Summary Report- August 2017

Aerial Photographic Survey of Brant Colonies on the Yukon-Kuskokwim Delta, Alaska, 2016

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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 27-28 May 2016. Overall, 2016 nest numbers appeared to be similar to 2015, with only TR experiencing notable decline (-16 %) relative to the previous year. The total estimated number of brant nests (11,675 [95% CI = 9,744-13,606]) was 41% higher in 2016 than in 2015 (8,255 [95%CI: 6797-9713), and was above the harvest closure benchmark (i.e., 50% below the 1993-2000 average nests) outlined by the Pacific Flyway in 2004. The long-term (1992-2016) trend in brant nests from the five primary colonies continued to be negative (-3.6%/yr; λlog-linear = 0.964 [95% CI 0.950-0.978]), with all colonies except BP demonstrating significant long-term decline (KB: 0.952 [95% CI: 0.923-0.981], TR: 0.954 [95% CI: 0.929-0.979], KI: 0.976 [95% CI: 0.956-0.997], BP: 0.977 [95% CI: 0.941-1.013], and BI: 0.979 [95% CI: 0.962-0.995]). The more recent 10-yr trend (2007-2016) also suggested decline across the colonies (λlog-linear 0.961 [95% CI: 0.913-1.011]), although was not significant at α=0.05. Although brant nests on the primary YKD colonies are declining, the overall population is still above thresholds for harvest closure established by the Pacific Flyway. 2016 represented a very early nesting year for brant on the YKD, with few indications of predation and/or flooding from survey photographs. Human activity (based on numbers of photos with boot prints and vehicle tracks at locations without researchers) was elevated at the BP, BI and KB colonies in 2016 (9-11% of photos in those colonies had boot prints); representing a 5-fold increase in boot prints from the previous year. Photos with vehicle tracks at KB also increased in 2016 relative to 2015, and as in 2015, 2016 KB photographs included boot prints of adults and children, as well as moose tracks.

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 individuals nesting in large colonies. Early efforts to survey colonial nesting YKD brant were accomplished by ground crews, who 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 and became operational in 1992 (Anthony et al. 1995), after which, aerial videographic surveys were conducted annually at the 5 major brant nesting colonies on the YKD from 1992-2004 (Anthony 1992-2006; Fig. 1). In 2004, the survey methodology changed from videography (i.e., digital camcorder) to still-frame, digital photography (Anthony 1992-2006, Wilson 2007-2015).

The objective of the survey is to provide annual YKD colony nest population estimates (based on the primary colonies) to help guide population recovery and management efforts for Pacific black brant, including annual harvest guidelines, as outlined by the Pacific Flyway Management Plan (Pacific Flyway Council 2002, technical clarification July 2004). The current 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 nests (Pacific Flyway Council 2002, technical clarification July 2004). Additionally, data collected from this photographic survey provides an index of human use of colony areas (via images with boot prints and vehicle tracks), nest abundances of other species (e.g., cackling goose; *Branta hutchinsii minima*) within the colonies, and has been used to quantify landscape-level habitat availability (Lake et al. 2006). Herein, I report the results of the 2016 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 27-28

May 2016.

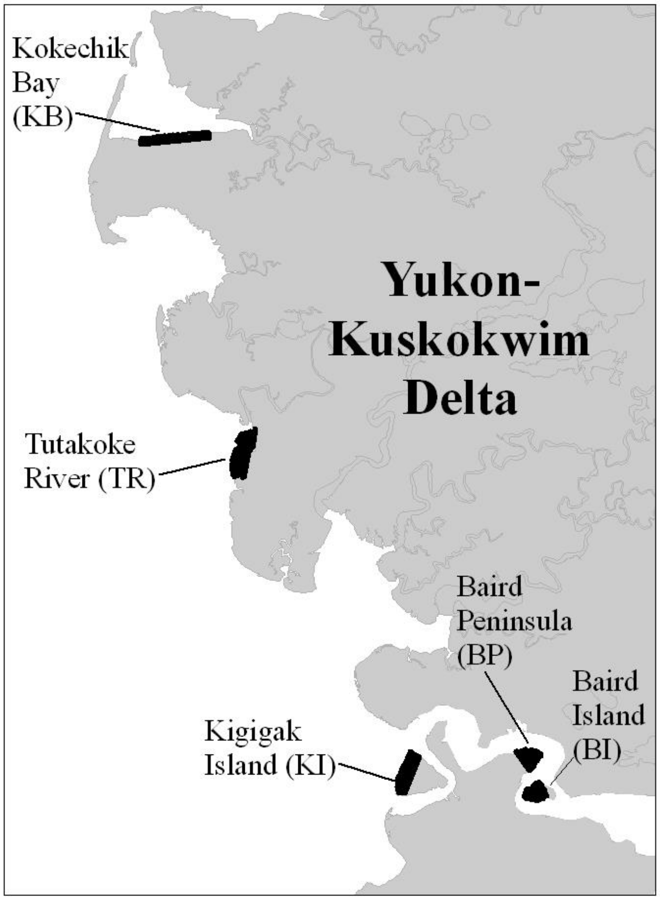

Figure 1. Photographic survey areas of the five primary Pacific black brant nesting colonies on the Yukon-Kuskokwim Delta's central coast.

