

# Aerial Photographic Survey of Brant Colonies on the Yukon-Kuskokwim Delta, Alaska, 2015

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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 2-3 June 2015. As indicated by the photos, total estimated number of nests for all colonies (8,255) was 11% lower in 2015 than in 2014 (9,251), 46% lower than the long term average (15,409; 1992-2014), and 19% lower than the most recent 3-yr running average (10,210, 2012-2014). The 2015 YKD colony nest population estimate also fell well below the productivity benchmark outlined by the Pacific Flyway (>50% below the 1993-2000 average of 19,683 nests). Three of five colonies (TR, KB, and KI) experienced declines in brant nests in 2015 relative to the previous year (range: -37 to -13%) and the composite trend in annual YKD estimates of nesting brant from the five primary colonies continued to be negative (-3.7%/yr; Fig. 4). Moreover, the long-term trends at TR and KB (including 2015) marked the eighth consecutive year of substantial negative departures from the long-term YKD colony trend (e.g., 4.7 and 5.4% annual declines at TR and KB versus ~2.4% annual decline for all colonies), indicating that most of the long term decline continues to be attributed to reductions at KB and TR. Although 2015 represented an early nesting year for brant on the YKD, and there were few indications of predation and/or flooding from the imagery survey, overall nesting was relatively poor. Human activity (based on numbers of photos with footprints and vehicle tracks at locations without researchers) continued to be elevated at the Baird colonies in 2015, while human presence at Kokechik Bay remained relatively low and stable in 2015. Notably, several images at Kokechik showed boot tracks of 5+ adults and/or accompanying children, and for the first time in the history of the survey, moose tracks were observed in the aerial imagery (at the Kokechik colony).

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

During the mid-1980's, declining numbers of nesting Pacific black brant (*Branta bernicla nigricans*) on the Yukon-Kuskokwim Delta (YKD), Alaska (Sedinger et al. 1993) generated interest in developing an efficient method to estimate the number of individuals nesting in large colonies. Previously, ground crews surveyed colonies with strip transects or circular plots (Byrd et al. 1982, J. Sedinger unpubl. data). However, due to high nest densities and large areas associated with colonies, labor intensive ground-plots were considered impractical and visual counts from aircraft were thought to be too imprecise for estimating colony size. Alternatively, aerial imagery was tested (Anthony et al. 1995), and beginning in 1992, aerial videographic surveys were conducted annually at the 5 major brant nesting colonies on the YKD (Anthony 1992-2003; Fig. 1). In 2004, the survey methodology changed from videography (i.e., digital camcorder) to still-frame, digital photography (Anthony 2004-2006). The objective of the survey is to establish YKD colony nest estimates to help guide population recovery efforts for Pacific black brant, including annual harvest guidelines (Pacific Flyway Council 2002). 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 this 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 2015 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 2-3 June 2015.

## METHODS

## Aerial Survey

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

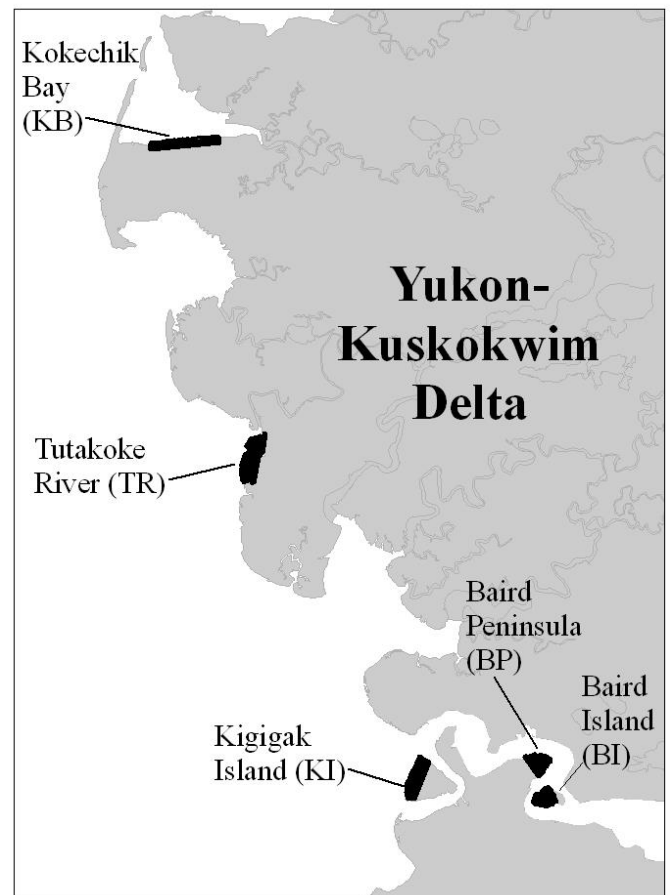
Sampling protocol was similar to that in previous years, where systematically spaced flight lines (200 m apart) were flown along the long axis of all colonies (Anthony 2003-2006). Transects were flown at 122 m (400 ft) above ground level, at ground speeds ranging from 70-80 kts, in a wheel-equipped Cessna 206 (N740). All transects were flown into the wind, with ~10° of flaps deployed. Flying transects into the winds helps slow the aircraft and maximize the number and quality of photos that can be taken on each transect. In 2015, photography of KB, TR, KI, BP, and BI required 0:50 (hours:minutes), 1:37, 1:14, 0:45, and 1:21, respectively, from start of first transect to end of last transect. Surveys at all colonies except KB were conducted on 2 June 2015 between 10:37 and 18:16 hrs with a stop in Newtok. After overnighing and refueling in Bethel, the crew completed surveys at KB the following day, 3 June 2015 (between 10:33 and 11:23 hrs).

