Summary Report- April 2018

Aerial Photographic Survey of Brant Colonies on the Yukon-Kuskokwim Delta, Alaska, 2017

HEATHER M. WILSON, U.S. Fish and Wildlife Service, Migratory Bird Management, Waterfowl Management Branch, 1011 East Tudor Road, Anchorage, AK 99503, USA. April 2018.

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 31 May and 1 June 2017; the second earliest the survey has ever been conducted. Overall, 2017 nest numbers were reduced relative to the previous year (range: -15 to -29%) and the long-term average (1992-2017; -10 to -61%). The total estimated number of brant nests (9,167 [95% CI = 8,416-10,428]) was 22% lower in 2017 than in 2016 (11,675 [95% CI: 9,744-13,606), and the long-term (1992-2017) trend in brant nests from the five primary colonies continued to be negative (-3.5%/yr; λlog-linear = 0.965 [95% CI 0.953-0.979]); with all colonies except BP demonstrating significant long-term decline (KB: 0.956 [95% CI: 0.929-0.982], TR: 0.952 [95% CI: 0.929-0.976], KI: 0.976 [95% CI: 0.957-0.995], BP: 0.981 [95% CI: 0.947-1.014], and BI: 0.977 [95% CI: 0.961-0.992]). In 2017, TR surpassed KB as the colony with the steepest rate of decline on the YKD. The most recent 10-yr trend (2008-2017) also suggested decline across the colonies (λlog-linear 0.981 [95% CI: 0.936-1.02]), although it was poorly estimated. Though brant nesting in these YKD colonies appear to be generally declining, the overall Pacific population is still above thresholds for closure established by the Pacific Flyway. 2017 represented a moderately early nesting year for brant on the YKD, with few indications of nest destruction by predation and/or flooding, as witnessed in survey photographs. Human activity (based on numbers of photos with footprints and vehicle tracks at locations without researchers) continued to be elevated at the BI and KB colonies in 2017 (~10.5% of photos in those colonies had boot tracks), similar to 2016 (11.3 and 10.9%, respectively), representing a 5x increase in boot tracks compared to recent historical (2001-2015) averages. Photos with vehicle tracks at KB were down slightly in 2017 (0.9% of photos), relative to the previous year (1.7%), and 2017 marked the third year of moose tracks being observed in photographs at KB.

KEY WORDS aerial photographic survey, nesting colonies, Pacific black brant, Yukon-Kuskokwim 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 nests 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. 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., digital camcorder) to still-frame, digital photography (Anthony 2004-2006). The objective of the survey is to provide YKD colony nest abundance estimates to help guide population recovery and management efforts for Pacific black brant, including annual harvest guidelines (Pacific Flyway Council 2002). The current Pacific 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 from this survey is 50% below the 1993-2000 average of 19,683 nests (Pacific Flyway Council 2002, technical clarification July 2004). Additionally, data collected from the aerial photographic survey provides an index of human use of colony areas, relative nest densities of other species (e.g., cackling goose; *Branta hutchinsii minima*), and has been used to quantify landscape-level habitat availability (Lake et al. 2006). Herein, I report the results of the 2017 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 31 May and 1 June 2017.

METHODS

Aerial Survey

A single, vertically-mounted Canon EOS 5DSR SLR® digital still camera with an image-stabilizing lens (70-200 mm) was used to photograph colonies from within the aircraft. The Canon 5DSR camera had a 50.6 -megapixel FX-format CMOS 23.9 x 36 mm photo sensor and sampled non-overlapping 0.082-hectare (35.1 x 23.4 m) ground footprints through a port in the floor of the Cessna 206 amphibious-equipped aircraft (N375F). The camera was set to shutter speed priority with a fixed aperture of f2.8, focal length of 125-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. Given total colony areas of 1,044 (KB), 1,468 (TR), 1,130 (KI), 666 (BP), and 584 (BI) ha, and a 0.082 ha footprint for each photograph in 2017, the survey crew sampled 9.5, 7.5, 9.3, 6.2, and 8.1% of each of the respective colony areas (ave.8.2%). In 2017, photography of KB, TR, KI, BP, and BI required 0:48 (hours:minutes), 1:23, 1:01, 0:48, and 0:55, respectively, from start of first transect to end of last transect. Surveys at BI, BP, KI, and TR colonies were conducted in the afternoon of 31 May (13:36-18:37 hrs), and KB was surveyed the following morning, 1 June 2017 (10:00-10:48 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 496®) 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 the digital camera, which was controlled by a laptop computer. 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. The time-differential between the time stamp on the GPS (track file) and the time stamp on the photos was used 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; 2009-present), rather than inter-transect variance (as had been done from 1992-2008), and calculated variance in the all-colony estimate of total brant nests, as the sum of individual colony variances, assuming independence among colonies.

