

**Richard H. Kerbes
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(editors)**

Distribution, survival, and numbers of Lesser Snow Geese of the Western Canadian Arctic and Wrangel Island, Russia

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Cover photo: Pair of Lesser Snow Geese near their nest on Wrangel Island, Russia, in June 1991. (R.H. Kerbes)

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Summary

Background

Recently, in both the scientific and the popular press, wildlife managers and administrators have proclaimed that there are too many Lesser Snow Geese *Anser caerulescens caerulescens* (hereafter referred to as Snow Geese) in North America. The experts have recommended that goose numbers be reduced in order to prevent the geese from destroying Arctic coastal habitats on which they and other wildlife depend as feeding grounds. It is important to realize that this reduction program is aimed at the Midcontinent Snow Goose Population, which nests in the Eastern and Central Canadian Arctic. So far, that program does not apply to the much smaller and more western populations of Snow Geese, which nest in the Western Canadian Arctic and on Wrangel Island, Russia. Those populations, which are the subject of this report, have shown quite different histories and have presented different management problems.

In the late 1980s, a convergence of concerns from Canada, Russia, and the United States led to an extensive international study of the Western Canadian Arctic and Wrangel Island populations of Snow Geese. The Wrangel Island Population (the only Snow Geese nesting outside North America) had dropped by over 50%, to fewer than 100 000 geese, and did not appear to be recovering. The Western Canadian Arctic Population had slowly increased to about 200 000 nesting birds in the 1980s. The Inuvialuit land claim settlement in the Western Canadian Arctic created both the need for enhanced waterfowl management and a source of funds for investigations of the geese there. Farther south, wildlife managers were concerned about apparent shifts in these populations on their wintering grounds.

Improved and updated information was needed on the year-round distribution, survival rates, and size of the Western Canadian Arctic and Wrangel Island populations. Those objectives were addressed by a cooperative neckbanding and monitoring program from 1987 to 1992, an analysis of recoveries of legbanded geese for the 1950s–1980s, and inventories of the geese on their nesting colonies. This Occasional Paper presents the results and management recommendations arising from that work. What follows are the main points of each paper and a summary of our management recommendations.

Project overview

The key objectives of this study were to determine 1) numbers and distribution of nesting adults on their Arctic breeding colonies and the size of total populations in different parts of their wintering grounds; 2) autumn and winter distributions and how they might have changed during the past 30 years; 3) routes and timing of migration between staging and wintering areas and fidelity of geese to specific staging and wintering areas; 4) survival rates for the Western Arctic Population and for each of the north- and south-wintering components of the Wrangel Island Population; and 5) the effectiveness of mineral staining in facial plumage of Wrangel Island geese as an indicator of wintering ground.

Flightless geese were captured on their Arctic breeding grounds, and the adults were fitted with individually coded plastic neckbands and numbered metal legbands. From 1987 to 1991, 2643 Western Arctic and 1462 Wrangel Island Snow Geese were neckbanded. An extensive network of cooperators monitored these birds throughout western North America, achieving direct observation rates of 58–77% each year.

Population size

Population size on the breeding grounds was estimated by ground transect surveys on Wrangel Island and by aerial photography in the Western Canadian Arctic. On Wrangel Island, the total number of adults in spring declined from 150 000 in 1970 to 56 000 in 1975. The population recovered during the 1980s to 100 000 geese but has averaged only about 65 000 geese in the 1990s. In contrast, the total number of nesting adults in the Western Arctic has increased almost threefold, from 170 000 in 1976 to nearly 490 000 in 1995. The average annual rate of population growth from 1976 to 1981 was 4.1%, but from 1981 to 1995 it was 6.3%.

Estimates of population size from mark:resight data were made for some wintering areas during 1987–1989. Those estimates agreed with independent aerial surveys made during the winter. Using the breeding ground inventory data and information on the winter distribution of collared geese, we estimated population sizes in different wintering areas. We found that counts from the aerial winter survey agreed with extrapolations from the 1987 count of breeding adults but not from that of 1995. The wintering ground

surveys accounted for 34% fewer geese in the Pacific and Western Central flyways than expected by extrapolation of total winter population from the combined 1995 counts of breeding birds on Wrangel Island and the Western Canadian Arctic. That discrepancy was most likely due to an underestimation of numbers in the winter surveys.

Autumn and winter distributions

Autumn and winter distributions were determined from legband recovery data for 1953–1979 and from legband recovery and neckband observation data for 1987–1992. In the autumn of recent years, all of the Western Canadian Arctic Population and less than 6% of the Wrangel Island Population migrated through the Canadian prairies, and the remainder of the Wrangel Island Population moved down the Pacific coast. The migration route used by the Western Arctic geese has shifted eastward on the Canadian prairies. Most geese (74%) moved through eastern Alberta in the 1950s and 1960s, whereas only 26% staged in western Saskatchewan. By the late 1980s, only 32–36% of the geese staged in eastern Alberta, and 64–68% staged in western Saskatchewan.

Snow Geese winter in three main regions in western North America: 1) the Fraser River Delta (British Columbia) and the Skagit River Delta (Washington); 2) the Western Central Flyway (composed of New Mexico, northwestern Texas, southeastern Colorado, and the Northern Highlands of Mexico); and 3) the Central Valley of California and the Klamath Basin in northern California and southern Oregon. In addition, smaller numbers winter in southern California and in the Columbia River area in Washington and Oregon.

On the wintering grounds in the 1960s and 1970s, 90% of the Western Arctic Population wintered in California, with about 8% in the Western Central Flyway. By the late 1980s, only 76% of the geese wintered in California, with 24% in the Western Central Flyway. Recent wintering ground counts suggest that an even greater proportion of the Western Arctic geese now winter in the Western Central Flyway. Most of the growth of the Western Arctic Population appears to be related to an increase in winter numbers in that area.

Legband recoveries in the 1960s and 1970s suggested that nearly 90% of the Wrangel Island Population wintered in California, with the remainder in the Fraser and Skagit river deltas of British Columbia–Washington. By 1987–1992, less than 50% wintered in California. The relative decline of both the Western Arctic and Wrangel Island populations in California seems to have been due more to changes in movement patterns than to population or regional differences in survival and productivity.

Routes and timing of migration

Routes and timing of migration during 1987–1992 were determined from observations of Snow Geese neck-banded on Wrangel Island and in the Western Canadian Arctic. Wrangel Island geese followed a coastal route in autumn to British Columbia–Washington and California, with a small number going to California via the prairies of southeastern Alberta, southwestern Saskatchewan, and western Montana. In spring, most of the Wrangel Island birds that wintered in California returned north through the

prairies, and those from British Columbia–Washington went north via southwestern Alaska. In autumn, Western Arctic geese travelled south via Alberta and Saskatchewan. Many of those going to California then went through western Montana and eastern Oregon. Most of those going to the Western Central Flyway apparently stayed on the eastern side of the Rocky Mountains. A small number of geese, however, went to the Western Central Flyway via California. In spring, most Western Arctic geese apparently followed the same routes in reverse, and those that wintered in southern California went north via Utah. More than 90% of both male and female geese resighted in consecutive years were observed on the same wintering area each year, indicating high rates of fidelity to wintering areas.

There was limited temporal separation between Wrangel Island and Western Arctic stocks on the migration and wintering areas where they both occurred. In autumn, the south-wintering Wrangel Island birds arrived later than Western Arctic birds in Alberta and Saskatchewan and earlier in eastern Oregon.

Survival rates

Survival rates were estimated for collared adult female geese marked in the Western Canadian Arctic and for each of the north- and south-wintering Wrangel Island stocks, as well as for geese neckbanded in Alaska, British Columbia, and New Mexico. About 75% of the marked geese were observed each year, leading to relatively small standard errors and a good ability to detect survival differences among groups of collared geese. The average survival rate for Western Canadian Arctic females during 1987–1989 (0.802) was higher than for Wrangel Island females (0.685). There was no strong evidence that average survival rates of the decreasing south-wintering Wrangel Island stock (0.656) were lower than those of the increasing north-wintering stock (0.628), although only two annual estimates were available. However, in California, the Western Arctic geese had significantly higher survival rates (0.844) than the Wrangel Island birds. Survival of adult females from both populations was similar during the November–January period of all years, but lower for Wrangel Island geese during the February–November period.

Survival rates from legband recoveries of adult geese from the Western Arctic were 0.935 in 1960–1963, 0.832 in 1973–1975, and 0.789 in 1987–1989, compared with 0.668 for Wrangel Island geese in 1975–1977. Comparison of these estimates as well as those from the neckband resighting data suggested that survival rates of Wrangel Island adults were 0.10–0.15 lower than for their Western Arctic counterparts during both the 1970s and 1980s. The survival rates of Western Arctic adults may have declined from the 1960s to the 1980s. The survival rates for Wrangel Island geese are among the lowest values reported for adult Snow Geese, whereas those for Western Arctic birds are relatively high. While differences in rates of survival might in part explain why the Western Arctic Population has increased whereas the Wrangel Island Population has not, we found no evidence that regional variations in survival rates could explain the recent changes in the winter distribution of either population.

Harvest rates, estimated using both legband recoveries and information on harvest and population size, for the combined Wrangel Island and Western Arctic populations

were 15–20% in the 1960s and 1970s and less than 10% in the late 1980s. The two populations appeared to be harvested at approximately the same rate in the late 1980s (comparable data for the earlier period were not available).

Mineral staining of facial plumage in Wrangel Island geese

Mineral staining in Wrangel Island geese had been investigated previously by Russian biologists. They had shown that the north-wintering birds, because they fed extensively by grubbing in tidal marshes, tended to have reddish-coloured faces from mineral staining. In contrast, the south-wintering geese fed in agricultural fields and tended to retain their white facial plumage. In the late 1970s and the early 1980s, face colour scores could be used to identify the wintering ground affiliations of 86–90% of the Wrangel Island geese. We evaluated the continued reliability of face staining as an indicator of the wintering grounds of Snow Geese neckbanded during 1988 and 1989 on Wrangel Island. Neckband observations of 1357 geese from Wrangel Island indicated that 86% of the lower three (white) classes wintered in California, while 90% of the upper three (red) classes wintered in British Columbia–Washington. Geese with intermediate scores, which made up 35% of the marked sample, could not be closely associated with either wintering area based on face staining. Although face staining is not now as broadly applicable as a natural marker as it had been previously, it still should be useful in studies comparing the productivity, survival, or migration patterns of the two different stocks of geese, while acknowledging that samples obtained by face staining scores may be missing a significant proportion of the population.

Management recommendations

Our studies clearly underline a continued concern for the Wrangel Island Snow Goose Population. If possible, hunting pressure on this population should be reduced. The north-wintering segment of the Wrangel Island Population could be further protected with hunting restrictions on its wintering grounds in British Columbia–Washington, although such action in turn might increase complaints of goose depredations on agricultural crops in that area. The south-wintering segment in California is difficult to manage selectively, because it shares that wintering ground with Snow Geese and Ross' Geese *Anser rossii* from other breeding areas. Hunting restrictions would need to be imposed on those populations as well, in order to protect Wrangel Island birds in California.

The rapid rate of increase in the Western Arctic Population shows that its Arctic habitats could be threatened by overgrazing, as has already been demonstrated for some areas along the coast of Hudson Bay. Studies of habitat and effects of grazing by Snow Geese should be conducted on Banks Island. A useful management goal would be to stabilize the number of Western Arctic Snow Geese at about the current level. That could be done by at least doubling the current total harvest — i.e., harvesting it at a rate of 15–20%. Similar harvest rates were attained in the 1960s and 1970s, a period when the population growth rate was apparently low. Increasing the harvest now would help prevent the population from growing beyond the level where its increase can be

controlled by hunting. The increase in harvest should be directed at the increasing numbers of geese using the Western Central Flyway, so that neither the south-wintering stock of Wrangel Island geese nor the apparently stable segment of the Western Arctic Population wintering in California would be impacted. Spring harvest in the Western Arctic could also be increased, although it would need to be focused on geese returning to Banks Island, avoiding geese from the small and less secure colonies at Anderson River and Kendall Island. However, a significant increase in harvest in the Western Arctic or the Western Central Flyway will be difficult to attain because of the relatively small number of waterfowl hunters in those areas.

The breeding ground inventories should continue, annually on Wrangel Island and at five-year intervals in the Western Arctic. To reconcile apparent differences between estimates of population size extrapolated from breeding inventories and population estimates from the winter surveys, we recommend improved winter surveys. The improved counts must have a ground truthing component to assess the accuracy of the aerial counts and to estimate the Ross':Snow goose ratio in surveys of white geese.

Further studies should use satellite tracking of radio-marked birds to obtain a better understanding of fall and spring migration of Wrangel Island and Western Arctic geese across northern areas and of the complete spring migration of geese returning to the Western Arctic from the Western Central Flyway.

Résumé

Historique

Récemment, dans la presse scientifique et populaire, les gestionnaires et les administrateurs de la faune ont déclaré qu'il y a trop de Petites Oies des neiges *Anser caerulescens caerulescens* (appelées ci-après Oies des neiges) en Amérique du Nord. Les experts ont en effet recommandé la réduction du nombre d'oies afin de prévenir la destruction des habitats côtiers de l'Arctique sur lesquels les oies et d'autres animaux comptent pour se nourrir. Il est important de se rendre compte que ce programme de réduction vise la population d'Oies des neiges du milieu du continent, qui niche dans l'est et le centre de l'Arctique canadien. Le programme ne s'applique pas encore aux populations beaucoup plus petites d'Oies des neiges qui habitent plus à l'ouest soit dans l'ouest de l'Arctique canadien et sur l'île Wrangel, en Russie. Ces populations, qui font l'objet de ce rapport, ont des antécédents assez différents et présentent des problèmes de gestion distincts.

À la fin des années 1980, des inquiétudes soulevées au Canada, en Russie et aux États-Unis ont abouti à une importante étude internationale des populations d'Oies des neiges de l'ouest de l'Arctique canadien et de l'île Wrangel. La population de l'île Wrangel (les seules Oies des neiges à nicher à l'extérieur de l'Amérique du Nord) a baissé de plus de 50 p. 100, pour atteindre un nombre inférieur à 100 000 oies et elle ne semblait pas vouloir se rétablir. La population de l'ouest de l'Arctique canadien a connu une croissance lente et se chiffrait à environ 200 000 oiseaux nicheurs dans les années 1980. Par ailleurs, le règlement des revendications territoriales d'Inuvialuit, dans l'ouest de l'Arctique canadien, a créé à la fois le besoin d'une meilleure gestion de la sauvagine et d'une source de financement pour réaliser des enquêtes sur les populations d'oies vivant à cet endroit. Plus au sud, les gestionnaires de la faune étaient préoccupés des changements apparents au sein de ces populations dans leurs aires d'hivernage.

Il était devenu nécessaire de compiler de meilleurs renseignements sur la répartition annuelle, les taux de survie et la taille des populations de l'ouest de l'Arctique canadien et de l'île Wrangel, et de les mettre à jour. Pour répondre à ces objectifs, on a procédé à un projet coopératif de marquage, au moyen d'un collier, et de surveillance de 1987 à 1992, on a réalisé une analyse des bagues récupérées au cours des années 1950 à 1980 et on a analysé les inventaires des oies dans leurs colonies de nidification. La présente

publication hors-série présente les résultats et les recommandations en matière de gestion découlant de ce travail. Le texte qui suit contient les points principaux de chaque cahier ainsi qu'un résumé de nos recommandations en matière de gestion.

Aperçu du projet

Les objectifs clés de cette étude consistaient à déterminer 1) le nombre et la répartition des adultes nicheurs dans leurs colonies de nidification de l'Arctique et la taille des populations totales dans les différents secteurs de leurs aires d'hivernage; 2) les distributions automnales et hivernales et leur évolution possible au cours des 30 dernières années; 3) les routes migratoires et le moment de la migration entre les aires de repos et d'hivernage et la fidélité des oies à certaines aires de repos et d'hivernage particulières; 4) les taux de survie pour la population de l'ouest de l'Arctique et pour chacun des segments de la population de l'île Wrangel, soit celui qui hiverne dans le nord ou celui qui hiverne dans le sud; et 5) l'efficacité des taches faciales des oies de l'île Wrangel comme indicateur de l'aire d'hivernage.

Des oies coureuses ont été capturées sur leur aire de reproduction de l'Arctique et on a posé, au cou des adultes, des colliers de plastique comportant un code individuel, ainsi que des bagues de métal numérotées à leur patte. De 1987 à 1991, on a posé des colliers au cou de 2 643 Oies des neiges de l'ouest de l'Arctique et de 1 462 Oies des neiges de l'île Wrangel. Un vaste réseau de collaborateurs a surveillé ces oiseaux dans l'ouest de l'Amérique du Nord, et un taux d'observation directe de 58 à 77 p. 100 par année a été atteint.

Taille de la population

La taille de la population sur les aires de reproduction a été estimée au moyen de relevés au sol par transect sur l'île Wrangel et de photographies aériennes prises dans l'ouest de l'Arctique canadien. Sur l'île Wrangel, le nombre total d'adultes au printemps a connu un déclin et est passé de 150 000 en 1970 à 56 000 en 1975. Durant les années 1980, il s'est produit une croissance de la population et cette dernière a augmenté à 100 000 oies. Elle ne se chiffrait toutefois qu'à environ 65 000 dans les années 1990. Par contraste, le nombre total d'adultes nicheurs dans l'ouest de

l'Arctique a presque triplé, passant de 170 000 en 1976 à près de 490 000 en 1995. Entre 1976 et 1981, le taux de croissance annuel moyen de la population était de 4,1 p. 100, mais de 1981 à 1995, il se chiffrait à 6,3 p. 100.

On a établi des estimations de la taille de la population d'après des données tirées des marquages-observations pour certaines aires d'hivernage de 1987 à 1989. Ces estimations ont confirmé des enquêtes par photographies aériennes indépendantes effectuées durant l'hiver. En utilisant les données et les renseignements de l'inventaire au sol des aires de reproduction portant sur la répartition hivernale des oies marquées, nous avons estimé la taille des populations dans les diverses aires d'hivernage. Selon nos constatations, les données provenant des enquêtes aériennes effectuées durant l'hiver correspondaient aux extrapolations établies lors du dénombrement, en 1987, des adultes nicheurs, mais elles ne concordaient pas avec celles de 1995. Les relevés des aires d'hivernage indiquaient qu'il y avait 34 p. 100 moins d'oies dans les voies migratoires du Pacifique et du centre-ouest qu'on l'avait estimé en se basant sur l'extrapolation de la population d'hiver totale à partir des relevés combinés des aires de nidification de 1995 sur l'île Wrangel et l'ouest de l'Arctique canadien. Cet écart était probablement attribuable à une sous-estimation des données dans les enquêtes réalisées en hiver.

Distributions automnales et hivernales

Les distributions automnales et hivernales ont été déterminées à partir des données tirées des bagues récupérées au cours des années 1953 à 1979, ainsi que des données tirées des bagues récupérées et des colliers observées pour la période s'étalonnant entre 1987 et 1992. Au cours des dernières années, à l'automne, l'ensemble de la population de l'ouest de l'Arctique canadien et moins de 6 p. 100 de la population de l'île Wrangel ont migré par les Prairies canadiennes, et le reste de la population de l'île Wrangel a descendu le long de la côte du Pacifique. La route migratoire utilisée par les oies de l'ouest de l'Arctique canadien s'est déplacée vers l'est dans les Prairies canadiennes. La plupart des oies (74 p. 100) se sont déplacées dans l'est de l'Alberta au cours des années 1950 et 1960, tandis que seulement 26 p. 100 se rassemblaient dans l'ouest de la Saskatchewan. À la fin des années 1980, seulement 32 à 36 p. 100 des oies trouvaient leur aire de repos dans l'est de l'Alberta et de 64 à 68 p. 100 trouvaient la leur dans l'ouest de la Saskatchewan.

Les Oies des neiges passent l'hiver dans trois régions principales de l'ouest de l'Amérique du Nord : 1) les deltas du fleuve Fraser (Colombie-Britannique) et de la rivière Skagit (État de Washington); 2) la voie migratoire du centre-ouest (qui se compose du Nouveau-Mexique, du nord-ouest du Texas, du sud-est du Colorado et des terres hautes du nord du Mexique); et 3) la vallée centrale de la Californie et le bassin de Klamath dans le nord de la Californie et dans le sud de l'Oregon. De plus, un nombre moins important d'oies passent l'hiver dans le sud de la Californie et dans la région de la rivière Columbia dans les États de Washington et de l'Oregon.

En ce qui a trait aux aires d'hivernage, dans les années 1960 et 1970, 90 p. 100 de la population de l'ouest de l'Arctique séjournait en Californie, et environ 8 p. 100 dans la voie migratoire du centre-ouest. À la fin des années 1980, seulement 76 p. 100 des oies passaient l'hiver en Californie

et environ 24 p. 100 dans la voie migratoire du centre-ouest. Le dénombrement effectué récemment dans les aires d'hivernage suggère qu'une proportion encore plus grande d'oies de l'ouest de l'Arctique passe l'hiver dans la voie migratoire du centre-ouest. La majeure partie de la croissance de la population de l'ouest de l'Arctique semble être reliée à une augmentation du nombre d'oies dans cette région.

Les bagues récupérées au cours des années 1960 et 1970 suggèrent que près de 90 p. 100 de la population de l'île Wrangel hivernait en Californie, et que le reste faisait halte dans les deltas du fleuve Fraser et de la rivière Skagit de la Colombie-Britannique et de l'État de Washington. De 1987 à 1992, moins de 50 p. 100 passait l'hiver en Californie. Le déclin relatif des populations de l'ouest de l'Arctique et de l'île Wrangel en Californie semble être attribuable plutôt à des changements de migration qu'à des différences de région ou de population liées à la survie et à la productivité.

Routes et moment de la migration

De 1987 à 1992, les routes et le moment de la migration ont été déterminés à partir des observations d'Oies des neiges à qui on a posé un collier sur l'île Wrangel et dans l'ouest de l'Arctique canadien. En automne, les oies de l'île Wrangel ont suivi une route le long de la côte jusqu'en Colombie-Britannique, dans l'État de Washington et en Californie, et un petit nombre s'est rendu en Californie en passant par les Prairies du sud-est de l'Alberta, le sud-ouest de la Saskatchewan et l'ouest du Montana. Au printemps, la plupart des oiseaux de l'île Wrangel qui avaient passé l'hiver en Californie sont retournés vers le nord par les Prairies et ceux de la Colombie-Britannique et de l'État de Washington se sont dirigés vers le nord par le sud-ouest de l'Alaska. En automne, les oies de l'ouest de l'Arctique se sont déplacées vers le sud par l'Alberta et la Saskatchewan. Un grand nombre des oies se dirigeant vers la Californie a traversé l'ouest du Montana et l'est de l'Oregon. La plupart des oies empruntant la voie migratoire du centre-ouest sont apparemment restées à l'est des montagnes Rocheuses. Un petit nombre d'oies, toutefois, s'est rendu à la voie migratoire du centre-ouest par la Californie. Au printemps, la plupart des oies de l'ouest de l'Arctique ont apparemment suivi les mêmes routes en direction inverse, et celles qui avaient passé l'hiver dans le sud de la Californie se sont dirigées vers le nord en passant par l'Utah. Plus de 90 p. 100 des oies mâles et femelles observées au cours des années consécutives ont été observées dans la même aire d'hivernage chaque année, ce qui indique un haut taux de fidélité envers ces aires d'hivernage.

Il y avait une différence temporelle limitée entre les troupeaux de l'île Wrangel et de l'ouest de l'Arctique en matière de migration et d'aires d'hivernage, dans les cas où il y avait occurrence des deux. En automne, les oiseaux de l'île Wrangel qui hivernaient dans le sud arrivaient plus tard que ceux de l'ouest de l'Arctique en Alberta et en Saskatchewan mais plus tôt que ceux de l'est de l'Oregon.

Taux de survie

On a estimé les taux de survie pour les oies femelles adultes marquées dans l'ouest de l'Arctique canadien et pour

le troupeau de l'île Wrangel hivernant dans le nord et celui hivernant dans le sud, de même que pour des oies à qui on a posé un collier en Alaska, en Colombie-Britannique et au Nouveau-Mexique. Environ 75 p. 100 des oies marquées ont été observées chaque année, ce qui a permis d'obtenir un taux d'erreur-type relativement faible et de déceler les différences de survie entre les groupes d'oies portant un collier. Le taux de survie moyen pour les femelles de l'ouest de l'Arctique canadien de 1987 à 1989 (0,802) était plus élevé que celui des femelles de l'île Wrangel (0,685). Nous n'avons constaté aucune preuve convaincante permettant de confirmer que les taux de survie moyens du troupeau de l'île Wrangel hivernant dans le sud (0,656), dont la population est en baisse, étaient inférieurs à ceux du troupeau hivernant dans le nord (0,628), dont la population est en hausse, bien que seulement deux estimations annuelles soient disponibles. Pourtant, en Californie, les oies de l'ouest de l'Arctique avaient des taux de survie considérablement plus élevés (0,844) que les oiseaux de l'île Wrangel. Les taux de survie des femelles adultes des deux populations étaient identiques au cours de la période allant de novembre à janvier pour toutes les années, mais ils étaient inférieurs pour les oies de Wrangel pendant la période s'échelonnant entre février et novembre.

L'analyse des bagues récupérées provenant des oies adultes de l'ouest de l'Arctique a permis de constater des taux de survie de 0,935 de 1960 à 1963, de 0,832 de 1973 à 1975 et de 0,789 de 1987 à 1989, par rapport à 0,668 pour les oies de l'île Wrangel de 1975 à 1977. La comparaison de ces estimations, de même que de celles tirées des données d'observation des colliers, suggère que les taux de survie des adultes de l'île Wrangel étaient inférieurs dans une proportion de 0,10 à 0,15 à ceux des oies de l'ouest de l'Arctique au cours des années 1970 et 1980. Les taux de survie des adultes de l'ouest de l'Arctique peuvent avoir connu un déclin entre les années 1960 et 1980. Les taux de survie des oies de l'île Wrangel comptent parmi les plus faibles rapportés pour les Oies des neiges adultes, tandis que ceux des oiseaux de l'ouest de l'Arctique sont relativement élevés. Bien que les différences entre les niveaux de survie puissent expliquer en partie pourquoi la population de l'ouest de l'Arctique a augmenté et celle de l'île Wrangel a baissé, nous n'avons constaté aucune preuve indiquant que les variations régionales des taux de survie pouvaient expliquer les changements récents de la distribution hivernale des deux populations.

Les niveaux de récolte, dont les estimations se fondent sur les bagues de patte récupérées ainsi que les renseignements relatifs à la récolte et à la taille de la population, étaient, dans les années 1960 et 1970, de 15 à 20 p. 100 pour l'ensemble des populations de l'île Wrangel et de l'ouest de l'Arctique, et de moins de 10 p. 100 vers la fin des années 1980. Les deux populations semblent avoir fait l'objet d'une récolte à peu près au même niveau vers la fin des années 1980 (des données comparables pour la période précédente n'étaient pas disponibles).

Taches de minéraux sur le plumage facial des oies de l'île Wrangel

Les biologistes russes ont déjà examiné la question des taches de minéraux sur les oies de l'île Wrangel. Ils avaient démontré que la face des oiseaux hivernant dans le

nord était souvent d'une couleur rougeâtre qui était attribuable aux minéraux se trouvant dans le sol des marais maritimes où les oiseaux se nourrissaient principalement. Par contraste, les oies hivernant dans le sud se nourrissaient dans les champs agricoles et avaient tendance à conserver leur plumage facial blanc. Vers la fin des années 1970 et au début des années 1980, on pouvait se servir d'un système d'attribution de points pour la couleur faciale afin d'identifier les aires d'hivernage de 86 à 90 p. 100 des oies de l'île Wrangel. Nous avons évalué la fiabilité continue des taches faciales pour indiquer les aires d'hivernage des Oies des neiges à qui on a posé un collier en 1988 et en 1989 sur l'île Wrangel. Les observations des colliers posés à 1 357 oies de l'île Wrangel ont indiqué que 86 p. 100 des trois classes inférieures (blanches) passait l'hiver en Californie, tandis que 90 p. 100 des trois classes supérieures (rouges) passaient l'hiver en Colombie-Britannique et dans l'État de Washington. On ne pouvait pas établir un lien clair entre les oies qui obtenaient des évaluations intermédiaires, qui représentaient 35 p. 100 des échantillons marqués, et l'une des aires d'hivernage en fonction des taches faciales. Bien que l'utilisation des taches faciales à titre d'indicateur naturel ne soit pas aujourd'hui aussi généralisée qu'auparavant, elle devrait toutefois s'avérer encore utile dans le cadre d'études comparant la productivité, la survie ou le comportement migratoire des deux troupeaux différents d'oies, tout en reconnaissant le fait que les échantillons obtenus au moyen de l'évaluation des taches faciales puissent ne pas inclure une partie importante de la population.

Recommandations en matière de gestion

Nos études soulignent clairement une préoccupation continue relative à la population des Oies des neiges de l'île Wrangel. Dans la mesure du possible, on devrait réduire les pressions que la chasse exerce sur ses populations. On pourrait mieux protéger la population de l'île Wrangel qui hiverne dans le nord en instaurant des restrictions sur la chasse dans les aires d'hivernage en Colombie-Britannique et dans l'État de Washington, bien que de telles mesures puissent également donner lieu à une augmentation des plaintes concernant les dommages que les oies infligent aux récoltes dans la région. Les oies hivernant dans le sud, soit en Californie, sont difficiles à gérer de façon sélective parce qu'elles partagent l'aire d'hivernage avec des Oies des neiges et des Oies de Ross *Anser rossii* provenant d'autres aires de nidification. Des restrictions sur la chasse devraient s'imposer sur ces populations aussi, en vue de protéger les oiseaux de l'île Wrangel en Californie.

Par ailleurs, le taux de croissance rapide de la population de l'ouest de l'Arctique montre que ses habitats pourraient être menacés par le surpâturage, comme cela a déjà été démontré pour certaines régions le long de la côte de la baie d'Hudson. On devrait réaliser des études de l'habitat et examiner les effets du pâturage des Oies des neiges sur l'île Banks. Un objectif de gestion valable consisterait à stabiliser le nombre d'Oies des neiges de l'ouest de l'Arctique à peu près à leur niveau actuel. Il serait possible d'atteindre cet objectif en doublant au moins la récolte totale actuelle, c.-à-d., en fixant la récolte à un niveau de 15 à 20 p. 100. Des niveaux de récolte semblables ont été atteints dans les années 1960 et 1970, au cours d'une période où le taux de

croissance de la population était apparemment faible. L'augmentation de la récolte dès maintenant contribuerait à prévenir la croissance de la population au-delà du point où elle peut être contrôlée au moyen de la chasse. La hausse du niveau de récolte devrait viser le nombre croissant des oies empruntant la voie migratoire du centre-ouest, afin que ni le troupeau des oies de l'île Wrangel hivernant dans le sud, ni le segment apparemment stable de la population de l'ouest de l'Arctique hivernant en Californie ne soient touchés. La récolte du printemps dans l'ouest de l'Arctique pourrait également être accrue, bien qu'elle doive se concentrer sur les oies retournant à l'île Banks, et éviter les oies des colonies plus petites et plus menacées de la rivière Anderson et de l'île Kendall. Toutefois, une augmentation importante de la récolte dans l'ouest de l'Arctique ou dans la voie migratoire du centre-ouest sera difficile à réaliser en raison du nombre peu important de chasseurs de sauvagine dans ces régions.

Les inventaires des aires de reproduction devraient se poursuivre sur une base annuelle sur l'île Wrangel et, à des intervalles de cinq ans, dans l'ouest de l'Arctique. Dans le but de faire concorder des différences apparentes entre les estimations de la taille de la population extrapolée des inventaires de reproduction et des estimations de population provenant des enquêtes hivernales, nous recommandons une amélioration des enquêtes hivernales. Les dénombrements améliorés doivent comporter un élément ancré dans les faits afin d'évaluer l'exactitude des dénombrements aériens et d'estimer le ratio des Oies de Ross et des Oies des neiges dans les enquêtes portant sur les oies blanches.

Les nouvelles études devraient utiliser un système de télédétection pour suivre des oiseaux marqués et mieux comprendre la migration automnale et printanière des oies de l'île Wrangel et de l'ouest de l'Arctique dans les régions nordiques, ainsi que l'ensemble de la migration des oies retournant vers l'ouest de l'Arctique depuis la voie migratoire centre-ouest.

КОНСПЕКТ

Введение

Недавно, и в научных и в популярных изданиях прессы, администраторы и управляющие в области живой природы объявили, что в Северной Америке существует слишком много белых гусей (*Anser caerulescens caerulescens*). Эксперты советуют сократить численность гусей, чтобы предотвратить разрушение берегов окружающей Арктической среды, которая является местом кормления не только гусей, но и других диких животных. Важно осознать, что эта же программа сокращения нацелена на население белых гусей среднего континента, которое гнездится на восточной и центральной частях арктической Канады. В данный момент эта программа не распространяется на меньшую и более западную часть населения белых гусей, которое гнездится в западной арктической части Канады и на острове Врангеля, в России.

В конце 1980 годов совпадение интересов Канады, России и США привело к интенсивным международным исследованиям населения белых гусей, гнездящихся в западной части арктической Канады и на острове Врангеля. Популяция острова Врангеля (единственное место поселения белых гусей за пределами северной Америки), уменьшилось больше чем наполовину, менее 100 000 гусей и возрождения в популяции не наблюдается. Население западной части арктической Канады в 1980 годах постепенно увеличилось на 200,000 гнездящихся пар. Требования Иньювьялюитов (коренное население северо-западной Канады) по возврату территории привели к исследованиям в области водных птиц и гусей. Управляющие живой природой в более южных областях, были обеспокоены явными изменениями зимних жизненных условий этого населения.

Назрела необходимость в улучшенной и модернизированной информации по нормам выживания и по размерам численности популяции западной части арктической Канады и острова Врангеля. Эти задачи были разрешены ошейным кооперативным кольцеванием и программой наблюдения с 1987 по 1992 года, также анализом окольцованных гусей за период 1950-1980 годов и подсчетом гусей в местах гнездования. В данной статье представлены результаты и административные рекомендации возникшие на основе проведённой работы.

Общее обозрение проекта

Целью данного исследования является: 1) численность и распределение гнездящихся пар в их арктических колониях размножения (гнездования), а также размеры и численность в различных частях их зимовок; 2) осенние и зимние распределения, и как они могли измениться за последние 30 лет; 3) пути миграции и их регулирование в местах кормления на зимовках и их привязанность к специфическим местам; 4) степень выживания населения гусей западной Арктики и также зимующих северных и южных компонентов населения острова Врангеля; 5) эффективность минеральной окраски лицевого оперения гусей острова Врангеля, как указатель зимовок.

Гуси, не способные летать, были пойманы в зимних арктических колониях размножения (гнездования), и зрелые гуси были индивидуально окольцованы закодированными пластиковыми ошейниками и пронумерованными металлическими кольцами. С 1987 по 1991 годы были окольцованы 2643 гусей западной Арктики и 1462 белых гусей острова Врангеля. Обширная сеть сотрудников западного полушария Северной Америки проводила наблюдения, добившись в каждом году от 58 до 77% успеха в непосредственных наблюдениях.

Численность населения

Численность населения в колониях размножения (гнездования) определялась трансектовыми обзорами на почве острова Врангеля с надземными обозрениями западной арктической части Канады. На острове Врангеля, весной, численность зрелых гусей снизилась от 150 000 в 1970 годах до 56 000 в 1975 годах. В 1980 годах численность поднялась до 100 000, но в 1990 годах она в среднем сравнялась до 65 000 гусей. По контрасту, количество зрелых гусей в западной арктической части Канады, утроилось с 170 000 в 1976 году практически до 490 000 в 1995 году. В среднем годовой рост населения с 1976 до 1981 годов был 4.1%, а с 1981 по 1995 годов был 6.3%.

Подсчёт размеров населения от данных меток оценивался на некоторых зимовках в течение 1987-1989 годов. Эти расчёты схожи с независимыми надземными обозрениями проведёнными зимой. На основе инвенторных данных гнездования на почве и информации о зимнем распределении гусей с ошейниками, мы подсчитали размеры населения в разных зимних

районах. Мы обнаружили, что расчёты надземного обозрения зимовок сходились с экстраполяциями подсчётов гнездования зрелых гусей 1987 года, но отличались от результатов 1995 года. Расчёты с мест зимовок показали 34% меньше гусей в районах Тихого и Западно-Центрального миграционного пути, чем предполагалось путем экстраполяции общего количества популяции со всех подсчетов 1995 года размножения с острова Врангеля и западной части арктической Канады. Вероятно, это расхождение было вызвано недооценкой численности гусей в зимних обозрениях.

Осенние и зимние распределения

Осенние и зимние распределения были основаны на данных собранных с гусей с ошейниками за период 1953-1979 годов и с гусей с кольцами и ошейниками с 1987 до 1992 годов. В течение нескольких последних осенних сезонов, население западной части арктической Канады и меньше чем 6% населения острова Врангеля мигрировали по канадским прериям, остальная часть населения Врангеля двигалась к побережью Тихого океана. Миграционный путь гусей западной Арктики поменялся в сторону восточных районов канадских прерий. Большая часть гусей (74%) мигрировала через восточную Альберту в 1950 и 1960 годах, когда лишь 26% пролетело над западом Саскачевана. В конце 1980 годов только 32-36% гусей остановились в восточной Альберте, и 64-68% в западном Саскатчеване.

Белые гуси зимуют в трёх районах западной части Северной Америки: 1) дельта реки Фрейзера (Британская Колумбия) и дельта реки Скейджита (штат Вашингтон); 2) центральный миграционный путь (Новая Мексика, северо-запад штата Техас, юго-восток штата Колорадо и плоскогорье севера Мексики); 3) центральная долина и бассейн Кламата штата Калифорния и юг штата Орегон. Кроме того, незначительная часть гусей зимуют в южной Калифорнии и в районе реки Колумбия в штатах Вашингтон и Орегон.

В 1960 и 1970 годах 90% западно-арктического населения гусей зимовало в Калифорнии, примерно 8% находилось в западной части центрального миграционного пути. В конце 1980 годов только 76% гусей зимовало в Калифорнии из них 24% в западной части центрального миграционного пути. Большинство современных отчётов о зимовке гусей наводят на мысль, что даже большие пропорции гусей западной Арктики зимуют в западной части центрального миграционного пути. Большой рост населения гусей западной Арктики является связанным с увеличением их численности во время зимовки в этом районе.

Возвраты колец в 1960 и 1970 годах дали возможность предположить, что почти 90% населения острова Врангеля зимовало в Калифорнии, а остаток в дельтах рек Фрейзер и Скейджит. К 1987-1992 годам менее 50% зимовали в Калифорнии. Относительное снижение численности гусей в Калифорнии происходило больше благодаря изменениям в характере переселений, чем в заселённости или районной разнице по отношению к выживанию или продуктивности.

Пути и выбор времени миграции

Пути и выбор времени миграции в 1987-1992 годах зависел от наблюдений за белыми гусями в ошейниках на острове Врангеля и на западной части арктической Канады. Осенью, гуси с острова Врангеля, придерживались дороги вдоль побережья к Британской Колумбии, Вашингтону и Калифорнии, и в незначительном количестве передвигались в Калифорнию через прерии юго-востока Альберты, юго-запада Саскачевана и западной части штата Монтана. Весной, большая часть птиц с острова Врангеля, которая зимовала в Калифорнии, возвращалась через прерии, а часть из Британской Колумбии-Вашингтона на север через юго-запад Аляски. Осенью, гуси из западной части Арктики путешествовали на юг через Альберту и Саскатчеван. Многие гуси, летящие в Калифорнию, затем отправились через западную Монтану и восточную часть Орегона. Большинство гусей передвигающихся по центральному миграционному пути придерживались восточной стороны Скалистых гор, хотя, небольшая группа направлялась в центральный миграционный путь через Калифорнию. Весной, большинство гусей западной Арктики следовало по тому же пути, но в обратном направлении. Гуси, зимовавшие в южной Калифорнии, летели на север через штат Юта. Более 90% самцов и самок, находившиеся под непосредственными наблюдениями в течение нескольких лет, были замечены на одной и той же зимовке каждый год, указывая этим высокую степень привязанности к местам зимовки.

Во время миграции и зимовки наблюдалось незначительное, временное разделение между гусями семьями острова Врангеля и западной Арктики. Осенью, птицы с острова Врангеля, зимующие на юге, прилетели в Альберту и Саскатчеван раньше западно-арктических птиц, а в восточный Орегон ещё раньше.

Коэффициенты выживания

Коэффициенты выживания были установлены для зрелых самок в ошейниках окольцованных в западной части арктической Канады, также в северной и южной области зимовки на острове Врангеля и на Аляске, в Британской Колумбии и в Новой Мексике. Около 75% меченных гусей были под наблюдением каждый год, что, естественно, привело к относительно незначительным стандартным ошибкам и к хорошей возможности выявить разницу выживания между группами гусей в ошейниках. Средний уровень выживания самок западной части арктической Канады с 1987-1989 годов (0.802) был выше, чем на острове Врангеля (0.685). Не было достаточно строгих свидетельств, что средний уровень выживания понижающегося населения гусей острова Врангеля, зимующего на юге (0.656) был ниже повышающегося населения зимующего на севере (0.628), хотя были доступны только двухгодичные сравнения. Тем не менее, степень выживания гусей западной арктической Канады в Калифорнии была значительно выше (0.844), чем та же степень на острове Врангеля. Выживание зрелых самок в обоих районах было схоже в течение всех лет с ноября по январь, но ниже для гусей с острова Врангеля в период с февраля по ноябрь.

