

Aerial Photographic Survey of Brant Colonies on the Yukon-Kuskokwim Delta, Alaska, 2014

HEATHER M. WILSON, U.S. Fish and Wildlife Service, Migratory Bird Management, Waterfowl Management Branch, 1011 East Tudor Road, Anchorage, AK 99503, USA. December 2014.

ABSTRACT An aerial photographic survey of nesting Pacific black brant (*Branta bernicla nigricans*) was conducted at the five primary colonies on the Yukon-Kuskokwim Delta (YKD), Alaska, USA: Kokechik Bay (KB), Tutakoke River (TR), Kigigak Island (KI), Baird Peninsula (BP), and Baird Island (BI), between 5-6 June 2014. As indicated by the photos, total estimated number of nests for all colonies (9,251) was 29% higher in 2014 than in 2013 (7,183), but 9% lower than the 3-yr running average (10,210, 2012-2014), and 40% lower than the long term average (15,273; 1992-2013). The 2014 YKD colony nest population estimate also fell below the productivity benchmark outlined by the Pacific Flyway (>50% below the 1993-2000 average of 19,683 nests). All colonies except BI experienced increases in brant nests in 2014 (range: 36 to 66%). However, the overall trend in annual YKD estimates of nesting brant among the five primary colonies continues to be negative ($\lambda = 0.963$; Fig. 4). Moreover, the long-term trends at TR and KB (including 2014) marked the seventh consecutive year of substantial negative departures from the long-term YKD colony trend (e.g., 5.3% annual declines at TR and KB versus 3.6% annual decline for all colonies), suggesting that most of the long term decline continues to be attributed to reductions at KB and TR. Based on aerial imagery, 2014 reflected only a moderate nesting year for colonial nesting brant on the YKD, despite early breeding opportunities (i.e., breeding grounds were snow-free upon arrival and nest initiation occurred ~5 days earlier than average: 1985-2013). Further, there were few indications of fox predation and/or flooding from either the imagery survey or observations from field researchers. However, human activity (based on numbers of photos with footprints and vehicle tracks at locations without researchers) was markedly increased at the Baird colonies in 2014, particularly Baird Island, where both boot and dog prints were observed. Human presence at Kokechik Bay remained relatively low and stable. Eider nests in the colonies reached historic lows in 2014 and have been precipitously declining since 2005 ($\lambda = 0.67$ SE: 0.10). Common eiders nest sympatrically with brant and likely benefit from associated predator swamping, or conversely suffer as brant colonies decline.

KEY WORDS aerial photographic survey, nesting colonies, Pacific black brant, Yukon-Kuskokim Delta

During the mid-1980's, declining numbers of nesting Pacific black brant (*Branta bernicla nigricans*) on the Yukon-Kuskokwim Delta (YKD), Alaska (Sedinger et al. 1993) generated interest in developing an efficient method to estimate the number of individuals nesting in large colonies. Previously, ground crews surveyed colonies with strip transects or circular plots (Byrd et al. 1982, J. Sedinger unpubl. data). However, due to high nest densities and large areas associated with colonies, labor intensive ground-plots were considered impractical and visual counts from aircraft were thought to be too imprecise for estimating colony size. Alternatively, aerial imagery was tested (Anthony et al. 1995), and beginning in 1992, aerial videographic surveys were conducted annually at the 5 major brant nesting colonies on the YKD (Anthony 1992-2003; Fig. 1). In 2004, the survey methodology changed from videography (i.e., using a digital camcorder) to still-frame, digital photography (Anthony 2004-2006). The goal of these surveys is to

establish YKD colony nest estimates to help guide population recovery efforts for Pacific black brant, including annual harvest guidelines (Pacific Flyway Council 2002). Additionally, data collected from photographic surveys provides information on human use of colony areas, relative nest densities of other species (e.g., cackling goose; *Branta hutchinsii minima*), and can inform studies of habitat change. Herein, I report the results of the 2014 survey.

STUDY AREA

Aerial photographic surveys of nesting Pacific black brant were conducted at the five primary colonies currently recognized on the YKD, Alaska, USA (Fig. 1): Kokechik Bay (KB; 165°56'59W, 61°38'51N), Tutakoke River (TR; 165°36'59W, 61°14'N), Kigigak Island (KI; 165°00'36W, 60°50'N), Baird Peninsula (BP; 164°41'16W, 60°53'N), and Baird Island (BI; 164°36'18W, 60°50'33N), on 5-6 June 2014.

METHODS

Aerial Survey

A single, vertically-mounted Nikon D700 SLR® digital still camera with an image-stabilizing lens (70-200 mm) was used to photograph colonies from within the aircraft. The Nikon D700 camera had a 12.1-megapixel FX-format CMOS 23.9 x 36 mm photo sensor and sampled non-overlapping 0.12-hectare (41.8 x 27.9 m) ground footprints through a hole in the floor of the Cessna 206 float-equipped aircraft (N740). The camera was set to maximum shutter speed with an aperture of f2.8, focal length of 105-mm, and auto-focused at survey altitude.

Sampling protocol was similar to that in previous years, where systematically spaced flight lines (200 m apart) were flown along the long axis of all colonies (Anthony 2003-2006). Transects were flown at 122 m (400 ft) above ground level, at ground speeds ranging from 70-80 kts, in a float-equipped Cessna 206 (N740). Most transects were flown into the wind, with ~10° of flaps deployed. Flying transects into the winds helps slow the aircraft and maximize the number and quality of photos that can be taken on each transect. In 2014, photography of KB, TR, KI, BP, and BI required 0:31 (hours:minutes), 1:12, 0:45, 0:62, and 0:38, respectively, from start of first transect to end of last transect. Surveys at all colonies except BP were conducted on 5 June 2014 between 10:28 and 15:50 hrs. After overnighting and refueling at Kanaryamiut field station, the crew completed surveys at BP the following day, 6 June 2014 (between 10:13 and 11:15 hrs).