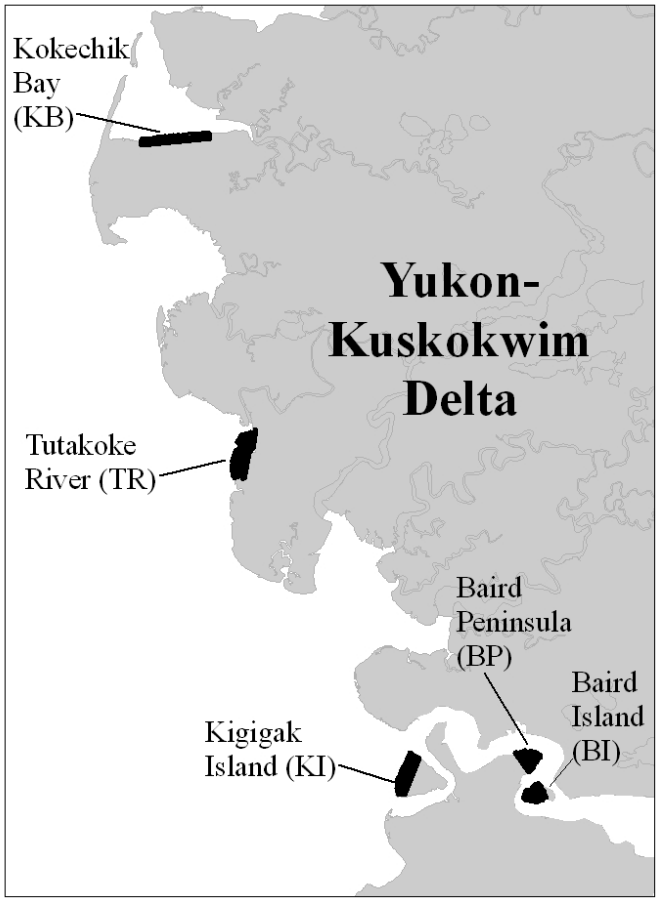

Figure 1. Photographic survey areas for the five primary Pacific black brant nesting colonies on the Yukon-Kuskokwim Delta.

Ground-truthing, nest detection, and correction factors

Due to logistical constraints, ground-truthing has not been accomplished since 2011. 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 of detection during this time period. In addition to brant, estimates for cackling geese were also adjusted for detection, 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). No other species were corrected for detection, because of insufficient sample

size. Details of previous ground-truthing methods and index ratio calculations can be found in Wilson (2007-2011).

Image processing

I determined total area for each colony with ArcGIS, using colony polygon boundaries as re-delineated in 2009 with 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® (R. Michael Anthony pers. comm.). To facilitate accurate species identification, 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. Time spent photo-processing was also recorded in 2017.

Species other than brant

In addition to recording observations of brant, we recorded nests of Pacific (*Gavia pacifica*) and red-throated loons (*G. stellata*), tundra swans (*Cygnus columbianus*), emperor geese (*Anser canagica*), white-fronted geese (*Anser albifrons frontalis*), cackling geese (*Branta hutchinsii minima*), 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. Of these species, I only had sufficient observations (e.g., a minimum of 20 observations per colony per year) to generate nest abundance estimates with CVs less than 30% for cackling Canada geese, and indices for emperor geese, greater white-fronted geese, and eiders (common and spectacled eiders combined) with CVs of 30-40%, within the brant colony study areas (2009-present; Appendix 1).

