MIGRATION ROUTE AND WINTERING AREA OF TUNDRA SWANS *CYGNUS COLUMBIANUS* NESTING IN THE KOBUK-SELAWIK LOWLANDS, NORTH-WEST ALASKA

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Tundra Swans were marked with colour-coded neck collars (n=115) on their nesting grounds in the Kobuk-Selawik lowlands of north-west Alaska during late summer 1984-89. Resightings of 62 individual swans were obtained in Alaska, four Canadian provinces and eight states in western United States (US) during 1984-96. Observations of Kobuk-Selawik Tundra Swans occurred along a narrow route through Alaska and the Yukon Territory, and along two trans-Rocky Mountain routes, before narrowing to their wintering grounds in north-central California, primarily the Sacramento Valley. Repeated observations of several marked swans indicated traditional use of the same migration stop-over sites and wintering areas during successive years. Occasionally, Tundra Swans marked in north-west Alaska mixed with swans of the Eastern population during migration and in winter.

Keywords: Alaska, Tundra Swan, Migration, Wintering, Marking

Tundra Swans *Cygnus columbianus* in North America occur in two main populations, Eastern and Western (Sladen 1973, Bellrose 1980, Limpert *et al.* 1991). Eight distinct nesting areas, and their estimated breeding populations, have been described in Alaska: Yukon-Kuskokwim Delta (40,000); Bristol Bay (11,000); Kobuk-Selawik-Noatak rivers (2,000); Seward Peninsula (1,000); Arctic Slope (1,000); Aleutian Islands (500); St. Lawrence Island (100); and Nunivak Island (50)(Bellrose 1980). Except for the Arctic Slope, these nesting areas are used mainly by swans of the Western Population (Pacific Flyway Council 1983, Limpert *et al.* 1991). Sladen (1973) and Bellrose (1980) provided maps of migration routes and wintering areas for Tundra Swans nesting across North America; however, the routes given for the Kobuk-Selawik-Noatak swans did not correspond to our initial observations. Therefore, we examined tarsal ring encounters and neck collar resightings to better describe the migration routes, stopover sites, and wintering areas of Tundra Swans breeding in the Kobuk-Selawik-Noatak lowlands of north-west Alaska.

Methods

Techniques used to capture Tundra Swans on the nesting grounds and to fit plastic neck collars and radio harnesses were described by Spindler & Hall (1991). Collar design and codes followed Sladen's (1973) protocol in which Alaska nesting swans are allocated a blue neck collar coded with white letter/number combinations unique to each swan. Collars were applied to Tundra Swans in 1984-89, from late July to early September during the annual moult. Aluminum tarsal rings were also fitted on all marked swans. Most swans were captured within the floodplains of the lower Selawik and Kobuk Rivers (Selawik National Wildlife Refuge [NWR]), but some were caught along the lower Noatak and Squirrel rivers, and on the Baldwin Peninsula (**Figure 1**).