During sampling, the location of transects, lead-in lines to transects, as well as the track of the moving aircraft were displayed on a GPS (Garmin 296®) mounted to the dash of the aircraft and monitored by the pilot during the survey. A separate handheld GPS unit (Garmin 60Cx®) was interfaced with a laptop computer attached to the digital camera. Latitude-longitude, GPS altitude, time-date, and other photographic information were stored in the metadata of each image (Anthony 2004). Additionally, a continuous GPS track-file (in which new coordinates were recorded every 3 sec.) was logged during all survey flights. I used the time-differential between the time stamp on the GPS (track file) and the time stamp on the photos to interpolate image locations using GPS-Photo Link software (GPS-PHOTO LINK 2006).

I calculated standard errors of estimated nests at each colony using inter-photo variance (photo as the sample unit), rather

than inter-transect variance (1992-2008).

Ground-truthing, nest detection, and correction factors

Due to logistical constraints, ground-truthing has not been accomplished since 2011. Alternatively, I used the average index ratio (photo:ground ratio of detected brant nests) from 2007-2011 (Wilson 2007-2011), after confirming that process variation among annual estimates was extremely low (0.002), and there was no correlation ($r^2 = 0.04$) between annual apparent nest success (in ground-truthed areas) and annual index ratios. Details of previous ground-truthing methods and index ratio calculations can be found in Wilson (2007-2011).

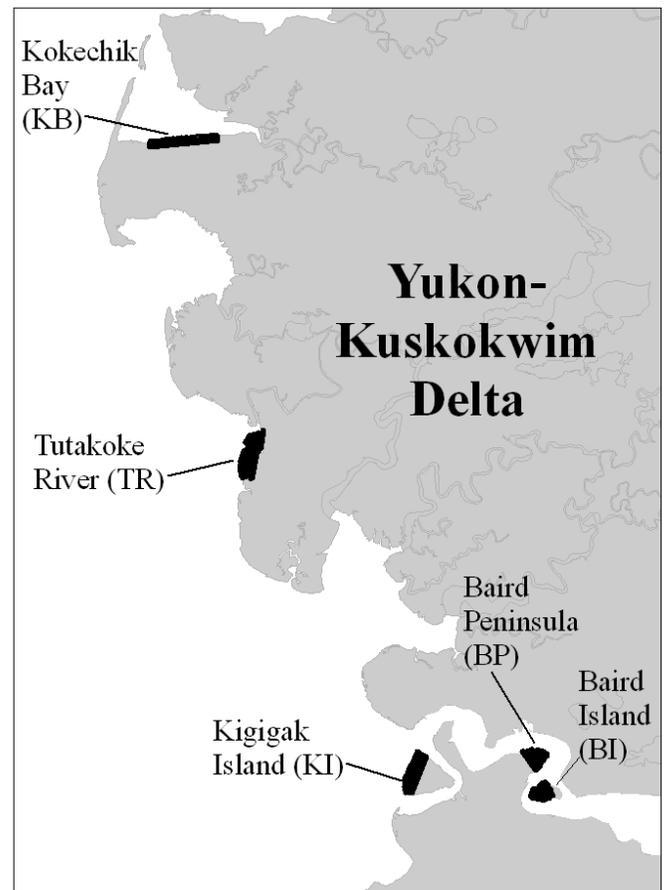


Figure 1. Photographic survey areas of the five primary Pacific black brant nesting colonies on the Yukon-Kuskokwim Delta.

Image processing

I determined total area in each colony with ArcGIS. I used the colony boundaries as re-outlined in 2009 (using IKONOS imagery base maps, 1m/pixel resolution). I

computed the area sampled by the photographs based on altitude, lens focal length, and the number of photographs taken per colony within the colony boundaries. Assistants and I viewed image files (.jpg) on computers with a custom program written in MATLAB®. Images of known nests from previous years were displayed as background on the computer monitor and on printed sheets as a reference for image-scale and appearance of different postures and behaviors of birds. As images were reviewed, text data files were created, including image file name, photo sub-area being viewed, and a two-digit observation code characterizing observed behavior (e.g., standing, sitting on nest, flying), and species identification. All photos with observations were reviewed by a second observer, as a means of quality control.

Boot tracks and motorized vehicle tracks were counted at KB, BP, and BI, but no measure of human activity was quantified at KI or TR because of ongoing research activity at those sites.

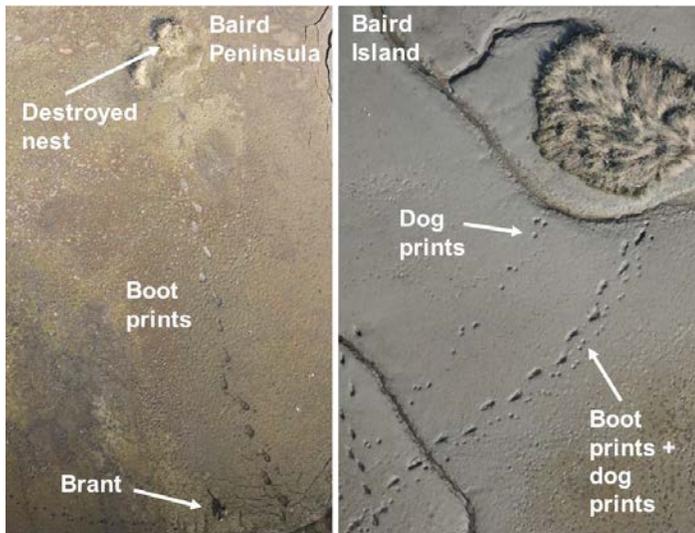


Figure 2a. Digital images from Baird Peninsula and Baird Island in 2014 illustrating human (and dog) presence at these colonies near Newtok, Alaska.

