Continuity and advancement of Trumpeter Swan *Cygnus buccinator* and Tundra Swan *Cygnus columbianus* population monitoring in Alaska

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In Alaska, four extensive censuses of Trumpeter Swans by the U.S. Fish and Wildlife Service have documented an exponential growth of the summering population since 1968 (white(>1 year-old) swans: 1968-1,924, 1975-2,993, 1980-5,259, 1985-7,773). A sampling design based on the census results using stratified random plots estimated 7,145 ± 660 white Trumpeter Swans in 1986. Annual line transect surveys over most of the Alaska nesting range, except for the North Slope, have documented an increasing breeding population of Tundra Swans 1965-1989. A modified sampling technique, similar to the one for Trumpeter Swans, but employing smaller sized plots, has been used successfully in parts of Alaska to better estimate subpopulations of Tundra Swans. Expanded sample surveys for both species on the summering grounds are recommended for North America. Enhanced management of both species, as well as for other less visible waterfowl, is envisioned with full implementation.

In North America, each year, approximately 80% of the Trumpeter Swans *Cygnus buccinator* and perhaps 50% of the Tundra Swans *Cygnus columbianus* migrate to Alaska for the summer. Trumpeter Swans summer primarily within the boreal and rain forest habitat, south and east of the tree line (Fig.1). The early history of the Trumpeter Swan work in Alaska was summarized by King and Conant (1981). Past records of Trumpeter Swans in Alaska go back to 1878 (Banko 1960). They were officially documented in Alaska in 1954 (Monson 1956). Tundra Swans summer mostly on tundra habitat, north and west of the tree line (Fig.1). They are more numerous than Trumpeter Swans in Alaska during the summer, but their population status is less well understood. These birds represent most of the Pacific coast population of Trumpeter Swans and virtually all of the western population of Tundra Swans.

Swans, the largest and most visible waterfowl, are the easiest to enumerate with aerial survey methods. Juveniles (cygnets) are easy to distinguish from white swans (adults and subadults) on the nesting grounds because of their darker colouration. A precise technique has been developed by the U.S. Fish and Wildlife Service (USFWS) to monitor annual population status including the current year's production as measured by juveniles present during the survey period. This survey system can provide an excellent long term record of swan population status in Alaska. The data will have greater value to future observers and, like weather data, will provide a baseline for conditions in our time.

Aims

1. To conduct quinquennial censuses of Trumpeter Swans summering in Alaska.
2. To monitor the annual population status and production of Trumpeter and Tundra swans summering in Alaska within a confidence interval of ±10%.
3. To encourage the use of one simple, standard method for collecting precise location and population status data for swans throughout Alaska.
4. To develop a computerized system for archiving, summarizing and mapping swan survey data.

Methods

Trumpeter Swans (census)

The aerial survey technique used was described by King (1973, 1982). Small aircraft were used to put observers over almost all known or sus-

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pected Trumpeter Swan summer habitat within the boreal and rain forest in Alaska (Fig.5). Surveys were conducted in August and early September when the cygnets were large enough to be easily counted from the air and before any had fledged. Observations were recorded directly onto 1:63,360 scale U.S. Geological Survey (USGS) maps. The locations are brood rearing sites, often coinciding with nesting sites. With an expanding population, the number of maps searched has increased with each census and reached 425 maps in 1985. Generally, a system of parallel tracks were flown within each quadrangle map at an altitude of 150 m above ground. Pilot-biologists were responsible for navigation, ensuring that all habitat was adequately surveyed and finding all swans. Consideration was given to factors such as sun glare and observer experience. The primary observer was responsible for tracking the flight path on the maps, making swan observations and recording them by type, number and precise location. Secondary observers, when available, were used to increase the "eye power" from the moving platform.

In 1985, as the survey progressed, all swan observations on completed maps were entered directly into portable Epson HX-20 computers in the field. The exact latitude and longitude of each sighting for all censuses was determined later from original survey maps with a Tektronix digitizing system. These coordinates were then merged with the observation data from the Epson computers. The combined data were later transferred to a Data General MV 8000 computer in Anchorage, which served as the primary data storage bank for all swan census data for Alaska.

Trumpeter Swans (sample)

Between 1980 and 1985 an opportunistic nonrandom sample of Trumpeter Swan nesting habitat was surveyed in Alaska (Conant *et al.* 1984). It provided valuable interim data between the two complete five year censuses. In 1986, an improved sample (Fig.3) using stratified random plots was designed and implemented (Hodges *et al.* 1986). It used data from the 1975, 1980 and 1985 censuses to predict desired sample size, survey cost, stratification, and optimum allocation of effort.

