

**RFI 095
Pebble Project EIS**

Request for Information

Title/Subject:	Trumpeter Swan Distribution Data
Requestor:	AECOM
Date Transmitted:	10/10/18
Recipient:	Debbie Groves - United States Fish and Wildlife Service - Migratory Bird Management
Response Requested by:	10/17/18
Rationale:	The most recent wildlife distribution data is required to adequately address potential project effects.
Describe the Information Requested and Level of Detail:	Please provide Trumpeter Swan survey data collected since 2010 for the general area from Iniskin Bay south to Amakdedori Creek and west to the proposed Mine site.

Recipient Response Form

Date Received from USACE:	Click here to enter text.
Response from Recipient:	Click here to enter text.
List Number and Type of Response Attachments:	Groves 2013 Alaska Trumpeter swan survey 2010.pdf Groves 2018 Alaska 2015 Trumpeter Swan Survey Report.pdf
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AECOM Intake Form

Date Response was Received:	12/18/2018
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A SURVEY OF TRUMPETER SWANS ON ALASKAN SUMMERING HABITATS, 2010

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ABSTRACT: The ninth quinquennial survey of Trumpeter Swans (*Cygnus buccinator*) in Alaska was conducted on 3-25 August 2010. We used a stratified random-sample plot design with optimal allocation of effort to maximize survey efficiency. We used adult swan abundance data from our 2000 and 2005 censuses to delineate strata. We used the number of miles flown and adult abundance from the 2005 census to estimate cost per plot and variance for optimally allocating sample sizes among strata. Of a total of 780 plots (1:63,360 topographic maps) in the survey area (493,573 km²), we surveyed 100 plots (63,891 km²) for swans, using an aerial cruise survey method that covered all potential swan habitat in each plot. The survey required 189 hours of flight time. Abundance estimates (and 95% confidence limits) in 2010 were 19,638 (\pm 1,845) adults, 5,709 (\pm 823) cygnets, 2,004 (\pm 279) broods, and 25,347 (\pm 2,020) total swans. The estimated mean brood size was 2.85, and 23% of the swans were cygnets. The mean brood size was 10% below the 1968-2005 average. The number of adult Trumpeter Swans increased at an average annual rate of 2.6% during 2005-2010.

KEY WORDS: aerial survey, Alaska, *Cygnus buccinator*, Trumpeter Swan, abundance, productivity, population trend

INTRODUCTION

The Alaska Trumpeter Swan survey has been conducted every five years as part of a cooperative, range-wide survey to monitor the status of Trumpeter Swans (*Cygnus buccinator*) in North America (Groves 2012). The first range-wide survey occurred in 1968, and the five-year cycle began in 1975. The objective was to assess Trumpeter Swan abundance and productivity by determining the numbers of adults (swans >1 year old), cygnets, and broods present on the breeding grounds in late summer. Through 2005, this was accomplished in Alaska via censuses of essentially the entire Alaskan summering range (Conant et al. 2002, Conant et al. 2007). The censuses provided accurate results, allowed comparisons of results among regions of the state, and produced complete, georeferenced datasets that were used for a variety of conservation purposes. However, as Trumpeter Swans increased and expanded their range over time, so did the cost and effort required to accomplish the census. In 2010, we determined that a census was cost-prohibitive and thus switched to a random sample design.

METHODS

Our survey area in 2010 was the same area that was covered in the 2005 census (Conant et al. 2007) (Figure 1). It included most of the known and potential Trumpeter Swan summering habitats in the interior Alaskan boreal forest and along the southern coastal plain from Cook Inlet to southeastern Alaska. From 1968 through 2005, survey coverage expanded with each successive survey to accommodate range expansion of the increasing Trumpeter Swan population. However, we did not extend the survey area in 2010 because the extension would have encroached on Tundra Swan (*Cygnus columbianus*) habitat. We were unable to differentiate Trumpeter and Tundra Swans during the aerial survey, so we wanted to minimize the likelihood of including Tundra Swans in our counts. A portion of the survey area along its western and northern peripheries likely did host an unknown number of Tundra Swans (Wilk

1993, Bryant et al. 2005, Bryant unpublished data); nevertheless, we included it because it had been included in previous quinquennial surveys.

We used a stratified random sample design with optimal allocation of effort to minimize cost for a fixed variance (Cochran 1977) (Figure 1, Table 1). Sample units were individual U.S. Geological Survey 1:63,360 topographic maps. We sorted the maps into five strata, based on the number of adult swans observed on each map during the previous (2005) survey: 1) 0 - 5, 2) 6 - 15, 3) 16 - 30, 4) 31 - 100, and 5) >100. Following Conant et al. (1991), we computed the predicted total sample size needed to obtain an abundance estimate of adult swans, \hat{T} , with 95% confidence limits of $\hat{T} \pm .10\hat{T}$. The sample-size formula required stratum-specific estimates of adult swan variability (standard deviation, s_h) and average survey cost per map (C_h), as well as a designated value of \hat{T} . We used the 2005 survey results to estimate the standard deviation in each stratum, but we used the 2000 survey results to stratify the maps, thereby assuring independence. Strata definitions were identical to those shown above. We defined “cost” as the number of statute miles flown to survey all potential swan habitat on a map. For each stratum, we computed the mean number of miles flown per map in 2005 and then added an arbitrary value of 40 miles to account for cross-country flights between maps. To project a value of \hat{T} , we multiplied the mean number of adult swans per map in each stratum in 2005 by the total number of maps in the stratum in 2010 and then summed the results for all strata. Our predicted total sample size was 97 maps, which we optimally allocated among the five strata in accordance with Cochran (1977). The resulting n_h values were fractions, so we rounded each number up to the next integer. We arbitrarily added one more map to stratum 3 to obtain a final sample size of 100 maps. We then randomly selected the samples in each stratum from the total available maps in each stratum.

We conducted the survey in August when the swans, especially families, were dispersed on the breeding grounds, and cygnets were flightless but large enough to be easily counted from the air. We apportioned the sample maps among five survey crews, each of which comprised a left-seat pilot-observer (hereafter pilot) and a right-seat observer (hereafter observer). We used the survey method that was described by King (1973, 1982), with modifications to record swan observations and the survey flight track digitally. Each crew used a single-engine aircraft to survey all suitable habitat within a sampled map, attempting to count all swans. The pilot was responsible for ensuring adequate survey coverage, modifying the flight path as necessary to account for factors that affected visibility (e.g., lighting conditions, vegetation height). The survey was generally flown at an altitude of 150-180 m above ground, but the crew sometimes descended to obtain an accurate count of cygnets. The crew also circled when necessary to verify counts. The observer recorded the location and attributes of each observation on a digital 1:63,360 topographic map, using a laptop computer that was linked to the aircraft’s GPS unit and a custom moving-map program developed by author Hodges. Observations were recorded as a single adult, adult pair, single with brood, pair with brood, or flock of adults, with cygnets and flocked swans enumerated. The pilot also used the moving map, which displayed the flight track, to determine where potential swan habitat occurred within the map and to monitor survey coverage. The program produced two files: a swan data file containing the geographic coordinates and attributes of each swan observation, and a flight track file containing point locations of the aircraft during the survey flight in five-second intervals. After the survey, we

linked each swan observation with its appropriate sample map. The resulting data file was used for analyses.

We generated estimates of population abundance and precision for several swan age and group categories using stratified sampling estimators (Cochran 1977). We then used the ratios of relevant estimates to estimate the mean brood size, the percentage of cygnets in the total population, and the percentage of pairs that had a brood. We did not correct for detection bias in our estimates, but detection was likely high and fairly constant due to the swans' large size, white plumage, and tendency to occupy relatively open habitats (Schmidt et al. 2009).

We compared the 2010 survey results with results from prior (1968-2005) surveys to assess potential trends in the population parameters. We treated the prior surveys as censuses with no associated sampling variances, because the entire suspected range of Trumpeter Swans at the time of each survey was searched, and detection bias was likely small. We performed two-sample *z*-tests to evaluate differences between the 2005 and 2010 estimates (Thompson et al. 1998). We used least-squares regression on log-transformed abundance estimates to estimate population growth rates, and we used linear regression to assess trends in productivity (percentage of cygnets and mean brood size). We tested the trends for equality to zero using *t*-tests. We selected an alpha level of 0.05 for all tests of significance.

RESULTS

The survey was conducted during 3-25 August. Five survey crews flew a total of 189 hours, using Cessna 206's on wheels, Cessna 206's on amphibious floats, and the USFWS modified de Havilland Turbine Beaver (N754).

The numbers of swans counted in each sample unit are listed in Appendix A. We estimated a total of 19,638 ($\pm 1,845$, 95% confidence limits) adults, 5,709 (± 823) cygnets, and 25,347 ($\pm 2,020$) total swans (Table 2). Compared to estimates from the 2005 survey, the number of adult swans increased 14% ($P = 0.01$), cygnets decreased 11% ($P = 0.07$), and total swans increased 7% ($P = 0.10$) (Table 3). Only the adult swan estimates were significantly different at our selected alpha level of 0.05. The estimated average growth rate of the adult swan population during 2005-2010 was +2.6% per year, which was lower than rates seen previously. A comparison of growth rates during the first and second halves of the 1968-2010 time period indicated that adult swans increased an average of 8.1% per year during 1968-1990 ($P = 0.0009$) and 3.6% per year during 1990-2010 ($P = 0.0002$) (Figure 2).

The 2010 productivity estimates indicated that Trumpeter Swan production was slightly below average that year (Tables 2, 3). The percentage of pairs with a brood, 27.2%, was 14% below the 1968-2005 mean, and the mean brood size of 2.85 was 10% below the 1968-2005 mean. Cygnets comprised 22.5% of the total population, 13% below the 1968-2005 mean. The mean brood size has experienced a downward trend since 1968 ($P = 0.04$) (Figure 3). We did not detect a significant long-term trend in the percentage of cygnets ($P = 0.12$) (Figure 4); however, the trend may be following a similar pattern to that of mean brood size but may require a few more data points to show significance.

DISCUSSION

Trumpeter Swans in Alaska continued to increase since the 2005 survey and reached a new record level since surveys began in 1968. The growth rate has slowed over time, which we expect to occur as the best nesting territories become filled and the population expands into less productive habitats. It is also possible that some areas of the state have reached or are approaching carrying capacity. A decline in the mean brood size since 1968 and a possible decline in the percentage of cygnets suggest that productivity has decreased for the statewide population. Productivity and growth rates during 2005-2010 undoubtedly varied among regions in the state, depending on factors such as habitat availability, habitat quality, and weather conditions during the breeding season.