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

I calculated standard errors of estimated nests at each colony using inter-photo variance (photo as the sample unit), rather than inter-transect variance (1992-2008).

## Ground-truthing, nest detection, and correction factors

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



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

## Image processing

I determined total area in each colony with ArcGIS, 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®. 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.

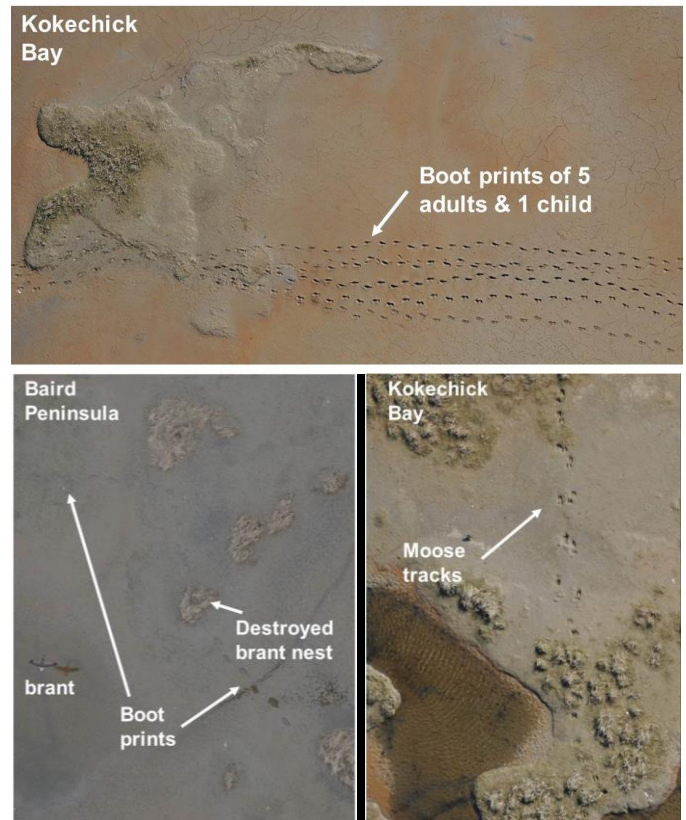
Boot tracks and motorized vehicle tracks were counted at KB, BP, and BI, but no measure of human activity was quantified at KI or TR because of ongoing research activity at those sites.

### Species other than brant

In addition to recording observations of brant, assistants and I recorded nests of Pacific (*Gavia pacifica*) and red-throated loons (*G. stellata*), tundra swans (*Cygnus columbianus*), emperor geese (*Chen canagica*), white-fronted geese (*Anser albifrons frontalis*), cackling geese (*Branta hutchinsii*), common and spectacled eiders (*Somateria mollissima*, *S. fischeri*), greater scaup (*Aythya marila*), long-tailed ducks (*Clangula hyemalis*), northern shovelers (*Anas clypeata*), and northern pintails (*Anas acuta*). We did not record gulls (*Larid* spp.) or shorebirds, although these are abundant in the photographs. Given the high resolution, large sample size, and improved coverage of images with the Nikon D700 camera, I had sufficient observations to generate nest population estimates for cackling, emperor, and greater white-fronted geese, as well as eiders (common and spectacled combined) within the brant colony study areas (2009-present; Appendix 1).

## RESULTS

The number of images analyzed at KB, TR, KI, BP, and BI within colony boundaries in 2015 was 950, 1322, 990, 500, and 364, respectively. Thus, given total colony areas of 1044 (KB), 1468 (TR), 1130 (KI), 666 (BP), and 584 (BI) hectares, the 2015 photos represented a sample of 10.6, 10.5, 10.2, 8.8, and 7.3% of each of the respective colony areas and was similar to the coverage achieved in previous years (2009-2015 coverage range: 7-16%).