The 1:63,360 USGS quadrangle maps were used as sample units and the aerial survey technique described was used for each map. Maps were sorted into three strata based on the number of paired and single swans seen in the 1985 census. Paired and single swans were chosen as the most consistent indicator of population size for comparisons between years. Flocked swans would have introduced undesirable variability because of their mobility, clumped distribution and the influence of the previous year's production. The three strata were low (0 to 5 swans), medium (6 to 20 swans) and high (21+ swans). Additional strata would have given only slightly improved results at the expense of additional calculations and confusion.

Table 1. Data used for design of the 1986 stratified random sample with optimum allocation of effort. Strata variances used the change observed by map between 1980 and 1985 for paired and single swans.

	Stratum			
	Low	Medium	High	Total
N_i = Stratum size (maps)	294	85	46	425
s_i = Variance	18.7	74.1	375.1	
C_i = Average Cost per map (Miles Flown)	86	144	258	
n_i = Sample size	30	23	27	80

To estimate sample sizes it was necessary to have an estimate of the variability within each stratum. The stratum variances, s_i (i=1, 2, 3), were computed from the 1985 results which were stratified according to paired and single swans seen in 1980 (Table 1).

By specifying the projected total number of paired and single swans, $\hat{T}$, (we used the 1985 total), and the degree of precision desired, it was possible to estimate the sample size needed. Degree of precision was expressed as the size of the 95% confidence interval about the estimated number of swans. This interval was designated as $\hat{T} \pm P\hat{T}$. Our desired precision was 95% confidence limits of $\pm .10\hat{T}$. The projected sample size was n=80 out of a possible 425 maps.

The projected sample size, n=80, was calculated with

$$n = \frac{\sum \left(\frac{N_i s_i}{\sqrt{C_i}}\right) \sum \left(\sqrt{C_i} N_i s_i\right)}{.25 P^2 \hat{T}^2 + \sum N_i s_i^2}$$

Where N_i = Number of maps in stratum i
s_i = Standard deviation in stratum i
C_i = Average cost of surveying a map in stratum i.

Sample sizes within each stratum, n_i (i=1, 2, 3), were selected using optimum allocation of effort (Cochran 1953, p. 75). The data analysis used paired comparisons, or differences by map, of the observed swans in 1986 to those censused in 1985.

Let T_{85} = total singles and pairs in 1985 = 5,569
N_i = number of maps in stratum i
n_i = sample size in stratum i
d_{ij} = difference between current year observation and 1985 observation for map j in stratum i.

Then

$$\bar{d}_i = \frac{\sum_i \sum_j d_{ij}}{n_i} \quad \text{and}$$

$$s_i^2 = \frac{\sum_j (d_{ij} - \bar{d}_i)^2}{n_i - 1}$$

The estimated total for the current year is

$$\hat{T} = T_{85} + \sum N_i \bar{d}_i \quad \text{with}$$

$$\hat{Var}(\hat{T}) = \sum N_i (N_i - n_i) s_i^2 / n_i \quad \text{and}$$

Confidence limits are $\hat{T} \pm 2 \sqrt{\hat{Var}(\hat{T})}$

Tundra Swans (sample)

The sheer amount of habitat occupied by Tundra Swans in Alaska and their density has so far prevented a complete census. An aerial transect survey (Fig.1) has provided a measure of the breeding population of Tundra Swans over most of their summer range in western Alaska, 1965-1989 (Conant & Dau 1989). This annual survey was flown at low level (50 m) and covered about one per cent of the available habitat in the Bristol Bay, Yukon Delta, Seward Peninsula and Kotzebue Sound units during late May and early June. It was assumed that all swans were observed in the 200 m survey strip on each side of the flight path. Total population estimates were achieved by applying direct area expansion factors in each unit. A simple linear regression, with its associated assumptions of normality, was used to fit the time series data for single and paired swans.

Since a complete census has not been made, a precise, Alaska-wide sampling design has not yet been developed. Instead, a combination of random and non-random plot data has been gathered from various regions of their summer range (Fig.5). Tundra Swans attain much higher densities in some coastal areas than Trumpeter Swans currently do. Therefore, equal size quarter sections of USGS quadrangle maps have proven to be more practical as sample units on the northern Alaska Peninsula (Wilk 1988), in the Kotzebue Sound area (Spindler 1989) and on the Yukon Delta (Wege 1987). All swan habitat within whole USGS maps has been surveyed on the southern Alaska Peninsula, on Kodiak Island and on the North Slope (Platte & Brackney 1986).

Wilk (1988) was able to design a sample survey using quarter sections based on almost complete coverage of the northern Alaska Peninsula. Spindler (1989) was able to do the same in the Kotzebue Sound area. Density distribution data from the Alaska- Yukon Breeding Population Survey (King & Hodges 1981) aided in the design of a similar sample plan on the Yukon Delta (Wege 1987). Methods of survey and computer tabulation were like those described for Trumpeter maps. Population estimates were obtained for those individual areas in different years (1986, 1987, 1988).

