Summary Report- 15 July 2010

Aerial Photographic Surveys of Brant Colonies on the Yukon-Kuskokwim Delta, Alaska, 2010

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ABSTRACT I conducted an aerial photographic survey of nesting Pacific black brant (*Branta bernicla nigricans*) 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 2010. Total number of nests for all colonies decreased by 21% between 2010 (9,641) and 2009 (12,206), and the 2010 estimate was ~41% lower than the long term average (16,310; 1992-2010). All colonies experienced a decrease in brant nests from the previous year (range: -1 to -35%, 8-1398 fewer nests). Overall, the trend in annual YKD estimates of nesting brant among the five primary colonies is becoming increasingly negative (currently -3.3%/yr), and the long-term trends at TR and KB (including 2010) marked the third consecutive year of substantial negative departures from the long-term YKD log-linear trend (e.g., 5-6% annual declines at TR and KB versus 3.3% annual decline for all YKD), indicating that most of the long term decline continues to be attributed to reductions at the KB and TR. 2010 reflected a poorer than average nesting year for colonial nesting brant on the YKD based on our aerial imagery, with indications of fox and avian predation, late initiation, nest abandonment and lower than average clutch sizes noted at several of the colonies. Human activity (based on counts of footprints and vehicle tracks) was the highest ever recorded at KB (beginning in 2001), while counts of human footprints at BI and BP were reduced from 2009.

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 considered imprecise for estimating colony size. As an alternative, aerial imagery was tested (Anthony et al. 1995), and beginning in 1992, aerial videographic surveys were conducted annually at 5 major brant nesting colonies on the YKD (Anthony 1992-2003; Fig. 1). In 2004, the survey 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 indices 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, nest densities of other species (e.g., cackling goose; *Branta hutchinsii minima*), and habitat change. Herein, I report the results of the 2010 survey.

STUDY AREA

I conducted aerial photographic surveys of nesting Pacific black brant 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 2010.

METHODS

Aerial Survey

Transects were flown at 122 m above ground level and I used a single, vertically-mounted Nikon D700 SLR® digital still camera with an image-stabilizing lens (70-200 mm) to photograph colonies. Transects were flown at speeds ranging from 125-148 km/hr (78-92 mph) over all colonies. All transects were flown into the wind, with ~10° of flaps deployed. This slowed the aircraft and maximized the number and quality of photos that could be taken on each transect. KB, TR, KI, BP, and BI required 0:50 (hours:minutes), 1:39, 1:43, 0:52, and 1:22, respectively, from start of first transect to end of last transect. 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 (usually near infinity). After the focus was set, I taped the focal ring in place and set the focus to 'manual'. This configuration produced images with ground footprints of ~41.8 x 27.87 m.

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 footprints (versus 0.05-hectare footprints in 2008 with a Nikon D200 camera) through holes in the floor of a Cessna-206 amphibious aircraft. Sampling protocol was similar to that in previous years -systematically spaced flight lines (~200 m apart) were flown along the long axis of all colonies (Anthony 2003-2006).