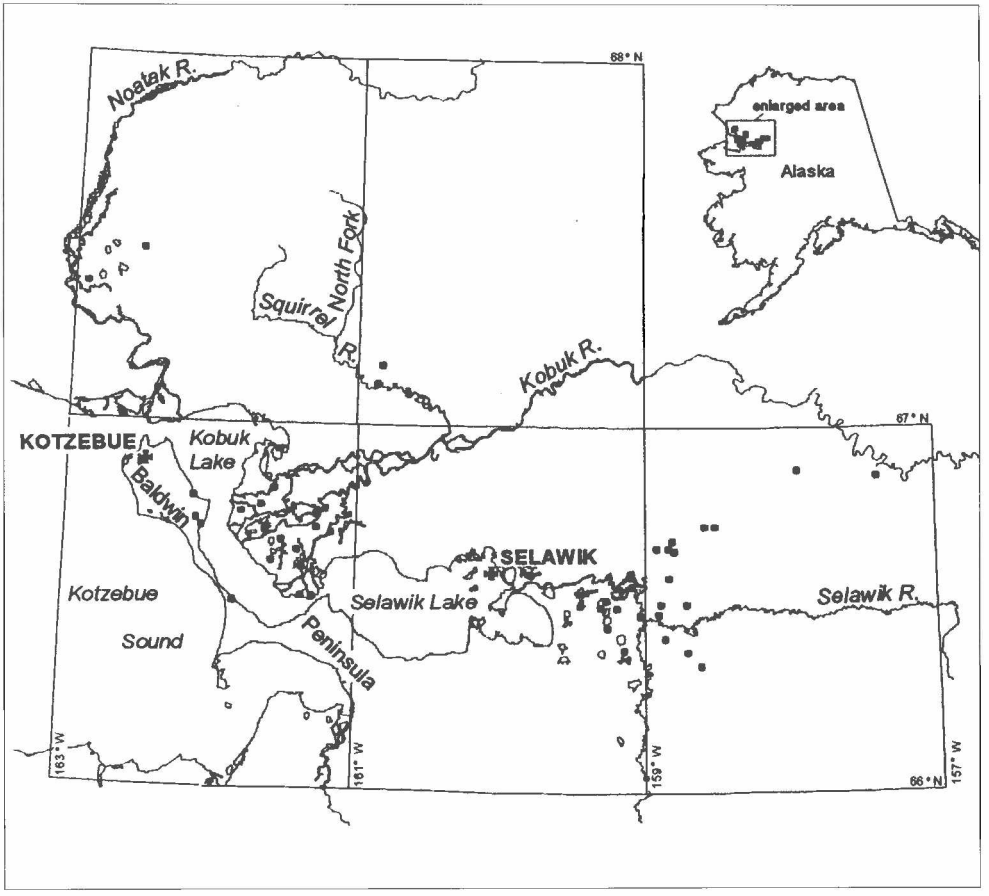

Figure 1. Capture sites of Tundra Swans marked in the Kobuk-Selawik lowlands of north-west Alaska, 1984-89.

We categorized observations from September to November as autumn migration; December and January as wintering; and February to April as spring migration. A resighting was considered 'unique' if it placed an individual swan at a specific migration stopover or wintering area each year. Resightings occurring in the autumn, winter, or spring immediately after marking were considered 'direct encounters'. Five marked swans subsequently found dead were included in analyses of distribution but not chronology because actual dates of occurrence at the sites could not be determined.

Resightings of neck collars were obtained in three ways. The U.S. Bird Banding Laboratory (BBL, Biological Resources Division, U.S. Dept. of Interior, Laurel, Maryland) collected reports of collared swan sightings that were added to their tarsal ring encounter records. Additional written observations obtained from conservation workers and volunteers resulted from an informational effort in all flyways where we considered resightings possible. Also, special radio-telemetry flights were made by cooperators in Alaska, Yukon, Montana, North Dakota and California. All sightings through 1996 were included in our analyses. Estimates of resighting probability were calculated with the Cormack-Jolly-Seber model (Lebreton *et al.* 1992).

Table 1. Number of individual Tundra Swans, marked at the Kobuk-Selawik lowlands of north-west Alaska, that were subsequently resighted during migration and winter in 1984-96 (*n* = number marked).

