

Memorandum

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

Subject: 2016 Yukon-Kuskokwim Delta Coastal Zone Survey of Geese, Swans, and Sandhill Cranes.

INTRODUCTION AND METHODS

This report summarizes information on the status of geese, tundra swans (*Cygnus columbianus*), and sandhill cranes (*Grus canadensis*) in the coastal zone of the Yukon-Kuskokwim Delta, Alaska. The Yukon-Kuskokwim Delta (YKD) Coastal Zone Survey was flown 25 May to 1 June 2016, representing the 32nd consecutive year the U.S. Fish and Wildlife Service (USFWS) has conducted this project. Goose species surveyed include cackling Canada geese (*Branta canadensis minima*), Pacific greater white-fronted geese (*Anser albifrons frontalis*), emperor geese (*Chen canagica*), Pacific black brant (*B. bernicla nigricans*), and Taverner's Canada geese (*B. c. taverneri*). Species nomenclature follows common names recognized by the Pacific Flyway and scientific names recognized by the USFWS (USFWS 2015). Species are referenced as cackling Canada geese, Pacific white-fronted geese, emperor geese, black brant, and Taverner's Canada geese throughout the remainder of this document.

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 1985–2016 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 the aircraft to transect "start" and "end" waypoints and maintain the aircraft along the transect. Two observers, one biologist-pilot and a right-seat observer, recorded all goose, swan, and crane observations out to 200 meters on their respective sides of the aircraft, except from 2012–2014, when only the front right-seat observer recorded observations. In 2016, two new observers completed the survey, with Heather Wilson, wildlife biologist-pilot, as the left-front seat observer, and Michael Swaim, wildlife biologist, as the right-front seat observer. Tamara Zeller, wildlife biologist, counted all other water birds from the right-rear seat for the second consecutive year. Aerial observations were recorded onto laptop computers using a moving-map survey program developed by John

Hodges. Survey data were recorded as GPS-linked sound files (.wav format) that were transcribed into text files and analyzed in Visual Basic using John Hodges' "PopEstimates" Program.

Population Indices

Population indices used in this report were calculated for the following species or groups of species as follows:

All Geese and Sandhill Cranes

$$\text{indicated breeding birds} = 2 \times (\text{singles} + \text{pairs}^a)$$

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

Tundra Swans

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

$$\text{singles and pairs} = \text{singles} + (2 \times \text{pairs})$$

$$\text{nests} = \text{number of active nests observed}$$

$$^a \text{ pairs} = \text{number of pairs and not number of birds in pairs}$$

This definition applies to all species in this report.

These population indices are based on the assumption that a single goose or crane observed represents a pair, with an unseen mate on a nest. Although cranes are larger than geese, we assume the visibility of cranes to be similar to that of geese because of the crane's cryptic coloration. We assume that all swans are observed and a complete count is attained. Therefore, the number of single swans is not doubled as with geese and cranes.

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). In 1998, the design was reduced to four primary strata based on goose densities, with survey transects systematically placed in an east-west orientation from randomly selected starting points within each strata. In the highest density stratum, transects were established at 1.6 km (1.0 mi) intervals, whereas transects were spaced at 3.2 km (2.0 mi), 6.4 km (4.0 mi), and 12.9 km (8.0 mi) intervals in successively less dense areas (Fig. 1). In 2004, an additional stratum was created to accommodate historical data for a high-density area that had variable spacing between transects for several years.

Since 1998 the survey design has utilized a rotating panel design to obtain a representative sample on an annual basis, with a more extensive sample over a four year period. Near complete coverage of the high density stratum is obtained during each four-year rotation by shifting transects 0.4 km each year. Transects in less intensively surveyed areas are proportionally adjusted each year to obtain optimal coverage over the four-year period. Years 1998–2000 comprised the first four-year rotation; 2002–2005, the second; 2006–2009, the third; and 2010–

2013, the fourth four-year rotation. The 2016 survey represents the third year of the fifth, four-year rotation during which 113 transects were surveyed, comprising a total of 2,485 linear km.

RESULTS AND DISCUSSION

Commencement of the 2016 YKD Coastal Zone Survey occurred at the earliest date in the history of this survey due to unseasonably mild temperatures, which resulted in early snow melt, ice breakup, and nest initiation. We performed a pre-survey reconnaissance flight on 23 May to verify timing, test equipment, and practice recording aerial observations. This flight revealed that the wetlands and ponds in the area were completely ice-free and the tundra was beginning to green-up. There was little indication of recent flooding, but we did experience high tides during the survey. Most days were clear and sunny, which somewhat diminished the quality of the survey conditions due to glare. High winds in the mountains near the west end of Kokechik Bay resulted in mechanical turbulence, requiring the termination of transect 86 approximately one-half mile from the endpoint.

Overall, the 2016 survey appeared to be well timed. From 25–28 May, the majority of geese were observed in pairs or in small family groups, and by 31 May, a higher proportion of geese were observed in flocks. The potential effects of survey timing relative to nesting phenology on population estimates has not been fully assessed. However, we assume that the number of failed breeders seen as flocked birds generally increases as the nesting season progresses. Surveys that are timed late likely record higher numbers of flocked birds with fewer observations of singles and paired birds. Likewise, more flocked birds are likely recorded during years when nest success is poor.

Cackling Canada Geese

In 2016, the indicated total bird index for cackling Canada geese was $95,667 \pm 4,191$ (SE) and indicated breeding bird index was $77,979 \pm 3,520$ (SE). This represents an increase of 20.0% and 39.9% in these indices, respectively, over the 2007–2016 mean (Tables 1, 2, 6). Indicated total birds and indicated breeding birds experienced average annual growth rates of 1.048 ± 0.007 (SE) and 1.047 ± 0.006 (SE), respectively, from 1985–2016 (Fig. 2).

The Pacific Flyway Council adopted a new method for estimating the fall population of cackling Canada geese in March 2011 (Stehn 2012). The original method, used to predict the fall population from 1998–2010, relied on a simple linear relationship between indicated total birds on the Yukon-Kuskokwim Delta breeding grounds (i.e., this aerial survey) regressed on the 1985–1998 fall coordinated count data (Pacific Flyway Council 1999). This new method used ratio estimation to establish the relationship between the indicated total bird index from the YKD Coastal Zone Survey (i.e., this aerial survey) and mark-resight data from 1989–2003. In 2016, the index ratio was updated to incorporate additional mark-resight data from 2011–2013 (Pacific Flyway Council 2016). The fall population index for cackling Canada geese for 1985–2016 is now calculated by multiplying the indicated total bird (ITB) index from the YKD Coastal Zone Survey by an index ratio:

$$\text{Fall Population Index} = (\text{ITB} \times 3.422843)$$

Using this method, the 2016 cackling Canada goose estimated fall population is $327,453 \pm 21,104$ (SE) birds and the 3-year (2014–2016) mean is 320,658 birds (Appendix 1). This represents an estimated change in these indices of -5.7 and +0.9%, respectively, from 2015.