The 2010 Alaska survey did not provide sufficient information by region to examine regional trends. However, four areas were intensively surveyed by the U.S. Fish and Wildlife Service (USFWS) in late summer 2010. During 2005-2010, adult swans increased an average of 7.3% per year on Kanuti National Wildlife Refuge (NWR) (Harwood 2010), 5.7% per year on Yukon Flats NWR (Guldager 2011), and 3.7% per year in the upper Tanana River valley (Tetlin NWR, unpublished data) (Figure 5). On the Copper River Delta, which was surveyed annually during 2005-2010, adult swans decreased 6.5% per year (Groves et al. 2010; USFWS-Migratory Bird Management, unpublished data). Whereas Kanuti NWR and Yukon Flats NWR both had substantial amounts of previously unoccupied habitat available to support population growth, the Copper River Delta has hosted swans since at least the mid-1950's (Hansen et al. 1971) and has likely reached carrying capacity, as evidenced by the cyclical trend that has been documented in the population there since 1968 (Groves et al. 2010).

Our decision to use the 2005 survey area boundary as our area of inference in 2010 had pros and cons. One benefit was that we could directly compare the 2010 estimates to the 2005 survey results. From 1968 to 2005, the survey area increased with each successive survey, and Schmidt et al. (2009) found that failing to account for the changing area resulted in slightly biased trend results. We did not account for the change in survey area when we calculated long-term growth rates, because doing so would have entailed more complicated analysis methods, and we felt that the bias was sufficiently minimal for our purposes. (For example, we estimated an average annual increase of 6.1% in adult swans during 1968-2005, compared to Schmidt et al.'s estimate of 5.9%.)

Another benefit of using the 2005 survey area was that we limited inclusion of sympatric Trumpeter and Tundra Swan summering areas to those that had been included in prior surveys. While this minimized the number of Tundra Swans in our counts, it also undoubtedly resulted in some Trumpeter Swans being missed. Based on the amount of boreal forest wetland habitats that were excluded, we believe that a maximum of a few hundred adult Trumpeter Swans might have been present outside our survey area in 2010. The number could be greater, however, if Trumpeter Swans were able to occupy wetlands within the nearby tundra landscape. Conversely, we do not know how many Tundra Swans were present or the extent to which they occupied habitats within our survey area in 2010. Bryant et al. (2005; unpublished data) estimated that 50%, 20%, and 0% of all swans nesting on the Koyukuk NWR, Northern Unit of Innoko NWR (Kaiyuh Flats), and Nowitna NWR, respectively, were Tundra Swans in 2004-2006 (Figure 5).

Wilk (1993) observed that 41% of nesting pairs in a study area within and near Kanuti NWR in 1989 were Tundra Swans, although this proportion had likely changed to an unknown degree by the time of our survey in 2010 (Harwood 2010). The accuracy of Trumpeter Swan survey results in the future will be improved if we can assess the spatial extent of species overlap in the state and determine the relative proportions of each species within the sympatric area. This information should be updated periodically, as the degree and location of overlap will likely not remain static.

ACKNOWLEDGMENTS

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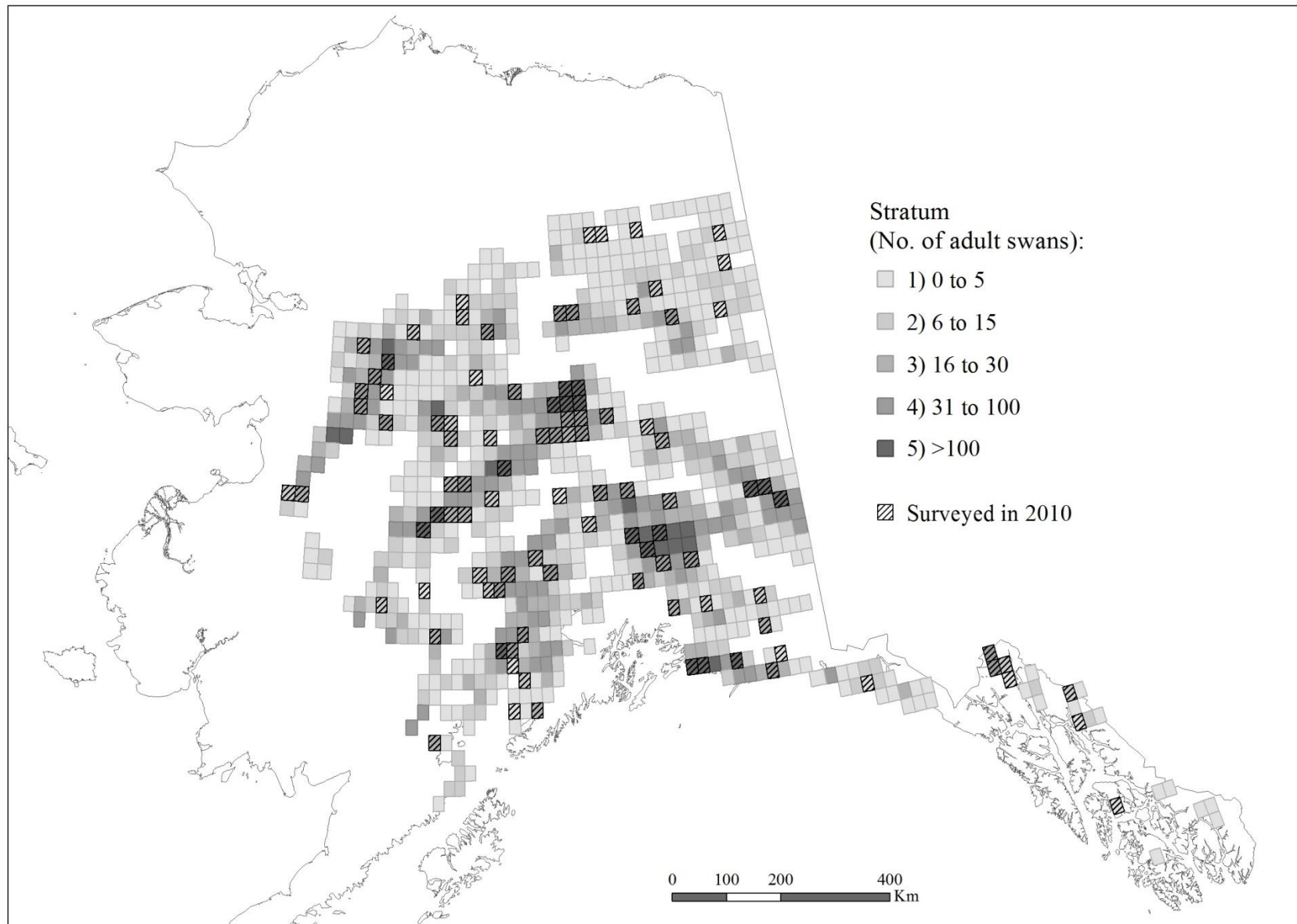


Figure 1. The 2010 Alaska Trumpeter Swan survey area, showing the distribution of sample units (1:63,360 maps) within five survey strata and the 100 randomly selected maps. The size of the survey area was 493,573 sq. km.

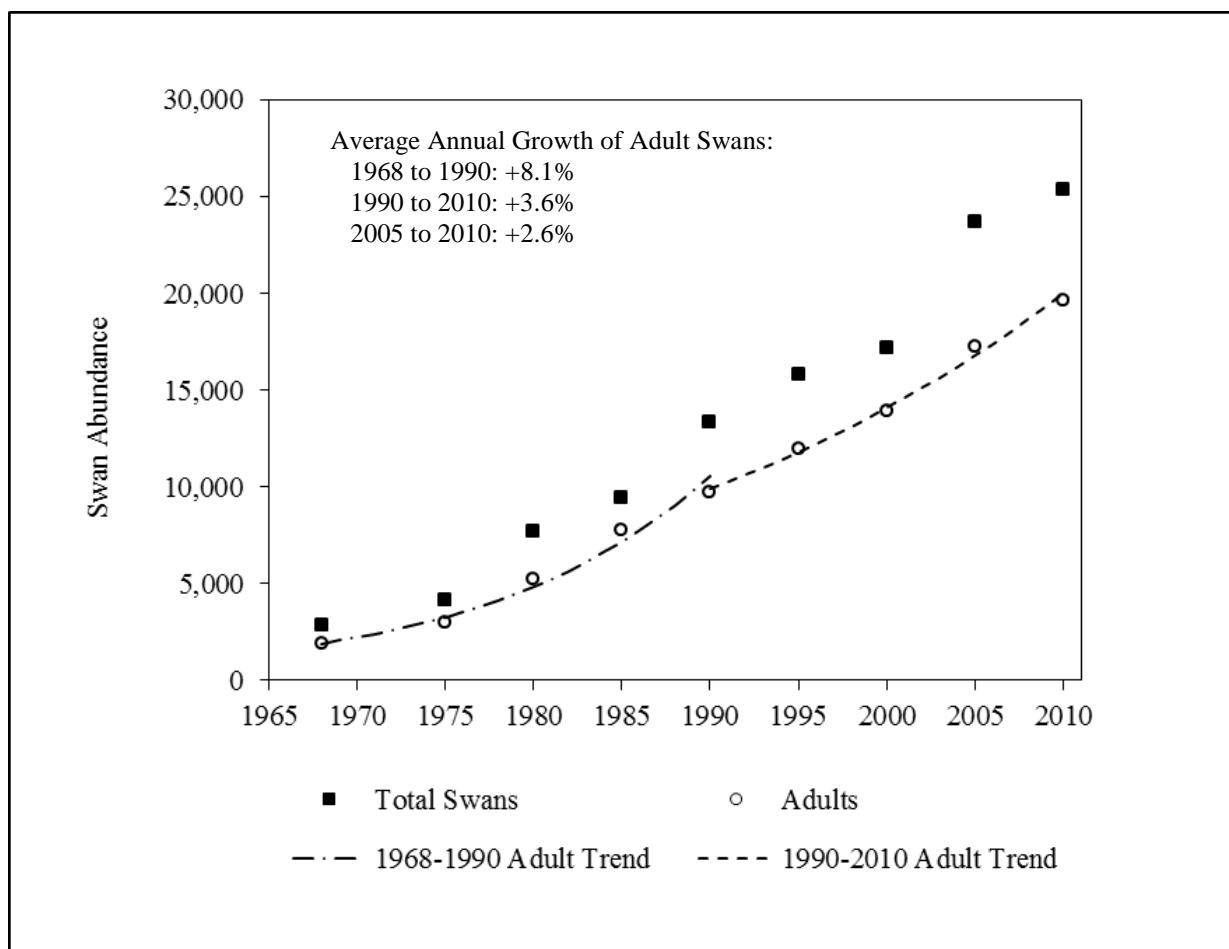


Figure 2. Trumpeter Swan abundance estimates from quinquennial surveys in Alaska, 1968-2010. Fitted lines are from least-squares regression performed on log-transformed adult swan estimates.