Results

Trumpeter Swans (census)

An aerial survey in 1959, hampered by a lack of 1:63,360 scale USGS maps, found 1,124 birds in the principal nesting areas. In 1968, when these maps were available, an improved census design found a total of 2,847, including 1,924 white swans (Hansen *et al.* 1971). These findings resulted in the removal of the Trumpeter from the American threatened species list. Complete censuses in 1968, 1975, 1980 and 1985 have shown a dramatic increase (Fig.2) in the population (Conant *et al.* 1986).

The results of the four Trumpeter Swans censuses completed to date are presented in Table 2 and Table 3 by sample unit (Fig.5). Expansion of Trumpeter Swans into peripheral habitat (Units 7-11) is demonstrated in Table 2. The production for 1985 was proportionally lower than for the other three years as indicated by the per cent juvenile, the average brood size and the per cent of pairs with broods (Table 3). The total number of cygnets and broods were both reduced from 1980, in spite of the large increase in the number of white swans recorded during the same time period.

Trumpeter Swans (sample)

Table 4 gives the estimates of swans by category obtained from the 1986 stratified random

Table 2. Summary of Trumpeter Swan observations from censuses during August-early September, by survey unit in Alaska for 1968, 1975, 1980 and 1985.

		White Swans				
Unit	Year	in Pairs	as Singles	in Flocks	Cygnets	Total Swans
1 Gulf Coast	68	442	29	191	363	1025
	75	442	32	190	193	857
	80	586	52	266	351	1255
	85	778	76	440	164	1458
2 Copper River	68	56	5	53	44	158
	75	56	2	72	49	179
	80	70	4	33	33	140
	85	74	8	108	11	201
3 Gulkana	68	288	31	81	190	590
	75	556	43	155	284	1038
	80	1026	42	632	660	2360
	85	1736	143	595	533	3007
4 Kenai	68	86	3	27	65	181
	75	72	5	29	39	145
	80	90	12	8	65	175
	85	92	5	40	51	188
5 Cook Inlet	68	224	19	50	124	417
	75	340	36	60	181	617
	80	608	38	186	369	1201
	85	800	66	454	241	1561
6 Lower Tanana	68	224	21	94	137	476
(Fairbanks)	75	518	21	185	388	1112
	80	746	6	585	773	2120
	85	1202	113	426	503	2244
7 Kuskokwim	68					
(McGrath)	75	20	6	4	7	37
	80	60	0	22	63	145
	85	122	0	62	55	239
8 Koyukuk	68					
	75	94	6	45	35	180
	80	124	4	27	104	259
	85	206	23	29	45	303
9 Yukon Flats	68					
(Ft. Yukon)	75	2	0	0	1	3
	80	2	0	0	4	6
	85	10	0	0	3	13
10 Chilkat Valley	68					
(Haines)	75	2	0	0	0	2
	80	6	0	3	11	20
	85	16	1	7	16	40
11 Upper Tanana	68					
(Fairbanks)	75					
	80	6	1	4	4	15
	85	84	14	43	64	205
TOTAL	68	1320	108	496	923	2847
	75	2102	151	740	1177	4170
	80	3324	169	1766	2437	7696
	85	5120	449	2204	1686	9459

Table 3. Summary of Trumpeter Swan production from censuses during August-early September, by survey unit in Alaska for 1968, 1975, 1980 and 1985.

Unit	Year	Number of Broods	Average Brood Size	Per cent Juvenile	Per cent Pairs with Broods
1 Gulf Coast	68	93	3.9	35	41
	75	61	3.2	23	27
	80	99	3.6	28	33
	85	57	2.9	11	14
2 Copper River	68	13	3.4	28	39
	75	16	3.1	27	57
	80	10	3.3	24	29
	85	3	3.7	5	8
3 Gulkana	68	52	3.7	32	36
	75	93	3.1	27	33
	80	194	3.4	28	36
	85	191	2.8	18	22
4 Kenai	68	21	3.1	36	49
	75	15	2.6	27	42
	80	19	3.4	37	42
	85	16	3.2	27	35
5 Cook Inlet	68	36	3.4	30	29
	75	61	3.0	29	36
	80	103	3.6	31	34
	85	85	2.8	15	21
6 Lower Tanana	68	42	3.3	29	33
(Fairbanks)	75	112	3.5	35	42
	80	202	3.8	36	54
	85	179	2.8	22	29
7 Kuskokwim	68				
(McGrath)	75	3	2.3	19	30
	80	16	3.9	43	53
	85	18	3.1	23	30
8 Koyukuk	68				
	75	16	2.2	19	34
	80	36	2.9	40	55
	85	16	2.8	15	13
9 Yukon Flats	68				
(Ft. Yukon)	75	1	1.0	33	100
	80	1	4.0	67	100
	85	1	3.0	23	20
10 Chilkat Valley	68				
(Haines)	75	0	—	—	—
	80	2	5.5	55	67
	85	3	5.3	40	38
11 Upper Tanana	68				
(Fairbanks)	75				
	80	1	4.0	27	33
	85	9	3.4	31	45
TOTAL	68	257	3.6	32	37
	75	378	3.1	28	35
	80	683	3.6	32	40
	85	588	2.9	18	23
4 Year Average			3.3		34

Table 4. Trumpeter Swan population estimate from a stratified sample of 80 maps (selected from 425, 1:63,360 scale USGS maps) in 1986, expanded for Alaska. The census results are given for 1985.