METHODS

Aerial Photographic 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 port in the floor of the Cessna 206 amphibious-equipped aircraft (N9623R). The camera was set to aperture priority (i.e., shutter speed controlled automatically relative to conditions) with a fixed 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 2016, photography of KB, TR, KI, BP, and BI required 0:45 (hours:minutes), 1:37, 1:17, 0:43, and 1:09, respectively, from start of first transect to end of last transect. Surveys at TR and KI colonies were conducted on 27 May between 14:56-18:07 hrs. The surveys were completed at KB, BI, and BP the following day, 28 May 2016, between 09:48 and 13:59 hrs.

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 a laptop computer and the digital camera. Latitude-longitude, GPS altitude, time-date, and other photographic information were stored in the metadata of each image. Additionally, a continuous GPS track-file logged the coordinates of the aircraft every 3 seconds during all survey flights. The time-difference between the time stamp on the GPS (track file) and the time stamp on the photos was used to interpolate image locations using photo geo-referencing software (GPS Photo-link 2006).

Beginning in 2009, I calculated standard errors of estimated nests at each colony using inter-photo variance (photo as the sample unit), rather than inter-transect variance (as had been done from 1992-2008; Anthony 1992-2006), and calculated variance in the all-colony estimate of total brant nests, as the sum of individual colony variances, assuming independence among colonies.

Ground-truthing, nest detection, and correction factors

Due to logistical constraints, annual ground-truthing has not been accomplished since 2011. Thus, I used the average index ratio (photo:ground ratio of detected brant nests) from 2007-2011 (Wilson 2007-2015), 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. I did not incorporate variance in the index ratio when applied as a correction factor for estimates. Details of previous ground-truthing methods and index ratio calculations can be found in 2007-2011 reports (Wilson 2007-2015).

Image processing

I determined total area for each colony by overlaying colony boundary polygons (as established by Anthony 1992-2006) on IKONOS imagery base maps (1m/pixel resolution) in ArcGIS. 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.). 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. In addition to this initial processing, a random sample of ~30 photos per colony, and all photos with observations, were reviewed by a second observer, as a means of quality control.

Boot prints 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. Photo-processing and photo-reviewing time was also recorded in 2016.

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 canagicas*), 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. Given the high resolution, large sample size, and improved coverage of images with the Nikon D700 camera (relative to older videography), 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 (2009-present; Appendix 1).

Nest detection

I applied 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), resulting in a correction factor for image-based counts of 1.05.

RESULTS

The number of images analyzed at KB, TR, KI, BP, and BI within colony boundaries in 2016 was 1,004, 1,340, 1,077, 460, and 593, respectively, for a total of 4,474 analyzed images. Thus, given total colony areas of 1044 (KB), 1468 (TR), 1130 (KI), 666 (BP), and 584 (BI) ha, and a 0.12 ha footprint for each photograph, we sampled 11.2, 11.1, 13.4, 8.0, and 11.8% of each of the respective colony areas, which was similar to the coverage achieved in previous years (2009-2016 coverage range: 7-16%). Of the 4,474 total images analyzed, 649 (14.5%) contained > 0 observations. Survey weather conditions were sunny and clear in 2016, with moderate winds (10-20 kts at TR, 5-10 kts elsewhere). Approximately 2% of photos at the KB colony had significant glare or shadows, and of these, 5 photos at KB were deemed too blurry or overexposed to be effectively processed, and were deleted from analysis.

The initial 2016 photo processing required 165 man-hrs, resulting in an average rate of 2.18 min/photo [95% CI: 1.74-2.62 min/photo]) for a single observer. Secondary photo review (a means of quality control using two additional observers) required another16 total hours. Given the relatively small fraction (~15%) of photos with any observations, I estimate that initial processing time could be reduced 7-fold if an automated process was used to delineate occupied photos.

