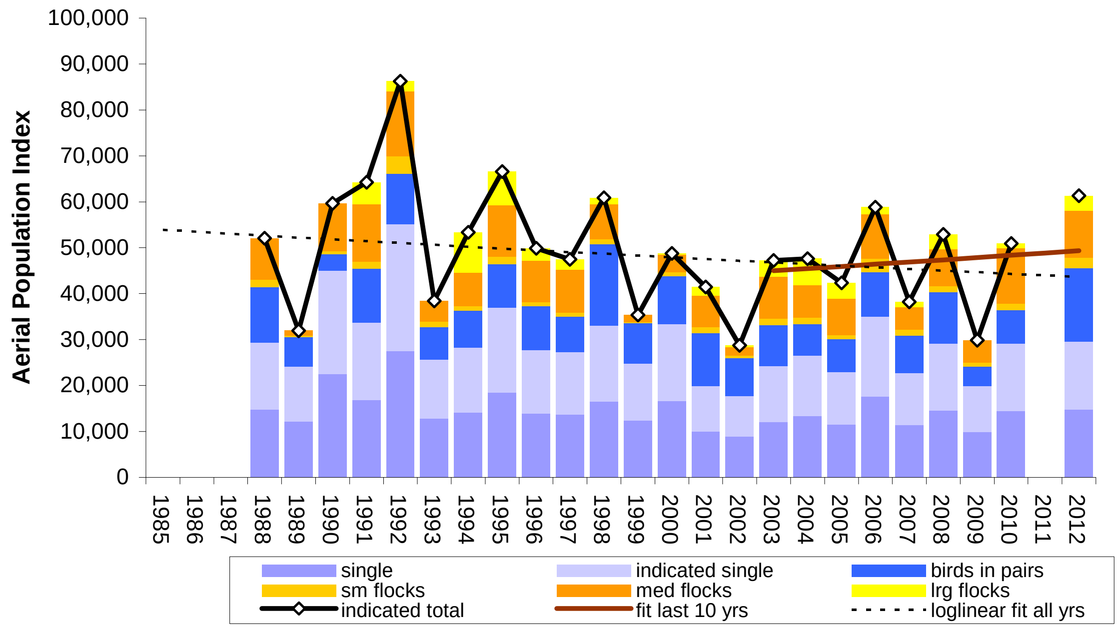


Figure 6. Percent snow cover for coastal zone survey area in spring and early winter from MODIS imagery (Hall et al. 2012) .

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



18 strata = 12,832 km^2 **Aerial index = Indicated Total birds**

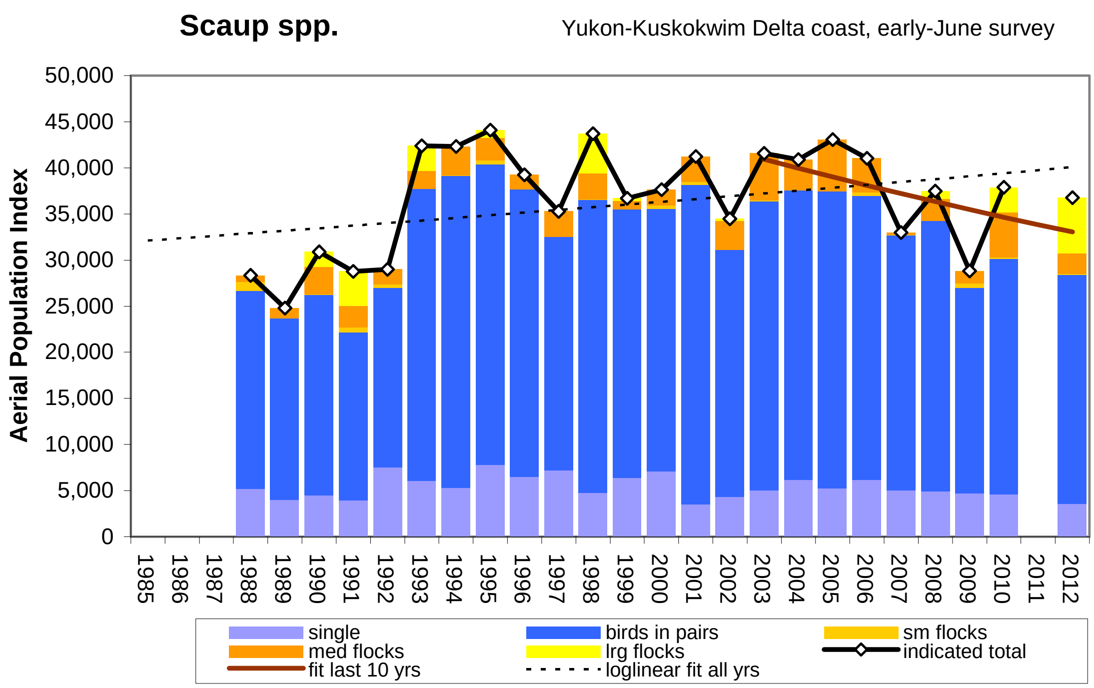
year	2*sg	2*npr	sm flk	md flk	lg flk	Index	StdErr
1985							
1986							
1987							
1988	29350	12109	1621	8972	0	**52052**	5916
1989	24168	6325	322	1148	0	**31962**	2842
1990	44941	3638	708	10377	0	**59663**	6490
1991	33658	11813	1486	12570	4724	**64250**	8719
1992	55085	11049	3819	14084	2235	**86272**	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

NOPI

Aerial index: Indicated total

n yrs =	24
mean index =	**49759**
std dev =	13279
std error =	2711
low 90%ci =	45300
high 90%ci =	54218
trend over all years :	
ln linear slope =	-0.008
SE ln slope =	0.0078
Growth Rate =	**0.992**
low 90%ci GR =	0.979
high 90%ci GR =	1.005
trend last 10 years :	
Growth Rate =	**1.010**
low 90%ci GR =	0.964
high 90%ci GR =	1.059
regression resid CV =	0.269
avg sampling err CV =	0.113
min yrs to detect -50%/20yr rate :	
w/ regression resid CV =	16.6
w/ sample error CV =	9.3

Figure 7. Population trend for Northern Pintail (*Anas acuta*) observed by a single rear-seat observer on aerial transects sampling 12,832 km^2 of the coastal Yukon-Kuskokwim Delta in western Alaska. The indicated total bird population index is the sum of birds observed as singles, an equal number of unseen single birds, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31+, indicated by column divisions from bottom to top. Average annual growth rate is calculated by log-linear regression. Power calculations use alpha set at p=0.10, beta set at p=0.20, and a coefficient of variation based on either regression residuals or sampling errors. The power to detect a significant trend can be compared among species as the estimated minimum number of years of data needed to detect a growth rate of -0.034, a 50% decline in 20 years, if it were to occur.



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

SCAU

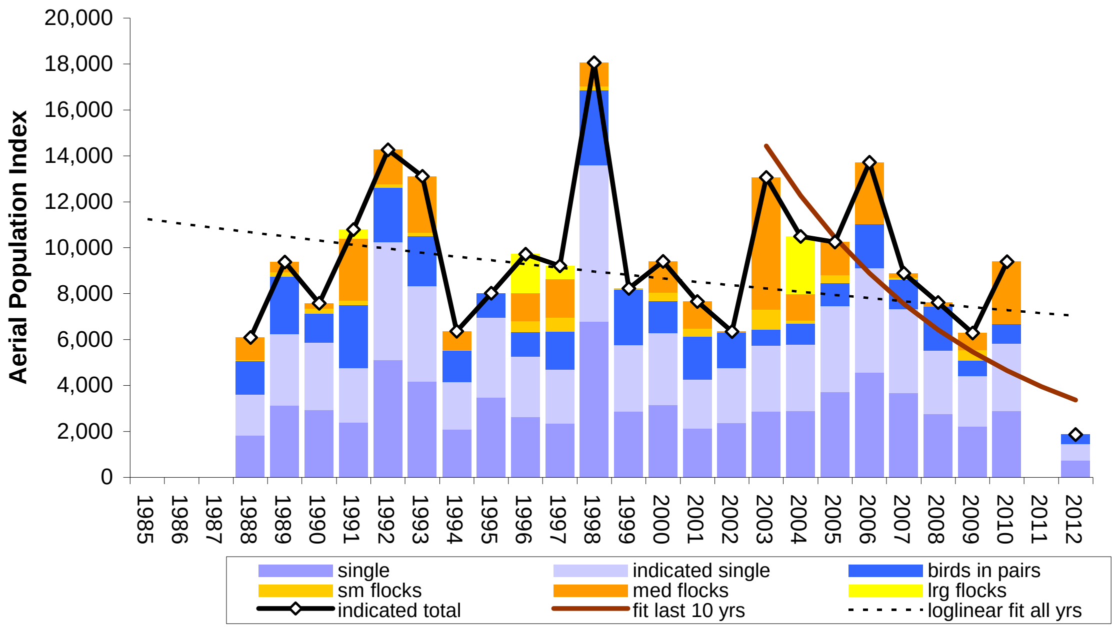
Aerial index: Indicated total

n yrs =	24
mean index =	**36637**
std dev =	5707
std error =	1165
low 90%ci =	34721
high 90%ci =	38554
trend over all years :	
ln linear slope =	0.0082
SE ln slope =	0.0046
Growth Rate =	**1.008**
low 90%ci GR =	1.001
high 90%ci GR =	1.016
trend last 10 years :	
Growth Rate =	**0.977**
low 90%ci GR =	0.954
high 90%ci GR =	0.999
regression resid CV =	0.158
avg sampling err CV =	0.104
min yrs to detect -50%/20yr rate :	
w/ regression resid CV =	11.6
w/ sample error CV =	8.8

Figure 8. Population trend for Unidentified Scaup, predominantly Greater Scaup (*Aythya marila*), observed by a single rear-seat observer on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta in western Alaska. The total bird population index is the sum of birds observed as singles, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31+, indicated by column divisions from bottom to top. Average annual growth rate is calculated by log-linear regression. Power calculations use alpha set at p=0.10, beta set at p=0.20, and a coefficient of variation based on either regression residuals or sampling errors. The power to detect a significant trend can be compared among species as the estimated minimum number of years of data needed to detect a growth rate of -0.034, a 50% decline in 20 years, if it were to occur.