	White Swans in Pairs	White Swans as Singles	White Swans in Flocks	White Swans Subtotal	Cygnets	Total Swans	Number of Broods	Average Brood Size	Per cent Juvenile	Broods per Pair
1985 Total	5120	449	2204	7773	1686	9459	588	2.9	18	0.23
1986										
Change, 1985 to 1986	+655	−71	-1212	−628	+1348	+720	+428	+0.1	+12	+0.12
1986 Total	5775	378	992	7145	3034	10179	1016	3.0	30	0.35
95% Confidence Limit	±439	±106	±612	±660	±535	±935	±165			
Per cent Error	± 8	± 28	± 62	± 9	± 18	± 9	± 16			

sample together with the 95% confidence interval. The 1986 sample survey found production closer to normal compared to the dismal production in 1985 (Table 4). Of interest was the 55% decline in flocked swans ($P<0.05$). Singles showed a non- significant decline of 16%. Significant increases ($P<0.05$) were seen in pairs (13%), cygnets (80%) and number of broods (73%). While cygnets nearly doubled, average brood size increased only slightly. Therefore, the additional young were primarily a result of a larger number of successful breeding pairs in 1986. Broods per pair increased from 0.23 to 0.35. Estimated total Trumpeter Swans topped 10,000 in 1986 for the first time in spite of 628 fewer white swans than in the previous year.

Tundra Swans (sample)

The results of 25 years of annual line transect surveys for most of the Tundra Swan nesting range, except the North Slope, show an increasing breeding population index (Fig.4). The plot of singles plus paired swans with a fitted line ($R=0.77$, $P<0.01$) best expresses the increasing summer population.

During the 1960s and 1970s annual productivity for Tundra Swans was determined on the Yukon Delta, primarily on an opportunistic basis (Lensink 1973, Dau 1981). The detailed results of various sample surveys and small scale censuses using the map method of survey have been presented individually (Wilk 1988, Spindler 1989, Wege 1987, Platte & Brackney 1985). A general summary of data collected by map and stored on computer, 1980-1988, is presented (Table 5). This table gives totals, by year, of observed swans only; no attempt has been made to expand the observations to a total population estimate for Alaska. A variable survey effort is evident and therefore results between years are not strictly comparable.

Discussion

Trumpeter Swans

An unknown, but small (probably less than 10%) proportion of Trumpeter Swans were not detected with this technique. Some swans were missed in habitat searched. Others were present in nearly empty habitat not intensively searched. Replicate counts or a concurrent, intensive search of a random sample of survey maps by helicopter could determine a proportion missed. The next Trumpeter census will be conducted in Alaska in 1990 and subsequently, every 5 years.

A well-designed plot sampling scheme, based on the results of the censuses, gave an estimate of summering Trumpeter Swans with narrow confidence limits in 1986. The suspected slight bias from swans missed during map searches applies to the sample survey as well. The sample survey of 80 stratified, randomly selected maps documented a return to average swan production in most Alaskan Trumpeter Swan survey units. The poor production of 1985 was reflected in 1986 as a drastic reduction in flocked swans. This implies that few of the cygnets recorded in 1985 survived their first year and that the numbers of swans in flocks were greatly affected by the yearling component. Recruitment failed to offset mortality as white swans declined ($P<0.06$) by an estimated 628 swans.

This sample of 80 maps was designed to provide 95% confidence limits within 10% of the estimated total for singles and pairs. The 1986 results were 6,153 ± 448 (±7%) singles and pairs. Because of a rapidly expanding population, the per cent error would be expected to increase through time as the number of years between the current sample and the 1985 census increase. If a complete census is not conducted in 1990, the per cent error for the sample will probably increase beyond 10%.

