Summary Report- 25 March 2013

Aerial Photographic Survey of Brant Colonies on the Yukon-Kuskokwim Delta, Alaska, 2012

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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 11-12 June 2012. Total number of nests for all colonies increased by 19% between 2012 (14,197) and 2011 (11,955), although the 2012 estimate remained 12% lower than the long term average (15,978; 1992-2012). All colonies experienced increases in brant nests from the previous year (range: 4 to 41%). Overall, the trend in annual YKD estimates of nesting brant among the five primary colonies continues to be negative (currently -3%/yr). The long-term trends at TR and KB (including 2012) marked the fifth consecutive year of substantial negative departures from the long-term YKD log-linear trend (e.g., 5% annual declines at TR and KB versus 3% annual decline for all YKD), indicating that most of the long term decline continues to be attributed to reductions at KB and TR. Based on aerial imagery, 2012 reflected a good nesting year for colonial nesting brant on the YKD relative to the 3-yr running average, with few indications of fox and avian predation or wind/tide-induced flooding. Although no ground-truthing occurred in 2012, researchers noted delayed initiations and shifts in density distributions, attributed to the late spring break-up and associated ice patterns. Human activity (based on numbers of photos with footprints and vehicle tracks at locations without researchers) was at an all time low on the colonies in 2012.

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 5 major brant nesting colonies on the YKD (Anthony 1992-2003; Fig. 1). In 2004, the survey methodology changed from videography (i.e., using a digital camcorder) to still-frame, digital photography (Anthony 2004-2006). The goal of these surveys is to establish YKD colony 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, relative nest densities of other species (e.g., cackling goose; *Branta hutchinsii minima*), and habitat change. Herein, I report the results of the 2012 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 11-12 June 2012.

METHODS

Aerial Survey

Transects were flown at 122 m above ground level in a float-equipped Found Bushawk. 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. Transects were flown at speeds ranging from 70-80 knots over all colonies. Most

transects were flown into the wind, with ~10° of flaps deployed. Flying transects into the winds helps slow the aircraft and maximize the number and quality of photos that can be taken on each transect. In 2012, KB, TR, KI, BP, and BI required 0:42 (hours:minutes), 1:10, 1:07, 1:39, and 0:42, 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). Auto-focus was used on approximately half of the photos, while the remainder of photos were taken with manual focus. For the latter, auto-focus was only used to initially set the focus at survey altitude, after which the auto focus function was disabled and the focal ring taped in place.

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 Found Bushawk float-equipped aircraft. 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).

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 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. The time-differential between the time stamp on the GPS (track file) and the time stamp on the photos was used to interpolate image locations using GPS-Photo Link software (GPS-PHOTO LINK 2006). I calculated standard errors of estimated nests at each colony using inter-photo variance (photo as the sample unit), rather than inter-transect variance (1992-2008).

Ground-truthing, nest detection, and correction factors

Due to logistical constraints, ground-truthing was not accomplished in 2012. Alternatively, I used the average index ratio (photo:ground ratio of detected brant nests) from 2007-2011 (Wilson 2007-2011), after confirming that process variation among annual estimates was extremely low (0.002), and there was no correlation ($r^2 = 0.04$) between annual apparent nest success (in ground-truthed areas) and annual index ratios. Details of previous ground-truthing methods and index ratio calculations can be found in Wilson (2007-2011).