All YKD brant colonies combined

Overall, 2016 marked a significant upturn in brant colony nests on the YKD. The total estimated number of brant nests (11,675 [95% CI = 9,744-13,606]) was 41% higher in 2016 than in 2015 (8,255 [95%CI: 6,797-9,713), and was above the harvest closure benchmark of 9,842 nests outlined by the Pacific Flyway in 2004 (50% of the 1993-2000 average nests); with only the TR colony experiencing a notable decline in numbers of brant nests relative to the previous year (-16 %).

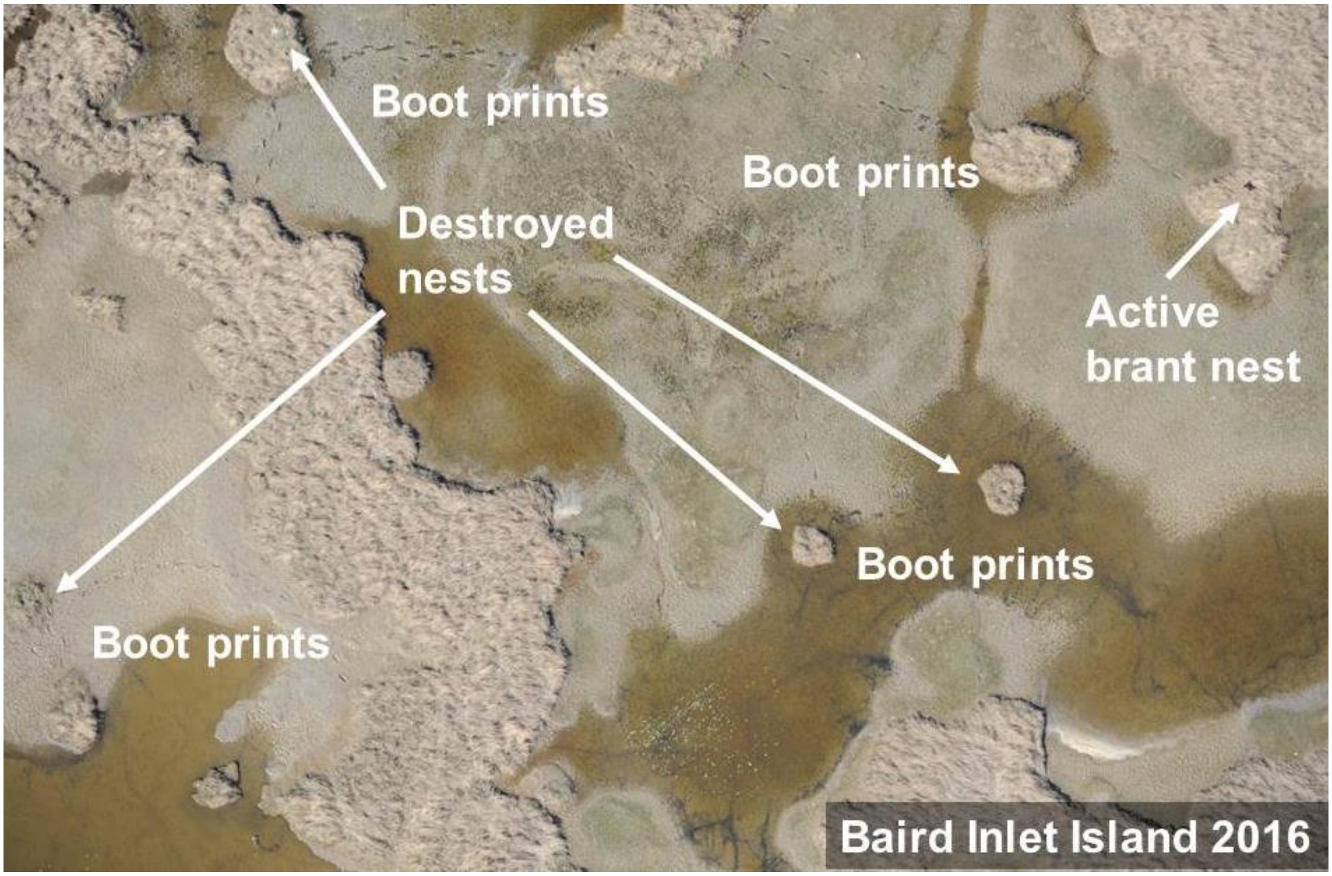

Figure 2. Digital image showing human boot prints (Baird Inlet Island), destroyed brant nests, and one active brant nest in 2016. Human presence at Baird Island, Baird Peninsula, and Kokechik colonies was elevated in 2016.