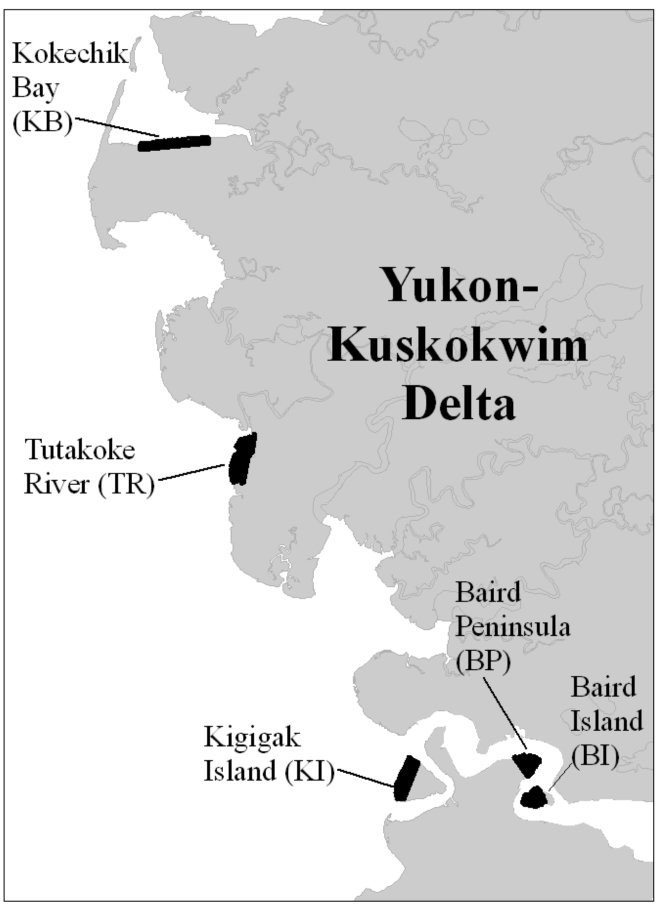

Figure 1. Photographic survey areas of the five primary Pacific black brant nesting colonies on the Yukon-Kuskokwim Delta.

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 Cessna-206 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 internally with 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 GPS (track file) and the camera's internal clock to interpolate image locations using GPS-Photo Link software (GPS-PHOTO LINK 2006).

Ground-truthing, nest detection, and correction factors

An assistant and I ground-truthed a sub-sample of photos at KI, KB, and TR (areas with good access by float plane), to determine the nest detection probability as estimated in digital images. Preparation for ground-truthing involved processing digital photos in GPS-Photo link®, printing 8.5 x 11" copies of photos to be truthed, creating ArcMap geographic information system (GIS) shapefiles (.shp) and Google Earth files (.kml) of photo locations, and mapping photo locations on high resolution IKONOS (IKONOS 2008) satellite imagery. To aid in navigation during ground-truthing, we created maps of photo locations and downloaded true photo center-point coordinates into hand-held GPSs. We performed the ground-truthing by carefully searching each of the selected photo locations and recording all nests observed, identified to species and considered active, abandoned, or destroyed, within the boundaries of each printed photo.

Because I included both errors of omission (not counting incubating brant) and commission (misidentifying other objects as incubating brant, e.g., standing brant or incubating cackling geese), my detection metric had the potential to be >1, and thus, was better termed an "index ratio" (Bart et al. 1998), than a probability. I calculated this index ratio ($\hat{R}$) as the pooled number of brant nests observed on aerial images (y) to brant nests located on the ground (x) across the three ground-truthed colonies, and used the variance of the index ratio (assuming no covariance between x and y) according to Cochran (1963),

$$Var\,\hat{R} = \frac{\sum\left(y_i - \hat{R}\,x_i\right)^2}{n(n-1)\cdot\left(x_i\right)^2}.$$

I then used the inverse of $\hat{R}$ as a visibility correction factor for all colonies to correct image-based counts (*y*) for combined errors of commission and omission, according to the formula,

$$\text{Corrected count} = \frac{y}{\hat{R}}.$$

Image processing

I determined total area in each colony with ArcGIS. I used the colony boundaries as re-outlined in 2009 (against 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 within the image-processing toolbox of 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.

Species other than brant

In addition to recording observations of brant, assistants and I recorded Pacific (*Gavia pacifica*) and red-throated loons (*G. stellata*), tundra swans (*Cygnus columbianus*), emperor geese (*Chen canagica*), white-fronted geese (*Anser albifrons frontalis*), cackling

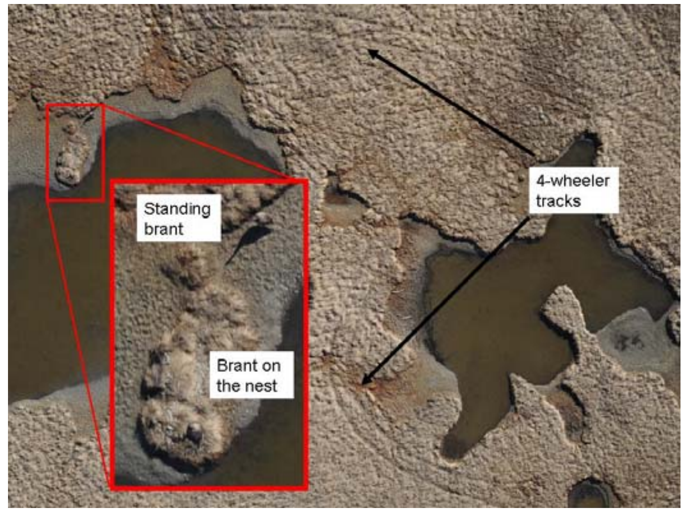

Figure 2. High-resolution digital image (Nikon D700 SLR camera) of nesting and standing brant, surrounded by 4-wheeler tracks at Kokechik Bay, 2010. This year marked the highest counts of 4-wheeler, snowmachine, and human footprint tracks at the Kokechik Bay colony in the history of the survey.