Коэффициент выживания на основе сбора

колец со зрелых гусей с западной арктической Канады был 0.935 в 1960-1963 годах, 0.832 в 1973-1975 годах, и 0.789 в 1987-1989 годах, по сравнению с 0.668 в 1975-1977 годах на острове Врангеля. Сравнение этих, а также предыдущих расчётов наводит на мысль, что коэффициент выживания зрелых гусей острова Врангеля был 0.10-0.15 ниже, чем в западной арктической Канаде в 1970-1980 годах. Процент выживания зрелых гусей западной арктической Канады с 1960 до 1980 годов вероятно снизился. Процент выживания гусей острова Врангеля один из числа самых низких, опубликованных отчётов о белых гусях, когда в западной арктической части Канады относительно выше. Хотя разница коэффициента выживания некоторым образом может объяснить причину повышения численности гусей на западной арктической части Канады по отношению к острову Врангеля, мы не обнаружили никаких фактов, что разница в районах роста выживания может объяснить современные изменения зимнего расселения популяции обоих районов. Коэффициенты лова, основанные на данных с возврата колец, информации улова и на размере численности птиц, объединённого населения острова Врангеля и западной арктической части Канады были 15-20% в 1960 и 1970 годах и 10% в конце 1980 годов. Оба населения в конце 1980 годов вылавливались примерно на одном уровне (даты сопоставления ранних периодов были нам не доступны).

Минеральная окраска лицевого оперения гусей острова Врангеля

Исследования минеральной окраски гусей острова Врангеля была проведена биологами России. Они показали, что гуси зимующие на севере, проявляли тенденцию к красноватой окраске лиц, благодаря постоянной кормежке болотистой массой во время приливов. С другой стороны, гуси зимующие на юге, кормились на сельскохозяйственных полях, их лицевое оперение проявляло тенденцию сохранения белой окраски. В начале 1970 и конце 1980 годов, шкала лицевой окраски использовалась для определения гусей присоединившихся во время зимовки на 86-90%. В 1988 и 1989 годах на острове Врангеля, нами проверялась надёжность шкалы лицевой окраски, как показатель зимовки окольцованных белых гусей

Наблюдения за 1357 гусями в ошейниках с острова Врангеля показало, что 86% трёх нижних (белых) классификаций зимовало в Калифорнии, когда 90% трёх верхних (красных) классов зимовало в Британской Колумбии-Вашингтоне. Гуси, имевшие среднюю степень окраски, примерно 35%, не поддавались четкой квалификации зимовки в зависимости от краски лицевого оперения. Хотя идея лицевой окраски не распространена в настоящее время так широко, как раньше, она всё же может быть использована для продуктивности, выживания или модели миграции между разновидностями гусей, однако, учитывая то, что значительная пропорция населения может быть упущена из процесса подсчёта.

Рекомендации руководству

Наши исследования явно подчёркивают непрерывное беспокойство по отношению к белым гусям острова Врангеля. Если возможно, охота на это население должна быть ослаблена.

Та часть птиц, которая передвигается на севере может быть предохранена более жесткими законами охоты на зимовках в Вританской Колумбии-Вашингтоне, в свою очередь это может вызвать жалобы на гусей в связи с опустошением ими сельскохозяйственных посевов в этих районах. Труднее управлять птиц зимующих на юге Калифорнии, потому что этот район заселён не только белыми гусями, но и гусями Росс (Anser rossii). Для защиты и предохранения гусей острова Врангеля в Калифорнии также необходимо ограничить охоту на всё население.

Быстрый рост численности населения западной арктической Канады показывает, что естественная среда Арктики может быть под угрозой потери постбиц, как это произошло в некоторых областях вдоль побережья залива на Гудзоне. Изучение естественной среды и угрозы потери постбиц под влиянием белых гусей должны проводиться на острове Ванкса. Полезной рекомендацией руководством является стабилизация численности гусей западной части Канады по крайней мере на существующий уровень. Это можно достичь хотя бы путём удвоения существующего лова; получить его в пропорции 15-20%. Подобные размеры лова поддерживались в 1960 и 1970 годах, в то время рост численности населения был замедлен. Увеличение лова сейчас поможет предотвратить рост населения до уровня, когда их рост можно регулировать охотой. Повышение лова направлялось бы на увеличивающееся количество гусей мигрирующих по западно-центральному пути. Таким образом, гуси острове Врангеля и население гусей западной части арктической Канады будут не затронуты. Весенний лов в западной Арктике можно так же увеличить, хотя нужно концентрироваться на гусях возвращающихся к острову Ванкса, избегая гусей с малых и менее устойчивых колоний у реки Андерсон и острова Кендалл. Конечно, достичь значительного повышения лова в западной арктической части Канады или западного центрального пути будет не легко осущетвить, из-за относительно маленькой численности водоплавающих охотников в этих районах.

Обзоры наземного гнездования должны продолжаться ежегодно на острове Врангеля и через каждые пять лет в западной Арктике. Для согласования разницы в предполагаемой численности населения и в существующей, выведенной на основе данных с зимовок, мы предлагаем улучшить зимние подсчёты. Усовершенственный подсчёт должен иметь точность почвенного компонента для оказания помощи в точности оценок наземного обзора, и оценка соотношения между гусями росс и белыми гусями.

Для дальнейших исследований предпочтительно использовать радио сигналы на меченных птицах через спутник, чтобы добиться лучшего понимания в осенних и весенних миграциях гусей с острова Врангеля и западной части арктической Канады. Через северные районы и полную весеннюю миграцию гусей возвращающихся в западную Арктику из западной части центрального миграционного пути.

Project overview

Richard H. Kerbes and Katherine M. Meeres

1. Introduction

In the late 1980s, a convergence of concerns from Canada, Russia, and the United States led to an extensive international study (Bartonek 1986) of Lesser Snow Geese *Anser caerulescens caerulescens* (hereafter referred to as Snow Geese). The study focused on the populations that nested in the Western Arctic of Canada and on Wrangel Island in Russia (Fig. 1). The Snow Goose population on Wrangel Island had dropped by more than 50%, from 150 000 to fewer than 60 000 geese, in the early 1970s and had not recovered to its former level (Baranyuk 1992). Wrangel Island was the last surviving colony of Snow Geese in Asia, and it provided the only wintering population of Snow Geese in Canada (Boyd 1995). The Western Canadian Arctic Population had increased from fewer than 100 000 nesting birds in the 1950s to more than 200 000 in the early 1980s (Kerbes 1986). The Inuvialuit land claim settlement in the Western Arctic created both the need for enhanced waterfowl management and a source of funds for investigations of the geese there. Farther south, wildlife managers were concerned about apparent shifts in these populations on the wintering grounds. Improved and updated information was needed on the distribution, survival rates, and size of both populations.

In the late 1980s, Western Canadian Arctic Snow Geese were known to winter in California and to a lesser extent in a region known as the Western Central Flyway, which is composed of New Mexico, the Northern Highlands of Mexico, northwestern Texas, and southeastern Colorado. Wrangel Island Snow Geese had two distinct wintering areas: a northern area composed of the Fraser River Delta of southern British Columbia and the Skagit River Delta of northern Washington (BC-WA); and a southern area in California (Subcommittee on White Geese 1992a, 1992b). Biologists were concerned that the proportion of Wrangel Island Snow Geese wintering in California was declining and that the proportion wintering in BC-WA was increasing. They were also concerned that California was losing Snow Geese and Ross' Geese *Anser rossii* to the Western Central Flyway (Bartonek 1986), where increasing numbers of wintering geese, particularly in New Mexico, were damaging agricultural crops (Taylor and Kirby 1990). Management of the populations was confounded by mixing of populations of Snow and Ross' geese in California and the Western Central Flyway, because these species could not be separately

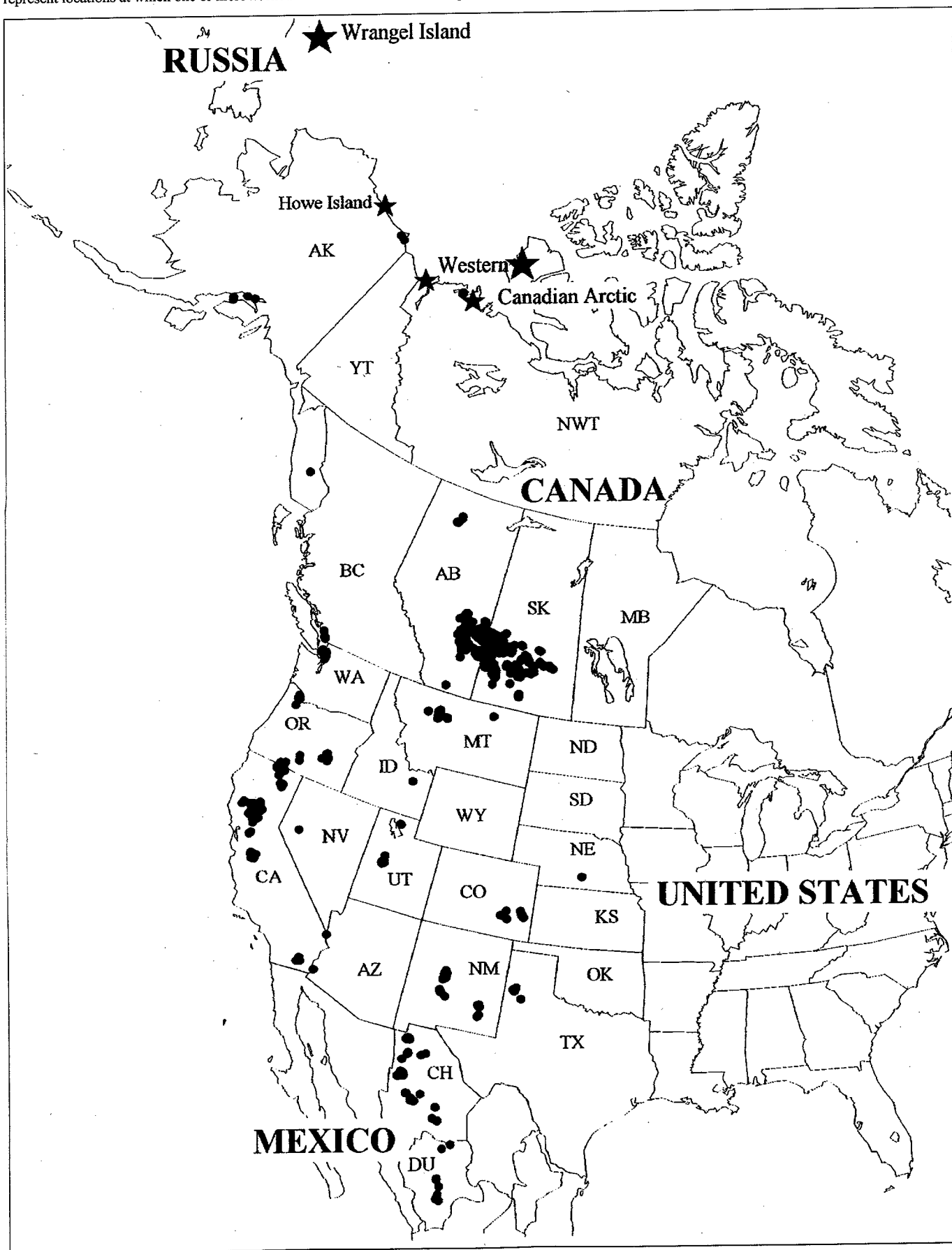
identified during winter aerial surveys (McLandress 1979; Silveira 1990).

The timing of these concerns in the flyways coincided with the implementation of the Inuvialuit Final Agreement in the Western Arctic and with a scientific exchange agreement between Canada and Russia to study the Wrangel Island Snow Geese. As a result, the International Snow Goose Neckbanding Project, a cooperative marking and monitoring program, was initiated in the summer of 1987 with the marking of Snow Geese in the Western Canadian Arctic (Bartonek 1986; Kerbes 1988). Wildlife agencies from Canada, the United States, and Mexico mobilized a network of observers to follow marked birds throughout fall, winter, and spring. The project expanded in 1988 to include neckbanding of Snow Geese on Wrangel Island and, in 1989, marking of both Snow and Ross' geese in the Central Canadian Arctic (Central Arctic results are not presented here). In this report, we include results from inventories of the breeding populations in the Western Canadian Arctic and on Wrangel Island, which provided important baseline data in analyzing the neckband results.

Snow Geese neckbanded in other projects were monitored within our project. Those studies, which are being reported elsewhere, included 1) work at the small colony in Alaska (500 birds, a satellite colony of the Western Canadian Arctic Population), monitored since the 1970s as a result of environmental concerns about oil field activity (Johnson 1996); 2) studies on the wintering grounds in British Columbia (McKelvey et al. 1989; Boyd 1995), New Mexico (Taylor and Kirby 1990), and Texas (D. Slack, pers. commun.); 3) a study of avian cholera in Snow Geese of the Pacific Flyway (Samuel et al. 1998); and 4) a project to restore wintering Snow Geese to Japan (Takekawa et al. 1994).

This Occasional Paper describes the major attributes of the Western Canadian Arctic and Wrangel Island Snow Goose populations. In this introductory paper, we outline the general objectives and scope of the project, summarize data on the numbers of geese neckbanded on their breeding grounds and subsequently observed on migration and wintering areas, and review the neckband observation effort and other concerns that are basic to a study of collared birds.

Figure 1
Arctic breeding areas (stars) with migration and wintering areas for Lesser Snow Geese from Wrangel Island, the Western Canadian Arctic, and Alaska. Dots represent locations at which one or more neckbands were observed over the period 1987–1988 to 1991–1992.



2. Objectives

The key objectives of this study were to determine the following parameters for the Western Canadian Arctic and Wrangel Island Snow Goose populations:

- 1) Numbers and distribution of nesting adults on their Arctic colonies, and the numbers of geese on their different wintering grounds;
- 2) Autumn and winter distributions, and how they might have changed during the past 30 years;
- 3) Temporal distribution and movements between migration staging and wintering areas, and fidelity of geese to specific wintering areas;
- 4) Survival rates for the Western Arctic Population and for each of the north- and south-wintering components of the Wrangel Island Population; and
- 5) Mineral staining in facial plumage of Wrangel Island geese as an indicator of wintering ground.

3. Neckbanding and monitoring

Flightless geese were captured on their breeding grounds from mid-July to early August by crews with helicopter support in the Western Arctic, using variations of methods described by Heyland (1970), Timm and Bromley (1976), and Maltby (1977); or by ground methods on Wrangel Island, using variations of methods described by Cooch (1953). Adult (after hatch year) geese received metal legbands and plastic neckbands. Neckband colour was black for the Western Canadian Arctic and red for Wrangel Island. Code colour was white. Associated projects in other areas used different neckband colours and, on the wintering grounds, different capture methods. Each neckband had a unique three-character code, which was etched into the neckband by removal of the outer layer of plastic to expose the underlying layer. Neckbands were 18 cm long, 5 cm wide, and 1.5 mm thick and were curled to a diameter of 4.5 cm, with a 1.5-cm overlap.

An extensive network of cooperators monitored the marked birds throughout western North America during migration and winter. Most of those observers were employed by federal, provincial, or state wildlife agencies, but some volunteers and some employees of nongovernment organizations were also involved. Data forms and instructions on field procedures (Kerbes 1987) were distributed to observers. Basic instructions for recording neckband observations included details on the information to be recorded in each field of the form. Locally appropriate methods were used to approach and observe feeding or resting flocks of geese, using spotting scopes from vehicles or tripods. Observers recorded neckband codes, location description, latitude and longitude to nearest minute, date, and start and end time of the observation session. Where feasible, observers also recorded numbers of geese present and estimates of the proportion of marked and unmarked adult geese in a sample of the total geese present.

Arctic marking and continental monitoring of geese under the International Snow Goose Neckbanding Project were coordinated through the Canadian Wildlife Service

office in Saskatoon, Saskatchewan. Data from banders and observers were compiled into a central database, and annual progress reports were distributed to cooperators (Kerbes 1988, 1989, 1990, 1991).

In total, 2643 Western Arctic and 1462 Wrangel Island Snow Geese were neckbanded on their Arctic breeding areas from 1987 to 1991. Direct annual observation rates (those recorded in the year immediately following banding) on those marked birds were over 50% in 1987–1988, rising to 65% and higher in subsequent years (Fig. 2; Table 1). Total observations of marked birds, direct and indirect (4410 for Western Arctic, 2215 for Wrangel), in each province and state are presented in Appendices 1 and 2.

3.1 Observation effort

Observers monitored geese on all major migration and wintering areas as much as possible, with some monitoring of “fringe” areas as well. Coordination and most of the fieldwork itself in each province and state were done by federal, state, or provincial wildlife agency personnel, with assistance from nongovernment and private observers. Thus, observers who were familiar with their region made a concerted effort to cover all areas within a given state or province where significant numbers of Snow Geese occurred.

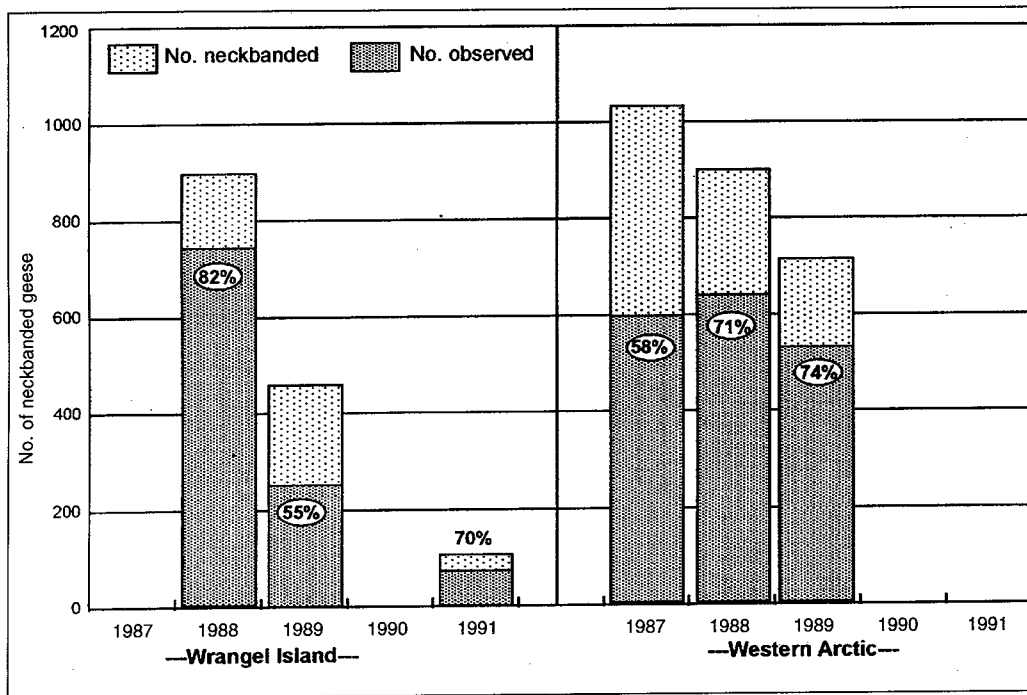
As an approximate measure of the amount and distribution of observer effort, we defined a *person-day* as a day on which an individual observer was in the field examining geese for neckbands. Approximately 66% of the 30 812 observation forms received from individual observers included observation times. That sample yielded an average of 135 minutes (standard deviation 56 minutes) of observation time per person-day.

Observation efforts increased from almost 700 person-days in 1987–1988 to over 1700 in 1991–1992 (Table 2). Figure 3 shows the distribution of observation effort by province and state in the three-year period, autumn 1987 to spring 1990. During that period, observers concentrated their efforts on Snow and Ross’ geese. Subsequent years were not included in this figure, because observers were also monitoring neckbanded White-fronted Geese *Anser albifrons* and small Canada Geese *Branta canadensis*, and separate times were not recorded (Kerbes 1991).

We believe that the amount and distribution of observation effort (Fig. 3; Table 2) were broadly related to the distribution and numbers of the geese. Observers covered the areas where geese were staging in migration and wintering throughout the range of the Western Arctic and Wrangel Island geese, in southern Canada, the United States, and Mexico. As noted above, those observers were very familiar with goose distribution in their regions and dedicated to monitoring both known and “new” areas of concentration. The efforts of more than 180 observers throughout the range were unlikely to have missed significant concentrations of geese. Owing to variation in the numbers and availability of the geese and in the resources available within a given province or state for making observations, some areas of concentration were undoubtedly covered more thoroughly than others. However, it is very unlikely that such variation was large enough to have affected the accuracy of the general patterns of goose distribution that we obtained from the neckband monitoring network.

Figure 2

Numbers of Lesser Snow Geese neckbanded from 1987 to 1991, by nesting region, with subsequent direct observations

**Table 1**Number of Lesser Snow Geese neckbanded in 1987, 1988, 1989, and 1991, by nesting region,^a with subsequent direct observations^b

Region	Neck-banded, 1987	Observed, 1987-1988		Neck-banded, 1988	Observed, 1988-1989		Neck-banded, 1989	Observed, 1989-1990		Neck-banded, 1991	Observed, 1991-1992		Total neck-banded, 1987-1991
		Uniques	%		Uniques	%		Uniques	%		Uniques	%	
Wrangel Island	—	—	—	897	739	82	460	251	55	105	73	70	1462
Western Arctic	1033	594	58	898	637	71	712	529	74	—	—	—	2643
Total	1033	594	58	1795	1376	77	1172	780	67	105	73	70	4105

^a See Figure 1 and note: Western Arctic = Anderson River, Egg River (Banks Island, includes Lennie River), Kendall Island (Big Lake).^b Those recorded in the year immediately following banding.

The observation effort in the major wintering regions during this study appeared to be sufficient to identify most of the neckbanded birds in a given region. Essentially, further observation effort and accumulation of sightings beyond a certain point did not increase the number of individual geese (unique neckband codes) identified. The number of sightings of "new" unique codes began to level off before the end of winter in at least one year on each major wintering region, except Mexico (Figs. 4-7).

The high average rate of resightings per winter in these major wintering regions also indicated that most marked birds present on the key wintering areas (with the exception of Mexico) were seen. Over the period 1987-1992, the mean annual number of resightings per marked bird for Western Arctic geese was 3.4 in California, 6.6 in New Mexico, 1.5 in Chihuahua, and 2.1 in Durango (Appendix 1); and for Wrangel Island geese, 4.0 in British Columbia, 3.2 in Washington, and 3.7 in California (Appendix 2).

A final line of evidence that the neckband observation network provided a good estimate of the winter distribution of Snow Geese is presented elsewhere in this volume (Hines et al. 1999a). Three independent methods (legband

recoveries from hunter-killed geese, numbers of neckband observations, and a mark:resight estimate of the number of collared geese present in different areas) all provided very similar pictures of winter distribution.

3.2 Errors in reading neckband codes

We found, as did Raveling et al. (1990) in a study of neckbanded Canada Geese, that less experienced or "casual" observers made more errors than experienced "primary" observers. As in that study, our monitoring network had a small number of primary observers (wildlife agency employees, contractors, and key volunteers) who reported most of the codes and had a lower error rate than the other observers. As a minimum measure of error rate, we used the frequency of "rejects" or reported codes that did not exist. (We used the 1991-1992 observation year, as we could not separate primary from casual observers with enough certainty prior to that year.) The error rate for primary observers (1.4%) was much lower than that for casual observers (10.5%) ($\chi^2 = 9.98$, 1 df, $P < 0.01$). As the rate for primary observers was low, and as the casual observers

Table 2
Observation effort on monitoring neckbanded geese, International Snow Goose Neckbanding Project, 1987–1992, measured in person-days^a

State/province ^b	Number of person-days				
	1987–1988	1988–1989	1989–1990	1990–1991	1991–1992
Canada					
British Columbia	83	73	64	36	87
Alberta	26	41	61	130	107
Saskatchewan	157	149	166	303	272
Manitoba	4	6	14	38	61
Pacific Flyway					
Alaska	3	12	26	1	–
Washington	9	41	52	33	12
Columbia River ^c	–	7	12	13	4
Oregon	16	23	54	41	47
California	196	327	373	252	186
Imperial Valley ^d	11	15	12	5	6
Montana	4	19	47	55	57
Utah	3	14	9	20	13
Nevada	2	3	8	5	7
Central Flyway					
North Dakota	21	16	32	77	116
South Dakota	5	23	11	64	53
Colorado	2	19	15	9	20
New Mexico	75	81	88	45	11
Kansas	–	4	23	43	104
Nebraska	–	6	19	77	203
Oklahoma	1	11	13	72	80
Texas	3	58	106	119	254
Mexico					
Chihuahua	67	47	58	17	8
Durango	3	13	16	2	4
Total	691	1008	1279	1457	1712

^a Person-day = a day in which an individual observer reported the examination of geese for neckbands, whether or not neckbands were actually seen.

^b Not included in this table are the Northwest Territories and Wrangel Island, as these included almost entirely breeding ground resightings, and Yukon Territory, Idaho, and Arizona, as these had less than five person-days in all years.

^c Northern Oregon/Southern Washington.

^d Southern California.

reported only a small proportion of the total data (2.0%), we concluded that observer error, after removal of known “reject” codes, was insignificant. The annual rate of known “rejects” over the five-year period ranged from 0.0% to 1.8%.

3.3 Problems caused by neckbands

Previous studies have indicated that neckbands can sometimes cause changes in behaviour or, in extreme cases, death of geese (Ankney 1975; Raveling 1976; Zicus et al. 1983; MacInnes and Dunn 1988; Ely 1990; Samuel et al. 1990). Many reported fatalities have been Canada Geese, which in general winter farther north than other geese and occasionally have ice buildup on their neckbands.

A few Snow Geese worked at the neckbands with their bills immediately after receiving them and got their lower mandibles stuck in the neckbands. Fortunately, they always managed to get them unstuck after, at most, a few minutes of struggling in the banding pen. The geese had “accepted” their new neckbands by the time they were released from the banding pen. However, three Snow Geese were reported to have drowned after release from banding

when they got their bills stuck in the neckbands while in deep water. A few geese were observed working at their neckbands well after the period of marking.

From 1987 to 1992, from over 7000 Snow Geese that had been neckbanded in the Western Canadian Arctic, on Wrangel Island, in Alaska, and in the Central Canadian Arctic, we received the following reports of ice accumulations on the neckbands, but not enough to affect the normal behaviour of the birds: five in Alberta, three in Saskatchewan, and one in Montana. During that period, two Snow Geese were reported shot in South Dakota and one in North Dakota with ice on their neckbands. One Snow Goose was found dead with an iced neckband in South Dakota. In addition to those, we had one report of a Snow Goose in California that was found dead with its lower mandible stuck in its neckband. Thus, the eight problem-related deaths reported, from the breeding to wintering grounds, out of 7000 collared Snow Geese represented a minimum mortality rate of 0.1% due to neckbands.

Figure 3
Observer effort, as measured in person-days per year (three-year average, 1987–1988 to 1989–1990), and calculated for each degree block

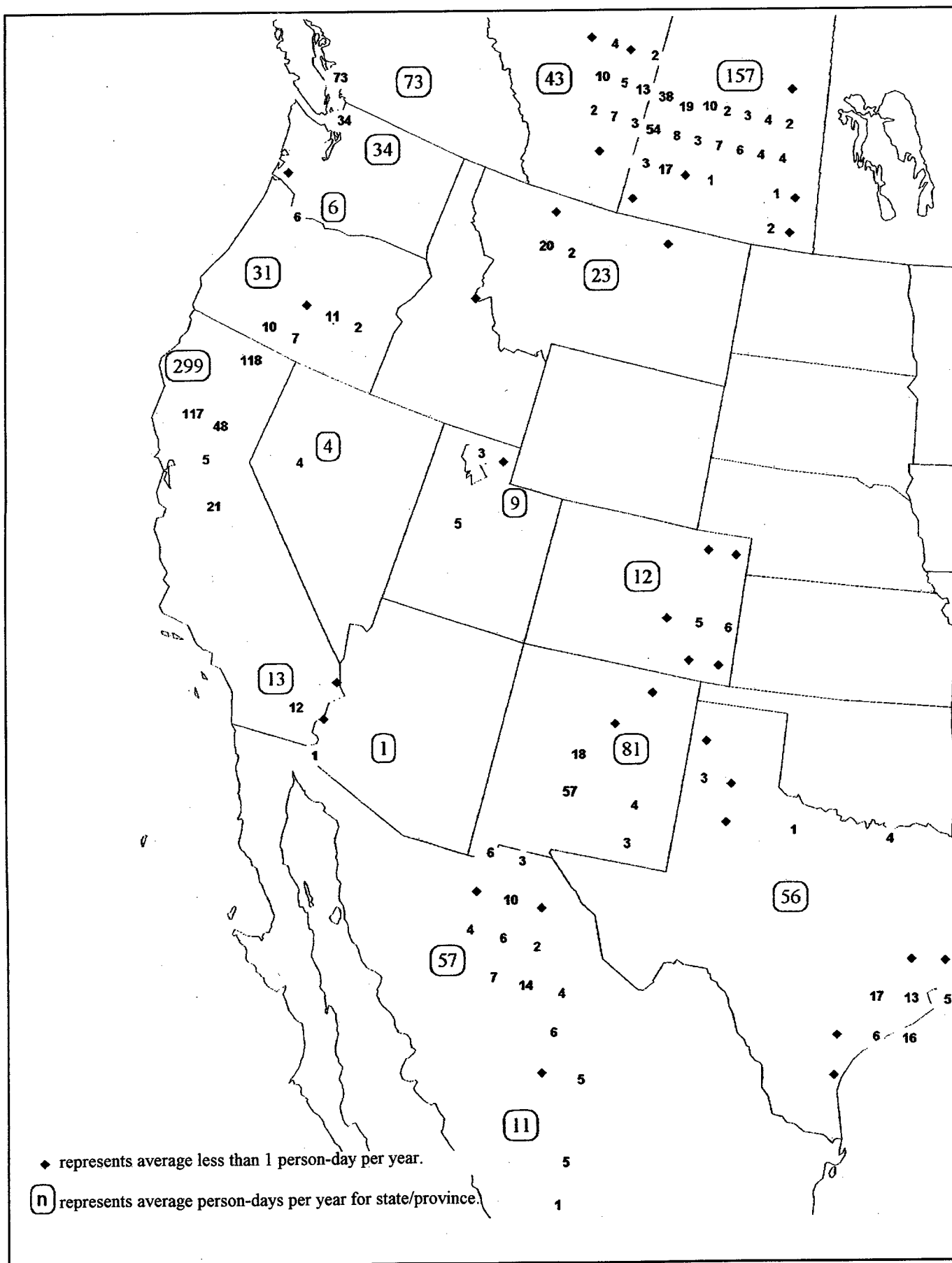
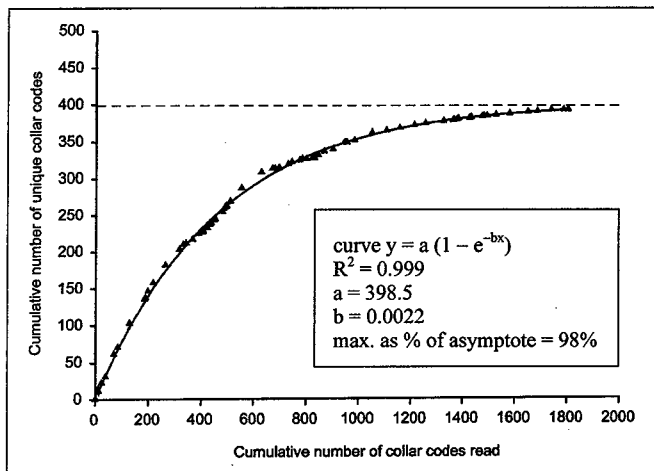
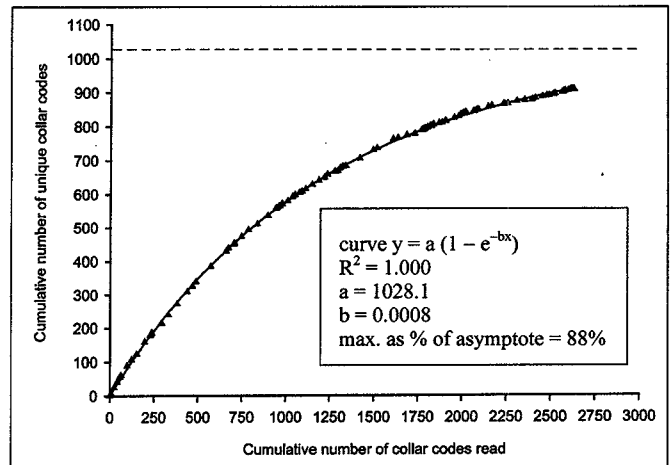


Figure 4

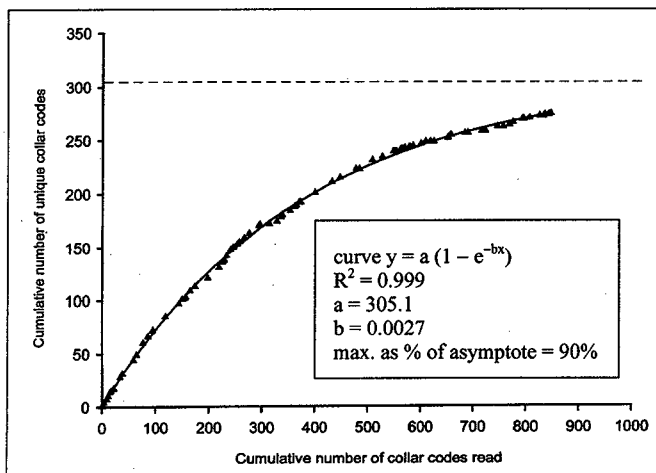
Relationship between cumulative collar codes read and new uniques encountered: wintering ground observations made in B.C.-Washington, 1988-1989, of birds neckbanded on Wrangel Island

**Figure 6**

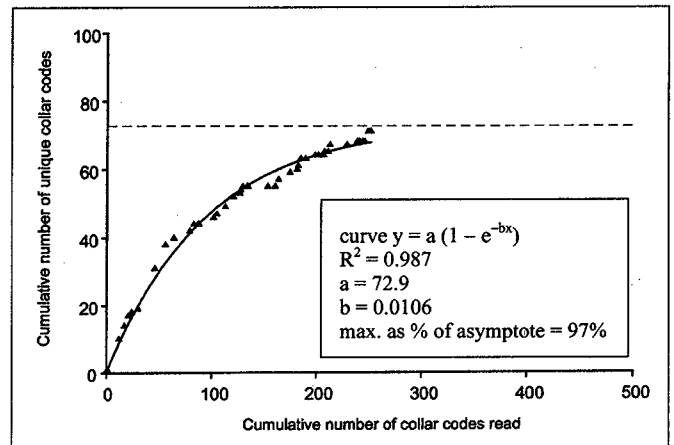
Relationship between cumulative collar codes read and new uniques encountered: wintering ground observations made in Central Valley, California, 1989-1990, of birds neckbanded in Western Canadian Arctic

**Figure 5**

Relationship between cumulative collar codes read and new uniques encountered: wintering ground observations made in Central Valley, California, 1989-1990, of birds neckbanded on Wrangel Island

**Figure 7**

Relationship between cumulative collar codes read and new uniques encountered: wintering ground observations made in New Mexico, 1990-1991, of birds neckbanded in Western Canadian Arctic



3.4 Neckband loss

Loss of neckbands from marked geese can cause biased estimates of survival or other population parameters. To determine if neckband loss was significant for Snow Geese, we used two sources of information: data on neckband retention collected during annual neckbanding at Howe Island, Alaska (Johnson et al. 1995); and questionnaires sent to hunters who had shot banded birds (see Samuel et al. 1990). The resulting estimates of neckband retention rates and their effects on survival estimates are described elsewhere in this volume (Hines et al. 1999b).

4. Literature cited

- Ankney, C.D. 1975. Neckbands contribute to starvation in female Lesser Snow Geese. *J. Wildl. Manage.* 39:825–826.
- Baranyuk, V.V. 1992. Wrangel Island Lesser Snow Geese population status, numbers, structure and problems of protection [abstract]. Page 23 in 7th North American Arctic Goose Conference and Workshop, 7–12 January 1992, Vallejo, California.
- Bartonek, J.C. 1986. Western Arctic and Wrangel Island Lesser Snow Goose marking/observation program — 1987 and beyond. Unpublished report, U.S. Fish and Wildlife Service, Portland, Oregon. 15 pp.
- Boyd, W.S. 1995. Lesser Snow Geese (*Anser c. caerulescens*) and American three-square bulrush (*Scirpus americanus*) on the Fraser and Skagit river deltas. Unpublished Ph.D. thesis, Department of Biological Sciences, Simon Fraser University, North Burnaby, B.C. 154 pp.
- Cooch, F.G. 1953. Techniques for mass capture of blue and Lesser Snow Geese. *J. Wildl. Manage.* 17:460–465.
- Ely, C.R. 1990. Effects of neck bands on the behavior of wintering Greater White-fronted Geese. *J. Field Ornithol.* 61:249–253.
- Heyland, J.D. 1970. Aircraft-supported Canada Goose banding operations in Arctic Quebec. *Trans. North East Fish Wildl. Conf.* 27:187–198.
- Hines, J.E.; Baranyuk, V.V.; Turner, B.; Boyd, W.S.; Silveira, J.G.; Taylor, J.P.; Barry, S.J.; Meeres, K.M.; Kerbes, R.H.; Armstrong, W.T. 1999a. Autumn and winter distributions of Lesser Snow Geese from the Western Canadian Arctic and Wrangel Island, Russia, 1953–1992. Pages 39–73 in R.H. Kerbes, K.M. Meeres, and J.E. Hines (eds.), *Distribution, survival, and numbers of Lesser Snow Geese of the Western Canadian Arctic and Wrangel Island, Russia*. Can. Wildl. Serv. Occas. Pap. No. 98, Ottawa, Ontario.
- Hines, J.E.; Wiebe, M.O.; Barry, S.J.; Baranyuk, V.V.; Taylor, J.P.; McKelvey, R.; Johnson, S.R.; Kerbes, R.H. 1999b. Survival rates of Lesser Snow Geese in the Pacific and Western Central flyways, 1953–1989. Pages 89–109 in R.H. Kerbes, K.M. Meeres, and J.E. Hines (eds.), *Distribution, survival, and numbers of Lesser Snow Geese of the Western Canadian Arctic and Wrangel Island, Russia*. Can. Wildl. Serv. Occas. Pap. No. 98, Ottawa, Ontario.
- Johnson, S.R. 1996. Staging and wintering areas of Snow Geese nesting on Howe Island, Alaska. *Arctic* 49:86–93.
- Johnson, S.R.; Schieck, J.O.; Searing, G.F. 1995. Neck band loss rates in Lesser Snow Geese. *J. Wildl. Manage.* 59:747–752.
- Kerbes, R.H. 1986. Lesser Snow Geese, *Anser c. caerulescens*, nesting in the western Canadian Arctic in 1981. *Can. Field-Nat.* 100:212–217.
- Kerbes, R.H. 1987. International Snow Goose Neckbanding Project instructions to observers for monitoring neckbanded birds. Unpublished report, Canadian Wildlife Service, Saskatoon, Saskatchewan. 10 pp.
- Kerbes, R.H. 1988. Progress report, International Snow Goose Neckbanding Project. Unpublished report, Canadian Wildlife Service, Saskatoon, Saskatchewan. 14 pp.
- Kerbes, R.H. 1989. International Snow Goose Neckbanding Project, progress report 1988–89. Unpublished report, Canadian Wildlife Service, Saskatoon, Saskatchewan. 18 pp.
- Kerbes, R.H. 1990. International Snow and Ross' Goose Project, progress report 1989–90. Unpublished report, Canadian Wildlife Service, Saskatoon, Saskatchewan. 14 pp.
- Kerbes, R.H. 1991. Arctic neckbanding and continental monitoring of geese, progress report, 1990–91. Unpublished report, Canadian Wildlife Service, Saskatoon, Saskatchewan. 27 pp.
- MacInnes, C.D.; Dunn, E.H. 1988. Effects of neck bands on Canada Geese nesting at the McConnell River. *J. Field Ornithol.* 59:239–246.
- Maltby, L. 1977. Techniques used for the capture, handling and marking of Brant in the Canadian High Arctic. *Can. Wildl. Serv. Prog. Notes* No. 72, Ottawa, Ontario. 6 pp.
- McKelvey, R.; Bousfield, M.; Reed, A.; Baranyuk, V.; Canniff, R. 1989. Preliminary results of the Lesser Snow Goose collaring program on the Alaksen National Wildlife Area, 1986 and 1987. *Can. Wildl. Serv. Prog. Notes* No. 183, Ottawa, Ontario. 5 pp.
- McLandress, M.R. 1979. Status of Ross' Geese in California. Pages 255–265 in R.L. Jarvis and J.C. Bartonek (eds.), *Management and biology of Pacific Flyway geese*. Oregon State University Book Stores, Corvallis, Oregon.
- Raveling, D.G. 1976. Do neckbands contribute to starvation of Lesser Snow Geese? [with response by C.D. Ankney]. *J. Wildl. Manage.* 40:571–572.
- Raveling, D.G.; Zedulak, D.S.; Silveira, J.G.; Weldon, J.A. 1990. Accuracy in recording neck-band codes of Cackling Canada Geese. *Calif. Fish Game* 76:205–210.
- Samuel, M.D.; Rusch, D.H.; Craven, S. 1990. Influence of neck bands on recovery and survival rates of Canada Geese. *J. Wildl. Manage.* 54:45–54.
- Samuel, M.D.; Takekawa, J.Y.; Baranyuk, V.V.; Orthmeyer, D.; Cooch, E.G. 1998. Effects of avian cholera on survival of Lesser Snow Geese in the Pacific Flyway [abstract]. Page 70 in 9th North American Arctic Goose Conference and Workshop, 7–11 January 1998, Victoria, B.C.
- Silveira, J.G. 1990. Distribution of Lesser Snow and Ross' geese in California, winter 1989–90. Unpublished report, California Department of Fish and Game, Sacramento, California. 7 pp.
- Subcommittee on White Geese. 1992a. Pacific Flyway management plan for the Wrangel Island Population of Lesser Snow Geese. Unpublished report, Pacific Flyway Study Committee, U.S. Fish and Wildlife Service, Portland, Oregon. 25 pp.
- Subcommittee on White Geese. 1992b. Pacific Flyway management plan for the Western Arctic Population of Lesser Snow Geese. Unpublished report, Pacific Flyway Study Committee, U.S. Fish and Wildlife Service, Portland, Oregon. 30 pp.
- Takekawa, J.Y.; Orthmeyer, D.L.; Kurechi, M.; Sabano, Y.; Syroechkovsky, E.V.; Litvin, K.E.; Baranyuk, V.V.; Andreev, A.V. 1994. Restoration of Lesser Snow Geese to East Asia: a north Pacific Rim conservation project. *Trans. North Am. Wildl. Nat. Resour. Conf.* 59:132–145.
- Taylor, J.P.; Kirby, R.E. 1990. Experimental dispersal of wintering Snow and Ross' geese. *Wildl. Soc. Bull.* 18:312–319.
- Timm, D.E.; Bromley, R.G. 1976. Driving Canada Geese by helicopter. *Wildl. Soc. Bull.* 4:180–181.
- Zicus, M.C.; Schultz, D.F.; Cooper, J.A. 1983. Canada Goose mortality from neck band icing. *Wildl. Soc. Bull.* 11:286–290.