Northern Shoveler

Yukon-Kuskokwim Delta coast, early-June survey



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

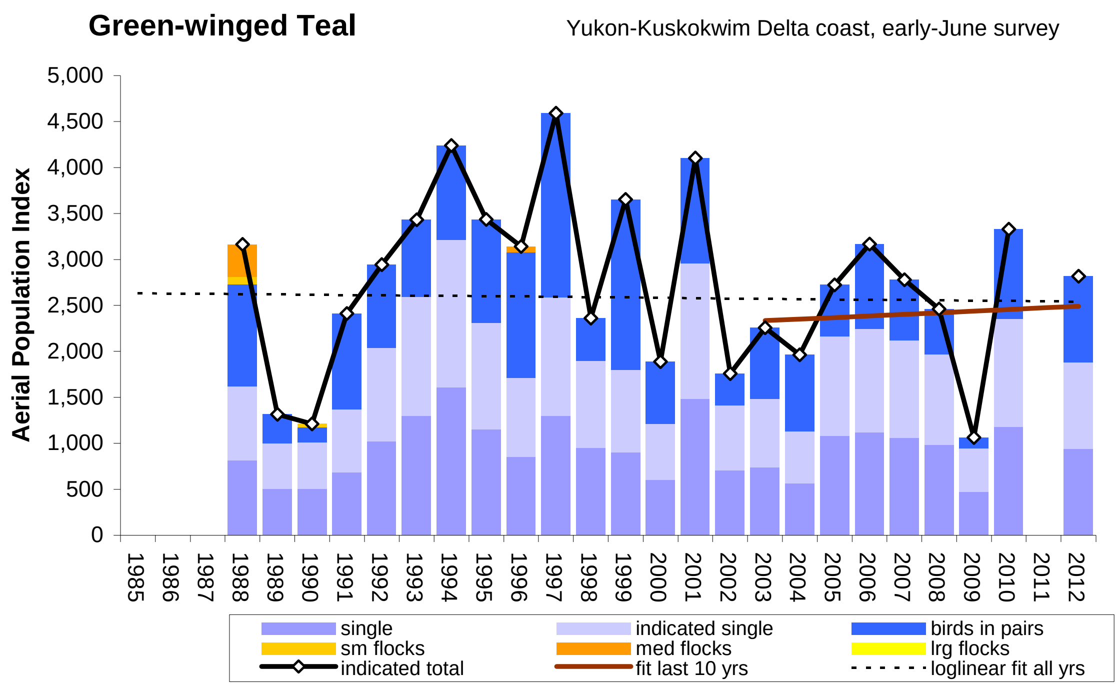
year	2*sg	2*npr	sm flk	md flk	lg flk	Index	StdErr
1985							
1986							
1987							
1988	3620	1442	42	982	0	**6085**	1180
1989	6250	2485	205	434	0	**9374**	1363
1990	5883	1260	205	226	0	**7574**	1210
1991	4755	2739	184	2704	410	**10791**	2136
1992	10233	2389	138	1502	0	**14263**	1951
1993	8326	2164	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

NSHO

Aerial index: Indicated total

n yrs =	24
mean index =	**9405**
std dev =	3347
std error =	683
low 90%ci =	8282
high 90%ci =	10529
trend over all years :	
ln linear slope =	-0.017
SE ln slope =	0.0124
Growth Rate =	**0.983**
low 90%ci GR =	0.963
high 90%ci GR =	1.003
trend last 10 years :	
Growth Rate =	**0.851**
low 90%ci GR =	0.787
high 90%ci GR =	0.919
regression resid CV =	0.425
avg sampling err CV =	0.179
min yrs to detect -50%/20yr rate :	
w/ regression resid CV =	22.5
w/ sample error CV =	12.7

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



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

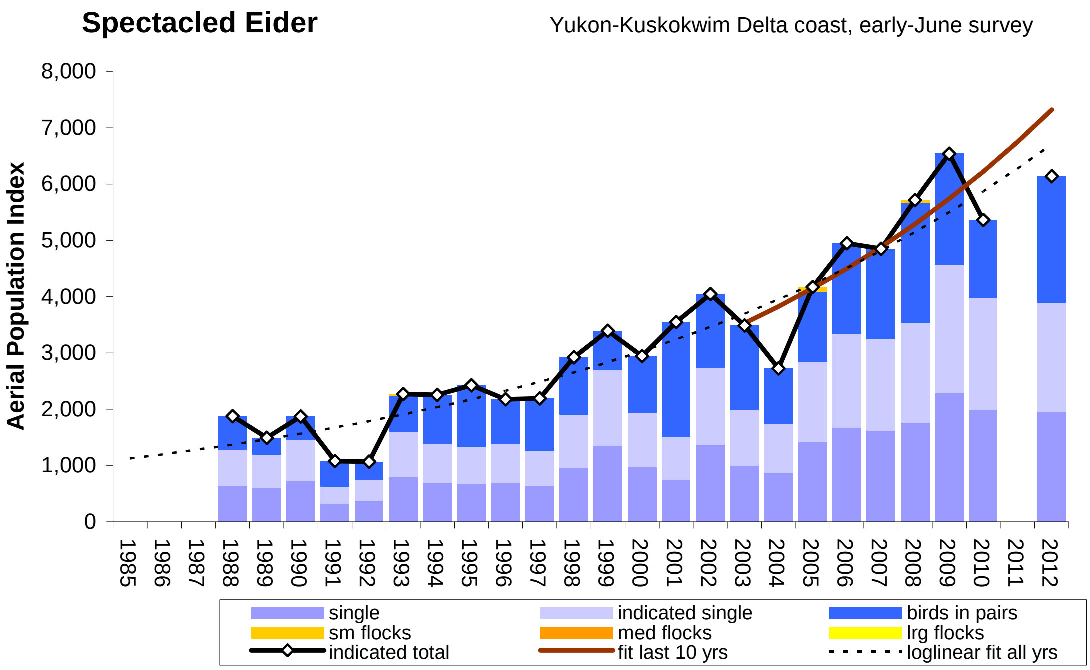
year	2*sg	2*npr	sm flk	md flk	lg flk	Index	StdErr
1985							
1986							
1987							
1988	1623	1105	82	354	0	**3163**	554
1989	1002	312	0	0	0	**1313**	328
1990	1007	164	41	0	0	**1212**	367
1991	1370	1042	0	0	0	**2412**	470
1992	2037	908	0	0	0	**2945**	472
1993	2595	836	0	0	0	**3431**	579
1994	3216	1023	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

AGWT

Aerial index: Indicated total	
n yrs =	24
mean index =	**2758**
std dev =	939
std error =	192
low 90%ci =	2443
high 90%ci =	3074
trend over all years :	
ln linear slope =	-0.001
SE ln slope =	0.0116
Growth Rate =	**0.999**
low 90%ci GR =	0.980
high 90%ci GR =	1.018
trend last 10 years :	
Growth Rate =	**1.007**
low 90%ci GR =	0.936
high 90%ci GR =	1.084
regression resid CV =	0.397
avg sampling err CV =	0.226
min yrs to detect -50%/20yr rate :	
w/ regression resid CV =	21.5
w/ sample error CV =	14.8

Figure 10. Population trend for Green-winged Teal (A*nas crecca*) observed by a single rear-seat observer on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta in western Alaska. The indicated total bird population index is the sum of birds observed as singles, an equal number of unseen single birds, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31+, indicated by column divisions from bottom to top. Average annual growth rate is calculated by log-linear regression. Power calculations use alpha set at p=0.10, beta set at p=0.20, and a coefficient of variation based on either regression residuals or sampling errors. The power to detect a significant trend can be compared among species as the estimated minimum number of years of data needed to detect a growth rate of -0.034, a 50% decline in 20 years, if it were to

occur.



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

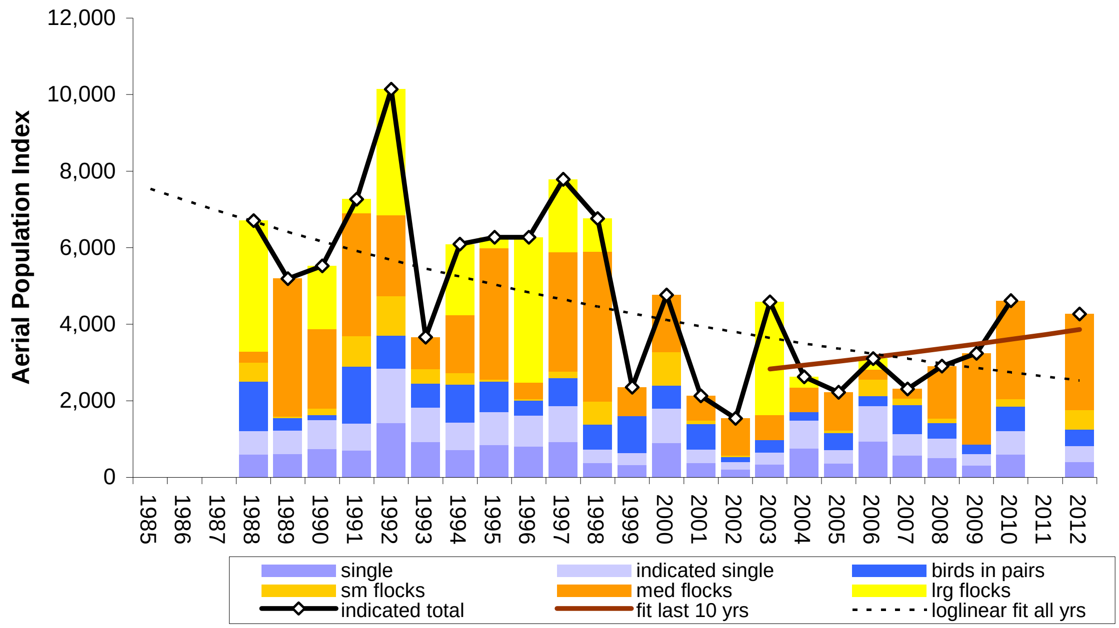
year	**2*sg**	**2*npr**	**sm flk**	**md flk**	**lg flk**	Index	StdErr
1985							
1986							
1987							
1988	1272	603	0	0	0	**1874**	349
1989	1187	303	0	0	0	**1490**	222
1990	1451	421	0	0	0	**1872**	284
1991	629	446	0	0	0	**1075**	222
1992	747	319	0	0	0	**1066**	180
1993	1589	640	42	0	0	**2272**	347
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