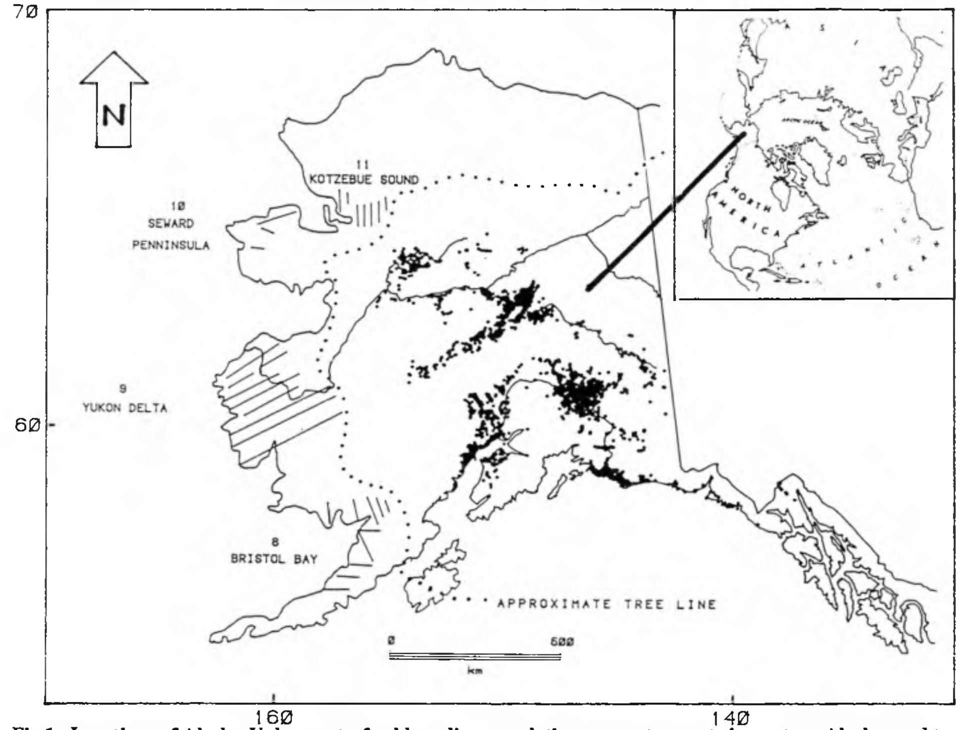

Fig.1. Locations of Alaska-Yukon waterfowl breeding population survey transects in western Alaska used to estimate a breeding population of Tundra Swans, 1965-1989. Exact locations of all 3327 observations of Trumpeter Swans from the 1985 census of boreal and rain forest habitat in Alaska.

There is a unique opportunity to design a random sample survey for the continent to monitor the probable expansion of the Trumpeter Swan population into its historical summer range. The sample could be surveyed, in sections, over a five year period. Within each sample unit, the presence or the absence of swans would be documented. Additionally, the actual habitat suitable for swans could be measured and expanded for the entire continent. This survey would provide a point of reference to which future researchers and managers may document the re-establishment of Trumpeter Swans. We recommend that such a survey be implemented as soon as possible.

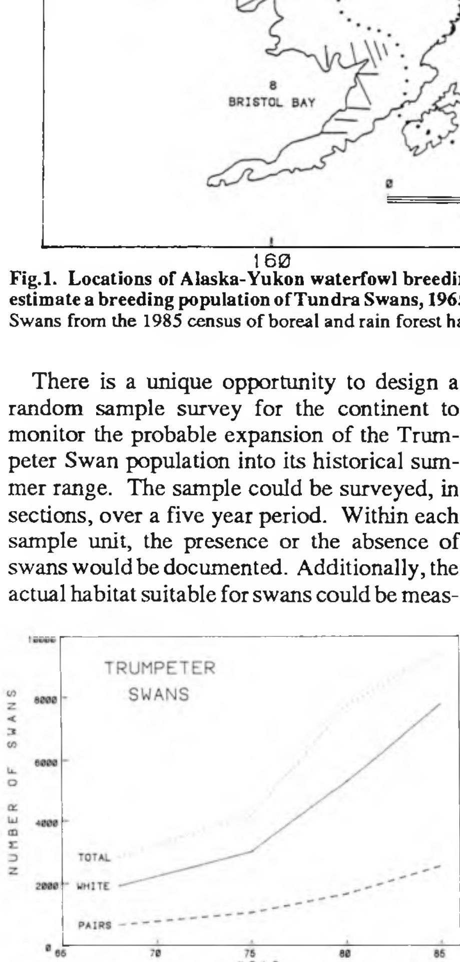

Fig.2. Numbers of Trumpeter Swans recorded on Alaska-wide censuses during August/September for 1968, 1975, 1980, and 1985. The line for white swans best shows the population increase.

The combination of the census and random sample surveys has provided the bulk of the high quality data on population status for effective management of Pacific coast Trumpeter Swans. An additional benefit has been the precise location data that has been gathered and stored in a computer for easy retrieval and depiction. Detailed map overlays at various scales have been useful to a substantial and varied group of biologists, developers, land managers and planners.

The return of Trumpeter Swans into their former range is an exciting phenomenon. Since swans are easily surveyed by aircraft with a high degree of accuracy, we have a rare opportunity to successfully monitor this event. Annual measurements of productivity, population structure and distribution are critical to understanding the interactions of weather, habitat and population dynamics.

