

Memorandum

To: Todd Sanders, Pacific Flyway Representative, USFWS, DMBM, HQ

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Through: Eric J. Taylor, Chief, Migratory Bird Management, USFWS, Region 7

Subject: 2018 Yukon-Kuskokwim Delta Coastal Zone Survey of Geese, Swans, and Sandhill Cranes.

INTRODUCTION AND METHODS

This report summarizes results from the Yukon-Kuskokwim Delta (YKD) Coastal Zone Survey, flown 25 May to 1 June, 2018. This was the 34th consecutive year the U.S. Fish and Wildlife Service (USFWS) has conducted this project. The survey provides an index to the breeding populations of cackling Canada geese (*Branta canadensis minima*), Pacific greater white-fronted geese (*Anser albifrons frontalis*), emperor geese (*Chen canagica*), Pacific black brant (*B. bernicla nigricans*), Taverner's Canada geese (*B. c. taverneri*), tundra swans (*Cygnus columbianus*), and sandhill cranes (*Grus canadensis*) in the coastal zone of the Yukon-Kuskokwim Delta, Alaska. Species nomenclature follows common names recognized by the Pacific Flyway and scientific names recognized by the USFWS (USFWS 2017).

Survey procedures followed established USFWS and Canadian Wildlife Service (CWS) protocol for aerial waterfowl breeding population surveys (USFWS and CWS 1987). This survey has been completed from 1985–2018 using a Cessna 206 except in 2012, when a Quest Kodiak 100 was used as the survey platform. Survey aircraft were flown 30–45 m (100–150 feet) above pre-determined transect lines at a ground speed of 145–170 km/hr (90–105 miles/hr; 78–90 knots). The aircraft's Global Positioning System (GPS) was used to navigate to transect "start" and "end" waypoints and maintain the aircraft along each transect line. Two observers, a pilot-observer and a right-seat observer, recorded all goose, swan, and crane observations out to 200 m (656 feet) on their respective sides of the aircraft; however, from 2012–2014, only the front right-seat observer recorded observations. The 2018 survey was completed by Heather Wilson, pilot-observer and Michael Swaim, right-seat observer. Aerial observations were recorded onto laptop computers using a moving-map survey program (John Hodges, USFWS unpubl. data). Survey data were recorded as GPS-linked sound files (.wav format) that were later transcribed into text files. The 2018 data was summarized, checked and analyzed using the R7 MBM survey analysis R package "AKAerial" (available at www.github.com/cfrost3/AKAerial Chuck Frost, USFWS unpubl. data). Data prior to 2018 was analyzed using the R7 MBM analysis Visual Basic package "PopEstimates" (Hodges, unpubl. USFWS data). Both approaches used a ratio estimation procedure (Caughley 1977). Differences in data treatment between analysis packages will be investigated and estimates revised as needed in the 2019 memo.

Population Indices

The population indices presented in this report were calculated for the following species or groups of species as:

All Geese and Sandhill Cranes

$$\textit{indicated breeding birds} = 2 \times (\textit{singles} + \textit{pairs})$$

$$\textit{indicated total birds} = 2 \times (\textit{singles} + \textit{pairs}) + \textit{birds in flocks}$$

Tundra Swans

$$\textit{total birds} = \textit{singles} + (2 \times \textit{pairs}) + \textit{birds in flocks}$$

$$\textit{breeding birds} = \textit{singles} + (2 \times \textit{pairs})$$

$$\textit{nests} = \textit{number of occupied nests}$$

Where *pairs* is the number of pairs and not number of birds in pairs. This definition applies to all species in this report.

Population indices are based on the assumption that a single goose or crane observed represents a pair, with the unseen mate on a nest undetected by the aerial survey crew. We assume that all swans are observed and a complete count is attained; thus, the number of single swans is not doubled as with geese and cranes. Growth rates were calculated from population indices by log linear regression for both 10-year (2009–2018) and long-term (1985–2018) time periods.

Stratification Design and Survey Design

The survey area extends from the Yukon-Kuskokwim Delta coast to approximately 50 km (31 mi) inland from Kuskokwim Bay in the south to Norton Sound in the north (Fig. 1).

The coastal zone was originally divided into 16 strata based on homogeneous physiographic regions determined from unclassified LANDSAT imagery (Butler 1988). The survey design was reduced to four primary strata based on goose densities in 1998. This was revised to the current 5-strata design in 2004, when an additional stratum was created to accommodate historic data in a high-density area where the spacing between transects varied over time (Fig. 1). A randomly selected starting point was used to construct a series of systematically placed transects in an east-west orientation. Transects were spaced at 1.6 km (1.0 mi) intervals in the highest density stratum, and at 3.2 km (2.0 mi), 6.4 km (4.0 mi), and 12.9 km (8.0 mi) intervals in high, medium, and low density stratum, respectively (Fig. 1).

Since 1998 this aerial survey has used a rotating panel design to balance (i) the spatial coverage of transects for estimating population means with (ii) temporal replication for monitoring trends over time. Near complete coverage (>95%) of the highest density stratum was obtained over a four-year rotation by shifting transects 0.4 km each year. The location of transects in areas surveyed less intensively were proportionally adjusted by approximately 0.8, 1.0, and 3.0 km in the high, medium, and low density stratum, respectively. The 2018 survey represents the first year of the sixth 4-year rotation, during which 110 transects were surveyed, comprising 2,506 linear km.

Population index estimates are presented followed by the upper and lower 95% confidence bounds.

RESULTS AND DISCUSSION

As in 2016 and 2017, the YKD Coastal Zone experienced an early spring breakup, resulting in the earliest start date in the history of the YKD Coastal Zone Survey. Based on the cumulative number of thaw-degree-days (where daily mean air temperature exceeded 32°F at Bethel, Cape Romanzof, Emmonak, Hooper Bay, Mekoryuk, and St Marys), spring was approximately 9 days earlier than the long-term (1985–2018) average, with the Kuskokwim River breaking up on 2 May, approximately 8 days earlier than the 1985–2018 average. Upon our arrival to Bethel on 25 May, 2018, the ponds and wetlands in the area were completely ice-free and the tundra was beginning to green-up. Weather conditions were generally favorable during the survey, with broken to overcast skies, good visibility, with very little glare. Wind velocities typically ranged from 3-12 knots, but gusts up to 20-knots were recorded on 28 May. We saw very little indication of recent flooding.

The majority of geese in 2018 were observed as singles, pairs, and small family groups, with few flocked birds being recorded over the course of the survey. While we believe that the low number of flocked birds indicates a well-timed survey, the potential effects of survey timing relative to population estimates has not been fully assessed.

Cackling Canada Geese

In 2018, the indicated total bird index for cackling Canada geese was 59,508 (95% CI = 54,548–64,468; Table 1), which is 24% lower (95% CI = -17% to -31%) than the most recent ten year (2009–2018) average index of 78,226 (75,723–80,729). The average annual growth rate of total indicated cackling Canada geese calculated over the most recent 10 years (2009–2018) was 1.021 (95% CI = 0.972–1.072), while the long-term (1985–2018) growth rate was 1.042 (1.030–1.055; Table 6, Fig. 2).

The Pacific Flyway Council adopted the 3-year average fall projected population size as the cackling Canada goose Management Index (Pacific Flyway Council 2016). The 3-year projected population size was derived from ratio estimation, using the ratio of indicated total birds from the YKD Coastal Zone Survey (i.e., this aerial survey) and population estimates from mark-resight data collected from 1989–2003 and 2011–2013 (Pacific Flyway Council 2016). The fall projected population index for cackling Canada geese was calculated by multiplying the indicated total bird (ITB) index from the YKD Coastal Zone Survey with the following ratio:

$$\text{Fall Projected Population} = \text{ITB} \times 3.422843 \text{ (SE} = 0.161651\text{)}$$

Using this method, the 2018 cackling Canada goose fall projected population is estimated to be 203,687 (178,302–229,072) geese and the 3-year average (2016–2018) is 273,669 indicated total birds, 9% above the current population objective of 250,000 (Appendix 1).

Pacific White-fronted Geese

In 2018, the population index for Pacific white-fronted goose was 190,586 (142,433–238,739) indicated total birds (Table 1), approximately 6% higher (-22% to 35%) than the most recent ten year (2009–2018) average index of 179,278 (166,367–192,189). Over the most recent ten years (2009–2018), indicated total birds grew at an average annual rate of 1.027 (0.999–1.056), while the long-term (1985–2018) growth rate of this species was 1.079 (1.069–1.089; Table 6, Fig. 3).

The Pacific Flyway Council established the 3-year average fall population size as the Pacific white-fronted goose Management Index (Pacific Flyway Council 2003). The fall population size is derived by expanding the combined indicated total white-fronts from the YKD Coastal Zone Survey (i.e., this aerial survey), Stratum 8 (Bristol Bay), and the inland portion of Stratum 9 (Yukon Delta) from the Waterfowl Breeding Population and Habitat Survey (Groves and Shults *in prep*) by a constant. The expansion factor originates from the historic relationship between summer and fall surveys from 1985–1998 (Pacific Flyway Council 2003). The fall estimate was calculated from the combined indicated total birds (ITB) of these three areas using the following equation:

$$\text{Fall Population Index} = (\text{ITB} \times 2.5498) + 71,339$$

In 2018, indicated total birds from Stratum 8-Bristol Bay and the inland portion of Stratum 9-Yukon Delta of the Waterfowl Breeding Population and Habitat Survey were 1,045 and 11,778, respectively (Groves and Shults *in prep*). Combined with the 2018 YKD Coastal Zone Survey estimate of 190,586, the Yukon-Kuskokwim Delta and Bristol Bay region supported 203,419 indicated total birds (Appendix 2). Using the equation above, the projected 2018 fall population index is 590,017 and the 3-year (2016–2018) average is 670,376 (Appendix 3). The Management Index (the 3-year average fall population index) of 670,376 is 123% higher than the population objective of 300,000 set forth in the Pacific Flyway Management Plan (Pacific Flyway Council 2003).