geese (*Branta hutchinsii*), common and spectacled eiders (*Somateria mollissima, S. fischeri)*, greater scaup (*Aythya marila*), long-tailed ducks (*Clangula hyemalis),* northern shovelers (*Anas clypeata*), northern pintails (*Anas acuta*); black turnstones (*Arenaria melanocephala*), glaucous gulls (*Larus hyperboreus*), Sabine's gulls (*Xema sabini*), arctic terns (*Sterna paradisaea*), and bar-tailed godwits (*Limosa lapponica*). Given the high resolution, large sample size, and improved coverage of images with the Nikon D700 camera (versus historical images a previously used Kodak 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 other species are presented in Appendix 1.

RESULTS

The number of images collected at KB, TR, KI, BP, and BI within colony boundaries was 954, 1508, 1156, 503, and 785, respectively. Thus, given total colony areas of 1044 (KB), 1468 (TR), 1130 (KI), 666 (BP), and 583 (BI) hectares, the 2010 photos represented a sample of 10.6, 12.0, 12.0, 8.8, and 15.7% of each of the respective colony areas; equivalent to the coverage achieved in the previous year (2009 coverage range: 10.3-12.3%). Surveys at BP, BI, and KI were each conducted in a single day between 12:33

and 19:50 hrs, under high overcast to scattered cloud conditions (2000 ft. overcast to broken clouds at 12,000 ft.) and moderate northwesterly winds (5-10 kts). The prevailing weather resulted in a range of photographic conditions from bright sunlight (allowing use of faster shutter speeds, and producing images with stronger shadows) to overcast/low-light conditions (producing photos with lower resolution, due to slower shutter speeds, but less of a strong shadow effect than under bright sunlight). Photos at KB and TR were taken the following day at 10:14-13:022 hrs, when even brighter, full-sunlight conditions prevailed.

Nest detection

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 previously: 1992-2008). The index ratio (i.e., brant nest detection probability) based on pooled image:ground counts across all ground-truthed colonies (KB, TR, and KI; n = 192 photos) was 0.93 (SE: 0.04, range: 0.71-1.13). Thus, the correction factor for image-based counts was 1.07.

All YKD brant colonies combined

Total estimated number of nests for all colonies (9,641) was 21% lower in 2010 than in 2009 (12,206), ~41% lower than the long term average (16,310; 1992-2010), and 10% lower than the 3-yr running average (2008-2010 Table 1). All colonies experienced a decrease in active brant nests from the previous year (range: -1 to -35%, 8 to 1398 fewer nests). The trend in annual YKD estimates of nesting brant continues to be negative (-3.3%/yr), with most of the long term decline continuing to be attributed to reductions at KB (-5%/yr) and TR (-6%/yr).

Kokechik Bay (KB)

The estimated number of nests at KB was 35% lower than in 2009, and 46% lower than the long-term average. Further, the within-colony trend at KB was 2 percentage points lower (λlog-linear(KB): 0.95, SE: 0.03) than the overall trend for the YKD. Nearby researchers at KB (located just west of the brant colony study area) reported a protracted brant nest initiation period within their study plots (6.25 ha ea.), with new nests being found from 28 May to 12 June. These researchers calculated an apparent nest survival estimate of ≥92% for the 103 brant nests they monitored over a ~2-wk period; suggesting high nest survival in that area (McCaffery 2010). Indications of fox and avian predation, as well as human nest predation (egging), within the KB brant colony study area were observed in digital photos (e.g., footprints leading to destroyed nests) and during ground-truthing, and could help explain the lower nest numbers observed in 2010 within the KB brant colony study area. Nearby researchers located to the west of the brant colony reported only one observation of an arctic fox, but several red fox (*Vulpes vulpes*) observations, including a red fox caching a brant egg. Although the majority of their fox observations centered around their upland camp area (well south of the primary brant colony habitat), these researchers also reported numerous fox tracks within their lowland-study plots (near the brant colony study area; McCaffery 2010). Fox control occurred at KB in April 2010, although only a small number of animals (~4) were taken at that time.