Pacific White-fronted Geese

In 2016, the Pacific white-fronted goose indices for indicated total birds and indicated breeding birds were $206,503 \pm 25,491$ (SE) and $135,637 \pm 14,009$ (SE), respectively, which represents an increase of 19.6% and 60.8% over their respective 10-year (2007–2016) means (Tables 1, 2, 6). From 1985–2016, the average annual growth rate for indicated total birds and indicated breeding pairs was 1.083 ± 0.006 (SE) and 1.091 ± 0.005 (SE), respectively (Fig. 3; Table 6).

To estimate the fall population of Pacific white-fronted geese, the indicated total bird estimate from the YKD Coastal Zone Survey is added to the estimates from Stratum 8-Bristol Bay and Stratum 9-Yukon Delta Interior of the Waterfowl Breeding Population and Habitat Survey (Groves and Shults *in prep*) and expanded based on the historical relationship between summer and fall surveys from 1985–1998. (Pacific Flyway Council 2003). The fall estimate is calculated from the cumulative indicated total using the following equation:

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

In 2016, indicated total birds from Stratum 8-Bristol Bay and Stratum 9-Yukon Delta of the Waterfowl Breeding Population and Habitat Survey were 3,309 and 31,042, respectively (Groves and Shults *in prep*). Combined with the 2016 YKD Coastal Zone Survey estimate, the Yukon-Kuskokwim Delta and Bristol Bay region supported 240,854 indicated total birds (Appendix 2). Using the calculation above, the projected 2016 fall population index and 3-year running average (2014–2016) are 685,469 and 600,592, respectively (Appendix 3). This represents an estimated increase in these indices of 43.1% and 6.2%, respectively, from 2015.

Emperor Geese

The 2016 emperor goose indices for indicated total birds ($34,109 \pm 2,490$ [SE]) and indicated breeding birds ($27,051 \pm 1,341$ [SE]) were 35.5% and 61.5% higher than their respective 10-year means (Table 6). From 1985–2016, the average annual population growth rates for indicated total birds and indicated breeding birds were 1.020 ± 0.003 (SE) and 1.026 ± 0.003 (SE), respectively (Fig. 4).

Black Brant

The YKD Coastal Zone Survey was not specifically designed to assess the population of colonial nesting species, such as black brant. However, we believe these survey data are useful in assessing the general population trends and distribution.

The 2016 indicated total birds index ($29,986 \pm 3,693$ [SE]) and the indicated breeding birds index ($13,460 \pm 1,459$ [SE]) were 27.4% higher and 29.6% higher than the 2007–2016 means for these indices, respectively (Fig. 5; Tables 3, 6). Because distinguishing single brant within larger groups is difficult in areas of high density, indicated breeding bird indices for this species may be biased low. Average (1985–2016) annual growth rates for indicated total birds and indicated

breeding birds over the last 32 years were 1.008 ± 0.007 (SE) and 1.043 ± 0.009 (SE), respectively (Fig. 5).

Taverner's Canada Geese

Taverner's Canada geese are found primarily interior to the coastal zone surveyed, 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 2016). In 2016, the indicated total birds index ($8,255 \pm 2,520$ [SE]) and the indicated breeding birds index ($6,422 \pm 1,657$ [SE]) for Taverner's Canada geese were 8.6% lower and 10.1% higher, respectively, than the 2007–2016 mean of these indices (Fig. 6; Tables 3, 6). Average (1985–2016) annual growth rates measured 1.012 ± 0.004 (SE) and 1.007 ± 0.005 (SE) for indicated total birds and indicated breeding birds, respectively (Fig. 6).

Tundra Swans

All swan population indices were higher in 2016 compared to their 2007–2016 means. Total birds ($31,251 \pm 5,939$ [SE]) were 3.4% higher; singles and pairs ($20,060 \pm 1,724$ [SE]), 0.9% higher; and the nest index (5,081), 16.6% higher, respectively, than the 2007–2016 means (Fig. 7; Tables 4, 6). Average annual growth rates for total birds, singles and pairs, and nests were 1.007 ± 0.004 (SE), 1.015 ± 0.004 (SE), and 1.019 ± 0.004 (SE), respectively, from 1985–2016.

Sandhill Cranes

In 2016, indices for indicated total birds ($22,887 \pm 3,638$ [SE]) and for indicated breeding birds ($17,764 \pm 1,681$ [SE]) were 43.8% and 27.5% higher than their respective 10-year means (Tables 5, 6). Average (1985–2016) annual growth rates for both indicated total birds and indicated breeding birds were 0.995 ± 0.003 (SE) and 0.999 ± 0.003 (SE), respectively (Fig. 8).

SURVEY RECOMMENDATIONS

Populations of geese on the YKD Coastal Zone have increased to the point that recording individual singles and pairs is challenging, especially in the highest-density areas near the coast. Several factors complicate our ability to accurately survey these populations. During aerial surveys, most geese (especially cacklers) are disturbed by the plane and flush from the ground approximately $\frac{1}{4}$ to $\frac{1}{2}$ mile in front of the aircraft, before regrouping into larger mixed flocks that fly perpendicular to the plane. Movement of birds in response to the plane may contribute to several sources of estimation error including: (1) potential misidentification and flock size estimation error with large mixed-flock groups; (2) determination whether birds originated from within the survey transect; and (3) determination of the social status of the flying birds (i.e., singles, pairs, flocks). To minimize potential sampling error associated with observers, we recommend increasing training for new observers and retaining experienced observers as long as possible.

ACKNOWLEDGMENTS

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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, 1985–2016.

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

^a Indicated total = 2 x (singles + pairs) + birds in flocks

Table 2. Indicated breeding bird^a indices for cackling Canada, Pacific white-fronted, and emperor geese on the Yukon-Kuskokwim Delta, 1985–2016.

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

^a Indicated breeding bird index = 2 x (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, 1985–2016.

Year	Black Brant		Taverner's Canada Geese	
	Indicated Breeding Bird ^a	Indicated Total ^b	Indicated Breeding Bird ^a	Indicated Total ^b
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	19,753	6,779	10,864
2016	13,460	29,986	6,422	8,255

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

^b Indicated total = 2 x (singles + pairs) + birds in flocks

Table 4. Tundra swan population indices on the Yukon-Kuskokwim Delta, 1985–2016.

Year	Singles and Pairs ^a	Total Birds ^b	Nests ^c
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	23,000	3,448
2016	20,060	31,251	5,081

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

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

^c Nests = number of active nest observations

Table 5. Sandhill Crane population indices on the Yukon-Kuskokwim Delta, 1987–2016.

Year	Indicated Breeding Bird ^a	Indicated Total Birds ^b
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	12,282
2016	17,764	22,887

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

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

Table 6. Summary of 2014–2016 population indices for all species surveyed on the Yukon-Kuskokwim Delta compared to their 32-year, 25-year, 10-year, and 3-year means.