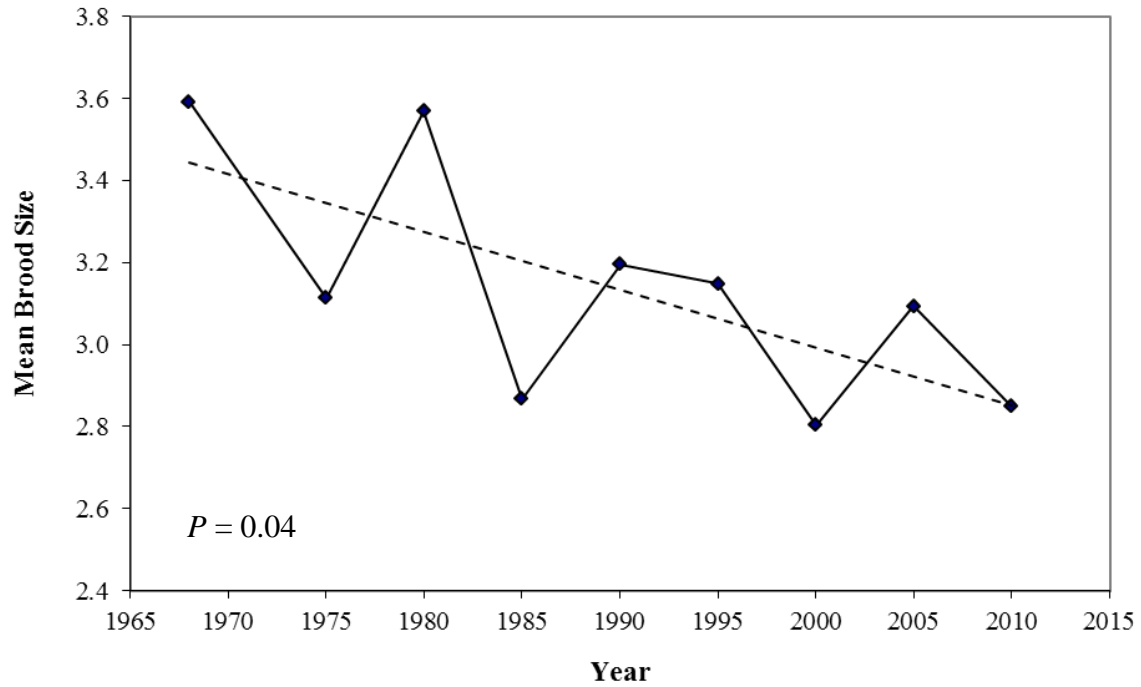


Figure 3. Mean size of Trumpeter Swan broods during quinquennial Alaska Trumpeter Swan surveys, 1968-2010. The fitted line is from linear regression.

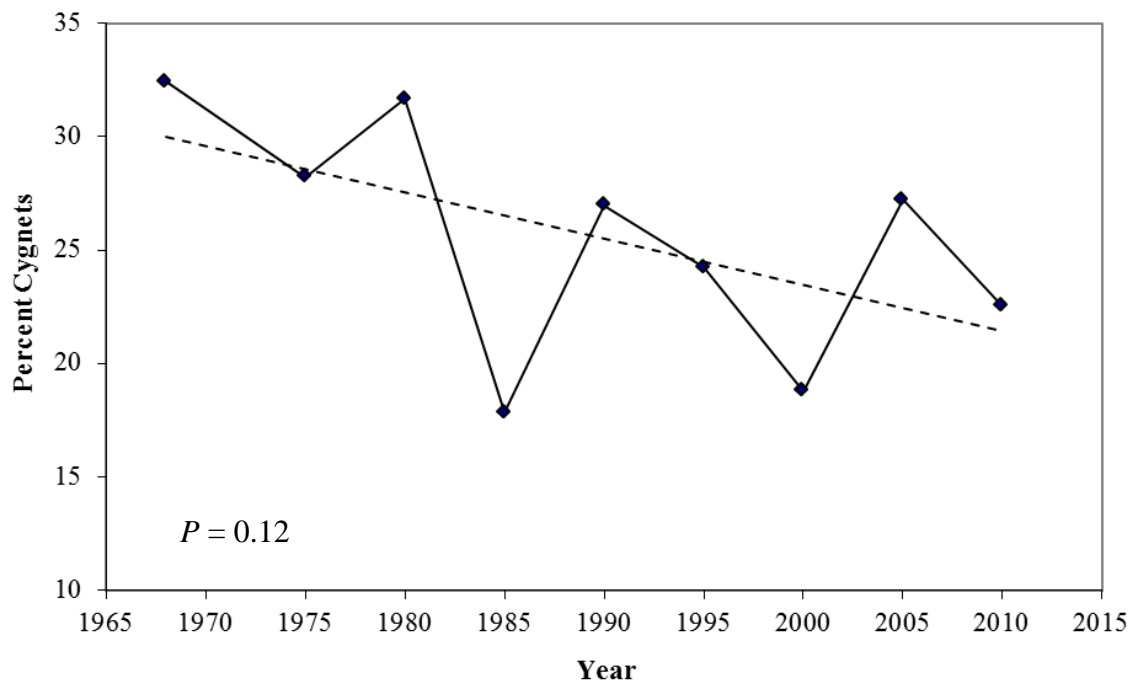


Figure 4. Percentage of cygnets in the total Alaska Trumpeter Swan population during quinquennial surveys, 1968-2010. The fitted line is from linear regression.

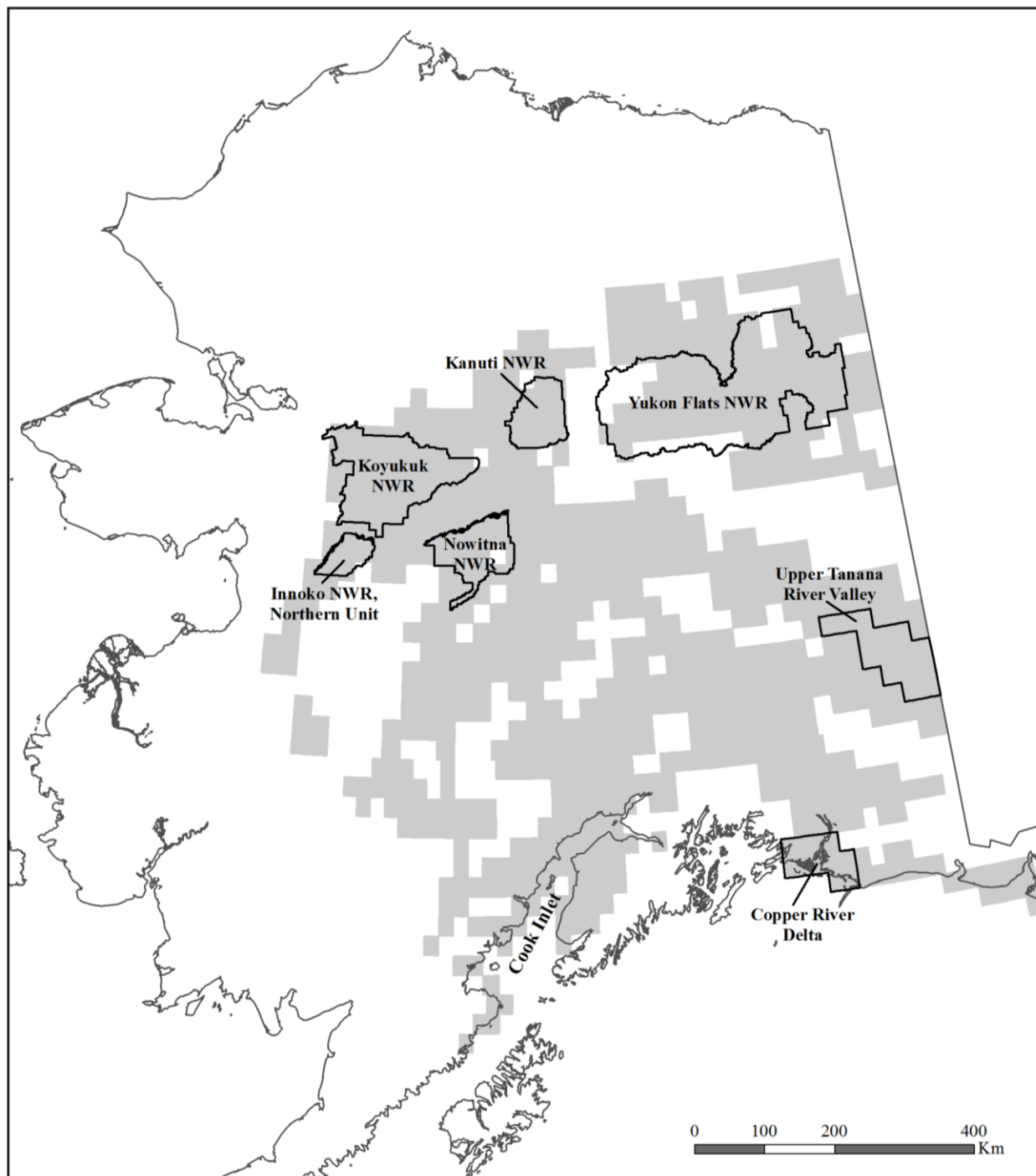


Figure 5. Locations of place names used in the text. The 2010 survey area (excluding southeast Alaska) is shown in gray.

Table 1. Data used to determine optimal allocation of sampling effort in the 2010 Alaska Trumpeter Swan survey.

Parameter	2010 Stratum (Number of adult swans per sample unit in 2005)					Total
	1 (0 to 5)	2 (6 to 15)	3 (16 to 30)	4 (31 to 100)	5 (>100)	
N_h = Stratum size in 2010 (number of maps)	350	168	102	128	32	780
Mean number of adults per sample unit (map) in 2005 ^a	3.52	14.77	30.65	60.87	185.32	
s_h = Standard deviation of adult swans in 2005 ^a	4.33	10.49	17.18	29.70	95.16	
T^{\wedge} = Projected total number of adult swans in 2010 (N_h *Mean Adults)	1,231.7	2,481.7	3,126.8	7,791.7	5,930.3	20,562.1
C_h = Mean cost per sample unit in 2005 (number of miles flown) ^a	94	143	176	216	337	
P = Degree of precision desired ^b						0.10
Predicted sample size	17.6	16.6	14.9	29.2	18.7	97
n_h = Final sample size	18	17	16	30	19	100

^aComputed using census maps stratified by 2000 adult swan data.

^bSize of 95% confidence interval about the estimated number of adult swans.

Table 2. Trumpeter Swan population estimates and associated precision from the 2010 Alaska Trumpeter Swan survey.

	Adult Swans					Cygnet	No. of Broods	No. of Pairs with Brood	Total Swans	Percent Cygnet	Mean Brood Size	Percent Pairs with Brood
	As Singles	In Pairs	In Flocks	No. of Flocks	Total Adults							
Population Estimate	1,591	14,276	3,771	605	19,638	5,709	2,004	1,938	25,347	22.5	2.85	27.2
Standard Error	127	622	437	57	923	411	140	133	1,010			
Coefficient of Variation	0.080	0.044	0.116	0.094	0.047	0.072	0.070	0.069	0.040			
± 95% Confidence Limits ^a	253	1,243	875	114	1,845	823	279	266	2,020			

^a2*standard error

Table 3. Historical Trumpeter Swan population estimates from Alaska Trumpeter Swan surveys, 1968-2010.