**Figure 2.** Digital images of human footprints (Kokechick Bay & Baird Peninsula) and moose tracks (Kokechick Bay). These were the first moose tracks recorded on the imagery survey during its history.

Survey weather conditions were partially cloudy or clear with light to moderate winds (15 kts at TR). Glare and shadows made identification difficult in a handful of photos.

### 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.

### All YKD brant colonies combined

Total estimated number of nests for all colonies (8,255) was 11% higher in 2015 than in 2014 (9,251), yet the 2015 estimate was still 46% lower than the long term average (15,409; 1992-2014), and 9% lower than the previous 3-yr running average (10,210, 2012-2014; Table 1). Three of five colonies (TR, KB, and KI) experienced declines in brant

nests in 2015 relative to the previous year (range of declines: -37 to -13%) and the composite trend in annual YKD estimates of nesting brant from the five primary colonies continues to be negative (-3.7%/yr; Fig. 4). Moreover, the long-term trends at TR and KB (including 2015) marked the eighth consecutive year of substantial negative departures from the long-term YKD colony trend (e.g., 4.7 and 5.4% annual declines at TR and KB versus ~2.4% annual decline for all colonies), indicating that most of the long term decline continues to be attributed to reductions at KB and TR.

### **Kokechik Bay (KB)**

The estimated number of nests at KB (1,592, SE: 141) was 37% lower in 2015 than in 2014, and 65% lower than the long-term average (4,566; 1992-2014) at that site. Further, the within-colony trend at KB remained 1.7 percentage points lower ( $\lambda$ log-linear (KB): 0.947, SE: 0.02) than the trend for all YKD colonies (0.963). No researchers visited KB in 2015, nor did any fox control occur at the site, and no indications of depredation or flooding were observed in digital photos. Boot tracks were observed in 20 of 950 photos at KB in 2015 (2.1%) and motorized vehicle tracks (snowmachine and/or ATV) were observed in 2 images (<1%), both similar to the previous year's estimates (2.9 and <1%, in 2014). Several images had boot tracks of 5+ adults and/or accompanying children (Fig. 2) and for the first time in the history of the survey, moose tracks were observed in the imagery at the KB colony (Fig. 2). Overall, the 2015 detectable human presence (as indicated by boot and vehicle tracks) at KB was consistent with a sustained, low level (range: 1-6%) of activity, similar to that occurring since 2006.

### **Tutakoke River (TR)**

The estimated number of nests at TR (2,078, SE: 176) was 13% lower than in 2014, and 37% lower than the long-term site-average (3,298; 1992-2014). Further, the within-colony trend at TR remained 1.3 percentage points lower ( $\lambda$ log-linear(TR): 0.953, SE: 0.01) than the overall trend for the YKD (0.963). The 2015 estimate indicated an average to moderately low nesting year at TR relative to recent years at that site (most recent 10-yr average: 2,829, Table 1). Local researchers (T. Riecke pers. comm.) also reported a low nesting year for brant in 2015. Overall depredation appeared to be minimal at the time of photography. Fox control did not occur at TR in 2015.

### **Kigigak Island (KI)**

The estimated number of brant nests within the KI brant colony study area (1,366, SE: 144) was 26% lower in 2015 than 2014, and 54% lower than the long-term average (2,964; 1992-2014) for the site. Further, the long-term, log-linear trend at KI showed a slight decline in 2015 ( $\lambda$ log-linear(KI): 0.975, SE: 0.01). Overall, nesting within the KI study area appeared to be normal to slightly depressed in 2015. However, there was little indication of nest destruction due to fox and avian (e.g., gull/jaeger) predation from the images and no fox control occurred at KI in 2015.

### **Baird Inlet Island (BI)**

The estimated number of nests at BI (2,308, SE: 181) was 29% higher in 2015 compared to 2014 and 26% lower than the long term site-average (3,094; 1992-2014). The long-term, log-linear trend at BI shows a decrease of ~2% per year ( $\lambda$ log-linear(BI): 0.98, SE: 0.01). No ground-based research at BI was conducted in 2015, and thus, no ground-based evaluations of factors influencing nest success are available. However, detectable human presence at BI, as indicated by boot tracks, continued to be elevated in 2015. Boot tracks were observed in 29 of 364 photos (7%) in 2015, representing a decrease from the initial spike in human presence observed in 2014 (14% of photos), but a substantial increase relative to historical levels of human activity at this site (~1%). BI and BP were the only colonies to experience increased brant nesting relative to the previous year. As in all previous years, 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 2015.

