A SAMPLING METHOD FOR TUNDRA SWANS SUMMERING IN THE BRISTOL BAY LOWLANDS NORTHERN ALASKA PENINSULA

A summary of a presentation given at the second Alaska Bird Conference, Juneau, Alaska, 3-4 April 1987

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Extensive aerial surveys of tundra swans nesting in the northern Alaska Peninsula were conducted in 1984-1985 to document population parameters. Sixty 1:63,360 quadrangle maps were surveyed then divided, a posteriori, into 1/4 map sampling units (SU's), and were stratified into three swan density classes based on paired and single swans/km^2. The amount of swan habitat within each SU was variable in area lending itself to a ratio estimate method for the final 186 SU's established. Based on optimum allocation from 1984-1985 "base-year" data, it is predicted that 37 SU's (19.9%) will provide a 95% confidence interval (CI) index of ± 0.10 for nesting swans. A sample of 87 SU's (46.8%) provides an index of ± 0.05 (95% CI). In June 1986, a random sample of 28 SU's (15.1% sample) was surveyed and provided an index of 2875 ± 503 (95% CI) potential breeding swans. An aerial swan sightability correction factor developed in the 1986 survey refined this index to an estimate of 3954 ± 809 swans, suggesting that 37.5% of the swans were not seen by the standard survey method. Estimates of swans in flocks, and recruitment can also be calculated by this method. This sampling method can be readily applied to other areas of Alaska and throughout the species" breeding range.

(note: this summary updates and comprises a minor revision of the same presentation given at the Refuges and Wildlife Project Leaders' Meeting, U. S. Fish and Wildlife Service, 8-11 December 1986.)

A "census" of tundra swans occurring in the northern Alaska Peninsula was conducted over 1984–1985, with supplemental information provided from preliminary surveys conducted in 1983. Eighty-seven percent of the 18,009 km^2 (6953 mi^2) survey area was flown in June 1984 with the remaining 13% surveyed in June 1985. The results enabled Alaska Peninsula/Becharof National Wildlife Refuges to develop a sampling method with predictable results. The 1:63360 U.S. Geological Survey topographic quadrangle maps were used to survey swans, and were then subdivided into "1/4 maps" (or quadrants) for subsequent sampling (Fig. 1).

Paired and single swans were used as the basis for stratifying 1/4 sampling units (SU's) (a posteriori). Three density strata, low (0–0.1 swans/km^2), medium (0.1–0.2) and high ($\geq$0.20–0.60) (Fig. 2), were developed. Summary statistics are in Table 1.

To estimate sample sizes needed for future surveys, it was necessary to estimate the variability of swans in each stratum. The stratum variances, S_{dh}^2 (h=1, 2, 3), were computed from the 1984–1985 "base-year" results (Table 1) (Cochran's formula 1977:173).

In the Alaska Peninsula study area, many of the SU's were not contiguous potential swan habitat, thus areas within 1/4 maps were unequal-sized (individual SU areas of swan habitat ranged from 5km^2 (2mi^2) to 159km^2 (61mi^2)). This information lends itself to calculations of the ratio method (Caughley 1977a, 1977b, Caughley and Grigg 1981, McLaren and McLaren 1984). Ratio estimates applied to wildlife populations are commonly used in transect sampling, having transects of unequal length. This same principle has been applied here to quadrant plots of unequal swan habitat area.

For a specific sample size, n, it is possible to select the number of SU's, n_h (h=1, 2, 3), which should be sampled in each stratum to minimize the uncertainty about the estimate of total swans. This uses optimum allocation of sampling effort with a ratio estimate (Cochran 1977:172), and the strata sample sizes are,

$$n_h = \frac{n\left(\frac{N_h S_{dh}}{\sqrt{C_h}}\right)}{\sum_{h=1}^{3}\left(\frac{N_h S_{dh}}{\sqrt{C_h}}\right)}$$

where N_h = No. of 1/4 maps in stratum h

S_{dh} = Standard deviation in stratum h

C_h = Mean area of a 1/4 map in stratum h (mean cost of surveying)

By specifying the projected total number of paired and single swans, Y, (using the 1984–1985 total), and the degree of precision desired (size of the 95% confidence interval (CI) about the estimated number of swans), the required sample size can be estimated (Table 2). Since sample sizes within strata become small beyond $\pm$ 0.10, no other data were calculated. Small sample sizes may bias estimates of the true variance.