Year	Adult (White) Swans					Cygnet	Total Swans	No. of Broods	Percent Cygnets	Mean Brood Size	Percent Pairs with Brood
	As Singles	In Pairs	In Flocks	No. of Flocks	Total Adults						
1968	108	1,320	496	69	1,924	923	2,847	257	32.4	3.59	37.1
1975	151	2,102	740	125	2,993	1,177	4,170	378	28.2	3.11	35.4
1980	169	3,324	1,766	210	5,259	2,437	7,696	683	31.7	3.57	40.3
1985	449	5,120	2,204	317	7,773	1,686	9,459	588	17.8	2.87	22.6
1990	647	7,056	2,039	326	9,742	3,595	13,337	1,124	27.0	3.20	31.2
1995	859	7,946	3,184	563	11,989	3,834	15,823	1,218	24.2	3.15	30.1
2000	899	9,986	3,049	530	13,934	3,221	17,155	1,149	18.8	2.80	22.4
2005	1,157	11,940	4,148	658	17,245	6,447	23,692	2,084	27.2	3.09	33.9
2010 ^a	1,591 (±253)	14,276 (±1,243)	3,771 (±875)	605 (±114)	19,638 (±1,845)	5,709 (±823)	25,347 (±2,020)	2,004 (±279)	22.5	2.85	27.2
% Change 2005 to 2010	38	20	-9	-8	14	-11	7	-4	-17	-8	-20
P-value ^b	0.0006	0.0002	0.39	0.35	0.01	0.07	0.10	0.57			
1968-2005 Mean									25.9	3.17	31.6
% Change from 1968-2005 Mean									-13	-10	-14

^a 95% confidence limits are in parentheses (2*standard error).

^b Results of a two-sample z-test comparing 2005 and 2010 estimates.

Appendix A. Raw counts and associated totals of swans on 100 stratified random sample plots (1:63,360 maps) surveyed during the 2010 Alaska Trumpeter Swan Survey.

Map	Stratum	Date Surveyed	No. of Observations	Adult (White) Swans								No. of Broods	Total Swans
				As Singles		In Pairs		In Flocks	No. of Flocks	Total Adults			
				With Cygnets	Without Cygnets	With Cygnets	Without Cygnets						
Bering Glacier B5	1	08/12/2010	1	0	0	0	2	0	0	2	0	0	2
Black River A4	1	08/10/2010	2	0	0	2	2	0	0	4	3	1	7
Black River D3	1	08/10/2010	2	0	1	2	0	0	0	3	1	1	4
Chandalar C1	1	08/09/2010	1	0	0	0	2	0	0	2	0	0	2
Chandalar C2	1	08/09/2010	2	0	0	0	4	0	0	4	0	0	4
Christian C4	1	08/09/2010	0	0	0	0	0	0	0	0	0	0	0
Coleen B3	1	08/10/2010	1	0	0	0	2	0	0	2	0	0	2
Healy B6	1	08/10/2010	0	0	0	0	0	0	0	0	0	0	0
Hughes C1	1	08/10/2010	1	0	1	0	0	0	0	1	0	0	1
Kateel River A1	1	08/11/2010	10	0	3	2	10	4	1	19	1	1	20
Kenai C5	1	08/03/2010	2	0	1	2	0	0	0	3	1	1	4
Lime Hills D5	1	08/19/2010	2	0	0	0	4	0	0	4	0	0	4
Petersburg C5	1	08/09/2010	0	0	0	0	0	0	0	0	0	0	0
Seldovia D5	1	08/03/2010	0	0	0	0	0	0	0	0	0	0	0
Skagway A2	1	08/07/2010	0	0	0	0	0	0	0	0	0	0	0
Taku River A6	1	08/09/2010	0	0	0	0	0	0	0	0	0	0	0
Tanana B6	1	08/13/2010	1	0	0	0	2	0	0	2	0	0	2
Yakutat C6	1	08/12/2010	1	0	1	0	0	0	0	1	0	0	1
Big Delta B5	2	08/14/2010	8	0	2	0	10	4	1	16	0	0	16
Fort Yukon C3	2	08/11/2010	0	0	0	0	0	0	0	0	0	0	0
Hughes A5	2	08/10/2010	6	0	1	2	6	3	1	12	2	1	14
Hughes B1	2	08/10/2010	3	0	0	2	4	0	0	6	3	1	9
Kantishna River B5	2	08/14/2010	3	0	0	4	2	0	0	6	5	2	11
Kenai B4	2	08/03/2010	4	0	0	4	4	0	0	8	7	2	15
McCarthy B6	2	08/11/2010	17	1	4	10	10	8	2	33	13	6	46
Mt. McKinley B5	2	08/20/2010	13	0	3	0	20	0	0	23	0	0	23
Ruby C2	2	08/13/2010	3	0	0	0	4	3	1	7	0	0	7
Skagway B2	2	08/07/2010	2	0	0	2	0	8	1	10	3	1	13
Sleetmute C1	2	08/19/2010	9	0	0	8	8	4	1	20	13	4	33
Taku River C6	2	08/09/2010	2	0	1	2	0	0	0	3	5	1	8
Talkeetna A6	2	08/13/2010	5	0	1	0	8	0	0	9	0	0	9
Talkeetna Mts. D4	2	08/06/2010	4	0	2	2	2	0	0	6	3	1	9
Tyonek D7	2	08/13/2010	2	0	0	2	2	0	0	4	1	1	5
Unalakleet B2	2	08/12/2010	5	0	0	2	8	0	0	10	3	1	13
Valdez B3	2	08/11/2010	2	0	0	0	4	0	0	4	0	0	4
Bering Glacier D6	3	08/11/2010	7	0	1	4	6	4	1	15	11	2	26
Big Delta A4	3	08/14/2010	11	0	1	8	12	0	0	21	6	4	27
Fairbanks B5	3	08/13/2010	25	0	4	6	32	8	2	50	8	3	58
Fort Yukon B5	3	08/12/2010	4	0	1	2	4	0	0	7	3	1	10
Iliamna B4	3	08/18/2010	7	0	3	4	2	5	1	14	4	2	18
Kateel River D3	3	08/10/2010	25	1	10	6	22	0	0	39	8	4	47
Lime Hills A4	3	08/19/2010	13	0	3	6	10	9	2	28	11	3	39
Medfra A1	3	08/20/2010	15	0	2	2	22	4	1	30	3	1	33
Medfra A2	3	08/20/2010	14	0	0	6	22	0	0	28	10	3	38
Medfra C2	3	08/21/2010	9	0	0	0	16	3	1	19	0	0	19
Mt. Hayes A4	3	08/07/2010	18	0	1	6	26	4	1	37	13	3	50
Ruby B2	3	08/13/2010	8	0	0	8	8	0	0	16	11	4	27
Seldovia D3	3	08/03/2010	10	0	0	8	10	3	1	21	13	4	34
Talkeetna B2	3	08/06/2010	13	0	5	6	10	0	0	21	6	3	27
Unalakleet B1	3	08/12/2010	15	0	2	6	20	0	0	28	11	3	39
Valdez B6	3	08/11/2010	6	0	0	4	8	0	0	12	5	2	17
Anchorage D1	4	08/08/2010	29	0	6	12	34	0	0	52	18	6	70
Beaver B4	4	08/09/2010	29	1	5	18	24	9	2	57	31	10	88
Beaver B5	4	08/09/2010	25	0	2	8	36	4	1	50	13	4	63
Bering Glacier A6	4	08/12/2010	27	0	4	8	36	3	1	51	18	4	69
Bettles A5	4	08/10/2010	22	0	4	18	18	0	0	40	21	9	61
Fairbanks B4	4	08/23/2010	27	0	3	6	34	18	4	61	8	3	69
Fairbanks B6	4	08/13/2010	24	0	1	8	30	17	4	56	11	4	67
Fairbanks C2	4	08/10/2010	30	1	5	8	40	0	0	54	15	5	69
Fairbanks C4	4	08/12/2010	31	0	4	16	38	0	0	58	23	8	81
Fairbanks C5	4	08/13/2010	40	0	6	22	38	16	4	82	36	11	118
Fort Yukon A2	4	08/10/2010	43	0	9	14	48	10	3	81	13	7	94
Gulkana A3	4	08/07/2010	25	0	6	4	32	6	1	48	8	2	56
Gulkana A5	4	08/08/2010	51	0	13	24	46	10	3	93	31	12	124

Appendix A (cont'd). Raw counts and associated totals of swans on 100 stratified random sample plots (1:63,360 maps) surveyed during the 2010 Alaska Trumpeter Swan Survey.

Map	Stratum	Date Surveyed	No. of Observations	Adult (White) Swans								No. of Broods	Total Swans
				As Singles		In Pairs		In Flocks	No. of Flocks	Total Adults	Cygnets		
				With Cygnets	Without Cygnets	With Cygnets	Without Cygnets						
Healy B1	4	08/10/2010	28	0	2	10	42	0	0	54	10	5	64
Healy B3	4	08/10/2010	19	0	2	12	20	4	1	38	17	6	55
Kantishna River B1	4	08/13/2010	23	0	4	2	30	13	3	49	4	1	53
Kateel River A3	4	08/10/2010	38	0	6	10	50	6	2	72	13	5	85
Kateel River B2	4	08/10/2010	35	1	3	18	44	0	0	66	21	10	87
Kenai D5	4	08/03/2010	32	0	6	14	34	8	2	62	20	7	82
Medfra C1	4	08/21/2010	30	0	4	8	42	4	1	58	8	4	66
Nulato C1	4	08/12/2010	43	0	9	22	44	3	1	78	33	11	111
Nulato D3	4	08/10/2010	28	0	4	8	34	10	3	56	11	4	67
Ruby C3	4	08/13/2010	30	0	5	0	42	14	4	61	0	0	61
Skagway B3	4	08/07/2010	32	2	1	24	28	23	3	78	40	14	118
Skagway C3	4	08/07/2010	19	0	2	14	14	15	3	45	16	7	61
Talkeetna A1	4	08/06/2010	23	1	6	4	28	0	0	39	9	3	48
Talkeetna A4	4	08/09/2010	22	0	6	6	22	9	2	43	11	3	54
Tanana A3	4	08/13/2010	34	0	7	6	36	55	6	104	9	3	113
Tyonek A4	4	08/05/2010	27	0	4	4	42	0	0	50	4	2	54
Tyonek D6	4	08/13/2010	24	0	5	10	28	0	0	43	13	5	56
Cordova B1	5	08/13/2010	33	0	2	6	42	143	7	193	13	3	206
Cordova B4	5	08/13/2010	66	0	9	36	66	26	6	137	51	18	188
Cordova B5	5	08/13/2010	31	0	9	8	34	7	1	58	12	4	70
Fairbanks D4	5	08/15/2010	128	2	12	108	106	175	7	403	170	56	573
Fairbanks D5	5	08/15/2010	205	2	23	116	216	64	14	421	161	60	582
Fairbanks D6	5	08/15/2010	87	2	13	26	96	133	11	270	44	15	314
Gulkana B6	5	08/06/2010	56	0	13	6	68	24	6	111	12	3	123
Gulkana C5	5	08/07/2010	69	0	18	6	92	6	2	122	7	3	129
Kateel River C1	5	08/10/2010	53	1	4	22	70	43	2	140	26	12	166
Kenai D6	5	08/13/2010	50	1	5	32	54	4	1	96	42	17	138
Livengood A4	5	08/25/2010	132	0	10	116	120	45	4	291	189	58	480
Livengood A5	5	08/25/2010	117	1	10	90	98	272	12	471	163	46	634
McGrath D4	5	08/20/2010	56	0	8	24	68	9	2	109	27	12	136
Medfra A3	5	08/20/2010	60	0	13	12	66	26	8	117	15	6	132
Mt. McKinley D4	5	08/14/2010	78	0	7	46	88	20	4	161	68	23	229
Nabesna D2	5	08/07/2010	230	2	44	68	264	82	18	460	136	36	596
Talkeetna Mts. C1	5	08/06/2010	61	0	19	14	68	3	1	104	17	7	121
Tanacross A3	5	08/07/2010	165	3	24	56	172	123	24	378	107	31	485
Tanacross A4	5	08/05/2010	37	0	10	16	34	9	2	69	26	8	95