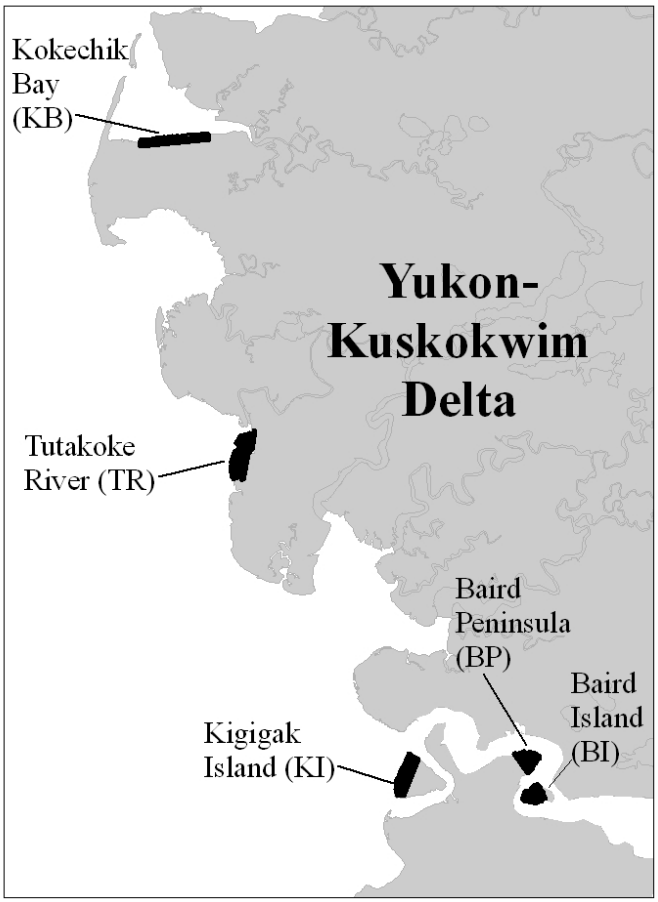
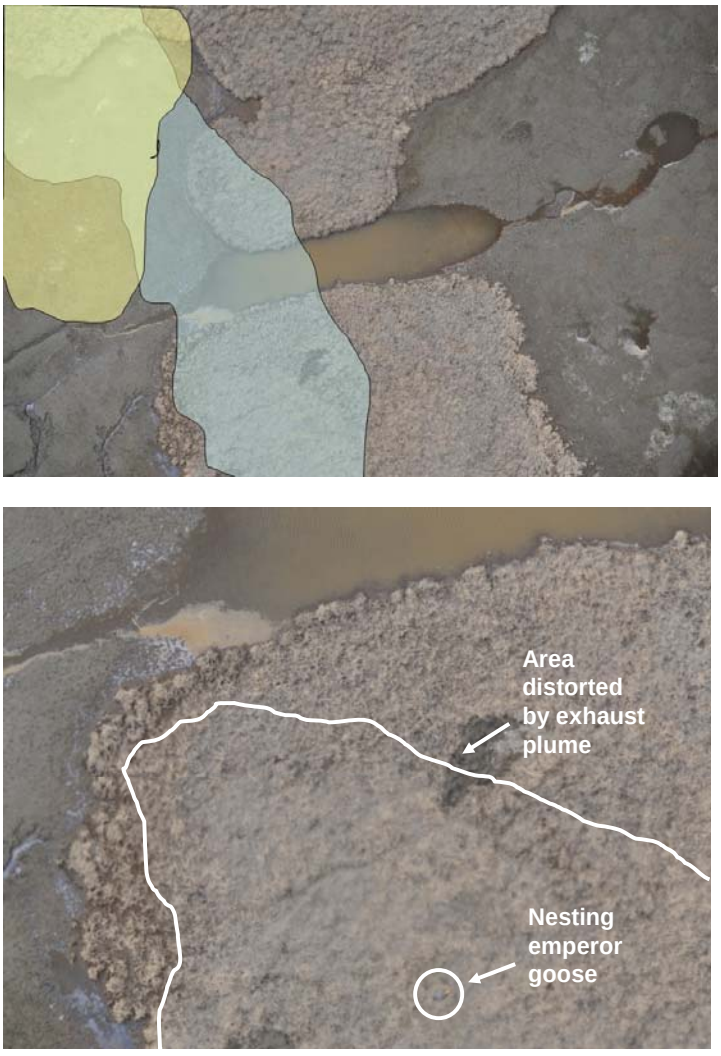


Figure 1. Photographic survey areas of the five primary Pacific black brant nesting colonies on the Yukon-Kuskokwim Delta.