Appendix 1

Lesser Snow Geese marked in the Western Canadian Arctic in 1987–1989: number of neckbanded birds observed in each of the years 1987–1988 to 1991–1992

State/province	1987–1988		1988–1989		1989–1990		1990–1991		1991–1992		Total	
	Unique ^a	Average ^b	Unique ^a	Average ^b	Unique ^a	Average ^b	Unique ^a	Average ^b	Unique ^a	Average ^b	Unique ^a	Average ^b
Russia												
Wrangel Island	–	–	4	1.0	2	1.0	1	1.0	– ^c	– ^c	7	1.0
Canada												
Northwest Territories	5	1.0	–	–	1	1.0	14	1.0	14	1.0	34	1.0
Alberta	26	1.1	59	1.1	303	1.3	199	1.4	62	1.1	649	1.3
Saskatchewan	199	1.3	424	1.4	602	1.6	158	1.3	43	1.1	1426	1.5
Pacific Flyway												
Alaska	–	–	–	–	15	1.0	–	–	–	–	15	1.0
Montana	5	1.0	73	1.1	258	1.5	190	1.7	125	1.9	651	1.6
Idaho	–	–	–	–	–	–	–	–	10	1.0	10	1.0
Oregon	21	1.0	46	1.2	107	1.3	27	1.7	6	1.3	207	1.3
Utah	1	1.0	32	1.4	44	2.0	36	2.8	23	2.2	136	2.1
Nevada	2	1.0	4	1.0	14	2.4	5	1.2	3	1.7	28	1.8
Arizona	–	–	1	1.0	–	–	–	–	–	–	1	1.0
Northern + Central California	397	3.1	754	4.2	949	3.6	493	2.6	230	2.0	2823	3.4
Southern California	13	1.8	38	2.6	59	1.9	6	1.0	5	1.4	121	2.1
Central Flyway												
Nebraska	–	–	–	–	–	–	2	1.0	–	–	2	1.0
Colorado	3	1.0	3	1.0	1	1.0	4	1.0	1	1.0	12	1.0
New Mexico	47	3.9	73	8.9	91	7.5	48	4.7	5	1.4	264	6.6
Texas	3	1.0	2	1.0	3	1.0	3	1.0	–	–	11	1.0
Mississippi Flyway												
Iowa	–	–	1	1.0	–	–	–	–	–	–	1	1.0
Mexico												
Chihuahua	27	1.4	84	1.1	130	1.9	16	1.1	1	1.0	258	1.5
Durango	–	–	24	1.7	70	2.3	2	1.5	–	–	96	2.1
Total	594 ^d	3.0	1132 ^d	4.4	1507 ^d	4.4	796 ^d	3.2	381 ^d	2.4	4410 ^d	3.8

^a Unique = Number of neckband codes unique within state/province per observation year.

^b Average = Mean number of observations per unique code.

^c 1991–1992 observations not available.

^d Number of neckband codes unique within all states and provinces combined.

Appendix 2

Lesser Snow Geese marked on Wrangel Island in 1988–1989 and 1991: number of neckbanded birds observed in each of the years 1988–1989 to 1991–1992

State/province	1988–1989		1989–1990		1990–1991		1991–1992		Total	
	Unique ^a	Average ^b	Unique ^a	Average ^b	Unique ^a	Average ^b	Unique ^a	Average ^b	Unique ^a	Average ^b
Russia										
Wrangel Island	214	1.9	185	1.3	160	1.6	— ^c	— ^c	559	1.6
Canada										
Northwest Territories	—	—	1	1.0	—	—	1	1.0	2	1.0
British Columbia	360	3.8	360	3.8	148	2.8	132	6.2	1000	4.0
Alberta	12	1.3	34	1.2	28	1.2	11	1.0	85	1.2
Saskatchewan	96	1.4	93	1.7	14	1.1	2	1.0	205	1.5
Pacific Flyway										
Alaska	24	2.3	92	1.5	—	—	—	—	116	1.6
Montana	42	1.2	86	1.5	38	1.8	57	2.2	223	1.7
Idaho	—	—	—	—	—	—	2	1.5	2	1.5
Washington	318	3.3	296	4.0	141	1.8	64	1.9	819	3.2
Northern Oregon/Southern Washington	15	1.6	15	2.5	5	7.8	6	2.3	41	2.8
Oregon	72	1.2	34	1.6	17	1.1	7	1.0	130	1.3
Utah	—	—	—	—	2	3.5	1	1.0	3	2.7
Nevada	—	—	2	2.5	1	1.0	1	2.0	4	2.0
Northern + Central California	336	4.5	302	4.1	193	2.7	125	2.0	956	3.7
Central Flyway										
New Mexico	1	16.0	1	24.0	1	12.0	—	—	3	17.3
Mexico										
Chihuahua	1	1.0	—	—	—	—	—	—	1	1.0
Durango	1	4.0	1	2.0	—	—	—	—	2	3.0
Total	739 ^d	6.4	727 ^d	6.3	453 ^d	3.7	296 ^d	4.6	2215 ^d	5.6

^a Unique = number of neckband codes unique within state/province per observation year.

^b Average = mean number of observations per unique code.

^c 1991–1992 observations not available.

^d Number of neckband codes unique within all states and provinces combined.

Estimated size of the Western Canadian Arctic and Wrangel Island Lesser Snow Goose populations on their breeding and wintering grounds

Richard H. Kerbes, Vasily V. Baranyuk, and James E. Hines

Abstract

The numbers of Lesser Snow Geese *Anser caerulescens caerulescens* (hereafter referred to as Snow Geese) nesting on Wrangel Island have been estimated annually since 1970 by ground surveys; numbers nesting in the Western Canadian Arctic were estimated in 1976, 1981, 1987, and 1995 by air photo surveys. On Wrangel Island, the total number of adults in spring (including nonbreeding birds) declined precipitously from 150 000 in 1970 to 56 000 in 1975. The population recovered during the 1980s to 100 000 but subsequently fell to an average of about 65 000 in 1990–1995. In contrast, the total number of nesting adults in the Western Canadian Arctic increased from 170 000 in 1976 to 207 500 in 1981 and to 486 000 in 1995 (an average annual growth rate of 4.1% from 1976 to 1981 and of 6.3% from 1981 to 1995). Since 1970, most of the Wrangel Island Snow Goose Population has nested at the Tundra River colony, with low and variable numbers nesting at a few other sites on Wrangel Island and on the coastal mainland of Siberia. Since 1976, over 95% of the Western Canadian Arctic Population has nested at the Egg River colony on Banks Island, and the remainder of the population has nested mainly in colonies at Anderson River and on Kendall Island.

Data collected during the neckband observation program were used to estimate the number of adult geese in some wintering areas. From 1987 to 1989, the average of our mark-resight estimates of adult Snow Geese was 241 000 in California and 41 000 in New Mexico. Independent winter aerial surveys, adjusted for the percentage of Ross' Geese *Anser rossii* in the counts, agreed with those results. The wintering ground surveys accounted for 34% fewer geese in the Pacific and Western Central flyways than expected by extrapolation of total winter population from the combined 1995 counts of breeding birds on Wrangel Island and the Western Canadian Arctic. It seems likely that the visual estimates of the winter inventory underestimated the actual number of birds.

Given the growth of the Western Arctic Population, we recommend that investigations be carried out to determine if overgrazing poses a threat to its Arctic habitats. We also recommend that breeding inventories continue on Wrangel Island and the Western Arctic and that wintering ground surveys in California and the Western Central Flyway be improved, including a ground-based estimate of the Ross':Snow goose ratio and correction for visual estimate bias.

Résumé

Depuis 1970, on estime le nombre annuel de Petites Oies des neiges *Anser caerulescens caerulescens* (appelées ci-après Oies des neiges) qui nidifient sur l'île Wrangler au moyen d'enquêtes sur le terrain. On a estimé le nombre d'oiseaux nicheurs de l'ouest de l'Arctique canadien en 1976, 1981, 1987 et 1995 au moyen de photographies aériennes. Sur l'île Wrangel, le nombre total d'adultes au printemps (incluant les oiseaux non nicheurs) a connu un déclin rapide et est passé de 150 000 en 1970 à 56 000 en 1975. Au cours des années 1980, la population a connu une remontée et se chiffrait à 100 000 individus, mais elle a par la suite connu une baisse et se situait à une moyenne de 65 000 de 1990 à 1995. Par contraste, le nombre total d'adultes nicheurs de l'ouest de l'Arctique canadien est passé de 170 000 en 1976 à 207 500 en 1981, puis à 486 000 en 1995 (un taux de croissance annuel moyen de 4,1 p. 100 de 1976 à 1981 et de 6,3 p. 100 de 1981 à 1995). Depuis 1970, la majeure partie de la population d'Oies des neiges de l'île Wrangel a nidifié dans la colonie de la rivière Tundra, tandis qu'un nombre variable nidifiait à d'autres endroits de l'île Wrangel et de la côte du continent de la Sibérie. Depuis 1976, plus de 95 p. 100 de la population de l'ouest de l'Arctique canadien a nidifié dans la colonie de la rivière Egg sur l'île Banks et le reste de la population a nidifié principalement dans des colonies de la rivière Anderson et sur l'île Kendall.

Les données recueillies pendant le programme d'observation des colliers ont servi à estimer le nombre d'oies adultes dans certaines aires d'hivernage. De 1987 à 1989, la moyenne de nos estimations de marquage-observation des Oies des neiges adultes était de 241 000 en Californie et de 41 000 au Nouveau-Mexique. Des enquêtes par photographies aériennes indépendantes réalisées en hiver, corrigées pour tenir compte dans les calculs du pourcentage des Oies de Ross *Anser rossii*, ont confirmé ces résultats. Les relevés des aires d'hivernage indiquaient qu'il y avait 34 p. 100 moins d'oies dans les voies migratoires du Pacifique et du centre-ouest qu'on l'avait estimé en se basant sur l'extrapolation de la population d'hiver totale à partir des relevés combinés des aires de nidification de 1995 sur l'île Wrangel et l'ouest de l'Arctique canadien. Il semble probable que les estimations visuelles des inventaires d'hiver ont sous-estimé le nombre réel d'oiseaux.

En raison de la croissance de la population de l'ouest de l'Arctique, nous recommandons que des enquêtes soient menées pour déterminer si le surpâturage présente une menace pour les habitats de l'Arctique. Nous recommandons également que les inventaires de reproduction se poursuivent à l'île Wrangel et dans l'ouest de l'Arctique et que les enquêtes sur les aires d'hivernage en Californie et dans la voie migratoire du centre-ouest soient améliorées et qu'elles comprennent une estimation fondée sur des observations au sol du ratio entre les Oies de Ross et les Oies des neiges et que l'on corrige le biais attribuable aux estimations visuelles.

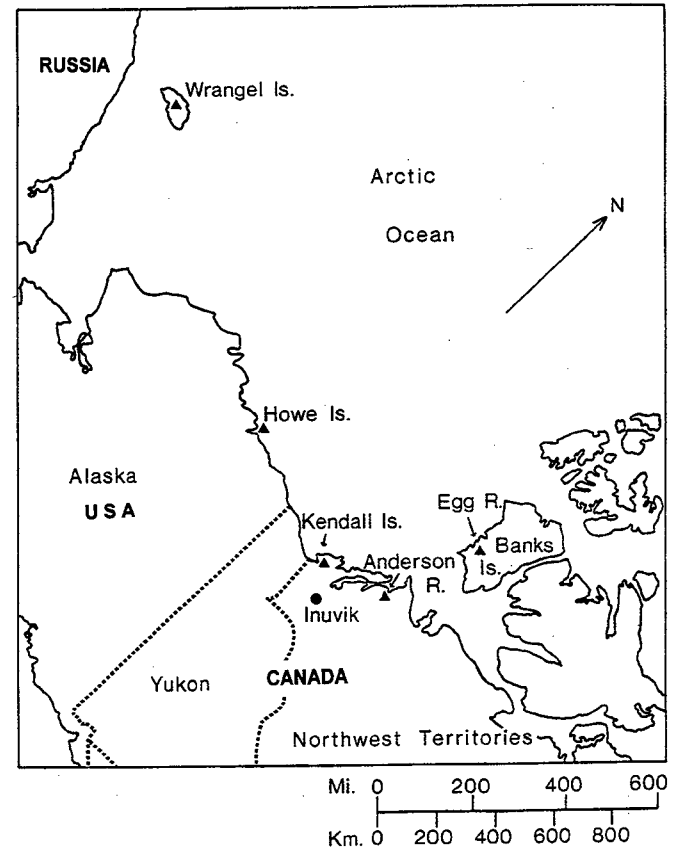
1. Introduction

An estimate of population size is perhaps the most fundamental information required for the management of any wildlife population. Surveys of breeding Lesser Snow Geese (*Anser caerulescens caerulescens* (hereafter referred to as Snow Geese) were first conducted in the 1960s on Wrangel Island, Russia (Uspenski 1965) and in the 1950s in the Western Canadian Arctic (Manning et al. 1956; McEwan 1958). More accurate inventories of nesting birds have been done in the Western Arctic periodically since 1976 using aerial photography (Kerbes 1983, 1986) and on Wrangel Island annually since 1970 using ground transects (Syroechkovsky and Litvin 1984; Bousfield and Syroechkovsky 1985).

The winter inventories of geese conducted annually in the Pacific Flyway include Snow Geese from the Western Canadian Arctic and Wrangel Island (Subcommittee on White Geese 1992a). Similar sorts of winter surveys conducted periodically in the Western Central Flyway include Snow Geese from both the Western and Central Arctic (Subcommittee on White Geese 1992b; Turner et al. 1994). Thus, both of these surveys have combined unknown proportions of geese from different breeding stocks. Ross' Geese *Anser rossii*, which also winter in California and the Western Central Flyway, have caused additional complications, because they cannot be distinguished from Snow Geese in visual aerial surveys. Except for a few special surveys that have included ground truthing to estimate the relative abundance of the two species (McLandress 1979; Silveira 1990; Turner et al. 1994), the winter surveys have combined Snow and Ross' geese as "white geese." The International Snow Goose Neckbanding Project (Kerbes and Meeres 1999, this volume) provided another means of estimating the numbers of combined Western Canadian Arctic and Wrangel Island stocks in certain wintering areas, using mark:resight methods (Hestbeck and Malecki 1989; Hestbeck et al. 1990).

The breeding ground inventory is the only current method to monitor the status of each of the Western Canadian Arctic and Wrangel Island Snow Goose populations (Fig. 1). In this paper, we review the historical and recent inventory results from the breeding grounds, and we present the 1987–1989 mark:resight estimates of total numbers in some wintering areas. We then discuss these results in relation to other surveys on the wintering grounds, long-term population trends, current population status of the geese, and the relevant applications of this information to research and management.

Figure 1
Nesting colonies of Lesser Snow Geese (triangles) in the Western Canadian Arctic, in Alaska, and on Wrangel Island



2. Methods

2.1 Breeding ground inventories

2.1.1 Wrangel Island

Annual numbers of nesting adults were estimated using a systematic ground survey of the main Wrangel Island colony located in the Tundra River valley, about 35 km inland from the ocean (Syroechkovsky and Litvin 1984). Each year, the boundary of the area occupied by nesting birds was determined from a ground survey walked during incubation. Following hatch in early July, after broods had left the colony, a ground survey was conducted of the number of nests present. Transects that were 8 m wide and spaced at 200-m intervals were run across the colony in an east–west orientation. Thus, the transects sampled 4% of the surface area of the colony. Observers walked the transects and counted all nests within 4 m of the centre line. The nests for the current year, both successful and unsuccessful (classified according to the presence or absence of egg membranes or shell remnants at the nest), were recorded per 250-m segment along each transect. The average nest density obtained from the transect segments was then multiplied by the area of the colony to estimate the number of nesting birds (two per nest) and 95% confidence limits of this estimate.

Nonbreeding birds were counted in early June on the Tundra River colony. Flocks of nonbreeders congregated on the colony at that time, generally in areas of low nest density or near the fringes of the occupied nesting area. The counts occurred before the nesting geese had begun to incubate and

before nonbreeders were thought to have dispersed to other areas. The nonbreeders were counted by an observer using binoculars and spotting scope from vantage points on hills overlooking the nesting grounds. This method provided a minimum estimate of nonbreeders, as some flocks of nonbreeders on Wrangel Island may not have come through the Tundra River colony in some years (V.V. Baranyuk, unpubl. data).

2.1.2 *Western Canadian Arctic*

Periodic inventories of the Snow Goose colonies in the Canadian Arctic have used large-format (23 × 23 cm) vertical aerial photography (Kerbes 1975, 1983, 1986; Reed et al. 1987). Air photos of the nesting colonies in the Western Arctic were obtained in June 1987 and June 1995, approximately midway through the incubation period. We used a small twin-engine aircraft equipped with a large-format camera and 153-mm lens. In 1987, Kodak Plus-X film was used to photograph the colonies from an altitude of 800 m above ground level, thereby providing a photo scale of 1:5000. In 1995, Kodak Panatomic-X film was used from an aircraft at 1600 m, providing a photo scale of 1:10 000. In 1995, the Panatomic-X film, which has much finer image resolution than Plus-X, permitted the higher flying height and increased strip width, for more cost-effective coverage.

The entire occupied nesting areas at Anderson River and Kendall Island were photographed in both years, and all birds were counted on those colonies. Because of the much larger size of the Egg River colony, the counts there were taken from samples of the photo coverage. In 1987, the photo lines covered a strip of ground 1.15 km wide, and line centres were spaced at 1.6-km intervals, which meant that 70% of the surface area of the colony was photographed. In 1995, the photo lines covered a 2.3-km-wide strip, and line centres were spaced at 2.0-km intervals, so that the nesting area was completely photographed. In both years, the counts were taken from photos that sampled all parts of the colony. The amount of the total surface area analyzed was 16.4% in 1987 and 18.0% in 1995.

The rolls of negatives were examined on a light table with a binocular microscope. Counts of geese were made using a transparent grid of 0.5- or 1.0-cm squares placed beneath the film. Birds were recorded as breeders (pairs or singles on the ground) or as nonbreeders (all geese in flight and flocks of five or more birds on the ground). The photo count of nonbreeders did not include geese that were located outside the nesting colonies at the time of the survey. The boundary of the colony was determined from the air photos, and the colony was divided into strata based on nest densities. Numbers of birds with 95% confidence limits in each stratum and the entire colony were then calculated (Kerbes 1986).

2.2 Mark:resight estimate of the number of geese on the wintering grounds

The mark:resight method involves capturing, marking, and releasing a sample of individuals, resampling the population later to determine what proportion of the population has been marked, and then calculating the population size based on this information (Krebs 1989; Hestbeck et al. 1990). In a Lincoln-Petersen or two-sample mark-recapture

study, the number of marked animals is known from trapping or banding data, and population size (N) can be estimated by the following or a similar formula:

$$N = M \times R$$

where M is the number of animals marked in the first sample and R is the ratio of the total animals to marked animals in the second sample.

Mark-recapture studies of neckbanded geese differ in a number of ways from a typical Lincoln-Petersen study. First, birds are marked on the breeding grounds, usually outside the period when the population estimate is derived. Second, marking typically occurs over a number of seasons, so neckbanded geese from several banding years are present. Finally, marked birds are "recaptured" by observers using spotting scopes to read their neckband codes rather than being physically recaptured.

Observations of Snow Geese made during the fall and winter on staging areas and on the wintering grounds (Kerbes and Meeres 1999, this volume) were used to estimate the total number of geese in certain wintering areas. The variables recorded at each observation site included date, location, individual neckband codes, estimated number of geese present, and the number of marked (neckbanded) and unmarked individuals in a sample of adult geese examined for neckbands.

Estimates of both the number of marked birds in the population (M) and the ratio of total to marked birds (R) must be obtained in order to determine population size. We estimated the number of marked birds (M) present in a given wintering area and year by the "closed" population methods described by Otis et al. (1978) using the computer program CAPTURE.

The approach endorsed by Otis et al. (1978) allows the testing of assumptions about the effects of heterogeneity, time dependence, and behavioural response on recapture (resighting) rates and, hence, the estimates of population size. Therefore, populations can be estimated according to a model that takes into account the different sources of variation and best fits the data. Behavioural or trap response is unlikely in resighting studies, so we eliminated models that included behavioural response. We chose Model M_{th} , which assumed that recapture (resighting) rates were time dependent and heterogeneous. This was because we expected resighting rates to vary with time and location as a result of variations in observer effort (Kerbes and Meeres 1999, this volume).

The wintering season (1 November – 31 March) was divided into 10 semimonthly sampling periods. The number of periods that could be used for a given location and year depended on data availability. Six to 10 sampling occasions were available for different individual year/wintering location combinations. The first time a neckbanded goose was sighted on the wintering grounds was treated as the time of marking, and each subsequent sighting was treated as a recapture. We attempted to estimate the number of neckbanded geese from Wrangel Island and the Western Canadian Arctic combined in each of the major wintering areas: British Columbia–Washington (BC-WA), California, New Mexico, and the Northern Highlands of Mexico.

The number of adult geese checked for neckbands differed from one occasion to another, depending on the

number of geese present at a particular site, how easy the birds were to observe, light and weather conditions, and a variety of other logistic constraints. Very large counts of marked and unmarked geese have been shown in one instance (Hestbeck and Malecki 1989) to underestimate the number of marked geese present. This would cause the estimate of R to be biased upwards and the estimate of population size to be too large. We wanted to evaluate the potential for a similar sort of bias, so we divided the data into classes by number of adult Snow Goose necks examined: <100, 101–200, 201–500, 501–1000, 1001–2000, and >2000. We then compared R for each observation size class.

An estimate of the ratio of total to marked geese in the observed samples (R) and its standard error ($SE(R)$) were calculated according to the formulas presented by Hestbeck and Malecki (1989):

$$R = \frac{\sum g}{\sum m}$$

$$SE(R) = \frac{1}{m} \sqrt{\frac{\sum (g - Rm)^2}{f(f-1)}}$$

where g is the number of adult geese checked for the presence of a neckband, m is the number of marked (neckbanded) adults among the g adults, and f is the number of flocks from which the information on total and marked geese was collected.

As explained above, the overall population estimate (N) is the product of M and R . Its standard error ($SE(N)$) can be computed by combining the variances (var) of M and R (Goodman 1960):

$$SE(N) = \sqrt{(R^2 var(M) + M^2 var(R) - var(M)var(R))}$$

3. Results and discussion

3.1 Breeding ground inventories

The inventories of nesting Snow Geese on Wrangel Island and in the Western Canadian Arctic have shown that these two populations have had very different trends over the past 30 years — a significant decline on Wrangel Island and a huge increase in the Western Arctic (Fig. 2; Table 1). The total number of adults present in spring (nesting plus nonbreeding birds) on Wrangel Island declined precipitously from 150 000 in 1970 to 56 000 birds in 1975, apparently due to four consecutive years of almost no reproductive success (Bousfield and Syroechkovsky 1985; Brault et al. 1994). The population increased during the 1980s to as many as 100 000 geese but has subsequently fallen to an average of 65 000 in 1990–1995. In contrast, the number of nesting adults in the Western Canadian Arctic increased almost threefold, from 170 000 in 1976 to 486 000 in 1995 (Fig. 2).

3.1.1 Wrangel Island

More than 98% of Asian Snow Geese nest on Wrangel Island, and over 90% of those birds nest at the Tundra River colony (Baranyuk 1992). Low and annually variable numbers nest at a few other sites on Wrangel Island and on the Arctic coast of Siberia. The largest and most

persistent of the small colonies is at the Mammoth River on Wrangel Island, approximately 10 km southeast of the Tundra River colony. Reported to have been a large colony until the 1950s, the Mammoth River colony has supported at most only a few hundred birds in recent decades (Takekawa et al. 1994; V.V. Baranyuk, pers. commun.). Southwest of Wrangel Island, on the Kolyma River Delta on the mainland coast, Uemura et al. (1998) recorded a small colony of 100–200 Snow Geese in 1993–1995. They reported that resightings of adults neckbanded there showed that those birds joined the Wrangel Island Population on migration to wintering grounds in North America.

Figure 3 shows the 10-km² area occupied in 1989 by nesting birds in the Tundra River valley. It represents a fairly typical distribution of the geese for many of the years from 1970 to 1995. However, in years with relatively large numbers of nesting birds, such as 1970 and 1981, the colony covered over 20 km², extending beyond the area shown in Figure 3, especially to the northeast (V.V. Baranyuk, pers. commun.).

On Wrangel Island, the annual number of nesting birds has been much more variable than the estimated number of nesting plus nonbreeding birds at the Tundra River colony in spring (Fig. 2; Table 1). From 1970 to 1995, the percentage of total birds that nested has varied widely, from 4% to 100%. The key factors affecting this proportion seemed to be the amount of snow cover in spring and the date by which it cleared (Bousfield and Syroechkovsky 1985; Baranyuk 1992).

3.1.2 Western Canadian Arctic

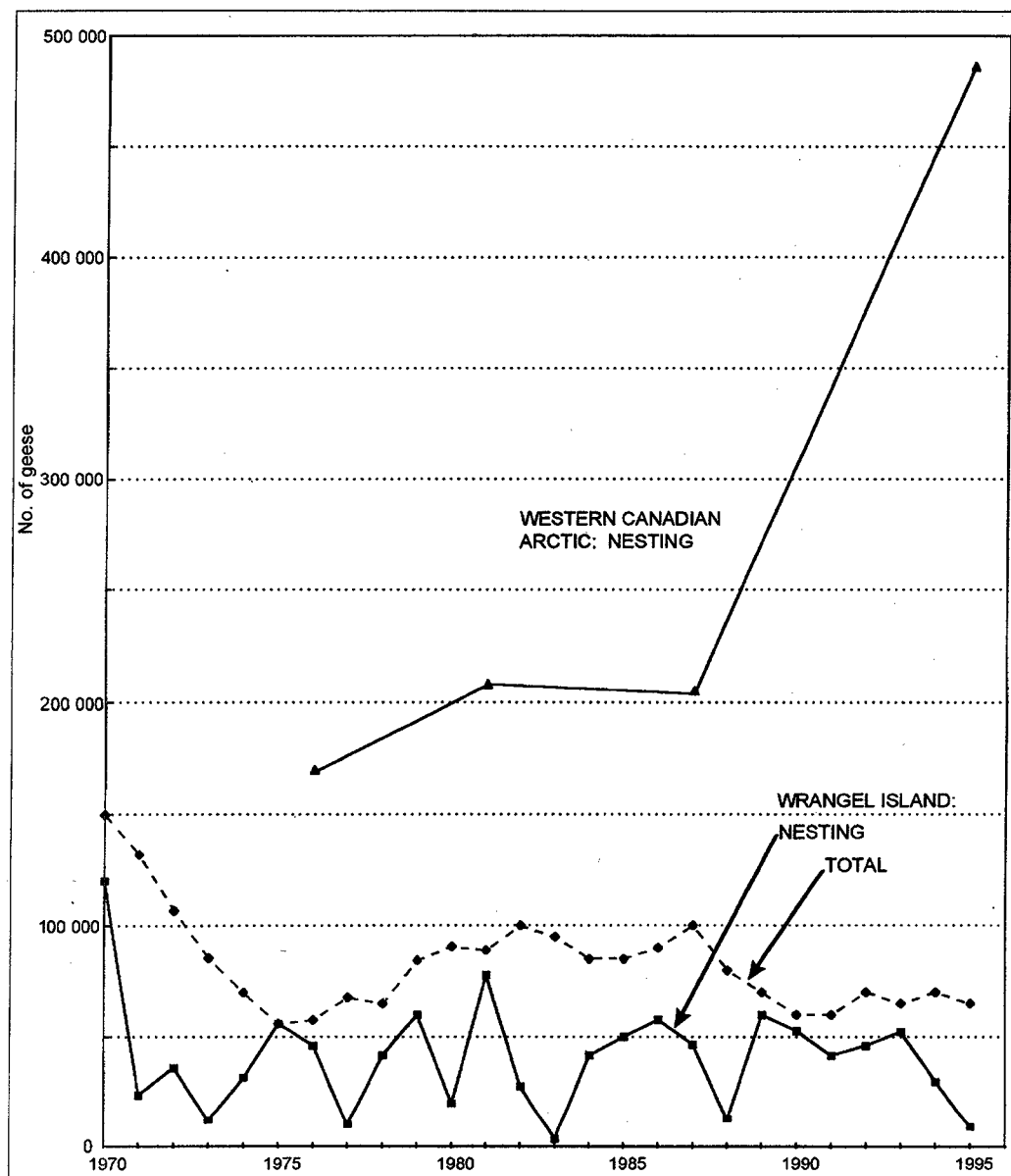
Since 1976, over 95% of the Western Canadian Arctic Population nested at the Egg River colony on Banks Island, and most of the remainder nested at coastal river deltas on the mainland at Anderson River and Kendall Island (Figs. 1, 4–6; Tables 2–4). A few other locations on the mainland, southwestern Banks Island, and southwestern Victoria Island have occasionally supported groups of nesting Snow Geese. The total number of geese in those small colonies has been estimated to be a few hundred birds at most (Kerbes 1986; T.W. Barry, pers. commun.; J.E. Hines, unpubl. data). Johnson (1996) considered the small colony of about 500 birds at Howe Island, Alaska, to be a satellite of the Western Canadian Arctic Population.

Nesting birds at Anderson River and Kendall Island have consistently occupied the same deltaic islands, with only minor variations in distribution of nests in 1987 and 1995 (Figs. 5 and 6) and in 1976 and 1981 (Kerbes 1986). Numbers and nesting success on these two small colonies appeared to be limited by annually variable but often severe loss to predation from barren-ground grizzly bears *Ursus arctos horribilis* or, less frequently, to flooding (T.W. Barry, S. Barry, and W.T. Armstrong, pers. commun.; J.E. Hines, unpubl. data).

On the main colony at Egg River (Kerbes 1986) (Fig. 4; Tables 3 and 4), the core nesting area consistently has been southwest of the junction of the Egg and Big rivers. The density of nests in the core has varied, as have the occupied areas outside the core. The total occupied area in 1976 (605 km²) was much larger than in later years (169, 109, and 112 km², respectively, in 1981, 1987, and 1995). Spring was unusually early in 1976 (T.W. Barry, pers. commun.). Apparently, without restrictions on the available

Figure 2

Annual number of nesting Lesser Snow Geese in June on Wrangel Island, Russia, 1970–1995, and the Western Canadian Arctic in 1976, 1981, 1987, and 1995; and total number of nesting plus nonbreeding birds on Wrangel Island



nesting area caused by snow cover, low densities of geese were extensive outside the core.

Spring habitat conditions on the Western Canadian Arctic colonies were assessed independently by ground work or visual air surveys in the years when air photo inventories were carried out. Of those years, 1976, 1981, and 1995 were rated as having average or early snowmelt (T.W. Barry and G. Samelius, pers. commun.), and we assumed that the majority of the birds in breeding condition were able to nest in those years. In 1987, snow clearance was later than average, resulting in reduced available nesting area. Thus, not all potential breeders may have been able to nest at Egg River that year.

Although the photo inventories could not detect the total number of nonbreeders, these surveys did provide an estimate of the number of nonbreeding geese on or near (within approximately 1 km) the nesting area. The minimum percentages of the geese at the Western Arctic colonies that

were nonbreeders were 7% and 8% in 1976 and 1981, respectively (Kerbes 1986), and 3% and 4% in 1987 and 1995, respectively. An unknown but probably large proportion of the nonbreeding geese was located outside the area covered by the air photos. On average, Snow Goose populations have been considered to have 25–35% nonbreeders in spring (Lynch and Singleton 1964; Lynch and Voelzer 1974). Therefore, the total breeding and nonbreeding geese in the spring Western Arctic Population could have numbered 270 000 in 1981 and 632 000 in 1995.

The Western Arctic Population grew at an average rate of 3.0% per annum from 1960 to 1976 (Table 5, assuming there were 105 000 *nesting* adults in 1960). From 1976 to 1981, the annual rate of increase was 4.1%, and from 1981 to 1995 it was 6.3%. That increasing growth rate raises concern for overpopulation with consequent risk of overgrazing of Arctic habitats, as noted below.

Table 1

Numbers of Lesser Snow Geese in June on Wrangel Island for 1970–1995 from annual ground surveys and in the Western Canadian Arctic for 1976, 1981, 1987, and 1995 from air photo inventories

Year	Wrangel Island			Western Canadian Arctic	
	Total no. of adults ^a	No. of nesting adults ± 2 SE ^b	% nesting adults	No. of nesting adults ± 2 SE ^b	
1970	150 000	120 000	80	—	
1971	132 000	24 000	18	—	
1972	107 000	36 000	34	—	
1973	86 000	12 000	14	—	
1974	70 000	32 000	46	—	
1975	56 000	56 000	100	—	
1976	58 000	46 000	79	169 600	
1977	68 200	10 000	15	—	
1978	65 400	42 000	64	—	
1979	84 500	60 000	71	—	
1980	90 700	20 000	22	—	
1981	89 000	78 000	88	207 500 (± 23 900)	
1982	100 000	28 000	28	—	
1983	95 000	3 400	4	—	
1984	85 000	42 000	49	—	
1985	85 000	50 000	59	—	
1986	90 000	58 000	64	—	
1987	100 000	47 000	47	205 100 (± 23 400)	
1988	80 000	13 000	16	—	
1989	70 000	60 000	86	—	
1990	60 000	53 000 ± 6 000	88	—	
1991	60 000	41 600 ± 3 200	69	—	
1992	70 000	46 200 ± 5 600	66	—	
1993	65 000	52 200 ± 5 600	80	—	
1994	70 000	30 000 ± 6 000	43	—	
1995	65 000	8 800 ± 2 400	14	486 000 (± 49 200)	

^a Nesting adults plus yearlings and other nonbreeders.

^b 95% confidence limits.

3.2 Wintering ground estimates compared with extrapolations from the breeding ground inventories

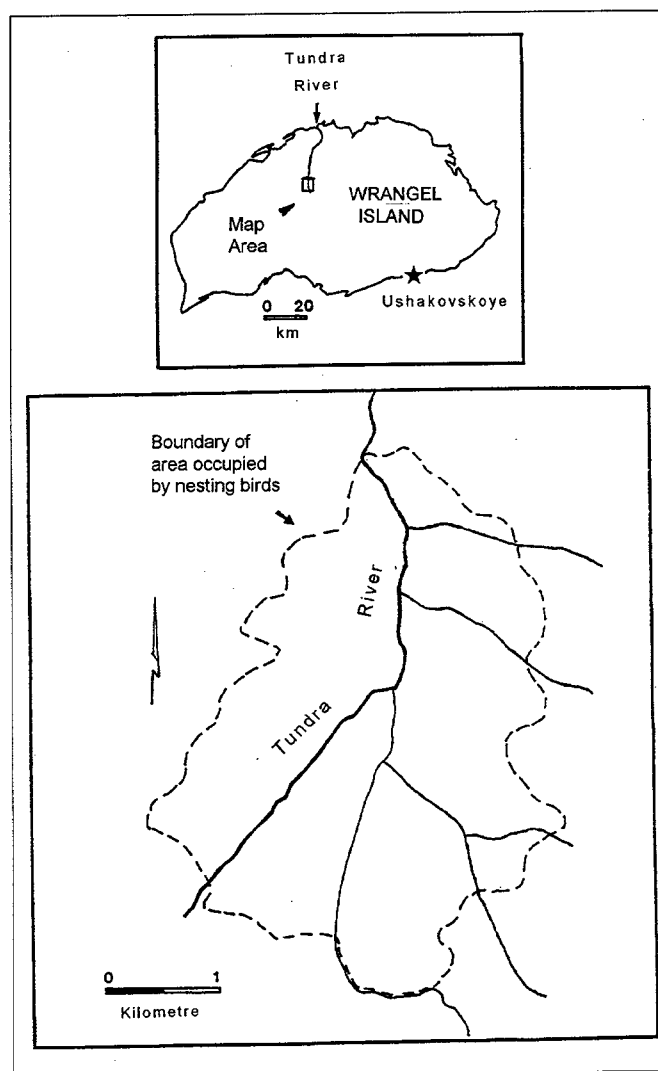
Adequate mark:resight data were available to provide good estimates of the number of neckbanded geese present in BC-WA, California, and New Mexico (Table 6). Although the sample size of marked:unmarked counts varied considerably from observation to observation, the proportion of marked birds did not decrease with size of the sample. Thus, data from all samples were used in calculating R for the different areas.

The average of our mark:resight estimates of total adult Snow Geese from 1987 to 1989 was 241 000 in California and 41 000 in New Mexico (Table 6). The difficulty in coverage of the wintering grounds in northern Mexico resulted in too few observations to estimate the number of neckbanded birds present there, and the size of the population could not be calculated. The population for BC-WA could not be estimated because marked:unmarked data were not recorded there.

Annual aerial surveys on the wintering grounds (Figs. 7–9) provide an independent set of data with which to compare our results. For California and the Western Central Flyway, we have further synthesized recent data from these surveys with data from “special” winter surveys to estimate the number of Snow and Ross’ geese in those areas (Table 7). This has allowed us to determine recent numbers and population trends of Snow Geese present in each

Figure 3

Lesser Snow Goose colony at Tundra River, Wrangel Island, Russia, June 1989



wintering area. For 1987–1990, our mark:resight estimates of adult snow geese wintering in California and New Mexico agreed with the ground count estimates.

In the Fraser–Skagit deltas, after a rapid decline of Snow Geese wintering in the early 1970s, the numbers returned to near their former level and have since fluctuated greatly (Fig. 7). Boyd (1995) documented the increased proportion of Wrangel Island geese wintering in the Fraser–Skagit deltas and the decline in the numbers and proportion of those wintering in California. Using analyses of legband recoveries, Hines et al. (1999a, this volume) documented that shift in distribution of wintering Wrangel Island geese and concluded that the most probable cause of the change in distribution is short-stopping of geese in the Fraser–Skagit area, where habitat conditions seem to have improved relative to those in California.