A SURVEY OF TRUMPETER SWANS ON ALASKAN SUMMERING HABITATS, 2015

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ABSTRACT: The tenth quinquennial survey of trumpeter swans (*Cygnus buccinator*) in Alaska was conducted by the U.S. Fish and Wildlife Service during 3 August–1 September 2015. A stratified random-sample plot design with optimum allocation of sampling effort was used to minimize cost for a fixed variance. Data from the 2005 swan survey was used to delineate strata, while data from the 2000 and 2005 surveys were used to estimate variance and cost per plot for optimally allocating sample sizes among strata. Of a total of 780 plots (1:63,360 topographic maps) in the survey area (493,573 km²), 100 plots (63,891 km²) were surveyed for swans, using an aerial cruise survey method that covered all potential swan habitat. The survey required 273 hours of flight time. Abundance estimates (\pm 95% confidence limits) in 2015 were 22,015 (\pm 2,224) adults, 6,793 (\pm 970) cygnets, 2,277 (\pm 299) broods, and 28,808 (\pm 2,855) total swans. Only the total swan estimate was significantly different from that of 2010 at the selected alpha level of 0.05; it showed an increase of 0.1% – 27% (95% CI; $P = 0.048$). The estimated mean brood size was 2.98, and 23.6% of the swans were cygnets. The mean brood size was 5% below the 1968–2010 average. The estimated average annual growth rate of adult trumpeter swans during 1968–2015 was 1.053 (95% CI = 1.042–1.063, $R^2 = 0.943$, $P < 0.001$). The growth rate declined from 1.088 during 1968–1985 (95% CI = 1.057–1.120, $R^2 = 0.987$, $P = 0.006$) to 1.030 during 2000–2015 (95% CI = 1.016–1.045, $R^2 = 0.977$, $P = 0.012$).

KEY WORDS: aerial survey, Alaska, *Cygnus buccinator*, trumpeter swan, abundance, productivity, population trend

INTRODUCTION

The tenth Alaska Trumpeter Swan Survey was conducted by the U.S. Fish and Wildlife Service, Division of Migratory Bird Management, Region 7 (hereafter MBM-R7) in the late summer of 2015. This survey was first conducted in 1968 and has been repeated at five-year intervals since 1975, in conjunction with the cooperative, range-wide North American Trumpeter Swan Survey (Groves 2017). The objectives of the Alaska Trumpeter Swan Survey are:

- Estimate the abundance of trumpeter swans (*Cygnus buccinator*) in Alaska during late summer (adult swans >1 year old, cygnets, and total swans);
- Estimate characteristics of productivity, including the numbers of cygnets, broods, adult pairs, and adult pairs with a brood, and the mean brood size, age ratio, and percentage of pairs with a brood; and
- Estimate the average annual growth rate of the Alaska population (1968–2015), using adult abundance estimates from the past and current iterations of the survey.

From 1968–2005, the survey was designed to census the entire Alaskan summering range (Conant et al. 2002, Conant et al. 2007). In 2010, MBM-R7 determined that a census was cost-prohibitive and thus switched to a sampling design (detailed below). MBM-R7 opted to use this sampling design again in 2015.

SURVEY AREA

The 2015 survey area was the same area covered in the 2005 and 2010 surveys (Conant et al. 2007, Groves and Hodges 2013; Figure 1). It included most of the known and potential trumpeter swan summering habitats in the interior Alaskan boreal forest and along the southern coastal plain from Cook Inlet to southeastern Alaska. From 1968–2005, survey coverage expanded with each successive survey in order to accommodate range expansion of the increasing trumpeter swan population. The survey area was not extended in 2010 or 2015, because the extension would have encroached on habitats known or suspected to host tundra swans (*Cygnus columbianus*). Observers were unable to differentiate trumpeter and tundra swans during the aerial survey, so excluding new areas minimized the likelihood of including tundra swans in the counts. A portion of the survey area along its western and northern peripheries likely did host an unknown number of tundra swans (Wilk 1993, Bryant et al. 2005, Bryant unpublished data); nevertheless, it was included because it had been included in previous quinquennial surveys.

METHODS

The sampling design was similar to a design originally developed by John Hodges (MBM-R7, retired; Conant et al. 1991). It consisted of a stratified random sample with optimum allocation of sampling effort to minimize cost for a fixed variance (Cochran 1977; Figure 1, Table 1). The 2015 design was the same as that used for the 2010 survey, including the same sampling frame, stratification, and stratum sample sizes (Groves and Hodges 2013); I simply selected a new set of sample units to be surveyed in 2015. The sampling frame contained 780 sample units (individual U.S. Geological Survey 1:63,360 topographic maps), totaling an area of 493,573 km². The sampling frame was stratified into five strata, based on the number of adult swans observed on each map during the 2005 survey: 1) 0–5, 2) 6–15, 3) 16–30, 4) 31–100, and 5) >100. The predicted total sample size, n , needed to obtain an abundance estimate of adult swans, \hat{T} , with 95% confidence limits of $\hat{T} \pm .10\hat{T}$, was computed following Conant et al. (1991):

$$n = \frac{\sum \left(\frac{N_h s_h}{\sqrt{C_h}} \right) \sum (\sqrt{C_h} N_h s_h)}{.25 P^2 \hat{T}^2 + \sum N_h s_h^2}$$

where N_h = total number of maps in stratum h ;
 s_h = standard deviation of adult swans in stratum h ;
 C_h = mean cost to survey a map in stratum h ; and
 P = desired precision (i.e., 95% confidence limits of $\hat{T} \pm P\hat{T}$).

Two survey datasets (2000 and 2005) were used to obtain estimates of s_h , C_h , and a projected value of \hat{T} , in an attempt to assure independence. First, the 2000 sampling frame was stratified using the 2000 data and the strata definitions described above. The 2005 data were then used with this stratification to compute s_h , C_h , and \hat{T} . “Cost” was defined as the number of statute miles flown to survey all potential swan habitat on a map. It was estimated for each stratum by computing the mean number of miles flown across maps in 2005 and then adding a value of 40

miles to account for cross-country flights between maps. \hat{T} was estimated by multiplying the mean number of adult swans across maps in each stratum in 2005 by the total number of maps in the stratum in 2015 and then summing the results for all strata. The predicted total sample size was 97 maps, which was optimally allocated among the five strata in accordance with Cochran (1977, p. 98). The resulting stratum sample sizes were rounded up to integers, and one map was added to stratum 3 to obtain a final sample size of 100 maps. Samples in each stratum were then randomly selected from the total available maps in each stratum.

The survey was conducted in late summer when the swans were dispersed on the breeding grounds, and cygnets were flightless but large enough to be easily counted from the air. The sample maps were apportioned among multiple survey crews, each of which comprised a left-seat pilot-observer (hereafter pilot) and a right-seat observer (hereafter observer). Four of the maps were surveyed in aircraft that required the observer to sit behind the pilot. The aerial survey technique followed that described by King (1973, 1982), with modifications to record swan observations and the survey flight track digitally (explained below). Each crew used a single-engine aircraft to survey all freshwater wetlands within a map, attempting to count all swans. The pilot was responsible for ensuring adequate survey coverage, modifying the flight path as necessary to account for factors that affected visibility (e.g., lighting conditions, vegetation height). The survey was flown at an altitude of 150–250 m above ground level (agl), with the crew circling and/or descending to as low as 45 m agl when needed to obtain an accurate count of cygnets. The observer recorded the location and attributes of each observation on a digital 1:63,360 topographic map, using a laptop computer that was linked to a GPS unit and the custom moving-map program RECORD (Hodges 2003). Observations were recorded as a single adult, adult pair, single with brood, pair with brood, or flock of adults, with cygnets and flocked swans enumerated. The pilot also used the RECORD program, which displayed the flight track on the digital topographic map, to determine where potential swan habitat occurred within the map and to monitor survey coverage. The program produced two files: a swan data file containing the geographic coordinates and attributes of each swan observation, and a flight track file containing point locations of the aircraft during the survey flight in five-second intervals. After the survey, I used another custom program (SwanTransform2.exe, version date 11 July 2002; J. Hodges, unpublished data) to link each swan observation with its appropriate sample map. I used the resulting data file for analyses.

I generated estimates of population abundance and precision for several swan age and group categories using stratified sampling estimators (Cochran 1977, Ch. 5). I then used the ratios of relevant estimates to estimate the mean brood size, the percentage of cygnets in the total population, and the percentage of pairs that had a brood. The estimates were not corrected for detection bias, but detection was likely high due to the swans' large size, white plumage, and tendency to occupy relatively open habitats (Schmidt et al. 2009).

I compared the 2015 survey results with results from prior (1968–2010) surveys to assess potential trends in the population parameters. I treated the 1968–2005 surveys as censuses with no associated sampling variances. I performed two-sample *z*-tests to evaluate differences between the 2010 and 2015 estimates (Thompson et al. 1998). I used least-squares regression on log-transformed abundance estimates to estimate average annual population growth rates for the

periods 1968–1985, 1985–2000, 2000–2015, and 1968–2015. I tested the trends for equality to zero using *t*-tests. I selected an alpha level of 0.05 for all tests of significance.