Emperor Geese

The 2018 emperor goose indicated total bird index was 30,112 (26,649–33,575; Table 1), which is approximately 13% above (-1% to 28%) the most recent ten year (2009–2018) average index of 26,540 (25,357–27,722). Over the past ten years (2009–2018) average annual growth rate of indicated total emperor geese was 1.059 (1.029–1.089), while the growth rate over the long-term (1985–2018) was 1.020 (1.015–1.025; Table 6, Fig. 4).

The Pacific Flyway Council and the Alaska Migratory Bird Co-management Council established the total indicated bird index from the YKD Coastal Zone Survey (i.e., this aerial survey) as the emperor goose Management Index (Pacific Flyway Council 2016, Alaska Migratory Bird Co-management Council 2016). The 2018 Management Index of 30,112 indicated total birds is 11% below the population objective of 34,000, 8% higher than the 28,000 threshold for considering new conservation measures, and 31% above the harvest closure threshold of 23,000 birds, as outlined in the 2016 Pacific Flyway Council and the Alaska Migratory Bird Co-management Council Emperor Goose Management Plans.

Black Brant

The number of indicated total brant in 2018 was 26,438 (20,545–32,330; Table 3, Fig. 5), 12% higher than the most recent ten year (2009–2018) average index of 23,505 indicated total birds. Average annual growth rates for indicated total birds over the most recent ten years (2009–2018) and over the long-term (1985–2018) were 1.021 (0.983–1.061) and 1.008 (0.996–1.019), respectively (Table 6, Fig. 5).

Taverner’s Canada Geese

Taverner’s Canada geese are found primarily interior to the coastal zone, but some overlap with cackling Canada geese occurs on the eastern, northern, and southern portions of the survey area. Geographic boundaries are used to categorize Canada goose observations as either cacklers or Taverner’s for population indices (Groves 2017). In 2018, the calculated population index was 15,973 (5,178–26,768) indicated total birds (Table 3; Fig. 6), which was 62% higher than the most recent ten year (2009–2018) average index of 9,847. The average annual growth rate of Taverner’s Canada geese over the most recent ten years (2009–2018) was 1.060 (1.009–1.113), while the estimated long term (1985–2018) growth rate was 1.014 (1.006–1.023; Table 6, Fig. 6).

Tundra Swans

In 2018, the tundra swan population index was 32,733 total birds (23,817–41,649; Table 4), which was 9% higher than the most recent ten year (2009–2018) average index of 30,118 total birds. The 2018 nest index was 5,087 (4,278–5,896), which was 10% higher than the most recent ten year (2009–2018) average nest index of 4,627. Over the past ten years (2009–2018) estimated growth rates of total birds and nests were 0.987 (0.941–1.036) and 1.014 (0.974–1.056), respectively, while the long term (1985–2018) growth rates for total birds and swan nests were 1.007 (1.001–1.014), and 1.019 (1.013–1.026), respectively (Table 6, Fig. 7).

Sandhill Cranes

The 2018 sandhill crane indicated total bird index was 21,134 (16,532–25,736; Table 5), which is 22% higher than the most recent ten year (2009–2018) average index of 17,254. Estimated annual population growth rates were 1.027 (0.981–1.076) and 0.998 (0.992–1.005) for the most recent 10 years (2009–2018) and over the long-term (1987–2018), respectively (Table 6, Fig. 8).

SURVEY RECOMMENDATIONS

Populations of geese on the YKD Coastal Zone have increased dramatically since the mid-1980’s to the point that recording individual singles and pairs is challenging, especially in high-density areas along the coast. Several factors complicate our ability to accurately survey these breeding populations. While conducting low-altitude aerial surveys, many geese, especially cackling Canada geese, are disturbed by the plane and flush from the ground approximately ¼ to ½ mile in front of the aircraft, before aggregating into groups that fly perpendicular to the plane. Movement of birds in response to the aircraft may contribute to multiple sources of estimation error including: (1) determination of whether birds originated from the survey transect; (2) determination of social status (i.e., singles, pairs, flocks) of large mixed-flock groups; and (3)

species identification and estimation of large mixed-flock groups. We recommend that these potential sources of bias and error be more thoroughly investigated and that new peer-reviewed protocol be developed specific to the YKD Coastal Zone Survey following guidelines outlined in the USFWS Survey Protocol Handbook (USFWS 2013).

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Table 1. Indicated total^a population indices for cackling Canada, Pacific white-fronted, and emperor geese on the Yukon-Kuskokwim Delta, 1985–2018.

Year	Cackling Canada Geese		Pacific White-fronted Geese		Emperor Geese	
	Index	SE	Index	SE	Index	SE
1985	13,963	1,605	18,914	1,482	19,805	1,960
1986	13,502	1,013	13,400	1,014	12,430	1,008
1987	19,921	1,390	15,717	1,413	13,035	1,121
1988	24,467	1,507	27,191	2,642	16,392	1,402
1989	25,475	1,567	28,004	2,430	16,855	1,220
1990	31,759	2,166	37,836	4,067	17,347	1,401
1991	28,843	1,688	31,286	2,294	14,888	1,284
1992	44,356	2,632	34,671	2,908	15,416	994
1993	45,749	2,534	39,748	3,020	17,147	1,230
1994	65,021	3,181	56,513	3,730	18,733	1,059
1995	69,888	3,756	77,710	5,483	18,764	1,072
1996	74,574	4,008	78,032	5,339	24,413	2,476
1997	88,018	4,359	83,215	5,738	23,287	1,451
1998	64,601	3,701	87,881	7,874	21,741	1,541
1999	72,173	3,509	95,040	8,876	21,406	1,591
2000	74,992	3,352	91,911	6,591	18,667	949
2001	75,620	3,734	113,603	9,358	27,297	1,473
2002	50,187	2,487	90,407	7,537	19,504	1,326
2003	69,867	3,482	117,951	12,034	21,378	1,746
2004	51,390	2,691	100,622	9,611	21,396	1,097
2005	65,484	3,091	121,017	12,000	19,798	1,190
2006	71,985	3,291	138,067	10,648	26,562	1,697
2007	74,152	3,138	178,515	15,035	24,362	1,508
2008	84,699	3,517	161,979	14,831	22,100	1,038
2009	67,434	2,909	144,678	14,065	20,684	1,092
2010	82,192	4,755	174,556	21,450	20,167	1,199
2011	53,799	2,137	168,925	16,068	21,223	1,284
2012	60,395	2,663	181,519	15,461	20,388	1,554
2013	93,200	5,202	164,399	18,318	29,840	2,222
2014	83,970	4,225	205,081	31,834	32,550	2,973
2015	101,408	6,144	140,313	14,159	26,235	1,581
2016	95,667	4,191	206,503	25,491	34,109	2,490
2017	84,686	3,706	216,219	19,534	30,087	2,030
2018	59,508	2,531	190,586	24,568	30,112	1,767

^a Indicated total = $2 \times (\text{singles} + \text{pairs}) + \text{birds in flocks}$

Table 2. Indicated breeding bird^a indices for cackling Canada, Pacific white-fronted, and emperor geese on the Yukon-Kuskokwim Delta, 1985–2018.

Year	Cackling Canada Geese		Pacific White-fronted Geese		Emperor Geese	
	Index	SE	Index	SE	Index	SE
1985	10,313	1,378	9,382	776	9,542	852
1986	10,770	854	6,713	513	7,413	611
1987	14,367	967	7,819	653	9,312	746
1988	16,290	1,009	11,953	890	8,695	829
1989	21,168	1,330	11,982	968	10,737	791
1990	20,330	1,341	11,705	938	9,282	787
1991	22,405	1,290	12,584	902	7,758	590
1992	28,443	1,697	14,077	1,086	9,879	686
1993	33,781	1,828	15,010	1,213	10,183	787
1994	41,200	2,135	20,155	1,432	12,007	712
1995	49,354	2,872	26,985	1,911	12,892	806
1996	39,543	2,371	21,887	1,626	12,433	604
1997	49,254	2,570	27,611	1,521	12,820	741
1998	46,372	2,896	40,872	3,888	15,686	1,136
1999	49,556	2,401	48,207	3,791	16,208	1,285
2000	52,855	2,428	42,558	2,693	12,798	680
2001	49,665	2,451	63,555	5,228	17,112	926
2002	41,982	2,033	51,381	4,491	15,646	1,215
2003	40,993	2,058	51,670	4,797	12,141	869
2004	40,848	2,219	47,928	4,973	14,410	848
2005	44,018	2,220	50,141	4,067	14,490	817
2006	47,500	2,293	71,484	6,104	17,460	936
2007	51,194	2,345	70,670	7,824	14,562	1,004
2008	52,368	2,444	73,022	5,980	16,110	724
2009	52,368	2,328	66,759	6,004	13,563	646
2010	50,232	2,200	74,791	9,359	14,103	781
2011	42,361	1,796	84,551	8,127	14,730	828
2012	51,729	2,349	97,654	8,422	17,207	1,307
2013	67,328	3,512	93,823	12,704	19,372	1,326
2014	55,733	2,736	86,079	12,013	16,188	1,132
2015	55,937	2,732	60,708	6,751	14,647	832
2016	77,979	3,520	135,637	14,009	27,051	1,341
2017	67,426	2,917	137,604	13,767	24,929	1,797
2018	54,057	2,197	141,549	13,381	28,440	1,690

^a Indicated breeding bird index = 2 × (singles + pairs)

Table 3. Indicated breeding bird and indicated total bird population indices for black brant and Taverner's Canada geese on the Yukon-Kuskokwim Delta, 1985–2018.