Trumpeter Swans were nearly eliminated

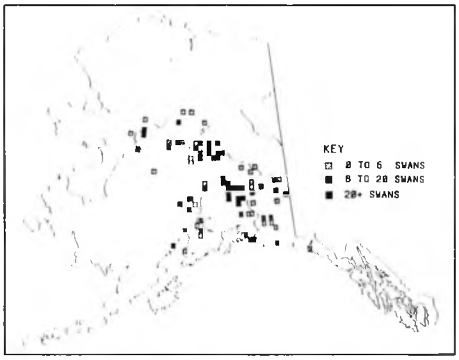

Fig.3. Locations of 80 sample maps (selected from 425, 1:63,360 scale USGS maps) for the 1986 Trumpeter Swan survey. Stratification was based on the number of single and paired swans only.

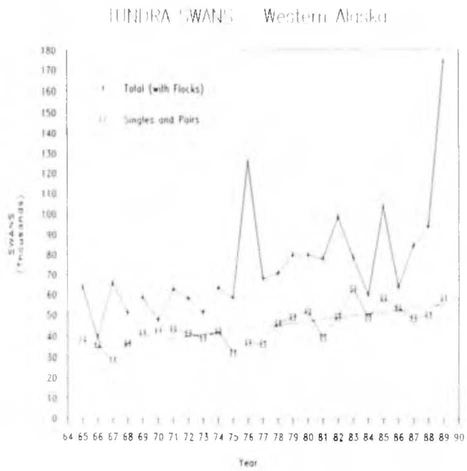

Fig.4. Tundra Swan annual breeding population index as measured during May/June on the Alaska-Yukon waterfowl breeding population survey, 1965-1989 (Bristol Bay, Yukon Delta, Seward Peninsula and Kotzebue Sound units only).

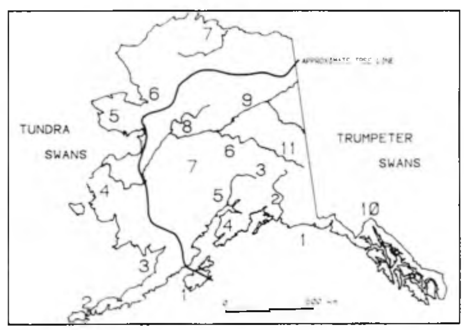

Fig.5. Locations of Alaska map survey units, 1-11 (Tables 2 & 3) for Trumpeter Swans in the boreal and rain forest habitat and 1-7 (Table 5) for Tundra Swans on the tundra habitat.

throughout most of North America by the early 1900s (Bellrose 1976). Population reductions may have occurred to a lesser extent in Alaska because of later settlement by caucasians, larger areas of remote nesting habitat or more isolated wintering habitat. White swans increased at an average annual rate of 6.5% from 1968 until 1975 (King 1976), then increased 12% per year until 1985 (Conant *et al.* 1986). The ability of these Trumpeter Swans to increase steadily may in large part have been due to minimal hazards from poisons, shooting and powerlines in their nesting and wintering grounds and over their migration route. As Pacific coast Trumpeter Swans continue to increase, they are being forced to pioneer new wintering sites, often further south, and will be subject to the hazards of an expanding human civilization. The measured increase might slow, stop or even reverse before all nesting habitat is fully occupied.

Tundra Swans

The same bias for missing swans during map searches also applies to Tundra Swan surveys. Although densities of swans in some coastal areas increase the difficulty of plotting swans, tundra habitat with sparse vegetation allows them to be more visible than are Trumpeter Swans in the boreal and rain forest. Complex patterns of wetlands can make navigation more difficult and further complicate the survey process. Careful pilot and observer training can reduce the proportion missed. Sightability correction factors could be developed for crews and areas (Wilk 1988) to increase accuracy.

Although Tundra Swans present a greater challenge, the technique used for Trumpeter Swans can be used effectively for summering Tundra Swans. A sampling scheme based on quarter sections of USGS quadrangle maps appears to be the best method for Tundra Swans. In Alaska, it would be feasible to conduct a stratified random survey of 1/5 of all the quarter section maps containing Tundra Swan summering habitat in each of five years without replication (Fig.6). Thus, at the end of five years, an almost complete data set would be available as a basis for an improved sampling design. The location data, although not as precise in high density areas, would be equally valuable to that for Trumpeter Swans. Likewise, it would be possible to expand the sampling effort eastward to measure the continental population on its

Table 5. Summary of Tundra Swan observations using the map method of survey during July-August, by survey unit in Alaska for 1980-1988.