RESULTS

The survey was conducted during 3 August–1 September 2015. MBM-R7 survey crews flew a total of 257 hours (including ferry time), using Cessna 206s on amphibious floats. In addition, crews from the Koyukuk/Nowitna/Innokko National Wildlife Refuge Complex flew 16 hours (excluding ferry time) to survey four of the sample units, using a CubCrafters Top Cub, a Piper Super Cub, and a Found Bush Hawk.

The numbers of swans counted in each sample unit are listed in Appendix A. Overall estimates of swan abundance included 22,015 adults (95% confidence interval [CI] = 19,791–24,239), 6,793 cygnets (95% CI = 5,823–7,763), and 28,808 total swans (95% CI = 25,953–31,663; Table 2). The estimated number of broods was 2,277 (95% CI = 1,978–2,576).

Tests that compared the 2015 estimates to those from 2010 did not detect a significant difference for adult swans ($P = 0.100$), cygnets ($P = 0.089$), or broods ($P = 0.183$; Table 3). Although the change in the total swan estimates (+14%, 95% CI = +0.1% – +27%, $P = 0.048$) was significant at the selected alpha level of 0.05, the lower limit of the confidence interval was very close to zero.

The estimated average annual growth rate of the adult swan population during 1968–2015 was 1.053 (95% CI = 1.042–1.063, $R^2 = 0.943$, $P < 0.001$). The growth rate declined over time, from 1.088 during 1968–1985 (95% CI = 1.057–1.120, $R^2 = 0.987$, $P = 0.006$) to 1.030 during 2000–2015 (95% CI = 1.016–1.045, $R^2 = 0.977$, $P = 0.012$; Figure 2).

The 2015 productivity estimates indicated that trumpeter swan production was slightly below the long-term (1968–2010) mean (Tables 2, 3): the percentage of pairs with a brood, 27.8%, was 11% below the 1968–2010 mean, and the mean brood size of 2.98 was 5% below the 1968–2010 mean. Cygnets comprised 23.6% of the total population, 8% below the 1968–2010 mean.

DISCUSSION

The results of the 2015 survey indicated that the abundance of adult trumpeter swans in Alaska in 2015 was likely similar to that of 2010. Evidence of density dependence is indicated by the slowing rate of growth over time, which can be expected to occur as the best nesting territories become filled and the population expands into less productive habitats. It is possible that some areas of the state have reached or are approaching carrying capacity. Productivity and growth rates during 2010–2015 undoubtedly varied among regions in the state, depending on factors such as habitat availability, habitat quality, and weather conditions during the breeding seasons.

My decision to use the 2005 (and 2010) survey area boundary as the area of inference in 2015 had pros and cons. One benefit was that I could directly compare the 2015 estimates to the 2010 survey results. From 1968–2005, the survey area increased with each successive survey, and Schmidt et al. (2009) found that failing to account for the changing area in the analysis methods

resulted in slightly biased trend results. I did not account for the change in survey area when I calculated long-term growth rates, because the bias was minimal. For example, my method produced a growth-rate estimate of 1.061 for adult swans during 1968–2005, compared to Schmidt et al.’s estimate of 1.059 during the same time period.

Another benefit of using the 2005 survey area was that I limited inclusion of sympatric trumpeter and tundra swan summering areas to those that had been included in prior surveys. While this minimized the number of tundra swans in the counts, it also resulted in an unknown number of trumpeter swans being missed. Within the survey area, the number and distribution of tundra swans present were unknown, although I presume they were limited to the western and northern portions, where habitat resembled a transition between boreal forest and tundra biomes. Bryant et al. (2005; U.S. Fish and Wildlife Service, unpublished data) estimated that 50%, 20%, and 0% of all swans nesting on the Koyukuk NWR, Northern Unit of Innoko NWR (Kaiyuh Flats), and Nowitna NWR, respectively, were tundra swans in 2004–2006 (Figure 3). More recent work on the Koyukuk NWR in 2015 indicated that the percentage of tundra swans nesting there had declined to 41% (Jenny Bryant, Koyukuk/Nowitna/Innoko NWR Complex, pers. comm.). Wilk (1993) observed that 41% of nesting pairs in a study area within and near Kanuti NWR in 1989 were tundra swans, although this proportion had likely changed to an unknown degree by the time of the MBM-R7 survey in 2015 (Harwood 2017). The accuracy of future statewide survey results would be improved if the spatial extent of species overlap could be delineated and the relative proportions of each species determined. This information would need to be updated periodically, as the degree and location of overlap will likely not remain static.

The recovery of trumpeter swans in Alaska and large parts of North America over the last several decades is a conservation success story. Extirpated from most of North America, and severely reduced in Alaska, by the early 1900s due to overharvest and habitat loss (Mitchell and Eichholz 2010), trumpeter swans have since become reestablished in a major portion of their historical breeding range, thanks to intensive reintroduction efforts in several states and long-term protections from hunting. The Pacific Flyway Council’s current management plan for the Pacific Coast Population (PCP) of trumpeter swans includes a population objective of $\geq 25,000$ total swans (i.e., adults and cygnets) for Alaska, western Yukon Territory, and western British Columbia combined (Pacific Flyway Council 2006); this objective was first met in 2010 and was exceeded again in 2015 with an estimate of 31,793 (SE = 1,519) total swans (Groves 2017). The PCP is not without its challenges, some of which include lead-shot poisoning, powerline collisions, and reduced availability and quality of winter habitat due to urban development and changing agricultural practices. Continued monitoring of the status and trend of PCP trumpeter swans is recommended.

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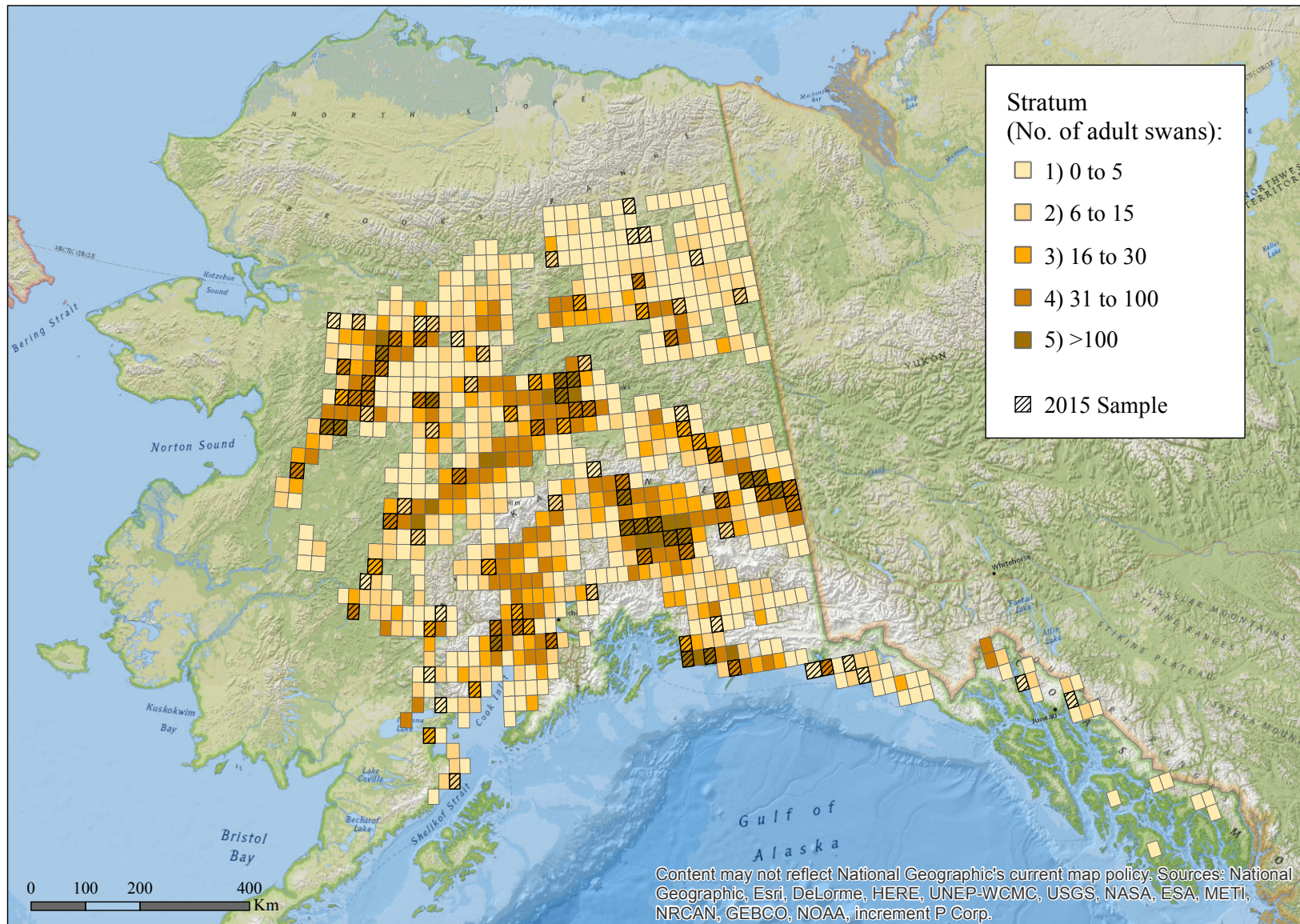


Figure 1. The 2015 Alaska Trumpeter Swan survey area, showing the distribution of sample units (1:63,360 maps) within five survey strata and the 100 randomly selected maps. Strata were delineated based on the number of adult swans observed during the 2005 survey. The size of the survey area was 493,573 sq. km.