In California, the winter inventories indicate that the total number of Snow Geese from Wrangel Island plus the Western Canadian Arctic has not increased during the past 15 years (Fig. 8; Table 7) and may well have decreased, considering the growing numbers of Ross’ Geese there (Silveira 1989, 1990; Silveira and Mensik 1992). Given the relatively

Figure 4

Lesser Snow Goose colony at Egg River, Western Canadian Arctic, showing the area occupied by nesting birds in June 1987 (*above*) and in June 1995 (*below*)

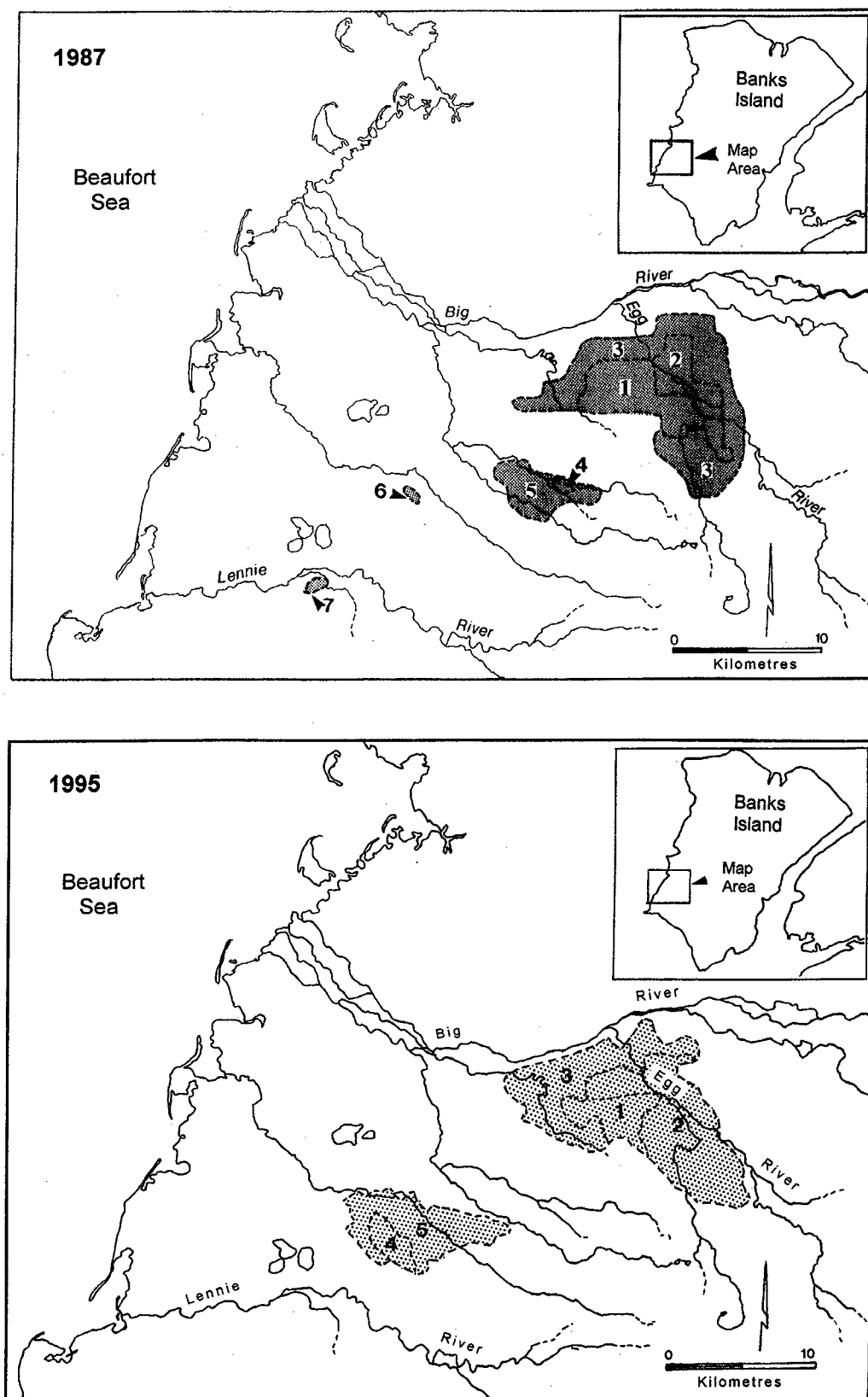
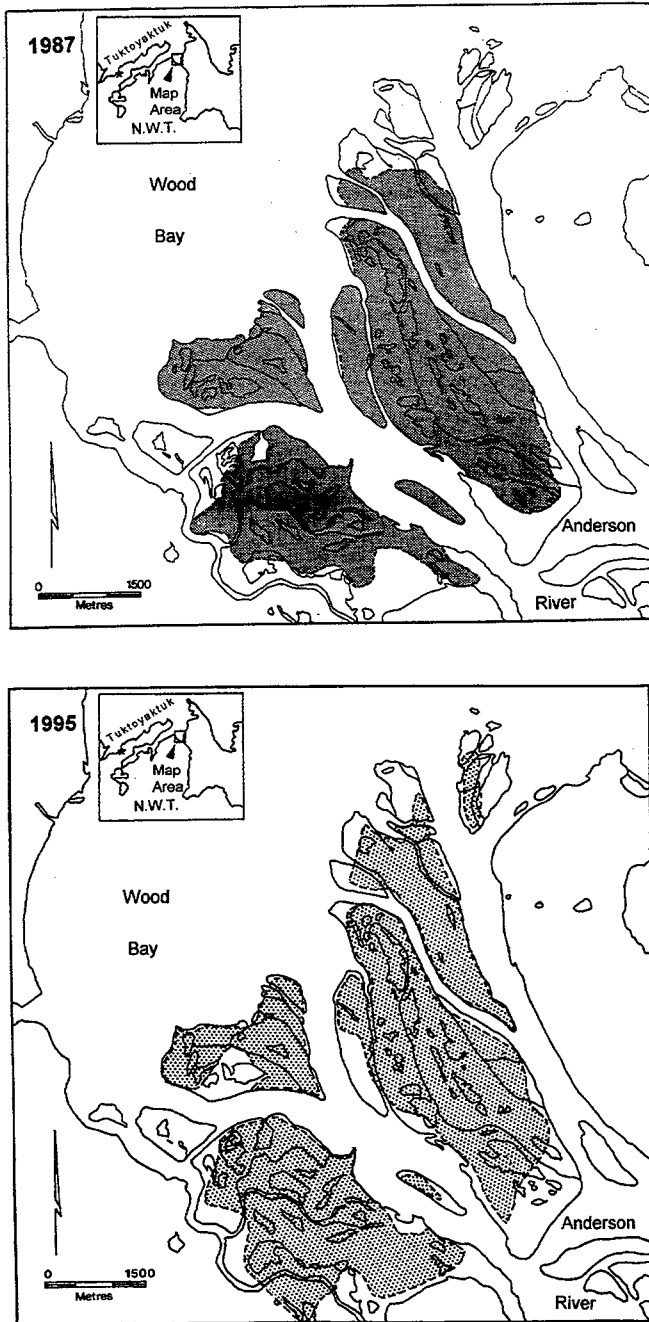


Figure 5

Lesser Snow Goose colony at Anderson River, Western Canadian Arctic, showing the area occupied by nesting birds in June 1987 (*above*) and in June 1995 (*below*)

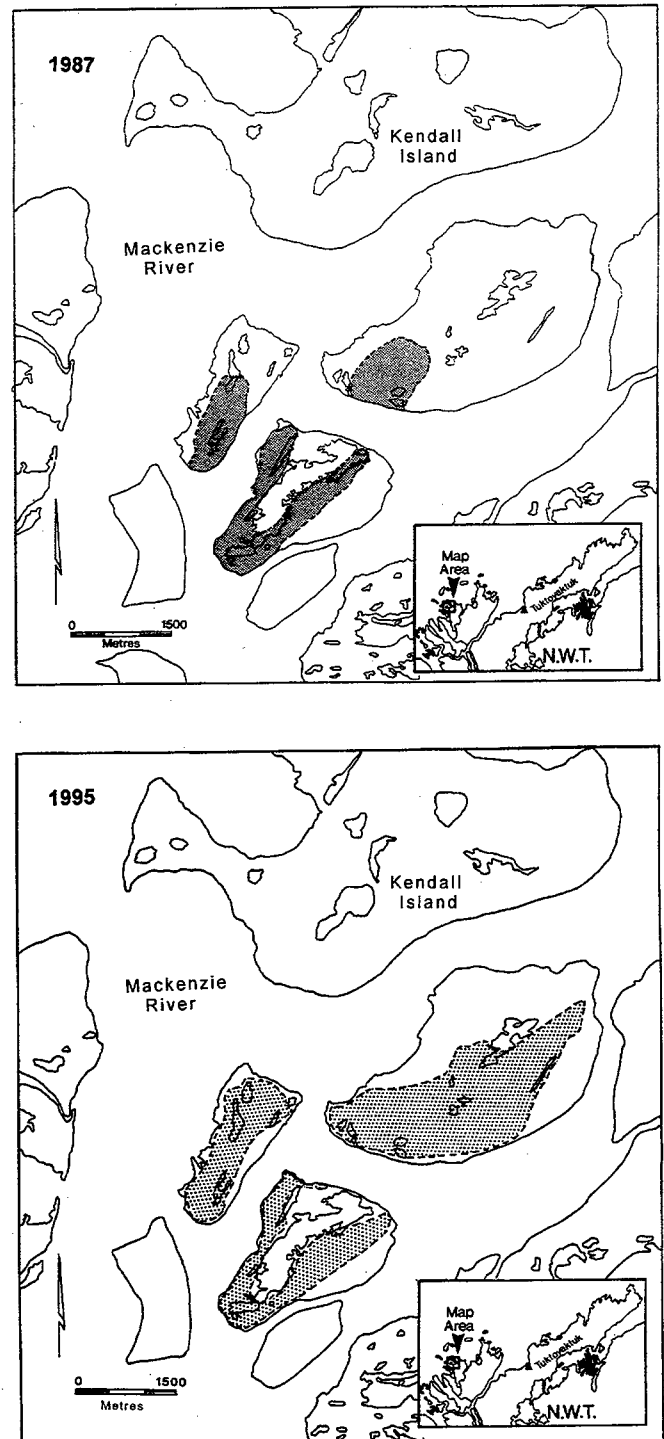


small number of Wrangel Island Snow Geese wintering in California, it appears that the number of Western Arctic geese in California has not increased, despite the substantial increase in the size of the Western Arctic Population.

In the Western Central Flyway, the number of wintering Snow Geese has increased since the early 1970s (Fig. 9), at least in part because of increased input from the Western Canadian Arctic (Hines et al. 1999a, this volume). The Central Arctic Snow Goose Population, which has also been increasing (Kerbes 1994), contributes substantial numbers to the Western Central Flyway as well. Turner et al. (1994), using neckband observations in Mexico and breeding population data, calculated that the Central Arctic

Figure 6

Lesser Snow Goose colony at Kendall Island, Western Canadian Arctic, showing the area occupied by nesting birds in June 1987 (*above*) and in June 1995 (*below*)



contributed approximately 40% of the Snow Geese in the Northern Highlands in 1989–1990. We recalculated that estimate, using their method, for Mexico (Appendices 1 and 2) and for New Mexico (Appendix 3). We used the actual proportions of western and eastern components of the Central Arctic Population (Kerbes 1994, Appendix 2) — i.e., 6000 and 273 000 birds, respectively, compared with 150 000 and 150 000 used by Turner et al. (1994). We

Table 2
Photographic inventory of Lesser Snow Goose colonies in the Western Canadian Arctic, 16–17 June 1987 and 11 June 1995

Year	Colony	No. of nesting birds \pm 2 SE ^a	Total nesting area (km ²)	% analyzed on photos	Mean density (birds/ha)
1987	Egg River	196 506 \pm 23 384	109.4	16	18.0
	Anderson River	7 186 \pm 0	15.9	100	4.6
	Kendall Island	1 380 \pm 0	3.2	100	4.4
	Total	205 072 \pm 23 384	128.5		16.0
1995	Egg River	479 362 \pm 49 151	112.1	18	42.8
	Anderson River	3 607 \pm 0	15.2	100	2.4
	Kendall Island	3 050 \pm 0	6.4	100	4.8
	Total	486 019 \pm 49 151	133.7		36.4

^a 95% confidence limits.

Table 3
Photographic inventory of Lesser Snow Goose colony at Egg River, Western Canadian Arctic, 16 June 1987

Stratum (see Fig. 3)	No. of nesting birds \pm 2 SE ^a	Total nesting area (km ²)	% area analyzed	Density (nests/ha)
1	152 936 \pm 19 955	28.48	22.8	26.85
2	23 114 \pm 10 551	15.12	19.1	7.64
3	11 723 \pm 7 327	51.42	9.8	1.14
4	1 686 \pm 0	0.64	100.0	13.17
5	1 572 \pm 781	12.41	11.7	0.63
6	1 518 \pm 0	0.66	100.0	11.50
7	3 956 \pm 0	0.71	100.0	27.86
Total	196 505 \pm 23 383	109.44	16.4	8.98

^a 95% confidence limits.

Table 4
Photographic inventory of Lesser Snow Goose colony at Egg River, Western Canadian Arctic, 11 June 1995

Stratum (see Fig. 3)	No. of nesting birds \pm 2 SE ^a	Total nesting area (km ²)	% area analyzed	Density (nests/ha)
1	148 486 \pm 13 451	11.48	17.7	64.67
2	241 907 \pm 42 093	48.05	18.5	25.17
3	40 235 \pm 20 535	27.18	15.6	7.40
4	20 539 \pm 6 152	3.47	30.0	29.60
5	28 148 \pm 10 133	21.94	18.5	6.41
Total	479 315 \pm 49 151	112.12	18.0	21.38

^a 95% confidence limits.

Table 5
Estimated numbers of Lesser Snow Geese in the Western Canadian Arctic colonies, 1952–1995

Year	Egg River	Anderson River	Kendall Island	Total	Reference
1952	120 000 ^a				Manning et al. (1956)
1953	100 000 ^b				Höhn (1954)
1955	41 000 ^b	500 ^b			McEwan (1958); Höhn (1959)
1960	116 000 ^a	8 000 ^a	7 500 ^a	131 500 ^a	Barry (1960)
1967	150 000 ^a				Barry (1967)
1976	165 000 ^b	3 800 ^b	800 ^b	169 600 ^b	Kerbes (1983)
1981	198 100 ^b	8 400 ^b	1 000 ^b	207 500 ^b	Kerbes (1986)
1987	196 500 ^b	7 200 ^b	1 400 ^b	205 100 ^b	This paper
1995	479 400 ^b	3 600 ^b	3 000 ^b	486 000 ^b	This paper

^a Total adult population, including nonbreeders.

^b Total nesting adult population.

thereby estimated that in 1989–1990, the Central Arctic contributed 20% of the birds wintering in the Northern Highlands north of 28°N (Appendix 1), 13% in the Northern Highlands south of 28°N (Appendix 2), and 16% in New Mexico (Appendix 3), or 17% in the three areas combined (Appendix 4).

The winter inventory in 1987–1992 seemed to account for most of the geese from Wrangel Island and the Western Canadian Arctic, based on our estimates of their numbers on the breeding colonies and their winter distribution as shown by neckband resightings and legband recoveries (see Hines et al. 1999a, this volume). However, an

extrapolation from the 1995 breeding inventories does not agree well with the recent winter inventory results. Those inventories suggest an extrapolated population total in 1995–1996 of at least 800 000 birds: 486 000 nesting adults for the Western Arctic and 65 000 total adults for Wrangel Island, plus nonbreeders and young birds from the Western Arctic (almost no young were fledged from Wrangel Island in 1995). The grand total from the winter counts on the Pacific and Western Central flyways was 566 500 (Table 7). Subtracting the proportion of that total which came from the Central Canadian Arctic (17% of the Western Central Flyway subtotal, as noted above) leaves 525 600. Thus, it

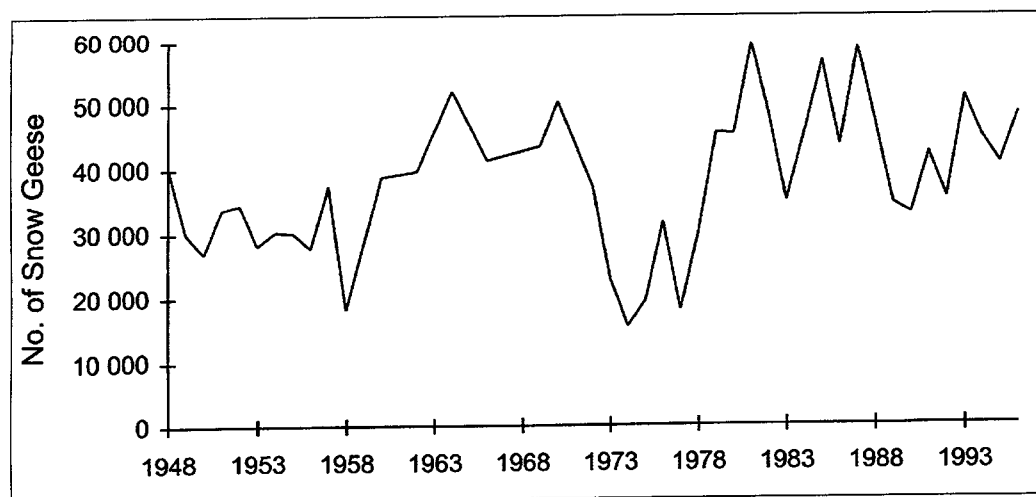
Table 6

The estimated numbers of Snow Geese in different wintering regions based on mark:resight data on geese marked (neckbanded) in the Western Canadian Arctic and Wrangel Island

Location	Year	Estimated no. of marked geese \pm SE	No. of geese examined		Ratio of total:marked \pm SE	Population estimate \pm SE	CV (%)
			Total	Marked			
British Columbia and Washington	1988	388 \pm 19					
	1989	337 \pm 12					
Average (1988–1989)							
California	1987	750 \pm 33	29 556	89	332.1 \pm 40.2	249 068 \pm 32 085	12.9
	1988	1 546 \pm 32	68 417	500	136.8 \pm 9	211 545 \pm 14 528	6.9
	1989	1 703 \pm 29	33 135	215	154.1 \pm 19.6	262 460 \pm 33 604	12.8
Average (1987–1989)						241 024	
New Mexico	1987	88 \pm 8	56 808	90	631.2 \pm 92.9	55 546 \pm 9 666	17.4
	1988	113 \pm 7	71 005	205	346.4 \pm 30.8	39 143 \pm 4 306	11
	1989	133 \pm 9	22 099	106	208.5 \pm 18.4	27 728 \pm 3 031	10.9
Average (1987–1989)						40 806	

Figure 7

Winter aerial visual counts of Lesser Snow Geese in the Fraser–Skagit Delta, BC-WA, 1948–1996 (from Boyd 1995)

**Figure 8**

Winter aerial visual counts of Lesser Snow and Ross' geese in California, 1979–1995 (from Trost 1996)

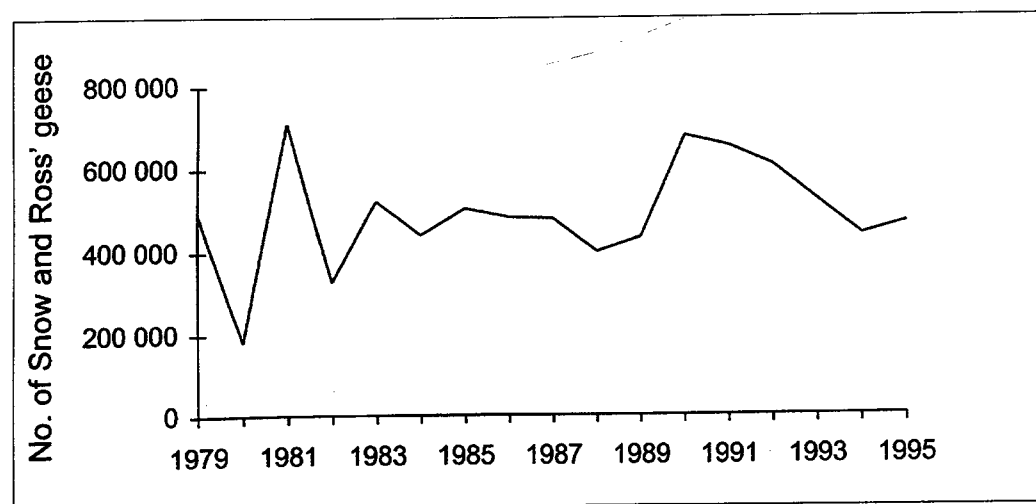
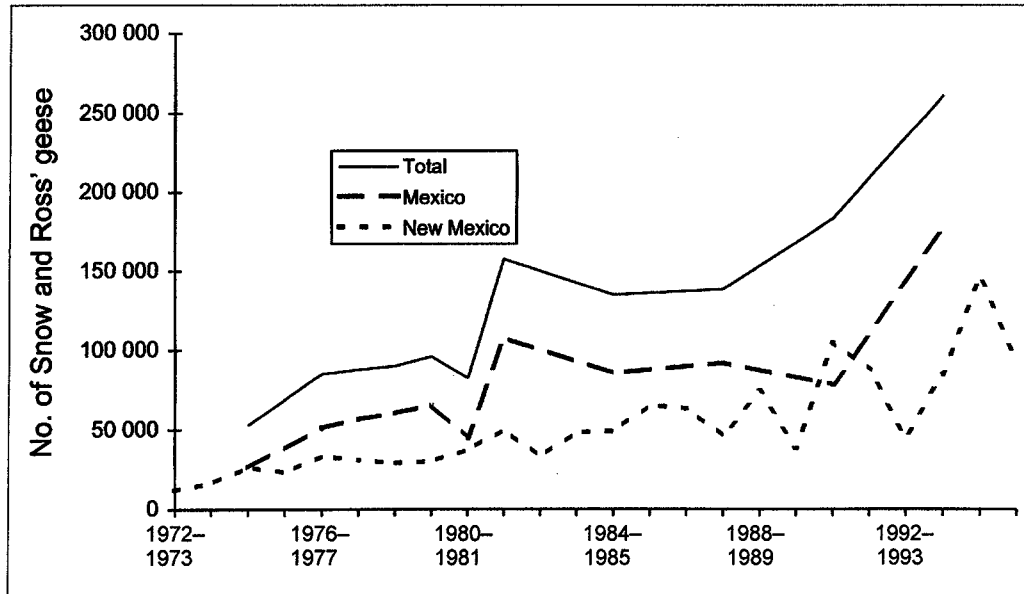


Figure 9

Winter aerial visual counts of Lesser Snow and Ross' geese in New Mexico and the Northern Highlands of Mexico, 1972–1973 to 1995–1996 (from Sharp 1996)

**Table 7**

Recent estimates of Lesser Snow Goose numbers on wintering grounds in the Pacific and Western Central flyways

Location	Years	No. of Snow Geese (thousands)			Method	Reference
		Adults	Young	Total		
Fraser-Skagit	1988–1989 to 1991–1992	–	–	37.4	Air	Boyd (1995)
	1992–1993 to 1994–1995	–	–	42.0	Air	Trost (1996)
California	1987–1988 to 1989–1990	241.0	–	–	Mark:resight	This paper
	1988–1989	224.4	100.8	325.2	Air/ground ^a	Silveira (1989)
	1989–1990	220.0	85.5	305.5	Air/ground ^a	Silveira (1990)
	1992–1993	–	–	376.8	Air/ground ^a	Mensik and Silveira (1993)
	1993–1994 to 1995–1996	–	–	284.1 (335?)	Air ^b	Trost (1996)
Western Central Flyway (U.S. portion)	1987–1988 to 1989–1990	40.8	–	–	Mark:resight	This paper
	1987–1988 to 1989–1990	–	–	46.2	Air ^c	Sharp (1996)
	1990–1991 to 1995–1996	–	–	81.5	Air ^c	Sharp (1996)
Western Central Flyway (Mexico portion)	1987–1988 to 1989–1990	–	–	90.0	Ground counts	Turner et al. (1994)
	1987–1988	–	–	82.9	Air ^d	Sharp (1996)
	1990–1991	–	–	70.4	Air ^d	Sharp (1996)
	1993–1994	–	–	158.9 (187?)	Air ^d	Sharp (1996)

^a Aerial counts of "white" geese corrected for percentage of Ross' Geese and Snow Geese in population (from ground counts).

^b Three-year average of adjusted fall aerial indices. Assumed 60% Snow Geese in fall counts of white geese (Silveira 1989, 1990; Mensik and Silveira 1993). During three comparable years, fall indices underestimated the winter counts of these authors by 15.2%, suggesting that 335 000 Snow Geese were present in 1993–1994 to 1995–1996.

^c Assumed 87% Snow Geese in winter aerial counts (R. Drewien, pers. commun.; D. Benning, pers. commun.).

^d Assumed 90% Snow Geese in winter aerial counts (Turner et al. 1994). Aerial counts were 14.8% lower than ground counts for 1987–1988 to 1990–1991, suggesting that 187 000 Snow Geese were present in Mexico in 1993–1994.

would appear that the winter count was about 34% lower than the total expected from extrapolation from the breeding ground counts. However, the count for Mexico used in Table 7 was for 1993–1994. Had one been made in 1995–1996, it probably would have been larger. In general, the winter inventories were probably low because of underestimation in the visual counts. Kerbes (1975) calculated that the winter inventory of Midcontinent Snow Geese in 1973–1974 had underestimated the actual population by 50%. More recently, W.S. Boyd (unpubl. data) compared visual estimates with photo counts of Snow Goose flocks ($n = 55$) on the Fraser Delta. He found that, on average, the visual estimates were

37.5% lower than the photo counts and recommended that this bias be recognized.

A second, less likely, explanation to account for the lower numbers in the winter inventory is that a large segment of the Western Arctic Population is wintering outside its "traditional" areas, perhaps in the main part of the Central Flyway. However, that explanation is not supported by our analysis of legband recoveries or neckband sightings of geese marked in the Western Canadian Arctic (Hines et al. 1999a, this volume).

3.3 Implications for research and management

Maintenance of the Wrangel Island Population is a continuing concern. In contrast, the rapid (6% per annum from 1981 to 1995) growth rate of the Western Arctic Population raises the possible problem of too many geese on the Arctic habitats. Overgrazing by Snow Geese on coastal areas of western and southern Hudson Bay, with destruction of vegetation and potential negative impacts on geese and other wildlife, has become a continental management issue (Kerbes et al. 1990; Ankney 1996; Abraham et al. 1997; Batt 1997). Extensive damage to vegetation from Snow Geese in the Western Canadian Arctic has not been reported, but detailed studies have not been carried out. We recommend that the effect of increasing numbers of Snow Geese on Western Arctic habitats be monitored, perhaps in conjunction with studies on Banks Island of the range of muskoxen, which use much of the same habitat as geese and have also dramatically increased in number in the past two decades (J. Nagy and N. Larter, pers. commun.). Elsewhere in this volume, Hines et al. (1999b) recommend that the growth of the Western Canadian Arctic Population be limited by increasing the annual harvest rate to 15–20% of the population.

To improve our understanding of the numbers of geese on the breeding grounds and their winter distribution, we recommend the following management actions: 1) annual inventories of nesting and nonbreeding geese on Wrangel Island; 2) another air photo inventory of the Western Canadian Arctic in the year 2000, and at five-year intervals after that; and 3) improved surveys of the winter distribution and abundance of Snow and Ross' geese in the Pacific and Western Central flyways (particularly in the Northern Highlands of Mexico), including ground surveys to estimate the Ross':Snow goose ratio and to adjust for the tendency for visual estimates to be too low.

4. Acknowledgements

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5. Literature cited

- Abraham, K.F.; Jefferies, R.L.; Rockwell, R.F.; MacInnes, C.D. 1997. Why are there so many white geese in North America? Pages 79–92 in J. Ratti (ed.), Proceedings of the 7th International Waterfowl Symposium. Ducks Unlimited, Memphis, Tennessee.
- Ankney, C.D. 1996. An embarrassment of riches: too many gaggles of geese. *J. Wildl. Manage.* 60:217–223.
- Baranyuk, V.V. 1992. Wrangel Island Lesser Snow Geese population status, numbers, structure, and problems of protection [abstract]. Page 23 in 7th North American Arctic Goose Conference and Workshop, 7–12 January 1992, Vallejo, California.
- Barry, T.W. 1960. Waterfowl reconnaissance in the western Arctic. *Arct. Circ.* 13:51–58.
- Barry, T.W. 1967. Geese of the Anderson River Delta, N.W.T. Ph.D. thesis, University of Alberta, Edmonton.
- Batt, B.D.J. (ed.). 1997. Arctic ecosystems in peril: report of the Arctic Goose Habitat Working Group. Arctic Goose Joint Venture Special Publication, U.S. Fish and Wildlife Service, Washington, D.C., and Canadian Wildlife Service, Ottawa, Ontario. 120 pp.
- Bousfield, M.A.; Syroechkovsky, E.V. 1985. A review of Soviet research on the Lesser Snow Goose on Wrangel Island, USSR. *Wildfowl* 36:13–20.
- Boyd, W.S. 1995. Lesser Snow Geese (*Anser c. caerulescens*) and American three-square bulrush (*Scirpus americanus*) on the Fraser and Skagit river deltas. Unpublished Ph.D. thesis, Department of Biological Sciences, Simon Fraser University, North Burnaby, B.C. 154 pp.
- Brault, S.; Boyd, W.S.; Cooke, F.; Takekawa, J. 1994. Population models as tools for research cooperation and management: the Wrangel Island Snow Geese. *Trans. North Am. Wildl. Nat. Resour. Conf.* 59:79–89.
- Goodman, L.A. 1960. On the variance of products. *J. Am. Stat. Assoc.* 55:292.
- Hestbeck, J.B.; Malecki, R.A. 1989. Mark–resight estimate of Canada Goose midwinter number. *J. Wildl. Manage.* 53:749–752.
- Hestbeck, J.B.; Rusch, D.H.; Malecki, R.A. 1990. Estimating population parameters for geese from band-recovery and mark–recapture data. *Trans. North Am. Wildl. Nat. Resour. Conf.* 55:350–373.
- Hines, J.E.; Baranyuk, V.V.; Turner, B.; Boyd, W.S.; Silveira, J.G.; Taylor, J.P.; Barry, S.J.; Meeres, K.M.; Kerbes, R.H.; Armstrong, W.T. 1999a. Autumn and winter distributions of Lesser Snow Geese from the Western Canadian Arctic and Wrangel Island, Russia, 1953–1992. Pages 39–73 in R.H. Kerbes, K.M. Meeres, and J.E. Hines (eds.), Distribution, survival, and numbers of Lesser Snow Geese of the Western Canadian Arctic and Wrangel Island, Russia. *Can. Wildl. Serv. Occas. Pap. No. 98*, Ottawa, Ontario.
- Hines, J.E.; Wiebe, M.O.; Barry, S.J.; Baranyuk, V.V.; Taylor, J.P.; McKelvey, R.; Johnson, S.R.; Kerbes, R.H. 1999b. Survival rates of Lesser Snow Geese in the Pacific and Western Central flyways, 1953–1989. Pages 89–109 in R.H. Kerbes, K.M. Meeres, and J.E. Hines (eds.), Distribution, survival, and numbers of Lesser Snow Geese of the Western Canadian Arctic and Wrangel Island, Russia. *Can. Wildl. Serv. Occas. Pap. No. 98*, Ottawa, Ontario.
- Höhn, E.O. 1954. In the home of the snow goose. *Beaver* 28:8–11.
- Höhn, E.O. 1959. Birds of the mouth of the Anderson River and Liverpool Bay, Northwest Territories. *Can. Field-Nat.* 73:93–114.
- Johnson, S.R. 1996. Staging and wintering areas of Snow Geese nesting on Howe Island, Alaska. *Arctic* 49:86–93.

- Kerbes, R.H. 1975.** The nesting population of Lesser Snow Geese in the eastern Canadian Arctic: a photographic inventory of June 1973. Can. Wildl. Serv. Rep. Ser. No. 35, Ottawa, Ontario. 47 pp.
- Kerbes, R.H. 1983.** Lesser Snow Goose colonies in the western Canadian Arctic. J. Wildl. Manage. 47:523–526.
- Kerbes, R.H. 1986.** Lesser Snow Geese, *Anser c. caerulescens*, nesting in the western Canadian Arctic in 1981. Can. Field-Nat. 100:212–217.
- Kerbes, R.H. 1994.** Colonies and numbers of Ross' Geese and Lesser Snow Geese in the Queen Maud Gulf Migratory Bird Sanctuary. Can. Wildl. Serv. Occas. Pap. No. 81, Ottawa, Ontario.
- Kerbes, R.H.; Meeres, K.M. 1999.** Project overview. Pages 17–26 in R.H. Kerbes, K.M. Meeres, and J.E. Hines (eds.), Distribution, survival, and numbers of Lesser Snow Geese of the Western Canadian Arctic and Wrangel Island, Russia. Can. Wildl. Serv. Occas. Pap. No. 98, Ottawa, Ontario.
- Kerbes, R.H.; Kotanen, P.M.; Jefferies, R.L. 1990.** Destruction of wetland habitats by Lesser Snow Geese: a keystone species on the west coast of Hudson Bay. J. Appl. Ecol. 27: 242–258.
- Krebs, C.J. 1989.** Ecological methodology. Harper and Row Publishers, New York, N.Y.
- Lynch, J.J.; Singleton, J.R. 1964.** Winter appraisals of annual productivity in geese and other water birds. Wildfowl Trust Annu. Rep. 15:114–126.
- Lynch, J.J.; Voelzer, J.F. (compilers). 1974.** 1973 productivity and mortality among geese, swans and brant wintering in North America. 1973 Progress Report, U.S. Fish and Wildlife Service.
- Manning, T.H.; Höhn, E.O.; Macpherson, A.H. 1956.** The birds of Banks Island. Natl. Mus. Can. Bull. No. 143, Biol. Ser. No. 48. 144 pp.
- McEwan, E.H. 1958.** Observation on the Lesser Snow Goose nesting grounds: Egg River, Banks Island. Can. Field-Nat. 72:122–127.
- McLandress, M.R. 1979.** Status of Ross' Geese in California. Pages 255–265 in R.L. Jarvis and J.C. Bartonek (eds.), Management and biology of Pacific Flyway geese. Oregon State University Book Stores, Corvallis, Oregon.
- Mensik, G.; Silveira, J. 1993.** Status of Ross' and Lesser Snow geese wintering in California, December 1992. Progress report for Pacific Flyway Technical Committee, July 1993. U.S. Fish and Wildlife Service, Sacramento, California. 14 pp.
- Otis, D.L.; Burnham, K.P.; White, G.C.; Anderson, D.R. 1978.** Statistical inference from capture data on closed animal populations. Wildl. Monogr. 62:1–135.
- Reed, A.; Dupuis, P.; Smith, G.E.J. 1987.** A survey of Lesser Snow Geese on Southampton and Baffin islands, NWT, 1979. Can. Wildl. Serv. Occas. Pap. No. 61, Ottawa, Ontario. 24 pp.
- Sharp, D.E. (compiler). 1996.** Central Flyway harvest and population survey data book 1996. Unpublished report, U.S. Fish and Wildlife Service, Golden, Colorado. 113 pp.
- Silveira, J.G. 1989.** Distribution of Lesser Snow and Ross' geese in California, winter 1988–89. Unpublished report, California Department of Fish and Game, Sacramento, California. 19 pp.
- Silveira, J.G. 1990.** Distribution of Lesser Snow and Ross' geese in California, winter 1989–90. Unpublished report, California Department of Fish and Game, Sacramento, California. 7 pp.
- Silveira, J.G.; Mensik, J.G. 1992.** Where have all the Snow Geese gone? [abstract]. Page 105 in 7th North American Arctic Goose Conference and Workshop, 7–12 January 1992, Vallejo, California.
- Subcommittee on White Geese. 1992a.** Pacific Flyway management plan for the Wrangel Island Population of Lesser Snow Geese. Unpublished report, Pacific Flyway Study Committee, U.S. Fish and Wildlife Service, Portland, Oregon. 25 pp.
- Subcommittee on White Geese. 1992b.** Pacific Flyway management plan for the Western Arctic Population of Lesser Snow Geese. Unpublished report, Pacific Flyway Study Committee, U.S. Fish and Wildlife Service, Portland, Oregon. 30 pp.
- Syroechkovsky, E.V.; Litvin, K.E. 1984.** The structure of the population of Snow Geese of Wrangel Island. Pages 85–86 in Material of the 4th All-Union Conference "The species and its productivity in its range." Sverdlovsk, Part I (in Russian).
- Takekawa, J.Y.; Orthmeyer, D.L.; Kurechi, M.; Sabano, Y.; Syroechkovsky, E.V.; Litvin, K.E.; Baranyuk, V.V.; Andreev, A.V. 1994.** Restoration of Lesser Snow Geese to East Asia: a north Pacific Rim conservation project. Trans. North Am. Wildl. Nat. Resour. Conf. 59:132–145.
- Trost, R.E. 1996.** Pacific Flyway data book. Unpublished report, U.S. Fish and Wildlife Service, Portland, Oregon. 96 pp.
- Turner, B.; Tomlinson, R.; Leyva, R.; Dominguez, P. 1994.** Wintering populations of Lesser Snow Geese and Ross' Geese in the Northern Highlands of México, 1988–1990. Can. Wildl. Serv. Occas. Pap. No. 84, Ottawa, Ontario. 21 pp.
- Uemura, S.; Sabano, Y.; Kurechi, M.; Andreev, A.V.; Takekawa, J.Y.; Kerbes, R.H.; Baranyuk, V.V. 1998.** Lesser Snow Goose breeding and moulting in Kolyma Lowland [abstract]. Page 81 in 9th North American Arctic Goose Conference and Workshop, 7–11 January 1998, Victoria, B.C.
- Uspenski, S.M. 1965.** The geese of Wrangel Island. Wildfowl 16:126–129.

Appendix 1

Estimated proportion of Lesser Snow Geese wintering in northern and central Chihuahua, Mexico (north of 28°N latitude), in 1989–1990 that came from colonies in the Western Arctic, western Central Arctic, and eastern Central Arctic

	Western Arctic	Western Central Arctic ^a	Eastern Central Arctic ^b
Population size ^c	205 000	6000	273 000
Number neckbanded, summer 1989	718	279	711
Ratio of population size to number neckbanded	286:1	22:1	384:1
Number of neckbands read, 1989–1990	52	28	8
Estimated number of geese from a given breeding area in observed sample	14 847	602	3072
% of geese from each region ^d	80.2	3.3	16.5

^a West of 101°W longitude.

^b East of 101°W longitude.

^c Number of nesting adults in the Western Arctic in 1987 and in Central Arctic in 1988 (Kerbes 1994, Appendix 2).

^d Calculated following the method of Turner et al. (1994:14).

Appendix 2

Estimated proportion of Lesser Snow Geese wintering in southern Chihuahua and Durango, Mexico (south of 28°N latitude), in 1989–1990 that came from colonies in the Western Arctic, western Central Arctic, and eastern Central Arctic

	Western Arctic	Western Central Arctic ^a	Eastern Central Arctic ^b
Population size ^c	205 000	6000	273 000
Number neckbanded, summer 1989	718	279	711
Ratio of population size to number neckbanded	286:1	22:1	384:1
Number of neckbands read, 1989–1990	39	6	4
Estimated number of geese from a given breeding area in observed sample	11 135	129	1536
% of geese from each region ^d	87.0	1.0	12.0

^a West of 101°W longitude.

^b East of 101°W longitude.

^c Number of nesting adults in the Western Arctic in 1987 and in Central Arctic in 1988 (Kerbes 1994, Appendix 2).

^d Calculated following the method of Turner et al. (1994:14).

Appendix 3

Estimated proportion of Lesser Snow Geese wintering in New Mexico in 1989–1990 that came from colonies in the Western Arctic, western Central Arctic, and eastern Central Arctic

	Western Arctic	Western Central Arctic ^a	Eastern Central Arctic ^b
Population size ^c	205 000	6000	273 000
Number neckbanded, summer 1989	718	279	711
Ratio of population size to number neckbanded	286:1	22:1	384:1
Number of neckbands read, 1989–1990	33	32	3
Estimated number of geese from a given breeding area in observed sample	9422	688	1152
% of geese from each region ^d	83.7	6.1	10.2

^a West of 101°W longitude.

^b East of 101°W longitude.

^c Number of nesting adults in the Western Arctic in 1987 and in Central Arctic in 1988 (Kerbes 1994, Appendix 2).

^d Calculated following the method of Turner et al. (1994:14).

Appendix 4

Estimated proportion of Lesser Snow Geese wintering in New Mexico and the Northern Highlands of Mexico in 1989–1990 that came from colonies in the Western Arctic, western Central Arctic, and eastern Central Arctic

	Western Arctic	Western Central Arctic ^a	Eastern Central Arctic ^b
Population size ^c	205 000	6000	273 000
Number neckbanded, summer 1989	718	279	711
Ratio of population size to number neckbanded	286:1	22:1	384:1
Number of neckbands read, 1989–1990	119	66	14
Estimated number of geese from a given breeding area in observed sample	33 976	1419	5376
% of geese from each region ^d	83.3	3.5	13.2

^a West of 101°W longitude.

^b East of 101°W longitude.

^c Number of nesting adults in the Western Arctic in 1987 and in Central Arctic in 1988 (Kerbes 1994, Appendix 2).

^d Calculated following the method of Turner et al. (1994:14).

Autumn and winter distributions of Lesser Snow Geese from the Western Canadian Arctic and Wrangel Island, Russia, 1953–1992

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Abstract

Recent and historical changes in the autumn and winter distributions of Lesser Snow Geese *Anser caerulescens caerulescens* (hereafter referred to as Snow Geese) that breed in the Western Canadian Arctic and on Wrangel Island were evaluated from legband recoveries from hunter-killed geese and from resightings of neckbanded geese, using data from banding in the Western Arctic in 1953–1966, 1973–1976, and 1987–1989 and on Wrangel Island in 1961–1963, 1975–1979, and 1988–1989.

There has been a gradual eastward shift in the location of the autumn staging area in the Canadian prairies used by Snow Geese from the Western Arctic. In the 1950s and 1960s, 74% of the legband recoveries in the Canadian prairies occurred in Alberta, and 26% were in Saskatchewan. By the late 1980s and early 1990s, only 36% of the legband recoveries and 32% of the neckband observations were in Alberta, and the remainder were in Saskatchewan. A small proportion (<6%) of the Wrangel Island Population moved through the Canadian prairies in autumn; most of the population apparently migrated along the Pacific coast. There was no evidence of broad-scale changes in the fall distribution of Wrangel Island geese using the Pacific route.

Nine major areas where geese from one or both populations spent the winter (December–February) were identified. Significant changes have occurred in the winter distribution of both populations. In the 1960s and 1970s, 90% of the Western Arctic geese wintered in California, and about 8% wintered in the Western Central Flyway. By the late 1980s, the Western Central Flyway component had increased to 24% of the total population, whereas the California component had declined to 76%. In the 1960s and 1970s, approximately 90% of the Wrangel Island Population wintered in California and 10% in the Fraser–Skagit region. Observations of neckbanded geese in the late 1980s and early 1990s indicated that only 47% moved south to California while at least 52% of the population wintered in the Fraser–Skagit region. Possible explanations of the changes in winter distribution of Wrangel Island and Western Arctic Snow Geese, including geographic differences in survival, productivity, and movement patterns, are discussed.

Further growth of the Western Arctic Population has occurred since the completion of the collaring study in 1992. Recent wintering ground counts suggest that most of the

population growth is associated with the segment of the population wintering outside California.

Résumé

Les changements récents et historiques dans les distributions automnales et hivernales des Petites Oies des neiges *Anser caerulescens caerulescens* (appelées ci-après Oies des neiges), qui se reproduisent dans l'ouest de l'Arctique canadien et sur l'île Wrangel, ont été évalués à partir des bagues récupérées auprès d'oies tuées par des chasseurs et de l'observation des oies à qui on a posé un collier, en utilisant les données provenant du baguage des oiseaux dans l'ouest de l'Arctique de 1953 à 1966, de 1973 à 1976 et de 1987 à 1989 ainsi que dans l'île Wrangel de 1961 à 1963, de 1975 à 1979 et de 1988 à 1989.