Resight Year		1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	Total
Capture Year	*n*														
1984	16	4	1			2			1						8
1985	16		5	2		1			1						9
1986	15			6	1		1	3	1	1		1	1		15
1987	27				9	10	4	3	2	5	4	4		1	42
1988	27					5	10	7	1	3	2	2	1		31
1989	14						3	2	3	1	1			1	11
Total	115	4	6	8	10	18	18	15	9	10	7	7	2	2	116

Results

Resighting rate

From 115 swans marked during 1984-89, we recorded 134 unique and 225 total resightings from 1984-96. Direct encounters occurred outside Alaska every year except 1985. Sixty-two marked swans (54%) were resighted at least once during the 13-year period of observation. Seven marked swans (11%) were resighted only in Alaska, while 24 (39%) were encountered only a single time outside of Alaska. Of the latter, five (4%) were reports of birds that were found dead. Thirty-one (50%) swans were seen more than one time and frequently over a period of several years. For each of six annual samples (cohorts) of marked swans, 1984-89, resightings occurred up to 6-9 years after marking (**Table 1**). The greatest number of resightings was recorded from the largest cohorts (n=27) that were marked in 1987 and 1988. The estimated probability of resighting a marked swan ranged from 0.09 $\pm$ 0.04 (SE) to 0.34 $\pm$ 0.05, depending on time since marking.

The most frequently sighted swan was a female (U175) that was seen in six different years in California, Montana and Yukon. This swan had the shortest interval from marking to first resighting in California (89 days, captured 6 August 1987 and resighted 3 November 1987 near Chico). We obtained observations of swan U175 over a 7.4 year period with the last sighting on 21 December 1994, at Sacramento NWR, California. Eleven other marked swans were seen at least once a year for periods spanning 3-6 years. The longest interval from marking to first resighting was 5.4 years for a swan (U187) marked on 4 August 1988 and first seen in California on 31 December 1993.

Migration route

Resightings of Tundra Swans from the Kobuk-Selawik lowlands were reported from a relatively narrow corridor across Alaska and the Yukon, and from two wider bands crossing the Canadian and U.S. Rocky Mountains before arriving at their California wintering grounds (**Figure 2**). The pattern of resightings during autumn and spring migration was similar, except that in spring several marked swans stopped at the Tule Lake-Klamath Basin area of northern California and southern Oregon (**Table 2**).

In autumn and spring, marked Kobuk-Selawik swans were reported using ponds, lakes and reservoirs immediately east of the Rocky Mountain Front from near Edmonton, Alberta south to near Great Falls, Montana (**Table 2**). Another band of resightings occurred in the western prairies along a line through south-west Saskatchewan and north-east Montana. Also, groups of resightings were reported from the Great Salt Lake Basin, Utah and Stillwater Basin, Nevada. We recorded observations of marked swans feeding on *Potamogeton sp.* while migrating through Alberta, Montana, Oregon and Nevada.

Two individual swans, representing four of 61 unique migration resightings, were documented using the same stopover in successive years. Swan U141 was seen on two dates one year and 16 km apart near Freezeout Lake, Montana (17 March 1991 and 1992), and swan U036 was seen near Calgary, Alberta two years apart (19 April 1990 and 3 April 1992).

Wintering area

Of the 62 individual Kobuk-Selawik swans resighted at least once during this study, 34 (55%) were seen on their wintering grounds in California. Most observations were on the east side of the Sacramento River between the cities of Sacramento and Chico, with fewer west of the river and on the deltas of the Sacramento and San Joaquin Rivers (**Table 2, Figure 3**). We recorded repeat observations of 11 individuals wintering in the east Sacramento Valley during $\geq$2 successive winters. One swan (U160) was observed in the Chico area at least once during five of the six winters it was seen in California; it was seen exactly a year apart within 4 km of the same site on 18 December 1991 and 1992.

Marked Kobuk-Selawik swans were frequently seen among large flocks (700-12,000) of Tundra Swans wintering in agricultural fields in the Sacramento and San Joaquin Valleys (J.

