Winter distribution of Tundra Swans *Cygnus columbianus columbianus* breeding in Alaska and Western Canadian Arctic.

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A total of 1,499 Tundra Swans was captured on their Alaskan and Canadian breeding grounds to determine their migration routes and wintering destinations. In 14 summers of banding (1968-81) 976 (65%) swans were marked with colour neckbands, 482 (32%) with colour tarsal bands, and 41 (3%) with metal bands only. Observations of the marked swans on migration or during the winter were used to determine the breeding areas used by two populations; Eastern (EP) and Western (WP). WP Tundra Swans were found to breed in Alaska from Point Hope to the Aleutian Islands. The EP breeding range overlapped with the WP in Alaska from the Yukon Delta to Point Hope. Swans breeding east of Point Hope were all associated with the EP. Only 11 individuals (<1%) of 4,194 Tundra Swans marked on the wintering grounds of EP were later encountered in the WP. No evidence of an age or sex bias was found in the likelihood of a swan switching between the two populations. Additional bandings are needed in the area of breeding range overlap to better define the relationship between the two populations.

Tundra Swans, *Cygnus columbianus columbianus*, are the most numerous of the three swan species commonly found in North America. The U.S. Fish and Wildlife Service's (USFWS) January 1989 Midwinter Waterfowl Survey found a total of 169,300 Tundra Swans wintering in the United States (Serie 1989). Wintering Tundra Swans can be divided into an Eastern Population (EP) of 90,600 found in the eastern U.S. and a Western Population (WP) of 78,700 in the western states. Approximately 85% of the WP winter in California; the wintering EP is divided primarily between North Carolina (58.6%), Maryland (31.5%) and Virginia (6.5%).

The breeding range of the Tundra Swan in North America extends from Baffin Island and the east side of Hudson Bay westward across the arctic tundra to the Bering Sea. However, large breeding concentrations are found in only a few areas. The major nesting area in Alaska is in the Yukon-Kuskokwim delta. Nesting swans in Canada are concentrated in the Mackenzie and Anderson River deltas in the western Northwest Territories (Palmer 1976). Increased human disturbance through mineral exploration, oil drilling, settlements and road building on the arctic nesting grounds and the increased interest in the sport hunting of Tundra Swans in parts of the U.S. including Alaska, requires a better understanding of the distribution of the two wintering populations of swans on their breeding grounds. Also, more accurate breeding ground surveys may have to be initiated to assess the status of each population. However, information on the extent to which the breeding ranges of the two populations of Tundra Swans overlap is not well known (Palmer 1976, Bellrose 1980). The objectives of this study were to determine where the breeding ranges of the two populations overlapped and the extent of interchange between the EP and WP.

Methods

Through the Swan Research Program (SRP) of the Johns Hopkins University banding Tundra Swans on the breeding grounds commenced in 1968. From 1968-81, 982 Tundra Swans were banded in Alaska and 517 were banded in the Yukon or Northwest Territories of Canada. Forty-one birds were banded with metal tarsal bands only; 482 were banded with both a metal tarsal band and a plastic, colour-coded tarsal band; and 976 were banded with both metal and plastic tarsal bands and collared with a plastic, colour-coded neckband following a continental marking protocol (Sladen 1973; Sladen &

Table 1. Numbers and age and sex distribution of Tundra Swans captured on the breeding grounds at 14 locations in Alaska and Canada, 1968-81. See Fig.; 1 for the banding locations.

	Banding Location														
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	Total
Adults															
Male				5	6	1	5		21	27	6		2	24	97
Female				9	7		6		18	22	7		1	26	96
Unknown									1						1
Subadults															
Male					5	2	6		2	2	2	9			28
Female					1		1		1	6	3	3	1		16
Cygnets															
Male	3	93	35	94	21	49	36	7	32	18	2				390
Female	8	94	43	118	23	29	38	7	35	11	1				407
Unknown		1	3	1					4	4			8		21

Kistchinski 1977).