Year	Black Brant				Taverner's Canada Geese			
	Indicated Breeding Bird ^a	SE	Indicated Total ^b	SE	Indicated Breeding Bird ^a	SE	Indicated Total ^b	SE
1985	1,180	-	5,164	-	4,285	-	5,517	-
1986	2,030	-	14,007	-	3,782	-	5,150	-
1987	4,652	-	14,893	-	3,187	-	4,059	-
1988	3,840	-	22,713	-	5,191	-	9,217	-
1989	4,220	-	26,231	-	7,142	-	8,865	-
1990	2,989	-	28,820	-	6,498	-	7,819	-
1991	4,528	-	27,151	-	5,454	-	8,063	-
1992	6,144	-	20,026	-	5,089	-	8,698	-
1993	4,446	-	32,004	-	6,519	-	8,643	-
1994	5,764	-	31,278	-	5,536	-	7,017	-
1995	5,858	-	34,401	-	5,780	-	6,475	-
1996	5,620	-	29,503	-	3,856	-	6,644	-
1997	6,818	-	30,738	-	4,466	-	6,630	-
1998	8,252	-	22,127	-	6,607	-	8,446	-
1999	9,492	-	22,520	-	7,532	-	12,532	-
2000	8,402	-	26,381	-	8,232	-	10,384	-
2001	5,686	-	31,242	-	6,063	-	7,701	-
2002	9,208	-	20,396	-	5,145	-	6,204	-
2003	3,588	-	20,621	-	5,426	-	8,043	-
2004	7,641	-	19,238	-	4,580	-	7,755	-
2005	5,634	-	20,560	-	3,942	-	6,385	-
2006	11,279	-	19,495	-	6,523	-	9,355	-
2007	8,937	-	19,191	-	3,800	-	7,042	-
2008	13,132	-	29,166	-	5,663	-	10,209	-
2009	8,847	-	23,033	-	4,245	-	7,610	-
2010	8,595	-	23,897	-	6,942	-	8,981	-
2011	12,375	-	16,156	-	4,543	-	5,952	-
2012	17,541	-	21,912	-	6,680	-	8,980	-
2013	13,104	-	24,048	-	4,073	-	9,283	-
2014	4,040	-	28,283	-	9,183	-	13,115	-
2015	3,844	550	19,753	2,142	6,779	3,034	10,864	5,328
2016	13,460	1,459	29,986	3,693	6,422	1,657	8,255	2,520
2017	11,932	1,761	21,561	2,801	6,872	2,906	9,461	5,068
2018	15,258	1,968	26,438	3,006	13,565	4,606	15,973	5,508

^a Indicated breeding bird index = $2 \times (\text{singles} + \text{pairs})$

^b Indicated total = $2 \times (\text{singles} + \text{pairs}) + \text{birds in flocks}$

Table 4. Tundra swan population indices on the Yukon-Kuskokwim Delta, 1985–2018.

Year	Singles and Pairs ^a		Total Birds ^b		Nests ^c	
	Pairs ^a	SE	Total Birds ^b	SE	Nests ^c	SE
1985	13,664	-	30,874	-	2,471	-
1986	14,093	-	24,299	-	3,093	-
1987	12,149	-	24,180	-	2,177	-
1988	13,872	-	24,459	-	3,159	-
1989	12,695	-	33,115	-	2,613	-
1990	12,759	-	30,006	-	2,802	-
1991	11,465	-	18,663	-	2,442	-
1992	13,174	-	19,411	-	3,009	-
1993	12,348	-	20,180	-	2,818	-
1994	13,204	-	18,787	-	3,086	-
1995	16,594	-	23,052	-	3,560	-
1996	17,238	-	23,121	-	3,975	-
1997	18,106	-	28,683	-	4,034	-
1998	19,947	-	33,355	-	4,964	-
1999	20,727	-	27,211	-	4,601	-
2000	20,048	-	28,306	-	4,494	-
2001	17,251	-	24,395	-	3,147	-
2002	21,356	-	31,193	-	5,713	-
2003	14,823	-	23,015	-	4,646	-
2004	17,760	-	27,099	-	5,301	-
2005	14,548	-	23,645	-	3,360	-
2006	22,663	-	31,545	-	4,224	-
2007	20,760	-	30,454	-	4,074	-
2008	20,233	-	32,184	-	3,649	-
2009	20,272	-	27,897	-	3,808	-
2010	21,340	-	37,790	-	4,678	-
2011	22,543	-	33,451	-	5,974	-
2012	26,201	-	39,291	-	4,275	-
2013	17,900	-	19,635	-	3,643	-
2014	18,367	-	27,413	-	4,965	-
2015	11,077	1,726	23,000	5,328	3,448	-
2016	20,060	1,724	31,251	2,520	5,081	-
2017	18,953	1,392	28,719	5,068	5,309	-
2018	23,621	1,295	32,733	4,549	5,087	413

^a Singles and Pairs = singles + (2 × pairs)

^b Total Birds = singles + (2 × pairs) + birds in flocks

^c Nests = number of active nests

Table 5. Sandhill Crane population indices on the Yukon-Kuskokwim Delta, 1987–2018.

Year	Indicated Breeding Bird ^a		Indicated Total Birds ^b	
	Breeding Bird ^a	SE	Birds ^b	SE
1985	-	-	-	-
1986	-	-	-	-
1987	14,246	-	15,079	-
1988	12,777	-	16,549	-
1989	13,247	-	16,719	-
1990	14,228	-	18,310	-
1991	14,358	-	20,601	-
1992	13,394	-	17,185	-
1993	16,012	-	19,312	-
1994	13,832	-	16,548	-
1995	16,906	-	18,182	-
1996	10,220	-	16,430	-
1997	11,446	-	13,530	-
1998	17,859	-	24,458	-
1999	16,236	-	18,612	-
2000	15,886	-	18,144	-
2001	14,923	-	16,211	-
2002	12,605	-	13,076	-
2003	10,779	-	13,778	-
2004	12,014	-	14,608	-
2005	11,468	-	14,464	-
2006	12,778	-	15,298	-
2007	12,599	-	13,138	-
2008	12,944	-	14,882	-
2009	13,207	-	16,188	-
2010	17,087	-	18,926	-
2011	12,264	-	13,138	-
2012	16,916	-	18,990	-
2013	12,771	-	13,830	-
2014	13,220	-	14,925	-
2015	10,500	1,117	12,282	1,210
2016	17,764	1,681	22,887	3,638
2017	17,173	1,421	20,236	1,966
2018	17,107	1,312	21,134	2,348

^a Indicated Breeding Bird Index = 2 × (singles + pairs)

^b Indicated Total Birds = 2 × (singles + pairs) + birds in flocks

Table 6. Summary of 2018 population indices for all species surveyed on the Yukon-Kuskokwim Delta compared to their 34-year, 10-year, and the previous year's means.

	Cackling Canada Goose		Pacific White-fronted Goose		Emperor Goose		Black Brant		Taverner's Canada Goose		Tundra Swan		Sandhill Crane ^a	
	Index	±95% CI	Index	±95% CI	Index	±95% CI	Index	±95% CI	Index	±95% CI	Index	±95% CI	Index	±95% CI
Indicated Total Birds														
2018 estimate	59,508	4,960	190,586	48,153	30,112	3,463	26,438	5,892	15,973	10,795	32,733	8,916	21,134	4,602
34-yr mean: 1985–2018	61,263	8,144	106,824	21,200	21,709	1,807	23,615	2,054	8,392	791	27,424	1,793	16,801 ^a	1,040
10-yr mean: 2009–2018	78,226	10,408	179,278	15,964	26,540	3,400	23,505	2,518	9,847	1,776	30,118	3,793	17,254	2,277
% change: 34-yr mean	-3	-	78	-	39	-	12	-	90	-	19	-	26 ^a	-
% change: 10-yr mean	-24	-	6	-	13	-	12	-	62	-	9	-	22	-
34-year growth rate	1.042	0.013	1.079	0.010	1.020	0.005	1.008	0.012	1.014	0.008	1.007	0.006	0.998 ^a	0.007
10-year growth rate	1.021	0.050	1.027	0.029	1.059	0.030	1.021	0.039	1.060	0.052	0.987	0.047	1.027	0.047
Indicated Breeding Birds														
2018 estimate	54,057	4,306	141,549	26,227	28,440	3,312	15,258	3,858	13,565	9,028	23,621	2,538	17,107	2,571
34-yr mean: 1985–2018	42,627	5512.77905	52,603	12,939	14,406	1,661	7,598	1,347	5,871	655	17,406	1,341	14,024 ^a	781
10-yr mean: 2009–2018	57,475	6392.38442	97,915	18,625	19,023	3,525	10,900	2,803	6,930	1,735	20,033	2,511	14,801	1,647
% change: 34-yr mean	27	-	169	-	97	-	101	-	131	-	36	-	22 ^a	-
% change: 10-yr mean	-6	-	45	-	50	-	40	-	96	-	18	-	16	-
34-year growth rate	1.044	0.010	1.090	0.009	1.028	0.006	1.043	0.015	1.011	0.010	1.015	0.006	1.002 ^a	0.006
10-year growth rate	1.033	0.034	1.075	0.052	1.082	0.037	1.012	0.122	1.082	0.069	0.984	0.051	1.017	0.042

^a Long-term indices for Sandhill Cranes are based on a 32-year (1987–2018) mean.