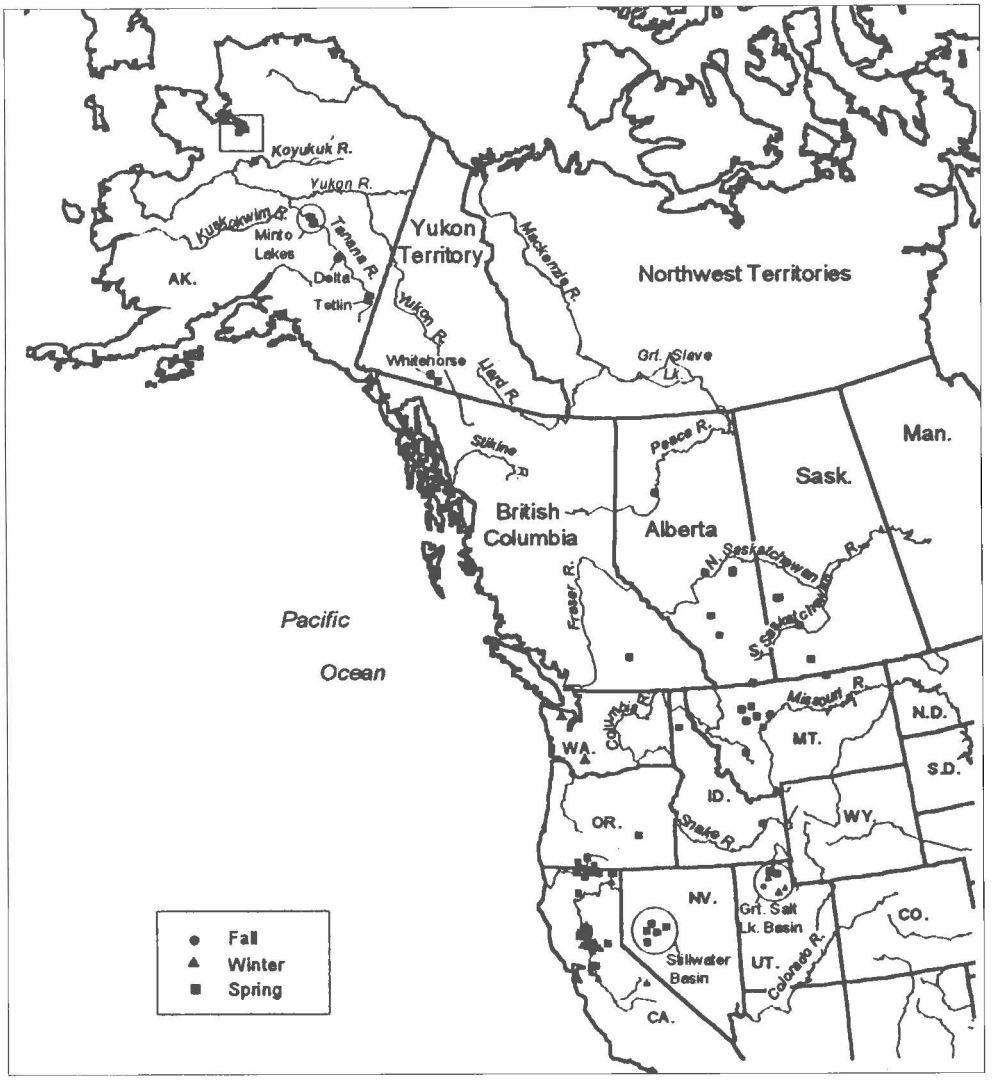

Figure 2. Resightings during 1984-96 of Tundra Swans marked on the Kobuk- Selawik lowlands of north-west Alaska (box) 1984-89.

Snowden, Calif. Dept. Fish & Game, Chico, *in litt.* 1989, 1992). Of 57 winter resightings that included observations of feeding activity, 81% of marked swans were in rice fields (stubble, burned stubble, or flooded) and 11% were in corn fields (disked, tilled, or 'old').

We recorded four instances of Kobuk-Selawik swans apparently wintering in coastal areas of British Columbia and Washington (**Figure 2**: one at the Fraser River delta near Vancouver; one along Puget Sound near Port Townsend; and two on the lower Columbia River at Ridgefield NWR).