Species other than brant

In addition to recording observations of brant, assistants and I recorded nests of Pacific (*Gavia pacifica*) and red-throated loons (*G. stellata*), tundra swans (*Cygnus columbianus*), emperor geese (*Chen canagica*), white-fronted geese (*Anser albifrons frontalis*), cackling geese (*Branta hutchinsii*), common and spectacled eiders (*Somateria mollissima*, *S. fischeri*), greater scaup (*Aythya marila*), long-tailed ducks (*Clangula*

hyemalis), northern shovelers (*Anas clypeata*), and northern pintails (*Anas acuta*). We did not record gulls (*Larid* spp.) or shorebirds, although these are abundant in the photographs. Given the high resolution, large sample size, and improved coverage of images with the Nikon D700 camera, I had sufficient observations to generate nest population estimates for cackling, emperor, and greater white-fronted geese, as well as eiders (common and spectacled combined) within the brant colony study areas. Results for these species are presented in Appendix 1.

RESULTS

The number of images analyzed at KB, TR, KI, BP, and BI within colony boundaries was 947, 1383, 954, 518, and 509, respectively. Thus, given total colony areas of 1044 (KB), 1468 (TR), 1130 (KI), 666 (BP), and 584 (BI) hectares, the 2014 photos represented a sample of 10.6, 11, 9.8, 9.0, and 10.2% of each of the respective colony areas and was similar to the coverage achieved in previous years (2009-2013 coverage range: 7-16%). Survey weather conditions were clear and calm with intermittent light winds. Occasional glare made identification difficult in a handful of photos. All photos had a darker area on the right side, presumed to be slight shadowing at the lens, possibly due to the placement of the camera in the belly port of the aircraft.



Figure 2b. A digital image from the Tutakoke River colony in 2014 demonstrating a very early nesting effort: a brant brood with 5 goslings on 5 June (average hatch date was 16 June). Estimated brant hatch dates across the Yukon Kuskokwim Delta were ~6 days earlier in 2014 than the long-term average (1985-2013; Fischer and Stehn in prep).

Nest detection

I used the average index ratio (i.e., brant nest detection probability) based on previous pooled image:ground counts across all ground-truthed colonies (KB, TR, and KI) from 2007-2011, which was 0.95 (SE: 0.03, Process variance: 0.002). Thus, the correction factor for image-based counts was 1.05.

All YKD brant colonies combined

Total estimated number of nests for all colonies (9,251) was 29% higher in 2014 than in 2013 (7,183), yet the 2014 estimate was still 40% lower than the long term average (15,273; 1992-2013), and 9% lower than the 3-yr running average (10,210, 2012-2014; Table 1). All colonies except BI experienced increases in brant nests in 2014 relative to the previous year (range: 36 to 66% higher than 2013). However, the overall trend in annual YKD estimates of nesting brant among the five primary colonies continues to be negative ($\lambda = 0.963$; Fig. 4). Moreover, the long-term trends at TR and KB (including 2014) marked the seventh consecutive year of substantial negative departures from the long-term YKD colony trend (e.g., 5.3% annual declines at TR and KB versus 3.7% annual decline for all YKD colonies), indicating that most of the long term decline continues to be attributed to reductions at KB and TR.

Kokechik Bay (KB)

The estimated number of nests at KB was 38% higher in 2014 than in 2013, and 44% lower than the long-term average (1992-2013) at that site. Further, the within-colony trend at KB remained 1.3 percentage points lower ($\lambda_{\text{log-linear}}(\text{KB}): 0.95$, SE: 0.02) than the trend for all YKD colonies. No researchers visited KB in 2014, nor did any fox control occur at the site, and no indications of depredation or flooding were observed in digital photos. Boot tracks were observed in 28 of 947 photos at KB in 2014 (2.9%) and motorized vehicle tracks (snowmachine and/or ATV) were observed in 4 images (<1%), both similar to the previous year's estimates (2.8 and 1%, in 2013). Overall, the 2014 detectable human presence (as indicated by boot and vehicle tracks) at KB was consistent with a sustained, low level (range: 1-6%) of activity, similar to that occurring since 2006.

Tutakoke River (TR)

The estimated number of nests at TR was 66% higher than in 2013, but still 28% lower than the long-term site-average. Further, the within-colony trend at TR remained

1.3 percentage points lower ($\lambda_{\text{log-linear}}(\text{TR}): 0.95$, SE: 0.02) than the overall trend for the YKD. The 2014 estimate indicated an average nesting year at TR relative to recent years at that site (Table 1). Local researchers (T. Riecke pers. comm.) reported that brant nests were present on the ground in early May and described the overall nesting effort as early (see Fig. 2b) and good. Overall depredation appeared to be minimal at the time of photography. Fox control did not occur at TR in 2014.