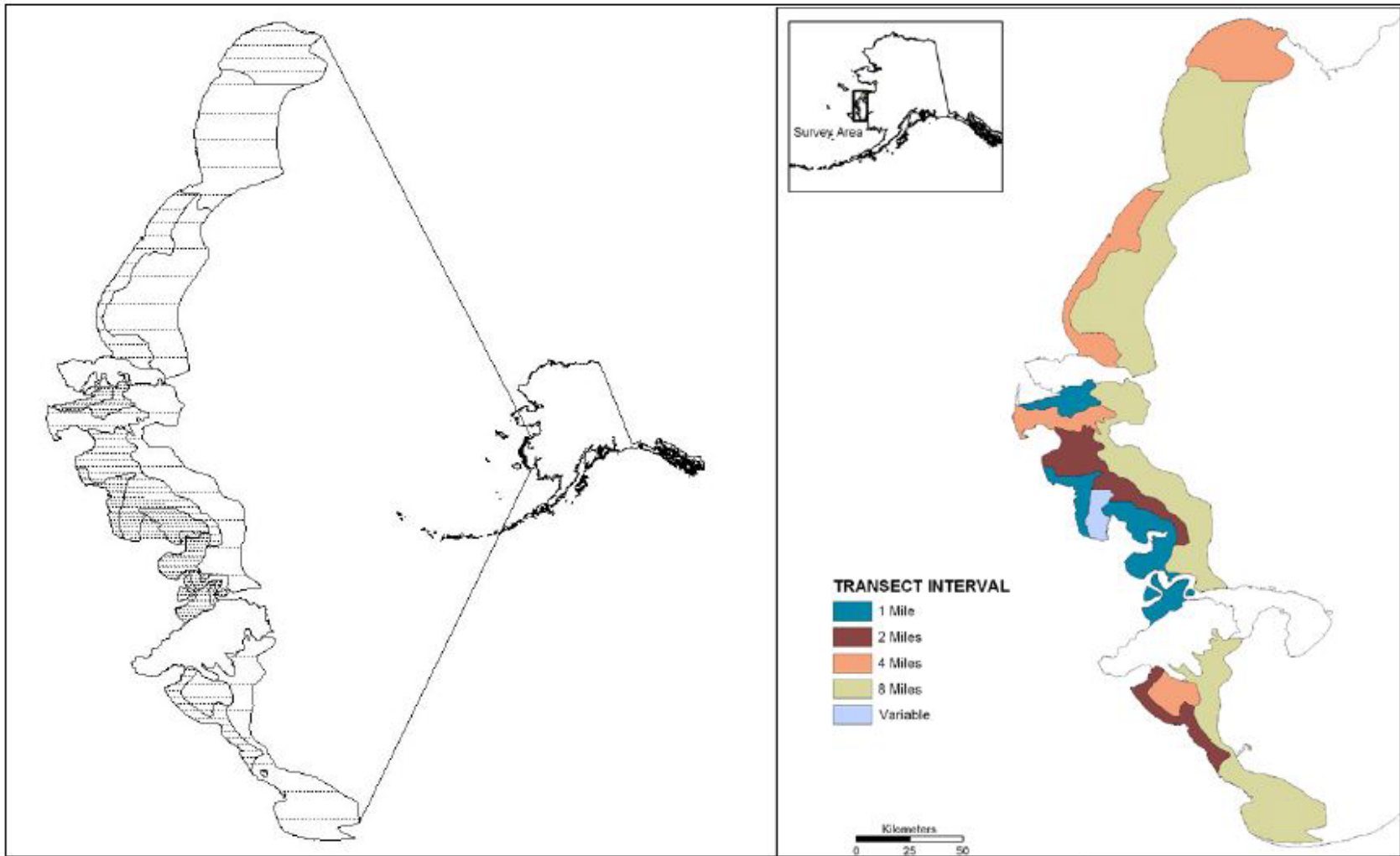


Figure 1. Yukon-Kuskokwim Delta (YKD) Coastal Zone Aerial Survey study area showing flight lines (left panel) and stratification (right panel).

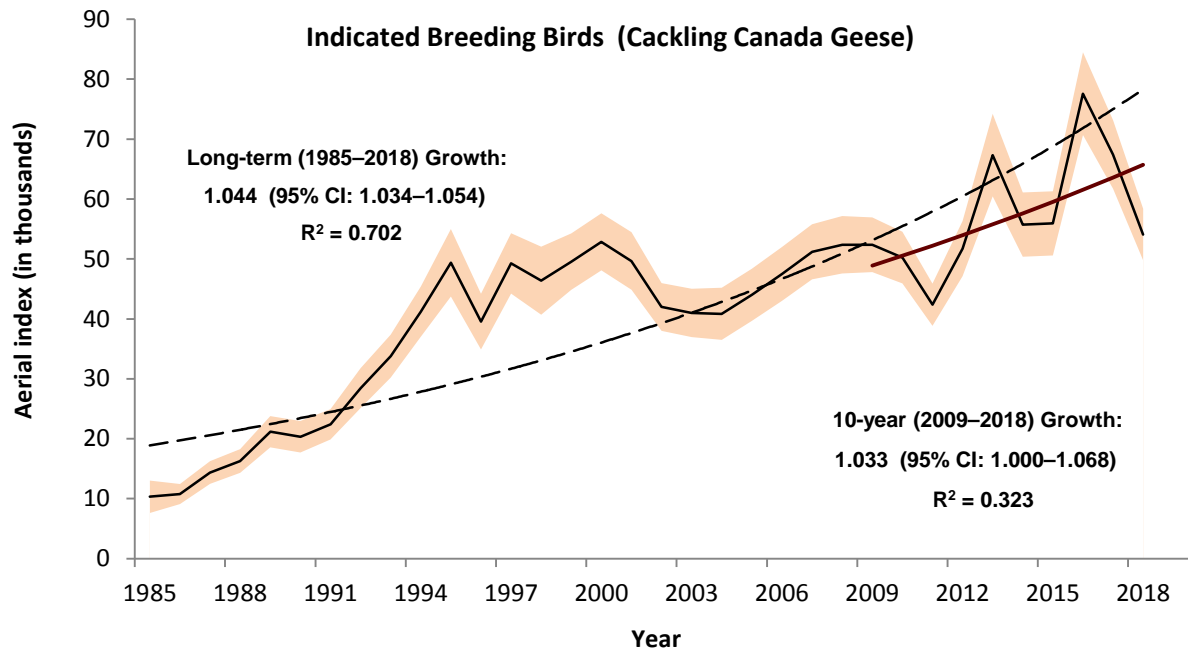
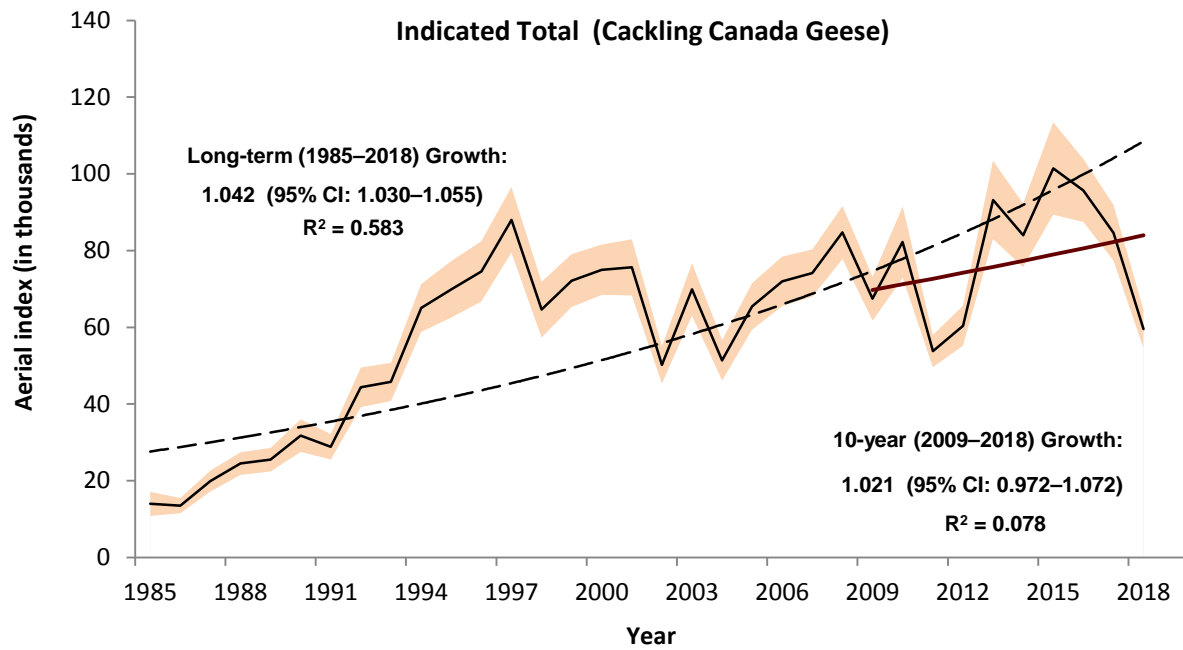


Figure 2. Indicated total and indicated breeding bird population indices for cackling Canada geese, with shaded 95% confidence intervals, 1985–2018. Dashed line represents the long-term (1985–2018) growth rate and the solid line represents the 10-year (2009–2018) growth rate calculated by log-linear regression.