		CCGO ^a	GWFG	EMGO	BLBR	TCGO	TUSW	SACR	TUNE ^b
Indicated Total Birds									
	2014	83,970	205,081	32,550	28,283	13,115	27,413	14,925	4,965
	2015	101,408	140,313	26,235	19,753	10,864	23,000	12,282	3,448
	2016	95,667	206,503	34,109	29,986	8,255	31,251	22,887	5,081
	32-yr mean: 1985–2016	60,586	100,788	21,185	23,592	8,122	27,218	16,543	3,853
	25-yr mean: 1992–2016	71,233	122,114	22,687	24,638	8,448	27,415	16,361	4,181
	10-yr mean: 2007–2016	79,692	172,647	25,166	23,543	9,029	30,237	15,919	4,360
	3-yr mean: 2014–2016	93,682	183,966	30,965	26,007	10,745	27,221	16,698	4,498
	% Change: 25-yr mean	34.3	69.1	50.3	21.7	-2.3	14.0	39.9	21.5
	% Change: 10-yr mean	20.0	19.6	35.5	27.4	-8.6	3.4	43.8	16.6
	% Change: 3-yr mean	2.1	12.3	10.2	15.3	-23.2	14.8	37.1	13.0
	Rank - 32 yrs	2	1	1	6	15	8	2	4
	Annual Growth Rate	1.048	1.083	1.020	1.008	1.012	1.007	0.995	1.019
	Growth Rate (SE)	0.007	0.006	0.003	0.007	0.004	0.004	0.003	0.004
Indicated Breeding Birds									
	2014	55,733	86,079	16,188	4,040	9,183	18,367	13,220	
	2015	55,937	60,708	14,647	3,844	6,779	11,077	10,500	
	2016	77,979	135,637	27,051	13,460	6,422	20,060	17,764	
	32-yr mean: 1985–2016	41,507	47,167	13,639	7,223	5,599	17,164	13,816	
	25-yr mean: 1991–2016	48,504	57,489	14,948	8,308	5,745	18,342	13,825	
	10-yr mean: 2007–2016	55,723	84,369	16,753	10,388	5,833	19,875	13,927	
	3-yr mean: 2014–2016	63,216	94,141	19,295	7,115	7,461	16,501	13,828	
	% Change: 25-yr mean	60.8	135.9	81.0	62.0	11.8	9.4	28.5	
	% Change: 10-yr mean	39.9	60.8	61.5	29.6	10.1	0.9	27.5	
	% Change: 3-yr mean	23.4	44.1	40.2	89.2	-13.9	21.6	28.5	
	Rank - 32 yrs	1	1	1	2	12	10	2	
	Annual Growth Rate	1.047	1.091	1.026	1.043	1.007	1.015	0.999	
	Growth Rate (SE)	0.006	0.005	0.003	0.009	0.005	0.004	0.003	
^a CCGO = cackling Canada goose									
^b TUNE = Tundra Swan Nests									

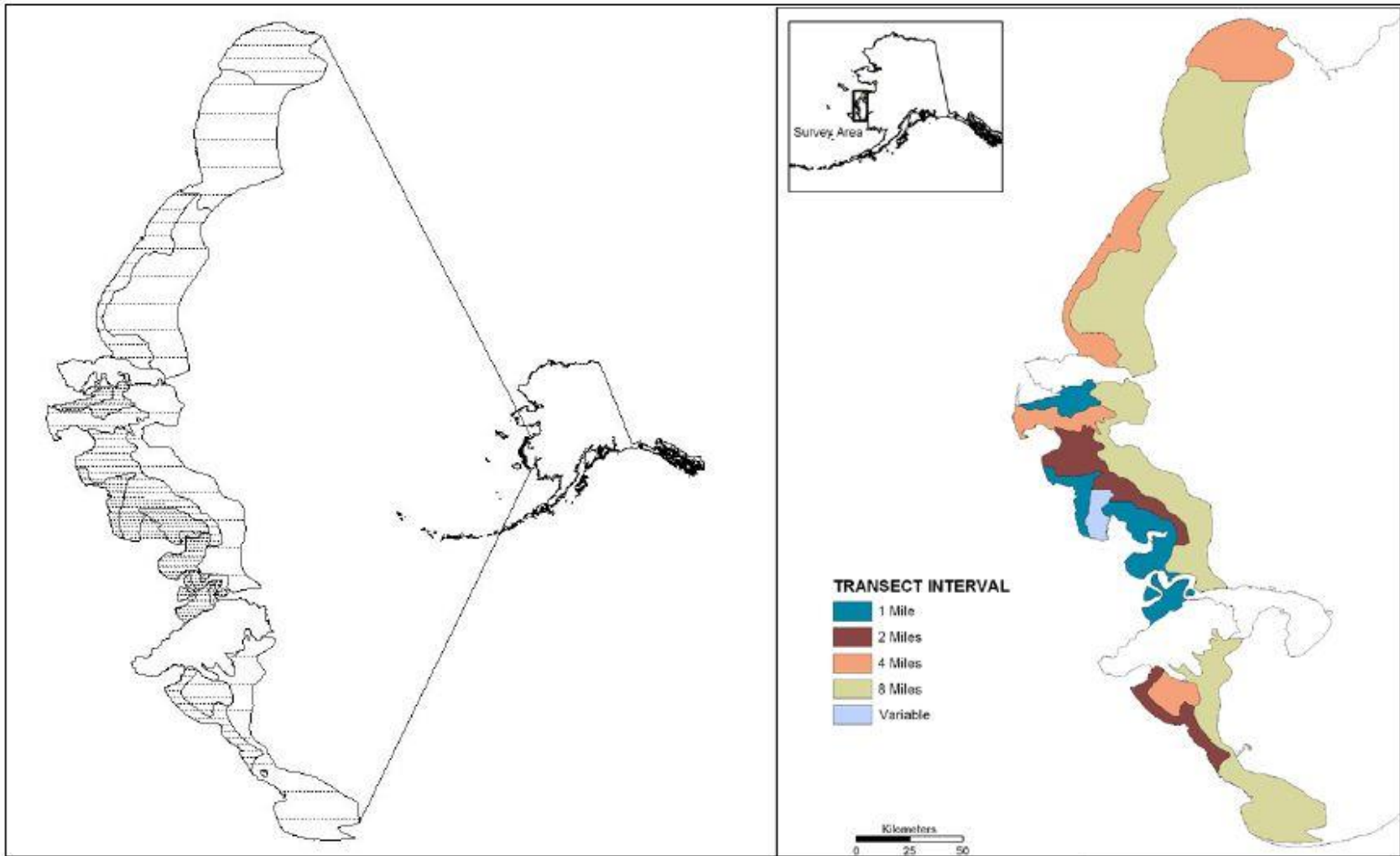


Figure 1. Yukon-Kuskokwim Delta (YKD) Coastal Zone Aerial Survey study area showing flight lines (left panel) and stratification (right panel).