### **Baird Peninsula (BP)**

The estimated number of nests at BP (911, SE: 102) was 29% higher in 2015 compared to 2014, but the colony still remained 38% below its long term site-average (1,472; 1992-2014). Further, the log-linear trend at BP continued to slope downward in 2015 ( $\lambda$ log-linear (BP): 0.97, SE: 0.02). Detectable human presence at BP noticeably decreased in 2015 (down to 2% from 8% in 2014). In 2015, only 9 of 500 photos (1.8%) had boot tracks, versus 58 of 516 photos (11%) in 2014. Recent years (2009-2013) averaged <1% of photos with detectable human presence. In 2015, no significant flooding or depredation was observed

in photos at BP, no fox control occurred, and as in all previous years, no motorized vehicle tracks were observed at this colony.

## DISCUSSION

Abundance and trends of Pacific black brant at nesting colonies on the YKD are important management indices used by the Pacific Flyway. The current Flyway Management Plan mandates harvest closure if: a) the 3-yr average of the midwinter survey is <90,000, and b) the YKD-wide colony nest population estimate is 50% below the 1993-2000 average of 19,683 nests (Pacific Flyway Council 2002, technical clarification July 2004). In 2015, the YKD colony nest population estimate (8,255) was 58% below the 1993-2000 average of 19,683, thus, falling below the current benchmark outlined by the Flyway. However, the most recent 3-yr average of the midwinter survey, 157,699 (derived from 2013-2015) estimates; Olson 2015 - Pacific Flyway Databook), was well above the harvest closure threshold. Given the variation in year to year estimates and survey conditions/timing, I believe use of a three year average would be preferable to a single year estimate for the YKD brant colonies.

In 2015, almost all colony estimates were similar to the previous year and overall, the 2015 YKD aerial imagery reflected a slightly lower than average nesting year (number of nests) for brant across the YKD, at least relative to recent year's estimates. This was despite continued earlier initiation dates (~5 days earlier, than 1985-2014; Fischer in prep), and earlier snow-free conditions on breeding grounds. Most of the data and observations from concurrent surveys and local researchers corroborated an average to low nesting year for brant in 2015, although there were also several areas of decline. For example, estimated brant nest success from the YKD Nest Plot Survey (Fischer and Stehn in prep.), was estimated at 66%, while numbers of nests across the YKD were estimated to be 28% higher than the previous year. Yet another survey, the YKD Coastal Zone aerial survey, found total indicated brant to be 30% lower, and indicated breeding brant to be 8% lower, than the previous year (Swaim et al. 2016). Overall, the long-term growth rate for nests in the primary colonies ( $\lambda = 0.963$  1993-2015) is 4.1 percentage points lower than that estimated for the larger the YKD coastal zone, based on annual nest plot surveys ( $\lambda = 1.004$ , 1985-2015; Fischer in prep) and 7.9 percentage points lower than that for indicated breeding birds across the YKD from aerial counts ( $\lambda = 1.042$ , 1985-

2015, Swaim in prep). This suggests that brant nesting in the historical colonies are in a significant long-term decline, while brant nesting elsewhere on the YKD may be experiencing a much slower rate of decline, and in some cases approaching stability (also see Stehn et al. 2011). No fox removal occurred at any of the colonies in 2015, and indications of fox and avian depredation were minimal, with no significant flooding. Aerial imagery data for other sympatrically nesting species within the brant colonies (e.g., cackling, emperor, and greater white-fronted geese, and eiders; Appendix 1), indicated substantial species-specific variation in nesting in 2015. With the exception of a doubling of nesting eiders at the Tutakoke River colony from 2014 to 2015, there was little change in colony-specific estimates from the previous year for a. Combined colony counts of photographic estimates of nests of cackling, emperor, and greater white-fronted geese, and eiders, all increased from 2014 to 2015 (Appendix 1). Trends for these species from other ground and aerial based surveys also demonstrate high levels of interspecific variation (Fischer in prep 2015, Platte et al. 2014).

Although human activity (based on numbers of photos with footprints and vehicle tracks) remained stable at Kokechik Bay in 2015, the elevated levels of human presence at Baird Peninsula and Baird Island colonies beginning in 2014 and continuing in 2015, remains a concern. These remote nesting grounds have had little to no human presence in this survey's history, until the last two years. Review of 2015 photos suggested several instances of human egg-predation at the Baird colonies, but also several photos in which nesting birds appeared undisturbed, despite evidence of human presence nearby. No biological studies occurred in the vicinity of these colonies in 2015. The Baird colonies lie between the village of Newtok on the mainland and the new village relocation site of Mertarvik, on Nelson Island; a ~13 km (8 mi.) boat transit across the Ninglick River. Overall, levels of human activity at the Baird colonies were slightly reduced from the initial uptick in 2014 and neither colony experienced a decrease in nesting brant in 2015 relative to the previous year. 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.