In 2010, boot tracks were observed in 222 image-sub-areas within the 954 (23%) images at KB (versus 6.7% of images in 2009) and motorized vehicle tracks (snowmachine and/or ATV) were observed in 150 image-subareas (16%) versus 3.3% of subareas within images in 2009. Overall, human activity at KB in 2010 nearly doubled relative to the highest historical counts (2001-2005 range: 30-166 image-subareas/year with boot tracks), and dramatically increased relative to 2006-2008 (when only 0-15 image-subareas/year were observed with boot tracks and 1-5 image-subareas/year were observed with vehicle tracks).

Tutakoke River (TR)

The estimated number of nests at TR decreased by 11% compared to 2009 and 44% relative to the long-term site-average. Further, the within-colony trend at TR was 3 percentage points lower (λlog-linear(TR): 0.94, SE: 0.03) than the overall trend for the YKD. Overall, the 2010 estimate indicated a below average nesting year at TR (Table 1), but reductions in nests did not appear catastrophic compared with other recent years (e.g., 2008 = 669 estimated nests, versus 2010 = 1,963 estimated nests). Some evidence of nest abandonment, late initiation, and nest destruction due to foxes was observed during ground-truthing in the northern section of the colony and corroborated by local researchers. Further, local researchers reported a dramatically protracted initiation period and lower than average clutch sizes, with many late nests being subsequently abandoned. Although researchers observed one fox in the northern colony, they did not report extensive damage or continued fox observations throughout the nesting season (A.Walker, pers. comm.). Fox control occurred at TR in April 2010 with a substantial number of animals taken (~42+)during the multi-week control period

Kigigak Island (KI)

The estimated numbers of brant nests within the KI brant colony study area (i.e., this survey) decreased by 14% in 2010 relative to the previous year, and by 35% relative to the long-term average at the site. Further, the long-term, log-linear trend at KI began to slope slightly downward in 2010 (λlog-linear(KI): 0.996, SE: 0.02). Overall, brant nest success within the colony study area at KI appeared lower than average in 2010 based on imagery data and nest monitoring of local researchers (~67% brant nest success, throughout KI in 2010, versus 90% in 2009; M. Wege unpubl. data), with some indications of nest destruction due to fox and avian (e.g., gull/jaegar) predation - primarily in the northern part of the island. No evidence of local flooding or delayed nest initiation was observed at KI in 2010, but average brant clutch size did appear to be reduced by ~1 egg, relative to previous years (M. Wege pers. comm.). Local researchers reported one arctic fox observation prior to nest initiation, coupled with a handful of subsequent fox signs (e.g., scat, fur, etc.) after nesting had commenced (M. Wege & M. Gabrielson pers. comm.). Overall, nest failure in the northwestern region of the island (43%) appeared noticeably higher than in the southern area (12%), based on nest monitoring by the resident field crew (M. Wege unpubl. data) and cooroborated by image ground-truthing. However, local researchers could not cause of depredation could not be reliably apportioned the between foxes and avian predators in any portion of the island. No fox control occurred at KI in 2010.

Baird Inlet Island (BI)

The estimated number of nests at BI decreased by 30% in 2010 compared to 2009, and was 46% lower than the long term average. Further, the long-term, log-linear trend at BI continued to be slightly decreasing (λlog-linear(BI): 0.98, SE: 0.01). No ground-based research at BI was conducted in 2010, and thus, no ground-based evaluations of factors influencing nest success are available for reporting. As in 2007-2009, no motorized vehicle tracks were observed on the island, but boot tracks were observed in 55 subareas of 785 photos; representing a substantial reduction from the previous year (7% this year versus 30% in 2009). No fox control occurred at BI in 2010.