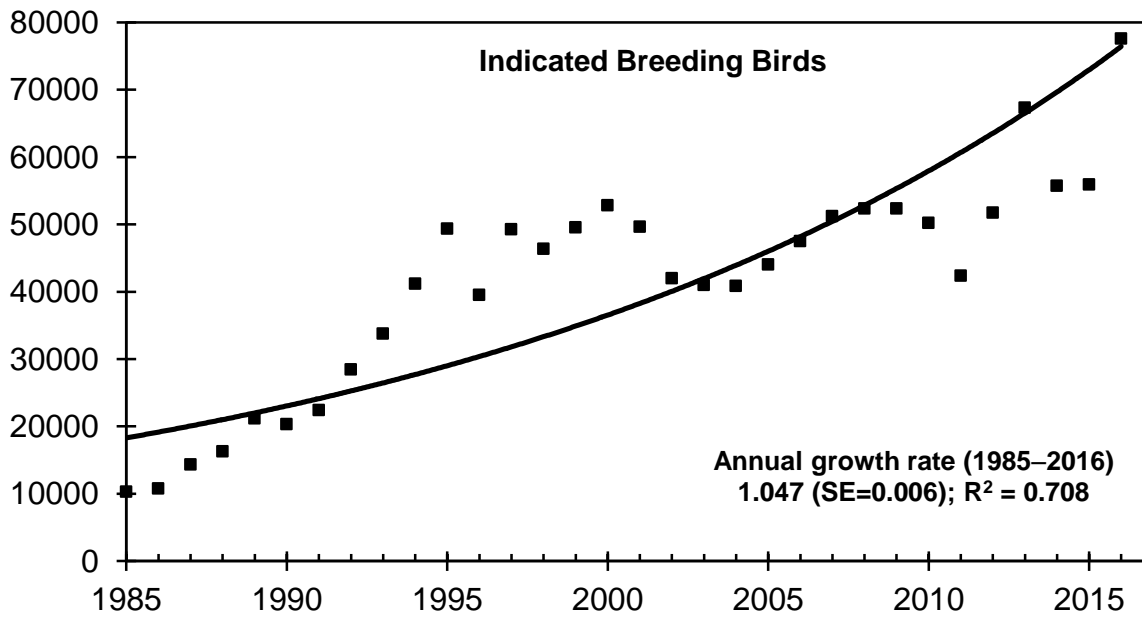
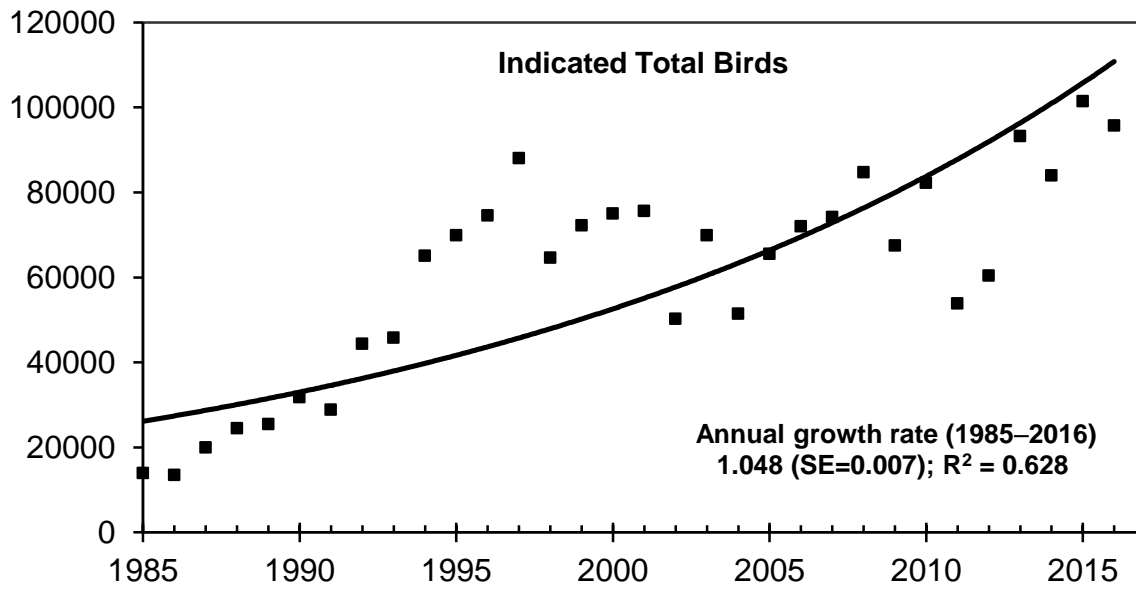


Figure 2. Population index growth curves and average annual growth rates from loglinear regression for cackling Canada geese, 1985–2016.

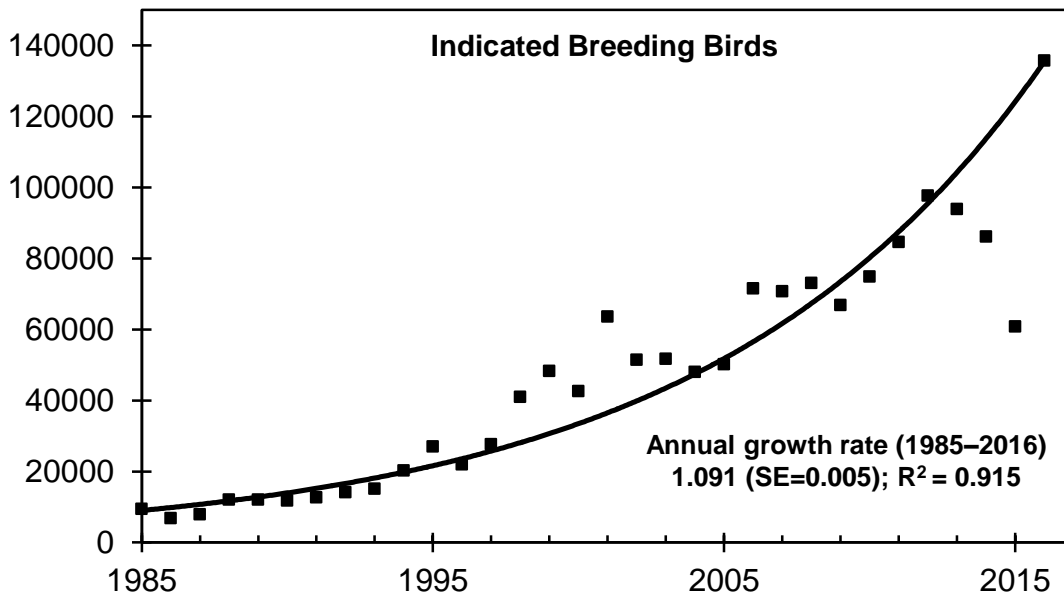
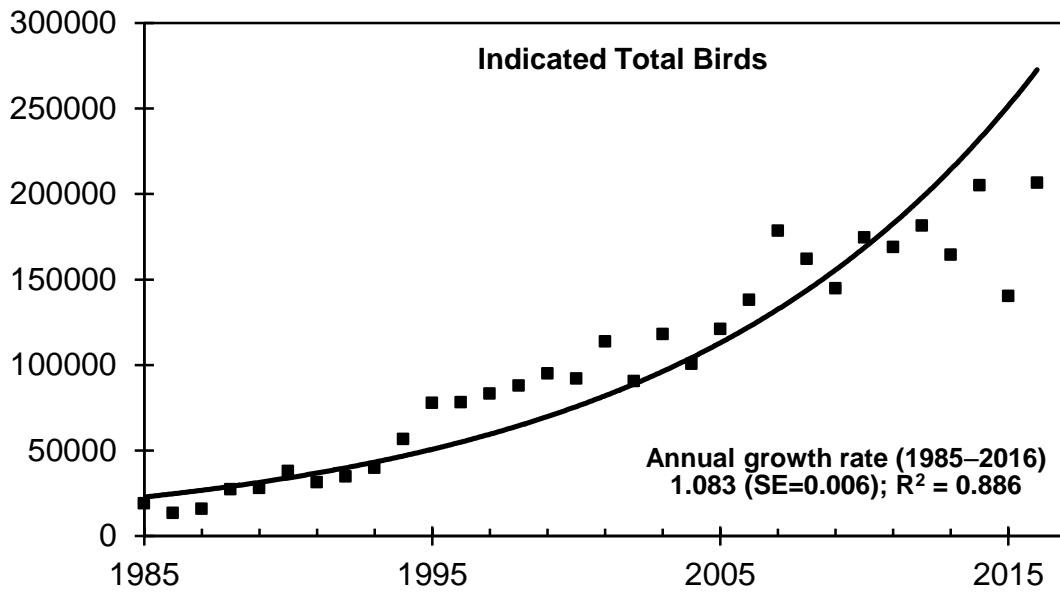