For the first time in the history of the imagery survey, moose tracks were observed in brant colony photos (at

Kokechik Bay), corroborating increasing observations of moose on the coastal fringe by research camps and aerial survey crews. At Kokechik Bay, fresh motorized vehicle tracks were observed in only two photos in 2015 (a substantial decline from previous years), and several photos indicated groups of 5+ adults and/or children accompanying the adults. Kokechik Bay continues to have the steepest decline nesting brant among the colonies (growth rate 0.947, SE: 0.015), even with apparent declines in human presence within images.

Finally, although the number of brant nests at all colonies, except the Baird colonies decreased from 2014 to 2015, the magnitude of the decrease varied substantially among colonies; from 13% at Tutatkoke River to 37% at Kokechik Bay. 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 2015) marked the eighth consecutive year of negative departures from the long-term YKD log-linear trend (e.g., 4.9 and 5.3% annual declines at TR and KB versus 3.6% annual decline for all YKD), indicating that most of the long term decline in numbers of nesting brant on the YKD continues to be attributed to reductions from historic estimates at KB and TR.

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**Table 1.** Annual estimates and standard errors ( $\pm 1$  SE, presented in # of nests) from photographic aerial surveys of brant nests at the five primary colonies on the Yukon-Kuskokwim Delta, Alaska (1992-2015); Tutakoke River (TR), Kokechik Bay (KB), Kigigak Island (KI), Baird Inlet Island (BI), and Baird Peninsula (BP).

Year	Colony Nest Estimates										
	TR	(SE)	KB	(SE)	KI	(SE)	BP	(SE)	BI	(SE)	Total
1992	4,600 <sup>2</sup>	(202)	6,134 <sup>2</sup>	(295)	3,440 <sup>1</sup>	(154)	2,157 <sup>1</sup>	(151)	3,258 <sup>1</sup>	(347)	19,589
1993	4,937 <sup>2</sup>	(190)	4,667 <sup>1</sup>	(577)	1,727 <sup>2</sup>	(90)	614 <sup>1</sup>	(77)	4,156 <sup>1</sup>	(357)	16,101
1994	4,807 <sup>1</sup>	(400)	6,978 <sup>2</sup>	(196)	2,260 <sup>2</sup>	(92)	2,441 <sup>1</sup>	(142)	4,461 <sup>1</sup>	(454)	20,947
1995	5,596 <sup>2</sup>	(297)	7,573 <sup>2</sup>	(351)	--- <sup>3</sup>	---	2,591 <sup>1</sup>	(184)	4,720 <sup>1</sup>	(474)	23,998
1997 <sup>2</sup>	4,588	(554)	9,144	(1092)	4,776	(595)	2,259	(282)	1,944	(242)	22,711
1998 <sup>2</sup>	3,448	(292)	5,655	(471)	3,105	(238)	1,431	(169)	2,747	(264)	16,386
1999 <sup>1</sup>	4,100	(96)	4,072	(74)	3,962	(402)	448	(81)	1,777	(80)	14,359
2000	7,437 <sup>2</sup>	(584)	8,021 <sup>2</sup>	(866)	4,286 <sup>1</sup>	(647)	1,962 <sup>1</sup>	(142)	4,088	(324)	25,794
2001 <sup>2</sup>	1,212	(73)	3,677	(215)	1,721	(107)	421	(36)	3,604	(198)	10,635
2002 <sup>2</sup>	4,524	(314)	4,634	(362)	4,380	(255)	2,708	(147)	3,052	(199)	19,298
2003 <sup>2</sup>	1,622	(79)	655	(52)	2,474	(118)	547	(46)	3,202	(135)	8,500
2004 <sup>2</sup>	2,704	(153)	1,996	(116)	3,284	(208)	1,687	(76)	2,759	(160)	12,430
2005 <sup>2</sup>	2,977	(205)	3,985	(177)	4,728	(213)	--- <sup>3</sup>	---	4,093	(256)	17,023 <sup>3</sup>
2006 <sup>2</sup>	3,714 <sup>4</sup>	(286)	5,280	(341)	3,920	(240)	793	(61)	3,628	(262)	17,335
2007 <sup>2</sup>	1,842	(137) <sup>4</sup>	4,521	(304) <sup>4</sup>	3,924	(304) <sup>4</sup>	2,241	(203) <sup>4</sup>	4,106	(264) <sup>4</sup>	16,634
2008 <sup>2</sup>	669	(68) <sup>5</sup>	2,062	(174) <sup>5</sup>	1,856	(158) <sup>5</sup>	3,695	(341) <sup>5</sup>	1,713	(151) <sup>5</sup>	9,995
2009 <sup>2</sup>	2,197	(235) <sup>6</sup>	3,958	(344) <sup>6</sup>	2,398	(226) <sup>6</sup>	1,154	(141) <sup>6</sup>	2,499	(239) <sup>6</sup>	12,206
2010 <sup>2</sup>	1,963	(176) <sup>6</sup>	2,560	(208) <sup>6</sup>	2,061	(184) <sup>6</sup>	1,146	(130) <sup>6</sup>	1,739	(142) <sup>6</sup>	9,469
2011 <sup>2</sup>	2,481	(221) <sup>6</sup>	3,682	(244) <sup>6</sup>	2,104	(187) <sup>6</sup>	580	(84) <sup>6</sup>	3,109	(445) <sup>6</sup>	11,956
2012 <sup>2</sup>	3,332	(256) <sup>6</sup>	3,811	(269) <sup>6</sup>	2,795	(258) <sup>6</sup>	819	(125) <sup>6</sup>	3,440	(285) <sup>6</sup>	14,197
2013 <sup>2</sup>	1,436	(132) <sup>6</sup>	1,847	(145) <sup>6</sup>	1,214	(137) <sup>6</sup>	519	(82) <sup>6</sup>	2,167	(168) <sup>6</sup>	7,183
2014 <sup>2</sup>	2,382	(174) <sup>6</sup>	2,540	(176) <sup>6</sup>	1,833	(176) <sup>6</sup>	705	(92) <sup>6</sup>	1,795	(153) <sup>6</sup>	9,251
<b>2015<sup>2</sup></b>	<b>2,078</b>	<b>(176)<sup>6</sup></b>	<b>1,592</b>	<b>(141)<sup>6</sup></b>	<b>1,366</b>	<b>(144)<sup>6</sup></b>	<b>911</b>	<b>(102)<sup>6</sup></b>	<b>2,308</b>	<b>(181)<sup>6</sup></b>	<b>8,255</b>
<b>Current 3-yr average (2013-2015)</b>	1,964		1,9993		1,471		712		2,090		8,230
<b>Long-term average (1992-2015)</b>	3,245		4,437		2,892		1,447		3,059		15,098