SPEI

Aerial index: Indicated total	
n yrs =	24
mean index =	**3312**
std dev =	1594
std error =	325
low 90%ci =	2777
high 90%ci =	3847
trend over all years :	
ln linear slope =	0.0661
SE ln slope =	0.0060
Growth Rate =	**1.068**
low 90%ci GR =	1.058
high 90%ci GR =	1.079
trend last 10 years :	
Growth Rate =	**1.085**
low 90%ci GR =	1.050
high 90%ci GR =	1.120
regression resid CV =	0.207
avg sampling err CV =	0.129
min yrs to detect -50%/20yr rate :	
w/ regression resid CV =	14.0
w/ sample error CV =	10.2

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

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



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

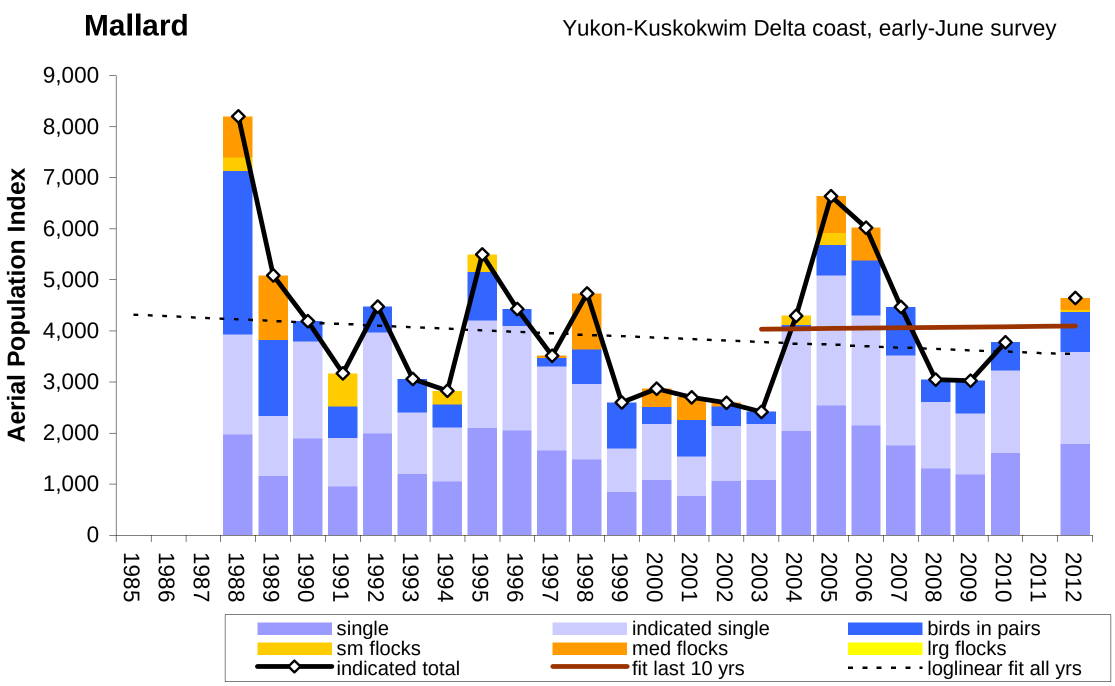
year	2*sg	2*npr	sm flk	md flk	lg flk	Index	StdErr
1985							
1986							
1987							
1988	1201	1311	480	297	3419	**6709**	3445
1989	1229	318	41	3605	0	**5192**	3102
1990	1493	141	171	2075	1644	**5524**	2261
1991	1403	1493	794	3211	369	**7270**	2235
1992	2841	864	1032	2111	3293	**10141**	2503
1993	1830	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

AMWI

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

n yrs =	24
mean index =	**4682**
std dev =	2179
std error =	445
low 90%ci =	3950
high 90%ci =	5414
<u>trend over all years :</u>	
ln linear slope =	-0.04
SE ln slope =	0.0120
Growth Rate =	**0.960**
low 90%ci GR =	0.942
high 90%ci GR =	0.979
<u>trend last 10 years :</u>	
Growth Rate =	**1.035**
low 90%ci GR =	0.979
high 90%ci GR =	1.094
regression resid CV =	0.410
avg sampling err CV =	0.369
<u>min yrs to detect -50%/20yr rate :</u>	
w/ regression resid CV =	22.0
w/ sample error CV =	20.5

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



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

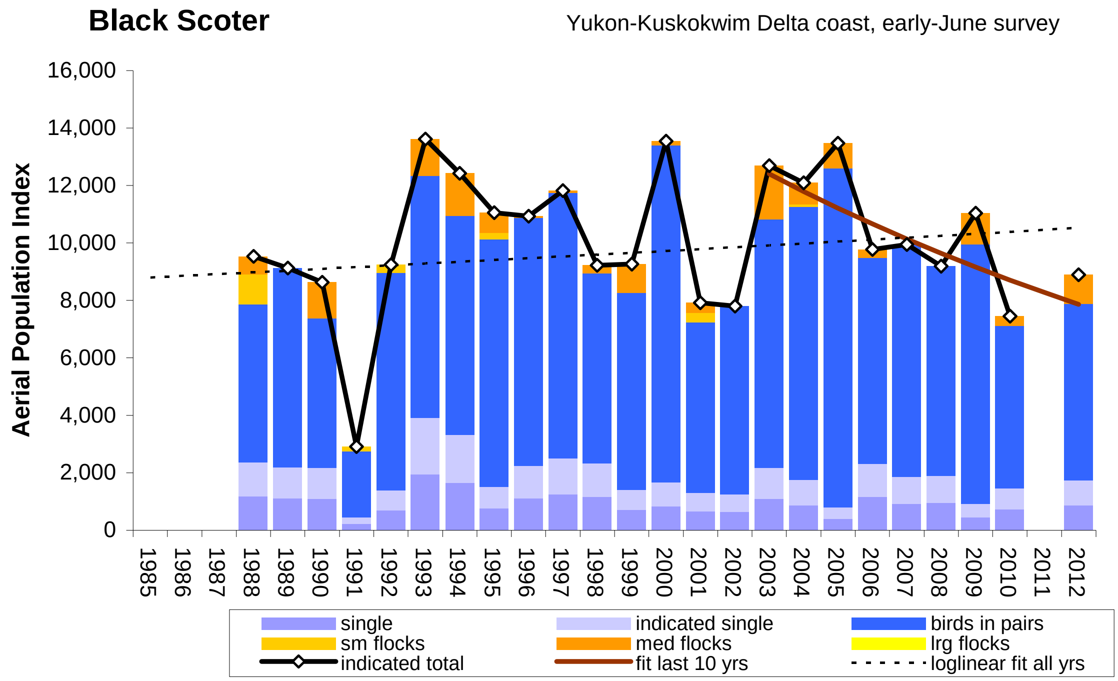
year	2*sg	2*npr	sm flk	md flk	lg flk	Index	StdErr
1985							
1986							
1987							
1988	3936	3200	266	800	0	**8202**	1205
1989	2334	1498	0	1258	0	**5090**	1593
1990	3790	401	0	0	0	**4191**	1091
1991	1907	615	649	0	0	**3171**	574
1992	3976	501	0	0	0	**4477**	867
1993	2403	658	0	0	0	**3061**	698
1994	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

MALL

Aerial index: Indicated total

n yrs =	24
mean index =	**4096**
std dev =	1447
std error =	295
low 90%ci =	3610
high 90%ci =	4581
trend over all years :	
ln linear slope =	-0.007
SE ln slope =	0.0097
Growth Rate =	**0.993**
low 90%ci GR =	0.977
high 90%ci GR =	1.009
trend last 10 years :	
Growth Rate =	**1.002**
low 90%ci GR =	0.934
high 90%ci GR =	1.074
regression resid CV =	0.332
avg sampling err CV =	0.217
min yrs to detect -50%/20yr rate :	
w/ regression resid CV =	19.1
w/ sample error CV =	14.4