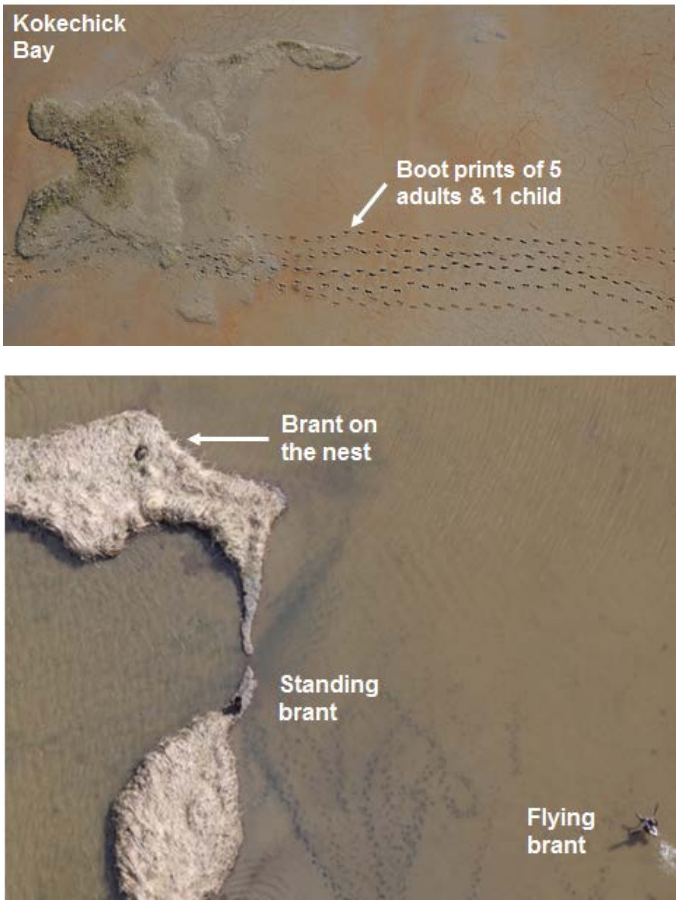

Figure 2. Digital images of boot prints of 5 adults and 1 child at the Kokechick Bay colony (top), and a brant nesting, standing, and flying at the Tutakoke River colony (bottom).

Nest detection

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, was 0.95 (SE: 0.03, Process variance: 0.002); resulting in a correction factor for image-based counts of 1.05. I applied this detection adjustment to brant and cackling Canada geese, but not to other species (e.g., emperor, greater white-fronted, eider spp.), as they had insufficient detection data to generate detection estimates.

RESULTS

The number of images analyzed at KB, TR, KI, BP, and BI within colony boundaries in 2017 was 1203, 1338, 1278, 504, and 577, respectively. Thus, given total colony areas of 1044 (KB), 1468 (TR), 1130 (KI), 666 (BP), and 584 (BI)

ha, and a 0.082 ha footprint for each photograph in 2017, the survey crew sampled 9.5, 7.5, 9.3, 6.2, and 8.1% of each of the respective colony areas (ave.8.2%). This was on the lower end of the range of coverage achieved in previous years (2009-2016 coverage range: 7-16%). Survey weather conditions were clear in 2017, except for intermittent, scattered cloud cover at TR, with light to moderate winds (5-12 kts). In addition to variable cloud cover, TR was also photographed late in the afternoon (17:14-18:37) relative to the other colonies. These two factors resulted in a portion of images at TR (9%) being taken with slower shutter speeds, resulting in blurry photos. All photos with shutter speeds less than 1/640 of a second were excluded from analysis (n=152).

The higher megapixel camera used in 2017 (50 mega-pixel vs. 12.1-megapixel 2009-2017) resulted in higher resolution photos, where lighting was adequate, and corresponded with reduced processing times. The initial 2017 photo processing required 125 man-hrs, resulting in an average rate of 1.47 min/photo [95% CI: 1.33-1.61 min/photo]) for a single observer. This was a 25% reduction (i.e., -40 man-hrs) in time spent completing initial processing in 2017 relative to 2016. However, because 2017 was also the third year with the same photo processor, I acknowledge that the increased experience of the observer could have contributed to reduced processing time. Secondary photo review (a means of quality control using two additional observers) required another16 man-hrs.

All YKD brant colonies combined

Overall, 2017 nest numbers were reduced relative to the previous year (range: -15 to -29%), and relative to the long-term (1992-2017) average (-10 to -61%). The total estimated number of brant nests in 2017 (9,167 [95% CI = 8,416-10,428]) was below the harvest closure benchmark of 9,842 nests outlined by the Pacific Flyway in 2004 (50% of the 1993-2000 average nests), and 22% lower than in 2016 (11,675 [95%CI: 9,744-13,606). The long-term (1992-2017; Fig. 5) trend in brant nests from the five primary colonies continues to be negative (-3.5%/yr; λlog-linear = 0.965 [95% CI 0.953-0.979]), with all colonies except BP, demonstrating significant long-term decline (KB: 0.956 [95% CI: 0.929-0.982], TR: 0.952 [95% CI: 0.929-0.976], KI: 0.976 [95% CI: 0.957-0.995], BP: 0.981 [95% CI: 0.947-1.014], and BI: 0.977 [95% CI: 0.961-0.992]).

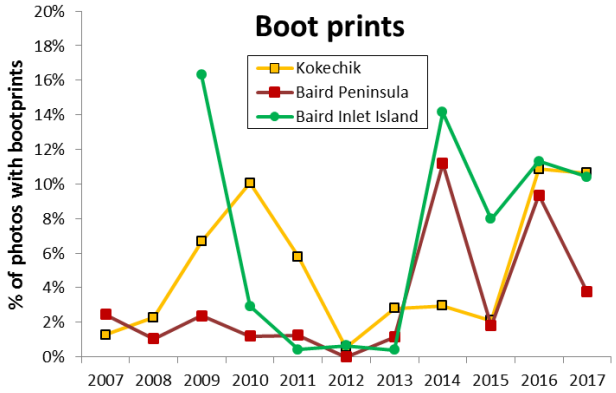

Figure 3. Percentage of photos with boot prints at Kokechick Bay, Baird Peninsula, and Baird Inlet Island Colonies (2007-2017). 2017 continued to have relatively high levels of boot prints at Baird Inlet and Kokechik colonies. No research activities occurred at these colonies.