Kigigak Island (KI)

The estimated numbers of brant nests within the KI brant colony study area were 51% higher in 2014, than 2013, but 8% lower than the long-term average for the site. Further, the long-term, log-linear trend at KI continues to be negative ($\lambda_{\text{log-linear}}(\text{KI}): 0.98$, SE: 0.02). Overall, nesting within the KI study area appeared to be normal to slightly depressed in 2014. There was little indication of nest destruction due to fox and avian (e.g., gull/jaeger) predation from the images and no fox control occurred at KI in 2014.

Baird Inlet Island (BI)

The estimated number of nests at BI was 17% lower in 2014 compared to 2013 and 42% lower than the long term site-average. The long-term, log-linear trend at BI shows a decrease of ~2% per year ($\lambda_{\text{log-linear}}(\text{BI}): 0.98$, SE: 0.02). No ground-based research at BI was conducted in 2014, and thus, no ground-based evaluations of factors influencing nest success are available. However, detectable human presence at BI, as indicated by boot tracks, significantly increased from the previous year (see Fig. 2a). Boot tracks, and occasional dog tracks accompanying boot tracks, were observed in 72 of 509 photos (14%), representing a substantial increase over the previous two years (where only 1% of photos showed human presence). BI was the only colony to experience a reduction in nesting from the previous year. As in all previous years, no motorized vehicle tracks were observed on the island. No flooding or significant fox/gull depredation was detected from photos and no fox control occurred at BI in 2014.

Baird Peninsula (BP)

The estimated number of nests at BP was 36% higher in 2014 compared to 2013, but the colony still remained 52% lower than the long term site-average. Further, the log-linear trend at BP continues to slope downward ($\lambda_{\text{log-linear}}$

(BP): 0.97, SE: 0.04). Detectable human presence at BP noticeably increased in 2014 (8%) with some indications of possible human-related nest failure (see Fig. 2a). In 2014, 58 of 516 photos (11%) had boot tracks, versus 6 of 519 (1%) in 2013. Recent years (2009-2010) averaged <1% of photos with detectable human presence. In 2014, no significant flooding or depredation was observed in photos at BP, no fox control occurred, and as in all previous years, no motorized vehicle tracks were observed at this colony.

DISCUSSION

Abundance and trends of Pacific black brant at nesting colonies on the YKD are important management indices used by the Pacific Flyway. The current Flyway Management Plan mandates harvest closure if: a) the 3-yr average of the midwinter survey is <90,000, and b) the YKD-wide colony nest population estimate is 50% below the 1993-2000 average of 19,683 nests (Pacific Flyway Council 2002, technical clarification July 2004). In 2014, the YKD colony nest population estimate (9,251) was 53% lower than the 1993-2000 average of 19,683. Thus, in 2014 the colony portion of the current management mandate fell below the benchmark outlined by the Flyway. However, the most recent 3-yr average of the midwinter survey, 160,948 (derived from 2008, 2010, and 2013 midwinter estimates; Olson 2014 - Pacific Flyway Databook), was well above the harvest closure threshold.

In 2009, the Pacific Flyway discussed adopting a revised brant management strategy which would dictate harvest closure when: a) the 3-yr average of the midwinter survey was <90,000 and b) the 3-yr average of the YKD-wide colony nest population estimate was <10,000 nests. In 2014, the 3-yr average was 10,210, only 209 nests above the proposed alternative, conditional closure threshold. Given the variation in year to year estimates and survey conditions/timing, I believe use of a three year average would be preferable to a single year estimate for the YKD brant colonies.

In 2014, almost all colony estimates were higher than the previous year. However, the 2013 survey was flown very late in the season (24-26 June) and lower numbers of active nests based on that imagery may have been at least partially related to delays in photography in 2013. Thus, an 'increase' over the previous year's estimate may not be as accurate a portrait of relevant change as comparison to a longer-term trend.

Overall, the 2014 YKD aerial imagery reflected an average nesting year for brant across the YKD, at least relative to the previous 5 years. This was despite a much earlier initiation date in 2014 than previous years (~ 5 days earlier, than 1985-2013; Fischer and Stehn in prep); likely a product of early snow-free conditions on the breeding grounds. Most of the data and observations from concurrent surveys and local researchers also corroborated an average to good nesting year for brant, although there were several areas of decline. For example, brant nest success from the YKD Nest Plot Survey (Fischer and Stehn in prep.), was estimated at 80%, while numbers of nests across the YKD were estimated to be 63% lower than the previous year. The YKD Coastal Zone aerial survey demonstrated similar discrepancies; total indicated brant were estimated to be 18% higher than in 2013, while indicated breeding brant were estimated to be 69% lower than the previous year (Platte et al. 2014).

Overall, the long-term growth rate for brant nests in the primary colonies as estimated by photography ($\lambda = 0.963$, 1993-2014) continues to be substantially lower than that estimated for brant nests across the YKD (from the nest plot survey, $\lambda = 0.995$, 1985-2014; Fischer and Stehn in prep), and lower than for indicated breeding birds from aerial counts ($\lambda = 1.049$, 1985-2014, Platte et al. 2014). This suggests that brant nesting in the historical colonies are in a significant long-term decline, while brant nesting elsewhere on the YKD are experiencing a much slower, rate of decline, and in some cases, may be approaching stability (also see Stehn et al. 2011).