Figure 3. Population index growth curves and average annual growth rates from loglinear regression for total Pacific white-fronted geese, 1985–2016.

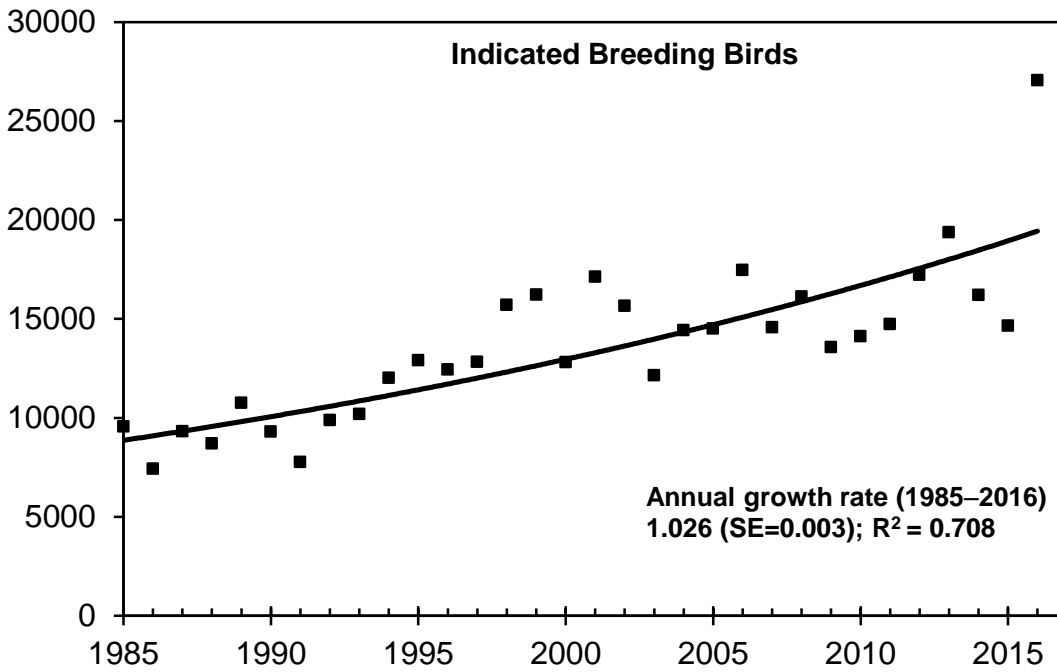
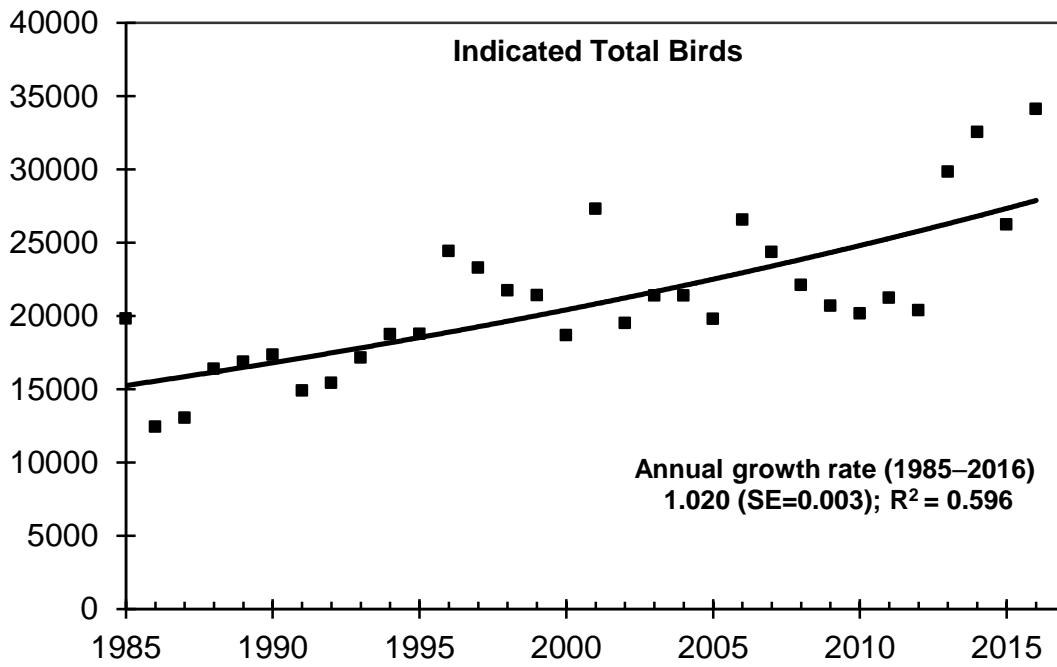


Figure 4. Population index growth curves and average annual growth rates from loglinear regression for emperor geese, 1985–2016.