Swans were banded from the Anderson River in the Northwest Territories of Canada westward to Point Barrow and then southward along the coast of Alaska to the Alaska Peninsula. Adult Tundra Swans were captured while molting during late July and August. Cygnets were caught during August when they were large enough to band but still incapable of flight. Float planes were used to capture most of the swans, either by herding them onto land where they were hand-caught, or on the water where they were netted by a person standing on one of the floats. Boats or helicopters were also used on a few occasions to capture birds. The swans were then banded, aged, sexed, weighed and measured before release back onto the water. Age and sex data were not available for 443 swans banded in Canada. Swans captured as a group were released as a group.

Information on movements of marked swans came from resightings of live birds or reports of swans either shot or found dead. Observations of marked Tundra Swans by SRP observers primarily concentrated on the migration routes and wintering grounds of the EP. Information about WP swans relied more on reports of hunter-killed swans in Montana, Utah and Nevada and the finding of dead birds.

No swans were marked on the wintering grounds of the WP by the SRP. However, 4,194 Tundra Swans in the EP were banded on the wintering grounds from 1967-1988. Encounters with these marked swans on the breeding grounds and wintering areas of the WP provided another means of evaluating breeding distribution and the exchange of swans between the EP and WP. All encounters obtained through the 1988-89 wintering seasons were used in the analysis.

Results

Breeding Ground Distribution

Of the 1,056 Tundra Swans marked on the breeding grounds and of known age and sex, 818 were caught as cygnets (77.5%), 44 as subadults (4.2%) and 194 as adults (18.4%). Sex ratios did not differ significantly from 1:1 in any of the age groups (Table 1).

Banding sites were grouped into 14 geographic locations (Fig. 1). The number of swans marked in each location ranged from 11-277 and the number of banding years in each location ranged from 1-8. Of the 1,499 swans marked on the breeding grounds, 526 individuals were encountered 2,923 times during migration or on the wintering grounds. The percentage of birds encountered from a given banding location averaged 36.8 (s.d.=23.7, range 7.4-76.2). The highest encounter rates involved swans banded from the northern Alaska and Canada locations while the lowest were from southwestern Alaska. The difference in encounter rates was due to more birds being neck and tarsal banded in northern Alaska and Canada instead of just tarsal banded and to the concentration of effort by the SRP on the wintering grounds of the EP.

Of the 110 Tundra Swans banded on the WP breeding grounds and later encountered, 104 (94.5%) were encountered on the WP wintering areas or migration routes; 5.5% (6 swans) were associated with the EP. Only 2 (0.5%) of the 416 Tundra Swans marked on the EP breeding areas and later encountered were encountered in the west. There was a gradual reduction in the percentage of birds associated with the EP the further south Tundra Swans breed along the Alaska coast. Tundra Swans banded in three locations (A-C) south of the Yukon River delta were all encountered in the wintering areas of