Baird Peninsula (BP)

The estimated number of nests at BP decreased by only 1% compared to 2009, but this colony remained 31% below the long term site-average. Further, the log-linear trend at BP began to slope downward in 2010 (λlog-linear(BP): 0.995, SE: 0.03). Evidence of flooding could be observed in many of the images at this site. Boot tracks were observed in 6 of 523 (1.2%) of images in 2010 at BP, versus 14 of 592 (2.3%) in 2009, indicating a slight decrease in local human disturbance of the area. As in all previous years, no motorized vehicle tracks were observed at BP and no fox control occurred at BP in 2010.

DISCUSSION

Abundance and trends of Pacific black brant at nesting colonies on the YKD are important management indices used by the Pacific Flyway. Previous Flyway prescriptions for Pacific black brant mandated harvest closure if: a) the 3-yr average of the midwinter survey was <90,000, *and* b) the YKD-wide colony nest population estimate declined by 50% relative to the previous year (Pacific Flyway Council 2002). The 2010 YKD colony nest population estimate (9,641) was substantially decreased (-21%) compared to the previous year's estimate, but was not in danger of reaching the 50% reduction benchmark outlined by the Flyway. However, 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 2010, the 3-yr average was 10,614, just 615 nests above the closure threshold (had the midwinter estimate also fallen below 90,000).

Overall, 2010 reflected a poorer than average nesting year for nesting brant within the five primary brant colony study areas on the YKD based on aerial imagery and ground-truthing. Indications of fox, avian, and human predation, protracted initiation, and nest abandonment were identified as the most some of the primary causes of reductions in numbers of active nests in these areas. Limited aerial imagery data for other sympatrically nesting species within the brant colonies (e.g., cackling and emperor geese, and eiders; Appendix 1), indicated that 2010 may have also been a poorer nesting year for species other than brant within the colony areas. However, this information, when coupled with very different trends for cackling and greater-white fronted geese elsewhere across the YKD (e.g., substantial increases; Fischer et al. 2010, Bollinger and Hodges 2010), would suggest that nesting patterns within the five primary brant colonies may be very different from those outside the colonies.

Fox removal occurred at the TR and KB colonies in April 2010, but was not conducted at any other colony locations. Although some evidence of fox depredation of nests was observed at TR, KB, and KI, fox-related nest loss appeared to represent only a small to moderate proportion of the total nest failures observed at these colonies. However, fox and avian predation coupled with late-initiation related abandonment may have contributed to the higher number of unoccupied nests we observed in the 2010 imagery. This in turn may have explained the increase in inter-photo variance (CV) in nest counts observed in 2010 (i.e., patchy predation, may have led to higher variation in numbers of unoccupied nests across photos). In addition to foxes and avian predation, significant spring flooding appeared to have occurred at some of the colonies (e.g., BP, the northern portion of the TR, and some areas of KB), indicated by uniform silty deposits and strong, consistent directionality of underlaying grasses (observed both in images and ground-truthing). Such flooding could have potentially contributed to changes in habitat availability, and thus numbers of nests at some locations. In general, predicted hatch dates for brant across the YKD appeared normal in 2010, suggesting an average nesting year would occur (B. Stehn pers. comm.; preliminary analysis of YKD random nest plot data; e.g., Fischer et al. 2010, and M.Wege pers. comm. for KI). However, researchers at colonies such as TR and KB, reported extremely long nest initiation periods, with newly initiated nests being found well into June, and lower than normal clutch sizes reported at TR and KI. Many of these late initiated nests were later found abandoned. One explanation for the pattern of protracted initiation, lower clutch sizes, and failure of late-initiated nests observed at TR, and possibly other locations on the YKD, could have been unusually cold climate conditions potentially altering patterns of habitat availability at staging and nesting grounds and/or affecting pre-nesting body condition of the breeding females. Ground data on clutch sizes, distribution of initiation dates (in relation to final nest fates), and body weights of nesting females, could help elucidate the influence of such factors at the primary colonies.

Finally, human activity (based on counts of footprints and vehicle tracks) was the highest ever recorded at KB (beginning in 2001) and indications of snow machine, four-wheeler, and humans footprints were extensive throughout the KB colony. Although some of these vehicle tracks could have been attributed to previous years' non-research activities, the 2010 counts were still almost double the highest counts recorded since 2001, indicating at least some new activity has occurred since that time. Based on our observations, human egg-predation and other disturbance may have been an important contributor to lower numbers of active brant nests at KB in 2010. In contrast, counts of human footprints at other colonies, such as BI and BP, were lower than in the previous year and lower than historical counts based on footprint data (2001-2005), suggesting human disturbance of those colonies was stable to decreasing. Although purely correlational, proportional reductions in numbers of nesting brant were also much lower at the colonies with lower indicated human use.