Image processing

I determined total area in each colony with ArcGIS. I used the colony boundaries as re-outlined in 2009 (using IKONOS imagery base maps, 1m/pixel resolution). I computed the area sampled by the photographs based on altitude, lens focal length, and the number of photographs taken per colony within the colony boundaries. Assistants and I viewed image files (.jpg) on computers with a custom program written in MATLAB®). Images of known nests from previous years were displayed as background on the computer monitor and on printed sheets as a reference for image-scale and appearance of different postures and behaviors of birds. As images were reviewed, text data files

were created, including image file name, photo sub-area being viewed, and a two-digit observation code characterizing observed behavior (e.g., standing, sitting on nest, flying), and species identification. All photos with observations were reviewed by a second observer, as a means of quality control.
Boot tracks and motorized vehicle tracks were counted at KB, BP, and BI, but no measure of human activity was quantified at KI or TR because of ongoing research activity at those sites.



Figures 2a, b. High-resolution digital images (Nikon D700 SLR camera) from 2012, demonstrating (a) two typical exhaust plume distortion patterns (highlighted in yellow and blue) as observed in many of the photos (aircraft: Found Bushawk on floats) and (b) an example of a partial-photo exhaust plume distortion over an emperor goose nest (exhaust plume outlined in white). Notice grass blades are clear outside the affected area.

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 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, as had been done in previous years. Given the high resolution, large sample size, and improved coverage of images with the Nikon D700 camera, I had sufficient observations to generate nest population estimates for cackling, emperor, and greater white-fronted geese, as well as eiders (common and spectacled combined) within the brant colony study areas. Results for these other species are presented in Appendix 1.

RESULTS

The number of images analyzed at KB, TR, KI, BP, and BI within colony boundaries was 747, 1189, 803, 424, and 461, respectively. Thus, given total colony areas of 1044 (KB), 1468 (TR), 1130 (KI), 666 (BP), and 583 (BI) hectares, the 2012 photos represented a sample of 8.3, 9.4, 8.2, 7.4, and 9.2% of each of the respective colony areas and was slightly lower than the coverage achieved in previous years (2009 coverage range: 10-12%, 2010 coverage range: 9-16%). Surveys at KB, TR, KI, and a portion of BI were conducted on 11 June 2012 between 12:01 and 17:49 hrs. Surveys at BI and BP were completed on the following day, 12 June 2012, between 11:15 and 13:15 hrs. Survey weather conditions were adequate on both days (Day 1: thin overcast to partly sunny with west to WNW winds at15-30 kts), but glare, variation in altitude and direction of flight relative to wind, in addition to exhaust-distortion issues produced high variation in the quality of images. Although conditions on the second day (high, dense overcast) resulted in darker lighting, the quality of the images was more consistent; perhaps as a result of more uniform sky conditions, less wind and thus, less exhaust distoring the photos, and/or improved pilot familiarity with the survey.
Exhaust-related partial distortion of images was noted in varying fractions of almost all colony photos. This distortion appeared as lower resolution patches in photos (see Fig. 2)

and shifted slightly among photos (i.e., it was not consistent, as would be expected due to obstructions on the lens), but rather, drifted, apparently with wind and/or airplane yaw and roll. The camera was mounted at the starboard (co-pilot) belly port (opposite the single exhaust stack of the Found Bushawk). Although most distortions were not significant enough to prevent observation of nesting birds (see Emperor goose example in Fig. 2b), their impact on future/other photographic surveys using the Bushawk should be considered. Another source of variation in image quality was variation in altitude. According to the GPS track associated with the photos, approximately 96% of the photos were taken at altitudes >122 m (400 ft)AGL (average: 150 m (487 ft), range 94-223 m (308-731 ft)). The lack of a radar altimeter in the borrowed survey aircraft, likely resulted in less precise measures of true altitude above the landscape making corrections difficult for the pilot. Overall, the combination of the following factors: 1) a new survey crew, 2) a new aircraft (and associated exhaust image-distortion issues), and 3) not all transects being flown into the wind, likely contributed to a slight decrease in coverage and image quality in 2012.