No fox removal occurred at any of the colonies in 2014, and indications of fox and avian depredation were minimal to non-existent, with no significant flooding. Limited aerial imagery data for other sympatrically nesting species within the brant colonies (e.g., cackling, emperor, and greater white-fronted geese, and eiders; Appendix 1), indicated substantial species-specific variation in nesting in 2014. Trends for ancillary species in the colonies (2009-2014) indicated precipitous declines for eiders ($\lambda = 0.67$ SE: 0.10), moderate declines for cackling geese ($\lambda = 0.95$ SE: 0.07), and increasing trends for emperor ($\lambda = 1.05$ SE: 0.04), and greater white-fronted geese ($\lambda = 1.05$ SE = 0.17). Interestingly, eider numbers in the brant colonies are at a historic low. Common eiders nest sympatrically with brant and likely benefit from associated predator swamping. Thus, as the large brant colonies decline, eider numbers may also continue to decline, as has been observed

for common eiders nesting in association with snow geese (*Anser caerulescens*; Iles et al. 2013). Although human activity (based on numbers of photos with footprints and vehicle tracks) remained stable at Kokechik Bay in 2014, the substantial increase at Baird Peninsula and Baird Island colonies is of concern. These remote nesting grounds have had little to no human presence in this survey's history. Review of 2014 photos suggested several instances of human egg-predation at the Baird colonies and use of dogs. Gathering of black brant eggs is closed on the Yukon-Kuskokwim Delta and spring hunting of black brant and cackling geese is closed during the period from when egg laying begins until young birds are fledged (Federal Register 2013a). Exact closure dates are announced locally each year. No biological studies occurred in the vicinity of these colonies in 2014. The Baird colonies lie between the village of Newtok on the mainland and the new village relocation site of Mertarvik, on Nelson Island; near the mouth of the Ninglick River. The Baird Island colony was the only colony to experience a decrease in nesting brant in 2014. However, brant nests at the neighboring BP colony increased in 2014, perhaps in part, due to displacement from BI. Fluctuations in numbers of nesting brant between BI and BP over the past six years continues to suggest that these neighboring colonies may functionally behave as one, with nesting brant shifting between sites based on differential local habitat conditions and/or disturbances. Finally, although the number of brant nests at all colonies, except Baird Island (17% decrease) increased from 2013 to 2014, the magnitude of the increase varied substantially among colonies; from 35% higher estimates at Baird Peninsula to 66% higher estimates at Tutakoke River. However, proportional changes in colony size relative to the previous year's estimates are not directly comparable in terms of actual numbers of nesting brant. A better metric may be comparison of the current year's estimate to long-term averages and evaluation of individual long-term trends at each colony. For example, the long-term trends at TR and KB (including 2014) marked the seventh consecutive year of negative departures from the long-term YKD log-linear trend (e.g., 5.3% annual declines at TR and KB versus 3.6% annual decline for all YKD), indicating that most of the long term decline in numbers of nesting brant on the YKD continues to be attributed to reductions from historic estimates at KB and TR.

ACKNOWLEDGEMENTS

Funding for this survey was provided by the NAWMP Arctic Goose Joint Venture and the U.S. Fish and Wildlife Service (USFWS). I thank the USFWS Yukon Delta National Wildlife Refuge (YDNWR), particularly Brian McCaffery, who coordinated refuge aircraft use for the survey. I also thank Hollis Twitchell, who piloted the survey aircraft, and Mike Anthony, who photographed the colonies. Marks, Nick Hajdukovich, and Chris Dau (USFWS, Migratory Bird Management, Anchorage) worked long hours to complete the image-processing and reviewing of photographs for this project. Julian Fischer and Paul Flint provided helpful reviews of this report.

LITERATURE CITED

- Anthony, R. M., W. H. Anderson, J. S. Sedinger, and L. L. McDonald. 1995. Estimating populations of nesting brant using aerial videography. *Wildlife Society Bulletin* 23:80-87.
- Anthony, R. M. 1992-2006. Aerial surveys of brant colonies on the Yukon Delta NWR. U.S. Geological Survey, Alaska Science Center, Anchorage, Alaska, USA. Unpubl. Reports (1992-2006).
- Byrd, G. V., S. Finger, C. A. Janik, M. Joseph, and P. Paniyak. 1982. The status of geese and swans nesting on the coastal fringe of the Yukon Delta National Wildlife Refuge in 1982. Unpublished report, Yukon Delta National Wildlife Refuge, Bethel, AK.
- Federal Register. 2014. Migratory bird subsistence harvest in Alaska; Harvest regulations for migratory birds in Alaska during the 2014 season; Final Rule. 50 CFR pt. 92, Federal Register 79 (67).
- Fischer, J. B., and R. A. Stehn. Nest population size and potential production of geese and spectacled eiders on the Yukon-Kuskokwim Delta, Alaska, 2014. U.S. Fish and Wildlife Service, Migratory Bird Management, Anchorage, Alaska, USA. Unpubl. Report. *In prep.*
- GPS Photo-link. 2006. Version 4.0. GeoSpatial Experts, Ft. Collins, Colorado, USA.
- IKONOS. 2008. Geoeye, Dulles, Virginia, USA.
- Iles, D. T., R. F. Rockwell, P. Matulonis, G. J. Robertson, K. F. Abraham, J. Chris Davies, and D. N. Koons. 2013. Predators, alternative prey, and climate influence annual breeding success of a long-lived sea duck. *Journal of Animal Ecology* 82:683-693.
- MATLAB. 2001. Version 6.1, release 12. MathWorks, Natic, Massachusetts, USA.
- Olson, S. M., Compiler. 2014 Pacific Flyway Data Book. U.S. Fish and Wildlife Service, Vancouver, WA
- Pacific Flyway Council. 2002. Pacific Flyway management plan for Pacific brant. Pacific Flyway Study Committee, U.S. Fish