Il s'est produit un déplacement graduel vers l'est de l'emplacement des aires de repos d'automne dans les Prairies canadiennes fréquentées par les Oies des neiges de l'ouest de l'Arctique. Dans les années 1950 et 1960, 74 p. 100 des bagues récupérées dans les Prairies canadiennes s'effectuaient en Alberta et 26 p. 100 avaient lieu en Saskatchewan. À la fin des années 1980 et au début des années 1990, seulement 36 p. 100 des bagues récupérées et 32 p. 100 des observations des colliers se produisaient en Alberta et le reste s'effectuait en Saskatchewan. Une faible proportion (<6 p. 100) de la population de l'île Wrangel se déplaçait dans les Prairies canadiennes à l'automne; la majeure partie de la population migrait apparemment le long de la côte du Pacifique. Il n'y avait aucune preuve de changement à grande échelle de la distribution automnale des oies de l'île Wrangel utilisant la route du Pacifique.

On a identifié neuf régions principales où les oies d'une population ou des deux populations hivernent (de décembre à février). Des changements importants se sont produits dans la distribution hivernale des deux populations. Dans les années 1960 et 1970, 90 p. 100 des oies de l'ouest de l'Arctique hivernaient en Californie et environ 8 p. 100 hivernaient dans la voie migratoire du centre-ouest. À la fin des années 1980, la voie migratoire du centre-ouest avait connu une hausse de 24 p. 100 de l'ensemble de la population, tandis que la composante de la Californie avait connu un déclin de 76 p. 100. Dans les années 1960 et 1970, environ 90 p. 100 de la population de l'île Wrangel hivernait en Californie et 10 p. 100 dans la région Fraser–Skagit. Les observations effectuées des oies à qui on a posé un collier

vers la fin des années 1980 et au début des années 1990 ont indiqué que seulement 47 p. 100 de la population se déplaçait vers le sud jusqu'en Californie, tandis qu'au moins 52 p. 100 de la population hivernait dans la région Fraser-Skagit. Des explications possibles de ces changements de la distribution hivernale des Oies des neiges de l'île Wrangel et de l'ouest de l'Arctique, y compris les différences des taux de survie, de productivité et des tendances de mouvements, font l'objet de discussion.

Une nouvelle croissance de la population de l'ouest de l'Arctique s'est produite depuis la conclusion de l'étude sur la pose de colliers de 1992. Les dénombrements récents effectués dans les aires d'hivernage suggèrent que la majeure partie de la croissance de la population est associée au segment de la population hivernant à l'extérieur de la Californie.

1. Introduction

The autumn and winter distributions of Lesser Snow Geese *Anser caerulescens caerulescens* (hereafter referred to as Snow Geese) from breeding colonies in the Western Canadian Arctic and on Wrangel Island, Russia, have been described previously in a number of general references, management plans, and technical reports (Rienecker 1965; Dzubin 1974; Dzubin et al. 1975; Bellrose 1976; Subcommittee on White Geese 1992a, 1992b). Much of this understanding was based on banding programs carried out before 1972. In the late 1980s, suspected changes in the distribution of these populations precipitated a major collaring and observation study of Snow Geese in western North America. In this paper, we describe the autumn and winter distributions of the geese based on information from individuals that were legbanded from 1953 to 1989 and collared from 1987 to 1989. Our objective is to document both recent and long-term changes in the distributions of Western Canadian Arctic and Wrangel Island Snow Geese and describe the management implications of these results.

2. Methods

Banding of Snow Geese has been carried out periodically since 1953 in the Western Arctic and since 1961 on Wrangel Island. Although significant numbers of birds were colour-marked by either collaring or dyeing plumage prior to 1980, the only data now available on distribution from this period come from legband recoveries. Most adult geese captured from 1987 to 1989, as well as being legbanded, were equipped with uniquely coded plastic neckbands. Thus, data from both legband recoveries and neckband sightings were collected for this sample of geese. Descriptions of field methods, observation effort, and general results of the 1987–1989 neckband study are included in Kerbes and Meeres (1999, this volume). Locations of major field activities and other areas referred to in the text are shown in Figure 1.

Although exact dates of neckband observations were recorded, dates of legband recoveries were sometimes known to the nearest month only. Thus, we defined the winter period as 1 December – 29 February for both legband recoveries and neckband observations. This corresponds to the interval when most migration was complete and the geese had settled on wintering areas (Armstrong et al. 1999, this

volume). This definition is somewhat broader than that used in Armstrong et al. (1999, this volume).

2.1 Band recoveries

We examined autumn and winter distributions of Snow Geese banded on Wrangel Island in 1961–1963, 1975–1979, and 1988–1989 and in the Western Arctic in 1953–1963, 1973–1976, and 1987–1989 by mapping the locations of legband recoveries from hunter-killed birds. As many of the banding and recovery records for 1961–1963 for Wrangel Island were destroyed in a fire, we used the data for this period reported by Dzubin et al. (1975:31), after Teplov and Shevareva (1965). All other recovery data were obtained from the Bird Banding Office of the Canadian Wildlife Service, Ottawa.

Important areas for wintering Snow Geese were identified from clusters of legband recoveries. Data for both adult (after hatch year) and young (hatch year) geese were combined in the analyses, as the distributions of these recoveries did not differ greatly (Appendices 1a–1f). Only combined data on direct recoveries (i.e., those made within one year of banding) and indirect recoveries (made more than one year after banding) were available for the 1961–1963 bandings on Wrangel Island (Dzubin 1974). Data summaries indicated that the distributions of direct and indirect recoveries were similar and that pooling samples would not alter the general results (Appendices 2 and 3).

Most (>95%) of the Snow Geese from the Western Arctic nest on Banks Island (Kerbes et al. 1999, this volume), where geese were banded in 1953, 1955, 1961, and 1987. As the geographic distribution of legband recoveries or neckband observations from geese banded on Banks Island did not differ greatly from that for geese banded on the mainland (Anderson River or Kendall Island) (Appendices 4 and 5), all Snow Geese banded in the Western Arctic were combined into a single sample for each year.

2.2 Neckband observations

Collared Snow Geese were observed between September 1987 and April 1992. An extensive network of observers equipped with spotting scopes recorded individual neckband codes of the geese as they fed in open agricultural fields or rested on land or water (Kerbes and Meeres 1999, this volume).

The distributions of Snow Geese from Wrangel Island and the Western Arctic were estimated from neckband resightings in two ways. First, we identified clusters of sightings. The numbers of collared individuals sighted in each 1) degree block, 2) province, state, or territory, or 3) general wintering area (e.g., Western Central Flyway) were determined. A second approach used mark:resight methods to estimate the number of collared geese from each breeding population present in the different wintering areas. This involved dividing the winter into six two-week intervals and treating each interval as a sampling period. The number of collared geese present in each area was then estimated using the computer program CAPTURE (Otis et al. 1978). Further details of how the method was applied to neckband data are described in Kerbes et al. (1999, this volume).

There were too few observations from the wintering grounds in the Northern Highlands of Mexico to allow us to

Figure 1
Major locations where Lesser Snow Geese were legbanded and neckbanded, where legbanded birds were recovered, and where neckbanded geese were resighted, 1953–1992



apply the mark:resight method. Instead, we estimated the number of collared geese present in this region using information on total population size and the estimated ratio of marked to total geese present (from Turner et al. 1994).

3. Results

Between 1953 and 1989, 14 477 Snow Geese were banded in the Western Arctic; from 1961 to 1989, more than 3565 Snow Geese were banded on Wrangel Island (the numbers banded from 1961 to 1963 are uncertain) (Table 1).

We used 2014 legband recoveries from hunter-shot geese from the Western Arctic and 693 recoveries from Wrangel Island geese (Appendices 1a–1f). In addition, the collaring of geese from 1987 to 1989 provided very detailed information on distribution in the late 1980s and early 1990s (Appendices 1a–1f): 17 094 observations of 2644 individuals from the Western Arctic and 11 927 observations of 1357 individuals from Wrangel Island were made between 1 September 1987 and 29 February 1992. The seasonal distributions of legband recoveries and neckband observations for Western Arctic Snow Geese for the different banding periods are

Table 1

The number of Lesser Snow Geese marked in the Western Canadian Arctic and on Wrangel Island, 1953–1989

Location	Year	Legbanded			Neckbanded		Total
		Adults	Young	Unknown age	Adults	Young	
Banks Island	1953	79	0	0	0	0	79
Banks Island	1955	177	122	0	0	0	299
Anderson River	1959	134	96	0	0	0	230
Anderson River	1960	614	1 056	0	0	0	1 670
Anderson River	1961	227	520	0	0	0	747
Banks Island	1961	535	530	0	0	0	1 065
Anderson River	1962	371	647	0	0	0	1 018
Anderson River	1963	190	976	0	0	0	1 166
Anderson River	1964	0	0	1	0	0	1
Anderson River	1966	103	121	0	0	0	224
Anderson River	1973	688	749	1	0	0	1 438
Anderson River	1974	269	205	0	0	0	474
Anderson River	1975	383	546	1	0	0	930
Anderson River	1976	71	126	0	0	0	197
Anderson River	1979	1	0	0	0	0	1
Kendall Island	1987	1	80	1	59	0	141
Anderson River	1987	22	179	0	492	0	693
Banks Island	1987	226	628	5	479	0	1 338
Anderson River	1988	2	834	0	886	1	1 723
Anderson River	1989	19	311	0	713	0	1 043
Total — Western Canadian Arctic		3 321	6 923	9	3 420	804	14 477
Wrangel Island ^a	1961–1963	?	?	?	?	?	?
Wrangel Island	1974	1	0	0	0	0	1
Wrangel Island	1975	0	372	0	224	0	596
Wrangel Island	1976	83	231	0	182	0	496
Wrangel Island	1977	103	231	0	386	0	720
Wrangel Island	1979	0	0	0	49	0	49
Wrangel Island	1988	339	0	3	901	0	1 243
Wrangel Island	1989	0	0	0	460	0	460
Total — Wrangel Island		≥526	≥834	≥3	≥2 202	≥0	≥3 565

^a Numbers uncertain.

summarized in Figures 2–10 and Appendices 1a–1c and for Wrangel Island Snow Geese in Figures 11–18 and Appendices 1d–1f.

3.1 Autumn distribution

Details of recent autumn and spring migration routes for Snow Geese from the Western Arctic and Wrangel Island are described by Armstrong et al. (1999, this volume). Here we focus on the major autumn staging area for the Western Arctic geese in the Canadian prairies (Fig. 1). Since 1953, this area has accounted for 52% of the legband recoveries for Western Arctic geese during September–November and for 48% of the autumn observations of collared geese from 1987 to 1992.

In the 1950s and 1960s, the migration corridor followed by Western Arctic geese was mainly through eastern Alberta (74% of the legband recoveries were in Alberta, compared with 26% in Saskatchewan; Fig. 2). By the 1970s, the recoveries were split almost equally between the two provinces (53% in Alberta, 47% in Saskatchewan; Fig. 3); in the late 1980s and early 1990s, only 36% of the legband recoveries and 32% of the neckband observations were in Alberta, compared with 64% of legband recoveries and 68% of the neckband observations in Saskatchewan

(Figs. 4 and 5). Thus, there has been a gradual but substantial shift eastward, with a larger percentage of the Western Arctic Population now staging in Saskatchewan.

Relatively few geese (<6% of the autumn recoveries) from either the 1975–1977 or 1988–1989 bandings on Wrangel Island were recovered in the Canadian prairies during September–November (Figs. 11–12), and only 4% of the collared geese sighted in the fall during 1988–1992 were seen there (Fig. 13). Thus, most of the Wrangel Island geese migrated along a Pacific coast route in fall (see Armstrong et al. 1999, this volume).

Since 1961, nearly all (14 of 15) of the small sample of Wrangel Island legband recoveries from the Canadian prairies were from Alberta (Figs. 11, 12, and 14; Appendices 1d and 1e). In contrast, the fall neckband observations of Wrangel Island geese made in the prairies from 1988 to 1992 were equally distributed between Saskatchewan and Alberta ($n = 42$; Fig. 13). Thus, unlike the situation with Western Arctic geese, the data seem equivocal on the question of whether the small numbers of Wrangel Island geese moving through the Canadian prairies in fall are taking a more easterly route than previously.

There were no obvious broad-scale changes in the use of fall staging areas by Wrangel Island geese that migrate

Figure 2

Distribution of legband recoveries for Lesser Snow Geese marked in the Western Canadian Arctic, 1953–1966, and shot during autumn (September–November). The numbers of recoveries per degree block are indicated, and the total recoveries per province or state are circled.

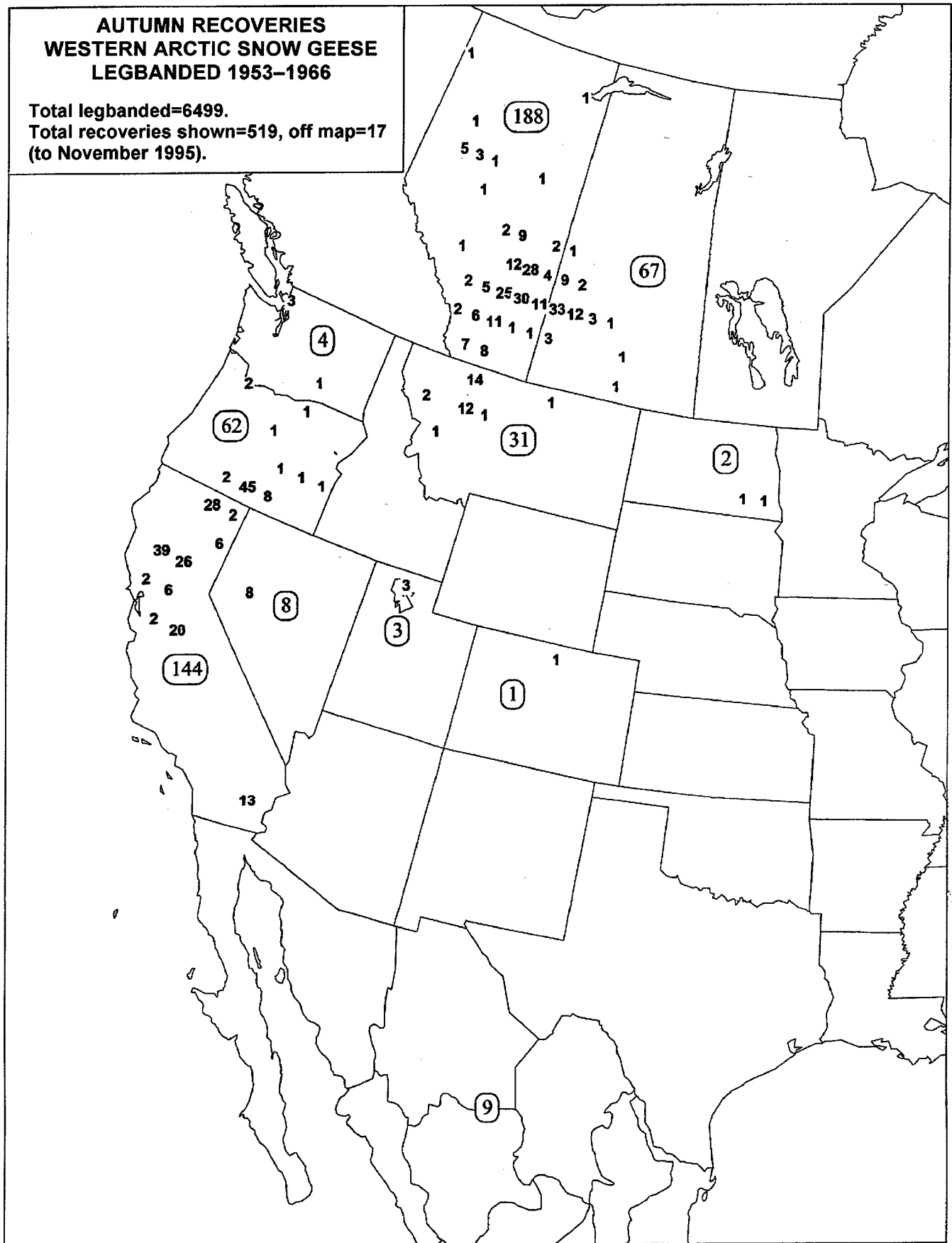


Figure 3

Distribution of legband recoveries for Lesser Snow Geese marked in the Western Canadian Arctic, 1973–1976, and shot during autumn (September–November). The numbers of recoveries per degree block are indicated, and the total recoveries per province or state are circled.

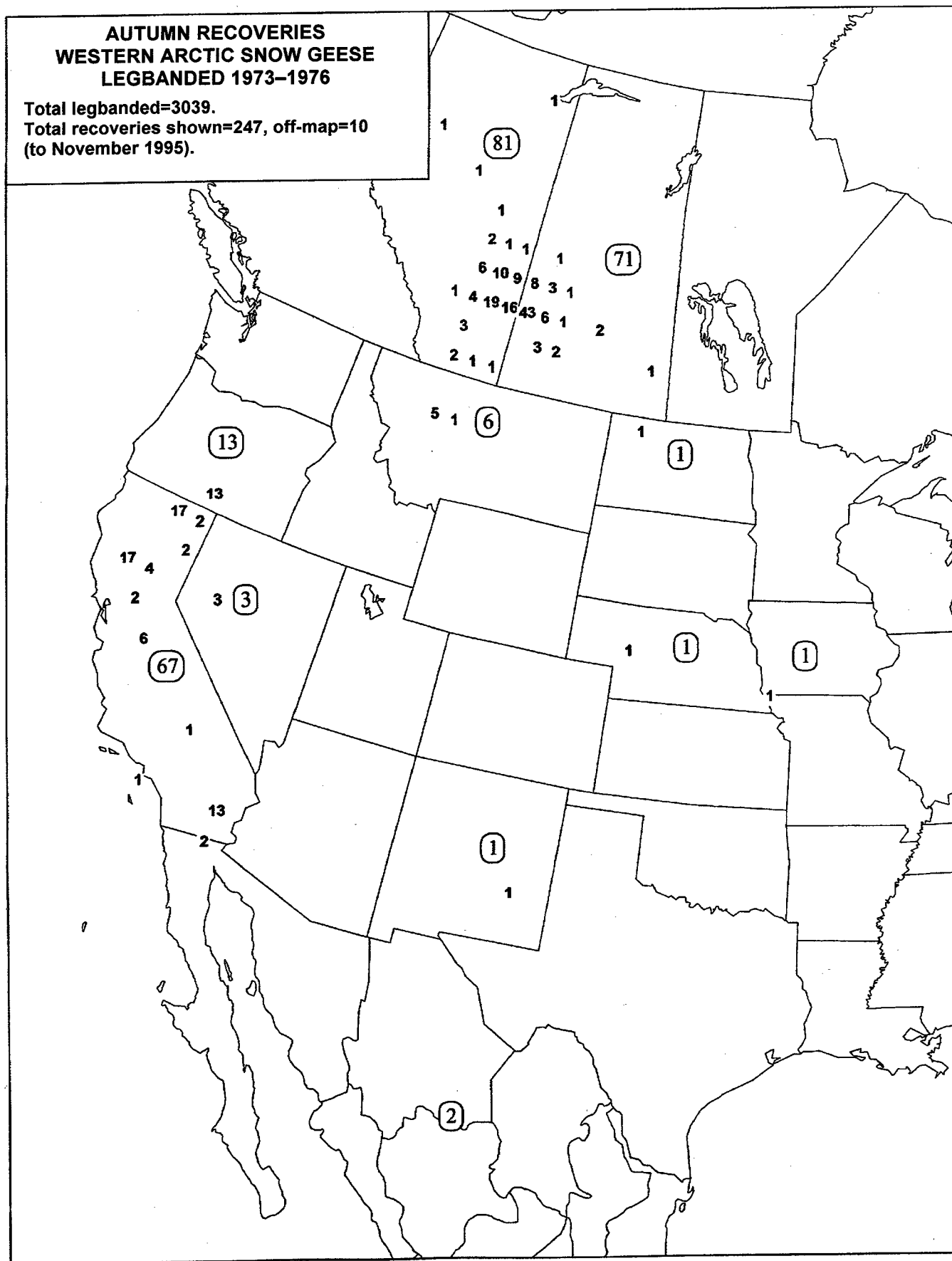


Figure 4

Distribution of legband recoveries for Lesser Snow Geese marked in the Western Canadian Arctic, 1987–1989, and shot during autumn (September–November). The numbers of recoveries per degree block are indicated, and the total recoveries per province or state are circled.

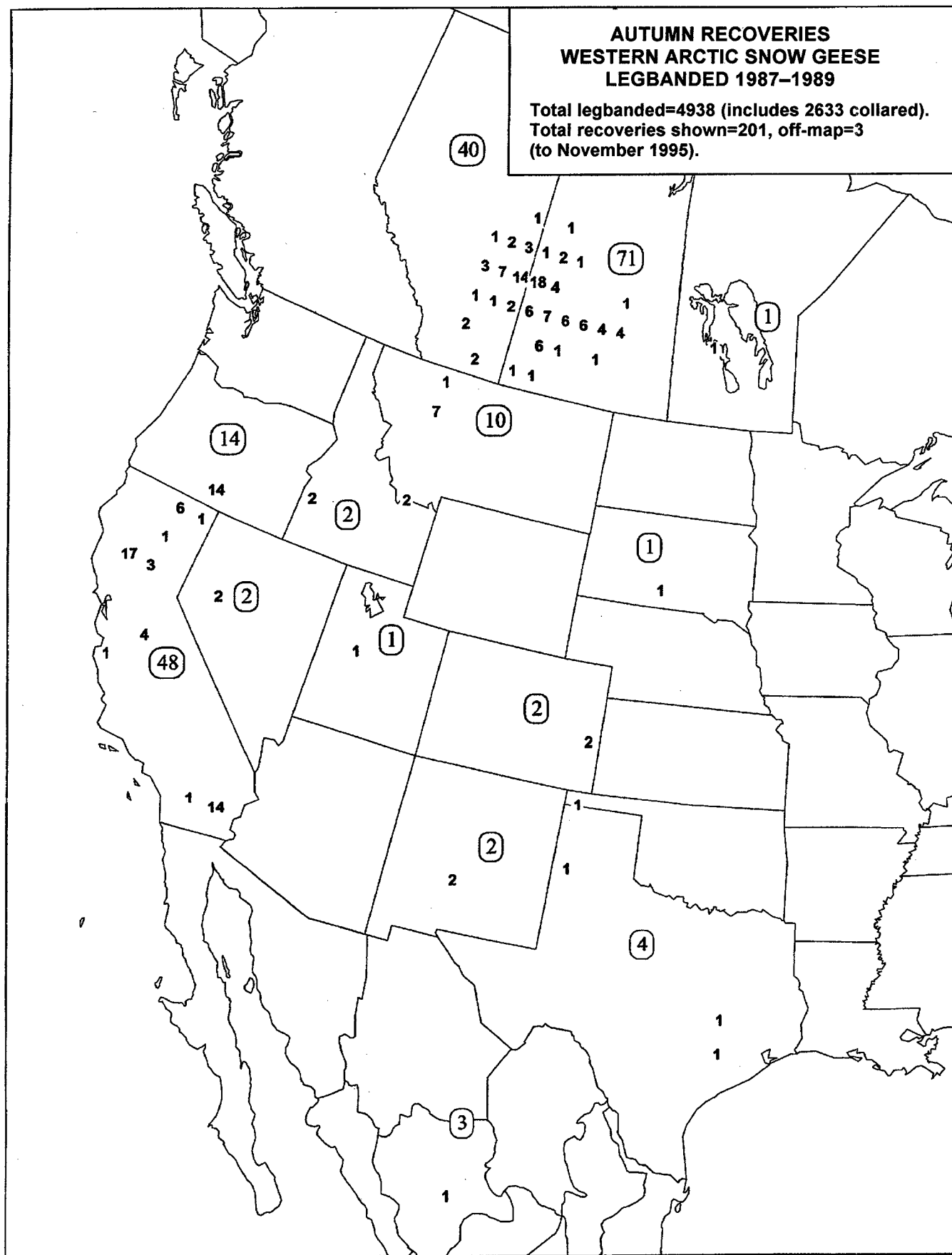
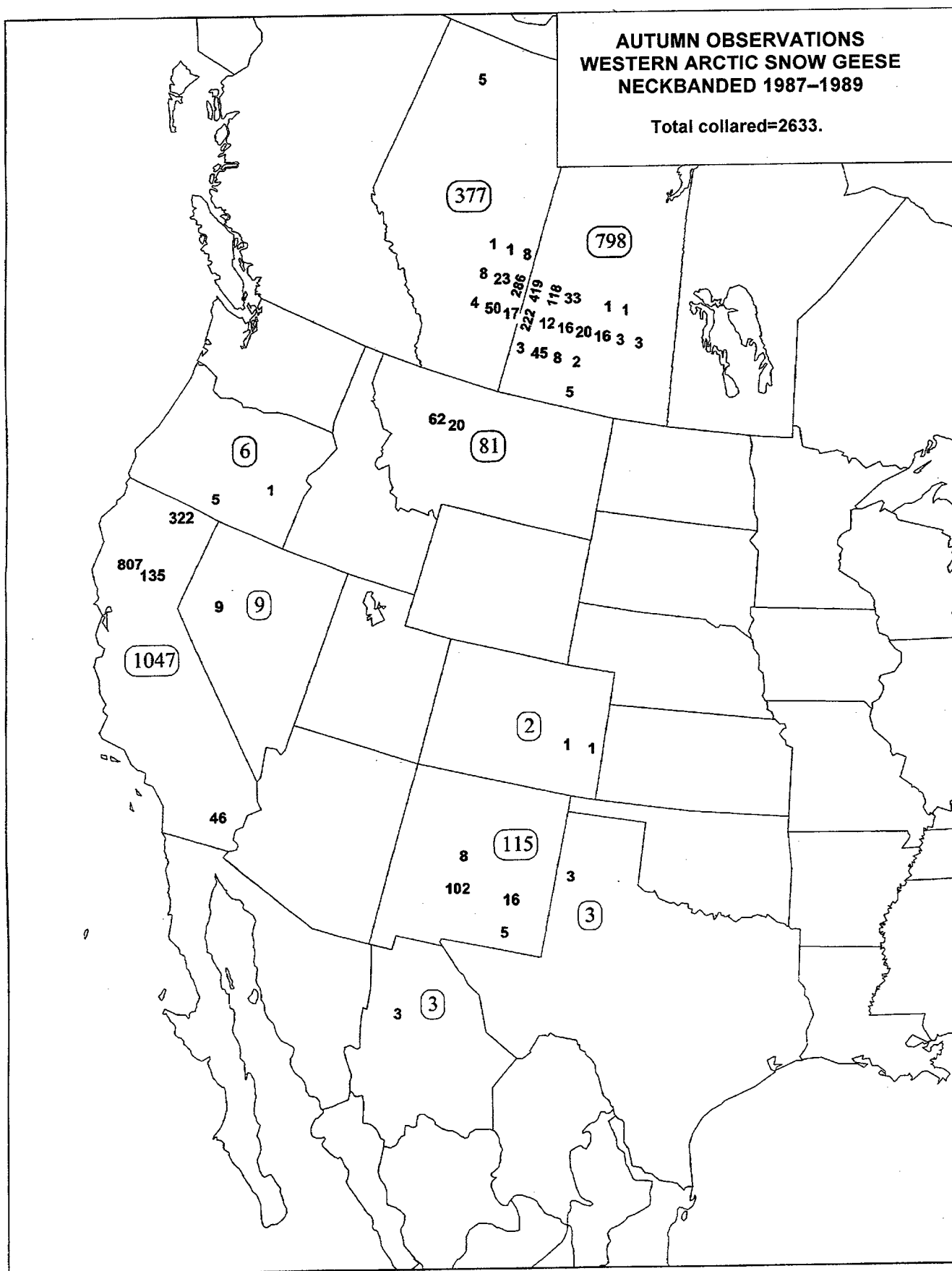


Figure 5

Distribution of neckband observations of Lesser Snow Geese marked in the Western Canadian Arctic, 1987–1989, and seen during autumn (September–November). The numbers of individual geese sighted per degree block are indicated, and the total numbers of individuals sighted per province or state are circled.



Distribution of legband recoveries for Lesser Snow Geese marked in the Western Canadian Arctic, 1953–1966, and shot during winter (December–February). The numbers of recoveries per degree block are indicated, and the total recoveries per province or state are circled.

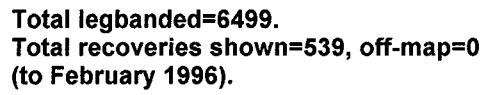
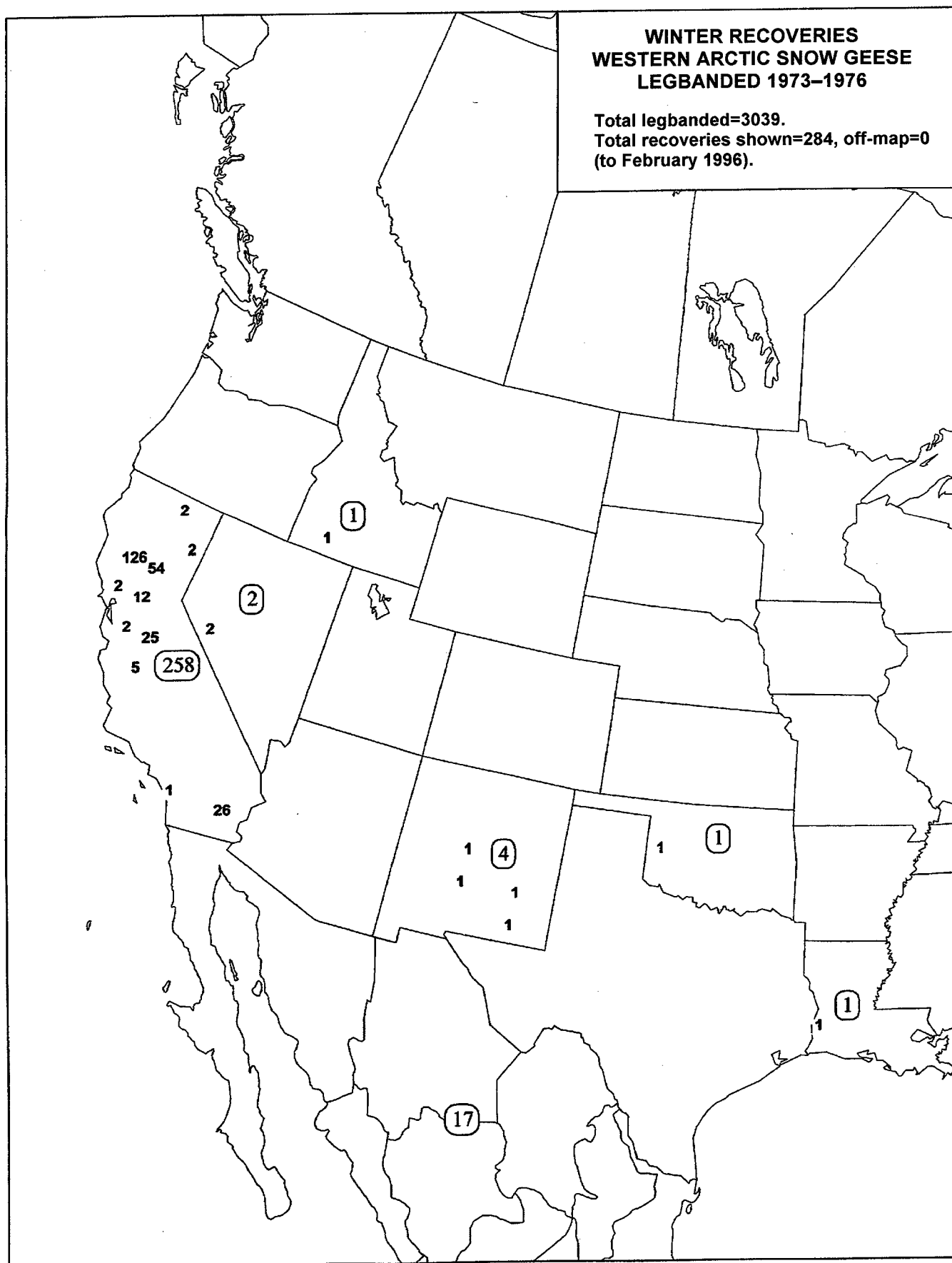


Figure 7

Distribution of legband recoveries for Lesser Snow Geese marked in the Western Canadian Arctic, 1973–1976, and shot during winter (December–February). The numbers of recoveries per degree block are indicated, and the total recoveries per province or state are circled.



Distribution of legband recoveries for Lesser Snow Geese marked in the Western Canadian Arctic, 1987–1989, and shot during winter (December–February). The numbers of recoveries per degree block are indicated, and the total recoveries per province or state are circled.



**Total legbanded=4938 (includes 2633 collared).
Total recoveries shown=191, off-map=0
(to February 1996).**

Figure 9

Distribution of neckband observations of Lesser Snow Geese marked in the Western Canadian Arctic, 1987–1989, and seen during winter (December–February). The numbers of individual geese sighted per degree block are indicated, and the total numbers of individuals sighted per province or state are circled.

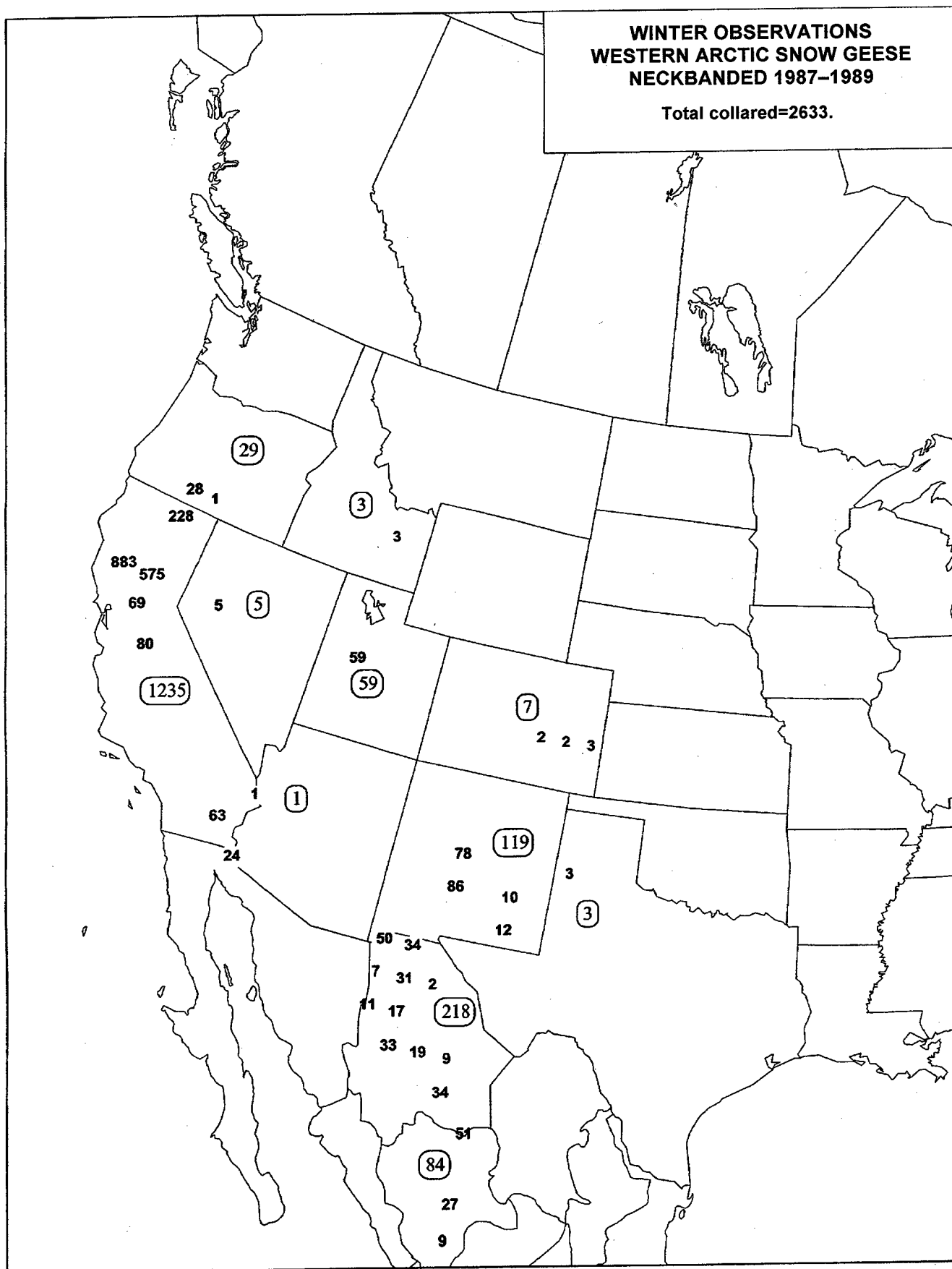
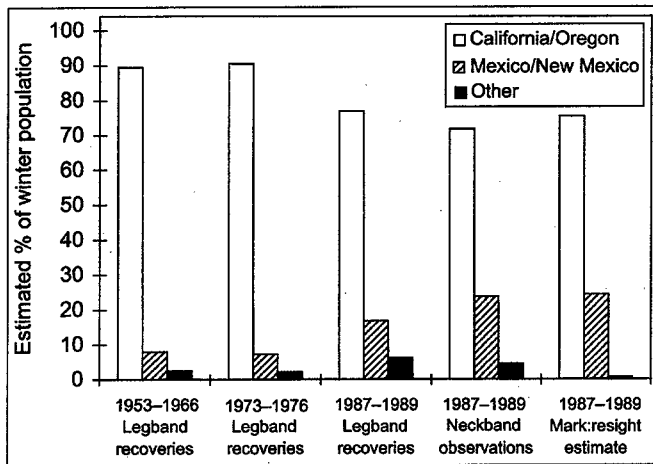


Figure 10

Changes in the winter distribution of Lesser Snow Geese from the Western Canadian Arctic determined by legband recoveries and neckband resightings



south along the Pacific Flyway route (Figs. 11-13; Appendix 1e).

3.2 Major wintering areas

Nine major wintering areas for Snow Geese were identified from the information on banded and collared individuals (Fig. 1) and related descriptions from the literature (see Bellrose 1976; Subcommittee on White Geese 1992a, 1992b; Armstrong et al. 1999, this volume). The areas included 1) the Fraser River and Skagit River deltas of British Columbia and Washington; 2) the Columbia River area in southern Washington and northern Oregon; 3) the Klamath Basin in southern Oregon and northern California; 4) the Central Valley of California; 5) the Salton

Sea-Imperial Valley area of southern California and Arizona; 6) western New Mexico (i.e., west of 105°W); 7) eastern New Mexico (i.e., east of 105°W), southern Colorado, and northwestern Texas; 8) the Northern Highlands of Mexico north of 28°N; and 9) the Northern Highlands of Mexico south of 28°N. For management purposes, the groups of geese wintering in the latter four areas are termed the Western Central Flyway Population. Similarly, geese wintering in areas 1-5 comprise the Pacific Flyway Population. This population is composed mainly of a north-wintering group from Wrangel Island (using mainly the Fraser-Skagit area) and a south-wintering group derived from colonies in the Western Arctic and Wrangel Island (using mainly the Klamath Basin and the Central Valley).

3.2.1 Winter distribution of Western Canadian Arctic Snow Geese

The geographic distributions of winter legband recoveries and neckband observations of Western Arctic Snow Geese are mapped in Figures 6-9, and the historical changes in distribution are summarized in Figure 10.

In the 1950s-1970s, 90% of the winter legband recoveries occurred in California, and only 8% were in the Western Central Flyway (Figs. 6 and 7). By the late 1980s, the proportion of the recoveries in the latter area had increased to 20%, whereas those in California had declined to 77% (Fig. 8). Neckband observations in the late 1980s and early 1990s suggested that 24% of the Western Arctic geese may have wintered in the Western Central Flyway and 72% in California (Figs. 9 and 10). Using the mark:resight approach to estimate total numbers of collared geese in each area, we found that 76% of the Western Arctic geese wintered in California and 24% in the Western Central Flyway in 1988-1990 (Table 2).

Table 2

The estimated number of neckbanded Lesser Snow Geese in different wintering areas in the Pacific and Western Central flyways, 1988-1989 and 1989-1990

Wintering location	Year	Wrangel Island		Western Canadian Arctic	
		Number ± SE	Percent	Number ± SE	Percent
British Columbia-Washington	1988-1989	382 ± 27	53.9	0	0.0
California	1988-1989	324 ± 17	45.7	827 ± 39	74.0
New Mexico	1988-1989	1	0.1	77 ± 4	6.9
Mexico	1988-1989	2	0.3	211	18.9
Other	1988-1989	0	0.0	3	0.3
All areas	1988-1989	709	100.0	1118	100.0
British Columbia-Washington	1989-1990	346 ± 33	51.0	0	0.0
California	1989-1990	330 ± 15	48.7	1077 ± 31	76.8
New Mexico	1989-1990	1	0.1	130 ± 15	9.3
Mexico	1989-1990	1	0.1	194	13.8
Other	1989-1990	0	0.0	1	0.1 ^a
All areas	1989-1990	678	100.0	1402	100.0
British Columbia-Washington	1988-1990 (mean)	364	52.4	0	0.0
California	1988-1990 (mean)	327	47.1	952	75.5
New Mexico	1988-1990 (mean)	1	0.1	104	8.2
Mexico	1988-1990 (mean)	2	0.3	203	16.1
Other	1988-1990 (mean)	0	0.0	2	0.2 ^a
All areas	1988-1990 (mean)	694	100.0	1261	100.0

^a Fifty-nine migrant geese appearing in Utah in February 1990 were excluded from the analyses.

Figure 11

Distribution of legband recoveries for Lesser Snow Geese marked on Wrangel Island, 1975–1979, and shot during autumn (September–November). The numbers of recoveries per degree block are indicated, and the total recoveries per province or state are circled.