The more recent 10-yr trend (2008-2017; Fig. 5) also suggests decline across the colonies (λlog-linear 0.981), although poorly estimated (95% CI: 0.936-1.02). In general, brant nesting in the colonies appear to be on a sustained downward trajectory, though the overall population is still above thresholds for closure established by the Pacific Flyway. 2017 represented a somewhat early nesting year for brant on the YKD, with few indications of predation and/or flooding from survey photographs.

Kokechik Bay (KB)

The long-term trend (1992-2017) at KB is the second lowest of the five primary colonies (λlog-linear (KB): 0.956, [95% CI: 0.929-0.982], Fig. 4b), and the recent 10-yr trend (2008-2017) also suggests decline (10-yr λlog-linear (KB): 0.992), although it is poorly estimated (95% CI: 0.917-1.066). No researchers visited KB in 2017, nor did any fox control occur at the site, and no indications of nest destruction were observed in digital photos. Boot tracks were observed in 128 of 1,203 photos at KB in 2017 (Figs. 2 and 3); representing a similar proportion (10.6%) to 2016 (10.9%). However, both 2016 and 2017 represent 5 fold increases from 2015 (Fig. 3). Motorized vehicle tracks (snowmachine and/or ATV) were observed in 11 of 1,203 images (0.9%); a proportion consistent with last 7 years at KB (range: 0.3-1.7%).

Tutakoke River (TR)

The estimated number of nests at TR in 2017 was 1,246 (SE: 153), representing the third lowest nest estimate at TR in the history of the survey. The long-term trend (1992-2017) at TR indicated a significant decline (λlog-linear (TR): 0.952 [95% CI: 0.928-0.976], Fig. 4b); the steepest decline of all the colonies. However, the more recent 10-yr trend at TR (2008-2016) suggests growth (10-yr λlog-linear (TR): 1.020), although it is poorly estimated (95% CI: 0.919-1.122). Overall, 2017 indicated a lower nesting year at TR relative to recent years at that site (most recent 10-yr average: 1,953, Table 1). No fox control occurred at TR in 2017.

Kigigak Island (KI)

The long-term (1992-2017), trend at KI (λlog-linear (KI): 0.976, [95% CI: 0.957-0.995], Fig. 4b) continues to be negative, along with the most recent 10-yr trend (10-yr λlog-linear (KI): 0.982), although the latter was poorly estimated (95% CI: 0.926-1.039]). Overall, nesting within the KI study area appeared to be normal to good in 2017, and from the images, there was little indication of nest destruction or flooding. No fox control occurred at KI in 2017.

Baird Inlet Island (BI)

The long-term (1992-2017), log-linear trend at BI continues to show a decrease of ~2% per year (λlog-linear(BI): 0.977, [95% CI: 0.961-0.992], Fig. 4b), consistent with a declining trend (albeit poorly estimated) in the most recent 10 years (0.988, [95% CI: 0.929-1.061]. No ground-based research at BI was conducted in 2017, and thus, no ground-based evaluations of factors influencing nest success are available, but detectable human presence at BI, as indicated by boot tracks, continued to be elevated in 2017 (Fig. 3). Boot tracks were observed in 60 of 577 photos (10%) in 2017, representing a decrease from earlier spikes in human presence (e.g., 2009 [16%] and 2014 [14%]), but an increase relative to low levels (~1%) observed between 2010-2012. As at KB and BP, the 2017 BI photos showed footprints leading up to both unoccupied and occupied brant and cackler nests, suggesting human presence may have resulted in some nest failure, but not failure at all nests. As in all previous years (except 2011), no motorized vehicle tracks were observed on the island. Also, no flooding or significant nest destruction was detected from photos, and no fox control occurred at BI in 2017.

Baird Peninsula (BP)

Both the long-term (1992-2017) and 10-yr (2008-2017) log-linear trends at BP suggest declines in the number of nests at BP (Long-term λlog-linear (BP): 0.977 [95% CI: 0.941-1.013], 10-yr λlog-linear (BP): 0.954 [95% CI: 0.827-1.083], Fig. 4b); although both trends are poorly estimated. In 2017, 19 of 504 photos (3.8%) had boot tracks, a marked decrease from the previous year (9.3%; Fig. 3). Prior to 2014 (i.e., 2009-2013) the average annual proportion of photos with detectable human presence was <1%. In general, my data suggest human presence at BP occurs in an irregular pattern, with 2014 and 2016 representing high years. As at other locations, boot prints were observed leading up to both occupied and unoccupied nests in 2017, suggesting human activity was not concurrent with nest failure in all cases. In 2017, 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.

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 each year.