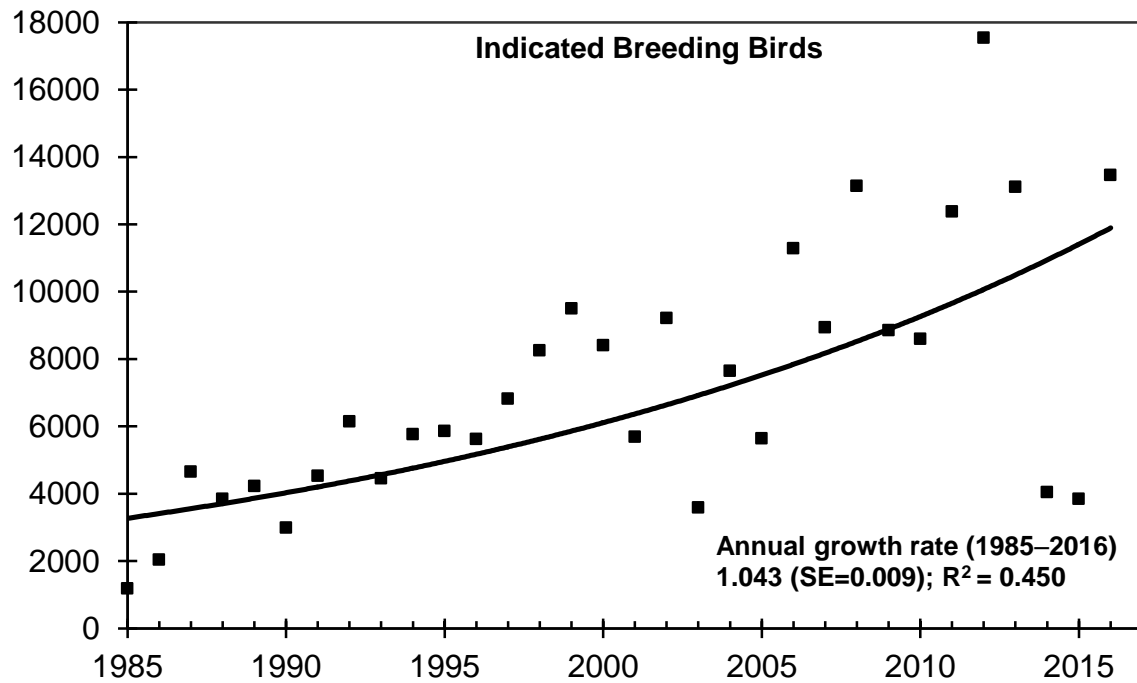
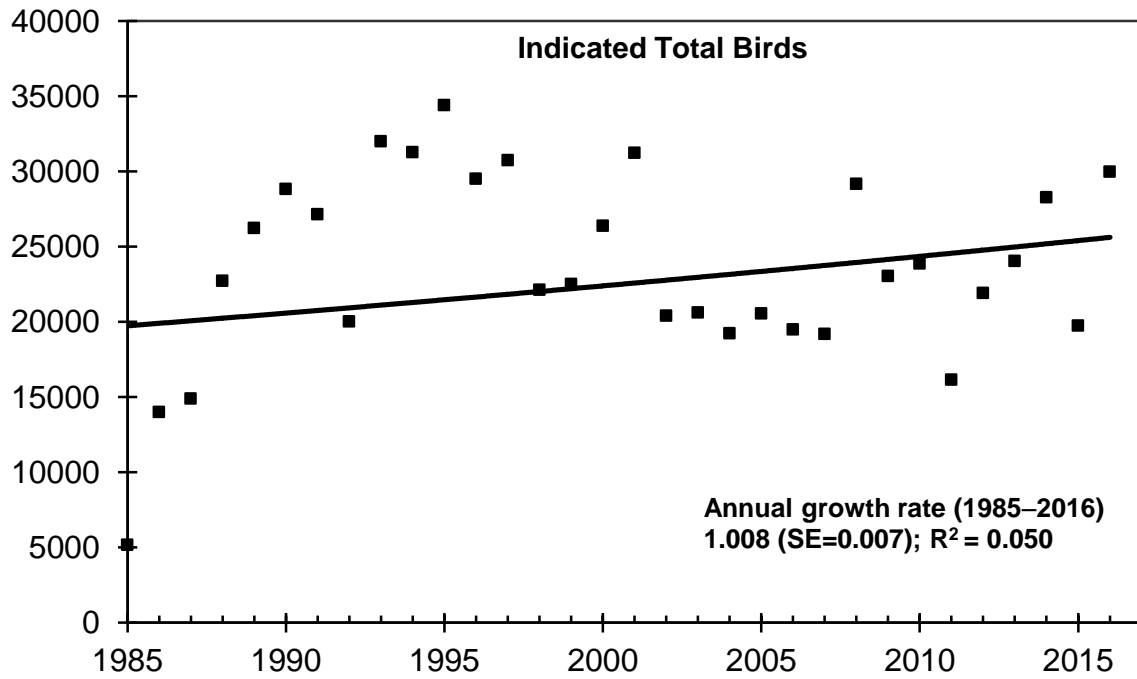


Figure 5. Population index growth curves and average annual growth rates from loglinear regression for black brant, 1985–2016.