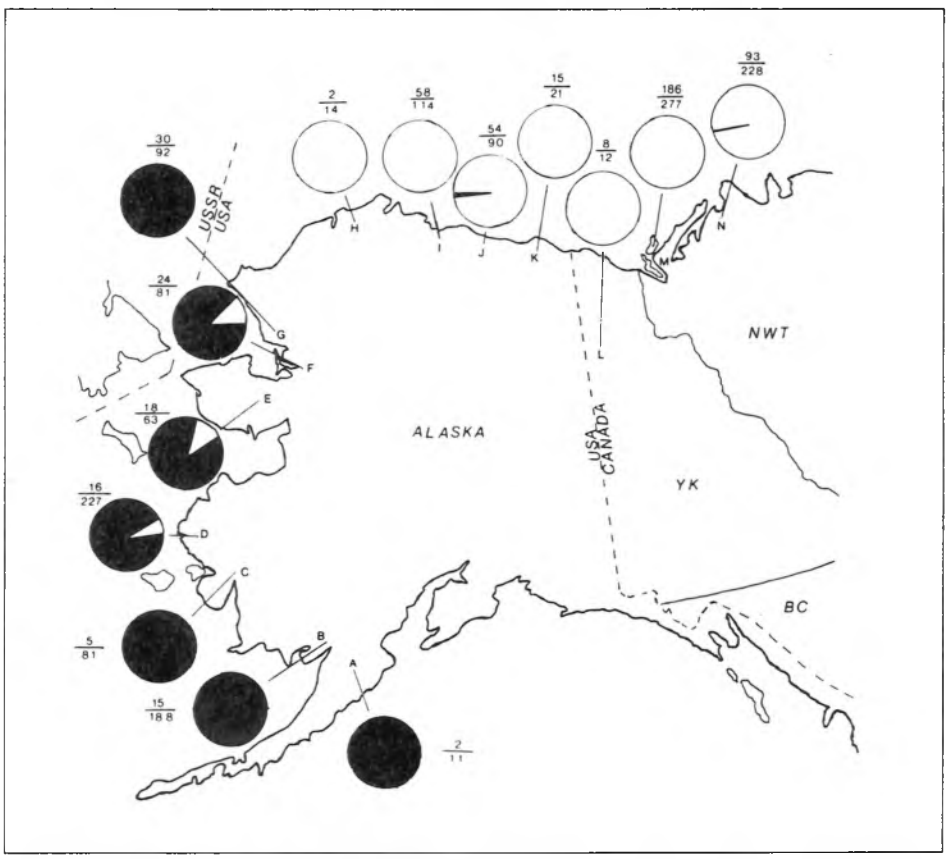

Fig. 1. Distribution of 14 Tundra Swan banding sites (A-N) in Alaska and Canada, 1968-81 and the proportion of swans encountered from each site associated with the Western Population (black area) and the Eastern Population (white area). Lower number denotes number of swans banded; top number denotes number encountered, 1968-88 from each site.

the WP (Fig. 1). The percentage of the birds encountered in the migration or wintering areas of the EP gradually increased from 6.3% (1/16) in the Yukon River delta (location D) to 11% (2/18) on the Seward Peninsula (location E) to 12.5% (3/21) in the Kotzebue-Selawik area (location F). However, the 30 Tundra Swans encountered out of 92 swans banded in the Noatak River area north of Kotzebue (location G) all were associated with the WP. Locations D-G could represent a zone of transition between the EP and WP. The distribution of members of each population in this zone may be clumped leading to the situation as in location G where all of the swans encountered were from the same population. No banding was done in the area between Point Hope and Wainwright although Tundra Swans do nest in this region (Palmer 1976). From Wainwright eastward, virtually all of the Tundra Swans marked and subsequently encountered, were part of the EP. The percentage of birds encountered from each location should be compared only with great caution because of the differing probabilities of resighting a bird with a neckband versus a bird with just tarsal bands and the greater observational effort in the range of the EP.

The six swans (four males, two females) banded in the western Alaskan locations (D,E,F,) and encountered in the east were all caught as flightless cygnets. Three of the males were encountered in the east during their first winter indicating that they had probably accompanied their parents to the wintering area of the EP since swans migrate as family groups and the other was encountered during his second winter. The females were resighted during their third and ninth winters respectively. The two swans from northern Alaska that were encountered in the wintering area of the WP had been banded as an adult male (location N) and as a yearling male (location J).

An additional 42 EP Tundra Swans banded on the wintering grounds were encountered on the breeding grounds in Alaska (12), Yukon (3), and the Northwest Territories (27). The Alaskan encounters were all in banding locations H,I,J,and K. The majority of encounters (7) occurred in location I. The three Yukon encounters all came from the Tent Island area. Ten of the Northwest Territories encounters occurred in location M and six in location N. The remaining Northwest Territories encounters all originated in more easterly sites ranging from Bathhurst Inlet to Coats Island in Hudson Bay.

Interchange between Eastern and Western Populations.

The banding of 4,194 EP Tundra Swans on their wintering grounds in Maryland and North Carolina resulted in 11 individuals (<1%) being encountered on the wintering grounds or migration routes of the WP. Six of these individuals (54.5%) were either shot or found dead while the others were resighted. Five of the adult swans were encountered in the west during their first winter after banding. The remaining three adults were encountered in their third, fifth and twelfth winters after banding. Only one swan, F241 banded as an adult female at Blackwater National Wildlife Refuge near Cambridge, Maryland, was seen back in the wintering area of the EP after having been seen wintering in California.