DISCUSSION

Abundance and trends of Pacific black brant at nesting colonies on the YKD have been important management indices used by the Pacific Flyway to gauge the health of the breeding population. 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 below 50% of the 1993-2000 average of 19,683 nests (Pacific Flyway Council 2002, technical clarification July 2004). In 2017, the YKD colony nest population estimate (9,167) was 53% below the 1993-2000 average of 19,683, but the most recent 3-yr average of the midwinter survey (144,076; Olson 2017 - Pacific Flyway Databook), was above the harvest closure threshold. Thus, no closures are warranted based on the current management plan.

Overall, the 2017 YKD aerial imagery reflected a slightly lower than average nesting year for brant (at least relative to the recent 10-year average of 10,335 [95% CI: 9,021-11,650]), and estimates of brant nests for all but one of the YKD colonies were lower than the previous year. In 2017,

Tutakoke River surpassed Kokechik Bay as the colony with the steepest long-term decline in nesting brant (growth rate 0.952, SE: 0.012, Fig. 4b). No fox removal occurred at any of the colonies in 2017, and indications of nest destruction were minimal (from the air), with no significant flooding. Most of the data and observations from concurrent surveys and local researchers also corroborated a moderate to low nesting year for brant in 2017. My findings were consistent with the general pattern for breeding brant on the YKD of decline over the short-term (10-yr: 2008-2017). For example, log-linear trends of breeding brant or brant nests across concurrent breeding surveys on YKD all indicated a 2-4% annual decline (although confidence intervals in trends overlapped 1.0); this study: $\lambda_{10\text{-yr}} = 0.981$ [95% CI: 0.936-1.056], Coastal Zone Aerial Survey of Geese, Swans, and Sandhill Cranes (Indicated Breeding Birds) $\lambda_{10\text{-yr}}$: 0.967 [95% CI: 0.861-1.085], Swaim and Wilson 2017, and the Nest Plot Survey (2007-2016): $\lambda_{10\text{-yr}} = 0.958$ [95% CI: 0.905-1.014], Fischer et al. 2017).

The aerial imagery data I collected for other sympatrically nesting species within the brant colonies (e.g., cackling, emperor, and greater white-fronted geese, and eiders; Appendix 1), indicated little change for most species in 2017 relative to the previous year (Appendix 1), with the exception of cackling Canada geese, that had increases in nesting at all colonies except BI.

In terms of other observations in photographs, moose tracks have now been observed in brant colony photos at Kokechik Bay each year since 2015; consistent with increasing observations of moose on the coastal fringe by research camps, aerial survey crews, and local people. Also, overall human activity (based on numbers of photos with footprints and vehicle tracks) in 2017 was at elevated levels similar to the previous year at the KB and BI colonies. However, 2017 showed a decrease in human activity at the BP colony (Fig. 3). Although the percentage of photos with boot prints at KB, BP, and BI colonies (2006-2017) has varied through the years (Fig. 3), there appears to be a consistent increase at the KB and BI colonies over the last two years, representing a change from the sustained, low level (range: 1-6%) of activity that had been the norm from 2006-2015. Also in Kokechik Bay, fresh motorized vehicle tracks (snowmachine and/or ATV) continue to be observed, but at relatively low levels (down from 1.7% in 2016 to 0.9% in 2017). 2017 also represented a continuation of the trend of increased human presence at BP and BI colonies (beginning in 2014). No research activities occurred at any of these colonies.

Review of 2015-2017 photos suggested several instances of human egg-predation at the Baird and Kokechik colonies, but also several photos in which nesting birds appeared undisturbed, despite evidence of human presence at the nests. This suggests that not all human activity in the colonies resulted in total nest failure. If partial-clutch egg-gathering techniques are being used by subsistence egg-harvesters, many incubating geese likely return to the nest to continue incubating partial clutches. However, it is important to note that collection of brant eggs on the YKD is currently closed, per Federal and Alaska Migratory Bird Co-Management Council (AMBCC) subsistence harvest regulations (50 CFR 92.31 Subpart D).

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2017 YKD Brant Colony Photo Survey Crew: at left - Richard "Mike" Anthony (Photographer/Retired Project Lead), right - Heather Wilson (Pilot/Current Project Lead) with survey aircraft Cessna 206 Amphib N385F.

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 (1992-2017); Tutakoke River (TR), Kokechik Bay (KB), Kigigak Island (KI), Baird Inlet Island (BI), and Baird Peninsula (BP). No survey was conducted in 1996.