<sup>1</sup>Estimates based on Lincoln-Petersen analysis of counts by two observers.

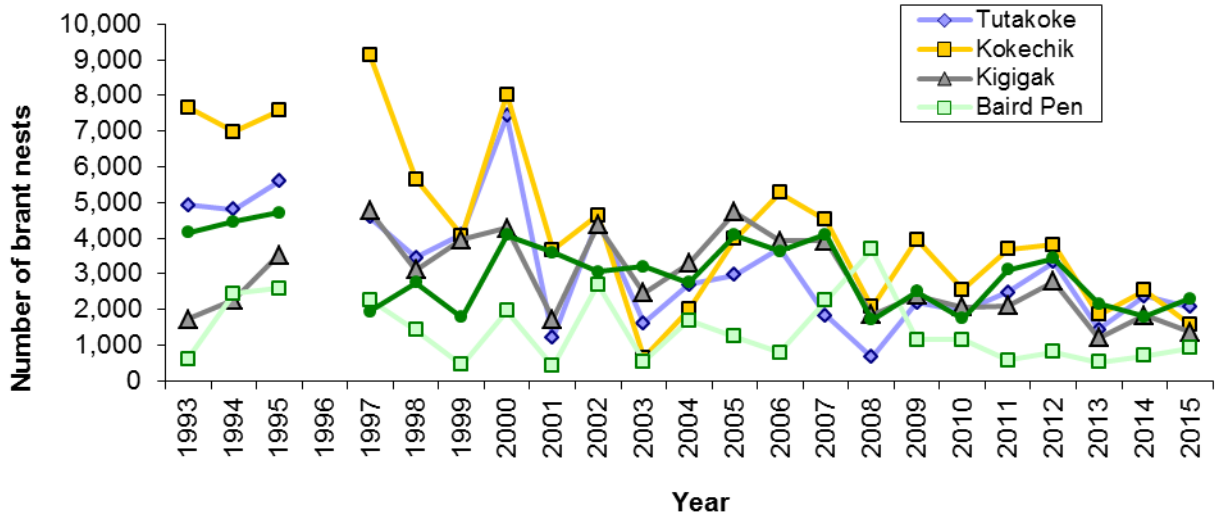
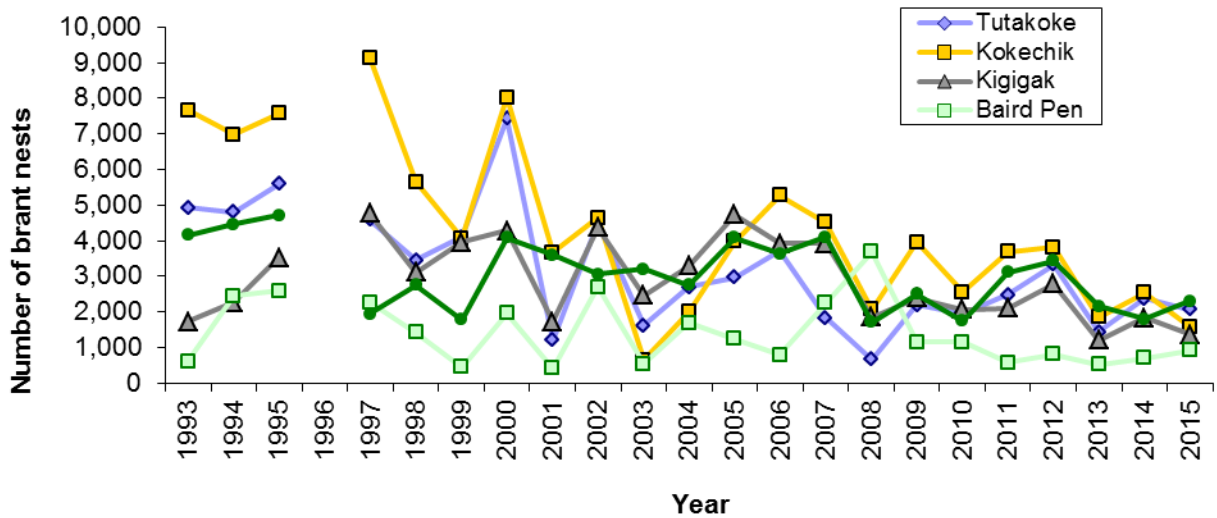
<sup>2</sup>Estimates based on correction factors from ground-truthed transects.