- and Wildlife Service, Portland, Oregon, USA. Unpubl. Report, 40 pp.
- Platte, R. M., J. I. Hodges, A. J. Anderson. 2014. Memo to the Pacific Flyway Committee on the 1985-2014 Coastal Zone Yukon-Kuskokwim Delta Survey of geese, swans, and sandhill cranes. U.S. Fish and Wildlife Service, Migratory Bird Management, Anchorage, Alaska, USA. Unpubl. Memo.
- Sedinger, J. S., C. J. Lensink, D. H. Ward, R. M. Anthony, M. L. Wege, and G. V. Byrd. 1993. Current status and recent dynamics of the black brant *Branta bernicla* breeding population. *Wildfowl* 44:49-59.
- Stehn, R. A., R. M. Platte, H. M. Wilson, and J. B. Fischer. 2011. Monitoring the nesting population of Pacific black brant. U.S. Fish and Wildlife Service, Migratory Bird Management, Anchorage, Alaska, USA. Report to the Pacific Flyway Study Committee.

Table 1. Annual estimates and standard errors (± 1 SE, presented in # of nests) from photographic aerial surveys of brant nests at the five primary colonies on the Yukon-Kuskokwim Delta, Alaska (1992-2014); Tutakoke River (TR), Kokechik Bay (KB), Kigigak Island (KI), Baird Inlet Island (BI), and Baird Peninsula (BP).

Year	Colony Nest Estimates										
	TR	(SE)	KB	(SE)	KI	(SE)	BP	(SE)	BI	(SE)	Total
1992	4,600 ²	(202)	6,134 ²	(295)	3,440 ¹	(154)	2,157 ¹	(151)	3,258 ¹	(347)	19,589
1993	4,937 ²	(190)	4,667 ¹	(577)	1,727 ²	(90)	614 ¹	(77)	4,156 ¹	(357)	16,101
1994	4,807 ¹	(400)	6,978 ²	(196)	2,260 ²	(92)	2,441 ¹	(142)	4,461 ¹	(454)	20,947
1995	5,596 ²	(297)	7,573 ²	(351)	--- ³	---	2,591 ¹	(184)	4,720 ¹	(474)	23,998
1997 ²	4,588	(554)	9,144	(1092)	4,776	(595)	2,259	(282)	1,944	(242)	22,711
1998 ²	3,448	(292)	5,655	(471)	3,105	(238)	1,431	(169)	2,747	(264)	16,386
1999 ¹	4,100	(96)	4,072	(74)	3,962	(402)	448	(81)	1,777	(80)	14,359
2000	7,437 ²	(584)	8,021 ²	(866)	4,286 ¹	(647)	1,962 ¹	(142)	4,088	(324)	25,794
2001 ²	1,212	(73)	3,677	(215)	1,721	(107)	421	(36)	3,604	(198)	10,635
2002 ²	4,524	(314)	4,634	(362)	4,380	(255)	2,708	(147)	3,052	(199)	19,298
2003 ²	1,622	(79)	655	(52)	2,474	(118)	547	(46)	3,202	(135)	8,500
2004 ²	2,704	(153)	1,996	(116)	3,284	(208)	1,687	(76)	2,759	(160)	12,430
2005 ²	2,977	(205)	3,985	(177)	4,728	(213)	--- ³	---	4,093	(256)	17,023 ³
2006 ²	3,714 ⁴	(286)	5,280	(341)	3,920	(240)	793	(61)	3,628	(262)	17,335
2007 ²	1,842	(137) ⁴	4,521	(304) ⁴	3,924	(304) ⁴	2,241	(203) ⁴	4,106	(264) ⁴	16,634
2008 ²	669	(68) ⁵	2,062	(174) ⁵	1,856	(158) ⁵	3,695	(341) ⁵	1,713	(151) ⁵	9,995
2009 ²	2,197	(235) ⁶	3,958	(344) ⁶	2,398	(226) ⁶	1,154	(141) ⁶	2,499	(239) ⁶	12,206
2010 ²	1,963	(176) ⁶	2,560	(208) ⁶	2,061	(184) ⁶	1,146	(130) ⁶	1,739	(142) ⁶	9,469
2011 ²	2,481	(221) ⁶	3,682	(244) ⁶	2,104	(187) ⁶	580	(84) ⁶	3,109	(445) ⁶	11,956
2012 ²	3,332	(256) ⁶	3,811	(269) ⁶	2,795	(258) ⁶	819	(125) ⁶	3,440	(285) ⁶	14,197
2013 ²	1,436	(132) ⁶	1,847	(145) ⁶	1,214	(137) ⁶	519	(82)	2,167	(168)	7,183
2014²	2,382	(174)	2,540	(176)	1,833	176	705	(92)	1,795	(153)	9,251
3-yr average (2010-2014)	2,382		2,733		1,947		681		2,467		10,210
Long-term average (1992-2013)	3,298		4,566		2,964		1,472		3,094		15,273

¹Estimates based on Lincoln-Petersen analysis of counts by two observers.