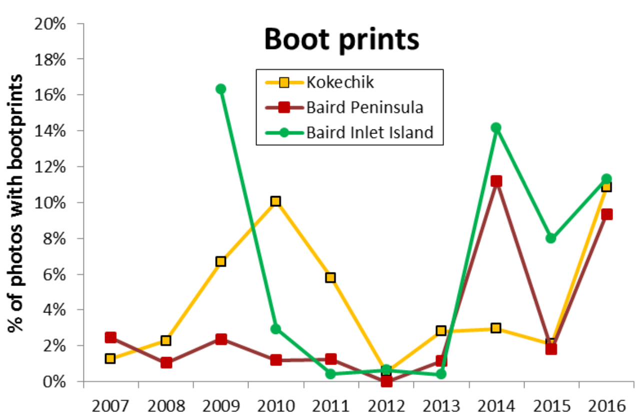

Figure 3. Percentage of photos with boot prints at Kokechik Bay, Baird Peninsula, and Baird Inlet Island colonies (2007-2016). For the first time, 2016 showed relatively high levels of boot prints at all three of the colonies, simultaneously. No research activities occurred at these colonies.

Despite this, both the long-term (1992-2016) and 10-yr (2007-2016) trends in annual YKD estimates of nesting brant from the five primary colonies continue to be negative (Long-term λlog-linear = 0.964 [95% CI: 0.950-0.978], and 10-yr λlog-linear = 0.961 [95% CI: 0.913-1.011]; Fig. 5), although the 10-yr trend was not significant at α=0.05.

Kokechik Bay (KB)

The estimated number of nests at KB in 2016 was 3,593 (95% CI: 3,078-4,109). The long-term trend (1992-2016) at KB continues to be the lowest of the five primary colonies (λlog-linear (KB): 0.952, [95% CI: 0.924-0.981], Fig. 4b) and the more recent 10-yr trend (2007-2016) also suggests decline, although was not significant at α = 0.05 (10-yr λlog-linear [KB]: 0.958, [95% CI: 0.881-1.036]). No researchers visited KB in 2016, nor did any fox control occur at the site, and no indications of depredation or flooding were observed in digital photos. Boot prints were observed in 109 of 1004 photos at KB in 2016; representing a 5-fold increase from 2015 (Figs. 2 and 3). Motorized vehicle tracks (snowmachine and/or ATV) were observed in 17 of 1004 images; representing a doubling from 2015. As in 2015, boot prints at KB continued to indicate groups of 2+ people, including children, walking to nests. Moose tracks were also observed, but were not tallied. Overall, the 2016 detectable human presence (as indicated by the percentage of photos with boot and vehicle tracks) at KB was elevated from the sustained, low level (range: 1-6%) activity that has been the norm since 2006.

Tutakoke River (TR)

The estimated number of nests at TR in 2016 was 1,745 (95% CI: 1,398-2,091), representing the fourth lowest nest estimate at TR in the history of the survey. The long-term trend (1992-2016) at TR indicated a significant decline (λlog-linear (TR): 0.954, [95% CI: 0.929-0.976], Fig. 4b); second only to KB, while the more recent 10-yr trend at TR (2007-2016) suggested an increase, although was poorly estimated (10-yr λlog-linear (TR): 1.045, [95% CI: 0.952-1.49]). Overall, 2016 indicated an average to low nesting year at TR relative to recent years at that site (most recent 10-yr average: 2,209, Table 1). Depredation appeared to be minimal at the time of the photographic survey and no fox control occurred at TR in 2016, but researchers on the ground reported significant nest depredation in the colony later in the season (T. Riecke and M. Lindberg pers. comm.).

Kigigak Island (KI)

The estimated number of nests at KI in 2016 was 2,360 (95% CI: 1,926-2,793). The long-term (1992-2016), trend at KI (λlog-linear (KI): 0.976, [95% CI: 0.956-0.997], Fig. 4b) continues to be negative, yet it remains the colony in the least severe decline of the primary 5. The more recent 10-yr trend at KI also suggested decline (10-yr λlog-linear (KI): 0.945, [95% CI: 0.878-1.011]), although poorly estimated. Overall, nesting within the KI study area appeared to be normal to good in 2016. From the images, there was little indication of nest destruction due to fox or avian (e.g., gull/jaegar) predation, despite no fox control occurring at KI in 2016.

Baird Inlet Island (BI)

The estimated number of nests at BI in 2016 was 2,258 (95% CI: 1,956-2,560). The long-term (1992-2016), log-linear trend at BI continued to show a decrease of ~2% per year (λlog-linear(BI): 0.979, [95% CI: 0.963-0.996], Fig. 4b), consistent with a declining 10-yr trend (albeit poorly estimated; 0.975 (95% CI: 0.909-1.041). No ground-based research at BI was conducted in 2016, and thus, no ground-based evaluations of factors influencing nest success are available. However, detectable human presence at BI, as indicated by boot prints, continued to be elevated in 2016 (Figs. 2 and 3). Boot prints were observed in 67 of 593 photos (11%) at BI in 2016, representing a decrease from earlier spikes in human presence (e.g., 2009 [16%] and 2014 [14%]), but an increase relative to lower levels (~1%) observed between 2010 and 2012. As at KB and BP, the 2016 BI photos showed boot prints leading up to both unoccupied and occupied brant and cackler nests, suggesting human presence may have resulted in some nest failure, although 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 fox/gull depredation was detected from photos, and no fox control occurred at BI in 2016.