Unit	Year	Maps Surveyed	White Swans in Pairs	White Swans as Singles	White Swans in Flocks	Cygnets	Total Swans	Number of Broods	Average Brood Size	Per cent Juvenile
1 Kodiak	80	8	46	5	0	32	83	11	2.9	39
	81	7	56	5	18	33	112	12	2.8	29
	84[a]	5	32	4	16	28	80	10	2.8	35
	85	8	32	0	21	31	112	12	2.6	28
	86	9	52	2	17	7	88	7	2.4	19
	87	9	82	12	16	35	145	11	3.2	24
	88	11	92	9	34	60	195	25	2.4	31
2 Izembek	88	1	100	1	259	40	400	14	2.9	10
3 Bristol Bay	84	32	1712	176	1169	1187	4244	359	3.3	28
	85	11	662	100	467	382	1611	133	2.9	24
	86	22[b]	370	45	170	199	784	58	3.4	25
	87	20[c]	420	33	220	261	934	87	3.0	28
	88	19[c]	324	27	192	108	651	47	2.3	17
4 Yukon Delta	87	50[b]	2640	547	2763	1541	7491	576	2.7	21
5 Seward Peninsula	NO DATA AVAILABLE									
6 Kotzebue Sound	83	4	276	26	127	281	710	81	3.5	40
	84	2	334	42	23	187	586	64	2.9	32
	85	23	1060	35	218	637	1950	234	2.7	33
	86	15	376	25	243	334	978	107	3.1	34
	87	26[d]	940	105	923	620	2588	224	2.8	24
	88	21[e]	746	132	527	745	2150	237	3.1	35
7 North Slope	82	4	140	7	105	85	337	35	2.4	25
	83	18	420	37	189	296	942	113	2.6	31
	84	19	324	42	149	202	717	80	2.5	28
	85	15	266	29	190	142	627	56	2.5	23
	86	11	414	45	255	95	809	42	2.2	12
	87	11	324	33	71	159	587	63	2.5	27
	88	10	334	40	32	126	532	60	2.1	24
TOTAL	80	8	46	5	0	32	83	11	2.9	39
	81	7	56	5	18	33	112	12	2.8	29
	82	4	140	7	105	85	337	35	2.4	25
	83	22	696	63	316	577	1652	194	3.0	35
	84	58	2402	264	1357	1604	5627	513	3.1	29
	85	57	2048	164	896	1192	4300	435	2.7	28
	86	57[f]	1212	117	685	645	2659	214	3.0	24
	87	116[g]	4438	731	3997	2626	11745	965	2.8	25
	88	62[h]	1596	209	1044	1079	3928	383	2.8	27
9 year average									2.8	29

a. gap in year sequence
b. all quarter quads
c. includes 11 quarter quads
d. includes 18 quarter quads
e includes 16 quarter quads
f. includes 22 quarter quads
g. includes 79 quarter quads
h. includes 27 quarter quads

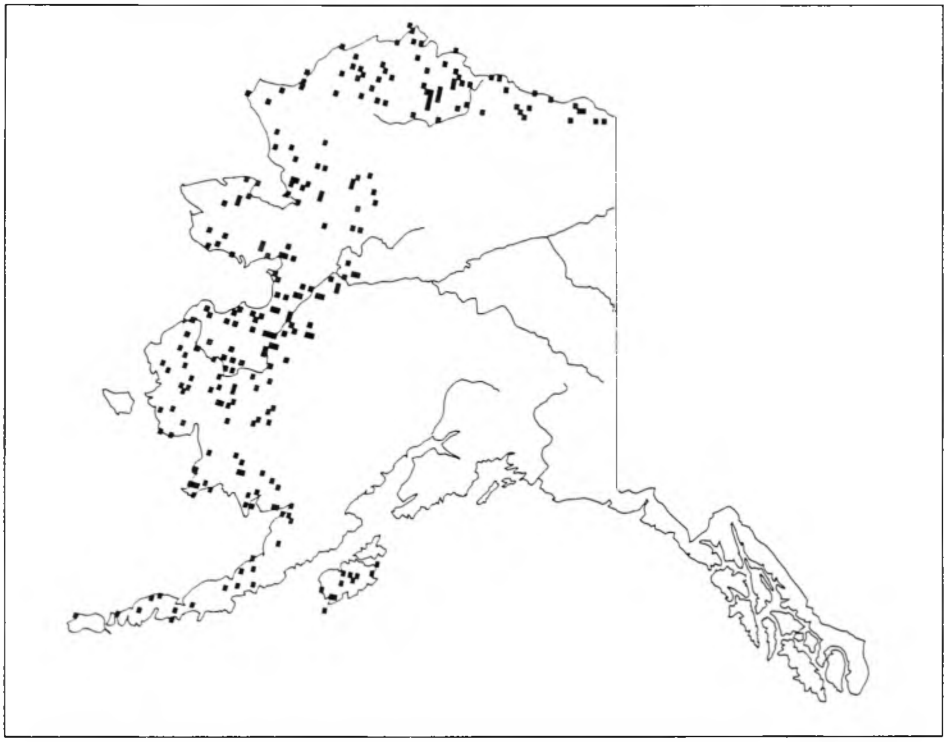

Fig.6. Theoretical random sample of 1/5 of the quarter sections of 1:63,360 scale USGS maps containing Tundra Swan summering habitat in Alaska.

summering grounds. It would seem prudent to do so considering the sport harvest and the subsistence take in Alaska and Canada.