	Colony Nest Estimates										
Year	**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)	7,667 [1]	(577)	1,727 [2]	(90)	614 [1]	(77)	4,156 [1]	(357)	19,101
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
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) [6]	2,167	(168) [6]	7,183
2014 [2]	2,378	(174) [6]	2,540	(176) [6]	1,833	(176) [6]	705	(92) [6]	1,795	(153) [6]	9,251
2015 [2]	2,078	(176) [6]	1,592	(141) [6]	1,366	(144) [6]	911	(102) [6]	2,308	(181) [6]	8,255
2016 [2]	1,745	(177)	3,593	(263)	2,360	(221)	1,719	(170)	2,258	(154)	11,675
2017 [2]	**1,246**	**(153)**	**3,045**	**(327)**	**1,962**	**(189)**	**1,314**	**(153)**	**1,600**	**(169)**	**9,167**
Current 3-yr average (2015-2017)	1,690		2,743		1,896		1,315		2,055		9,699
Long-term average & growth rate (1992-2017)	3,105		4,347		2,831		1,453		2,969		14,724
	0.953	(0.012)	0.956	(0.014)	0.976	(0.014)	0.980	(0.017)	0.977	(0.008)	0.965 (0.007)

[1]Estimates based on Lincoln-Petersen analysis of counts by two observers. A typo in KB 1993 was corrected in reports prior to 2017, which changed the estimate from 4,667, to 7,667.

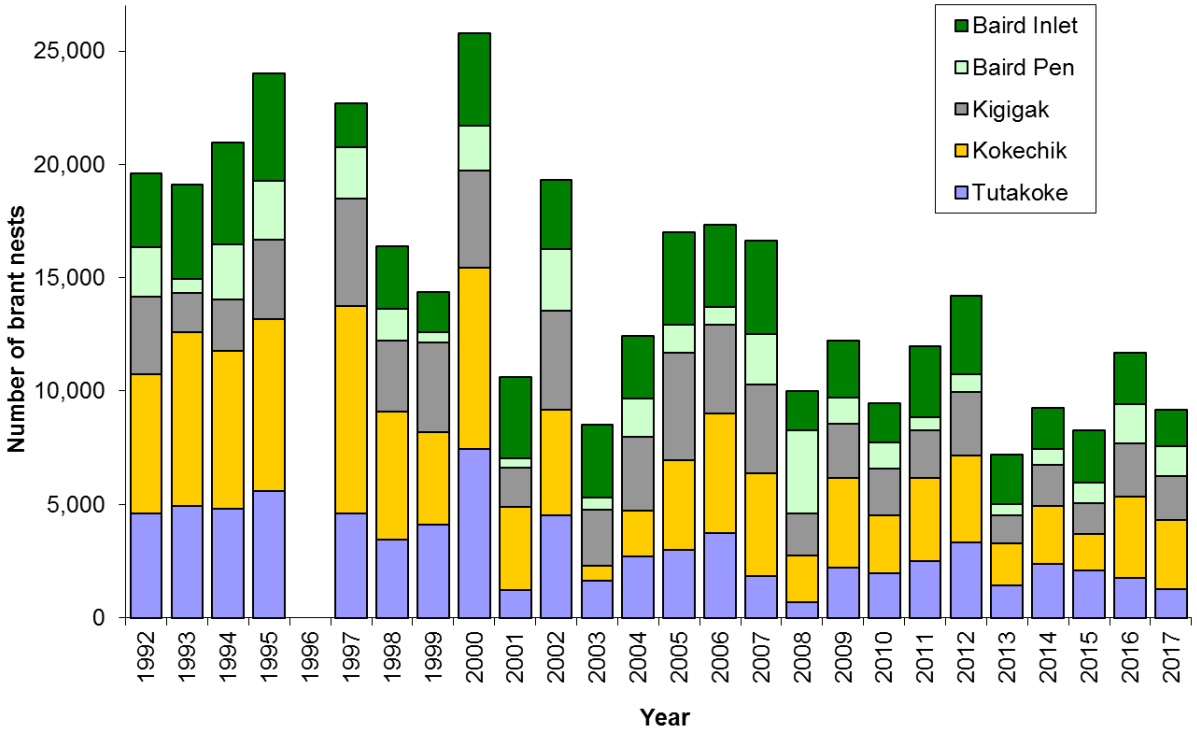
[2]Estimates based on correction factors from ground-truthed transects.