Of the EP Tundra Swans encountered in wintering areas or on migration routes of the WP 45.5% had been banded as adult males. Swans banded as adult females accounted for 27.3% of the birds switching from the East to the West. Three of the eleven swans (27.3%) were banded as juveniles (2 males, 1 unknown sex). Two of the three juveniles were encountered in the west during their first winter after banding as 2-year-old birds. The other juvenile was shot in Utah during his second winter after banding, as a 3-year-old.

Discussion

The two populations of Tundra Swans found in North America have breeding ranges which overlap to a limited extent in western Alaska. The WP breeds in Alaska from Point Hope southwest to the Aleutian Islands. The EP shares the breeding range of the WP from the Yukon River Delta to Point Hope. However, from Point Hope north and east, virtually all nesting swans belong to the EP.

The mechanism which allows birds to winter in the "wrong" area deserves some attention. For many waterfowl the birds change wintering and summering areas through mating (and then staying) with a bird from a strange area. Tundra Swans habitually migrate as family groups and so the young from a pair whose dominant partner heads for the "wrong" wintering area would be likely to learn this migration route. A bird which swapped mates, or whose mate died, could swap wintering or breeding grounds when remating. For example, F241 may have mated with a WP male, in an EP breeding area, in her second summer after banding and subsequently mated again with an EP male.

It has been proposed that the migration corridors of the EP and WP overlap in the region of Lake Athabasca in Northern observations of large concentrations of Tundra Swans at this location. WP and EP swans may also both use the Mackenzie River delta in the Northwest Territories as a staging area (Bellrose 1976, Paullin & Kridler 1988). Either of these locations may be where the EP swans breeding in locations D-F leave the WP and continue on to the east coast of the U.S. However, without the verification of marked individuals, the importance of the two regions as a staging ground for the two populations is uncertain. If the two populations do meet on migration it is easy to see how swapping could arise. If they do not then a lost bird or two, every few years, which eventually joined the other population could sustain the level of anomaly encountered.

The two North American populations of Tundra Swan may have arisen as a result of Pleistocene glaciation. During the last glacial advance, a single Tundra Swan population may have been divided into two groups. One group wintered south of the ice along the Atlantic coast and bred in an ice-free area in the Canadian Arctic. This group would have become the present day EP. The other group, wintering on the Pacific coast, may have bred in an ice-free area in the Bering Sea region. This group would have become the present day WP. Expansion of the EP westward from its Pleistocene breeding area would have brought it into contact with the WP along the central Alaskan Bering Sea coast. The WP, which occupies more productive breeding area than the EP (Lensink 1973) may not have needed to expand its breeding range as much as the EP to accommodate an increasing population. However, Tundra Swans have recently been found breeding on the Chukotski Peninsula in northeast Siberia (Kistchinski *et al.* 1975) and probably wintering in California

(Evans & Sladen 1980). The movement of EP swans westward across northern Alaska would have resulted in the present migration pattern of the Tundra Swans from the Arctic Slope of Alaska, migrating almost 6,000 km across the continent, to winter in the east. In contrast, they would only need to fly 4,500 km to winter in California.

The importance of glacial isolation in the development of subspecies and species of birds was first postulated by Rand (1948). Geographical isolation by glaciation has been proposed as the mechanism resulting in present northern swan species and subspecies (*C. cygnus* and *C. columbianus*) (Ploeger 1968; Johnsgard 1974). Palmer (1976) felt that Pleistocene glaciation could have contributed to the formation of Canada Goose (*Branta canadensis*) subspecies. Mengel (1964) proposed a model of species formation in wood warblers (*Parulidae*) in North America based on the isolation of populations during the glacial ages. The isolation of the two North American Tundra Swan populations was not of sufficient duration to result in the formation of separate subspecies, although WP swans may have a greater amount of yellow in the lores than do EP Tundra Swans. (Allen & Limpert unpubl.).