If one were estimating paired and single swans in the northern Alaska Peninsula, a CI of $\pm$ 5% could be accomplished by sampling 87 (46.8%) of the 186 SU's (Table 2). The sample size is reduced to 37 (19.9%) when the CI increases to $\pm$ 10%. The projected sample sizes, n = 87, n = 37, were calculated with (Hodges et al. 1986),

$$n_h = \frac{\sum_{h=1}^{3}\left(\frac{N_h S_{dh}}{\sqrt{C_h}}\right)\sum_{h=1}^{3}\left(\sqrt{C_h}\, N_h S_{dh}\right)}{.25\, P^2 \hat{Y}^2 + \sum_{h=1}^{3} N_h S_{dh}^2}$$

where,

Sdh = standard deviation for stratum h

C_h = Mean area of an SU in stratum h

P = proportional error (precision)

$\hat{Y}$ = estimated population index = 2862

In 1986, we randomly chose 30 SU's to survey, optimally allocated, estimating the number of units we could survey in one week. We were able to survey 28 (Table 5). Concurrent with standard surveys, we used an intensive survey method (Fig. 3) to compare the number of swans seen and estimate a simple preliminary "sightability correction factor". The results are seen in Tables 3 and 4.

This method for sampling numbers of swans can be used to estimate the number of swans in flocks, and recruitment. This paper presents a summary of only swans seen in pairs or as singles.

Once the stratified sample has been flown and the data collected, the analysis is as follows:
The subscript **h** denotes the stratum and **i** the SU within the stratum. The following symbols all refer to stratum h.

N_h = total number of sampling units

n_h = number of units sampled

y_{hi} = number of swans in the ith unit

$\bar{y}_h$ = mean number of swans per unit sampled

syh^2 = variance of numbers between sampled units

$\hat{Y}$ = estimate of total number of animals in all strata

Designating the area of a sampled unit (area of potential habitat within a quadrant) as z_i and total area under survey as **Z**,

$$\hat{Y} = \frac{\sum_h N_h \; y_{hi}}{\sum_h N_h \; \bar{z}_{hi}} \quad Z$$

To calculate the $\widehat{SE}$ of $\hat{Y}$, we first define

$$\hat{R} = \hat{Y} \,/\, Z$$

and

$$s_{hzy} = \frac{1}{n_h - 1} \quad \sum_i z_{hi} y_{hi} - \frac{\left(\sum_i z_{hi}\right)\left(\sum_i y_{hi}\right)}{n_h}$$

$$\widehat{Variance}_{\hat{Y}} = \frac{N_h \; (N_h - n_h)}{n_h} \quad syh^2 - 2Rshzy + R^2 szh^2$$

$$\widehat{SE}_{\hat{Y}} = \sqrt{\widehat{Variance}_{\hat{Y}}}$$

with s_{yh}^2 being the variance of numbers per sampled unit in the hth stratum and s_{zh}^2 the variance of the sampled units in the same stratum.

The population index estimate pools the stratum estimates to provide an overall estimate of swans and its SE.

BENEFITS
are axiomatic

* Statistically valid method for estimating tundra swan population indexes with predictable precision, based on a sample of < 1/5 the cost of a census (for a ± 0.10 95% CI about the estimate)
* Since tundra swan densities in Alaska are much higher than trumpeter swans' (which use large map units for estimating populations), plot-sampling of tundra swans lends itself to the smaller 1/4 maps which reduces the variance of swan numbers in strata, especially high-density strata, thus providing more precise estimates
* Estimates of swans in flocks (non- or failed breeders), and recruitment can be calculated using the same methods
* Estimate based on areas of actual swan habitat provides way to monitor waterfowl habitat conditions in small land blocks with tundra swan as the "indicator species"
* Per unit surveyed, 1/4 units are cheaper and quicker to survey than larger maps - has psychological spin-off for pilots and observers
* During years when population indexes are not needed, ≤ 20 SU's can be monitored annually to compare between/among year trend changes
* Method could be readily applied to other areas of Alaska and throughout the species range - 1/4 maps could be stratified, a priori, based on pond / wetland densities in tundra swan nesting habitats (Fig. 4)

Table 1. Summary statistics and stratum variances from 1984-1985 base-year census.