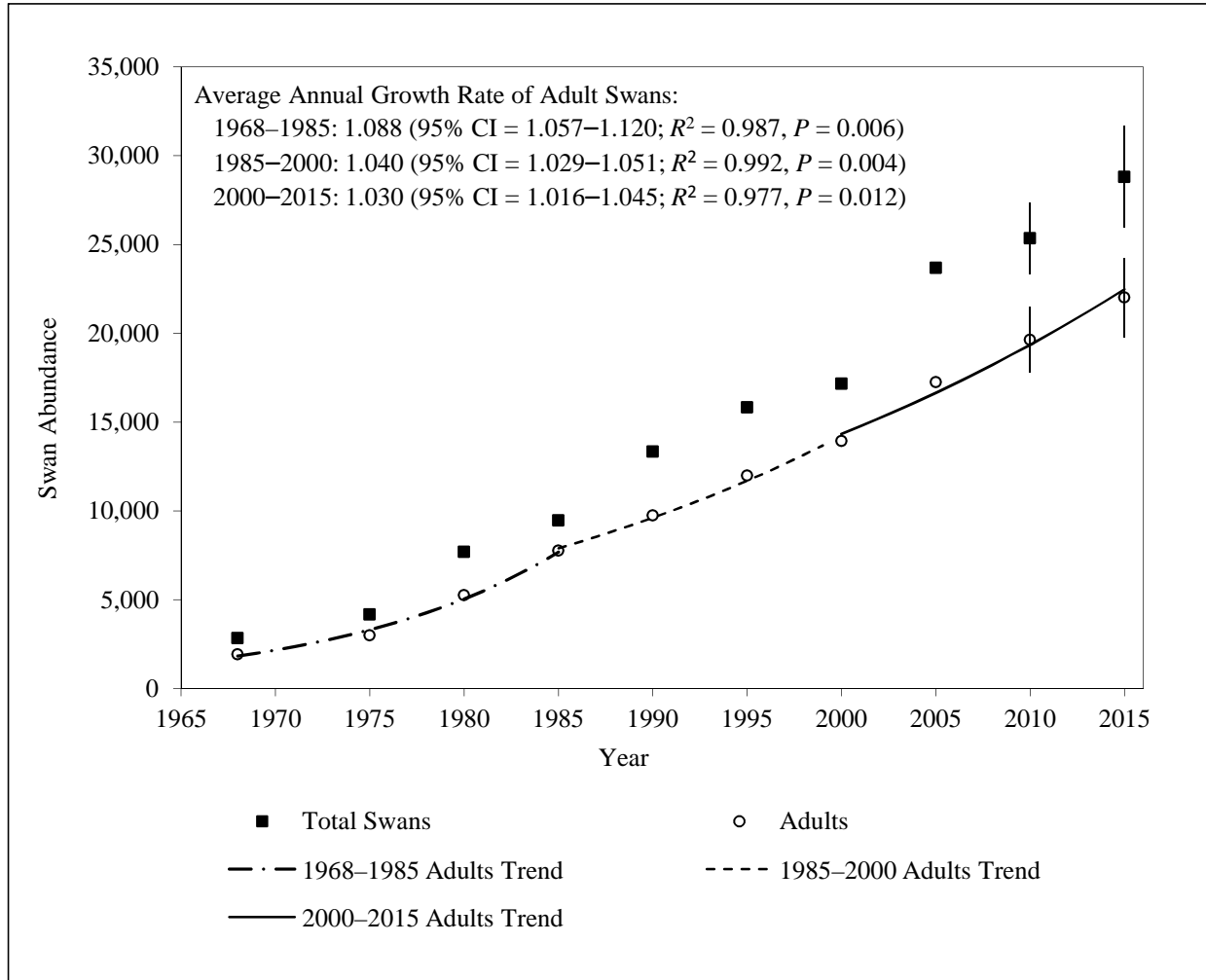


Figure 2. Trumpeter Swan abundance estimates from Alaska Trumpeter Swan surveys, 1968–2015. 95% confidence intervals are shown for the 2010 and 2015 estimates; estimates from other years were treated as censuses without sampling error. Trend lines are from least-squares regression performed on log-transformed adult swan estimates.

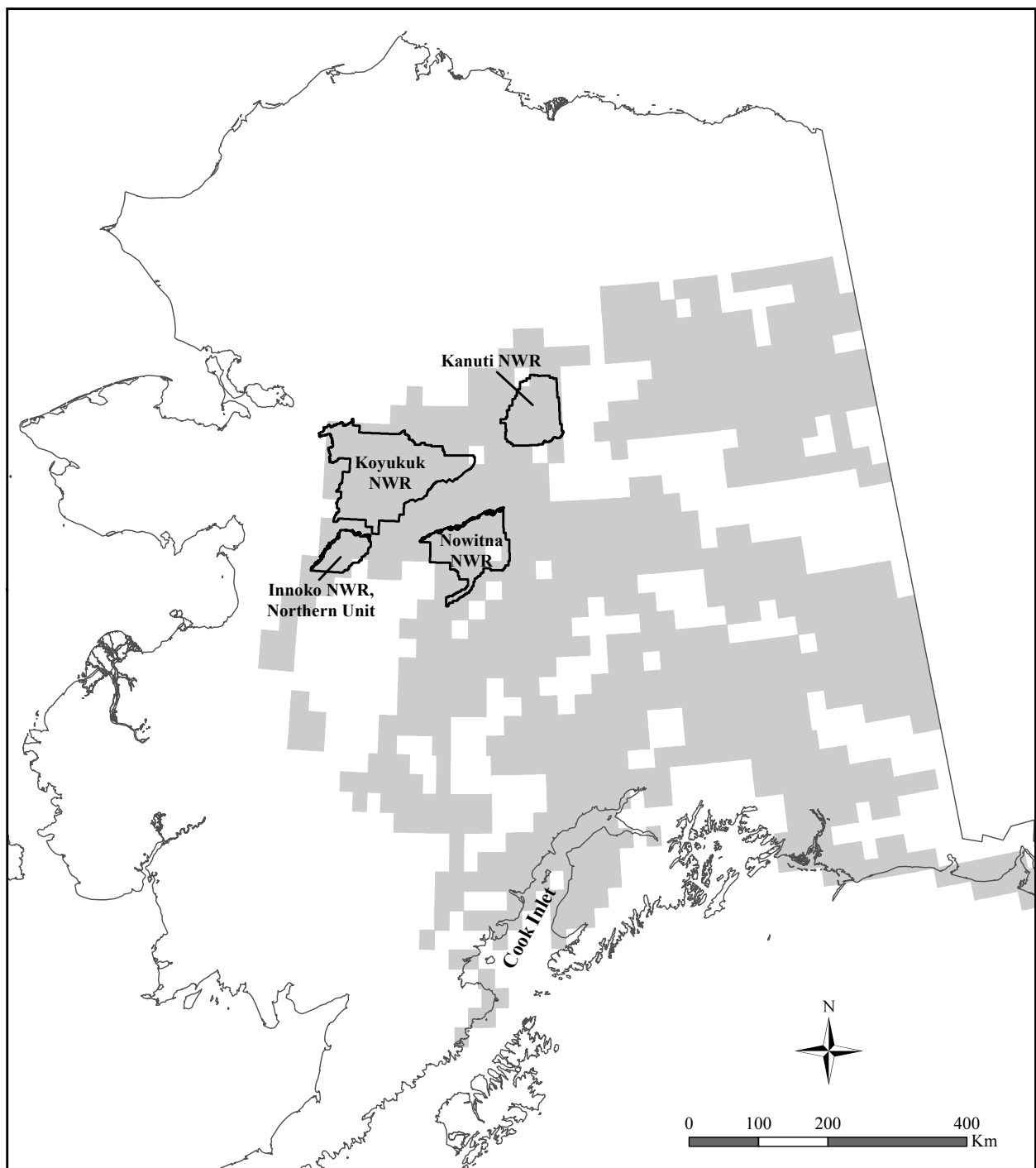


Figure 3. Locations of place names used in the text. The 2015 survey area (excluding southeast Alaska) is shown in gray.

Table 1. Data used to determine optimum allocation of sampling effort in the 2015 Alaska Trumpeter Swan survey.

Parameter	Stratum (Number of adult swans per sample unit in 2005)					Total
	1 (0 to 5)	2 (6 to 15)	3 (16 to 30)	4 (31 to 100)	5 (>100)	
N_h = Stratum size in 2015 (number of maps)	350	168	102	128	32	780
Mean number of adults across sample units (maps) in 2005 ^a	3.52	14.77	30.65	60.87	185.32	
s_h = Standard deviation of adult swans in 2005 ^a	4.33	10.49	17.18	29.70	95.16	
T^{\wedge} = Projected total number of adult swans in 2015 (N_h *Mean Adults)	1,231.7	2,481.7	3,126.8	7,791.7	5,930.3	20,562.1
C_h = Cost per sample unit in 2005 (number of miles flown) ^a	94	143	176	216	337	
P = Degree of precision desired ^b						0.10
Predicted sample size	17.6	16.6	14.9	29.2	18.7	97
Final sample size	18	17	16	30	19	100

^aComputed using 2000 survey maps stratified by 2000 adult swan data.

^bSize of 95% confidence interval about the estimated number of adult swans.

Table 2. Trumpeter Swan population estimates and associated precision from the 2015 Alaska Trumpeter Swan survey.

	Adult Swans					Cygnets	No. of Broods	No. of Pairs with Brood	Total Swans	Percent Cygnets	Mean Brood Size	Percent Pairs with Brood
	As Singles	In Pairs	In Flocks	No. of Flocks	Total Adults							
Population Estimate	1,987	15,806	4,222	644	22,015	6,793	2,277	2,199	28,808	23.6	2.98	27.8
Standard Error	132	752	535	65	1,113	487	150	147	1,431			
Coefficient of Variation	0.066	0.048	0.127	0.101	0.051	0.072	0.066	0.067	0.040			
Lower 95% Confidence Limit	1,724	14,308	3,154	514	19,791	5,823	1,978	1,906	25,953			
Upper 95% Confidence Limit	2,250	17,304	5,290	774	24,239	7,763	2,576	2,492	31,663			

Table 3. Trumpeter Swan population estimates from Alaska Trumpeter Swan surveys, 1968–2015.

Year	Adult (White) Swans					Cygnet	Total Swans	No. of Broods	Percent Cygnets	Mean Brood Size	Percent Pairs with Brood
	As Singles	In Pairs	In Flocks	No. of Flocks	Total Adults						
1968	108	1,320	496	69	1,924	923	2,847	257	32.4	3.59	37.1
1975	151	2,102	740	125	2,993	1,177	4,170	378	28.2	3.11	35.4
1980	169	3,324	1,766	210	5,259	2,437	7,696	683	31.7	3.57	40.3
1985	449	5,120	2,204	317	7,773	1,686	9,459	588	17.8	2.87	22.6
1990	647	7,056	2,039	326	9,742	3,595	13,337	1,124	27.0	3.20	31.2
1995	859	7,946	3,184	563	11,989	3,834	15,823	1,218	24.2	3.15	30.1
2000	899	9,986	3,049	530	13,934	3,221	17,155	1,149	18.8	2.80	22.4
2005	1,157	11,940	4,148	658	17,245	6,447	23,692	2,084	27.2	3.09	33.9
2010 ^a	1,591 (±253)	14,276 (±1,243)	3,771 (±875)	605 (±114)	19,638 (±1,845)	5,709 (±823)	25,347 (±2,020)	2,004 (±279)	22.5	2.85	27.2
2015 ^a	1,987 (±263)	15,806 (±1,498)	4,222 (±1,068)	644 (±130)	22,015 (±2,224)	6,793 (±970)	28,808 (±2,855)	2,277 (±299)	23.6	2.98	27.8
% Change											
2010 to 2015 ^a	25 (2–48)	11 (-3–24)	12 (-24–48)	6 (-22–34)	12 (-2–27)	19 (-3–41)	14 (0.1–27)	14 (-6–34)	5	5	2
<i>P</i> -value ^b	0.031	0.117	0.513	0.651	0.100	0.089	0.048	0.183			
1968–2010 Mean											
									25.5	3.14	31.1
% Change from 1968–2010 Mean											
									-8	-5	-11

^a 95% confidence limits are in parentheses.