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



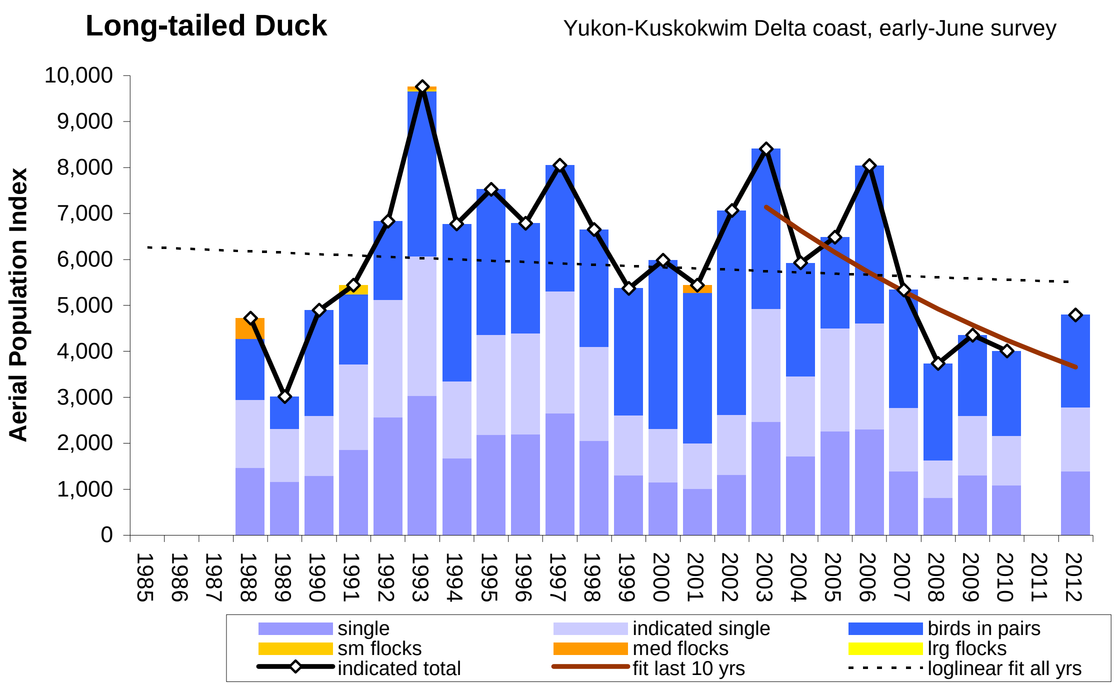
18 strata = 12,832 km² **Aerial index = Indicated Total birds**

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

BLSC
Aerial index: Indicated total

n yrs =	24
mean index =	**10067**
std dev =	2412
std error =	492
low 90%ci =	9257
high 90%ci =	10877
trend over all years :	
ln linear slope =	0.0066
SE ln slope =	0.0092
Growth Rate =	**1.007**
low 90%ci GR =	0.992
high 90%ci GR =	1.022
trend last 10 years :	
Growth Rate =	**0.951**
low 90%ci GR =	0.927
high 90%ci GR =	0.975
regression resid CV =	0.316
avg sampling err CV =	0.196
min yrs to detect -50%/20yr rate :	
w/ regression resid CV =	18.5
w/ sample error CV =	13.5

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



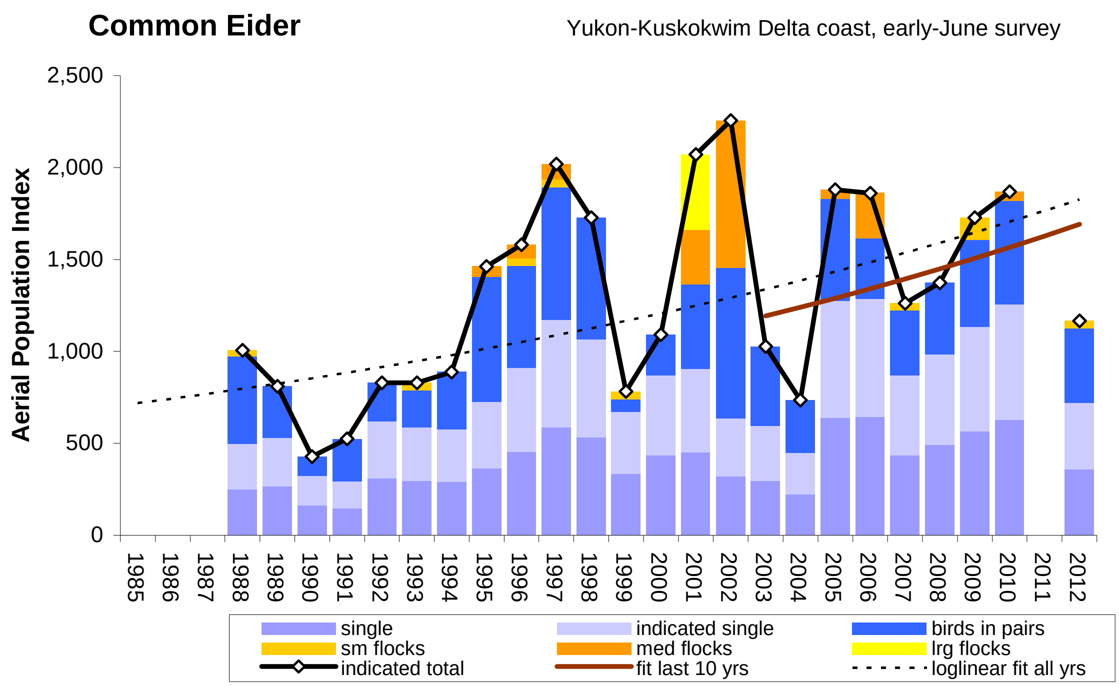
18 strata = 12,832 km^2 **Aerial index = Indicated Total birds**

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

LTDU

Aerial index: Indicated total	
n yrs =	24
mean index =	**6059**
std dev =	1625
std error =	332
low 90%ci =	5513
high 90%ci =	6605
trend over all years :	
ln linear slope =	-0.005
SE ln slope =	0.0083
Growth Rate =	**0.995**
low 90%ci GR =	0.982
high 90%ci GR =	1.009
trend last 10 years :	
Growth Rate =	**0.928**
low 90%ci GR =	0.891
high 90%ci GR =	0.967
regression resid CV =	0.284
avg sampling err CV =	0.148
min yrs to detect -50%/20yr rate :	
w/ regression resid CV =	17.2
w/ sample error CV =	11.2

Figure 15. Population trend for Long-tailed Duck (*Clangula hyemalis*) observed by a single rear-seat observer on aerial transects sampling 12,832 km^2 of the coastal Yukon-Kuskokwim Delta in western Alaska. The indicated total bird population index is the sum of birds observed as singles, an equal number of unseen single birds, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31+, indicated by column divisions from bottom to top. Average annual growth rate is calculated by log-linear regression. Power calculations use alpha set at p=0.10, beta set at p=0.20, and a coefficient of variation based on either regression residuals or sampling errors. The power to detect a significant trend can be compared among species as the estimated minimum number of years of data needed to detect a growth rate of -0.034, a 50% decline in 20 years, if it were to occur



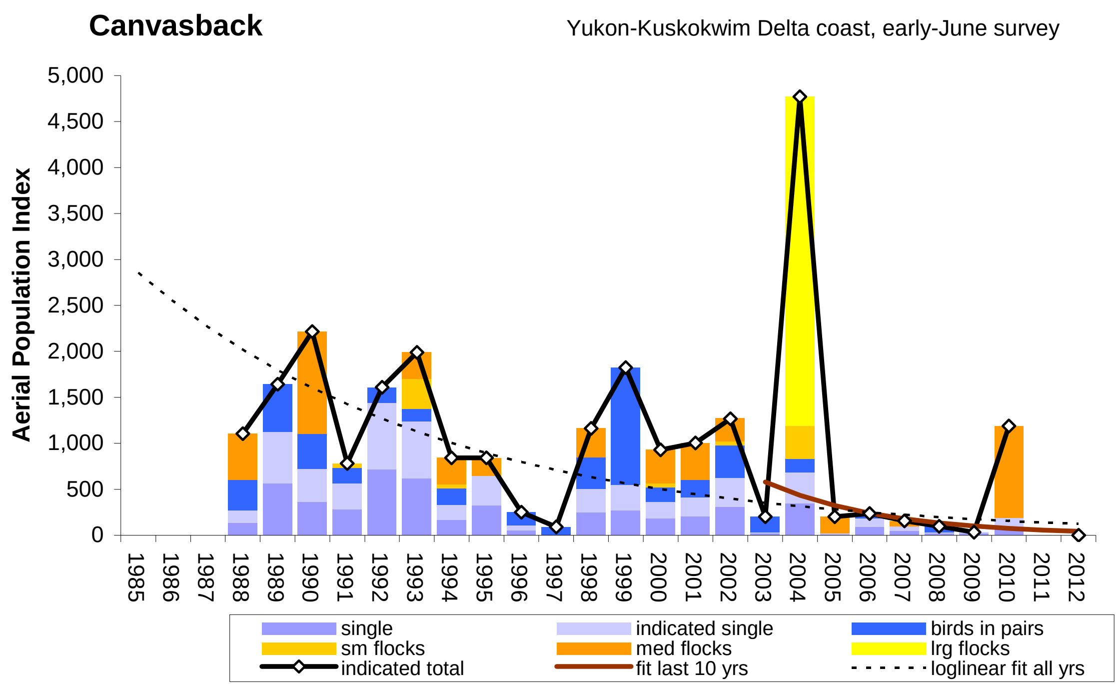
18 strata = 12,832 km² **Aerial index = Indicated Total birds**

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

COEI

Aerial index: Indicated total	
n yrs =	24
mean index =	**1300**
std dev =	532
std error =	109
low 90%ci =	1121
high 90%ci =	1479
trend over all years :	
ln linear slope =	0.0346
SE ln slope =	0.0113
Growth Rate =	**1.035**
low 90%ci GR =	1.016
high 90%ci GR =	1.055
trend last 10 years :	
Growth Rate =	**1.040**
low 90%ci GR =	0.975
high 90%ci GR =	1.109
regression resid CV =	0.388
avg sampling err CV =	0.234
min yrs to detect -50%/20yr rate :	
w/ regression resid CV =	21.2
w/ sample error CV =	15.2