Nest detection

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

All YKD brant colonies combined

Total estimated number of nests for all colonies (14,197) was 19% higher in 2012 than in 2011 (11,956), 12% lower than the long term average (15,978; 1992-2012), and 16% higher than the 3-yr running average (11,874, 2010-2012 Table 1). All colonies experienced increases in brant nests from the previous year (range: 4 to 41%). The overall trend in annual YKD estimates of nesting brant among the five primary colonies continues to be negative (-3%/yr; Fig. 4), although most colony trends improved in 2012 relative to the previous year. However, the long-term trends at TR and KB (including 2012) marked the fifth consecutive year of substantial negative departures from the long-term YKD log-linear trend (e.g., 5% annual declines at TR and KB versus 3% annual decline for all YKD), indicating that most of the long term decline continues to be attributed to reductions at KB and TR.

Kokechik Bay (KB)

The estimated number of nests at KB was 3.5% higher than in 2011, and 21% lower than the long-term average at that site. Further, the within-colony trend at KB remained 2 percentage points lower (λlog-linear(KB): 0.95, SE: 0.03) than the overall trend for the YKD. No researchers visited KB, nor did any fox control occur at this site in 2012. No indications of depredation or flooding were observed in digital photos. Evidence of likely human disturbance (e.g., footprints leading to destroyed nests) was observed in only one digital photo (an all time low). Overall, boot tracks were observed in only 4 of 1,062 photos at KB (0.4%), down from 62 of 1070 images (5.8%) in 2011. Further, motorized vehicle tracks (snowmachine and/or ATV) were observed in only 2 images (<1%) in 2012. Overall, detectable human presence (as indicated by boot and vehicle tracks) was reduced to nearly nothing in 2012. Encouragingly, the noticeable decrease coincided with with a slight increase in brant nests relative to the previous year.

Tutakoke River (TR)

The estimated number of nests at TR increased by 34% compared to 2011, but was still 3% lower than the long-term site-average. Further, the within-colony trend at TR remained 1.9 percentage points lower (λlog-linear(TR): 0.951, SE: 0.02) than the overall trend for the YKD. The 2012 estimate indicated a good nesting year at TR relative to the previous 5 yrs at that site (Table 1). Local researchers (J. Sedinger pers. comm.) reported similar increases in nesting brant (~36% more than in 2011) based on ground-plots in the survey area. Researchers noted that the late break-up resulted in a redistribution of nests, such that the usually high density plots north of the Kashunuk River were compromised (resulting in less nests in that area), while normally less dense areas immediately south of the Tutakoke River realized substantial increases. Overall depredation appeared to be minimal at the time of photography. Fox control did not occur at TR in 2012.

Kigigak Island (KI)

The estimated numbers of brant nests within the KI brant colony study area increased by 33% in 2012 relative to the previous year, but decreased by 10% relative to the long-term average for the site. Further, the long-term, log-linear

trend at KI began to approach stability in 2012 (λlog-linear(KI): 0.991, SE: 0.02). Overall, brant nest success within the KI colony study area appeared high in 2012 based on imagery data and nest monitoring by local researchers (M. Gabrielson pers comm.). Similar to observations at TR, field crews at KI noted that the late break-up resulted in a redistribution of nests into areas outside of the historical high density locations. The photos and ground-personnel observations suggested little indication of nest destruction due to fox and avian (e.g., gull/jaegar) predation. No fox control occurred at KI in 2012.

Baird Inlet Island (BI)

The estimated number of nests at BI increased by 11% in 2012 compared to 2011 and was 7% higher than the long term site-average. The long-term, log-linear trend at BI continued to be slightly decreasing (λlog-linear(BI): 0.985, SE: 0.01). No ground-based research at BI was conducted in 2012, and thus, no ground-based evaluations of factors influencing nest success are available. As in 2007-2011, no motorized vehicle tracks were observed on the island, and boot tracks were only observed in only 3 of 581 photos (<1%) in 2012, similar to the previous year. No flooding or significant depredation was detected from photos and no fox control occurred at BI in 2012.