Migration timing and duration

The earliest sighting of a marked swan (U175) on California wintering grounds was 3 November 1987, although most initial sightings in the Sacramento Valley occurred in mid- to

late November. We estimated duration of autumn migration at 5-8 weeks (based on telemetry-determined late September departures from the nesting grounds; Spindler & Hall 1991). Departures of marked swans from the California wintering area occurred by late February (latest sighting was 6 March 1994). We estimated duration of spring migration at 10-11 weeks, based on the early May arrival of marked swans on the Kobuk-Selawik lowlands.

Cross-flyway movements

At Arrowwood NWR, North Dakota, a traditional staging site for Eastern Population Tundra Swans (Earnst 1994, Limpert & Earnst 1994), one Kobuk-Selawik swan, U198, marked as a second year non-breeder on 10 August 1989, was observed consorting with a swan marked as an adult in North Carolina on 5 November 1990 (R. Bohn, report to BBL; Laurel, Maryland). Nevertheless, ten days later, the same individual was seen *c.* 1760 km to the south-west in Nevada, apparently heading for California where it had wintered in 1989. During four consecutive years we obtained reports of swans marked in the Kobuk-Selawik lowlands associating with marked swans from the Eastern Population but apparently wintering as accidentals in California (n = 1-4, 1989-92; J. Snowden, California Dept. Fish & Game, Chico *in litt.*).

Discussion

Resighting rate

About half (54%) of the Tundra Swans marked in the Kobuk-Selawik lowlands were resighted at least once. In comparison, Nichols *et al.* (1992) reported a resighting rate of *c.* 75% for Eastern Population Tundra Swans, most of which were marked on their wintering grounds along the U.S. Atlantic coast. Resighting rates were similar for swans seen only in the year subsequent to marking: 21% for this study and 25% for Nichols *et al.* (1992), but 50% of these Eastern swans were resighted 2-10 years after marking compared to 27% of the Kobuk-Selawik swans. Differences between these rates may have been due to radio harness effects, observer effort, or greatly differing sample sizes (n=5963 [Nichols et al. 1992] vs. n=115 in this study). The number of observers in the north-eastern U.S. and along the Atlantic coast is greater compared to the less populated Canadian provinces and western states traversed by the Kobuk-Selawik swans. Ely *et al.* (1997) also noted a paucity of resightings and tarsal ring encounters from these remote areas also crossed by marked Tundra Swans nesting on the Yukon-Kuskokwim delta.

Migration route

Earlier studies and reviews suggested that Tundra Swans breeding in several parts of Alaska migrate along a south-west to north-east line to join Eastern Population birds from arctic Alaska and Canada before heading south (Bellrose 1980). Instead, Tundra Swans marked in the Kobuk-Selawik lowlands followed a narrow corridor along a north-west to south-east line across Alaska and the Yukon in both spring and autumn. Similarly, Cooper & Ritchie (1988) observed that Tundra Swans migrated along a narrow corridor through Alaska's Tanana River Valley. This corridor may be narrow because of topographical constraints; nearly continuous mountains in excess of 3000 m extend along the southern margin of the corridor in Alaska, Yukon and extreme northern British Columbia.

Two interior migration corridors across western North America have been described: (1) *via* south-western Saskatchewan to Freezeout Lake, Montana; then to the Salt Lake Basin in northern Utah; then to the Stillwater Basin of north-west Nevada; and finally to the California Central Valley, and (2) a more westerly corridor, through British Columbia and Alberta; then to Malheur Lake, Oregon; then to the Klamath Basin, and finally to the California Central Valley (Sladen 1973, Bellrose 1980, Pacific Flyway Council 1983). We recorded only two observations indicating marked Kobuk-Selawik swans used the western corridor. Instead, the pattern of resightings suggested that most Kobuk-Selawik swans used

Table 2. Number of unique resightings in 1984-96 at migration stopovers and wintering areas (from north to south) used by swans marked on the Kobuk-Selawik Lowlands, Alaska, 1984-89.