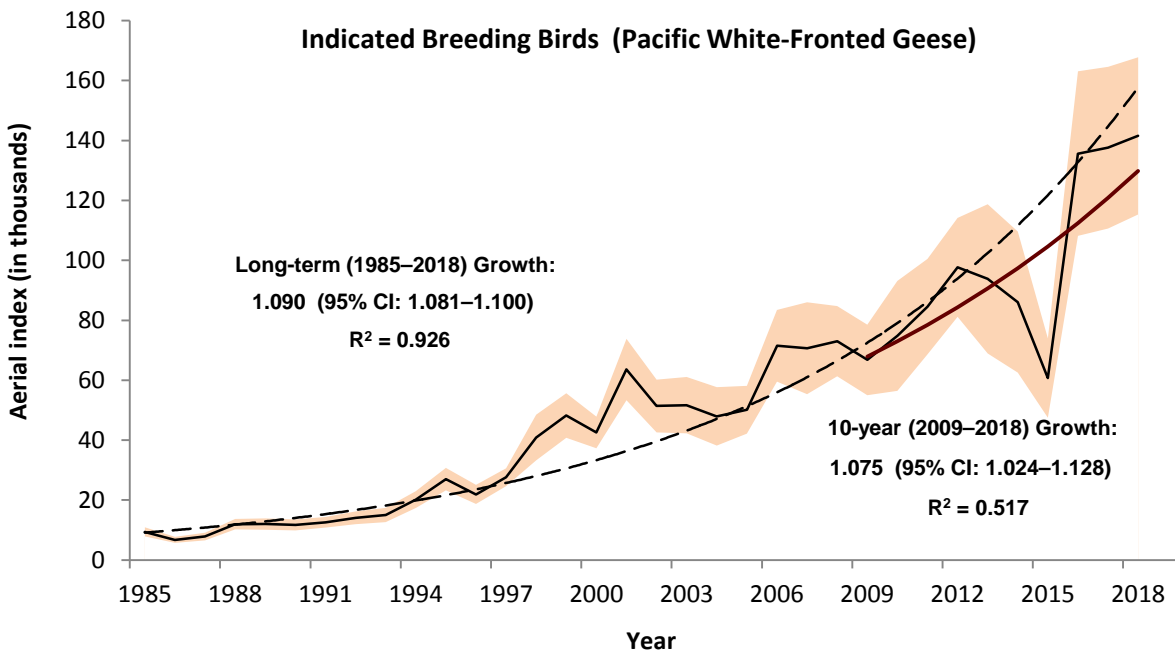
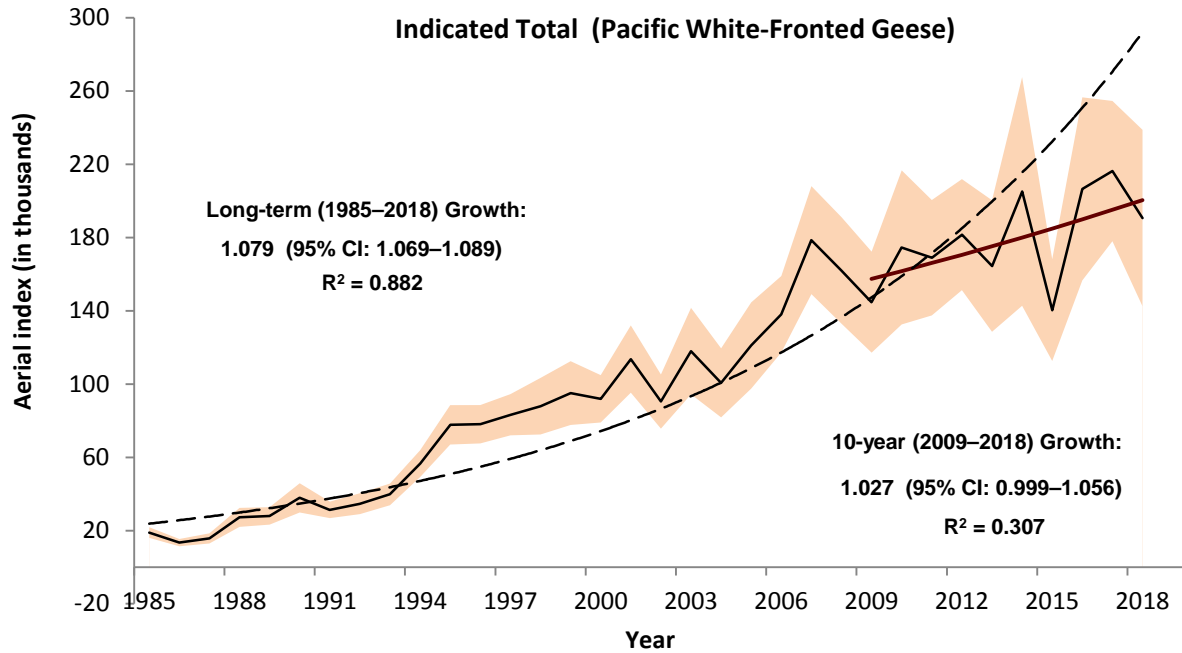


Figure 3. Indicated total and indicated breeding bird population indices for Pacific white-fronted geese, with shaded 95% confidence intervals, 1985–2018. Dashed line represents the long-term (1985–2018) growth rate and the solid line represents the 10-year (2009–2018) growth rate calculated by log-linear regression.

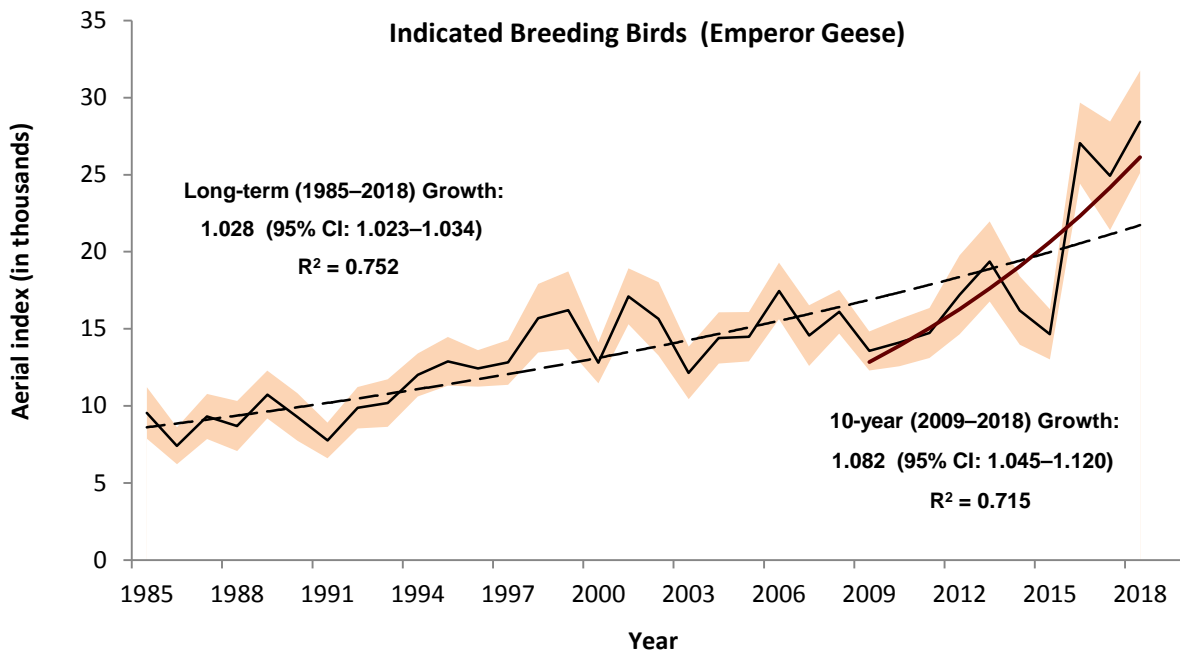
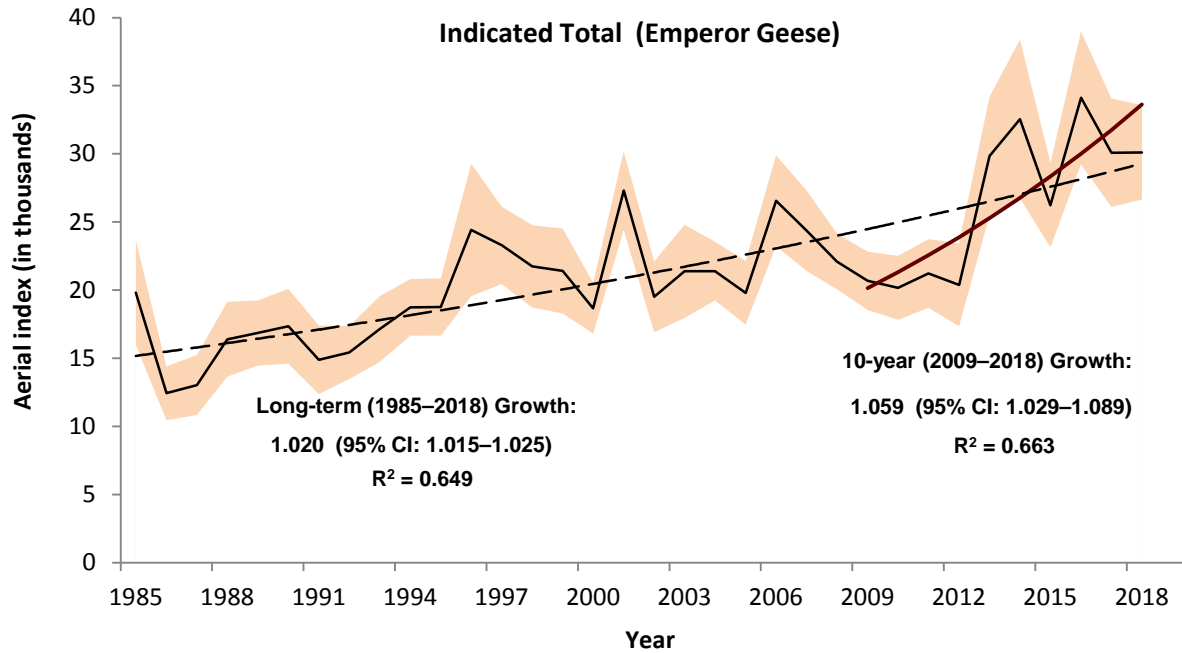


Figure 4. Indicated total and indicated breeding bird population indices for emperor geese, with shaded 95% confidence intervals, 1985–2018. Dashed line represents the long-term (1985–2018) growth rate and the solid line represents the 10-year (2009–2018) growth rate calculated by log-linear regression.