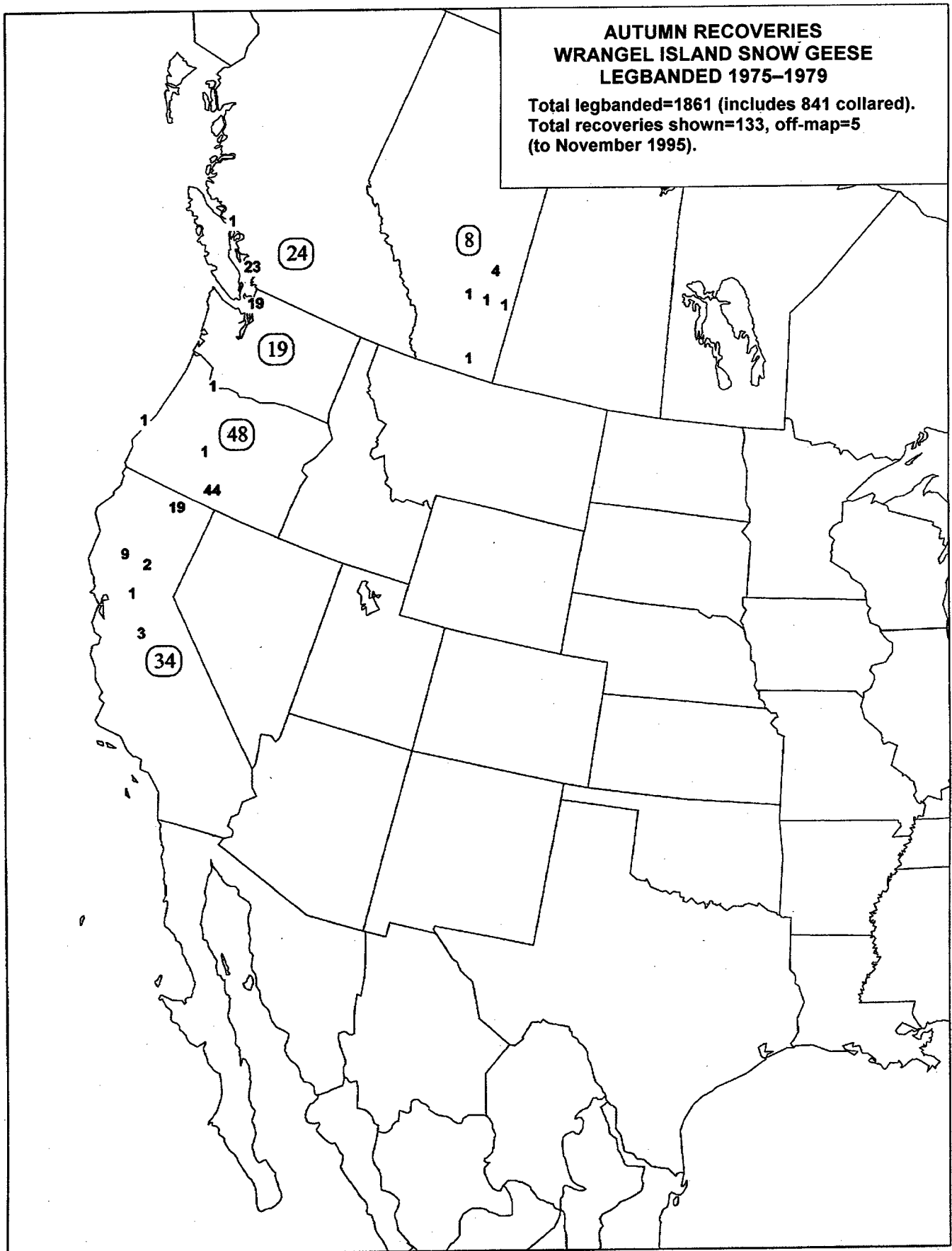


Figure 12

Distribution of legband recoveries for Lesser Snow Geese marked on Wrangel Island, 1988–1989, and shot during autumn (September–November). The numbers of recoveries per degree block are indicated, and the total recoveries per province or state are circled.

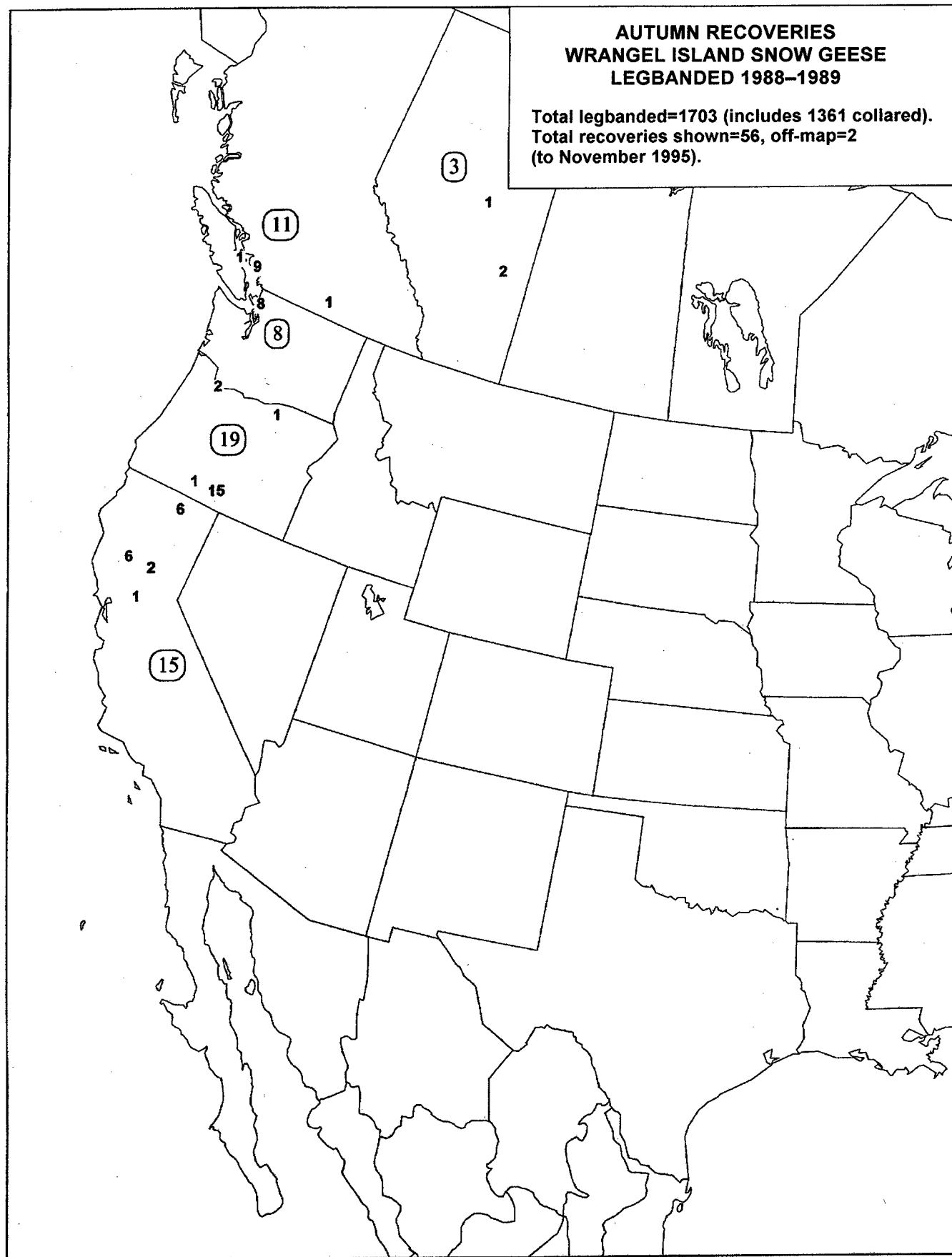


Figure 13
Distribution of neckband observations of Lesser Snow Geese marked on Wrangel Island, 1988–1989, and seen during autumn (September–November). The numbers of individual geese sighted per degree block are indicated, and the total numbers of individuals sighted per province or state are circled.



Figure 14

Distribution of legband recoveries for Lesser Snow Geese marked on Wrangel Island, 1961–1963, and shot during autumn and winter (September–February). Total recoveries per province or state are circled. More detailed information on either locations or dates of recoveries was not available.

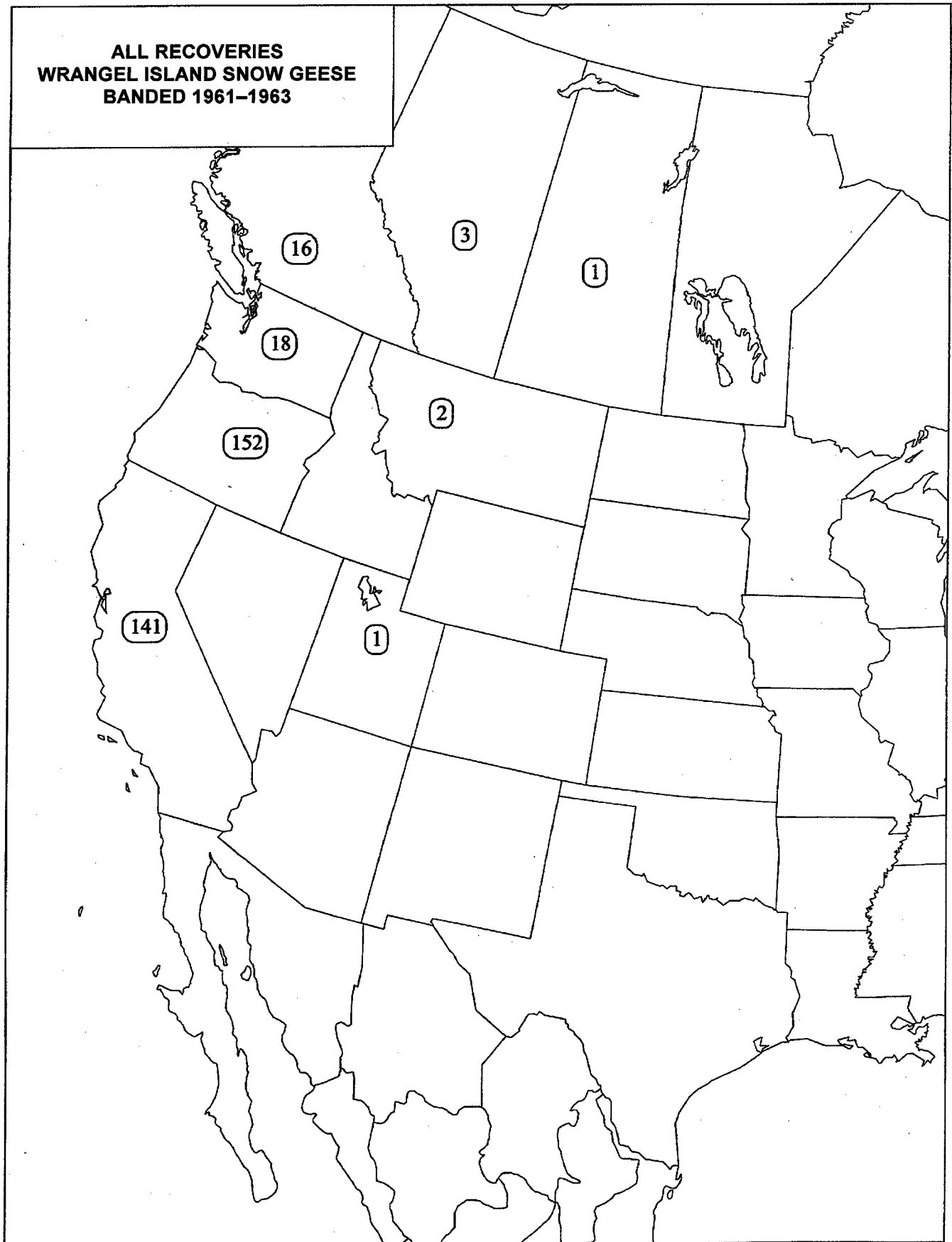


Figure 15
Distribution of legband recoveries for Lesser Snow Geese marked on Wrangel Island, 1975–1979, and shot during winter (December–February). The numbers of recoveries per degree block are indicated, and the total recoveries per province or state are circled.

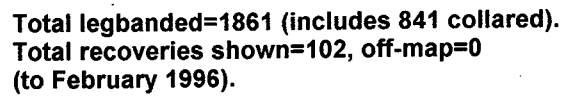


Figure 16

Distribution of legband recoveries for Lesser Snow Geese marked on Wrangel Island, 1988–1989, and shot during winter (December–February). The numbers of recoveries per degree block are indicated, and the total recoveries per province or state are circled.

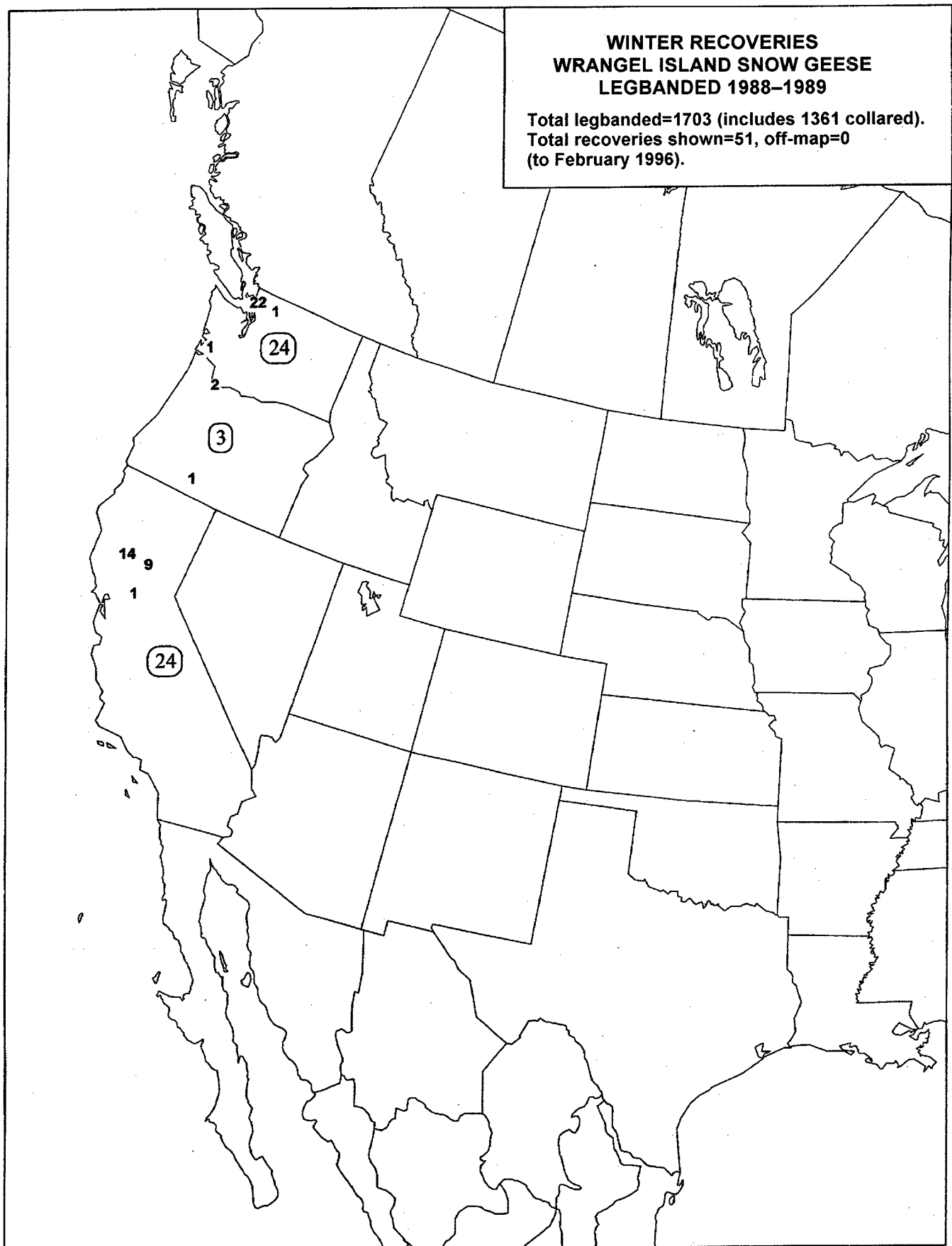


Figure 17

Distribution of neckband observations of Lesser Snow Geese marked on Wrangel Island, 1988–1989, and seen during winter (December–February). The numbers of individual geese sighted per degree block are indicated, and the total numbers of individuals sighted per province or state are circled.

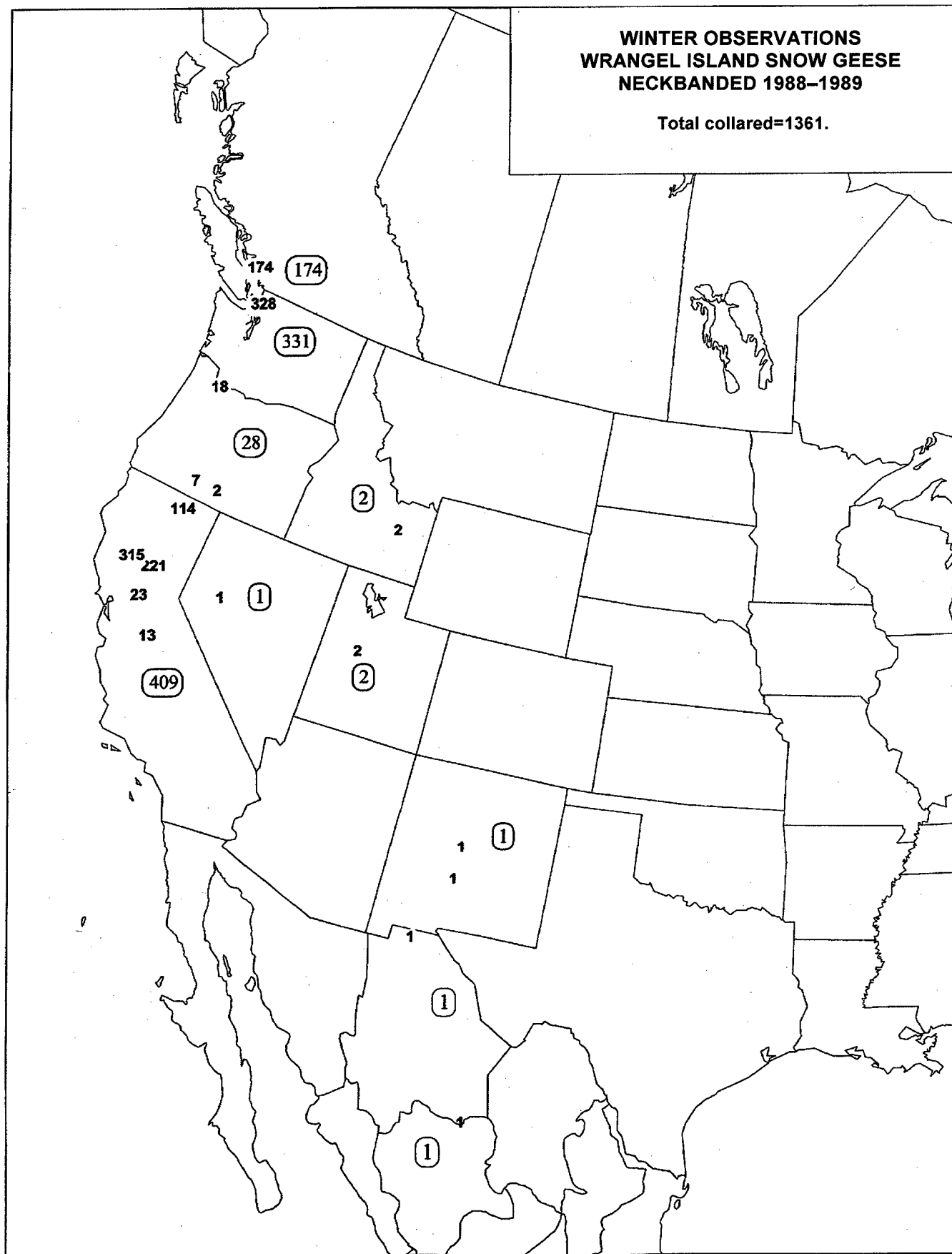
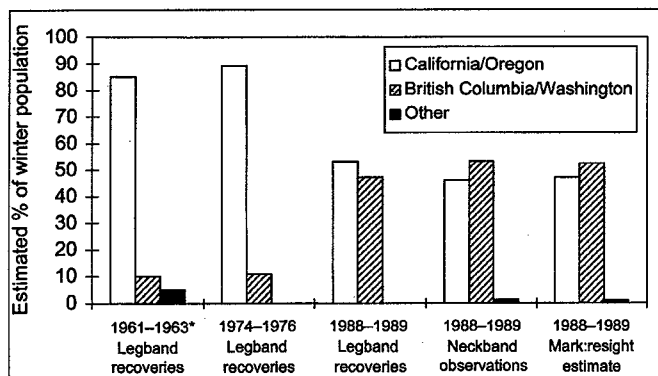


Figure 18

Changes in the winter distribution of Lesser Snow Geese from Wrangel Island determined by legband recoveries and neckband resightings



* Data for 1961-1963 are for fall and winter and likely underestimate the percentage of geese in California/Oregon.

3.2.2 Winter distribution of Wrangel Island Snow Geese

The previously published 1961-1963 legband recovery data were pooled by the age of the birds and the month of recovery and could not be separated into fall and winter categories, as were the other samples. Most recoveries were from California-Oregon (85%), and few (10%) were from British Columbia and Washington (Figs. 14 and 18). As some of the geese were likely killed on their southward migration, probably 90% or more of the winter recoveries would have been from California-Oregon. These proportions did not change significantly in the 1970s (Figs. 15 and 18).

By the late 1980s, a significant shift in the winter distribution of Wrangel Island geese had occurred: recoveries indicated that 47% of the geese (Figs. 16 and 18) now wintered in British Columbia and Washington, with the remainder using the California-Oregon wintering area. Neckband observations carried out from 1988 to 1992 indicated that 46% of the wintering population was in California-Oregon and 53% was in British Columbia-Washington (Figs. 17 and 18). The mark:resight estimates of the number of collared geese present in each wintering area yielded quite similar results (Fig. 18; Table 2).

Despite a wide distribution of observer effort throughout a broad geographic area and over an extended period (Kerbes and Meeres 1999, this volume), relatively few Wrangel Island geese collared in 1988-1989 were sighted outside the traditional wintering and migration sites (Fig. 17). The pattern of legband recoveries was similar (Fig. 16).

4. Discussion

A major objective of this study was to describe the recent autumn and winter distributions of Snow Geese from the Western Canadian Arctic and Wrangel Island and to determine how the distribution of geese from the two areas might have changed over the past several decades. The reliability of the results depends on how representative legband recoveries and neckband observations are of the true distribution of wintering geese from the different breeding areas.

The relative merits of the legband recovery and neckband resighting approaches have been discussed by Hestbeck et al. (1990). The results of legband recovery analyses depend on the distribution of hunters. Geographic variations in hunting effort and band reporting rates could potentially give misleading indications of the proportion of a population using different areas. Likewise, the neckband resighting approach depends on the distribution and efficiency of observers. Resightings have the potential to provide much more detailed and reliable results than legband recoveries, because the resighting rates for collared geese (about 75%) are much higher than the legband recovery rates (2-3%) (Hines et al. 1999, this volume). In addition, possible biases in the neckband resighting data can be overcome if the number of collared geese wintering in each area can be estimated from the data. The broad similarity of distribution patterns derived from numbers of legband recoveries, numbers of neckband observations, and mark:resight estimates of the numbers of collared geese present in different wintering areas increases our confidence in the general reliability of the results.

4.1 Western Canadian Arctic Population

The long-term legband recovery data and the more recent information on collared geese clearly demonstrate changes in the autumn distribution of Western Arctic Snow Geese. On the staging grounds of the Canadian prairies, the eastward shift from about 75% of the geese staging in Alberta in the 1950s and 1960s to >60% of the geese staging in Saskatchewan in the late 1980s and early 1990s was possibly related to differences in hunting regulations in the two provinces. Goose hunting has been restricted to "morning-only" throughout the southern Saskatchewan staging area since the early 1960s (G.W. Pepper, pers. commun.) but is "all-day" in Alberta, which undoubtedly increased the degree of disturbance in Alberta relative to that in Saskatchewan. The eastward shift may also have been related to drought in the early 1960s, the impact of which was more pronounced on the shallow wetlands used by staging geese in Alberta than in the more permanent wetlands available to staging geese in Saskatchewan.

Significant changes in the winter distribution of the Western Arctic Snow Geese have also occurred. The proportion of the population wintering in the Central Valley of California decreased from 90% in the 1960s to 76% in the late 1980s and early 1990s (most of this change occurring since the late 1970s), while the proportion wintering in the Western Central Flyway increased to 24%.

The extent to which changes in the winter distribution of the Western Arctic Population are related to variations in survival, productivity, or movements is difficult to determine. For 1987-1989, survival estimates for the increasing Western Central Flyway component of the population were not higher than those for the stable California wintering segment (Hines et al. 1999, this volume). Productivity data, although not collected continuously for both wintering areas, suggest that the reproductive success of the Western Central

Flyway stock is lower than that of the California-wintering stock (Silveira 1989, 1990; Subcommittee on White Geese 1992a; Turner et al. 1994).¹ Therefore, the shifting distribution of wintering geese from the Western Arctic does not appear to be a product of regional differences in survival or productivity and might be related to changes in movement patterns. Specifically, either there has been an influx to the Western Arctic breeding colonies of birds from the Central Arctic (perhaps facilitated through mixing on staging areas or the wintering grounds in the Western Central Flyway) (see Dzubin 1979) or significant numbers of geese from the Western Arctic colonies have shifted to the Western Central Flyway, rather than following the traditional migration route to California (Bartonek 1986). Snow Geese from the Central Arctic share wintering grounds with Western Arctic geese in New Mexico and Mexico and are the most probable source of immigrating geese. In 1988, 20% of Central Arctic Snow Geese were blue phase, and individual colonies ranged from 5% to 33% blue (Kerbes 1994). A substantial increase in the number of blue geese in the Western Arctic would be expected if geese formerly breeding in the Central Arctic have shifted to the Western Arctic. Although the proportion of blue-phase geese on Banks Island increased from about 0.01% in the mid-1970s (Dzubin 1979) to 0.5% in 1995–1997 (G. Samelius, pers. commun.), it remains very low. This change in the colour phase ratio suggests that, in 1995, fewer than 2500 blue-phase and 45 000 white-phase geese on Banks Island would have originated from the Central Arctic (assuming the immigrants were only 5% blue). As the population increased by more than 280 000 breeding geese during this period, immigrating geese seem to have made a relatively small contribution to the overall population growth (at most 17%). Most of the increase in the Western Arctic Population must have been internal.

There are few available data that can be used to evaluate what effect emigration (i.e., the abandonment by individual geese of their traditional wintering area in California for the wintering area in the Western Central Flyway) has had on the winter distribution of Western Arctic geese. The high degree of philopatry of collared adult geese to previous staging and wintering areas (Armstrong et al. 1999, this volume) suggests that any wide-scale changes in use of wintering areas would have had to involve young geese. If there has been a shift from the California migration route to the Western Central Flyway, then numerous hatch-year birds that first wintered in California must have shifted to the Western Central Flyway in subsequent winters. Unfortunately, young geese were not collared, so there is no information on their movements.

4.2 Wrangel Island Population

The results from the 1988–1989 collaring study clearly support earlier observations that there are two major wintering areas for Wrangel Island Snow Geese (Subcommittee on White Geese 1992b). As previously noted by Baranyuk (1992, 1995) and Boyd (1995), the proportions of

the population using the northern and southern wintering areas have changed greatly over the past 30 years. In the 1960s and 1970s, <10% of the Wrangel Island geese remained in the Fraser–Skagit (northern) area, whereas 90% moved south to California (Fig. 19). By the late 1980s, about 50% of the geese wintered in each area. Using data from annual photo counts of geese wintering in the Fraser–Skagit area and spring counts of both breeding and nonbreeding geese on Wrangel Island, Boyd (1995) estimated that the proportion of the Wrangel Island Population wintering in the north had increased from about 22% in 1968 to 56% in 1992. The percentages of north-wintering geese determined in this manner are slightly higher than those obtained for similar periods through the legbanding and neckbanding studies.

According to the legband recovery and neckband observation data, much of the change in the distribution of wintering geese occurred in the late 1970s or during the 1980s. Similarly, the annual photo counts of wintering birds in the Fraser–Skagit region (Boyd 1995) indicated a very rapid increase in goose numbers between 1974–1975 and 1980–1981, at a rate (>19% per annum) far too high to be explained entirely in terms of enhanced reproductive success or high survivorship. In 1988–1989, the survival rates of the north-wintering stock of geese were not higher than those of the south-wintering ones (Hines et al. 1999, this volume) and are among the lowest values reported for adult Snow Geese (see Rienecker 1965; Francis and Cooke 1992; Hines et al. 1999, this volume). Information on the productivity of the south-wintering stock of Wrangel Island geese is not available; however, the average productivity of the northern stock of geese has not increased since the 1970s and is quite low (19%) compared with other values reported in the literature (see Bellrose 1976; Jeffrey and Kaiser 1979; Boyd 1995). Therefore, it seems probable that changing movement patterns must account, at least in part, for the increasing percentage of the population wintering in the north.

The rapid increase in the proportion of the population wintering in the Fraser–Skagit region seems to have occurred in the late 1970s, when the geese first began to feed in agricultural fields (see Hatfield, referred to by Campbell et al. 1990) and were no longer entirely dependent on salt-marsh habitat. This timing of the increase also corresponds to a period when the Wrangel Island Population, having sustained four consecutive years of weather-induced reproductive failure, was recovering from all-time low numbers. Thus, a possible explanation of the increasing proportion of geese in the Fraser–Skagit area is that reduced competition for food resources there has “short-stopped” some fall migrants formerly bound for California.

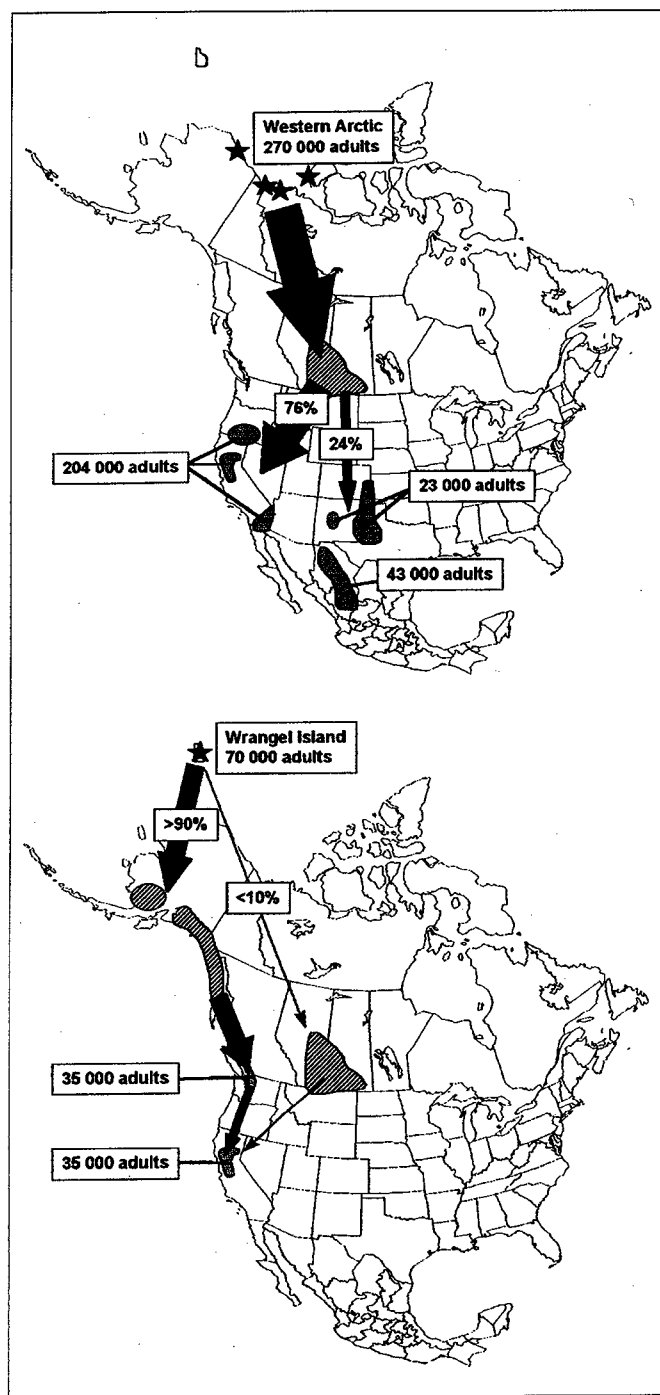
4.3 Integration of distribution and population data from 1987–1992, and possible changes since then

In Figure 19, we have summarized the findings on the fall and winter distributions of geese in the context of our current understanding of population size on both breeding and wintering grounds (Kerbes et al. 1999, this volume).

¹ The percent young in wintering flocks of Snow Geese in New Mexico and Mexico averaged 22% during 1979–1992. In the Pacific Flyway, where >75% of the wintering geese are from the Western Arctic, there was an average of 31% young in the population from 1973 to 1981. In 1988–1989 and 1989–1990, there was an average of 30% young in California. The estimates for the Pacific Flyway include Wrangel Island geese (known to have low productivity) and would probably underestimate the reproductive success of Snow Geese from the Western Arctic.

Figure 19

The numbers of adult Lesser Snow Geese from the Western Arctic and Wrangel Island wintering in different regions. Numbers presented are for adult geese (both breeders and nonbreeders) and represent average values for 1987–1992.



When combined, the population and distribution data from the late 1980s and early 1990s are compatible and seem to present a fairly complete picture of the distribution of both Wrangel Island and Western Arctic populations. However, more recent population estimates indicate that the Western Canadian Arctic Population has continued to grow substantially and that a significant change in the winter distribution of these geese may have occurred.

Between 1987 and 1995, the Western Arctic Population grew from more than 250 000 to over 500 000 adults

(breeders and nonbreeders). Surprisingly, the numbers of birds wintering in California did not increase during this period, so in recent years more than half the population may have wintered outside California. Numbers of wintering Snow Geese in the Western Central Flyway apparently doubled in the early 1990s to more than 250 000. This total includes both adult and young geese and may be composed of only about 80% Western Arctic birds (see Turner et al. 1994:14–15; Kerbes et al. 1999:33, this volume). Thus, despite the substantial increase in numbers of Snow Geese wintering in the Western Central Flyway, we can now account for only <70% of the Western Arctic geese in winter. The most likely explanation for this is that the winter counts in the Western Central Flyway and California have more significantly underestimated the number of geese present in recent years than they did a few years earlier (Kerbes et al. 1999, this volume).

4.4 Management implications

Increasing numbers of Snow Geese of the Midcontinent Population of the Eastern and Central Canadian Arctic have severely overgrazed large areas of tundra near some breeding colonies on the southern and western coasts of Hudson Bay (Kerbes et al. 1990; Batt 1997). Although we have not detected any evidence of widespread overgrazing in the Western Arctic, it would be useful to take a proactive approach in the management of this population before it increases to a level where it cannot be readily controlled by hunting. We believe a desirable goal would be to stabilize the size of the population at its current level, thereby maintaining maximum opportunities for subsistence harvest of the geese in northern Canada and for sport hunting and nonconsumptive recreational use in southern Canada, the United States, and Mexico.

Any management efforts aimed at stabilizing the numbers of Western Arctic Snow Geese must also consider the south-wintering Wrangel Island geese, which have greatly declined in numbers during the past 30 years. In addition, the available evidence from the wintering grounds suggests that the total number of wintering birds in California (>85% Western Arctic geese, <15% Wrangel Island geese) has not increased with the overall Western Arctic population. Thus, neither of the stocks of geese wintering in California may be able to sustain increased harvest. Elsewhere in this volume, we have suggested that the safest approach to population management would be to increase the fall harvest of Snow Geese in Alberta, Saskatchewan, and Montana, the winter harvest in the Western Central Flyway, and the spring subsistence harvest in the Western Arctic (Hines et al. 1999). This approach would help protect the Wrangel Island geese while focusing the harvest more directly on the increasing eastern segment of the Western Arctic Population.

5. Acknowledgements

The numerous individuals involved in the marking and observation programs and the agencies and organizations that supported the fieldwork are outlined elsewhere in this volume. In addition, we wish to thank M. Wiebe for assistance in analyses and for reviewing the manuscript and S. Slattery, D. Duncan, and H. Welch for their comments.

6. Literature cited

- Armstrong, W.T.; Meeres, K.M.; Kerbes, R.H.; Boyd, W.S.; Silveira, J.G.; Taylor, J.P.; Turner, B. 1999.** Routes and timing of migration of Lesser Snow Geese from the Western Canadian Arctic and Wrangel Island, Russia. Pages 75–88 in R.H. Kerbes, K.M. Meeres, and J.E. Hines (eds.), Distribution, survival, and numbers of Lesser Snow Geese of the Western Canadian Arctic and Wrangel Island, Russia. Can. Wildl. Serv. Occas. Pap. No. 98, Ottawa, Ontario.
- Baranyuk, V.V. 1992.** Wrangel Island Lesser Snow Geese population status, numbers, structure and problems of protection [abstract]. Page 23 in 7th North American Arctic Goose Conference and Workshop, 7–12 January 1992, Vallejo, California.
- Baranyuk, V.V. 1995.** The distribution of two subpopulations of Wrangel Island Snow Geese at the breeding and moulting grounds [abstract]. Page 30 in 8th North American Arctic Goose Conference and Workshop, 9–14 January 1995, Albuquerque, New Mexico.
- Bartonek, J.C. 1986.** Western Arctic and Wrangel Island Lesser Snow Goose marking/observation program — 1987 and beyond. Unpublished report, U.S. Fish and Wildlife Service, Portland, Oregon. 15 pp.
- Batt, B.D.J. (ed.). 1997.** Arctic ecosystems in peril: report of the Arctic Goose Habitat Working Group. Arctic Goose Joint Venture Special Publication, U.S. Fish and Wildlife Service, Washington, D.C., and Canadian Wildlife Service, Ottawa, Ontario. 120 pp.
- Bellrose, F.C. 1976.** The ducks, geese, and swans of North America. 2nd ed. Stackpole Books, Harrisburg, Pennsylvania. 544 pp.
- Boyd, W.S. 1995.** Lesser Snow Geese (*Anser c. caerulescens*) and American three-square bulrush (*Scirpus americanus*) on the Fraser and Skagit river deltas. Unpublished Ph.D. thesis, Department of Biological Sciences, Simon Fraser University, North Burnaby, B.C. 154 pp.
- Campbell, R.W.; Dawe, N.K.; McTaggart-Cowan, I.; Cooper, J.M.; Kaiser, G.W.; McNall, M.C.E. 1990.** The birds of British Columbia. Royal British Columbia Museum/Canadian Wildlife Service, Victoria, B.C.
- Dzubin, A. 1974.** Snow and blue goose distribution in the Mississippi and Central flyways: a compendium of results of band recovery analyses. Unpublished report, Canadian Wildlife Service, Saskatoon, Saskatchewan. 566 pp.
- Dzubin, A. 1979.** Recent increases of blue geese in western North America. Pages 141–175 in R.L. Jarvis and J.C. Bartonek (eds.), Management and biology of Pacific Flyway geese. Oregon State University Book Stores, Corvallis, Oregon.
- Dzubin, A.; Boyd, H.; Stephen, W.J.D. 1975.** Blue and Snow goose distribution in the Mississippi and Central flyways, 1951–71. Can. Wildl. Serv. Prog. Notes No. 54, Ottawa, Ontario. 34 pp.
- Francis, C.M.; Cooke, F. 1992.** Sexual differences in survival and recovery rates of Lesser Snow Geese. J. Wildl. Manage. 56:287–296.
- Hestbeck, J.B.; Rusch, D.H.; Malecki, R.A. 1990.** Estimating population parameters for geese from band-recovery and mark-recapture data. Trans. North Am. Wildl. Nat. Resour. Conf. 55:350–373.
- Hines, J.E.; Wiebe, M.O.; Barry, S.J.; Baranyuk, V.V.; Taylor, J.P.; McKelvey, R.; Johnson, S.R.; Kerbes, R.H. 1999.** Survival rates of Lesser Snow Geese in the Pacific and Western Central flyways, 1953–1989. Pages 89–109 in R.H. Kerbes, K.M. Meeres, and J.E. Hines (eds.), Distribution, survival, and numbers of Lesser Snow Geese of the Western Canadian Arctic and Wrangel Island, Russia. Can. Wildl. Serv. Occas. Pap. No. 98, Ottawa, Ontario.
- Jeffrey, R.; Kaiser, G. 1979.** The Snow Goose flock of the Fraser and Skagit deltas. Pages 266–279 in R.L. Jarvis and J.C. Bartonek (eds.), Management and biology of Pacific Flyway geese. Oregon State University Book Stores, Corvallis, Oregon.
- Kerbes, R.H. 1994.** Colonies and numbers of Ross' Geese and Lesser Snow Geese in the Queen Maud Gulf Migratory Bird Sanctuary. Can. Wildl. Serv. Occas. Pap. No. 81, Ottawa, Ontario.
- Kerbes, R.H.; Meeres, K.M. 1999.** Project overview. Pages 15–24 in R.H. Kerbes, K.M. Meeres, and J.E. Hines (eds.), Distribution, survival, and numbers of Lesser Snow Geese of the Western Canadian Arctic and Wrangel Island, Russia. Can. Wildl. Serv. Occas. Pap. No. 98, Ottawa, Ontario.
- Kerbes, R.H.; Kotanen, P.M.; Jefferies, R.L. 1990.** Destruction of wetland habitats by Lesser Snow Geese: a keystone species on the west coast of Hudson Bay. J. Appl. Ecol. 27:242–258.
- Kerbes, R.H.; Baranyuk, V.V.; Hines, J.E. 1999.** Estimated size of the Western Canadian Arctic and Wrangel Island Lesser Snow Goose populations on their breeding and wintering grounds. Pages 25–38 in R.H. Kerbes, K.M. Meeres, and J.E. Hines (eds.), Distribution, survival, and numbers of Lesser Snow Geese of the Western Canadian Arctic and Wrangel Island, Russia. Can. Wildl. Serv. Occas. Pap. No. 98, Ottawa, Ontario.
- Otis, D.L.; Burnham, K.P.; White, G.C.; Anderson, D.R. 1978.** Statistical inference from capture data on closed animal populations. Wildl. Monogr. 62:1–135.
- Rienecker, W.C. 1965.** A summary of band returns from Lesser Snow Geese (*Chen hyperborea*) of the Pacific Flyway. Calif. Fish Game 51:132–146.
- Silveira, J.G. 1989.** Distribution of Lesser Snow and Ross' geese in California, winter 1988–89. Unpublished report, California Department of Fish and Game, Sacramento, California. 19 pp.
- Silveira, J.G. 1990.** Distribution of Lesser Snow and Ross' geese in California, winter 1989–90. Unpublished report, California Department of Fish and Game, Sacramento, California. 7 pp.
- Subcommittee on White Geese. 1992a.** Pacific Flyway management plan for the Western Arctic Population of Lesser Snow Geese. Unpublished report, Pacific Flyway Study Committee, U.S. Fish and Wildlife Service, Portland, Oregon. 30 pp.
- Subcommittee on White Geese. 1992b.** Pacific Flyway management plan for the Wrangel Island Population of Lesser Snow Geese. Unpublished report, Pacific Flyway Study Committee, U.S. Fish and Wildlife Service, Portland, Oregon. 25 pp.
- Teplov, V.P.; Shevareva, T.P. 1965.** On seasonal movements and the bag of Snow Geese. Pages 25–38 in G.P. Dementiev (ed.), The migration of birds and mammals. USSR Academy of Science, Moscow (in Russian). Translated from Russian by the Canadian Department of State for the Canadian Wildlife Service, Ottawa, Ontario.
- Turner, B.; Tomlinson, R.; Leyva, R.; Dominguez, P. 1994.** Wintering populations of Lesser Snow Geese and Ross' Geese in the Northern Highlands of México, 1988–1990. Can. Wildl. Serv. Occas. Pap. No. 84, Ottawa, Ontario. 21 pp.