Baird Peninsula (BP)

The estimated number of nests at BP increased by 41% compared to 2011, yet this colony remained 5% below its long term site-average. Further, the log-linear trend at BP continued to slope downward in 2012 (λlog-linear (BP): 0.981, SE: 0.04). No boot tracks were observed in 2012; a decrease from 2011 estimates (7 of 562 with boot tracks (1.2%)); confirming a sustained decrease in detectable local human presence in the area. In 2012, no significant flooding or depredation was observed in photos, 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. 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 2012 YKD colony nest population estimate (14,197) represented a substantial increase (+19%) compared to the previous year's estimate, and thus, was not in danger of reaching the 50% reduction benchmark outlined by the Flyway. 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 2012, the 3-yr average was 11,874; 1,874 nests above the proposed alternative, conditional closure threshold.

Overall, 2012 reflected a good nesting year for brant across the YKD based on aerial imagery, data or observations from local researchers (e.g., brant nest success was estimated at 88% by Fischer et al. 2013), as well as relative to the 3-yr running average of the photographic survey. Even greater increases in brant were indicated from the Yukon Delta Coastal Zone Aerial Survey (36% increase in total birds, and 41% increase in breeding birds from 2011 to 2012; Bollinger 2012), suggesting improved nesting in 2012 occurred at a broad scale across the YK Delta. No fox removal occurred at any of the colonies in 2012, yet indications of fox and avian depredation were minimal to non-existent, with no significant flooding. Only late-break-up and associated restrictions in historically preferred habitats, appeared to result in geographic shifts in nesting densities at some sites. Limited aerial imagery data for other sympatrically nesting species within the brant colonies (e.g., cackling, emperor, and greater white-fronted geese, and eiders; Appendix 1), indicated substantial species-specific variation in nesting in 2012. Overall, the photographic data indicated that nests of eiders, and perhaps cackling geese, declined from the previous year, while nests of emperor and greater white-fronted geese substantially increased. Trends for these species from other ground and aerial based surveys also demonstrated high levels of interspecific variation (Fischer et al. 2013, Bollinger 2012).

Human activity (based on numbers of photos with footprints and vehicle tracks) decreased remarkably at KB, and remained almost non-existant at BP and BI in 2012. Review of photos suggested one instance of possible human egg-predation at KB, but almost no vehicle tracks were indicated at that site. Overall, non-research-related human presence at these colonies continued to decrease in 2012.

Finally, although the number of brant nests at all colonies increased from 2011 to 2012, the magnitude of the increase varied substantially among colonies; from a 4% increase at

KB to a 41% increase at BP. 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 2012) marked the fifth consecutive year of negative departures from the long-term YKD log-linear trend (e.g., 5% 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 from historical estimates at KB and TR.

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LITERATURE CITED

Anthony, R. M., W. H. Anderson, J. S. Sedinger, and L. L. McDonald. 1995. Estimating populations of nesting brant using aerial videography. Wildlife Society Bulletin 23:80-87.

Anthony, R. M. 1992-2006. Aerial surveys of brant colonies on the Yukon Delta NWR. U.S. Geological Survey, Alaska Science Center, Anchorage, Alaska, USA. Unpubl. Reports (1992-2006).

Bollinger, K. 2012. Memoto the Pacific Flyway Committee on the 1985-2012 Coastal Zone Yukon-Kuskokwim Delta Survey of geese, swans, and sandhill cranes. U.S. Fish and Wildlife Service, Migratory Bird Management, Anchorage, Alaska, USA. Unpubl. Memo.