Our study found that while interchange between the two populations does occur, the numbers of birds involved is small since <1% of 4,194 EP Tundra Swans banded on the wintering grounds were encountered in areas used by the WP. However, increased observer effort on the wintering areas of the WP could result in more EP Tundra Swans being observed there. There was no evidence that a particular age or sex group was more likely to switch between the two populations. We also have evidence that at least three individuals that switched populations later return to winter in a subsequent year with the original population. Two of these swans were marked as adults in the EP and the other had been marked as a cygnet on the Seward Peninsula.

It seems likely that the mechanism for the anomalous migrations observed will have been some form of abmigration. The premature breakup of family groups may have a bearing on the frequency with which this happens. Further human disturbance on the breeding grounds, or on migration and in the winter from shooting, may increase the number of EP and WP birds wintering in the other's range.

If human activity in the arctic nesting areas of the Tundra Swan continues to increase and as more states have sport hunting seasons on Tundra Swans, the need for more information on the biology and population dynamics of the Tundra Swan will also increase. Although the breeding range of the Tundra Swan is extensive, breeding concentrations are few and located primarily in vulnerable river deltas. The present hunting plan for Tundra Swans calls for an annual harvest of <10% of the population found in any state or province (USFWS 1982). A single annual winter population census may not continue to be an adequate means of monitoring the Tundra Swan population or on which to base management decisions. While our results provide an indication of the relationship between the breeding areas of the two Tundra Swan populations, increased banding of birds in the area of overlap in Alaska is needed. This action should also coincide with greater observer effort on the migration routes and wintering areas of both populations.

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References

Bellrose, F.C. 1976. *Ducks, geese and swans of North America.* Stackpole Books, Harrisburg, Pennsylvania.

Bellrose, F.C. 1980. *Ducks, geese and swans of North America.* 3rd ed. Stackpole Books, Harrisburg, Pennsylvania.

Evans, M.E. & Sladen, W.J.L. 1980. A comparative analysis of the bill markings of Whistling and Bewick's Swans and out-of-range occurrences of the two taxa. *Auk* 97:697-703.

Johnsgaard, P.A. 1974. The taxonomy and relationships of the northern swans. *Wildfowl* 25:155-161.

Kistchinski, A.A., Zlotin, R.I., & Flint, V.E. 1975. The breeding of the Whistling Swan (*Cygnus columbianus*) in the USSR. *Zool. J.* 54:1525-1528.

Lensink, C.J. 1973. Population structure and productivity of Whistling Swans on the Yukon Delta, Alaska. *Wildfowl* 24:21-25.

Mengel, R.M. 1964. The probable history of species formation in some northern wood warblers (Parulidae). *Living Bird* 3:9-43.

Palmer, R.S. 1976. *Handbook of North American Birds.* Vol. 2, Part 1. Yale Univ. Press. New Haven, CT. 521pp.

Paullin, D.G. & Kridler, E. 1988. Spring and fall migration of Tundra Swans dyed at Malheur National Wildlife Refuge, Oregon. *Murrelet* 69:1-9.

Ploeger, P.L. 1968. Geographical differentiation in Arctic Anatidae as a result of isolation during the Last Glacial. *Ardea* 56:1-159.

Rand, A.L. 1948. Glaciation, an isolation factor in speciation. *Evolution* 2:314-321.

Serie, J.R. 1989. *Results of the 1989 midwinter waterfowl survey in the Atlantic Flyway states.* U.S. Fish Wildl. Serv., Laurel, MD. Unpubl. Rep. 7pp.

Sladen, W.J.L. 1973. A continental study of Whistling Swans using neck collars. *Wildfowl* 24:8-14.

Sladen, W.J.L. & Kistchinski, A.A. 1977. Some results from circumpolar marking programs on northern swans and geese. *Proc. Congr. Game Biol.* 13:498-507.

US Fish and Wildlife Service. 1982. *Management plan for the Eastern Population of Whistling Swans.* U.S. Fish Wildl. Serv., Washington, DC. 23pp.

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