Appendix 1a

Locations where adult and young Lesser Snow Geese banded in the Western Canadian Arctic were recovered or their neckbands were resighted. Recoveries or resightings are for autumn and winter (September–February).

Western Arctic — adults

Location	Legband recoveries (to 1996)					Neckband observations (to 1992)	
	banded 1953–1966	banded 1973–1976	banded 1987–1989	Total		banded 1987–1989	
Alberta	88 17.1%	43 14.6%	23 9.5%	154	14.6%	377	11.8%
Arizona	1 0.2%	0 0.0%	0 0.0%	1	0.1%	1	0.0%
California	300 58.4%	183 62.0%	124 51.0%	607	57.7%	1375	42.9%
Colorado	1 0.2%	0 0.0%	6 2.5%	7	0.7%	8	0.2%
Idaho	0 0.0%	0 0.0%	1 0.4%	1	0.1%	3	0.1%
Iowa	0 0.0%	1 0.3%	0 0.0%	1	0.1%	0	0.0%
Louisiana	0 0.0%	0 0.0%	1 0.4%	1	0.1%	0	0.0%
Mexico	23 4.5%	7 2.4%	20 8.2%	50	4.8%	301	9.4%
Montana	15 2.9%	4 1.4%	8 3.3%	27	2.6%	81	2.5%
Nevada	6 1.2%	1 0.3%	2 0.8%	9	0.9%	12	0.4%
New Mexico	1 0.2%	5 1.7%	6 2.5%	12	1.1%	151	4.7%
North Dakota	1 0.2%	0 0.0%	0 0.0%	1	0.1%	0	0.0%
Northwest Territories	10 1.9%	4 1.4%	1 0.0%	15	1.4%	0	0.0%
Oregon	26 5.1%	6 2.0%	8 3.3%	40	3.8%	34	1.1%
Saskatchewan	35 6.8%	38 12.9%	35 14.4%	108	10.3%	798	24.9%
South Dakota	0 0.0%	0 0.0%	1 0.4%	1	0.1%	0	0.0%
Texas	0 0.0%	0 0.0%	6 2.5%	6	0.6%	6	0.2%
Utah	3 0.6%	0 0.0%	1 0.4%	4	0.4%	59	1.8%
Washington	2 0.4%	0 0.0%	0 0.0%	2	0.2%	0	0.0%
Yukon	2 0.4%	3 1.0%	0 0.0%	5	0.5%	0	0.0%
Total	514 100.0%	295 100.0%	243 100.0%	1052	100.0%	3206	100.0%

Western Arctic — young

Location	Legband recoveries (to 1996)						
	banded 1953–1966	banded 1973–1976	banded 1987–1989	Total			
Alaska	2 0.4%	0 0.0%	0 0.0%	2	0.2%		
Alberta	102 18.1%	38 15.4%	17 11.3%	157	16.4%		
Arkansas	0 0.0%	0 0.0%	1 0.7%	1	0.1%		
California	328 58.3%	142 57.5%	69 46.0%	539	56.1%		
Colorado	0 0.0%	0 0.0%	1 0.7%	1	0.1%		
Idaho	1 0.2%	1 0.4%	2 1.3%	4	0.4%		
Louisiana	0 0.0%	1 0.4%	0 0.0%	1	0.1%		
Manitoba	0 0.0%	0 0.0%	1 0.7%	1	0.1%		
Mexico	28 5.0%	12 4.9%	8 5.3%	48	5.0%		
Montana	17 3.0%	2 0.8%	2 1.3%	21	2.2%		
Nebraska	0 0.0%	1 0.4%	0 0.0%	1	0.1%		
Nevada	9 1.6%	4 1.6%	0 0.0%	13	1.4%		
New Mexico	0 0.0%	0 0.0%	3 2.0%	3	0.3%		
North Dakota	1 0.2%	1 0.4%	0 0.0%	2	0.2%		
Northwest Territories	3 0.5%	2 0.8%	2 0.0%	7	0.7%		
Oklahoma	0 0.0%	1 0.4%	0 0.0%	1	0.1%		
Oregon	36 6.4%	7 2.8%	6 4.0%	49	5.1%		
Saskatchewan	32 5.7%	34 13.8%	36 24.0%	102	10.6%		
Texas	0 0.0%	0 0.0%	2 1.3%	2	0.2%		
Utah	1 0.2%	0 0.0%	0 0.0%	1	0.1%		
Washington	3 0.5%	0 0.0%	0 0.0%	3	0.3%		
Yukon	0 0.0%	1 0.4%	0 0.0%	1	0.1%		
Total	563 100.0%	247 100.0%	150 100.0%	960	100.0%		

Continued

Appendix 1a (cont'd)

Locations where adult and young Lesser Snow Geese banded in the Western Canadian Arctic were recovered or their neckbands were resighted. Recoveries or resightings are for autumn and winter (September–February).

Western Arctic — adults and young

Location	Legband recoveries (to 1996)						Neckband observations (to 1992)	
	banded 1953–1966	banded 1973–1976	banded 1987–1989	Total			banded 1987–1989	
Alaska	2 0.2%	0 0.0%	0 0.0%	2	0.1%		0	0.0%
Alberta	190 17.6%	81 14.9%	40 10.1%	311	15.4%		377	11.8%
Arizona	1 0.1%	0 0.0%	0 0.0%	1	0.0%		1	0.0%
Arkansas	0 0.0%	0 0.0%	1 0.3%	1	0.0%		0	0.0%
California	628 58.3%	325 60.0%	195 ^a 49.4%	1148	57.0%		1375	42.9%
Colorado	1 0.1%	0 0.0%	7 1.8%	8	0.4%		8	0.2%
Idaho	1 0.1%	1 0.2%	3 0.8%	5	0.2%		3	0.1%
Iowa	0 0.0%	1 0.2%	0 0.0%	1	0.0%		0	0.0%
Louisiana	0 0.0%	1 0.2%	1 0.3%	2	0.1%		0	0.0%
Manitoba	0 0.0%	0 0.0%	1 0.3%	1	0.0%		0	0.0%
Mexico	51 4.7%	19 3.5%	28 7.1%	98	4.9%		301	9.4%
Montana	32 3.0%	6 1.1%	10 2.5%	48	2.4%		81	2.5%
Nebraska	0 0.0%	1 0.2%	0 0.0%	1	0.0%		0	0.0%
Nevada	15 1.4%	5 0.9%	2 0.5%	22	1.1%		12	0.4%
New Mexico	1 0.1%	5 0.9%	9 2.3%	15	0.7%		151	4.7%
North Dakota	2 0.2%	1 0.2%	0 0.0%	3	0.1%		0	0.0%
Northwest Territories	13 1.2%	6 1.1%	3 0.8%	22	1.1%		0	0.0%
Oklahoma	0 0.0%	1 0.2%	0 0.0%	1	0.0%		0	0.0%
Oregon	62 5.8%	13 2.4%	14 3.5%	89	4.4%		34	1.1%
Saskatchewan	67 6.2%	72 13.3%	71 18.0%	210	10.4%		798	24.9%
South Dakota	0 0.0%	0 0.0%	1 0.3%	1	0.0%		0	0.0%
Texas	0 0.0%	0 0.0%	8 2.0%	8	0.4%		6	0.2%
Utah	4 0.4%	0 0.0%	1 0.3%	5	0.2%		59	1.8%
Washington	5 0.5%	0 0.0%	0 0.0%	5	0.2%		0	0.0%
Yukon	2 0.2%	4 0.7%	0 0.0%	6	0.3%		0	0.0%
Total	1077 100.0%	542 100.0%	395 100.0%	2014	100.0%		3206	100.0%

^a Two individuals were recorded as unknown age.

Appendix 1b

Locations where adult and young Lesser Snow Geese banded in the Western Canadian Arctic were recovered or their neckbands were resighted. Recoveries or resightings are for autumn (September–November).

Western Arctic — adults

Location	Legband recoveries (to 1995)						Neckband observations (to 1991)
	banded 1953–1966	banded 1973–1976	banded 1987–1989	Total		banded 1987–1989	
Alberta	87 34.9%	43 30.9%	23 19.8%	153	30.4%	377	15.4%
California	62 24.9%	38 27.3%	29 25.0%	129	25.6%	1047	42.9%
Colorado	1 0.4%	0 0.0%	2 1.7%	3	0.6%	2	0.1%
Iowa	0 0.0%	1 0.7%	0 0.0%	1	0.2%	0	0.0%
Mexico	4 1.6%	2 1.4%	2 1.7%	8	1.6%	3	0.1%
Montana	15 6.0%	4 2.9%	8 6.9%	27	5.4%	81	3.3%
Nebraska	0 0.0%	0 0.0%	0 0.0%	0	0.0%	115	4.7%
Nevada	2 0.8%	0 0.0%	2 1.7%	4	0.8%	6	0.2%
New Mexico	0 0.0%	1 0.7%	1 0.9%	2	0.4%	9	0.4%
North Dakota	1 0.4%	0 0.0%	0 0.0%	1	0.2%	0	0.0%
Northwest Territories	10 4.0%	4 2.9%	1 0.9%	15	3.0%	0	0.0%
Oregon	26 10.4%	6 4.3%	8 6.9%	40	7.9%	0	0.0%
Saskatchewan	35 14.1%	37 26.6%	35 30.2%	107	21.2%	798	32.7%
South Dakota	0 0.0%	0 0.0%	1 0.9%	1	0.2%	0	0.0%
Texas	0 0.0%	0 0.0%	3 2.6%	3	0.6%	3	0.1%
Utah	2 0.8%	0 0.0%	1 0.9%	3	0.6%	0	0.0%
Washington	2 0.8%	0 0.0%	0 0.0%	2	0.4%	0	0.0%
Yukon	2 0.8%	3 2.2%	0 0.0%	5	1.0%	0	0.0%
Total	249 100.0%	139 100.0%	116 100.0%	504	100.0%	2441	100.0%

Western Arctic — young

Location	Legband recoveries (to 1995)					
	banded 1953–1966	banded 1973–1976	banded 1987–1989	Total		
Alaska	2 0.7%	0 0.0%	0 0.0%	2	0.4%	
Alberta	101 35.2%	38 32.2%	17 19.5%	156	31.7%	
California	82 28.6%	29 24.6%	18 20.7%	129	26.2%	
Idaho	0 0.0%	0 0.0%	2 2.3%	2	0.4%	
Manitoba	0 0.0%	0 0.0%	1 1.1%	1	0.2%	
Mexico	5 1.7%	0 0.0%	1 1.1%	6	1.2%	
Montana	16 5.6%	2 1.7%	2 2.3%	20	4.1%	
Nebraska	0 0.0%	1 0.8%	0 0.0%	1	0.2%	
Nevada	6 2.1%	3 2.5%	0 0.0%	9	1.8%	
New Mexico	0 0.0%	0 0.0%	1 1.1%	1	0.2%	
North Dakota	1 0.3%	1 0.8%	0 0.0%	2	0.4%	
Northwest Territories	3 1.0%	2 1.7%	2 2.3%	7	1.4%	
Oregon	36 12.5%	7 5.9%	6 6.9%	49	10.0%	
Saskatchewan	32 11.1%	34 28.8%	36 41.4%	102	20.7%	
Texas	0 0.0%	0 0.0%	1 1.1%	1	0.2%	
Utah	1 0.3%	0 0.0%	0 0.0%	1	0.2%	
Washington	2 0.7%	0 0.0%	0 0.0%	2	0.4%	
Yukon	0 0.0%	1 0.8%	0 0.0%	1	0.2%	
Total	287 100.0%	118 100.0%	87 100.0%	492	100.0%	

Continued

Appendix 1b (cont'd)

Locations where adult and young Lesser Snow Geese banded in the Western Canadian Arctic were recovered or their neckbands were resighted. Recoveries or resightings are for autumn (September–November).

Western Arctic — adults and young

Location	Legband recoveries (to 1995)						Neckband observations (to 1991)	
	banded 1953–1966	banded 1973–1976	banded 1987–1989	Total			banded 1987–1989	
Alaska	2 0.4%	0 0.0%	0 0.0%	2	0.2%		0	0.0%
Alberta	188 35.1%	81 31.5%	40 19.6%	309	31.0%		377	15.4%
California	144 26.9%	67 26.1%	48 ^a 23.5%	259	26.0%		1047	42.9%
Colorado	1 0.2%	0 0.0%	2 1.0%	3	0.3%		2	0.1%
Idaho	0 0.0%	0 0.0%	2 1.0%	2	0.2%		0	0.0%
Iowa	0 0.0%	1 0.4%	0 0.0%	1	0.1%		0	0.0%
Manitoba	0 0.0%	0 0.0%	1 0.5%	1	0.1%		0	0.0%
Mexico	9 1.7%	2 0.8%	3 1.5%	14	1.4%		3	0.1%
Montana	31 5.8%	6 2.3%	10 4.9%	47	4.7%		81	3.3%
Nebraska	0 0.0%	1 0.4%	0 0.0%	1	0.1%		115	4.7%
Nevada	8 1.5%	3 1.2%	2 1.0%	13	1.3%		6	0.2%
New Mexico	0 0.0%	1 0.4%	2 1.0%	3	0.3%		9	0.4%
North Dakota	2 0.4%	1 0.4%	0 0.0%	3	0.3%		0	0.0%
Northwest Territories	13 2.4%	6 2.3%	3 1.5%	22	2.2%		0	0.0%
Oregon	62 11.6%	13 5.1%	14 6.9%	89	8.9%		0	0.0%
Saskatchewan	67 12.5%	71 27.6%	71 34.8%	209	21.0%		798	32.7%
South Dakota	0 0.0%	0 0.0%	1 0.5%	1	0.1%		0	0.0%
Texas	0 0.0%	0 0.0%	4 2.0%	4	0.4%		3	0.1%
Utah	3 0.6%	0 0.0%	1 0.5%	4	0.4%		0	0.0%
Washington	4 0.7%	0 0.0%	0 0.0%	4	0.4%		0	0.0%
Yukon	2 0.4%	4 1.6%	0 0.0%	6	0.6%		0	0.0%
Total	536 100.0%	257 100.0%	204 100.0%	997 100.0%			2441 100.0%	

^a One individual was recorded as unknown age.

Appendix 1c

Locations where adult and young Lesser Snow Geese banded in the Western Canadian Arctic were recovered or their neckbands were resighted. Recoveries or resightings are for winter (December–February).

Western Arctic — adults

Location	Legband recoveries (to 1996)					Neckband observations (to 1992)	
	banded 1953–1966	banded 1973–1976	banded 1987–1989	Total		banded 1987–1989	
Arizona	1 0.4%	0 0.0%	0 0.0%	1 0.2%		1 0.1%	
California	238 90.2%	145 93.5%	95 74.8%	478 87.5%		1235 70.2%	
Colorado	0 0.0%	0 0.0%	4 3.1%	4 0.7%		7 0.4%	
Idaho	0 0.0%	0 0.0%	1 0.8%	1 0.2%		3 0.2%	
Louisiana	0 0.0%	0 0.0%	1 0.8%	1 0.2%		0 0.0%	
Mexico	19 7.2%	5 3.2%	18 14.2%	42 7.7%		298 16.9%	
Nevada	4 1.5%	1 0.6%	0 0.0%	5 0.9%		5 0.3%	
New Mexico	1 0.4%	4 2.6%	5 3.9%	10 1.8%		119 6.8%	
Oregon	0 0.0%	0 0.0%	0 0.0%	0 0.0%		29 1.6%	
Texas	0 0.0%	0 0.0%	3 2.4%	3 0.5%		3 0.2%	
Utah	1 0.4%	0 0.0%	0 0.0%	1 0.2%		59 3.4%	
Total	264 100.0%	155 100.0%	127 100.0%	546 100.0%		1759 100.0%	

Western Arctic — young

Location	Legband recoveries (to 1996)				Total
	banded 1953–1966	banded 1973–1976	banded 1987–1989		
Arkansas	0 0.0%	0 0.0%	1 1.6%	1 0.2%	
California	246 89.5%	113 87.6%	51 81.0%	410 87.8%	
Colorado	0 0.0%	0 0.0%	1 1.6%	1 0.2%	
Idaho	1 0.4%	1 0.8%	0 0.0%	2 0.4%	
Louisiana	0 0.0%	1 0.8%	0 0.0%	1 0.2%	
Mexico	23 8.4%	12 9.3%	7 11.1%	42 9.0%	
Montana	1 0.4%	0 0.0%	0 0.0%	1 0.2%	
Nevada	3 1.1%	1 0.8%	0 0.0%	4 0.9%	
New Mexico	0 0.0%	0 0.0%	2 3.2%	2 0.4%	
Oklahoma	0 0.0%	1 0.8%	0 0.0%	1 0.2%	
Texas	0 0.0%	0 0.0%	1 1.6%	1 0.2%	
Washington	1 0.4%	0 0.0%	0 0.0%	1 0.2%	
Total	275 100.0%	129 100.0%	63 100.0%	467 100.0%	

Western Arctic — adults and young

Location	Legband recoveries (to 1996)					Neckband observations (to 1992)	
	banded 1953–1966	banded 1973–1976	banded 1987–1989	Total		banded 1987–1989	
Arizona	1 0.2%	0 0.0%	0 0.0%	1 0.1%		1 0.1%	
Arkansas	0 0.0%	0 0.0%	1 0.5%	1 0.1%		0 0.0%	
California	484 89.8%	258 90.8%	147 ^a 77.0%	889 87.7%		1235 70.2%	
Colorado	0 0.0%	0 0.0%	5 2.6%	5 0.5%		7 0.4%	
Idaho	1 0.2%	1 0.4%	1 0.5%	3 0.3%		3 0.2%	
Louisiana	0 0.0%	1 0.4%	1 0.5%	2 0.2%		0 0.0%	
Mexico	42 7.8%	17 6.0%	25 13.1%	84 8.3%		298 16.9%	
Montana	1 0.2%	0 0.0%	0 0.0%	1 0.1%		0 0.0%	
Nevada	7 1.3%	2 0.7%	0 0.0%	9 0.9%		5 0.3%	
New Mexico	1 0.2%	4 1.4%	7 3.7%	12 1.2%		119 6.8%	
Oklahoma	0 0.0%	1 0.4%	0 0.0%	1 0.1%		0 0.0%	
Oregon	0 0.0%	0 0.0%	0 0.0%	0 0.0%		29 1.6%	
Texas	0 0.0%	0 0.0%	4 2.1%	4 0.4%		3 0.2%	
Utah	1 0.2%	0 0.0%	0 0.0%	1 0.1%		59 3.4%	
Washington	1 0.2%	0 0.0%	0 0.0%	1 0.1%		0 0.0%	
Total	539 100.0%	284 100.0%	191 100.0%	1014 100.0%		1759 100.0%	

^a One individual was recorded as unknown age.

Appendix 1d

Locations where adult and young Lesser Snow Geese banded on Wrangel Island were recovered or their neckbands were resighted. Recoveries or resightings are for autumn and winter (September–February).

Wrangel Island — adults

Location	Legband recoveries (to 1996)					Neckband observations (to 1992)	
	banded 1961–1963	banded 1975–1979	banded 1988–1989	Total		banded 1988–1989	
Alaska	? ?	2 1.3%	2 1.8%	4 1.5%		0 0.0%	
Alberta	? ?	4 2.6%	3 2.8%	7 2.6%		21 1.4%	
British Columbia	? ?	17 10.9%	11 10.1%	28 10.6%		564 37.4%	
California	? ?	86 55.1%	39 35.8%	125 47.2%		453 30.0%	
Idaho	? ?	0 0.0%	0 0.0%	0 0.0%		2 0.1%	
Mexico	? ?	0 0.0%	0 0.0%	0 0.0%		2 0.1%	
Montana	? ?	0 0.0%	0 0.0%	0 0.0%		5 0.3%	
Nevada	? ?	0 0.0%	0 0.0%	0 0.0%		2 0.1%	
New Mexico	? ?	0 0.0%	0 0.0%	0 0.0%		1 0.1%	
Oregon	? ?	22 14.1%	22 20.2%	44 16.6%		66 4.4%	
Russia	? ?	1 0.6%	0 0.0%	1 0.4%		0 0.0%	
Saskatchewan	? ?	0 0.0%	0 0.0%	0 0.0%		21 1.4%	
Utah	? ?	0 0.0%	0 0.0%	0 0.0%		2 0.1%	
Washington	? ?	24 15.4%	32 29.4%	56 21.1%		369 24.5%	
Total	? ?	156 100.0%	109 100.0%	265 100.0%		1508 100.0%	

Wrangel Island — young

Location	Legband recoveries (to 1996)				
	banded 1961–1963	banded 1975–1979	banded 1988–1989	Total	
Alaska	? ?	1 1.2%	0 0.0%	1 1.2%	
Alberta	? ?	4 4.8%	0 0.0%	4 4.8%	
British Columbia	? ?	8 9.5%	0 0.0%	8 9.5%	
California	? ?	37 44.0%	0 0.0%	37 44.0%	
Ontario	? ?	1 1.2%	0 0.0%	1 1.2%	
Oregon	? ?	28 33.3%	0 0.0%	28 33.3%	
Washington	? ?	5 6.0%	0 0.0%	5 6.0%	
Total	? ?	84 100.0%	0 0.0%	84 100.0%	

Wrangel Island — adults and young

Location	Legband recoveries (to 1996)					Neckband observations (to 1992)	
	banded 1961–1963	banded 1975–1979	banded 1988–1989	Total		banded 1988–1989	
Alaska	10 2.9%	3 1.3%	2 1.8%	15 2.2%		0 0.0%	
Alberta	3 0.9%	8 3.3%	3 2.8%	14 2.0%		21 1.4%	
British Columbia	16 4.7%	25 10.4%	11 10.1%	52 7.5%		564 37.4%	
California	141 41.0%	123 51.3%	39 35.8%	303 43.7%		453 30.0%	
Idaho	0 0.0%	0 0.0%	0 0.0%	0 0.0%		2 0.1%	
Mexico	0 0.0%	0 0.0%	0 0.0%	0 0.0%		2 0.1%	
Montana	2 0.6%	0 0.0%	0 0.0%	2 0.3%		5 0.3%	
Nevada	0 0.0%	0 0.0%	0 0.0%	0 0.0%		2 0.1%	
New Mexico	0 0.0%	0 0.0%	0 0.0%	0 0.0%		1 0.1%	
Ontario	0 0.0%	1 0.4%	0 0.0%	1 0.1%		0 0.0%	
Oregon	152 44.2%	50 20.8%	22 20.2%	224 32.3%		66 4.4%	
Russia	0 0.0%	1 0.4%	0 0.0%	1 0.1%		0 0.0%	
Saskatchewan	1 0.3%	0 0.0%	0 0.0%	1 0.1%		21 1.4%	
Utah	1 0.3%	0 0.0%	0 0.0%	1 0.1%		2 0.1%	
Washington	18 5.2%	29 12.1%	32 29.4%	79 11.4%		369 24.5%	
Total	344 100.0%	240 100.0%	109 100.0%	693 100.0%		1508 100.0%	

Appendix 1e

Locations where adult and young Lesser Snow Geese banded on Wrangel Island were recovered or their neckbands were resighted. Recoveries or resightings are for autumn (September–November).

Wrangel Island — adults

Location	Legband recoveries (to 1995)						Neckband observations (to 1991)	
	banded 1953–1966	banded 1975–1979	banded 1987–1989	Total			banded 1987–1989	
Alaska	?	2 2.4%	2 3.4%	4	2.9%		0	0.0%
Alberta	?	4 4.9%	3 5.2%	7	5.0%		21	2.0%
British Columbia	?	16 19.5%	11 19.0%	27	19.3%		543	52.1%
California	?	25 30.5%	15 25.9%	40	28.6%		298	28.6%
Montana	?	0 0.0%	0 0.0%	0	0.0%		5	0.5%
Nevada	?	0 0.0%	0 0.0%	0	0.0%		1	0.1%
New Mexico	?	0 0.0%	0 0.0%	0	0.0%		1	0.1%
Oregon	?	20 24.4%	19 32.8%	39	27.9%		43	4.1%
Russia	?	1 1.2%	0 0.0%	1	0.7%		0	0.0%
Saskatchewan	?	0 0.0%	0 0.0%	0	0.0%		21	2.0%
Washington	?	14 17.1%	8 13.8%	22	15.7%		110	10.5%
Total	?	82 100.0%	58 100.0%	140	100.0%		1043	100.0%

Wrangel Island — young

Location	Legband recoveries (to 1995)			
	banded 1953–1966	banded 1975–1979	banded 1987–1989	Total
Alaska	?	1 1.8%	0 0.0%	1 1.8%
Alberta	?	4 7.1%	0 0.0%	4 7.1%
British Columbia	?	8 14.3%	0 0.0%	8 14.3%
California	?	9 16.1%	0 0.0%	9 16.1%
Ontario	?	1 1.8%	0 0.0%	1 1.8%
Oregon	?	28 50.0%	0 0.0%	28 50.0%
Washington	?	5 8.9%	0 0.0%	5 8.9%
Total	?	56 100.0%	0 0.0%	56 100.0%

Wrangel Island — adults and young

Location	Legband recoveries (to 1995)						Neckband observations (to 1991)	
	banded 1953–1966	banded 1975–1979	banded 1987–1989	Total			banded 1987–1989	
Alaska	?	3 2.2%	2 3.4%	5	2.6%		0	0.0%
Alberta	?	8 5.8%	3 5.2%	11	5.6%		21	2.0%
British Columbia	?	24 17.4%	11 19.0%	35	17.9%		543	52.1%
California	?	34 24.6%	15 25.9%	49	25.0%		298	28.6%
Montana	?	0 0.0%	0 0.0%	0	0.0%		5	0.5%
Nevada	?	0 0.0%	0 0.0%	0	0.0%		1	0.1%
New Mexico	?	0 0.0%	0 0.0%	0	0.0%		1	0.1%
Ontario	?	1 0.7%	0 0.0%	1	0.5%		0	0.0%
Oregon	?	48 34.8%	19 32.8%	67	34.2%		43	4.1%
Russia	?	1 0.7%	0 0.0%	1	0.5%		0	0.0%
Saskatchewan	?	0 0.0%	0 0.0%	0	0.0%		21	2.0%
Washington	?	19 13.8%	8 13.8%	27	13.8%		110	10.5%
Total	?	138 100.0%	58 100.0%	196	100.0%		1043	100.0%

Appendix 1f

Locations where adult and young Lesser Snow Geese banded on Wrangel Island were recovered or their neckbands were resighted. Recoveries or resightings are for winter (December–February).

Wrangel Island — adults

Location	Legband recoveries (to 1996)						Neckband observations (to 1992)	
	banded 1961–1963	banded 1975–1979	banded 1988–1989	Total			banded 1988–1989	
British Columbia	?	1 1.4%	0 0.0%	1	0.8%		174	18.3%
California	?	61 82.4%	24 47.1%	85	68.0%		409	43.1%
Idaho	?	0 0.0%	0 0.0%	0	0.0%		2	0.2%
Mexico	?	0 0.0%	0 0.0%	0	0.0%		2	0.2%
Nevada	?	0 0.0%	0 0.0%	0	0.0%		1	0.1%
New Mexico	?	0 0.0%	0 0.0%	0	0.0%		1	0.1%
Oregon	?	2 2.7%	3 5.9%	5	4.0%		28	2.9%
Utah	?	0 0.0%	0 0.0%	0	0.0%		2	0.2%
Washington	?	10 13.5%	24 47.1%	34	27.2%		331	34.8%
Total	?	74 100.0%	51 100.0%	125	100.0%		950	100.0%

Wrangel Island — young

Location	Legband recoveries (to 1996)			
	banded 1961–1963	banded 1975–1979	banded 1988–1989	Total
California	?	28 100.0%	0 0.0%	28 100.0%
Total	?	28 100.0%	0 0.0%	28 100.0%

Wrangel Island — adults and young

Location	Legband recoveries (to 1996)						Neckband observations (to 1992)	
	banded 1961–1963	banded 1975–1979	banded 1988–1989	Total			banded 1988–1989	
British Columbia	?	1 1.0%	0 0.0%	1	0.7%		174	18.3%
California	?	89 87.3%	24 47.1%	113	73.9%		409	43.1%
Idaho	?	0 0.0%	0 0.0%	0	0.0%		2	0.2%
Mexico	?	0 0.0%	0 0.0%	0	0.0%		2	0.2%
Nevada	?	0 0.0%	0 0.0%	0	0.0%		1	0.1%
New Mexico	?	0 0.0%	0 0.0%	0	0.0%		1	0.1%
Oregon	?	2 2.0%	3 5.9%	5	3.3%		28	2.9%
Utah	?	0 0.0%	0 0.0%	0	0.0%		2	0.2%
Washington	?	10 9.8%	24 47.1%	34	22.2%		331	34.8%
Total	?	102 100.0%	51 100.0%	153	100.0%		950	100.0%

Appendix 2

Locations where adult and young Lesser Snow Geese banded in the Western Canadian Arctic were recovered or their neckbands were resighted. Both direct and indirect recoveries or resightings for autumn and winter are reported.^a

Location	Legband recoveries (1953–1996)												Neckband observations (1987–1992)			
	banded 1953–1966				banded 1973–1976				banded 1987–1989				banded 1987–1989			
	Direct		Indirect		Direct		Indirect		Direct		Indirect		Direct		Indirect	
Alaska	0	0.0%	2	0.3%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Alberta	80	21.3%	110	15.7%	31	13.7%	50	15.8%	21	12.1%	19	8.6%	132	17.0%	179	14.5%
Arizona	0	0.0%	1	0.1%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	1	0.1%
Arkansas	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	1	0.5%	0	0.0%	1	0.1%
California	207	55.1%	421	60.1%	139	61.5%	186	58.9%	64	36.8%	131	59.3%	410	52.8%	738	59.6%
Colorado	1	0.3%	0	0.0%	0	0.0%	0	0.0%	5	2.9%	2	0.9%	6	0.8%	2	0.2%
Idaho	0	0.0%	1	0.1%	0	0.0%	1	0.3%	0	0.0%	3	1.4%	0	0.0%	5	0.4%
Iowa	0	0.0%	0	0.0%	0	0.0%	1	0.3%	0	0.0%	0	0.0%	0	0.0%	1	0.1%
Louisiana	0	0.0%	0	0.0%	0	0.0%	1	0.3%	1	0.6%	0	0.0%	1	0.1%	1	0.1%
Manitoba	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	1	0.5%	0	0.0%	1	0.1%
Mexico	19	5.1%	32	4.6%	6	2.7%	13	4.1%	10	5.7%	18	8.1%	35	4.5%	63	5.1%
Montana	15	4.0%	17	2.4%	2	0.9%	4	1.3%	5	2.9%	5	2.3%	22	2.8%	26	2.1%
Nebraska	0	0.0%	0	0.0%	1	0.4%	0	0.0%	0	0.0%	0	0.0%	1	0.1%	0	0.0%
Nevada	8	2.1%	7	1.0%	3	1.3%	2	0.6%	2	1.1%	0	0.0%	13	1.7%	9	0.7%
New Mexico	0	0.0%	1	0.1%	0	0.0%	5	1.6%	4	2.3%	5	2.3%	4	0.5%	11	0.9%
North Dakota	0	0.0%	2	0.3%	0	0.0%	1	0.3%	0	0.0%	0	0.0%	0	0.0%	3	0.2%
Northwest Territories	0	0.0%	13	1.9%	3	1.3%	3	0.9%	2	1.1%	1	0.5%	5	0.6%	17	1.4%
Oklahoma	0	0.0%	0	0.0%	1	0.4%	0	0.0%	0	0.0%	0	0.0%	1	0.1%	0	0.0%
Oregon	31	8.2%	31	4.4%	7	3.1%	6	1.9%	7	4.0%	7	3.2%	45	5.8%	44	3.6%
Saskatchewan	14	3.7%	53	7.6%	31	13.7%	41	13.0%	46	26.4%	25	11.3%	91	11.7%	119	9.6%
South Dakota	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	1	0.5%	0	0.0%	1	0.1%
Texas	0	0.0%	0	0.0%	0	0.0%	0	0.0%	6	3.4%	2	0.9%	6	0.8%	2	0.2%
Utah	0	0.0%	4	0.6%	0	0.0%	0	0.0%	1	0.6%	0	0.0%	1	0.1%	4	0.3%
Washington	0	0.0%	5	0.7%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	5	0.4%
Yukon	1	0.3%	1	0.1%	2	0.9%	2	0.6%	0	0.0%	0	0.0%	3	0.4%	3	0.2%
Total	376	100.0%	701	100.0%	226	100.0%	316	100.0%	174	100.0%	221	100.0%	776	100.0%	1238	100.0%

^a Direct recoveries or resightings occur during the first autumn and winter following marking. All later recoveries or resightings are termed indirect.

Appendix 3

Locations where adult and young Lesser Snow Geese banded at Wrangel Island were recovered or their neckbands were resighted. Both direct and indirect recoveries or resightings for autumn and winter are reported.^a

Location	Legband recoveries (1953–1996)										Neckband observations (1987–1992)			
	banded 1975–1979				banded 1987–1989				Total		banded 1987–1989			
	Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect
Alberta	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	5	0.4%	18	2.1%
British Columbia	1	2.0%	0	0.0%	0	0.0%	0	0.0%	1	1.3%	456	36.8%	290	34.2%
California	45	90.0%	44	84.6%	8	27.6%	16	72.7%	53	67.1%	405	32.7%	275	32.5%
Idaho	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	2	0.2%
Mexico	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	2	0.2%	1	0.1%
Montana	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	5	0.6%
Nevada	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	1	0.1%	1	0.1%
New Mexico	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	1	0.1%	1	0.1%
Oregon	2	4.0%	0	0.0%	3	10.3%	0	0.0%	5	6.3%	46	3.7%	28	3.3%
Saskatchewan	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	3	0.2%	20	2.4%
Utah	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	2	0.2%
Washington	2	4.0%	8	15.4%	18	62.1%	6	27.3%	20	25.3%	321	25.9%	204	24.1%
Total	50	100.0%	52	100.0%	29	100.0%	22	100.0%	79	100.0%	1240	100.0%	847	100.0%

^a Direct recoveries or resightings occur during the first autumn and winter following marking. All later recoveries or resightings are termed indirect.

Appendix 4

Locations where adult and young Lesser Snow Geese banded at Banks Island and Anderson River were recovered. Recoveries are for autumn and winter (September–February).

Band recoveries (1953–1996)

Location	Banding location (banding years)					
	Banks Island (1953, 1955, 1961)		Anderson River (1959–1964, 1966)		Both areas	
Alaska	0	0.0%	2	0.2%	2	0.2%
Alberta	54	20.7%	136	16.7%	190	17.6%
Arizona	0	0.0%	1	0.1%	1	0.1%
California	137	52.5%	491	60.2%	628	58.3%
Colorado	0	0.0%	1	0.1%	1	0.1%
Idaho	0	0.0%	1	0.1%	1	0.1%
Mexico	17	6.5%	34	4.2%	51	4.7%
Montana	8	3.1%	24	2.9%	32	3.0%
Nevada	3	1.1%	12	1.5%	15	1.4%
New Mexico	1	0.4%	0	0.0%	1	0.1%
North Dakota	1	0.4%	1	0.1%	2	0.2%
Northwest Territories	2	0.8%	11	1.3%	13	1.2%
Oregon	18	6.9%	44	5.4%	62	5.8%
Russia	0	0.0%	0	0.0%	0	0.0%
Saskatchewan	15	5.7%	52	6.4%	67	6.2%
Utah	1	0.4%	3	0.4%	4	0.4%
Washington	3	1.1%	2	0.2%	5	0.5%
Yukon	1	0.4%	1	0.1%	2	0.2%
Total	261	100.0%	816	100.0%	1077	100.0%

Appendix 5

Locations where adult and young Lesser Snow Geese banded at Banks Island, Kendall Island, and Anderson River were recovered or their neckbands were resighted. Recoveries or resightings are for autumn and winter (September–February).

Band recoveries (1987–1996)

Location	Banding location (banding years)									
	Banks Island (1987)		Kendall Island (1987)		Anderson River (1987)		Anderson River (1987–1989)		All areas (1987–1989)	
Alberta	13	11.7%	2	10.5%	5	9.3%	25	9.4%	40	10.1%
Arkansas	0	0.0%	0	0.0%	0	0.0%	1	0.4%	1	0.3%
California	48	43.2%	7	36.8%	30	55.6%	140	52.8%	195	49.4%
Colorado	1	0.9%	0	0.0%	3	5.6%	6	2.3%	7	1.8%
Idaho	1	0.9%	0	0.0%	1	1.9%	2	0.8%	3	0.8%
Louisiana	0	0.0%	0	0.0%	0	0.0%	1	0.4%	1	0.3%
Manitoba	0	0.0%	0	0.0%	0	0.0%	1	0.4%	1	0.3%
Mexico	6	5.4%	1	5.3%	6	11.1%	21	7.9%	28	7.1%
Montana	2	1.8%	0	0.0%	2	3.7%	8	3.0%	10	2.5%
Nevada	0	0.0%	0	0.0%	1	1.9%	2	0.8%	2	0.5%
New Mexico	1	0.9%	1	5.3%	1	1.9%	7	2.6%	9	2.3%
Northwest Territories	2	1.8%	0	0.0%	0	0.0%	1	0.4%	3	0.8%
Oregon	11	9.9%	0	0.0%	0	0.0%	3	1.1%	14	3.5%
Saskatchewan	25	22.5%	7	36.8%	3	5.6%	39	14.7%	71	18.0%
South Dakota	0	0.0%	0	0.0%	0	0.0%	1	0.4%	1	0.3%
Texas	1	0.9%	1	5.3%	1	1.9%	6	2.3%	8	2.0%
Utah	0	0.0%	0	0.0%	1	1.9%	1	0.4%	1	0.3%
Total	111	100.0%	19	100.0%	54	100.0%	265	100.0%	395	100.0%

Neckband observations (1987–1992)

Location	Banding location (banding years)									
	Banks Island (1987)		Kendall Island (1987)		Anderson River (1987)		Anderson River (1987–1989)		All areas (1987–1989)	
Alberta	52	10.1%	6	9.5%	65	11.2%	319	12.1%	377	11.8%
Arizona	0	0.0%	0	0.0%	0	0.0%	1	0.0%	1	0.0%
California	223	43.1%	33	52.4%	255	43.9%	1119	42.6%	1375	42.9%
Colorado	2	0.4%	0	0.0%	1	0.2%	6	0.2%	8	0.2%
Idaho	0	0.0%	0	0.0%	1	0.2%	3	0.1%	3	0.1%
Mexico	49	9.5%	3	4.8%	50	8.6%	249	9.5%	301	9.4%
Montana	10	1.9%	1	1.6%	16	2.8%	70	2.7%	81	2.5%
Nevada	6	1.2%	0	0.0%	1	0.2%	6	0.2%	12	0.4%
New Mexico	26	5.0%	2	3.2%	31	5.3%	123	4.7%	151	4.7%
Oregon	7	1.4%	0	0.0%	8	1.4%	27	1.0%	34	1.1%
Saskatchewan	136	26.3%	18	28.6%	148	25.5%	644	24.5%	798	24.9%
Texas	2	0.4%	0	0.0%	0	0.0%	4	0.2%	6	0.2%
Utah	4	0.8%	0	0.0%	5	0.9%	55	2.1%	59	1.8%
Total	517	100.0%	63	100.0%	581	100.0%	2626	100.0%	3206	100.0%

Routes and timing of migration of Lesser Snow Geese from the Western Canadian Arctic and Wrangel Island, Russia, 1987–1992

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Abstract

Routes and timing of migration and philopatry to staging and wintering areas of Lesser Snow Geese *Anser caerulescens caerulescens* (hereafter referred to as Snow Geese) from the Western Canadian Arctic and Wrangel Island, Russia, were determined from geese neckbanded on nesting areas and observed on migration and wintering areas from 1987 to 1992. Snow Geese from the Western Arctic staged on the Arctic coast of the western Northwest Territories, Yukon Territory, and northeastern Alaska in early fall and migrated from there to the prairies of southeastern Alberta and southwestern Saskatchewan (AB-SK). From there, 80% migrated to the Klamath Basin and Central Valley area of California, some stopping in Montana along the way. A small number wintered in southern California's Imperial Valley, and the remainder followed an interior path to the Western Central Flyway. During spring migration, Western Arctic Snow Geese reversed their fall routes. Most Snow Geese from Wrangel Island apparently followed a Pacific route to reach their winter destinations in British Columbia–Washington (BC-WA) and California. Small numbers (11% of the neckbanded geese) migrated south via the prairies (AB-SK). In spring, most of the south-wintering Wrangel Island birds returned north via the prairies. Timing of migration was similar for the two nesting populations except in the fall, when Western Arctic geese seemed to arrive earlier and stay later in AB-SK and Wrangel Island geese arrived on average perhaps two weeks earlier in eastern Oregon. Both sexes were highly philopatric to wintering areas from year to year, with 96–97% of the geese sighted in consecutive years being in the same area. Opportunities to selectively harvest the two populations occurred in BC-WA and in the Western Central Flyway, where there was little or no geographic overlap of the two stocks, and possibly during short periods of temporal separation in fall in AB-SK and eastern Oregon. Further investigations using satellite-tracking of radio-marked birds are needed to determine the routes and timing of fall and spring migration of Wrangel Island and Western Arctic geese across north-western Canada, Alaska, and northeastern Siberia and of spring migration of geese returning from the Western Central Flyway.