Byrd, G. V., S. Finger, C. A. Janik, M. Joseph, and P. Paniyak. 1982. The status of geese and swans nesting on the coastal fringe of the Yukon Delta National Wildlife Refuge in 1982. Unpublished report, Yukon Delta National Wildlife Refuge, Bethel, AK.

Fischer, J. B., and R. A. Stehn. 2013. Nest population size and potential production of geese and spectacled eiders on the Yukon-Kuskokwim Delta, Alaska, 2012. U.S. Fish and Wildlife Service, Migratory Bird Management, Anchorage, Alaska, USA. Unpubl. Report. *In review.*

GPS Photo-link. 2006. Version 4.0. GeoSpatial Experts, Ft. Collins, Colorado, USA.

IKONOS. 2008. Geoeye, Dulles, Virginia, USA.

MATLAB. 2001. Version 6.1, release 12. MathWorks, Natic, Massachusetts, USA.

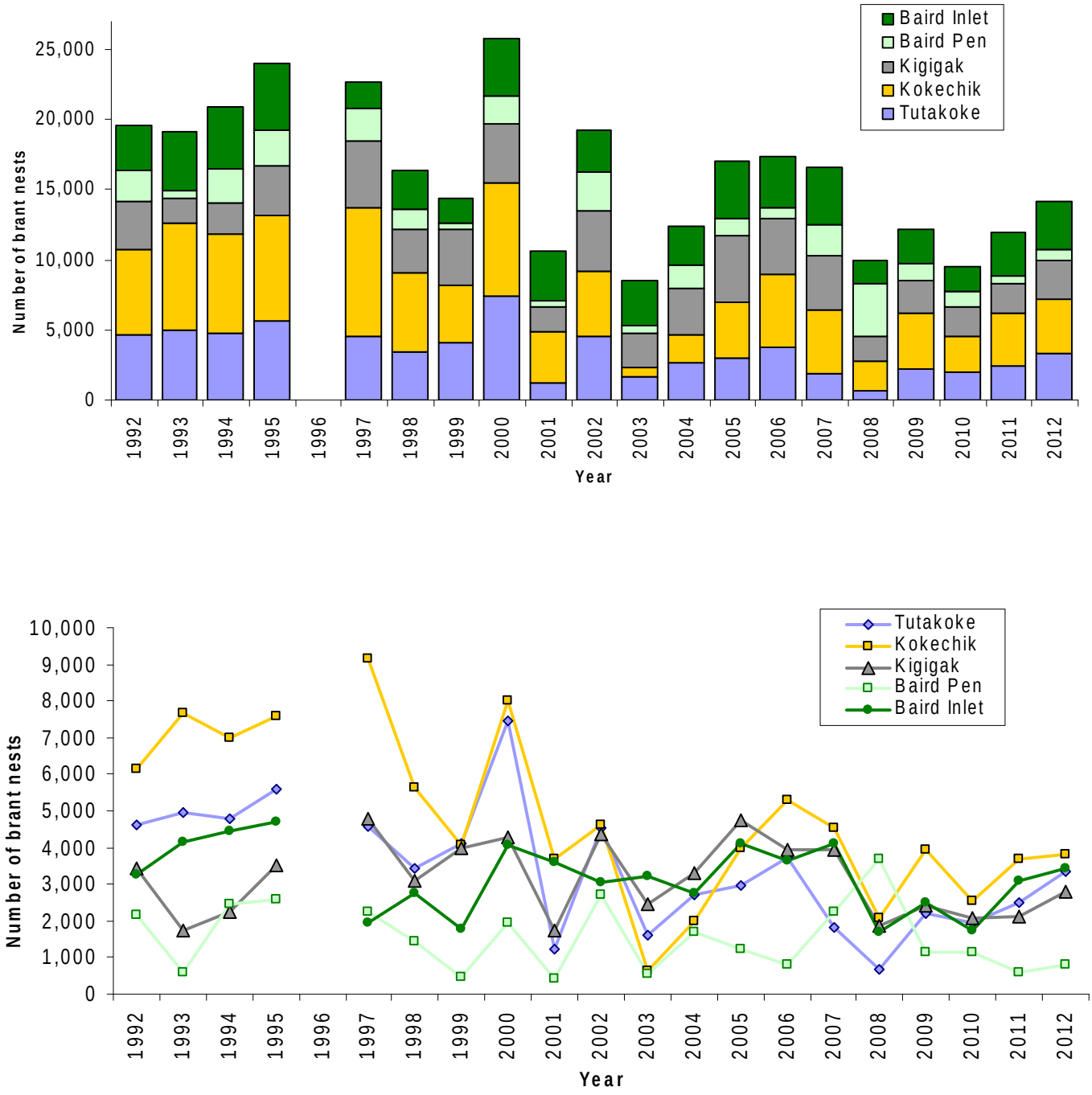
Pacific Flyway Council. 2002. Pacific Flyway management plan for Pacific brant. Pacific Flyway Study Committee, U.S. Fish and Wildlife Service, Portland, Oregon, USA. Unpubl. Report, 40 pp.