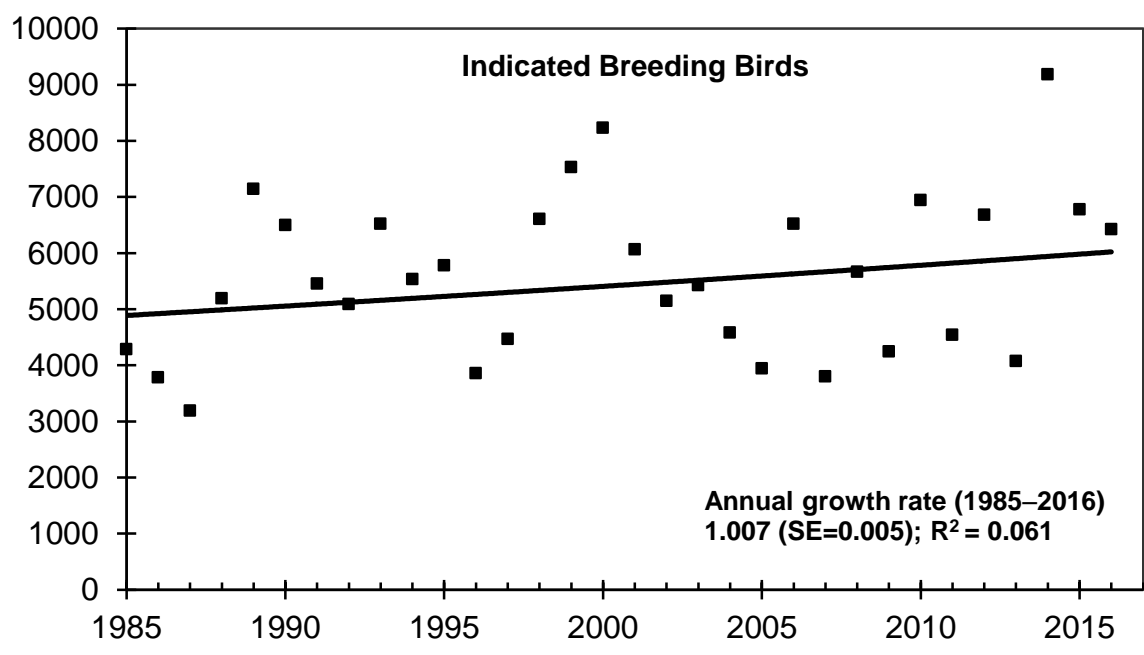
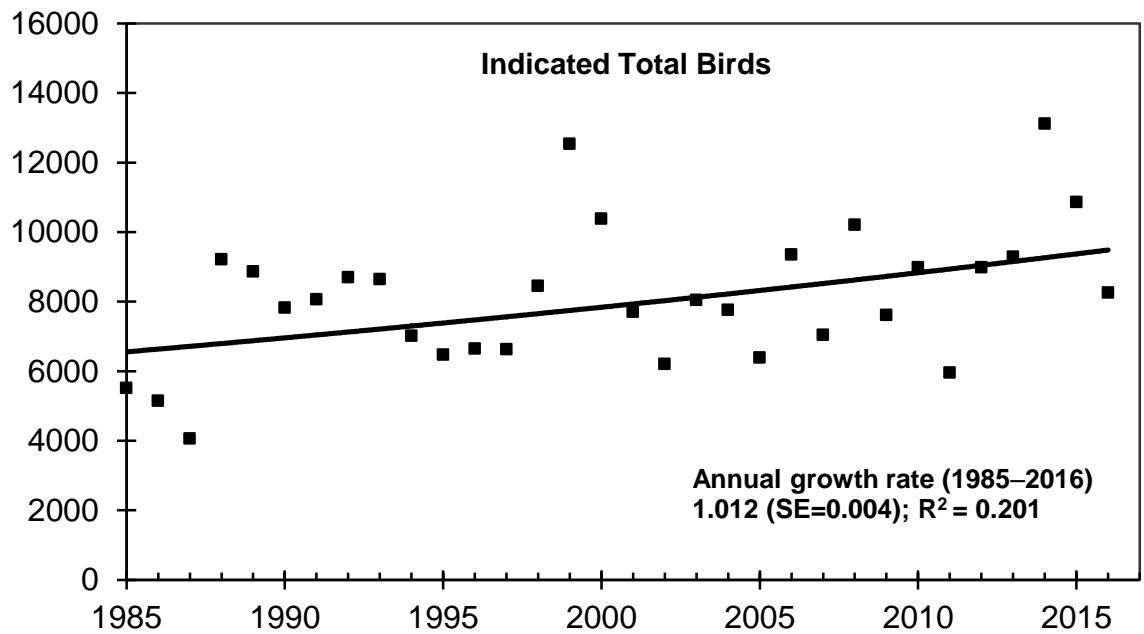


Figure 6. Population index growth curves and average annual growth rates from loglinear regression for Taverner's Canada goose, 1985-2016.

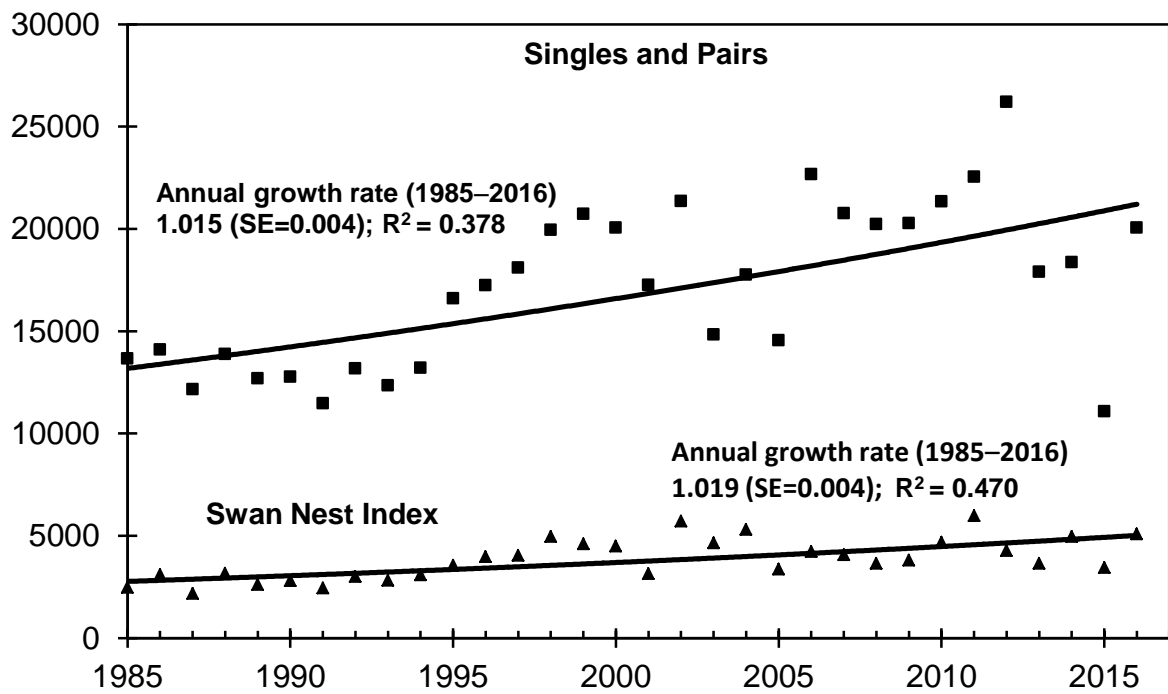
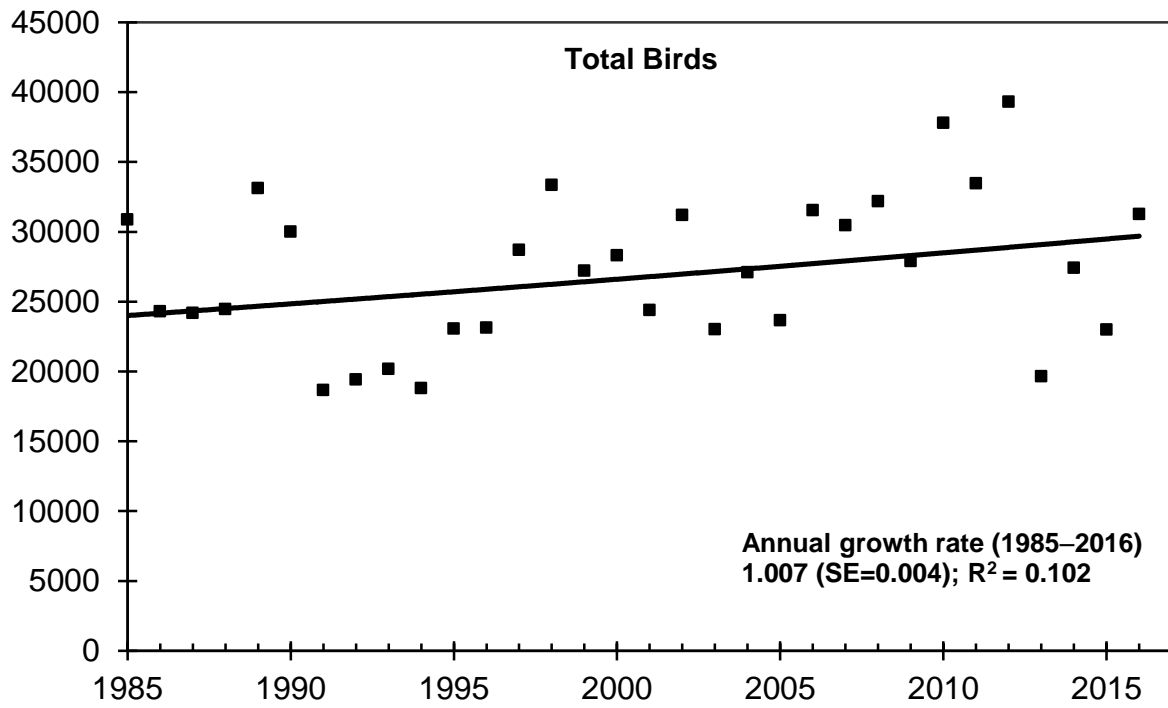