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



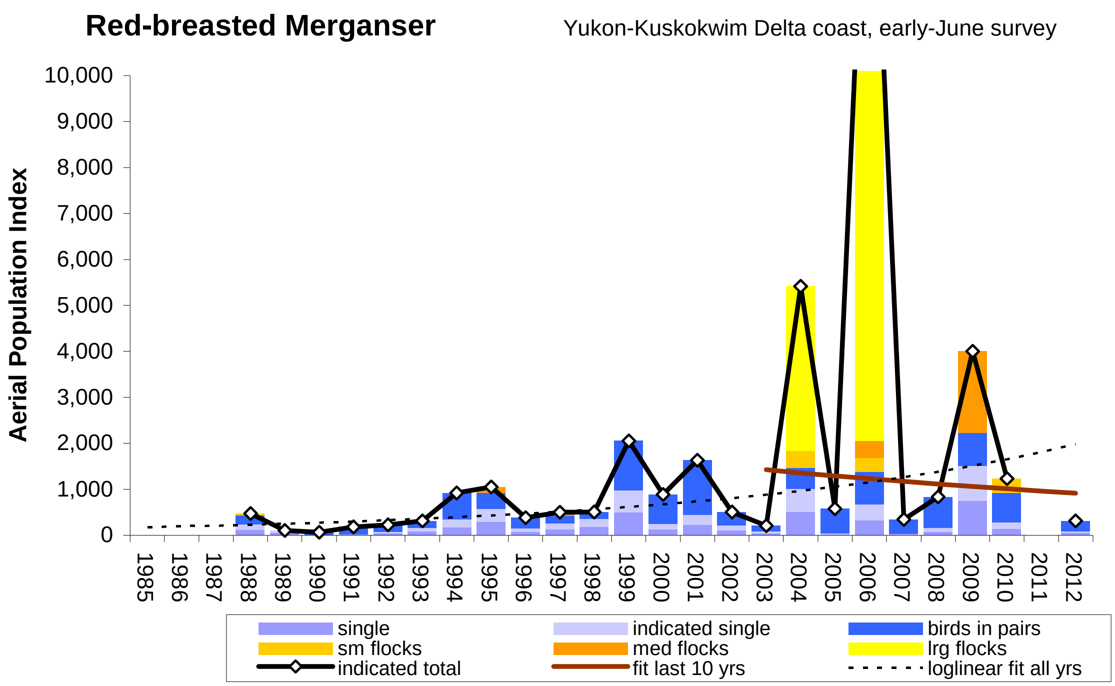
18 strata = 12,832 km² **Aerial index = Indicated Total birds**

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

CANV

Aerial index: Indicated total	
n yrs =	24
mean index =	**1019**
std dev =	1043
std error =	213
low 90%ci =	668
high 90%ci =	1369
trend over all years :	
ln linear slope =	-0.116
SE ln slope =	0.0339
Growth Rate =	**0.890**
low 90%ci GR =	0.842
high 90%ci GR =	0.941
trend last 10 years :	
Growth Rate =	**0.746**
low 90%ci GR =	0.551
high 90%ci GR =	1.010
regression resid CV =	1.164
avg sampling err CV =	0.577
min yrs to detect -50%/20yr rate :	
w/ regression resid CV =	44.1
w/ sample error CV =	27.6

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



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

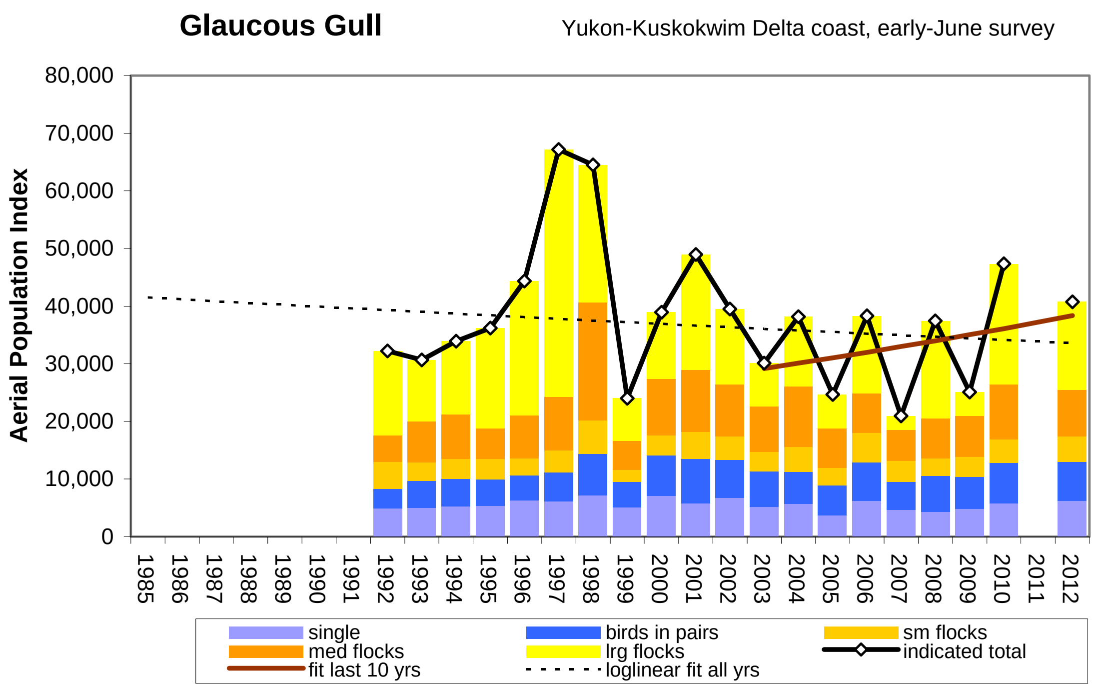
year	**2*sg**	**2*npr**	**sm flk**	**md flk**	**lg flk**	Index	StdErr
1985							
1986							
1987							
1988	236	197	41	0	0	**473**	195
1989	104	0	0	0	0	**104**	73
1990	0	66	0	0	0	**67**	68
1991	18	164	0	0	0	**182**	100
1992	74	152	0	0	0	**226**	78
1993	164	146	0	0	0	**310**	131
1994	344	572	0	0	0	**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

RBME

Aerial index: Indicated total

n yrs =	24
mean index =	**1664**
std dev =	3547
std error =	724
low 90%ci =	473
high 90%ci =	2855
trend over all years :	
ln linear slope =	0.0899
SE ln slope =	0.0322
Growth Rate =	**1.094**
low 90%ci GR =	1.038
high 90%ci GR =	1.154
trend last 10 years :	
Growth Rate =	**0.952**
low 90%ci GR =	0.694
high 90%ci GR =	1.306
regression resid CV =	1.106
avg sampling err CV =	0.467
min yrs to detect -50%/20yr rate :	
w/ regression resid CV =	42.6
w/ sample error CV =	24.0

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



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

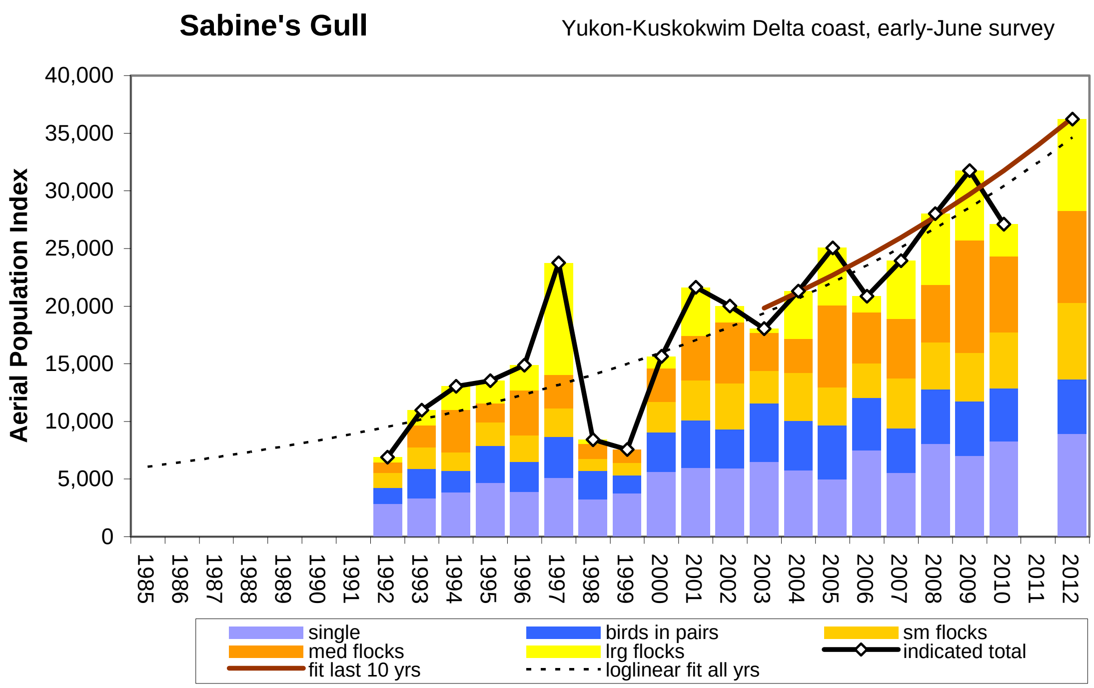
year	sg	2*npr	sm flk	md flk	lg flk	Index	StdErr
1985							
1986							
1987							
1988							
1989							
1990							
1991							
1992	4881	3480	4619	4636	14606	**32221**	6858
1993	4938	4726	3215	7136	10672	**30688**	5275
1994	5243	4790	3438	7730	12746	**33947**	5663
1995	5336	4633	3529	5284	17400	**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

GLGU

Aerial index: Indicated total

n yrs =	20
mean index =	**38170**
std dev =	12162
std error =	2719
low 90%ci =	33697
high 90%ci =	42644
trend over all years :	
ln linear slope =	-0.008
SE ln slope =	0.0119
Growth Rate =	**0.992**
low 90%ci GR =	0.973
high 90%ci GR =	1.012
trend last 10 years :	
Growth Rate =	**1.031**
low 90%ci GR =	0.976
high 90%ci GR =	1.089
regression resid CV =	0.311
avg sampling err CV =	0.173
min yrs to detect -50%/20yr rate :	
w/ regression resid CV =	18.3
w/ sample error CV =	12.4

Figure 19. Population trend for Glaucous Gull (*Larus hyperboreus)* observed by a single rear-seat observer on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta in western Alaska. The total observed bird population index is the sum of birds observed as singles, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31+, indicated by column divisions from bottom to top. Average annual growth rate is calculated by log-linear regression. Power calculations use alpha set at p=0.10, beta set at p=0.20, and a coefficient of variation based on either regression residuals or sampling errors. The power to detect a significant trend can be compared among species as the estimated minimum number of years of data needed to detect a growth rate of -0.034, a 50% decline in 20 years, if it were to occur.