Migration or wintering area	State or Province	Autumn	Spring	Winter
Koyukuk River	Alaska	1		
Minto Lakes	Alaska	3		
Delta	Alaska	2		
Tetlin Nat. Wildl. Refuge	Alaska	4		
Whitehorse	Yukon	3		
Rocky Mountain Front or Trans-Rocky Mountain	Alberta/B.C.			
	Montana			
	Idaho	11	10	
Western Prairies	Saskatchewan			
	Montana	2	4	
Lower Fraser & Columbia R. Puget Sound	B.C.			
	Washington			4
Malheur-Harney Lakes Basin	Oregon		1	
Great Salt Lake Basin	Utah	3		3
Tule Lake-Klamath Basin	California			
	Oregon		11	1
Stillwater Basin	Nevada	3	2	
West Sacramento River Valley	California			8
East Sacramento River Valley	California			47
Sacramento-San Joaquin Delta	California			9
Mono Lake	California			1
Total		32[a]	28	73

[a] Does not include sighting of one swan (U198) in North Dakota.

the eastern corridor, paralleling the Rocky Mountain Front in spring and autumn. Some of these birds even used a more easterly corridor through the prairies of south-west Saskatchewan. Marked Tundra Swans breeding on the Yukon-Kuskokwim delta also used a trans-Rocky Mountain route: in autumn, four satellite radio-equipped swans followed the eastern corridor and in spring one followed each of the eastern and western corridors (Ely *et al.* 1997).

During migration, marked Kobuk-Selawik swans were most often observed along the Rocky Mountain Front east to the prairies of south-west Saskatchewan, and in the intermountain basins of Great Salt Lake, Stillwater and Klamath-Tule Lake. These are migration stopovers and habitats that were previously described as main use areas for Western Population Tundra Swans (Bellrose 1980, Pacific Flyway Council 1983, Ely *et al.* 1997). However, one widely used Western Population stopover, the Malheur-Harney Lake Basin of Oregon (Paullin & Kridler 1988) produced only one sighting of a marked Kobuk-Selawik swan.

Wintering areas

The main wintering area of Tundra Swans in the Western Population is the central valley of California (Moffitt 1939, Sladen 1973, Bellrose 1980, Pacific Flyway Council 1983, Heitmeyer *et al.* 1989), where U.S. Fish & Wildl. Serv. (1995) estimated a five-year (1991-95) mean of 47,953 wintering swans. Marked swans from the Kobuk-Selawik lowlands wintered mainly on the east side of the Sacramento River valley, but resightings also occurred on the west side and on the deltas of the Sacramento and San Joaquin Rivers.

Repeat observations of 11 individual Kobuk-Selawik swans wintering in the east Sacramento Valley in successive years indicated traditional use and, at least in one case, a high degree of site fidelity to wintering area. Sladen (1973) and Munro (1981a) reported that a majority of marked Eastern Population swans returned to winter in the same area where they were marked. Limpert *et al.* (1991) reported that few (4%) Tundra Swans marked on the Yukon-Kuskokwim delta were found outside the normal wintering area of the Western Population.

Migration resightings of Kobuk-Selawik Tundra Swans were all in wetland habitats, and observed forage use was mainly pondweed *Potamogeton sp.*. In contrast, winter observations of marked swans were mostly in agricultural habitats, and forage observations showed frequent use of rice and corn. Earnst (1994) observed Tundra Swans feeding mainly in wetlands with *Potamogeton* in North Dakota during migration, as did Sherwood (1960) in Utah, and Moffitt (1939) in California. Nagel (1965) observed use of post-harvest corn when aquatic forage in wetlands of the Great Salt Lake Basin was unavailable due to ice. As early as the 1930's rice was a frequent item in the winter diet of Tundra Swans in California (Moffitt 1939), and this pattern has continued recently (Heitmeyer *et al.* 1989). Past conversion of natural wetland habitats to agriculture, and present decisions as to type of crop that is cultivated may therefore influence use of migration and wintering sites by Western Population swans.