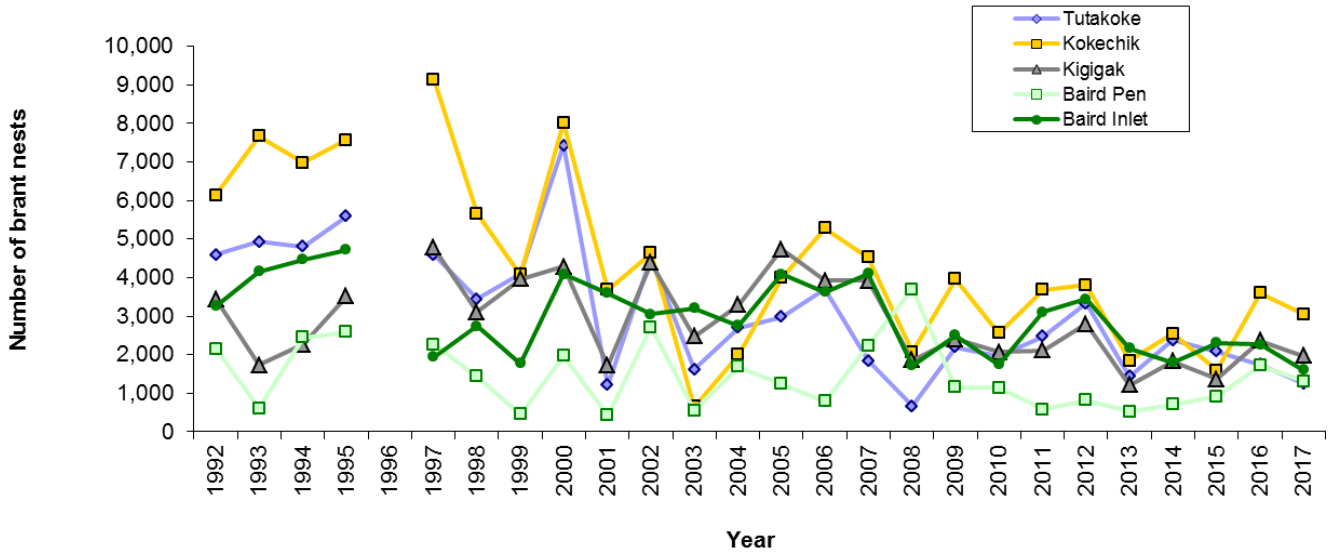
[3]Mean of 1994 and 1997 KI estimates included in 1995 KI total and average, and mean of 2004 and 2006 BP estimates included in 2005 BP total and average.

[4]2006 TR estimate based on 63% of the images analyzed.

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

[6]Standard 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 4a and 4b. Estimates of number of nests at the five primary brant colonies on the Yukon-Kuskokwim Delta (1992-2017) from photographic surveys; Tutakoke River (TR), Kokechik Bay (KB), Kigigak Island (KI), Baird Peninsula (BP), and Baird Island (BI). Note: To account for lack of surveys at KI in 1995 and BP in 2005, the previous and following year's estimates at those locations (i.e., 1994 and 1997 at KI, and 2004 and 2006 BP) were averaged and substituted for the missing site-year. No survey was conducted in 1996.