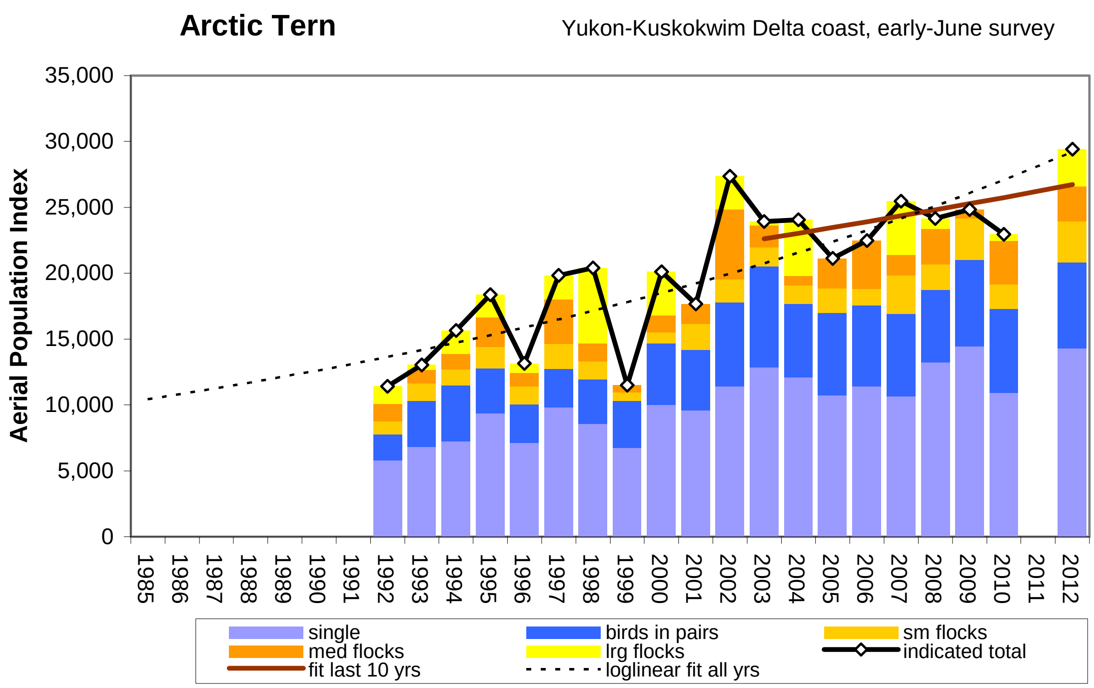
18 strata = 12,832 km² **Aerial index = Total birds**

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

SAGU

Aerial index: Indicated total	
n yrs =	20
mean index =	**19435**
std dev =	8114
std error =	1814
low 90%ci =	16450
high 90%ci =	22419
trend over all years :	
ln linear slope =	0.0645
SE ln slope =	0.0107
Growth Rate =	**1.067**
low 90%ci GR =	1.048
high 90%ci GR =	1.086
trend last 10 years :	
Growth Rate =	**1.070**
low 90%ci GR =	1.049
high 90%ci GR =	1.091
regression resid CV =	0.280
avg sampling err CV =	0.117
min yrs to detect -50%/20yr rate :	
w/ regression resid CV =	17.1
w/ sample error CV =	9.5

Figure 20. Population trend for Sabine's Gull (*Xema sabini)* observed by a single rear-seat observer on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta in western Alaska. The total observed bird population index is the sum of birds observed as singles, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31+, indicated by column divisions from bottom to top. Average annual growth rate is calculated by log-linear regression. Power calculations use alpha set at *p*=0.10, beta set at *p*=0.20, and a coefficient of variation based on either regression residuals or sampling errors. The power to detect a significant trend can be compared among species as the estimated minimum number of years of data needed to detect a growth rate of -0.034, a 50% decline in 20 years, if it were to occur.



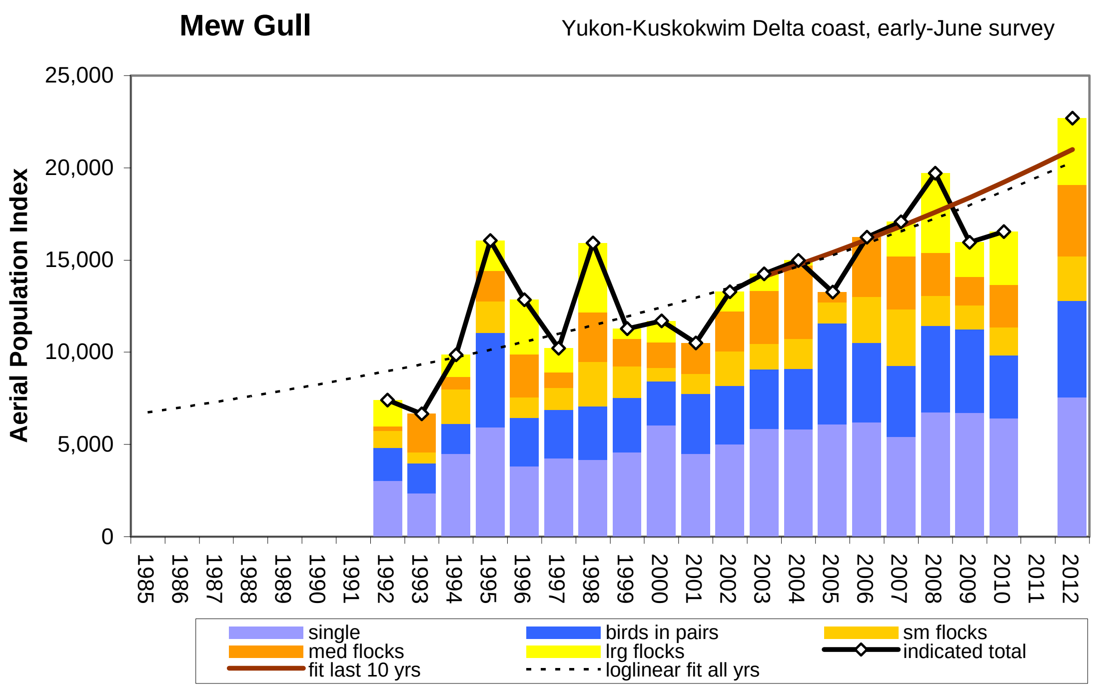
18 strata = 12,832 km² **Aerial index = Total birds**

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

ARTE

Aerial index: Indicated total	
n yrs =	20
mean index =	**20347**
std dev =	5271
std error =	1179
low 90%ci =	18408
high 90%ci =	22286
trend over all years :	
ln linear slope =	0.0381
SE ln slope =	0.0067
Growth Rate =	**1.039**
low 90%ci GR =	1.027
high 90%ci GR =	1.050
trend last 10 years :	
Growth Rate =	**1.019**
low 90%ci GR =	1.003
high 90%ci GR =	1.035
regression resid CV =	0.175
avg sampling err CV =	0.129
min yrs to detect -50%/20yr rate :	
w/ regression resid CV =	12.5
w/ sample error CV =	10.2

Figure 21. Population trend for Arctic Tern (*Sterna paradisaea)* observed by a single rear-seat observer on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta in western Alaska. The total observed bird population index is the sum of birds observed as singles, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31+, indicated by column divisions from bottom to top. Average annual growth rate is calculated by log-linear regression. Power calculations use alpha set at *p*=0.10, beta set at *p*=0.20, and a coefficient of variation based on either regression residuals or sampling errors. The power to detect a significant trend can be compared among species as the estimated minimum number of years of data needed to detect a growth rate of -0.034, a 50% decline in 20 years, if it were to occur.