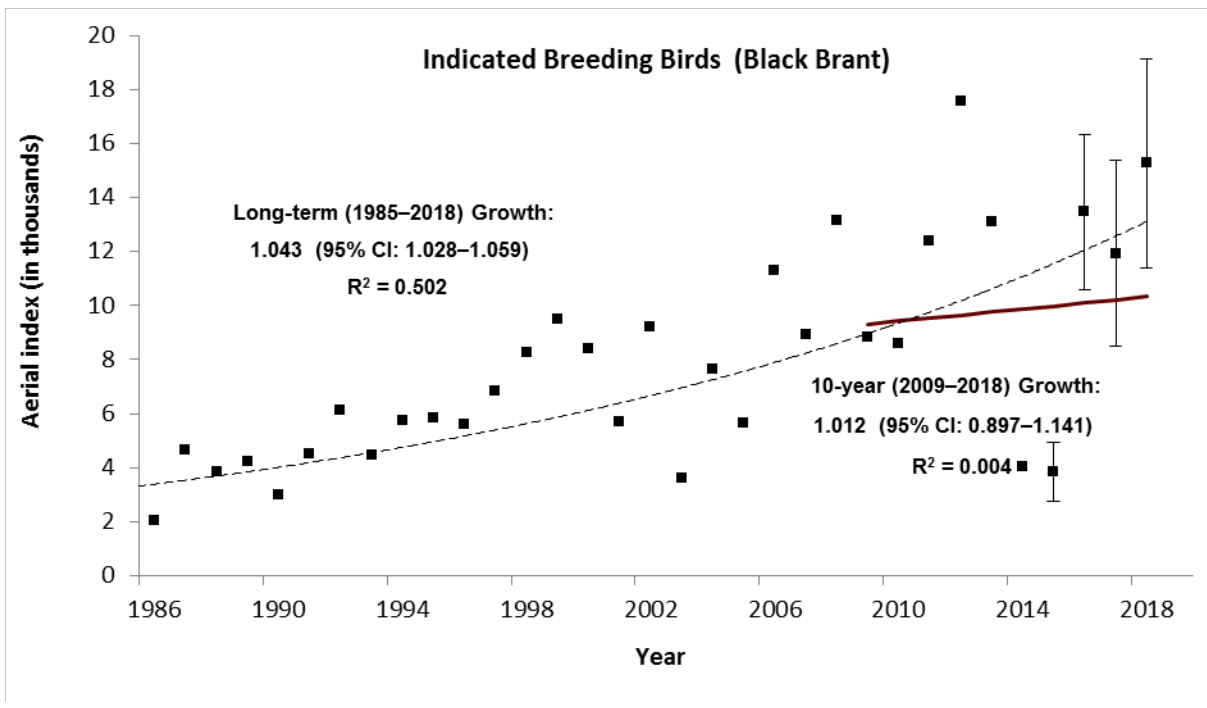
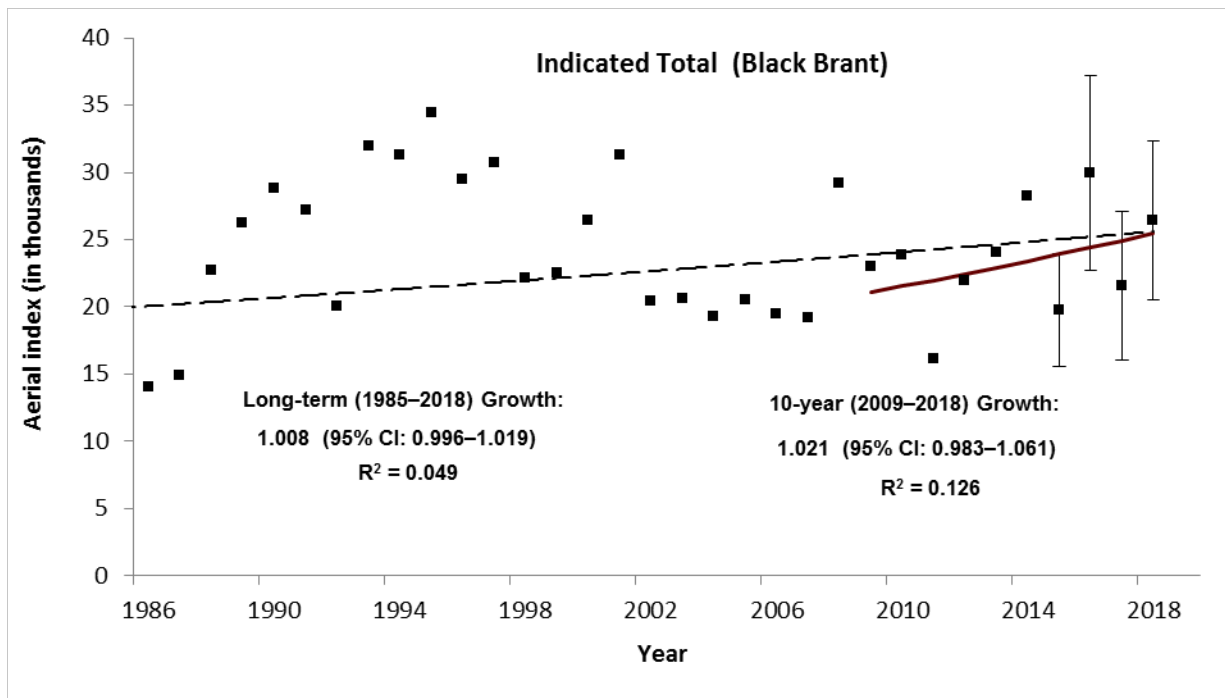


Figure 5. Indicated total and indicated breeding bird population indices for black brant, with error bars showing 95% confidence for years 2016–2018 (error estimates prior to 2015 were unavailable). Dashed line represents the long-term (1985–2018) growth rate and the solid line represents the 10-year (2009–2018) growth rate calculated by log-linear regression.

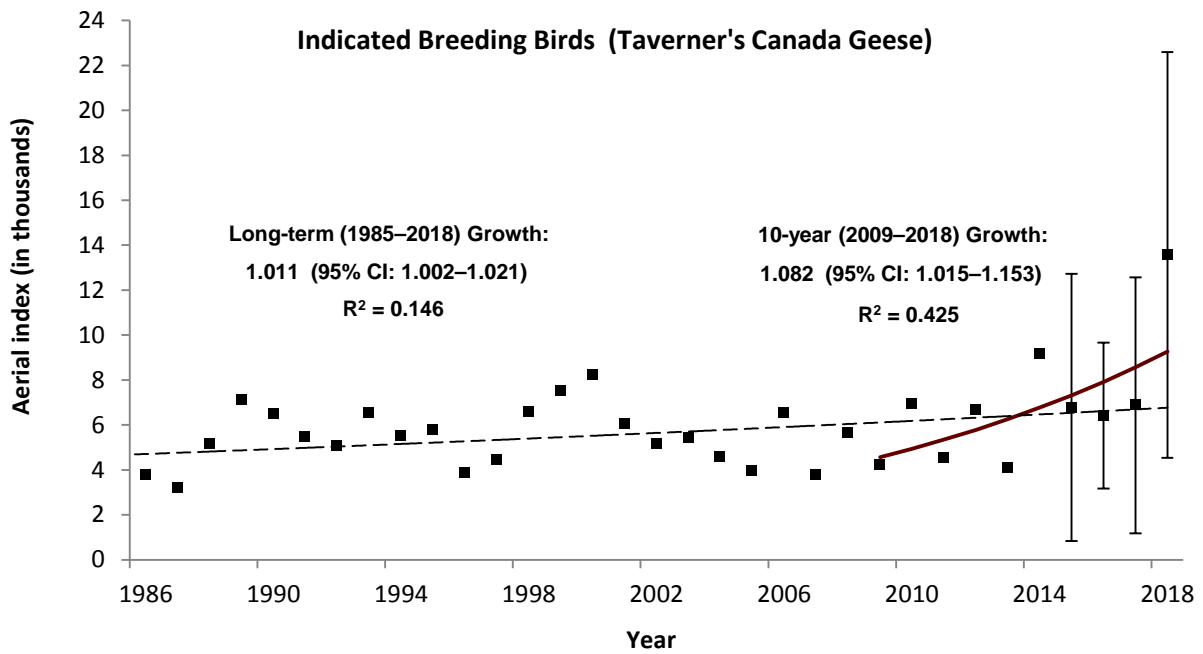
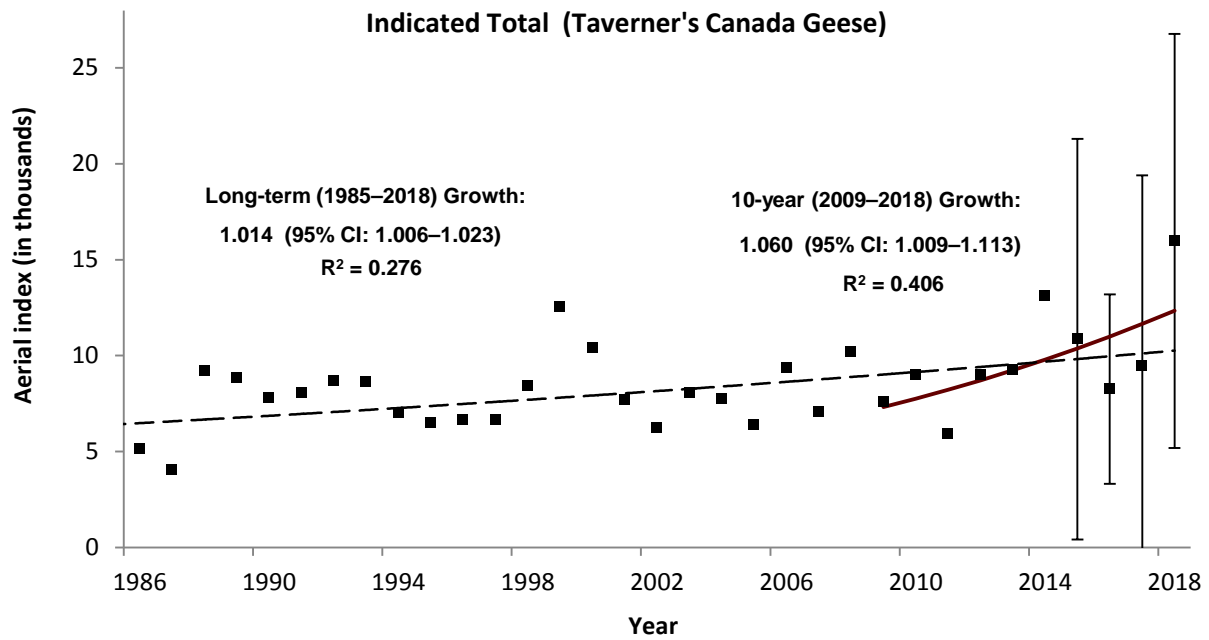