Finally, although the number of brant nests at all colonies decreased from 2009 to 2010, the magnitude of the decrease varied substantially among colonies; from a <1% decrease at BP to a >35% decrease at KB. 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 2010) marked the third consecutive year of substantial negative departures from the long-term YKD log-linear trend (e.g., 5-6% annual declines at TR and KB vs. ~3% 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 at KB and TR. Fluctuations in numbers of nesting brant between BI and BP over the past two years continues to suggest that the two nearby colonies may functionally behave as one, with alternating nesting conditions influencing annual nesting densities.

ACKNOWLEDGEMENTS

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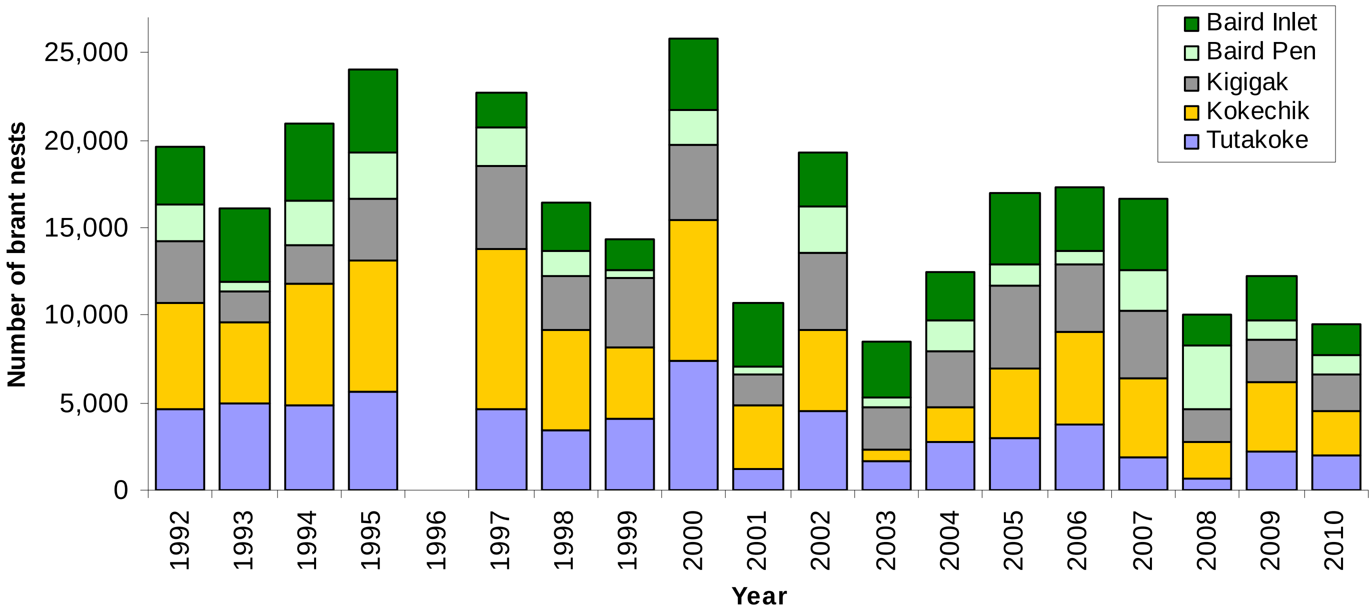
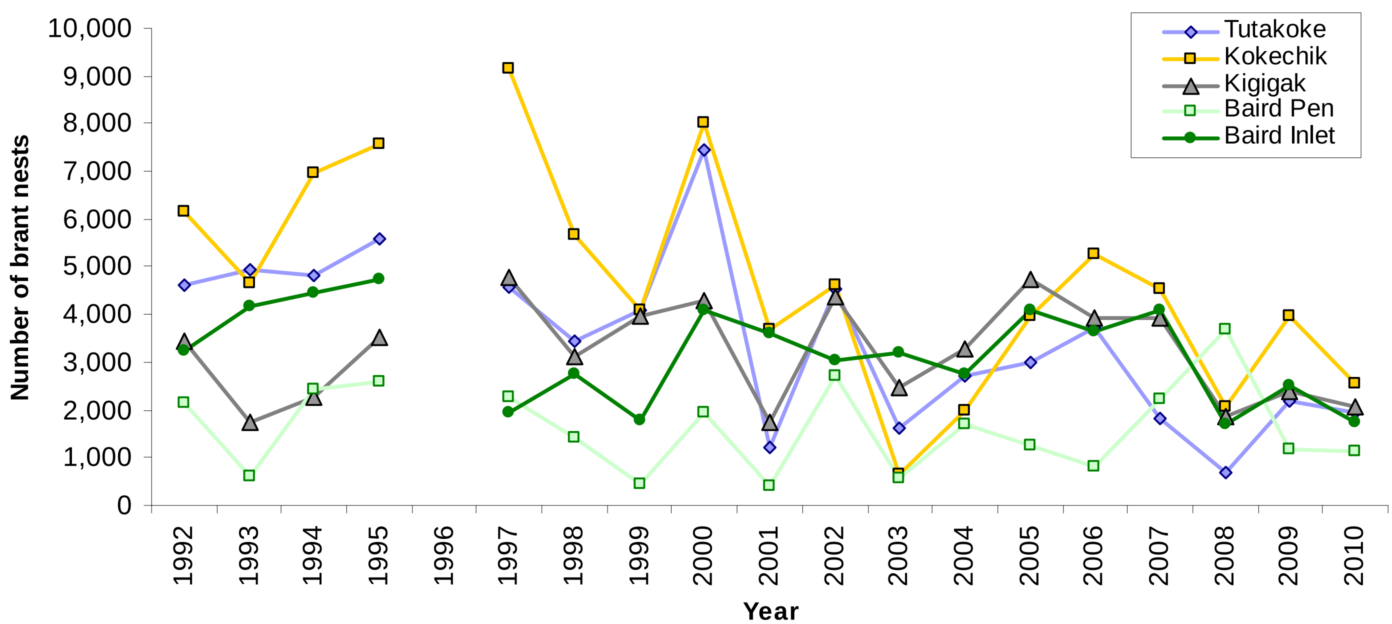
Table 1. Annual estimates and standard errors (± 1 SE, presented in # of nests) from photographic aerial surveys of brant nests at the five primary colonies on the Yukon-Kuskokwim Delta, Alaska (1992-2010); Tutakoke River (TR), Kokechik Bay (KB), Kigigak Island (KI), Baird Inlet Island (BI), and Baird Peninsula (BP).