^b Results of a two-sample z-test comparing 2010 and 2015 estimates.

Appendix A. Counts and associated totals of swans on 100 stratified random-sample plots (1:63,360 maps) surveyed during the 2015 Alaska Trumpeter Swan Survey.

Map	Stratum	Date Surveyed	No. of Observations	Adult (White) Swans										No. of Broods	Total Swans
				As Singles		In Pairs		In Flocks	No. of Flocks	Total Adults	Cygnets				
				With	Without	With	Without								
				Cygnets	Cygnets	Cygnets	Cygnets								
Big Delta B2	1	09/01/2015	0	0	0	0	0	0	0	0	0	0	0		
Black River D5	1	08/07/2015	3	0	0	0	6	0	0	6	0	0	6		
Christian B3	1	08/04/2015	1	0	0	0	2	0	0	2	0	0	2		
Christian B4	1	08/04/2015	0	0	0	0	0	0	0	0	0	0	0		
Christian D4	1	08/04/2015	0	0	0	0	0	0	0	0	0	0	0		
Cordova D2	1	08/04/2015	1	0	0	0	2	0	0	2	0	0	2		
Healy C3	1	08/07/2015	0	0	0	0	0	0	0	0	0	0	0		
Hughes A4	1	08/15/2015	2	0	0	0	4	0	0	4	0	0	4		
Iliamna D3	1	08/11/2015	2	0	1	0	2	0	0	3	0	0	3		
Juneau D4	1	08/07/2015	2	0	1	2	0	0	0	3	1	1	4		
Lake Clark B4	1	08/11/2015	5	0	1	0	8	0	0	9	0	0	9		
Lime Hills B3	1	08/14/2015	2	0	0	2	2	0	0	4	4	1	8		
Melozitna D1	1	08/15/2015	0	0	0	0	0	0	0	0	0	0	0		
Shungnak A5	1	08/14/2015	0	0	0	0	0	0	0	0	0	0	0		
Sleetmute D2	1	08/20/2015	7	0	1	2	8	3	1	14	1	1	15		
Taku River B6	1	08/07/2015	0	0	0	0	0	0	0	0	0	0	0		
Yakutat C6	1	08/07/2015	4	0	0	2	4	4	1	10	4	1	14		
Yakutat D7	1	08/07/2015	5	0	3	0	2	3	1	8	0	0	8		
Afognak C5	2	08/11/2015	4	0	0	2	6	0	0	8	5	1	13		
Anchorage C5	2	08/03/2015	2	0	1	0	2	0	0	3	0	0	3		
Black River A2	2	08/08/2015	9	0	0	0	18	0	0	18	0	0	18		
Chandalar A5	2	08/05/2015	2	0	1	2	0	0	0	3	2	1	5		
Fort Yukon A1	2	08/07/2015	6	0	3	4	2	0	0	9	5	2	14		
Healy A6	2	08/07/2015	12	0	2	8	8	7	2	25	12	4	37		
Hughes A3	2	08/15/2015	9	0	2	4	8	6	1	20	7	2	27		
Icy Bay D2	2	08/05/2015	4	0	1	0	4	3	1	8	0	0	8		
Livengood B3	2	08/14/2015	7	0	1	2	10	0	0	13	1	1	14		
McGrath C4	2	08/20/2015	2	0	0	2	2	0	0	4	7	1	11		
Medfra A5	2	08/20/2015	10	0	2	2	12	12	1	28	1	1	29		
Nabesna B6	2	08/05/2015	3	0	1	0	4	0	0	5	0	0	5		
Nulato C2	2	08/17/2015	17	0	4	10	16	0	0	30	11	5	41		
Ruby B3	2	08/19/2015	11	0	3	2	12	15	1	32	4	1	36		
Shungnak A3	2	08/14/2015	3	0	0	2	4	0	0	6	4	1	10		
Tanana A6	2	08/21/2015	15	0	3	4	20	0	0	27	4	2	31		
Tanana C5	2	08/15/2015	10	0	4	0	12	0	0	16	0	0	16		
Beaver B3	3	08/05/2015	21	0	6	8	22	0	0	36	15	4	51		
Big Delta A2	3	09/01/2015	12	0	0	8	16	0	0	24	9	4	33		
Cordova C5	3	08/05/2015	16	1	0	18	8	13	2	40	23	10	63		
Fairbanks B5	3	08/12/2015	17	0	3	14	14	0	0	31	21	7	52		
Fort Yukon A4	3	08/06/2015	14	0	2	10	14	0	0	26	15	5	41		
Iditarod A1	3	08/20/2015	13	0	2	12	8	4	1	26	20	6	46		
Iliamna B4	3	08/11/2015	10	0	2	0	16	0	0	18	0	0	18		
Kantishna River C3	3	08/17/2015	5	0	1	0	8	0	0	9	0	0	9		
Kenai A8	3	08/11/2015	9	0	5	0	8	0	0	13	0	0	13		
Lime Hills A4	3	08/14/2015	11	0	2	2	14	3	1	21	5	1	26		
Mt. Hayes D1	3	09/01/2015	11	0	2	4	12	4	1	22	4	2	26		
Nulato D4	3	08/18/2015	22	0	4	14	20	3	1	41	21	7	62		
Talkeetna A5	3	08/12/2015	13	0	6	2	12	0	0	20	4	1	24		
Tanana A1	3	08/17/2015	9	0	2	4	10	0	0	16	5	2	21		
Tyonek A3	3	08/06/2015	18	0	4	8	16	10	2	38	9	4	47		
Tyonek B4	3	08/13/2015	22	0	3	10	28	0	0	41	13	5	54		
Circle C2	4	08/08/2015	12	0	2	6	12	3	1	23	10	3	33		
Cordova A1	4	08/05/2015	45	0	8	22	50	3	1	83	36	11	119		
Fairbanks C3	4	08/09/2015	35	0	5	18	42	0	0	65	31	9	96		
Fairbanks C4	4	08/09/2015	48	0	9	30	44	7	2	90	57	15	147		
Fort Yukon C4	4	08/06/2015	8	0	1	2	12	0	0	15	4	1	19		
Gulkana A3	4	08/04/2015	27	1	3	26	18	3	1	51	37	14	88		
Gulkana A6	4	08/03/2015	42	0	7	12	46	88	6	153	20	6	173		
Healy B1	4	08/04/2015	34	1	7	16	36	0	0	60	29	9	89		
Icy Bay D1	4	08/05/2015	16	0	3	10	12	31	2	56	13	5	69		
Kantishna River B1	4	08/17/2015	24	0	0	10	38	0	0	48	18	5	66		
Kateel River A2	4	08/19/2015	41	0	4	12	52	21	5	89	16	6	105		
Kateel River B1	4	08/17/2015	51	0	15	22	44	10	3	91	26	11	117		

Appendix A (cont'd.). Counts and associated totals of swans on 100 stratified random-sample plots (1:63,360 maps) surveyed during the 2015 Alaska Trumpeter Swan Survey.

Map	Stratum	Date Surveyed	No. of Observations	Adult (White) Swans								No. of Broods	Total Swans
				As Singles		In Pairs		In Flocks	No. of Flocks	Total Adults			
				With Cygnets	Without Cygnets	With Cygnets	Without Cygnets						
Kateel River B4	4	08/14/2015	24	0	4	8	30	3	1	45	8	4	53
Kenai D1	4	08/12/2015	25	1	9	10	20	0	0	40	19	6	59
McGrath D6	4	08/20/2015	14	0	0	10	12	36	3	58	19	5	77
Medfra C1	4	08/22/2015	27	0	7	8	30	6	1	51	12	4	63
Melozitna D4	4	08/15/2015	26	0	5	10	26	13	3	54	16	5	70
Melozitna D6	4	08/15/2015	50	0	9	16	52	26	7	103	20	8	123
Nabesna C1	4	08/30/2015	42	0	7	6	60	13	2	86	10	3	96
Nabesna D1	4	08/29/2015	25	0	5	6	34	0	0	45	7	3	52
Nabesna D3	4	08/25/2015	56	0	5	26	70	14	3	115	43	13	158
Nabesna D6	4	08/05/2015	55	0	17	44	28	8	2	97	80	22	177
Nulato D2	4	08/15/2015	37	0	10	18	26	22	5	76	42	9	118
Nulato D3	4	08/18/2015	36	1	8	14	34	10	3	67	21	8	88
Ruby D4	4	08/14/2015	34	0	4	10	42	15	4	71	17	5	88
Sleetmute B3	4	08/14/2015	20	0	1	6	32	0	0	39	10	3	49
Tanacross C6	4	08/24/2015	32	3	1	14	40	3	1	61	23	10	84
Tyonek A4	4	08/13/2015	23	0	3	14	26	0	0	43	21	7	64
Tyonek A6	4	08/13/2015	15	1	2	6	18	0	0	27	10	4	37
Unalakleet C1	4	08/18/2015	30	1	9	14	24	3	1	51	29	8	80
Cordova B3	5	08/04/2015	52	0	3	34	60	6	2	103	50	17	153
Cordova B5	5	08/05/2015	18	0	4	8	20	0	0	32	10	4	42
Fairbanks D5	5	08/12/2015	199	2	39	120	174	91	11	426	209	62	635
Gulkana B3	5	08/04/2015	59	1	16	28	52	7	2	104	45	15	149
Gulkana B4	5	08/04/2015	122	3	24	44	136	41	5	248	63	25	311
Gulkana C5	5	08/05/2015	54	1	12	12	68	5	1	98	16	7	114
Gulkana C6	5	08/05/2015	63	0	10	8	94	8	2	120	11	4	131
Healy A1	5	08/04/2015	49	4	13	8	44	51	6	120	19	8	139
Kateel River C1	5	08/14/2015	72	0	12	22	86	42	6	162	28	11	190
Kenai D6	5	08/13/2015	64	0	11	38	68	0	0	117	51	19	168
Livengood A4	5	08/14/2015	171	2	23	86	190	49	8	350	135	45	485
Livengood A5	5	08/21/2015	146	2	21	60	160	110	13	353	99	32	452
Nabesna D2	5	08/29/2015	251	2	33	68	326	182	19	611	96	36	707
Nulato B4	5	08/10/2015	89	0	13	46	84	79	9	222	73	25 ^a	295
Nulato B5	5	08/11/2015	114	1	18	70	104	25	8	218	114	36	332
Ruby D3	5	08/20/2015	46	0	6	16	58	10	3	90	14	8	104
Talkeetna Mts. C1	5	08/04/2015	56	0	14	12	60	28	6	114	22	6	136
Tanacross A3	5	08/25/2015	180	0	16	46	250	182	16	494	59	23	553
Tanacross A4	5	08/25/2015	59	0	5	24	42	227	21	298	30	12	328

^a Two broods were observed with no adults present.