<sup>3</sup>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.

<sup>4</sup>2006 TR estimate based on 63% of the images analyzed.

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

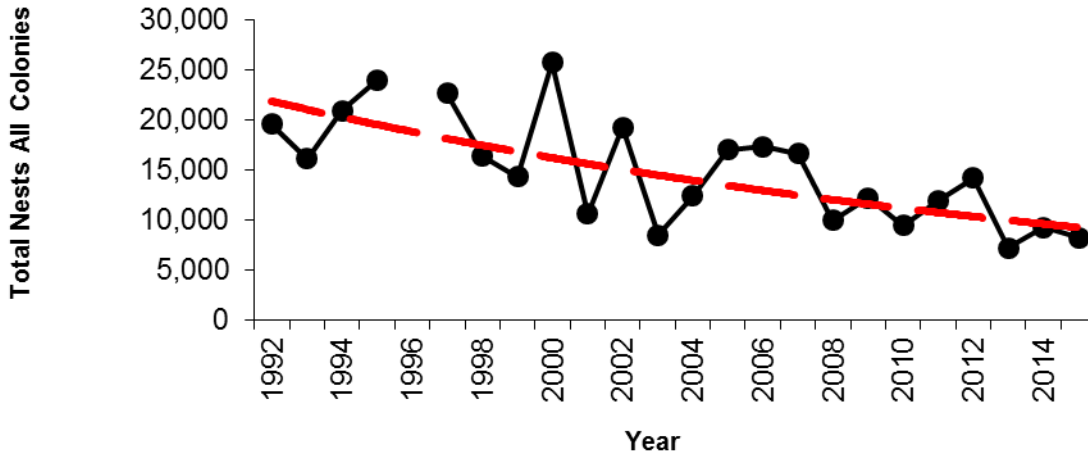
<sup>6</sup>Standard errors in 2009-present were calculated using inter-photo variance (photos as the sample unit), rather than inter-transect variance (as in 1992-2008).



**Figures 3a and 3b.** Estimates of number of nests at the five primary brant colonies on the Yukon-Kuskokwim Delta (1992-2015) from photographic surveys; Tutakoke River (TR), Kokechik Bay (KB), Kigigak Island (KI), Baird Peninsula (BP), and Baird Island (BI). Note: Due to lack of surveys at KI in 1995 and BP in 2005, the mean of the 1994 and 1997 KI estimates were used to derive a 1995 KI estimate, and the mean of 2004 and 2006 BP estimates were used to derive a 2005 BP estimate.