	Colony Nest Estimates										
Year	**TR**	**(SE)**	**KB**	**(SE)**	**KI**	**(SE)**	**BP**	**(SE)**	**BI**	**(SE)**	**Total**
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)	---	---	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)	---	---	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]	3958	(344) [6]	2,398	(226) [6]	1,154	(141) [6]	2,499	(239) [6]	12,206
2010 [2]	**1,963**	**(426) [6]**	**2,560**	**(547) [6]**	**2,061**	**(447) [6]**	**1,146**	**(261) [6]**	**1,739**	**(372) [6]**	**9,641**
3-yr average (2008-2010)	1,610		2,860		2,105		1,998		1,984		10,614
Long-term average (1992-2010)	3,497		4,754		3,194		1,664		3,197		16,310

[1]Estimates based on Lincoln-Petersen analysis of counts by two observers.
[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 2009-2010 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 (1992-2010) from photographic surveys; Tutakoke River (TR), Kokechik Bay (KB), Kigigak Island (KI), Baird Peninsula (BP), and Baird Island (BI).

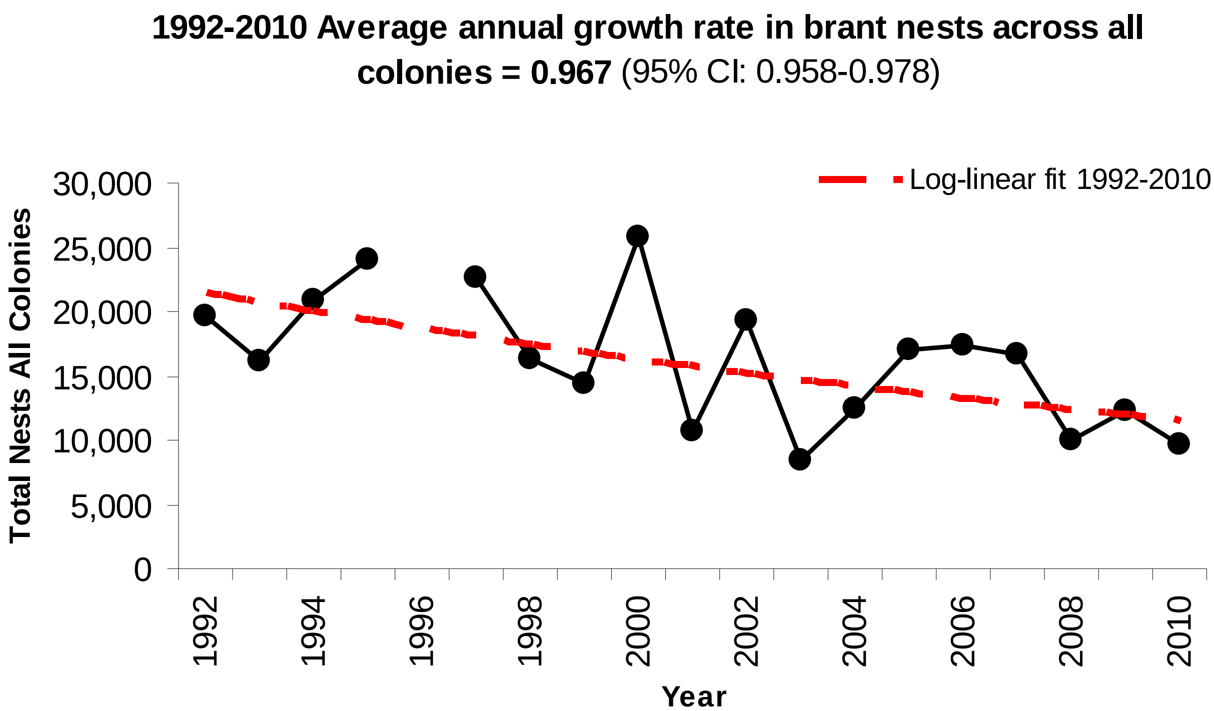


Figure 4. Log-linear trend of annual estimates of brant nests (red dashed line) from photographic surveys across all brant colonies on the Yukon-Kuskokwim Delta (1992-2010). Note: Estimates do not exist for 1996, and in 2005 only four of five colonies were surveyed.

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		Estimates of number of nests										
Species		**TR**	**(SE)**	**KB**	**(SE)**	**KI** [2]	**(SE)**	**BP**	**(SE)**	**BI**	**(SE)**	**Total (SE)**
Cackling goose [1]	2009	1,615	(248) [6]	1,582	(288)	2,271	(382)	2609	(436)	1,999	(349) [6]	9,898 (1556)
	2010	**616**	(139)	**601**	(136)	**1214**	(257)	**1264**	(274)	**808**	(172)	**4453** (915)
Emperor goose	2009	96	(29)	75	(27)	392	(61)	205	(50)	196	(47)	969 (111)
	2010	**60**	(21)	**48**	(20)	**282**	(48)	**69**	(27)	**241**	(38)	**767** (85)
Greater white-fronted goose	**2010**	**109**	(30)	**57**	(22)	**34**	(16)	**35**	(19)	**13**	(9)	244 (46)
Eider spp. [3]	2009	420	(97)	289	(79)	245	(66)	96	(38)	46	(26)	**1103** (208)
	2010	**153**	(52)	**48**	(20)	**265**	(71)	**---**	---	**---**	---	**471** (93)

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) in 2010.

[1] Estimates for cackling geese were based on a detection index ratio specific to cackling geese (1.44, SE: 0.09), from ground-truthed transects at (KB, TR, and KI in 2010; n = 191 photos). Estimates for emperor geese and eiders were based on the 2010 combined detection index ratio for brant and cackling geese (0.98, SE: 0.04).

[2] Estimates for the area covered at KI overlap with coverage from the YKD random nest plots survey (Fischer et al. 2009).

[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.