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

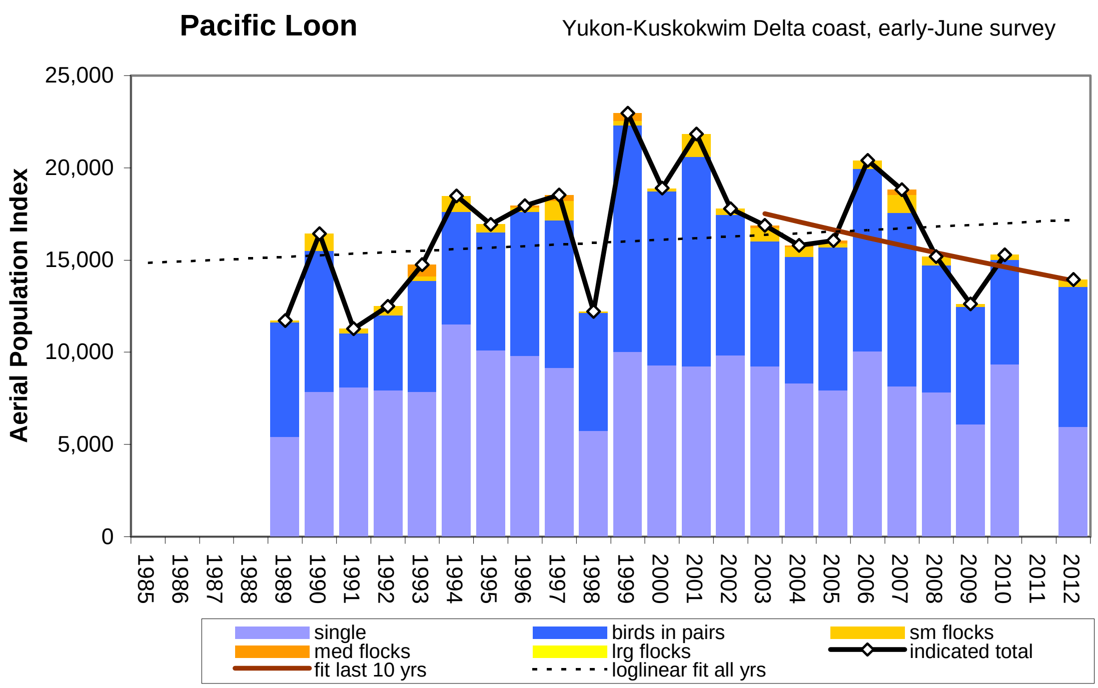
year	**sg**	**2*npr**	**sm flk**	**md flk**	**lg flk**	Index	StdErr
1985							
1986							
1987							
1988							
1989							
1990							
1991							
1992	3025	1792	934	238	1422	**7411**	1359
1993	2349	1634	591	2088	0	**6663**	1459
1994	4494	1626	1870	669	1207	**9866**	1368
1995	5915	5145	1695	1653	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

MEGU

Aerial index: Indicated total

n yrs =	20
mean index =	**13824**
std dev =	3955
std error =	884
low 90%ci =	12369
high 90%ci =	15279
trend over all years :	
ln linear slope =	0.0408
SE ln slope =	0.0072
Growth Rate =	**1.042**
low 90%ci GR =	1.029
high 90%ci GR =	1.054
trend last 10 years :	
Growth Rate =	**1.045**
low 90%ci GR =	1.023
high 90%ci GR =	1.068
regression resid CV =	0.189
avg sampling err CV =	0.158
min yrs to detect -50%/20yr rate :	
w/ regression resid CV =	13.2
w/ sample error CV =	11.7

Figure 22. Population trend for Mew Gull (*Larus canus*) observed by a single rear-seat observer on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta in western Alaska. The total observed bird population index is the sum of birds observed as singles, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31+, indicated by column divisions from bottom to top. Average annual growth rate is calculated by log-linear regression. Power calculations use alpha set at p=0.10, beta set at p=0.20, and a coefficient of variation based on either regression residuals or sampling errors. The power to detect a significant trend can be compared among species as the estimated minimum number of years of data needed to detect a growth rate of -0.034, a 50% decline in 20 years, if it were to occur.



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

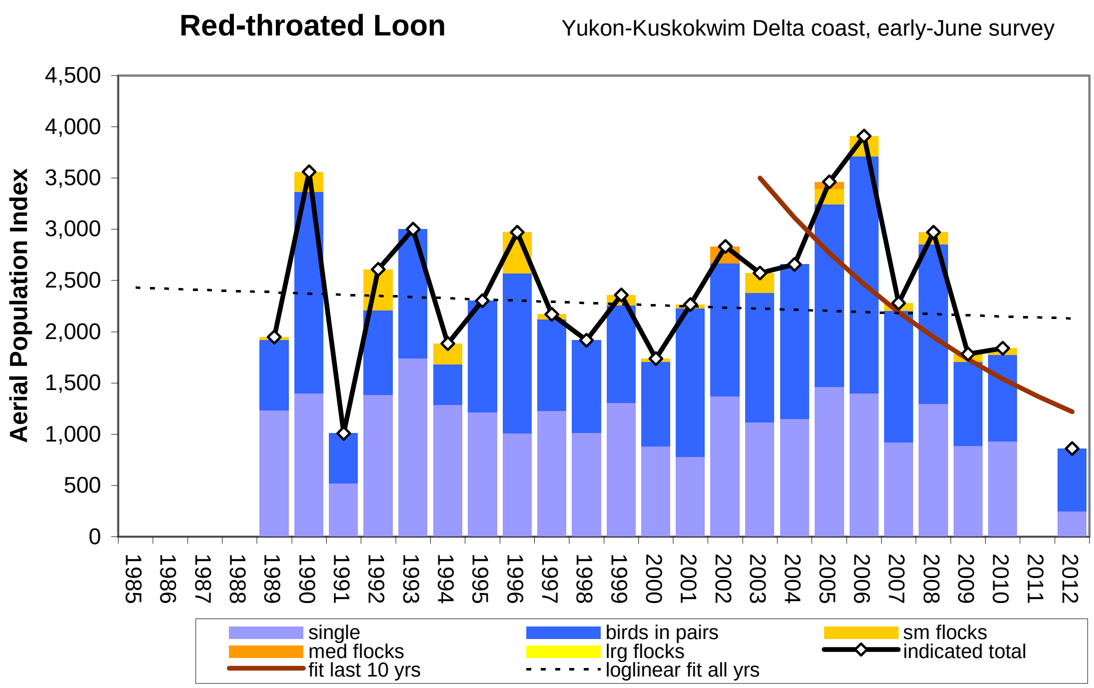
year	sg	2*npr	sm flk	md flk	lg flk	Index	StdErr
1985							
1986							
1987							
1988							
1989	5408	6215	90	0	0	**11712**	1317
1990	7861	7628	943	0	0	**16432**	1710
1991	8096	2928	257	0	0	**11281**	969
1992	7925	4069	500	0	0	**12495**	979
1993	7849	6037	222	652	0	**14759**	1298
1994	11527	6104	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

PALO

Aerial index: Indicated total

n yrs =	23
mean index =	**16403**
std dev =	3175
std error =	662
low 90%ci =	15314
high 90%ci =	17492
trend over all years :	
ln linear slope =	0.0054
SE ln slope =	0.0062
Growth Rate =	**1.005**
low 90%ci GR =	0.995
high 90%ci GR =	1.016
trend last 10 years :	
Growth Rate =	**0.975**
low 90%ci GR =	0.949
high 90%ci GR =	1.000
regression resid CV =	0.198
avg sampling err CV =	0.090
min yrs to detect -50%/20yr rate :	
w/ regression resid CV =	13.6
w/ sample error CV =	8.0

Figure 23. Population trend for Pacific Loon (*Gavia pacifica*) observed by a single rear-seat observer on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta in western Alaska. The total observed bird population index is the sum of birds observed as singles, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31+, indicated by column divisions from bottom to top. Average annual growth rate is calculated by log-linear regression. Power calculations use alpha set at *p*=0.10, beta set at *p*=0.20, and a coefficient of variation based on either regression residuals or sampling errors. The power to detect a significant trend can be compared among species as the estimated minimum number of years of data needed to detect a growth rate of -0.034, a 50% decline in 20 years, if it were to occur.



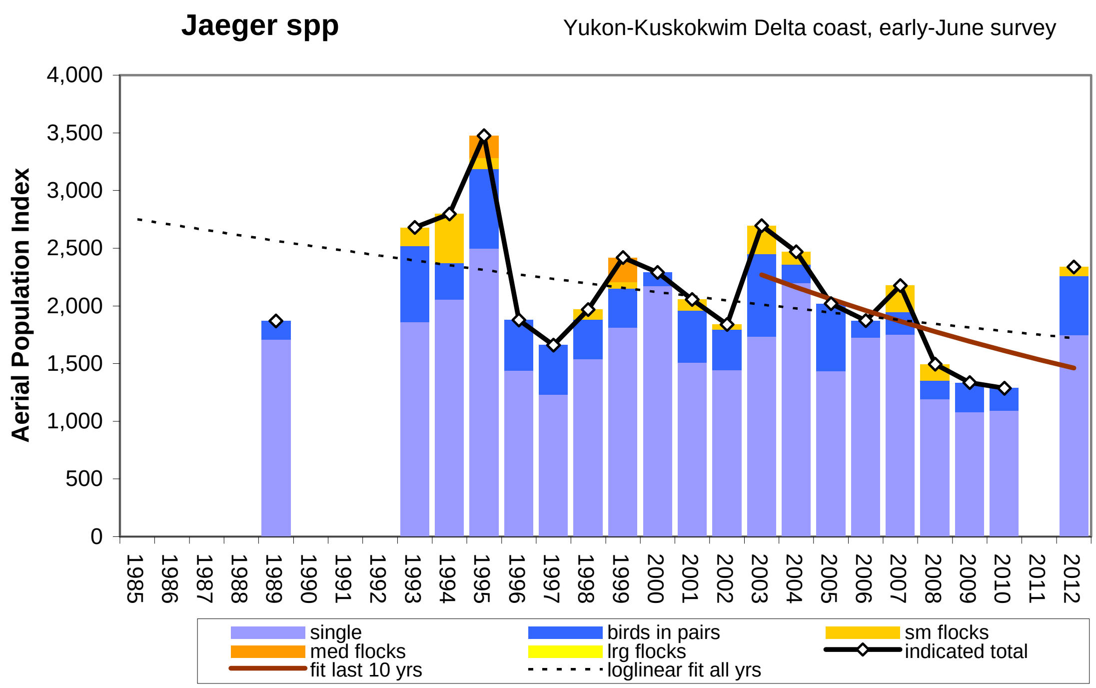
18 strata = 12,832 km² **Aerial index = Total birds**

year	sg	2*npr	sm flk	md flk	lg flk	Index	StdErr
1985							
1986							
1987							
1988							
1989	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

RTLO

Aerial index: Indicated total	
n yrs =	23
mean index =	**2388**
std dev =	749
std error =	156
low 90%ci =	2131
high 90%ci =	2644
trend over all years :	
ln linear slope =	-0.005
SE ln slope =	0.0114
Growth Rate =	**0.995**
low 90%ci GR =	0.977
high 90%ci GR =	1.014
trend last 10 years :	
Growth Rate =	**0.889**
low 90%ci GR =	0.836
high 90%ci GR =	0.946
regression resid CV =	0.368
avg sampling err CV =	0.164
min yrs to detect -50%/20yr rate :	
w/ regression resid CV =	20.5
w/ sample error CV =	11.9

Figure 24. Population trend for Red-throated Loon (*Gavia stellata*) observed by a single rear-seat observer on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta in western Alaska. The total observed bird population index is the sum of birds observed as singles, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31+, indicated by column divisions from bottom to top. Average annual growth rate is calculated by log-linear regression. Power calculations use alpha set at p=0.10, beta set at p=0.20, and a coefficient of variation based on either regression residuals or sampling errors. The power to detect a significant trend can be compared among species as the estimated minimum number of years of data needed to detect a growth rate of -0.034, a 50% decline in 20 years, if it were to occur.