Figure 6. Indicated total and indicated breeding bird population indices for Taverner’s Canada geese, with error bars showing 95% confidence for years 2016–2018 (error estimates prior to 2015 were unavailable). Dashed line represents the long-term (1985–2018) growth rate and the solid line represents the 10-year (2009–2018) growth rate calculated by log-linear regression.

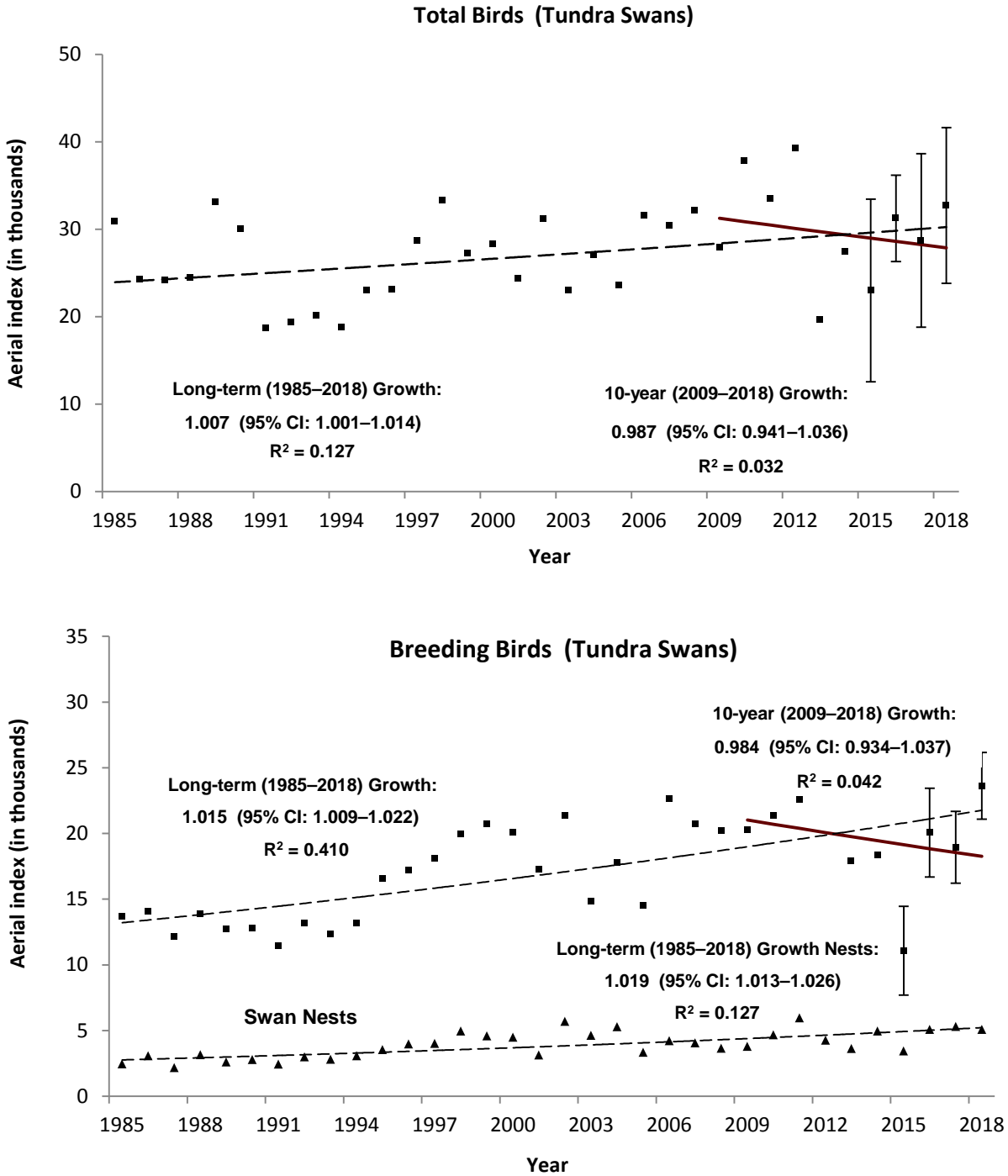


Figure 7. Total bird and breeding bird population indices for tundra swans, with error bars showing 95% confidence for years 2016–2018 (error estimates prior to 2015 were unavailable). Dashed lines represent long-term (1985–2018) growth rates and the solid line represents the 10-year (2009–2018) growth rate calculated by log-linear regression.

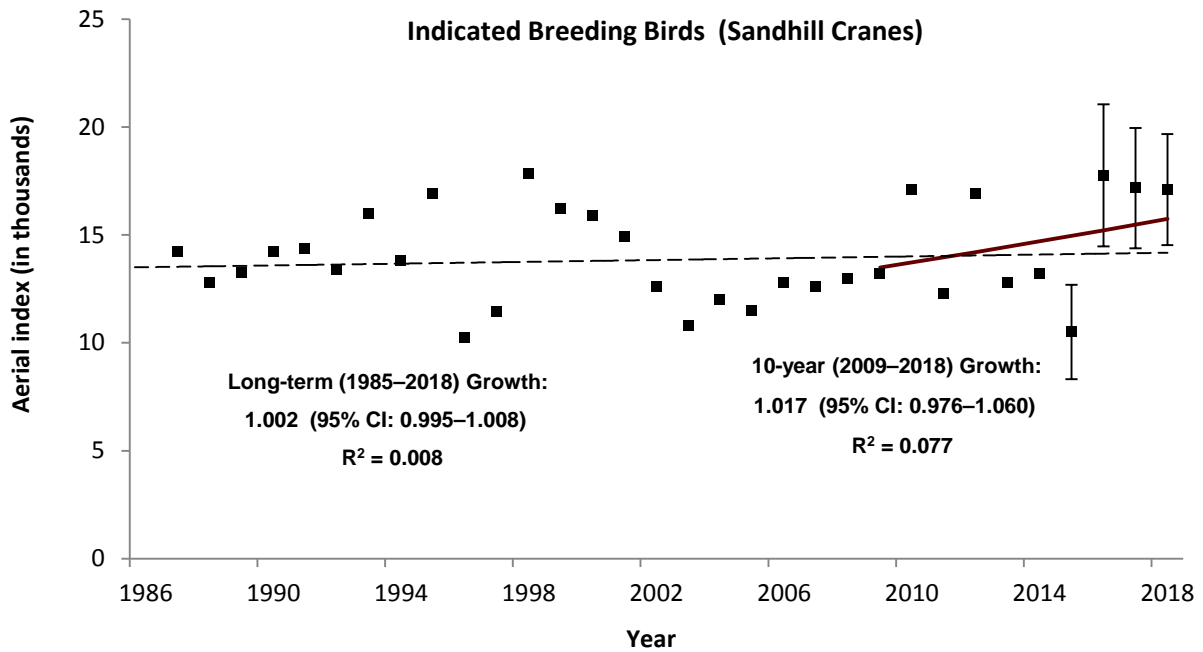
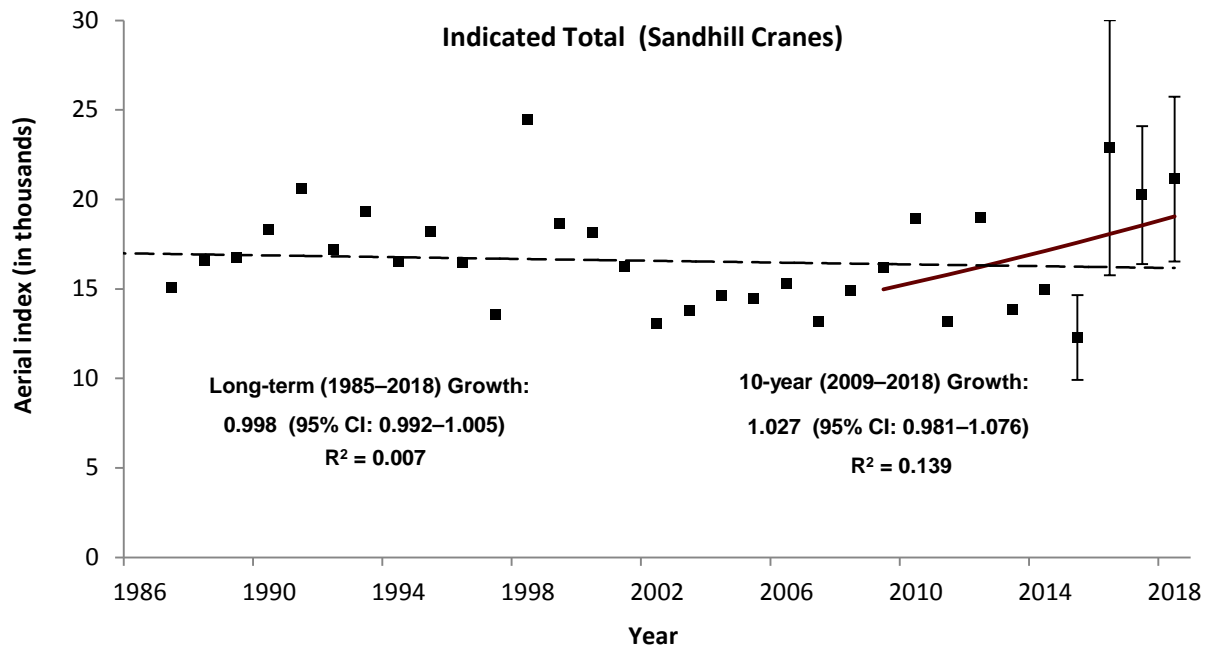


Figure 8. Total bird and breeding bird population indices for sandhill cranes, with error bars showing 95% confidence for years 2016–2018 (error estimates prior to 2015 were unavailable). Dashed lines represent long-term (1985–2018) growth rates and the solid line represents the 10-year (2009–2018) growth rate calculated by log-linear regression.