**1992-2015 Average annual growth rate in brant nests across all colonies = 0.963 (95% CI: 0.948-0.979; R<sup>2</sup>=0.53)**



**Figure 4.** Trend in annual estimates of brant nests (red dashed line) from photographic surveys across all brant colonies on the Yukon-Kuskokwim Delta (1992-2015). Note: No YKD colony survey occurred in 1996. Thus, no estimate for 1996 is included in the trend analysis. However, the mean of 1994 and 1997 Kigigak Island estimates was substituted for the 1995 Kigigak Island total and average, and the mean of 2004 and 2006 Baird Peninsula estimates was substituted for the 2005 Baird Peninsula total and average.

**Appendix 1.** Estimates and standard errors ( $\pm 1$  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) 2009-2015.

Species <sup>1</sup>	Estimates of number of nests											
	TR	(SE)	KB	(SE)	KI <sup>2</sup>	(SE)	BP	(SE)	BI	(SE)	Total (SE)	
<b>Cackling goose</b>	2009	1,615	(248) <sup>6</sup>	1,582	(288)	2,271	(382)	2,609	(436)	1,999	(349) <sup>6</sup>	10,076 (1556)
	2010	616	(139)	601	(136)	1,214	(257)	1,264	(274)	808	(172)	4,503 (915)
	2011	1,783	(381)	1,372	(295)	1,642	(350)	1,527	(330)	1,624	(350)	7,948 (1606)
	2012	1,255	(124)	1,409	(137)	1,741	(154)	1,878	(158)	1,278	(120)	7,561 (308)
	2013	1,196	(98)	852	(87)	1,356	(123)	1,639	(130)	1,411	(112)	6,454 (248)
	2014	955	(92)	853	(86)	1,044	(99)	1,526	(115)	1,310	(113)	5,688 (227)
	<b>2015</b>	<b>879</b>	<b>(92)</b>	<b>930</b>	<b>(91)</b>	<b>1,602</b>	<b>(120)</b>	<b>1,438</b>	<b>(129)</b>	<b>1,616</b>	<b>(136)</b>	<b>6,465 (246)</b>
<b>Emperor goose</b>	2009	96	(29)	75	(27)	392	(61)	205	(50)	196	(47)	964 (111)
	2010	60	(21)	48	(20)	282	(48)	69	(27)	241	(38)	700 (85)
	2011	163	(43)	59	(21)	259	(52)	91	(30)	298	(62)	870 (113)
	2012	145	(41)	151	(41)	276	(67)	71	(36)	399	(72)	1,042 (113)
	2013	96	(29)	112	(34)	323	(61)	254	(59)	343	(57)	1,128 (108)
	2014	96	(28)	99	(32)	405	(66)	150	(22)	237	(54)	987 (101)
	<b>2015</b>	<b>80</b>	<b>(27)</b>	<b>129</b>	<b>(34)</b>	<b>390</b>	<b>(62)</b>	<b>204</b>	<b>(54)</b>	<b>592</b>	<b>(93)</b>	<b>1,395 (116)</b>
<b>Greater white- fronted goose</b>	2010	109	(30)	57	(22)	34	(16)	35	(19)	13	(9)	248 (46)
	2011	234	(57)	42	(18)	28	(15)	10	(10)	10	(10)	324 (63)
	2012	256	(54)	352	(65)	64	(27)	85	(33)	46	(22)	803 (98)
	2013	163	(39)	20	(14)	65	(28)	23	(16)	0	(0)	271 (53)
	2014	162	(43)	40	(19)	96	(30)	46	(39)	0	(0)	344 (61)
	<b>2015</b>	<b>160</b>	<b>(40)</b>	<b>99</b>	<b>(37)</b>	<b>144</b>	<b>(36)</b>	<b>48</b>	<b>(23)</b>	<b>0</b>	<b>(0)</b>	<b>451 (73)</b>
<b>Eider spp.<sup>3</sup></b>	2009	420	(97)	289	(79)	245	(66)	96	(38)	46	(26)	1,096 (208)
	2010	187	(38)	220	(45)	462	(63)	69	(27)	20	(10)	958 (96)
	2011	324	(85)	209	(57)	240	(66)	49	(23)	69	28	855(201)
	2012	355	(61)	453	(63)	267	(58)	57	(27)	11	(11)	1,143 (116)
	2013	335	(53)	244	(52)	194	(48)	23	(16)	40	(19)	836 (115)
	2014	296	(50)	278	(49)	267	(150)	0	(0)	0	(0)	841 (88)
	<b>2015</b>	<b>670</b>	<b>(85)</b>	<b>267</b>	<b>(68)</b>	<b>390</b>	<b>(62)</b>	<b>60</b>	<b>(26)</b>	<b>44</b>	<b>(24)</b>	<b>1,431 (139)</b>

<sup>1</sup> 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).

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

<sup>3</sup>"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. Previously reported eider estimates (2010-2014), were changed in 2015 after discovering a tabulation error in those years.