Sedinger, J. S., C. J. Lensink, D. H. Ward, R. M. Anthony, M. L. Wege, and G. V. Byrd. 1993. Current status and recent dynamics of the black brant *Branta bernicla* breeding population. Wildfowl 44:49-59.

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 (1992-2011); 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)	---[3]	---	2,591 [1]	(184)	4,720 [1]	(474)	23,998
1997 [2]	4,588	(554)	9,144	(1092)	4,776	(595)	2,259	(282)	1,944	(242)	22,711
1998 [2]	3,448	(292)	5,655	(471)	3,105	(238)	1,431	(169)	2,747	(264)	16,386
1999 [1]	4,100	(96)	4,072	(74)	3,962	(402)	448	(81)	1,777	(80)	14,359
2000	7,437 [2]	(584)	8,021[2]	(866)	4,286 [1]	(647)	1,962 [1]	(142)	4,088	(324)	25,794
2001[2]	1,212	(73)	3,677	(215)	1,721	(107)	421	(36)	3,604	(198)	10,635
2002 [2]	4,524	(314)	4,634	(362)	4,380	(255)	2,708	(147)	3,052	(199)	19,298
2003 [2]	1,622	(79)	655	(52)	2,474	(118)	547	(46)	3,202	(135)	8,500
2004 [2]	2,704	(153)	1,996	(116)	3,284	(208)	1,687	(76)	2,759	(160)	12,430
2005 [2]	2,977	(205)	3,985	(177)	4,728	(213)	---[3]	---	4,093	(256)	17,023 [3]
2006 [2]	3,714 [4]	(286)	5,280	(341)	3,920	(240)	793	(61)	3,628	(262)	17,335
2007 [2]	1,842	(137) [4]	4,521	(304) [4]	3,924	(304) [4]	2,241	(203) [4]	4,106	(264) [4]	16,634
2008 [2]	669	(68) [5]	2,062	(174) [5]	1,856	(158) [5]	3,695	(341) [5]	1,713	(151) [5]	9,995
2009 [2]	2,197	(235) [6]	3958	(344) [6]	2,398	(226) [6]	1,154	(141) [6]	2,499	(239) [6]	12,206
2010 [2]	1,963	(176) [6]	2,560	(208) [6]	2,061	(184) [6]	1,146	(130) [6]	1,739	(142) [6]	9,469
2011 [2]	2,481	(221) [6]	3,682	(244) [6]	2,104	(187) [6]	580	(84) [6]	3,109	(445) [6]	11,956
2012 [2]	**3,332**	**(256) [6]**	**3,811**	**(269) [6]**	**2,795**	**(258) [6]**	**819**	**(125) [6]**	**3,440**	**(285) [6]**	**14,197**
3-yr average (2010-2012)	2,592		3,351		2,320		848		2,763		11,874
Long-term average (1992-2012)	3,438		4,803		3,116		1,563		3,205		15,978

[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 2009-2012 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 (1992-2012) 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.