Baird Peninsula (BP)

The estimated number of nests at BP in 2016 was 1,719 (95% CI: 1,385-2,052). Both the long-term (1992-2016) and 10-yr (2007-2016) 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): 0.904 [95% CI: 0.780-1.027], Fig. 4b); although both trends were poorly estimated at $\alpha = 0.05$. Detectable human presence at BP increased in 2016 from the previous year (up 7.5 percentage points from 1.8% in 2015). In 2016, 43 of 460 photos (9.3%) had boot prints, similar to 2014 (11%; Fig. 3). However, prior to 2014 (i.e., 2009-2013) the 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 noticeably high years. As at other locations, boot prints were observed leading up to both occupied and unoccupied nests at BP in 2016, suggesting human activity was not always concurrent with nest failure. In 2016, no significant flooding or depredation was observed in photos at BP and no fox control occurred. The 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 annually, based on differential local habitat conditions and/or disturbances.

DISCUSSION

Abundance and trends of Pacific black brant at nesting colonies on the YKD are important management indices used by the Pacific Flyway to gauge the health of the breeding population and assess harvest goals. 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 nests (Pacific Flyway Council 2002, technical clarification July 2004). In 2016, the YKD colony nest population estimate (11,675) was 14% above the benchmark outlined by the Flyway. The most recent 3-yr average of the midwinter survey, 140,025 (derived from 2014-2016 estimates; Olson 2016 - Pacific Flyway Databook), was also well above the harvest closure threshold of 90,000. Thus, no closures were warranted based on these surveys.

Overall, the 2016 YKD aerial imagery (11,675 nests) reflected an average nesting year for brant (at least relative to the recent 10-year mean of 11,082 [95% CI: 9,314-12,850]), and estimates of brant nests in almost all of the YKD colonies were similar to or higher than the previous year. Brant nest initiation and timing of snow-free conditions in 2016 marked the earliest on record based on the annual YKD Nest Plot Survey (1982-present, Fischer et al. 2017); a full 10 days earlier initiation than the long-term (1982-2016) mean of May 26. No fox removal occurred at any of the colonies in 2016, and indications of fox and avian depredation were minimal (at least from the air), with no significant flooding. 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 general increases for most species in 2016 relative to the previous year (Appendix 1). However, substantial species-specific variation in nesting exists in this data.

Although most 2016 data and observations from concurrent surveys suggested a normal to good nesting year (Fischer et al. 2017, Swaim et al. 2016), the long-term and 10-year trends for breeding brant on the YKD corroborate a pattern of general decline. Log-linear trends of breeding brant or brant nests across all concurrent breeding surveys on the YKD indicated a 4-5% annual decline in breeding brant (i.e., this study: $\lambda_{10\text{-yr}} = 0.961$ [95% CI: 0.913-1.011], the Coastal Zone Aerial Survey of Geese, Swans, and Sandhill Cranes (Indicated breeding brant) $\lambda_{10\text{-yr}}$: 0.957 [95% CI: 0.844-1.07], Swaim et al. 2016, and the YKD Nest Plot Survey [brant]: $\lambda_{10\text{-yr}} = 0.958$ [95% CI: 0.905-1.014], Fischer et al. 2017), although confidence intervals in all 10-yr trends overlapped 1.0.

Originally, researchers estimated that >75% of Pacific Brant nesting occurred on the YKD (Derksen and Ward 1993, Sedinger et al. 1993), with models suggesting 77-100% of the Pacific brant young counted each fall could plausibly be attributed to production from the primary YKD colonies (Sedinger et al. 1993). However, more recent work has indicated the proportion of the total Pacific population originating from the primary YKD colonies may be lower than previously thought (Stehn et al. 2011); offset by the growing arctic population (Stehn et al. 2014, Ritchie et al. 2015), and increasing numbers of "dispersed" brant nests on the YKD outside of the primary colonies (Stehn et al. 2011). Nevertheless, the large colonies on the YKD continue to serve as an important indicator of ecosystem function; not only due to their potentially higher productivity (as indicated by gosling growth rates; Nicolai et al. 2008), but also in terms of their high value to subsistence hunters in the region.