	Stratum		
	Low	Medium	High
Mean area (km^2) (cost) of swan habitat (C_h)	78.1	109.5	106.1
Standard deviation	49.0	37.6	44.1
Mean no. swans observed	4.5	15.6	27.6
Standard deviation	4.6	6.7	14.4
Variance (Sdh^2)	13.0	16.5	72.5

Table 2. Sample sizes and allocation of sampling units to obtain various 95 % confidence intervals on total observed paired and single swans using the standard survey in the northern Alaska Peninsula.

	Sampling units (N)				
Interval	Low	Medium	High	Total	Percentage of sampling units
± 0.00	68	58	60	186	100.0
± 0.05	24	20	43	87	46.8
± 0.10	10	9	18	37	19.9

Table 3. Preliminary results from tundra swan aerial surveys conducted by two different methods in the northern Alaska Peninsula, 1986.

JUNE

Swans	152m	75m	% not seen	P value	Simple VCF
In pairs	188	248	24.2	P<0.005	
Singles	62	80	22.5	NS	
Potential breeders	250	328	23.8	P<0.002	1.31

JULY

Swans	152m	75m	% not seen	P value	Simple VCF
In pairs	82	118	30.5	P<0.02	
Singles	14	17	17.6	NS	
Potential breeders	96	135	28.9	P<0.05	1.41

Table 4. Results from June 1986 aerial survey of tundra swans in the northern Alaska Peninsula.

	Stratum			
	Low	Medium	High	Totals
Area (km^2)	5310	6350	6363	18023
No. SU's	68	58	60	186
No. SU's surveyed	7 (8)[a]	9 (6)	12 (14)	28 (15.1%)
No. km^2 surveyed	784	1017	1426	3192 (17.7%)
No. swans seen	49	122	398	569
(x simple SCF	64	159	521	744)
Swans/km^2	0.0625	0.1200	0.2803	0.1783
(x simple SCF	0.0816	0.1563	0.3654	0.2331)
Population index	332	762	1783	2877
(x simple SCF	433	993	2325	3751)
(x SCF and associated variance				3954)[b]
SE	103.7	100.1	212.6	256.8 (8.9%)
(x simple SCF	136.0	132.1	278.3	336.9
(x SCF and associated variance				412.9)

[a]Number of units that should have been surveyed based on optimum allocation is in parentheses. The number of units actually surveyed in each stratum was adjusted to minimize bias from the small sample size in 1986.

[b]Calculations from Gasaway et al. (1986).