Figure 7. Population index growth curves and average annual growth rates from loglinear regression for Tundra Swans and nests, 1985–2016.

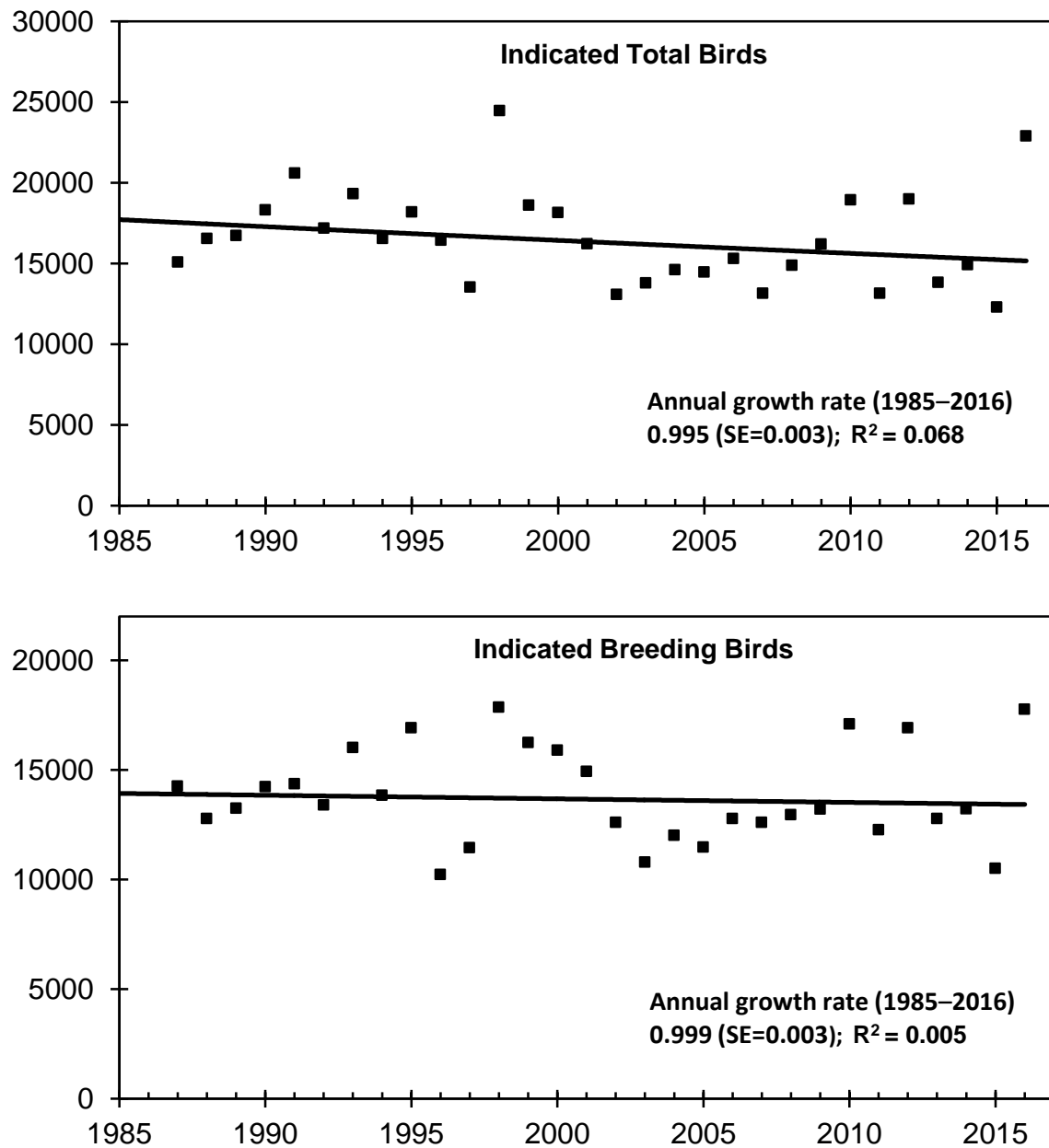


Figure 8. Population index growth curves and average annual growth rates from loglinear regression for Sandhill Cranes, 1987–2016.

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

Year	Total	Mark	Fall		3-year
	Indicated Birds ^a	Resight Estimate	Population Index	SE	Running Average
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

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

^b Fall Population Index = (ITB x 3.422843)

Appendix 2. Indices of Pacific white-fronted geese as indicated breeding birds (IBB: 2 x singles + paired) and indicated total birds (ITB) from June aerial surveys of the Yukon-Kuskokwim Delta and Bristol Bay Lowlands, 1985–2016.

	Yukon-Kuskokwim Delta coastal zone		Yukon-Kuskokwim Delta Interior		Bristol Bay		Yukon-Kuskokwim Total		All Pacific White-fronts	
Year	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

Appendix 3. Fall population index for Pacific white-fronted geese based on the relationship of indicated total geese from June surveys on the Yukon-Kuskokwim Delta and Bristol Bay Lowlands with the 1985–1998 fall survey counts. The 3-year average is also presented.

	Total		Fall	
Year	Indicated Birds ^a	Fall Survey	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

^a Indicated Total Birds (ITB) = 2 x (pairs + singles) + group birds - Pacific Flyway - Yukon-Kuskokwim Delta and Bristol Bay.

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