APPENDIX 1. Cackling Canada goose fall projected population estimate based on indicated total bird index from the Yukon-Kuskokwim Delta breeding ground survey and the 1989–2003 and 2011–2013 mark-resight estimate. This fall index calculation method was adopted in 2016. The 3-year running average is also presented.

Year	Total Indicated Birds ^a	Mark Resight Estimate	Fall Projected Population		3-year Running Average
			Index	SE	
1985	13,963		47,793	5,945	
1986	13,502		46,215	4,100	
1987	19,921		68,186	5,749	54,065
1988	24,467		83,747	6,505	66,049
1989	25,475	92,062	87,197	6,767	79,710
1990	31,759	94,237	108,706	9,025	93,217
1991	28,843	148,628	98,725	7,429	98,209
1992	44,356	149,542	151,824	11,522	119,752
1993	45,749	184,844	156,592	11,406	135,713
1994	65,021	198,558	222,557	15,142	176,991
1995	69,888	202,969	239,216	17,126	206,121
1996	74,574	193,531	255,255	18,274	239,009
1997	88,018	256,715	301,272	20,629	265,248
1998	64,601	215,644	221,119	16,428	259,215
1999	72,173	306,065	247,037	16,754	256,476
2000	74,992	273,108	256,686	16,700	241,614
2001	75,620	206,249	258,835	17,696	254,186
2002	50,187	177,794	171,782	11,766	229,101
2003	69,867	251,594	239,144	16,429	223,254
2004	51,390		175,900	12,411	195,609
2005	65,484		224,141	14,975	213,062
2006	71,985		246,393	16,204	215,478
2007	74,152		253,811	16,103	241,448
2008	84,669		289,809	18,236	263,338
2009	67,434		230,816	14,771	258,145
2010	82,192		281,330	21,024	267,318
2011	53,799	242,467	184,146	11,369	232,097
2012	60,395	272,493	206,723	13,364	224,066
2013	93,200	259,323	319,009	23,339	236,626
2014	83,970		287,416	19,846	271,049
2015	101,408		347,104	26,683	317,843
2016	95,667		327,453	21,104	320,658
2017	84,686		289,867	18,673	321,475
2018	59,508		203,687	12,952	273,669

^a Indicated Total Birds (ITB) = 2 × (pairs + singles) + group birds Yukon-Kuskokwim Delta.

^b Fall Population Index = (ITB × 3.422843)

Appendix 2. Indices of Pacific white-fronted geese as indicated breeding birds (IBB: 2 × singles + paired) and indicated total birds (ITB) from June aerial surveys of the Yukon-Kuskokwim Delta and Bristol Bay Lowlands, 1985–2018.

Year	Yukon-Kuskokwim Delta coastal zone		Yukon-Kuskokwim Delta Interior		Bristol Bay		Yukon-Kuskokwim Total		All Pacific White-fronts	
	IBB	ITB	IBB	ITB	IBB	ITB	IBB	ITB	IBB	ITB
1985	9,382	18,914	5,698	12,082	1,219	5,050	15,080	30,996	16,299	36,046
1986	6,713	13,400	5,894	10,019	1,915	4,266	12,607	23,419	14,522	27,685
1987	7,819	15,717	4,715	7,564	1,045	3,657	12,534	23,281	13,579	26,938
1988	11,953	27,191	9,037	14,145	522	3,918	20,990	41,336	21,512	45,254
1989	11,982	28,004	5,108	16,307	1,045	5,398	17,090	44,311	18,135	49,709
1990	11,705	37,836	8,841	18,468	871	2,003	20,546	56,304	21,417	58,307
1991	12,584	31,286	6,287	13,262	1,741	4,527	18,871	44,548	20,612	49,075
1992	14,077	34,671	6,287	16,110	522	7,052	20,364	50,781	20,886	57,833
1993	15,010	39,748	8,055	22,790	697	1,306	23,065	62,538	23,762	63,844
1994	20,155	56,513	6,680	12,966	871	4,092	26,835	69,479	27,706	73,571
1995	26,985	77,710	7,859	10,215	1,393	2,612	34,844	87,925	36,237	90,537
1996	21,887	78,032	15,914	36,543	697	4,353	37,801	114,575	38,498	118,928
1997	27,611	83,215	15,521	30,452	871	3,657	43,132	113,667	44,003	117,324
1998	40,872	87,881	16,307	34,381	1,567	1,915	57,179	122,262	58,746	124,177
1999	48,207	95,040	10,806	27,800	1,393	3,483	59,013	122,840	60,406	126,323
2000	42,558	91,911	8,841	16,798	871	1,654	51,399	108,709	52,270	110,363
2001	63,555	113,603	10,806	24,460	348	6,095	74,361	138,063	74,709	144,158
2002	51,381	90,407	14,146	17,387	1,219	5,311	65,527	107,794	66,746	113,105
2003	51,670	117,951	11,002	17,387	522	2,177	62,672	135,338	63,194	137,515
2004	47,928	100,622	9,234	16,601	1,045	1,828	57,162	117,223	58,207	119,051
2005	50,141	121,017	10,216	18,566	174	6,530	60,357	139,583	60,531	146,113
2006	71,484	138,067	13,360	28,979	3,309	4,702	84,844	167,046	88,153	171,748
2007	70,670	178,515	16,503	28,488	697	2,177	87,173	207,003	87,870	209,180
2008	73,022	161,979	20,040	54,913	522	1,045	93,062	216,892	93,584	217,937
2009	66,759	144,678	17,486	32,712	1,045	5,137	84,245	177,390	85,290	182,527
2010	74,791	174,556	23,773	44,402	2,786	7,923	98,564	218,958	101,350	226,881
2011	84,551	168,925	19,254	33,989	1,219	6,095	103,805	202,914	105,024	209,009
2012	97,654	181,519	23,380	47,250	1,045	3,744	121,034	228,769	122,079	232,513
2013	93,823	164,399	14,342	29,568	1,219	5,485	108,165	193,967	109,384	199,452
2014	86,079	205,081	9,823	16,503	348	348	95,902	221,584	96,250	221,932
2015	60,708	140,313	8,654	18,468	871	1,132	69,362	158,781	70,233	159,913
2016	135,637	206,503	20,433	31,042	697	3,309	156,070	237,545	156,767	240,854
2017	137,604	216,219	21,218	43,616	697	697	158,822	259,835	159,519	260,532
2018	141,549	190,586	6,483	11,788	1,045	1,045	148,032	202,374	149,077	203,419

Appendix 3. Fall population index for Pacific white-fronted geese based on the relationship of indicated total birds from breeding pair surveys conducted on the Yukon-Kuskokwim Delta and Bristol Bay Lowlands to the 1985–1998 fall survey counts. The indicated total bird (ITB) index represents the combined total from the YKD Coastal Zone Survey and Stratum 8 (Bristol Bay) and Stratum 9 (Yukon Delta) from the Waterfowl Breeding Population and Habitat Survey. The 3-year average is also presented.

Year	Indicated Total Birds ^a	Fall Survey	Fall Population Index ^b	3-year Average
1985	36,046	93,800	163,249	
1986	27,685	107,100	141,930	
1987	26,938	130,600	140,026	148,402
1988	45,254	161,500	186,728	156,228
1989	49,709	218,800	198,087	174,947
1990	58,307	240,800	220,010	201,608
1991	49,075	236,500	196,470	204,856
1992	57,833	230,900	218,802	211,761
1993	63,844	295,100	234,128	216,467
1994	73,571	324,800	258,930	237,287
1995	90,537	277,500	302,190	265,083
1996	118,928	344,100	374,582	311,901
1997	117,324	319,000	370,492	349,088
1998	124,177	413,100	387,966	377,680
1999	126,323		393,437	383,965
2000	110,363		352,743	378,048
2001	144,158		438,913	395,031
2002	113,105		359,734	383,797
2003	137,515		421,975	406,874
2004	119,051		374,895	385,535
2005	146,113		443,898	413,589
2006	171,748		509,262	442,685
2007	209,180		604,706	519,289
2008	217,937		627,035	580,334
2009	182,527		536,746	589,496
2010	226,881		649,840	604,540
2011	209,009		604,270	596,952
2012	232,513		664,201	639,437
2013	199,452		579,902	616,124
2014	221,932		637,221	627,108
2015	159,913		479,085	565,403
2016	240,854		685,469	600,592
2017	260,532		735,643	633,399
2018	203,419		590,017	670,376

^a Indicated Total Birds (ITB) = 2 × (pairs + singles) + group birds

^b Fall Population Index = (ITB × 2.5498) + 71,339