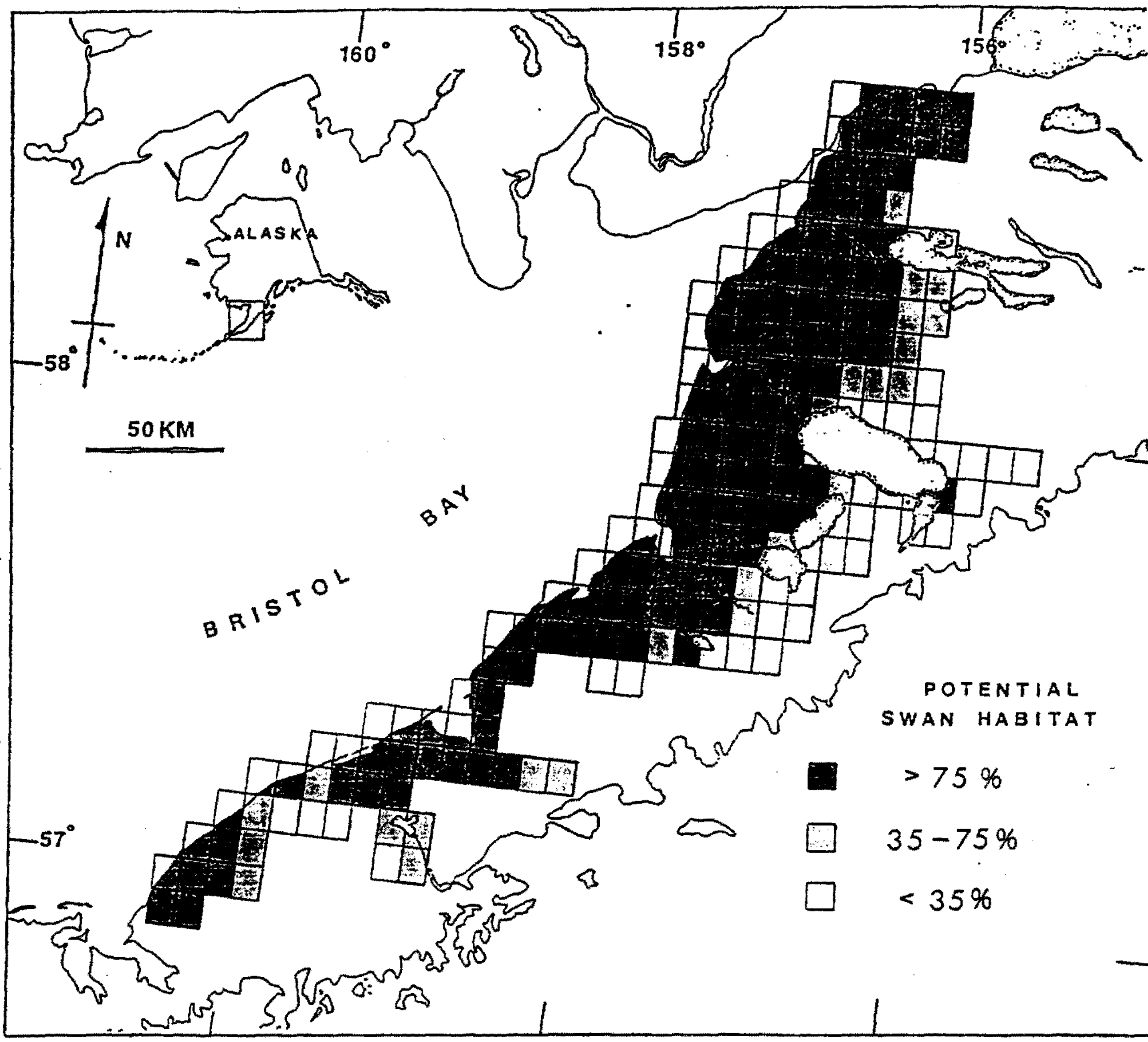

Fig. 1. Sampling units and swan habitat in northern Alaska Peninsula survey area.