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

JAEG

Aerial index: Indicated total	
n yrs =	20
mean index =	**2131**
std dev =	535
std error =	120
low 90%ci =	1934
high 90%ci =	2328
trend over all years :	
ln linear slope =	-0.017
SE ln slope =	0.0085
Growth Rate =	**0.983**
low 90%ci GR =	0.969
high 90%ci GR =	0.997
trend last 10 years :	
Growth Rate =	**0.952**
low 90%ci GR =	0.907
high 90%ci GR =	1.000
regression resid CV =	0.232
avg sampling err CV =	0.173
min yrs to detect -50%/20yr rate :	
w/ regression resid CV =	15.1
w/ sample error CV =	12.4

Figure 25. Population trend for Jaeger spp (*Stercorarius parasiticus, S. longicauda, S. pomarinus*) observed by a single rear-seat observer on aerial transects sampling 12,832 km² of the coastal Yukon-Kuskokwim Delta in western Alaska. The total observed bird population index is the sum of birds observed as singles, birds in pairs, and all birds in flocks of 3-5, 6-30, and 31+, indicated by column divisions from bottom to top. Average annual growth rate is calculated by log-linear regression. Power calculations use alpha set at p=0.10, beta set at p=0.20, and a coefficient of variation based on either regression residuals or sampling errors. The power to detect a significant trend can be compared among species as the estimated minimum number of years of data needed to detect a growth rate of -0.034, a 50% decline in 20 years, if it were to occur.

Table 1. Number of birds sighted by category and expanded numbers for waterbirds counted by the right-rear-seat observer on the June 2012 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 km2 and sampled area = 466.4 km2. Number of transects (n) = 221. 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	641	301	601	2,485	4.78	61,307	11,225	3.05	**186,986**
Greater scaup	114	391	187	1,083	2.87	36,764	5,451	1.93	**70,955**
American green-winged teal	18	10	0	56	0.22	2,818	686	8.36	**23,558**
Spectacled eider	229	121	0	700	0.48	6,138	504	3.58	**21,974**
Mallard	55	18	12	158	0.36	4,644	1,073	4.01	**18,622**
American wigeon	12	7	76	114	0.33	4,268	1,941	3.84	**16,389**
Black scoter	21	82	23	229	0.69	8,896	1,740	1.17	**10,408**
Long-tailed duck	44	42	0	172	0.37	4,793	823	1.87	**8,963**
Northern shoveler	22	6	0	56	0.15	1,867	495	3.79	**7,076**
Common eider	49	20	5	143	0.09	1,166	211	3.58	**4,174**
Red-breasted merganser	2	8	0	20	0.02	308	117	1.27	**391**
Glaucous gull	475	266	2,563	3,570	3.18	**40,744**	5,462	unknown	n/a
Sabine's gull	819	226	2,392	3,663	2.82	**36,224**	3,722	unknown	n/a
Arctic tern	726	195	332	1,448	2.29	**29,427**	2,964	unknown	n/a
Mew gull	508	167	975	1,817	1.77	**22,700**	3,063	unknown	n/a
Pacific loon	254	143	18	558	1.09	**13,946**	1,311	unknown	n/a
Jaeger species	53	10	3	76	0.18	**2,337**	352	unknown	n/a
Red-throated loon	19	19	0	57	0.07	**860**	211	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 2010 and from the long-term average (1988-2010), sorted in decreasing order of percent change from long-term average, first for waterfowl and then for other species.

Species	Population estimate 2010	Population estimate 2012	Change between 2010 and 2012	Long term (1988-2010) average population estimate	Change between 2012 and long term average
Spectacled eider	19,196	21,974	14%	11,857	85%
Northern pintail	155,184	186,986	20%	151,765	23%
Mallard	15,142	18,622	23%	16,425	13%
Green-winged teal	27,822	23,558	-15%	23,057	2%
Greater scaup	73,151	70,955	-3%	70,709	0%
American wigeon	17,737	16,389	-8%	17,979	-9%
Common eider	6,691	4,174	-38%	4,654	-10%
Black scoter	8,717	10,408	19%	11,778	-12%
Long-tailed duck	7,502	8,963	19%	11,330	-21%
Northern shoveler	35,573	7,076	-80%	35,645	-80%
Red-breasted merganser	1,563	391	-75%	2,113	-81%
Canvasback	2,884	0	-100%	2,476	-100%
Sabine's gull	27,104	36,224	34%	19,435	86%
Mew gull	16,544	22,700	37%	13,824	64%
Arctic tern	22,958	29,427	28%	20,347	45%
Jaeger spp.	1,287	2,337	82%	2,131	10%
Glaucous gull	47,334	40,744	-14%	38,170	7%
Pacific loon	15,286	13,946	-9%	16,403	-15%
Red-throated loon	1,839	860	-53%	2,388	-64%

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 2012. Other species have been added to the survey as indicated. Geographic stratification into 18 regions represents a balance determined by sampling intensity, similar physiographic areas, and reasonable gains in precision for most of the species. Green-shaded cells indicate growth rates significantly above 1.0 and yellow-shaded cells indicate significantly declining trends.

Fig. #	Species	N of yrs	Average pop. Index	Std dev pop. Index	Log-linear slope	SE slope	**Growth Rate**	Low 90%CI GR	High 90%CI GR	CV regress resids	CV sampling error	Yrs. to detect change: Residuals CV	Yrs. to detect change: Sample error CV	**Growth rate last 10 yrs.**	Low 90%CI GR last 10 yrs.	High 90%CI GR last 10 yrs.
7	Northern pintail	23	**49257**	13342	-0.0122	0.0083	**0.988**	0.975	1.001	0.262	0.110	16.3	9.2	**1.005**	0.968	1.043
8	Greater scaup	23	**36632**	5835	0.0093	0.0050	**1.009**	1.001	1.018	0.160	0.099	11.8	8.5	**0.981**	0.960	1.002
9	Northern Shoveler	23	**9733**	3002	-0.0003	0.0093	**1.000**	0.984	1.015	0.296	0.176	17.7	12.5	**0.993**	0.952	1.036
10	Green-winged teal	23	**2756**	960	-0.0026	0.0127	**0.997**	0.977	1.018	0.406	0.225	21.8	14.8	**0.994**	0.935	1.057
11	Spectacled eider	23	**3189**	1509	0.0673	0.0066	**1.070**	1.058	1.081	0.211	0.131	14.1	10.3	**1.073**	1.046	1.100
12	American wigeon	23	**4700**	2227	-0.0471	0.0126	**0.954**	0.934	0.974	0.401	0.365	21.7	20.4	**1.020**	0.962	1.082
13	Mallard	23	**4072**	1474	-0.0108	0.0105	**0.989**	0.972	1.006	0.333	0.217	19.2	14.4	**1.036**	0.982	1.093
14	Black scoter	23	**10118**	2453	0.0088	0.0101	**1.009**	0.992	1.026	0.321	0.196	18.7	13.5	**0.983**	0.949	1.019
15	Long-tailed duck	23	**6114**	1638	-0.0030	0.0091	**0.997**	0.982	1.012	0.289	0.147	17.4	11.1	**0.952**	0.919	0.986
16	Common eider	23	**1306**	543	0.0403	0.0120	**1.041**	1.021	1.062	0.382	0.237	21.0	15.3	**1.017**	0.960	1.077
17	Canvasback	23	**1062**	1045	-0.0926	0.0347	**0.912**	0.861	0.965	1.107	0.577	42.6	27.6	**0.807**	0.657	0.991
18	Red-breasted merganser	23	**1723**	3615	0.1138	0.0326	**1.120**	1.062	1.182	1.040	0.471	40.9	24.1	**1.085**	0.878	1.339
19	Glaucous gull	19	**38035**	12479	-0.0115	0.0132	**0.989**	0.967	1.010	0.315	0.176	18.5	12.5	**0.978**	0.927	1.031
20	Sabine's gull	19	**18551**	7281	0.0636	0.0121	**1.066**	1.045	1.087	0.288	0.117	17.4	9.6	**1.047**	1.027	1.068
21	Arctic tern	19	**19869**	4950	0.0380	0.0076	**1.039**	1.026	1.052	0.180	0.131	12.7	10.3	**1.012**	0.990	1.034
22	Mew gull	19	**13357**	3451	0.0387	0.0081	**1.039**	1.026	1.053	0.193	0.159	13.3	11.7	**1.047**	1.027	1.068
23	Pacific loon	22	**16515**	3203	0.0083	0.0066	**1.008**	0.997	1.019	0.196	0.089	13.5	8.0	**0.968**	0.945	0.992
24	Red-throated loon	22	**2457**	686	0.0079	0.0102	**1.008**	0.991	1.025	0.304	0.160	18.0	11.8	**0.972**	0.929	1.017
25	Jaeger spp.	19	**2120**	548	-0.0228	0.0089	**0.977**	0.963	0.992	0.224	0.176	14.7	12.5	**0.942**	0.912	0.973