Trumpeter and Tundra swans

A definitive line of differentiation between Trumpeter and Tundra swan summering grounds is not apparent in Alaska. There appears to be overlap, especially in unit 8, the Koyukuk River Valley (Loranger 1988, R.J. Wilk, unpubl. data). Incidental records of Tundra Swans in traditional Trumpeter summering range and vice-versa exist. Expanding populations of both species can be expected to confuse this aspect further. Speciation of swans from fixed wing aircraft is not practiced. Systematic ground searches should be conducted over a number of years to sort out swan species composition throughout the combined ranges.

Swans may be an ideal indicator species for predicting duck or goose production in interior Alaska. Environmental conditions should affect these groups of waterfowl in a similar way on the nesting grounds and a strong relationship may exist between them. A positive correlation, R=0.74, between six years of data from an annual sample of boreal forest duck production surveys in Alaska (Hodges & Conant 1987) and six years

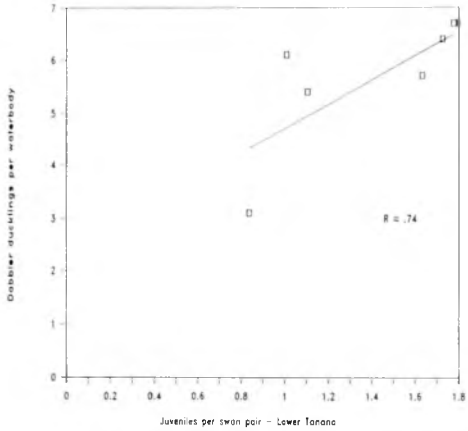

Fig.7. Correlation of Trumpeter Swan production data from a combination of census, random and non-random sample surveys in unit 6, the lower Tanana, with boreal forest duck production data from a combination of non-random sample surveys in Alaska, 1983-1988.

of data from census, random and non-random Trumpeter production surveys (Fig.7) is encouraging. There are inherent deficiencies in each data set. The data for duck production were collected over a broad area, while the data for Trumpeter Swan production all came from unit 6, the lower Tanana (Fig.5). The duck production survey was non-random and samples varied widely each year. The non-random Trumpeter Swan samples (1983, 1984, 1987, 1988) may not have reflected Alaska-wide production accurately. Nevertheless, the correlation suggests that a true relationship exists. Refined sampling methods for surveys for both waterfowl groups could determine its authenticity. It would be reasonable to expect similar results from such an approach on tundra waterfowl habitats. Consistent duck, goose and swan production surveys over broad areas and over a period of years would provide the data necessary to establish these relationships.

Since 1980, the USFWS has been producing high quality plots of swan data. They can be overlayed onto USGS 1:63,360 and 1:250,000 scale maps with a computer using custom-designed software. Complete censuses have provided data without major geographical gaps for thorough planning processes. The USFWS is currently converting this unique system over to an ARC/INFO geographical information system (GIS) for IBM compatible PC operation. With ARC/INFO, it will be possible to query and map multiple years of data to address more complex biological questions relating to swan distribution. Other GIS data bases, such as land ownership throughout Alaska, could be merged directly with the swan data base. This will be a valuable tool for setting land management priorities relating to acquisitions, exchanges and opportunities for preservation. ARC/INFO can provide a more standard, available format for other swan data bases elsewhere.

New technology offers exciting possibilities for easing the burdens of data acquisition and archival. Long range (loran-C) and satellite navigation positioning for small aircraft can enable transfer of observations and exact positions directly to computers. Eventually, remote sensing data from satellites could make a total census of the swans of the world possible.

Many people have had varying degrees of involvement in the development of the survey system described, and in collecting the substantial amount of data. A few require special recognition. H.A. Hansen was responsible for much of the early swan work in Alaska. J.G. King organized the first complete census for Trumpeter Swans in 1968 and set the pattern for the future. We are indebted to the many aircraft mechanics who maintained the various aircraft depended upon over the years. Special thanks are due T. Smith, J. Lawhorn, and E.L. Mitchell in the U.S. Department of the Interior aviation branch. Numerous skilful wildlife pilots were an essential part of the team effort. The authors personally flew many hours of surveys. H.A. Hansen, R.J. King, M.A. Spindler, W.I. Butler and many other government and non-government pilots participated. A dedicated cadre of biologists also served as observers during the many surveys. The computer manipulation of data required the skills of many computer programmers and technicians. Special recognition is due to B.C. Dearborn and R. Slothower for the ARC/INFO adaptation and to S.L. Cain for much of the custom programming. Others involved in initial programming efforts include G. Konkel and G. Fuller. Administrative support for the program was needed from D.V. Derksen, J. Bartonek, W. Ladd, J. Baker, R. Pospahala and others.

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