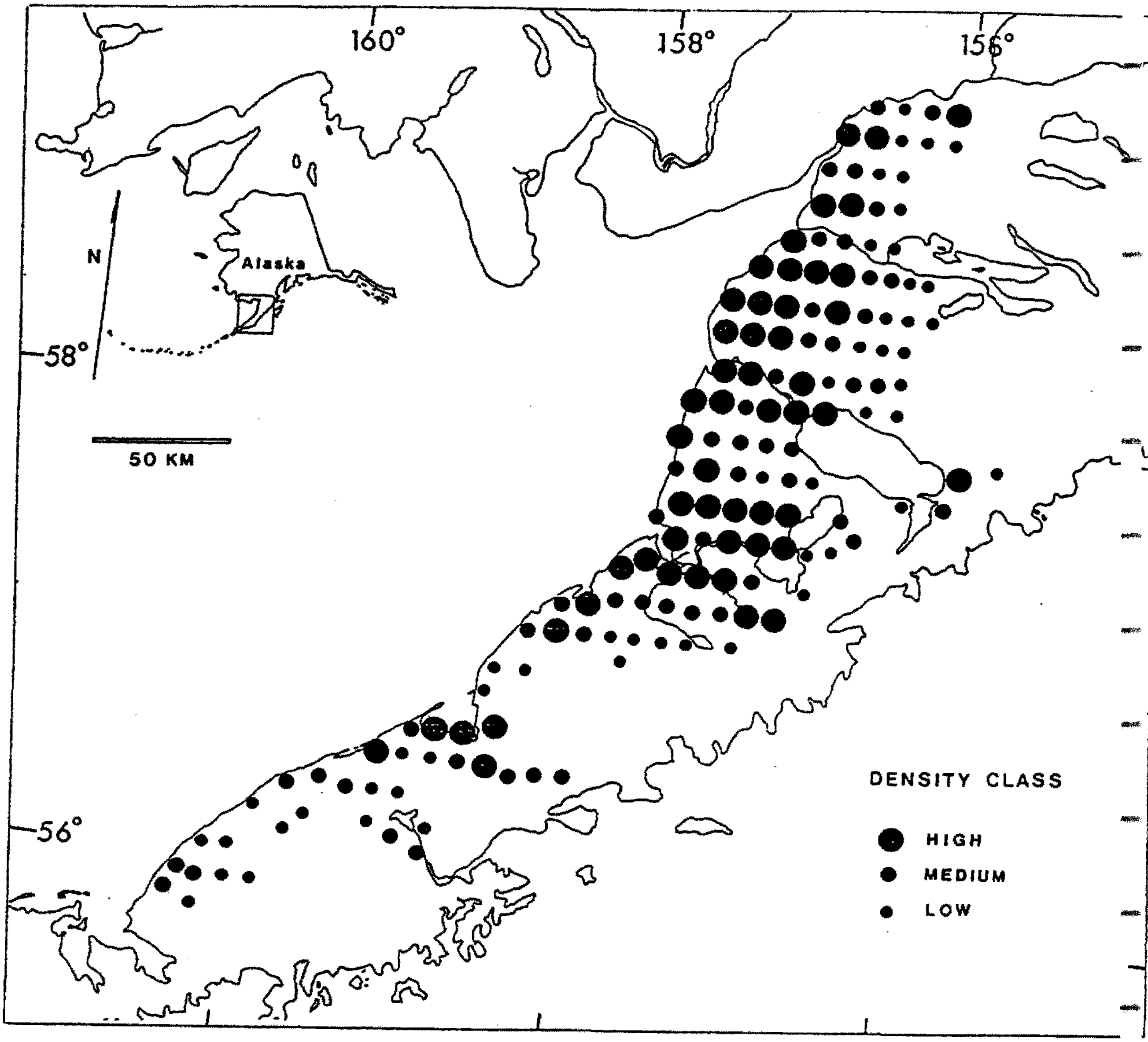

Fig. 2. Preliminary densities of swans by survey sampling unit in the northern Alaska Peninsula.

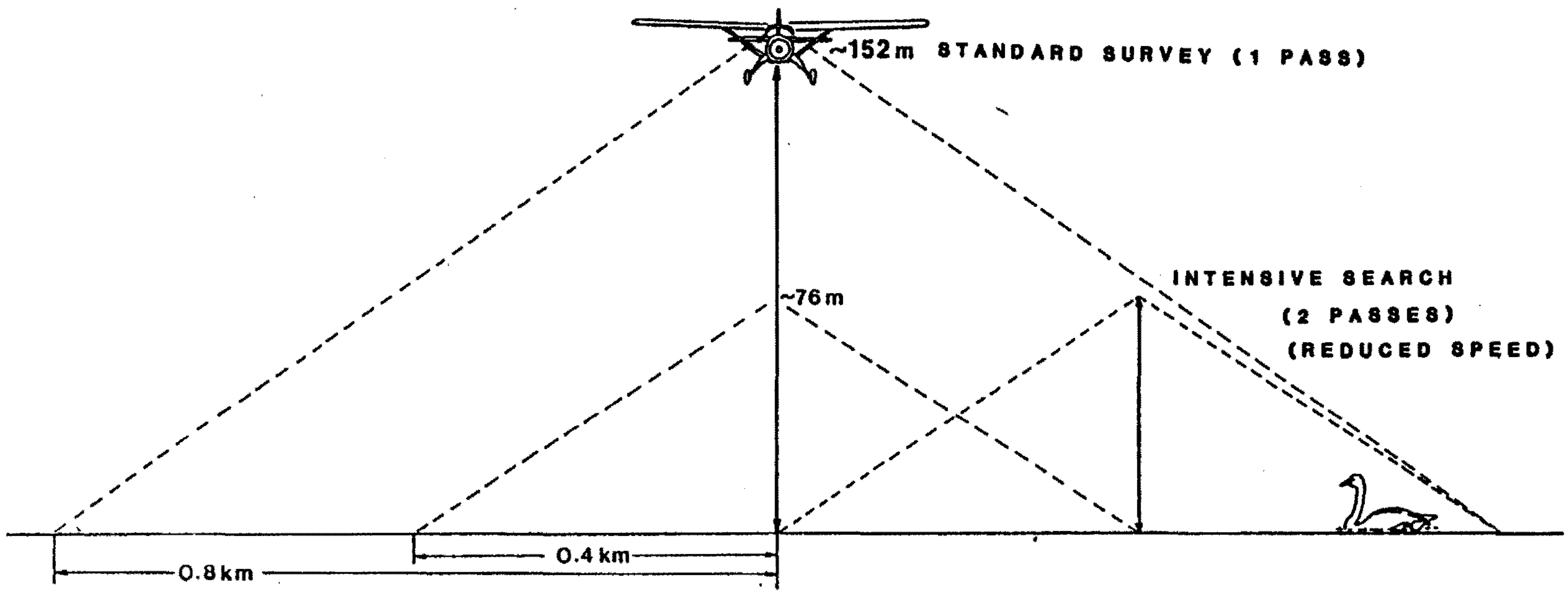

Figure 3. Two survey procedures used to estimate a preliminary tundra swan sightability correction factor in northern Alaska Peninsula study.