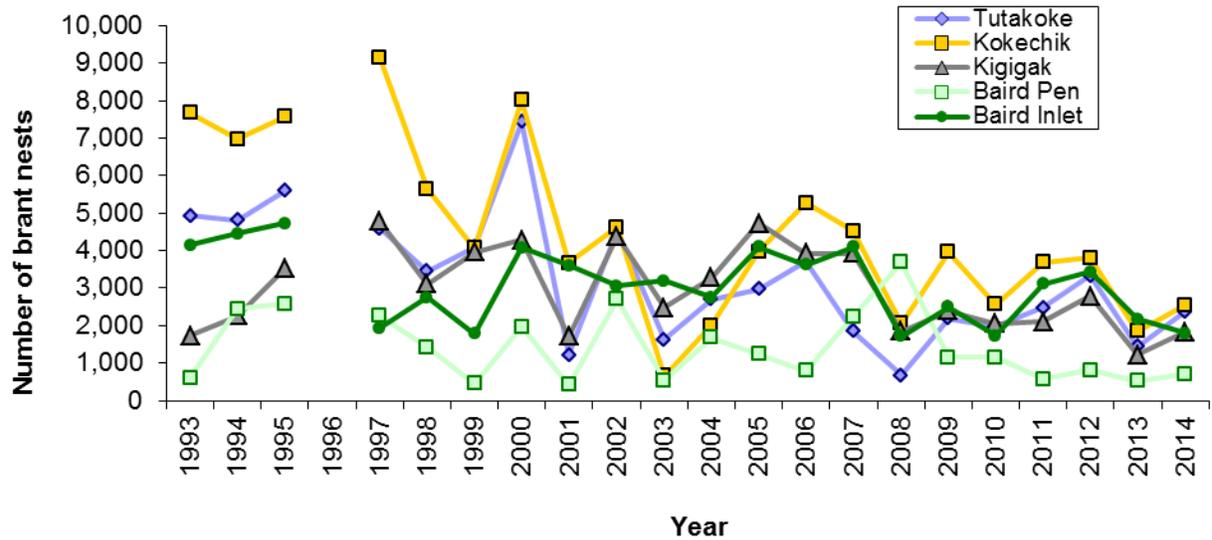
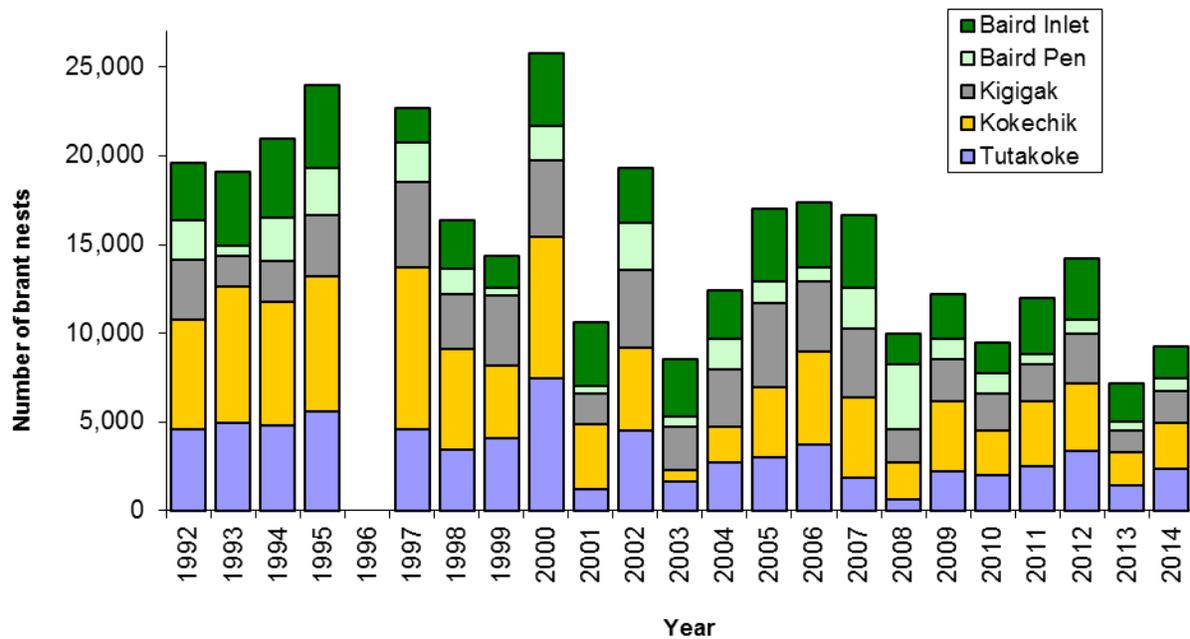
²Estimates based on correction factors from ground-truthed transects.

³Mean of 1994 and 1997 KI estimates included in 1995 KI total and average, and mean of 2004 and 2006 BP estimates included in 2005 BP total and average.

⁴2006 TR estimate based on 63% of the images analyzed.

⁵Standard errors in 2007-2009 calculated using the variance of the ratio estimate, rather than binomial variance (as in 1992-2006).

⁶Standard errors in 2009-present were calculated using inter-photo variance (photos as the sample unit), rather than inter-transect variance (as in 1992-2008).



Figures 3a and 3b. Estimates of number of nests at the five primary brant colonies on the Yukon-Kuskokwim Delta (1992-2014) from photographic surveys; Tutakoke River (TR), Kokechik Bay (KB), Kigigak Island (KI), Baird Peninsula (BP), and Baird Island (BI). Note: Due to lack of surveys at KI in 1995 and BP in 2005, the mean of the 1994 and 1997 KI estimates were used to derive a 1995 KI estimate, and the mean of 2004 and 2006 BP estimates were used to derive a 2005 BP estimate.