Overall, human activity (based on numbers of photos with boot prints and vehicle tracks) was relatively high across all colonies in 2016 (Figs. 2 and 3). Although, the percentage of photos with boot prints at KB, BP, and BI colonies (2006-2016) has varied through the years (Fig. 3), 2016 represented the first time relatively high levels of human activity were observed at all three of the colonies simultaneously. No research activities occurred at these colonies. At the KB colony, fresh motorized vehicle tracks (snowmachine and/or ATV) were observed in 17 of 1004 images in 2016; representing a doubling from 2015 and an increase from recent years. Coincidentally, KB continues to have the steepest long-term decline in nesting brant among the colonies (growth rate 0.952, SE: 0.015, Fig. 4b).

In general, my data suggests a pattern of increased human presence at BP and BI colonies (beginning in 2014), as well as an increase in human activity (boot prints and vehicle tracks) KB in 2016; representing a shift from the sustained, low level (range: 1-6%) of activity that has been the norm since 2006 (Fig. 3). Review of 2015 and 2016 photos suggested several instances of human egg-predation at the

Baird (BI, BP) and Kokechik (KB) 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 nest failure. If partial-clutch egg-gathering techniques are being used by subsistence egg-harvesters, and disturbance to the colonies is not prolonged, some incubating geese likely return to the nest to continue incubating partial clutches. However, 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).

Finally, as in 2015, moose tracks were observed in brant colony photos (at Kokechik Bay) in 2016, consistent with increasing observations of moose on the coastal fringe by research camps, aerial survey crews, and local people.

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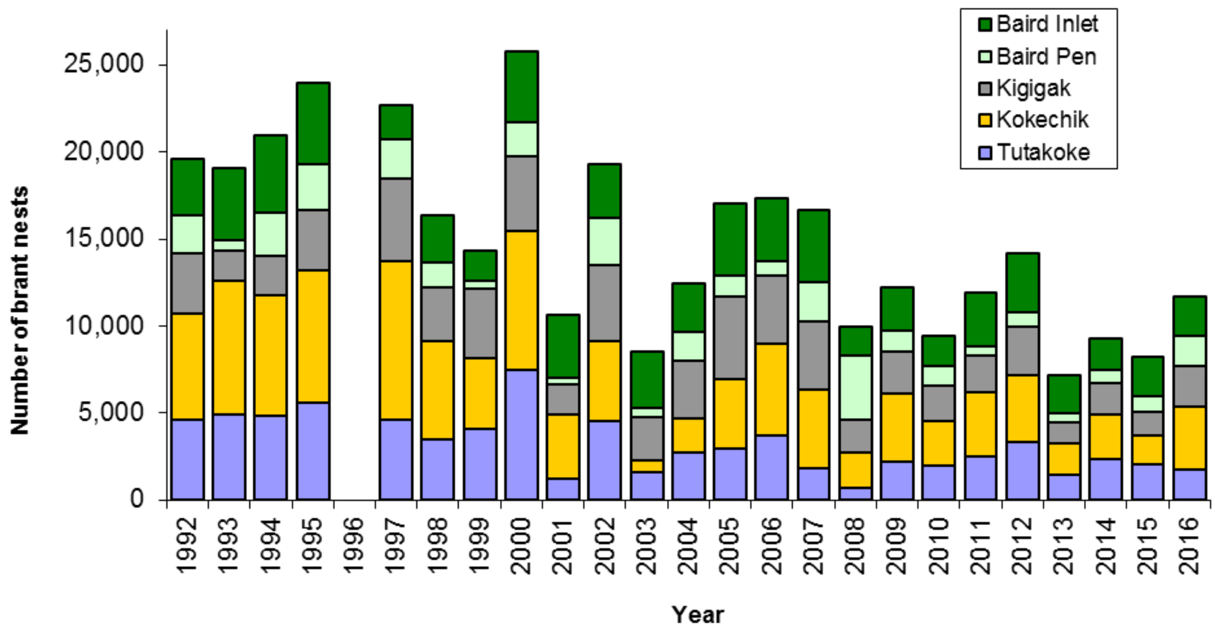
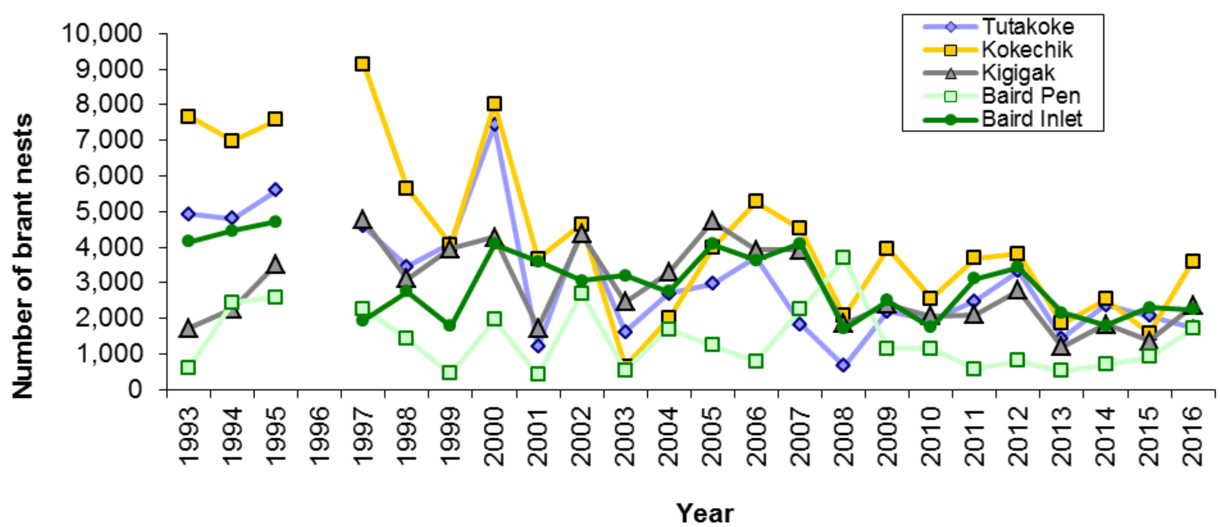
Table 1. Annual estimates and standard errors (± 1 SE, presented in # of nests) from photographic aerial surveys of brant nests at the five primary colonies on the Yukon-Kuskokwim Delta, Alaska (1992-2016); Tutakoke River (TR), Kokechik Bay (KB), Kigigak Island (KI), Baird Inlet Island (BI), and Baird Peninsula (BP).