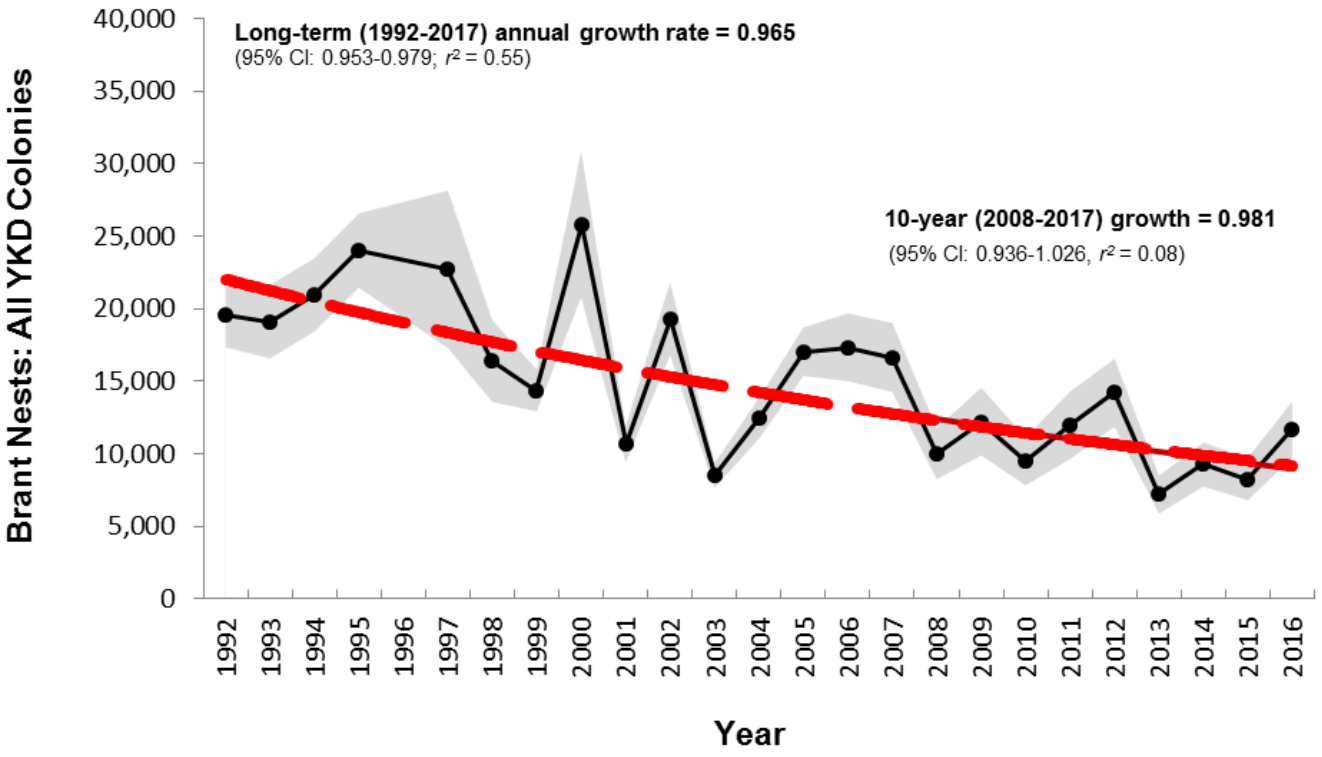


Figure 5. Trend (red line) and annual estimates (95% CI in grey) of brant nests from photographic surveys across all primary brant colonies on the Yukon-Kuskokwim Delta (1992-2017).
Note: No YKD colony survey occurred in 1996. Thus, no estimate for 1996 is included in the trend analysis. However, where individual colony data was missing within a given year, an average from the preceding and following years was used (i.e., 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) 2009-2017.

		Estimates of number of nests										
Species[1]		**TR**	(SE)	**KB**	(SE)	**KI**[2]	(SE)	**BP**	(SE)	**BI**	(SE)	**Total**
Cackling goose	2009	1,615	248	1,582	288	2,271	382	2,609	436	1,999	349	10,076
	2010	616	139	601	136	1,214	257	1,264	274	808	172	4,503
	2011	1,783	381	1,372	295	1,642	350	1,527	330	1,624	350	7,948
	2012	1,255	124	1,409	137	1,741	154	1,878	158	1,278	120	7,561
	2013	1,196	98	852	87	1,356	123	1,639	130	1,411	112	6,454
	2015	879	92	930	91	1,602	120	1,438	129	1,616	136	6,465
	2016	1271	106	1797	128	2,020	137	1,797	147	1,337	17	8,222
	2015	879	92	930	91	1,602	120	1,438	129	1,616	136	6,465
	2017	**1441**	**280**	**1284**	**110**	**1,895**	**133**	**2,359**	**207**	**1,303**	**127**	8,282
Emperor goose	2009	96	29	75	27	392	61	205	50	196	47	964
	2010	60	21	48	20	282	48	69	27	241	38	700
	2011	163	43	59	21	259	52	91	30	298	62	870
	2012	145	41	151	41	276	67	71	36	399	72	1,042
	2013	96	29	112	34	323	61	254	59	343	57	1,128
	2014	96	28	99	32	405	66	150	22	237	54	987
	2015	80	27	129	34	390	62	204	54	592	93	1,395
	2016	108	31	122	32	378	58	169	18	496	63	1,273
	2017	**98**	**36**	**122**	**35**	**248**	**52**	**236**	**72**	**361**	**64**	**1,065**
Greater white-fronted goose	2009	54	27	46	26	26	18	46	26	0	0	172
	2010	109	30	57	22	34	16	35	19	13	9	248
	2011	234	57	42	18	28	15	10	10	10	10	324
	2012	256	54	352	65	64	27	85	33	46	22	803
	2013	163	39	20	14	65	28	23	16	0	0	271
	2014	162	43	40	19	96	30	46	39	0	0	344
	2015	160	40	99	37	144	36	48	23	0	0	451
	2016	246	106	103	29	189	39	13	13	18	12	569
	2017	**280**	**98**	**66**	**26**	**147**	**41**	**152**	**54**	**52**	**25**	**697**
Eider spp. [3]	2009	420	97	289	79	245	66	96	38	46	26	1,096
	2010	187	38	220	45	462	63	69	27	20	10	958
	2011	324	85	209	57	204	66	49	23	69	28	855
	2012	355	61	453	63	267	58	57	27	11	11	1,143
	2013	335	53	244	52	194	48	23	16	40	19	836
	2014	296	50	278	49	267	150	0	0	0	0	841
	2015	670	85	267	64	390	62	60	26	44	24	1,431
	2016	335	55	515	68	312	58	26	18	27	14	1,215
	2017	**294**	**64**	**343**	**62**	**383**	**74**	**34**	**23**	**0**	**0**	**1,054**

[1]Estimates for cackling geese were adjusted for detection, 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). No other species were corrected for detection.

[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*). This is because incubating hens without attending males could not consistently be identified to species. Previously reported eider estimates (Wilson 2010-2014), were changed in 2015, after discovering a tabulation error in those years.