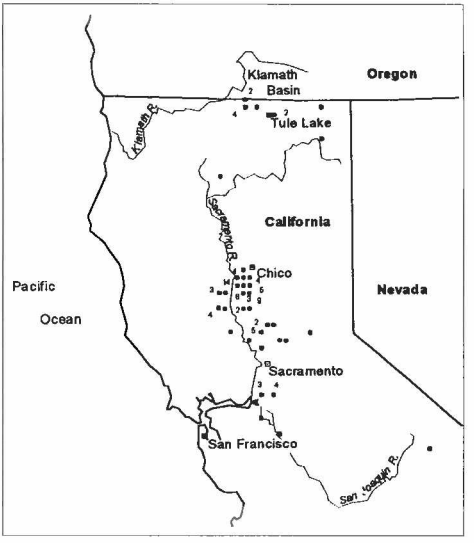

Figure 3. Wintering ground resightings in California during 1984-96 of Tundra swans collared in the Kobuk-Selawik lowlands of north-west Alaska, 1984-89. Dot indicates single resighting; numbers indicate several individuals or resightings per location.

Cross-flyway movements

Individual Tundra Swans or family groups sometimes change flyways (Jensen 1971, Pacific Flyway Council 1983, Limpert *et al.* 1991, Ely *et al.* 1997). Occasional movement of Western Population birds into areas normally inhabited by the Eastern Population and *vice versa* was recorded in this study and others. During four consecutive winters, small numbers (n=1-4) of Eastern Population swans were sighted in the same farm fields as Kobuk-Selawik birds in California. Conversely, Limpert *et al.* (1991) reported that six (5.5%) banded Western Population swans (including three from the Kobuk-Selawik area) were seen with Eastern Population swans during migration or in winter. Limpert *et al.* (1991) also found that three swans (two Eastern and one Western) that had switched populations were later observed back with the original populations. Indeed, Swan U198 was later seen in Nevada after straying as

far east as North Dakota. Further evidence of such intermingling comes from an Izembek NWR swan resighted in New York (26 February 1992, C. Dau, U.S. Fish & Wildl Serv., Anchorage, Alaska *in litt.*). Also, nesting season observations of swans dye-marked at Oregon's Malheur NWR, a major Western Population migratory stopover, occurred in both Western and Eastern Population nesting areas (Paullin & Kridler 1988).

Mixing occasionally occurs among Western Population swans that usually do not winter together. For example, resightings of four Kobuk-Selawik swans in coastal British Columbia and Washington occurred where other Western Population birds, mainly Izembek NWR breeders, have usually wintered (Caniff 1988).

Habitat conservation for migrating and wintering swans

More than a third (38%) of unique resightings of marked Kobuk-Selawik swans occurred in established conservation areas. In much of the semi-arid western U.S., these sites represent some of the few wetland habitats available for waterfowl. Loss of wetland habitat in the region has been extensive, and has exceeded 95% in California (Gilmer *et al.* 1982, Heitmeyer *et al.* 1989). Perhaps because of the diminution of natural wetland foods in the wintering habitat (Heitmeyer *et al.* 1989), agricultural crops have become an increasingly important source of food for wintering Tundra Swans (Nagel 1965, Tate & Tate 1966, Munro 1981b). While corn and rice may provide a plentiful source of energy for wintering swans, these foods probably do not provide all the needed nutrients (Heitmeyer *et al.* 1989, Ball *et al.* 1989). Hence, conservation of the few remaining natural wetlands, and rehabilitation of historical wetlands when possible, seems critical to a balanced diet for swans. Further documentation of how and why swans use particular migratory and wintering areas will hopefully result in continued efforts to acquire and maintain these vital habitats.

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