1992-2014 Average annual growth rate in brant nests across all colonies = 0.963 (95% CI: 0.947-0.981; R²=0.49)

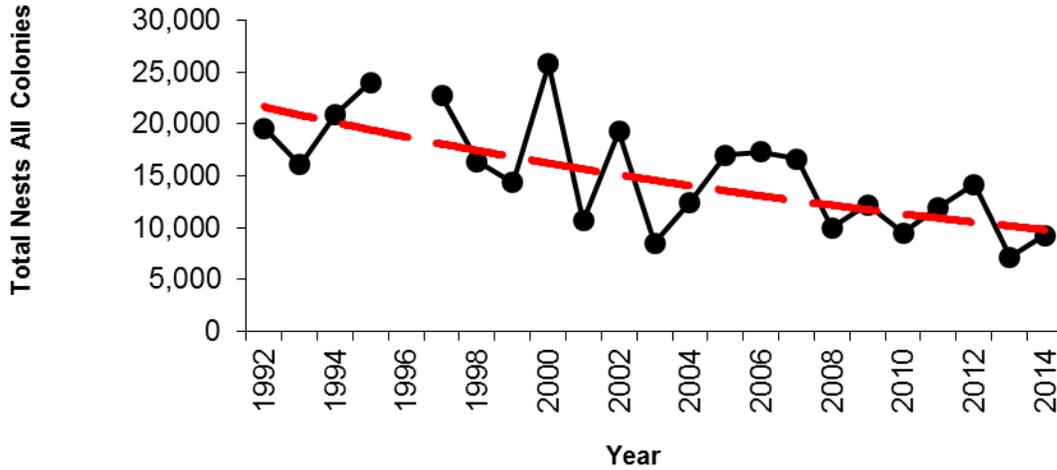


Figure 4. Trend in annual estimates of brant nests (red dashed line) from photographic surveys across all brant colonies on the Yukon-Kuskokwim Delta (1992-2014). Note: No YKD colony survey occurred in 1996. Thus, no estimate for 1996 is included in the trend analysis. However, the mean of 1994 and 1997 Kigigak Island estimates was substituted for the 1995 Kigigak Island total and average, and the mean of 2004 and 2006 Baird Peninsula estimates was substituted for the 2005 Baird Peninsula total and average.

Appendix 1. Estimates and standard errors (± 1 SE, presented in # of nests) of species other than brant from photographic aerial surveys within the five primary brant colonies on the Yukon-Kuskokwim Delta, Alaska; Tutakoke River (TR), Kokechik Bay (KB), Kigigak Island (KI), Baird Inlet Island (BI), and Baird Peninsula (BP) 2009-2014.

Species ¹	Estimates of number of nests												
	TR	(SE)	KB	(SE)	KI ²	(SE)	BP	(SE)	BI	(SE)	Total	(SE)	
Cackling goose	2009	1,615	(248) ⁶	1,582	(288)	2,271	(382)	2,609	(436)	1,999	(349) ⁶	10,076	(1,556)
	2010	616	(139)	601	(136)	1,214	(257)	1,264	(274)	808	(172)	4,503	(915)
	2011	1,783	(381)	1,372	(295)	1,642	(350)	1,527	(330)	1,624	(350)	7,948	(1,606)
	2012	1,255	(124)	1,409	(137)	1,741	(154)	1,878	(158)	1,278	(120)	7,561	(308)
	2013	1,196	(98)	852	(87)	1,356	(123)	1,639	(130)	1,411	(112)	6,454	(248)
	2014	955	(92)	853	(86)	1,044	(99)	1,526	(115)	1,310	(113)	5,688	(227)
Emperor goose	2009	96	(29)	75	(27)	392	(61)	205	(50)	196	(47)	964	(111)
	2010	60	(21)	48	(20)	282	(48)	69	(27)	241	(38)	700	(85)
	2011	163	(43)	59	(21)	259	(52)	91	(30)	298	(62)	870	(113)
	2012	145	(41)	151	(41)	276	(67)	71	(36)	399	(72)	1,042	(113)
	2013	96	(29)	112	(34)	323	(61)	254	(59)	343	(57)	1,128	(108)
	2014	96	(28)	99	(32)	405	(66)	150	(22)	237	(54)	987	(101)
Greater white- fronted goose	2010	109	(30)	57	(22)	34	(16)	35	(19)	13	(9)	248	(46)
	2011	234	(57)	42	(18)	28	(15)	10	(10)	10	(10)	324	(63)
	2012	256	(54)	352	(65)	64	(27)	85	(33)	46	(22)	803	(98)
	2013	163	(39)	20	(14)	65	(28)	23	(16)	0	(0)	271	(53)
	2014	162	(43)	40	(19)	96	(30)	46	(39)	0	(0)	344	(61)
Eider spp.³	2009	420	(97)	289	(79)	245	(66)	96	(38)	46	(26)	1,096	(208)
	2010	153	(52)	48	(20)	265	(71)	0	(0)	0	(0)	466	(93)
	2011	265	(72)	125	(39)	323	(82)	0	(0)	0	(0)	713	(126)
	2012	300	(74)	176	(48)	191	(68)	0	(0)	11	(11)	678	(114)
	2013	77	(34)	30	(17)	155	(58)	0	(0)	20	(19)	282	(66)
	2014	57	(22)	60	(30)	32	(16)	0	(0)	0	(0)	149	(42)

¹ Estimates for cackling geese were based on the average detection index ratio for brant (0.95, SE: 0.03), from ground-truthed transects at (KB, TR, and KI, 2007-2011).

² Estimates for the area covered at KI overlap with coverage from the YKD random nest plots survey (Fischer et al. 2013).

³ "Eider spp." indicates combined observations of spectacled (*Somateria fischeri*) and common eiders (*S. mollissima v. nigra*), as incubating hens without attending males could not consistently be identified to species.