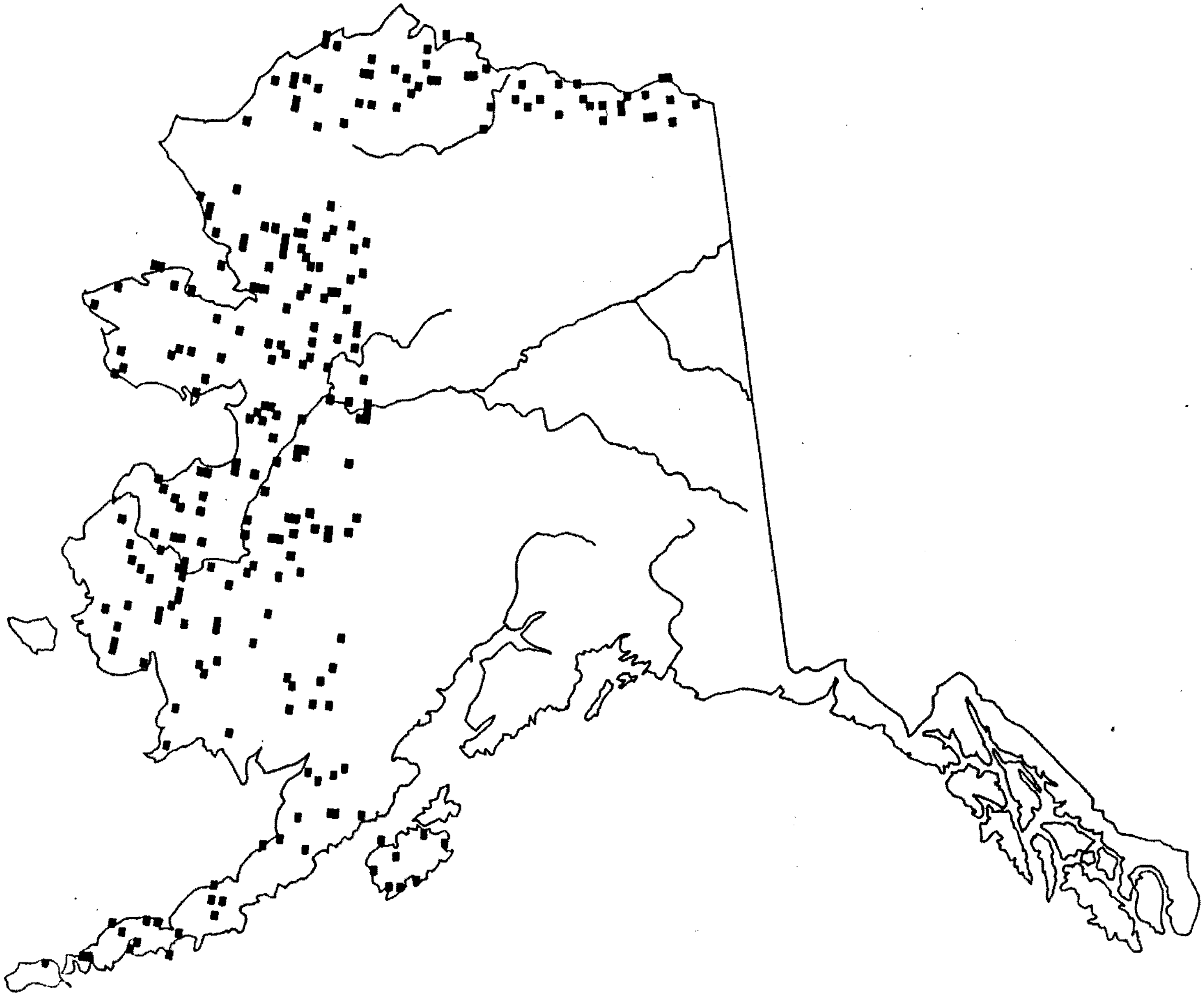

Fig. 4 . An example of random 1/4 maps distributed throughout the tundra swans' breeding range in Alaska (generated by Office of Migratory Bird Management-Waterfowl Investigations, Juneau. Alaska).

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