	Colony Nest Estimates											
Year	**TR**	**(SE)**	**KB**	**(SE)**	**KI**	**(SE)**	**BP**	**(SE)**	**BI**	**(SE)**	**Total**	**(SE)**
1992	4,600 [2]	(202)	6,134 [2]	(295)	3,440 [1]	(154)	2,157 [1]	(151)	3,258 [1]	(347)	19,589	(1,149)
1993	4,937 [2]	(190)	7,667 [1]	(577)	1,727 [2]	(90)	614 [1]	(77)	4,156 [1]	(357)	19,101	(1,291)
1994	4,807 [1]	(400)	6,978 [2]	(196)	2,260 [2]	(92)	2,441 [1]	(142)	4,461 [1]	(454)	20,947	(1,284)
1995	5,596 [2]	(297)	7,573 [2]	(351)	---[3]	---	2,591 [1]	(184)	4,720 [1]	(474)	23,998	(1,306)
1997 [2]	4,588	(554)	9,144	(1092)	4,776	(595)	2,259	(282)	1,944	(242)	22,711	(2,765)
1998 [2]	3,448	(292)	5,655	(471)	3,105	(238)	1,431	(169)	2,747	(264)	16,386	(1,434)
1999 [1]	4,100	(96)	4,072	(74)	3,962	(402)	448	(81)	1,777	(80)	14,359	(733)
2000	7,437 [2]	(584)	8,021[2]	(866)	4,286 [1]	(647)	1,962 [1]	(142)	4,088	(324)	25,794	(2,563)
2001 [2]	1,212	(73)	3,677	(215)	1,721	(107)	421	(36)	3,604	(198)	10,635	(629)
2002 [2]	4,524	(314)	4,634	(362)	4,380	(255)	2,708	(147)	3,052	(199)	19,298	(1,277)
2003 [2]	1,622	(79)	655	(52)	2,474	(118)	547	(46)	3,202	(135)	8,500	(430)
2004 [2]	2,704	(153)	1,996	(116)	3,284	(208)	1,687	(76)	2,759	(160)	12,430	(713)
2005 [2]	2,977	(205)	3,985	(177)	4,728	(213)	---[3]	---	4,093	(256)	17,023	(851)
2006 [2]	3,714 [4]	(286)	5,280	(341)	3,920	(240)	793	(61)	3,628	(262)	17,335	(1,190)
2007 [2]	1,842	(137) [4]	4,521	(304)[4]	3,924	(304) [4]	2,241	(203) [4]	4,106	(264) [4]	16,634	(1,212)
2008 [2]	669	(68) [5]	2,062	(174) [5]	1,856	(158) [5]	3,695	(341) [5]	1,713	(151) [5]	9,995	(892)
2009 [2]	2,197	(235) [6]	3,958	(344) [6]	2,398	(226) [6]	1,154	(141) [6]	2,499	(239) [6]	12,206	(1,185)
2010 [2]	1,963	(176) [6]	2,560	(208) [6]	2,061	(184) [6]	1,146	(130) [6]	1,739	(142) [6]	9,469	(840)
2011 [2]	2,481	(221) [6]	3,682	(244) [6]	2,104	(187) [6]	580	(84) [6]	3,109	(445) [6]	11,956	(1,181)
2012 [2]	3,332	(256) [6]	3,811	(269) [6]	2,795	(258) [6]	819	(125) [6]	3,440	(285) [6]	14,197	(1,193)
2013 [2]	1,436	(132) [6]	1,847	(145) [6]	1,214	(137) [6]	519	(82) [6]	2,167	(168) [6]	7,183	(664)
2014 [2]	2,378	(174) [6]	2,540	(176) [6]	1,833	(176) [6]	705	(92) [6]	1,795	(153) [6]	9,251	(771)
2015 [2]	2,078	(176) [6]	1,592	(141) [6]	1,366	(144) [6]	911	(102) [6]	2,308	(181) [6]	8,255	(744)
2016 [2]	**1,745**	**(177)**	**3,593**	**(263)**	**2,360**	**(221)**	**1,719**	**(170)**	**2,258**	**(154)**	**11,675**	**(985)**
3-yr ave. (2014-2016)	2,067		2,575		1,853		1,112		2,120		9,727	
Long-term ave. & growth rate (1992-2016)	3,183		4,402		2,868		1,459		3,026		14,955	
	0.954	0.013	0.952	0.015	0.976	0.011	0.977	0.018	0.979	0.008	0.964	(0.007)