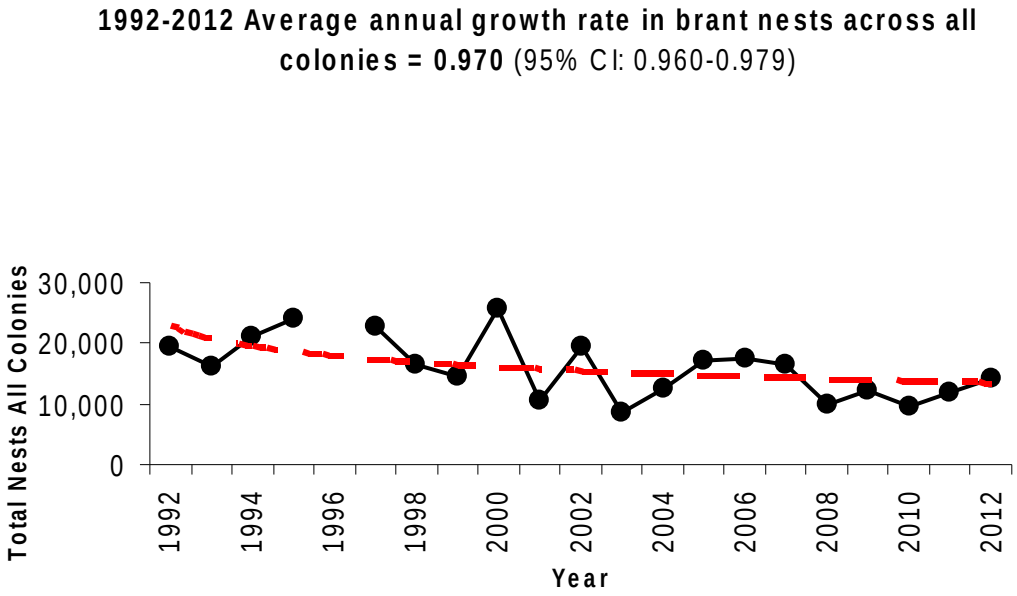


Figure 4. Log-linear trend of annual estimates of brant nests (red dashed line) from photographic surveys across all brant colonies on the Yukon-Kuskokwim Delta (1992-2012). Note: Estimates do not exist for 1996, and in 2005 only four of five colonies were surveyed.

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) 2009-2012.

		Estimates of number of nests										
Species[1]		**TR**	(SE)	**KB**	(SE)	**KI** [2]	(SE)	**BP**	(SE)	**BI**	(SE)	**Total** (SE)
Cackling goose	2009	1,615	(248) [6]	1,582	(288)	2,271	(382)	2609	(436)	1,999	(349) [6]	9,898 (1556)
	2010	616	(139)	601	(136)	1,214	(257)	1,264	(274)	808	(172)	4,453 (915)
	2011	1,783	(381)	1,372	(295)	1,642	(350)	1,527	(330)	1,624	(350)	7,852 (1606)
	2012	**1,255**	(124)	**1,409**	(137)	**1,741**	(154)	**1,878**	(158)	**1,278**	(120)	**7,561** (308)
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)
	2011	163	(43)	59	(21)	259	(52)	91	(30)	298	(62)	848 (113)
	2012	**145**	(41)	**151**	(41)	**276**	(67)	**71**	(36)	**399**	(72)	**1,042** (113)
Greater white-fronted goose	2010	109	(30)	57	(22)	34	(16)	35	(19)	13	(9)	244 (46)
	2011	234	(57)	42	(18)	28	(15)	10	(10)	10	(10)	315 (63)
	2012	**256**	(54)	**352**	(65)	**64**	(27)	**85**	(33)	**46**	(22)	**803** (98)
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)
	2011	265	(72)	125	(39)	323	(82)	---	---	--	---	724 (126)
	2012	**300**	(74)	**176**	(48)	**191**	(68)	**---**	---	**11**	(11)	**678** (114)

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

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

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