[1]Estimates based on Lincoln-Petersen analysis of counts by two observers. A typo in KB 1993 was corrected in 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 (1992-2016) 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.

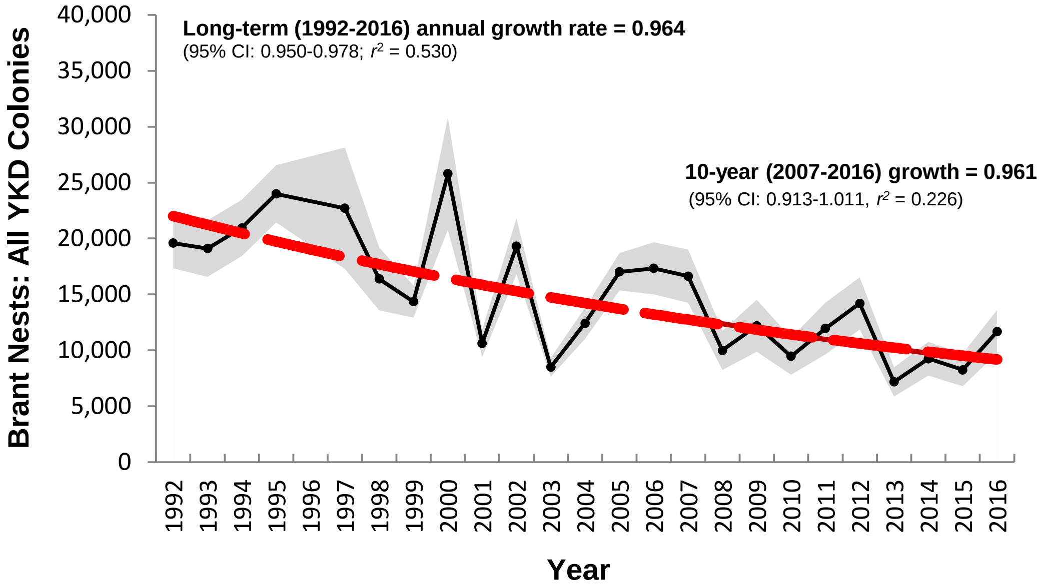


Figure 5. Trend (red line) and annual estimates (95% CI in grey) of brant nests from photographic surveys across all primary brant colonies on the Yukon-Kuskokwim Delta (1992-2016).

Note: No YKD colony survey occurred in 1996. Thus, no estimate for 1996 is included in the trend analysis. 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.

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) 2009-2016.

		Estimated of number of nests										
Species[1]	**Year**	**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
	2014	955	92	853	86	1,044	99	1,526	115	1,310	113	5,688
	2015	879	92	930	91	1,602	120	1,438	129	1,616	136	6,465
	2016	**1,271**	106	**1,797**	128	**2,020**	137	**1,797**	147	**1,337**	17	**8,222**
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**
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**
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**

[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*). 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.