Résumé

Les routes et le moment de migration ainsi que la philopatrie envers les aires de repos et d'hivernage des Petites Oies des neiges *Anser caerulescens caerulescens* (appelées ci-après Oies des neiges) de l'ouest de l'Arctique canadien et de l'île Wrangel, en Russie, ont été déterminés à partir des oies à qui on a posé un collier dans les aires de nidification et observées dans les aires de migration et d'hivernage de 1987 à 1992. Les Oies des neiges de l'ouest de l'Arctique se sont rassemblées sur la côte arctique de l'ouest des Territoires du Nord-Ouest, du territoire du Yukon et du nord-est de l'Alaska au début de l'automne et ont migré de cet endroit jusqu'aux Prairies du sud-est de l'Alberta et du sud-ouest de la Saskatchewan (AB-SK). À partir de ces lieux, 80 p. 100 ont migré vers le bassin de Klamath et la région de la vallée centrale de la Californie, certains oiseaux s'arrêtant au Montana en cours de route. Un faible nombre a hiverné dans la vallée Imperial de la Californie et le reste a suivi une voie intérieure jusqu'à la voie migratoire du centre-ouest. Au cours de la migration printanière, les Oies des neiges de l'ouest de l'Arctique ont emprunté les routes automnales en direction inverse. La plupart des Oies des neiges de l'île Wrangel ont apparemment suivi une route le long du Pacifique pour se rendre à leur destination hivernale en Colombie-Britannique et dans l'État de Washington (CB-WA) et en Californie. Un faible nombre (11 p. 100 des oies à qui on a posé un collier) ont migré vers le sud par les Prairies (AB-SK). Au printemps, la plupart des oiseaux de l'île Wrangel hivernant au sud sont retournés vers le nord par les Prairies. Le moment de la migration était semblable pour les deux populations nicheuses, à l'exception de l'automne, lorsque les oies de l'ouest de l'Arctique semblaient arriver plus tôt et rester plus longtemps en AB-SK, et les oies de l'île Wrangel arrivaient en moyenne peut-être deux semaines plus tôt dans l'est de l'Oregon. Les deux sexes ont fait preuve d'une grande philopatrie par rapport aux aires d'hivernage d'une année à l'autre, et 96 à 97 p. 100 des oies ont été repérées dans la même aire d'hivernage pendant des années consécutives. Des occasions de récolte sélective des deux populations se sont produites en CB-WA et dans la voie migratoire du centre-ouest, où il y avait peu ou pas de chevauchement géographique des deux troupeaux, et peut-être pendant de courtes périodes de séparation temporelle en automne en AB-SK et dans l'est de l'Oregon. Il est nécessaire de réaliser de nouvelles enquêtes en utilisant un

système de télédétection pour déterminer les routes et le moment des migrations automnales et printanières des oies de l'île Wrangel et de l'ouest de l'Arctique dans le nord-ouest du Canada, l'Alaska et le nord-est de la Sibérie ainsi que la migration printanière des oies retournant de la voie migratoire du centre-ouest.

1. Introduction

Lesser Snow Geese *Anser caerulescens caerulescens* (hereafter referred to as Snow Geese) from Wrangel Island declined in number in the early 1970s and have not since recovered, whereas those from the Western Canadian Arctic have increased in number (Kerbes et al. 1999, this volume). Current management concerns are that there are too few Wrangel Island geese and perhaps too many Western Arctic geese. Historical changes in the relative use of different wintering areas by the two populations have been discussed by Hines et al. (1999a). In this paper, we focus on the routes and timing of migration. As the two populations overlap during the fall through spring periods, a detailed understanding of the spatial and temporal distribution and the year-to-year consistency of migration is valuable for management purposes (Raveling 1979).

Female waterfowl tend to be highly philopatric to their nesting areas, but males are generally less likely to return to their previous breeding site unless they accompany their previous mate (Greenwood 1980; Anderson et al. 1992). When applying harvest management strategies to Snow Geese on migration and wintering areas, it is important to know the degree of philopatry to nonbreeding areas and whether such philopatry is sex biased. A management strategy that assumes mortality is distributed evenly between the sexes might have a greater effect than anticipated if mortality is concentrated on just one sex, owing to sex-biased philopatry and dispersal during fall and winter.

From 1987 to 1992, collared Snow Geese from the Western Canadian Arctic and Wrangel Island were observed on their migration routes and wintering grounds in western North America (Kerbes and Meeres 1999, this volume). The primary objectives of our study were to determine 1) the spring and fall migration routes used by these populations; 2) rates of philopatry to staging and wintering areas; and 3) whether those rates were sex biased. We also estimated arrival dates, departure dates, and length of stay of geese on staging and wintering areas. Our focus was on determining how Wrangel Island Snow Geese differed from the Western Arctic Population in their routes and timing of migration.

2. Methods

Major staging and wintering areas for Snow Geese were delineated from observations of neckbanded individuals. Temporal distribution of geese was estimated using the number of neckbanded individuals from Wrangel Island and the Western Canadian Arctic that were sighted in each staging and wintering area from early fall to late spring. We defined early fall as 1 August – 31 October, late fall as 1 November – 15 December, winter as 16 December – 15 February, early spring as 16 February – 31 March, and late spring as 1 April – 30 June. Our definition of winter was shorter and more restrictive than that used by Hines et al. (1999a), who had to deal with the imprecise nature of

legband recovery dates; differences in interval definitions cause some slight discrepancies in observed winter distributions.

Arrival dates were defined by the date on which the first neckband was read, and departure dates by the date of the last neckband observation; the difference between those dates estimated the minimum duration at that location. To document the period that geese were present in the different areas, we summarized the number of unique neckband observations for each area by 10-day time periods (1st to 10th, 11th to 20th, and 21st to the end of each month).

Fall migration routes were determined by analyzing observations of marked geese on each staging and wintering area and determining where each collared goose had been previously observed in the same fall–winter season. Spring migration routes were determined from birds seen in two or more areas during any single winter–spring season. Southward migration routes were determined from observations made from early fall to the end of winter. Northward migration included movements from the beginning of winter through late spring. Individual geese were said to be philopatric to a wintering or staging area if they were observed in the same area in consecutive years. When estimating philopatry, early and late fall were combined for analyses of fall migration and early and late spring for spring migration. We compared, using G-tests of independence, the proportion of male and female geese that were sighted in the same areas in successive years in order to find out if there were sex-related biases in philopatry.

The winter period was included in the time span of observations for both fall and spring migration to include the southern terminus of fall migration and the most distant origin of spring migration. Thus, our analyses included wintertime movements that were neither fall nor spring migration. Some records of individual Snow Geese moving among wintering areas (Appendices 1 and 2) may have reflected wintertime dispersal or resulted from errors in reading or recording neckband codes.

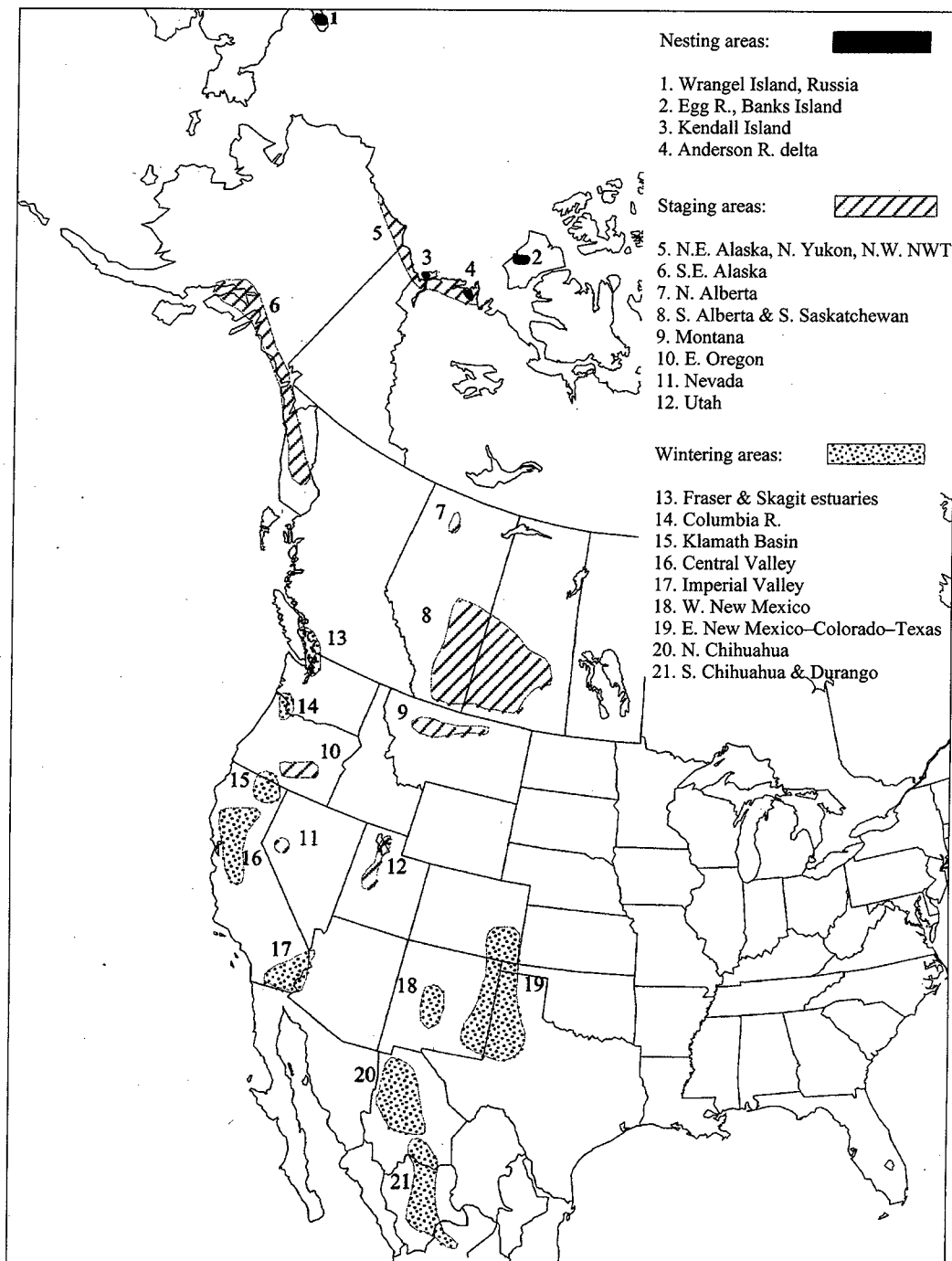
3. Results and discussion

In total, 27 651 complete observations of 4001 neckbanded Snow Geese from the Western Canadian Arctic and Wrangel Island were recorded during this study. Observations were made at six staging areas during fall: the north-eastern Arctic coast of Alaska; the Hay Lake area of northwestern Alberta; southeastern Alberta and southwestern Saskatchewan (AB-SK); western Montana (primarily the Freezeout Lake area); the Summer Lake and Malheur Lake area in eastern Oregon; and Carson Sink in Nevada (Fig. 1). During spring migration, geese were observed in several of the same areas as on fall migration, with the addition of western Utah and the southeastern Pacific coast of Alaska.

Based on the distribution of neckband sightings, we recognized nine wintering areas (Fig. 1): the estuaries of the Fraser River in British Columbia and the Skagit River in Washington (BC-WA) (area 13 in Fig. 1); the Columbia River area of southern Washington and northern Oregon (14); the Klamath Basin of southern Oregon and northern California (15); California's Central Valley (16); the Imperial Valley area of southern California (17); New Mexico west of 105°W (including the Rio Grande Valley) (18); the combined area of New Mexico east of 105°W

Figure 1

Nesting, staging, and wintering areas of Lesser Snow Geese from Wrangel Island and the Western Canadian Arctic



(including the Pecos River), northwestern Texas, and southeastern Colorado (19); northern Chihuahua (i.e., north of 28°N latitude) (20); and southern Chihuahua and Durango (21). For management purposes, the first five areas are known as the Pacific Flyway, and the remaining areas as the Western Central Flyway. Wintering areas in Mexico were divided at 28°N, following Turner et al. (1994), who found there was little movement of geese between the two areas in winter.

3.1 Western Canadian Arctic Population

During fall migration, Snow Geese from the Western Canadian Arctic arrived at their main fall staging locations in AB-SK about mid-September. The exact timing and path followed from the Arctic to the prairies are unknown, as we have only 15 observations of collared geese from the north (all from the northeastern coast of Alaska in late August). Western Arctic Snow Geese, after leaving the breeding grounds in late August or early September, staged on the Bathurst Peninsula, the Tuktoyaktuk Peninsula, the outer part of the Mackenzie Delta, and the Yukon and Alaska North

Slope (Fig. 1) (Barry 1967; J.E. Hines, pers. commun.). Barry (1967) reported that their southward migration followed the Mackenzie Valley to the Peace–Athabasca Delta in northeastern Alberta or to Hay Lakes in northwestern Alberta. Small numbers (a few thousand geese) also stage at Mills Lake in the southwestern Northwest Territories each year (Alexander 1991).

AB-SK was the main fall staging location for Western Arctic geese (Fig. 2; Table 1). Geese remained in AB-SK longer than on any other fall staging area; the average span of observations was more than six weeks (Appendix 3). From the Canadian prairies, some geese moved on to western Montana and eastern Oregon in late October and remained on those staging areas until mid-November, before moving on to the wintering areas of the Klamath Basin and the Central Valley of California, although some Snow Geese were already there by the end of October (Fig. 3).

Most (83%) of the geese wintering in southern California's Imperial Valley migrated there directly from AB-SK and Montana, probably via Utah (Nagel 1969; Johnson 1996). The remaining Imperial Valley birds arrived by way of a secondary route through the Klamath Basin and the Central Valley (Appendix 1).

During winter, >20% of the observations occurred in the Western Central Flyway, with the remainder in California (Table 1). Most geese that wintered in the Western Central Flyway were not observed in Montana after departing AB-SK, nor were they observed on any other staging areas between AB-SK and the wintering areas. A small number of geese wintering in the Western Central Flyway (22%) arrived there via the Klamath Basin and California's Central Valley (Fig. 4; Appendix 1). Western Arctic geese began arriving on Western Central Flyway wintering areas the first week of November (Fig. 2).

Geese were observed over an average span of 144 days in the Central Valley and 105 days in western New Mexico; in other areas, they were recorded over shorter time spans, in some cases possibly reflecting a lower degree of observation effort in those areas (Appendix 4).

In early spring, Western Arctic geese were still present on all wintering areas, but most observations were on staging areas to the north, mainly the Klamath Basin and Montana (Table 1). Spring migration of Snow Geese from the Central Valley to the Western Arctic proceeded by way of the Klamath Basin, eastern Oregon, Montana, and AB-SK (Fig. 4; Appendix 1). Most geese that wintered in the Western Central Flyway apparently made a more direct return to AB-SK, but some followed a secondary route to California's Central Valley and then on to AB-SK (Fig. 4; Appendix 1). The migration routes we described follow closely those routes described by Bellrose (1980) and Nagel (1969). Two spring records in Nebraska, as well as evidence from radio-tracking in the spring of 1997 (J.Y. Takekawa, pers. commun.), suggest that some Western Central Flyway geese may return north by a more easterly route.

Spring migration brought southern California-wintering Western Arctic geese to Utah in the last week of February, Nevada in the first week of March, eastern Oregon and Montana by mid-March, and the Canadian prairies in the first week of April (Fig. 2). A few geese from southern California went to the Central Valley and then on to the Klamath Basin and eastern Oregon before passing through Montana

and AB-SK (Fig. 4; Appendix 5). Geese were observed from early April to early May in AB-SK (Fig. 2).

3.2 Wrangel Island Population

BC-WA was a major staging area in fall as well as an important wintering area for Snow Geese neckbanded on Wrangel Island (Fig. 5). Snow Geese arrived in BC-WA by mid-October and in the Central Valley by late October (Fig. 3). Most apparently moved directly to the Central Valley from BC-WA, but some stopped at Columbia River, eastern Oregon, and the Klamath Basin on the way. A secondary route to the Central Valley was from AB-SK via Montana and the Klamath Basin (Fig. 5; Appendix 3). By late fall and over winter, observations were evenly split between BC-WA and California, with only a few additional sightings in the Columbia River area and the Western Central Flyway (Table 1).

Bellrose (1980) described the primary fall migration route of Wrangel Island Snow Geese as "across the Gulf of Alaska to make landfall near the mouth of the Columbia River and on to Summer Lake, Oregon, and Klamath Basin," with a secondary route from Alaska to the Fraser–Skagit deltas (BC-WA) along the Pacific coast and a minor route through the prairies (AB-SK and Montana) and then southwest to the Klamath Basin. Syroechkovsky and Litvin (1986), using results from neckbanding on Wrangel Island in the 1970s, argued that Snow Geese had not used offshore migration routes and that most Wrangel Island Snow Geese that wintered in California had migrated there by way of the Canadian prairies. We have no data to support or refute the hypothesis of an oceanic migration route across the Gulf of Alaska. Our data clearly show that many more geese (78%) arrived in the Central Valley via BC-WA than by way of AB-SK (Fig. 5; Appendix 2). The relatively few Wrangel Island geese that were observed in AB-SK in autumn and were subsequently resighted appeared to follow the same route as Western Arctic geese to California's Central Valley (Appendix 2).

Most (83%, $n = 54$) of the Wrangel Island geese observed on the Canadian prairies in the fall were males, compared with 51% males in the sample banded on Wrangel Island ($n = 1355$, G-test, $P < 0.01$). A similar male bias among Wrangel Island Snow Geese in the fall on the prairies was also reported by Syroechkovsky and Litvin (1986). Pairing of males from Wrangel Island with females from the Western Arctic and the subsequent adoption of the females' migration route might explain the observed sex bias, but it does not explain why the same sex bias (nine of 11 being males) occurred in observations recorded in the fall immediately following banding, before males would have had the opportunity to pair with females from other areas. In contrast, there was no such sex bias among Wrangel Island geese observed on the prairies in spring (1988–1992, 54.5% males, $n = 396$, G-test, $P > 0.05$).

As northward migration began in early spring, the proportion of Wrangel Island Snow Goose observations increased in BC-WA and the Klamath Basin, with some geese also sighted in eastern Oregon, Idaho, and Montana (Table 1). Half of the late spring sightings occurred in BC-WA, one-third in Montana and AB-SK, and over 12% in southeastern Alaska (Table 1). Neckbanded Snow Geese were observed in BC-WA over a longer period than at any

Figure 2

Seasonal changes in the number of neckbanded Lesser Snow Geese from Wrangel Island and the Western Canadian Arctic observed in major inland staging and wintering areas. Histogram heights indicate 1987–1992 averages for each 10-day interval.

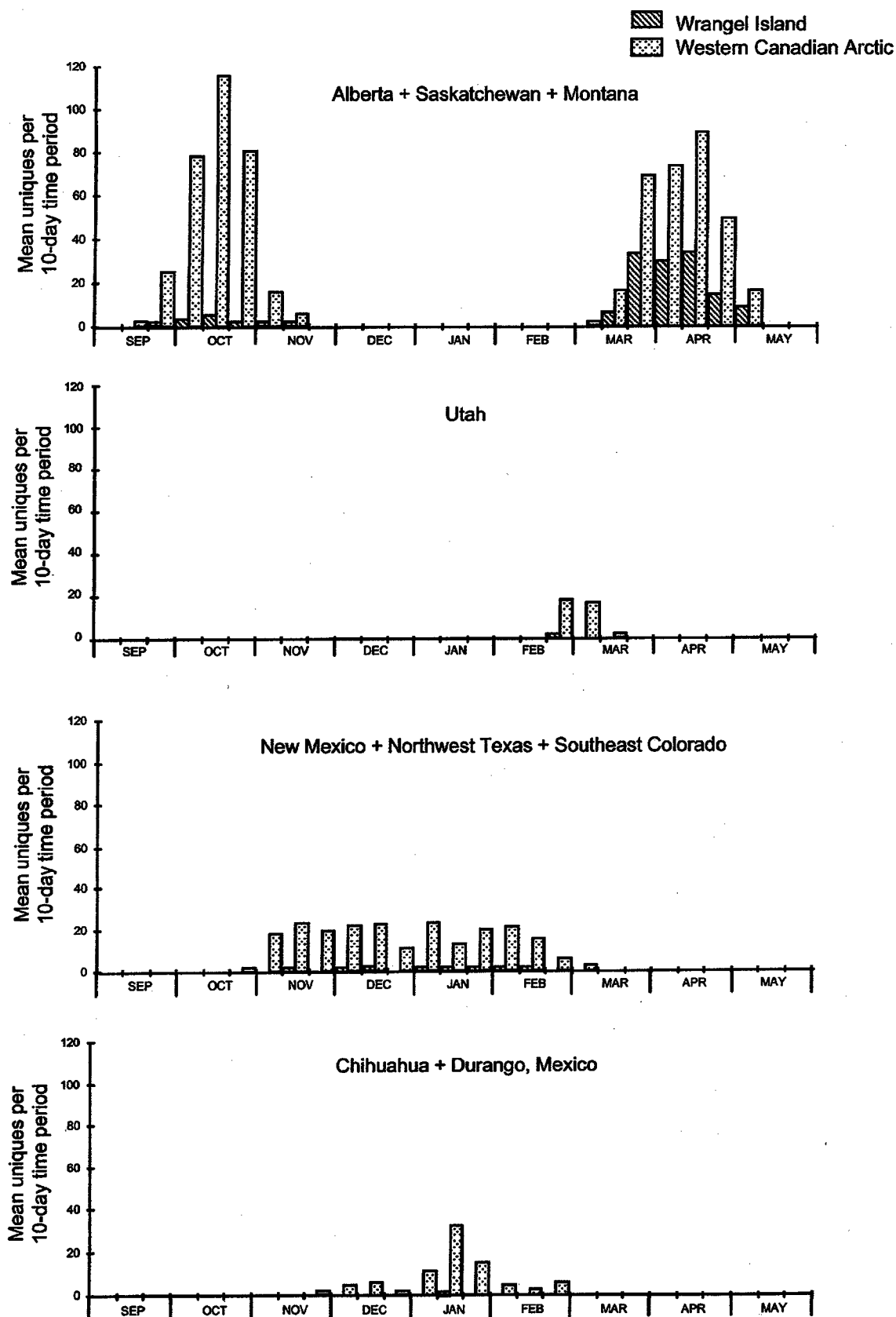


Table 1

Seasonal^a distribution, 1987–1992, of neckbanded Lesser Snow Geese from the Western Canadian Arctic and Wrangel Island. Values represent within-season distribution (%) of observations, averaged across years.

	Banded in Western Canadian Arctic					Banded on Wrangel Island				
	Early fall (n = 1555)	Late fall (n = 2372)	Winter (n = 2279)	Early spring (n = 1970)	Late spring (n = 1133)	Early fall (n = 788)	Late fall (n = 1318)	Winter (n = 1184)	Early spring (n = 1316)	Late spring (n = 895)
Staging area										
Northeastern Alaska	2.3	–	–	–	–	–	–	–	–	–
Southeastern Alaska	–	–	–	–	–	–	–	–	–	12.9
Northern Alberta	0.6	–	–	–	–	–	–	–	–	–
Southern Alberta/ Southern Saskatchewan	72.3	3.5	–	0.5	63.2	7.9	0.2	–	–	20.8
Montana	6.0	2.7	–	19.6	24.0	0.8	0.7	–	13.4	12.1
Idaho	–	–	–	4.9	–	–	–	–	1.7	–
Eastern Oregon	–	0.3	–	3.7	5.3	3.5	2.3	–	3.6	1.8
Nevada	–	0.5	–	1.0	1.4	–	0.2	–	0.5	–
Utah	–	–	–	8.0	–	–	–	–	0.9	–
Wintering area										
B.C./Washington	–	–	–	–	–	69.1	49.0	44.1	51.1	49.0
Columbia River	–	–	–	–	–	–	1.0	3.1	0.7	–
Klamath Basin	8.8	12.8	2.4	32.5	6.1	11.1	9.8	2.7	12.9	3.4
California – Central Valley	7.5	66.1	74.2	22.4	–	7.5	36.6	49.4	14.9	–
California – Imperial Valley	1.1	2.4	2.5	1.2	–	–	–	–	–	–
Western New Mexico	0.7	8.5	7.0	2.7	–	–	0.3	0.3	0.3	–
Eastern New Mexico/ Colorado/Texas	0.7	1.8	1.4	0.1	–	–	–	–	–	–
Northern Chihuahua	–	1.4	5.9	1.9	–	–	–	0.2	–	–
Southern Chihuahua/ Durango	–	–	6.7	1.0	–	–	–	0.2	–	–

^a Early fall = 1 August – 31 October; late fall = 1 November – 15 December; winter = 16 December – 15 February; early spring = 16 February – 31 March; late spring = 1 April – 30 June.

other wintering area, over 180 days in most years (Appendix 4). Bellrose (1980) and Syroechkovsky and Litvin (1986) agreed that most Wrangel Island geese wintering in California passed through the prairies as they migrated back to their breeding grounds. Our observations of birds seen in more than one area during winter–spring migration support this interpretation: of the Wrangel Island geese wintering in the southern areas, more than 74% were known to migrate north through the prairies (Appendix 2).

On spring migration, neckbanded geese were first observed in Utah in the last week of February, in Nevada by the first week of March, and in eastern Oregon by mid-March. They were recorded in Montana in mid-March and in AB-SK in the first week of April (Fig. 2). Wrangel Island Snow Geese reached coastal southeastern Alaska in mid-April. The duration of staging on the Canadian prairies was shorter in spring than in autumn (Appendix 5).

As with fall migration, our study provided little information on the details of spring migration in northern Canada, Alaska, or northeastern Siberia. The observer network of our study did not cover that area, owing to the remoteness and inaccessibility of the regions between the prairies and Wrangel Island. The spring route has been assumed to follow the Mackenzie River to its mouth, then turn westward along the Arctic coast of Alaska (Bellrose 1980). However, too few Snow Geese have been reported on the north coast of Alaska to verify it as the major route (S.R. Johnson and T. Rothe, pers. commun.). Evidence for an inland route through Alaska comes from a limited number of spring records from the period 1955–1980, which showed several thousand Snow

Geese following a route through the upper Tanana River of eastern Alaska (T. Rothe, pers. commun.). The Tanana River has also been documented as a major route for other geese and swans (T. Rothe, pers. commun.) and for Sandhill Cranes *Grus canadensis*, many of which are going to breeding grounds in Siberia (Kessel 1984).

Wrangel Island Snow Geese travel farther each year than other geese wintering in North America (with the exception of some Black Brant *Branta bernicla nigricans*). For example, in 1988–1989, the bird with neckband F27, an adult male marked on Wrangel Island in 1988, first travelled from Wrangel Island through British Columbia to winter in Durango (6741 km), then in spring returned through Saskatchewan to Wrangel Island (6922 km), for an annual total of almost 14 000 km, computed as the shortest (great circle) distances between points where he was observed. Typical of Wrangel Island geese wintering in California, in 1994–1995, the bird with neckband 01J, an adult male, went from Wrangel Island through British Columbia to California (5100 km), then through Montana and Saskatchewan back to Wrangel Island (5840 km), for an annual total of 11 000 km.

3.3 Philopatry

Observed philopatry rates of marked Snow Geese varied by season and by population. Philopatry to wintering areas (96.8%, n = 1115) was higher than philopatry to fall (79.9%, n = 1688) and spring (74.1%, n = 1365) staging areas, but the latter estimates are undoubtedly low because

Figure 3

Seasonal changes in the number of neckbanded Lesser Snow Geese from Wrangel Island and the Western Canadian Arctic observed in major inland staging and wintering areas. Histogram heights indicate 1987–1992 averages for each 10-day interval.

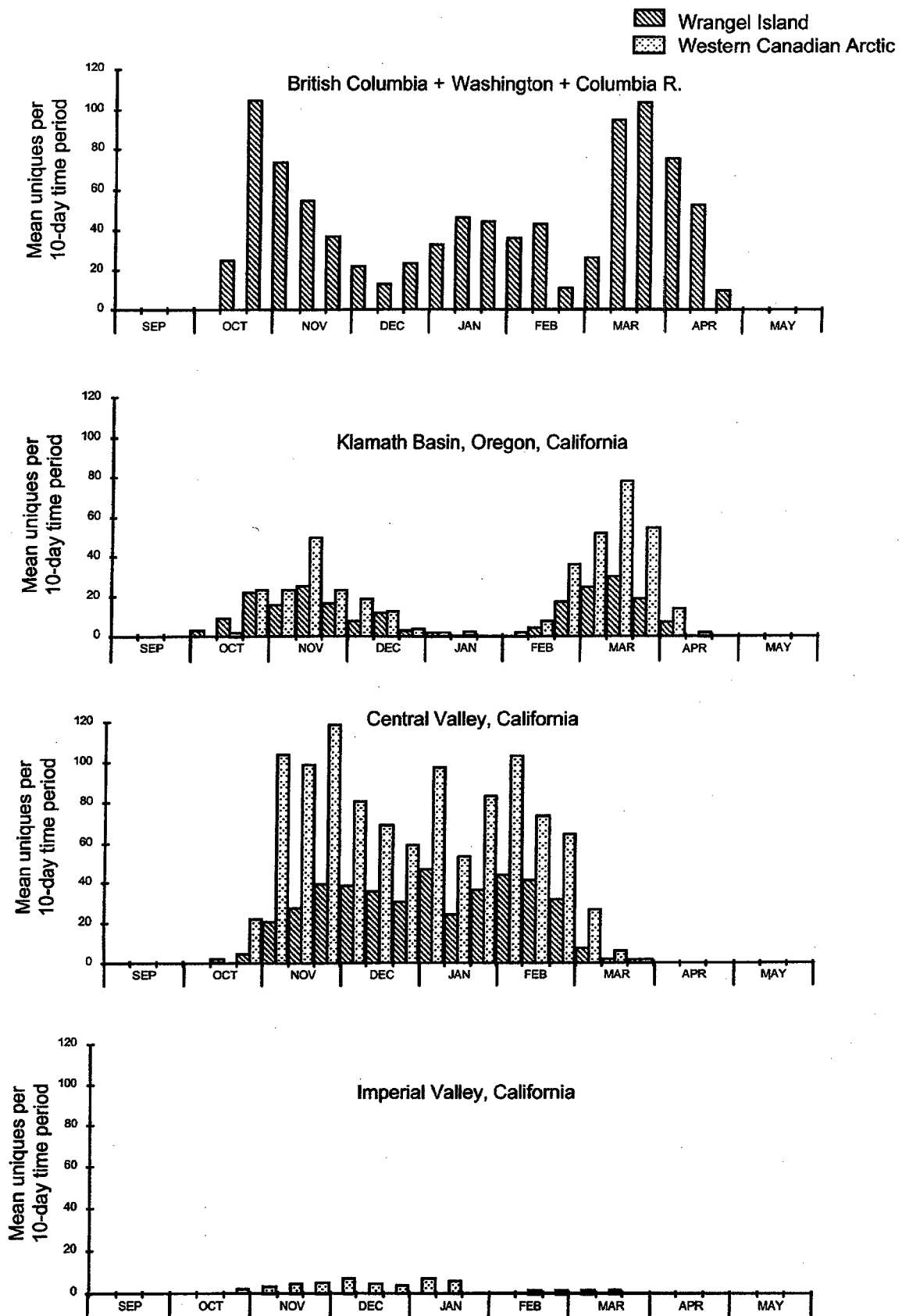
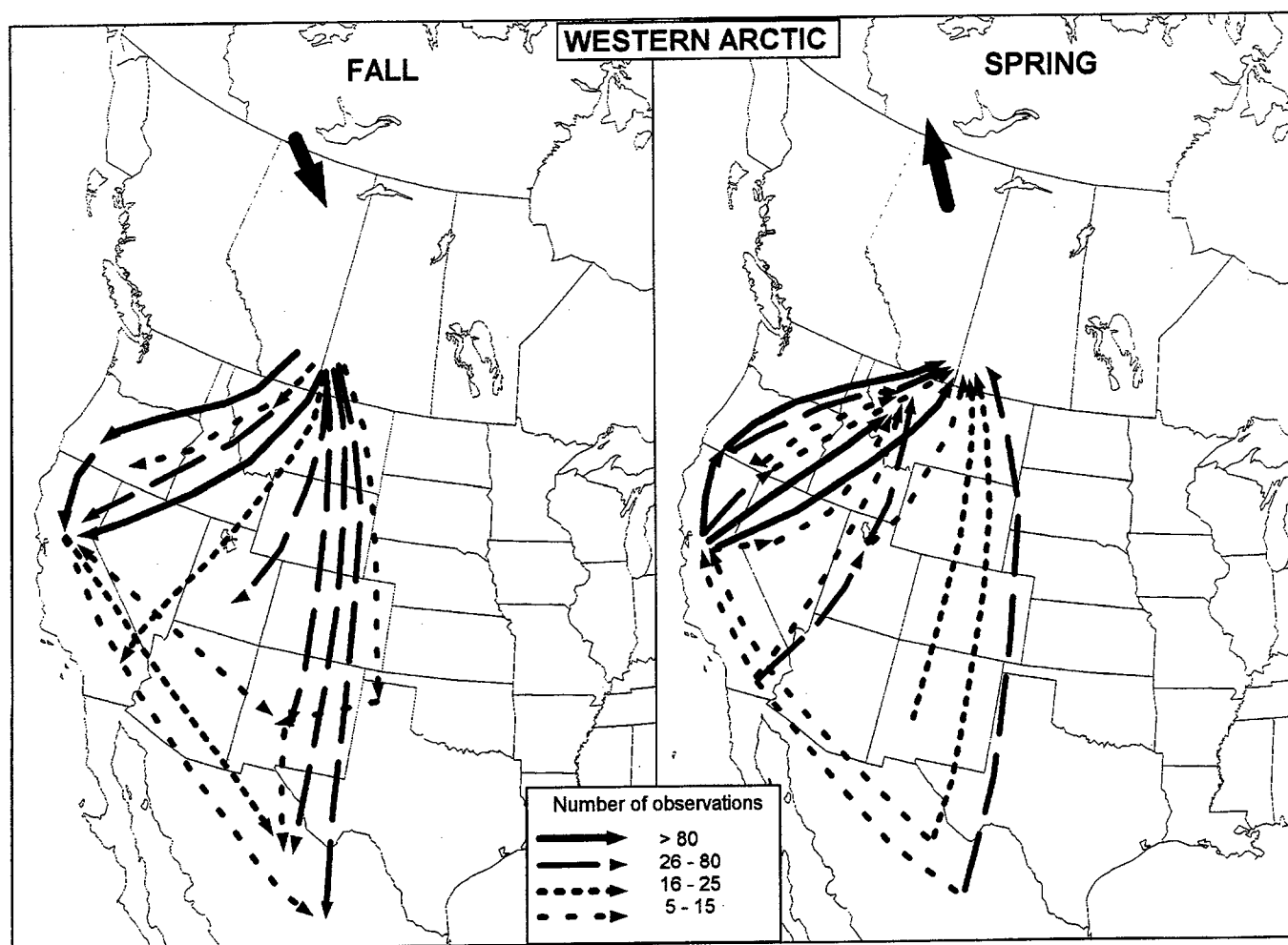


Figure 4

Major migration routes of Lesser Snow Geese neckbanded in the Western Canadian Arctic, 1987–1989, and observed from 1987–1988 to 1991–1992



staging areas were not covered by observers as thoroughly as wintering ones. Wrangel Island geese had higher philopatry rates to staging areas during both fall and spring migration than did Western Arctic geese, presumably reflecting the more thorough coverage of the more geographically compact spring staging areas in British Columbia. There was no difference in philopatry to wintering areas by geese from the two populations (Table 2). In contrast to findings on natal and breeding philopatry (Cooke et al. 1975), there were no differences in philopatry rates of males and females to either staging or wintering areas (Table 3).

Philopatry rates to staging areas were remarkably high considering the number of areas used on migration and the short time geese remained on each relative to time spent on wintering areas. These philopatry rates to staging areas suggest that Snow Geese are highly conservative in their use of migration routes and that conclusions based on the migration patterns observed in this study are likely to be applicable to the population at least in the near future. The higher estimates of philopatry for Wrangel Island geese could be due to population differences in migration route philopatry or may have been a result of that population following less dispersed migration routes than Snow Geese from the Western Arctic.

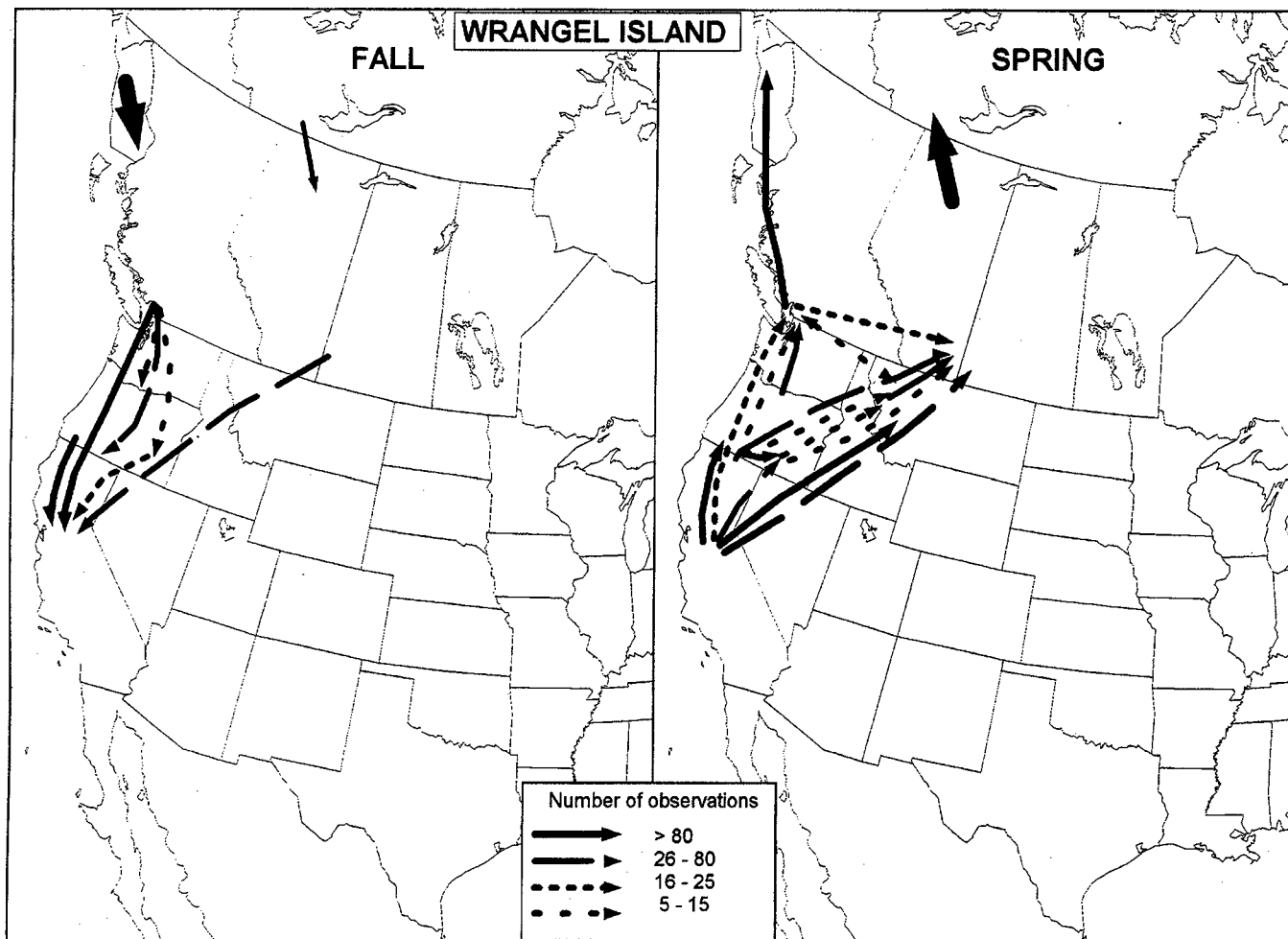
4. Management implications

The decline of the Wrangel Island Snow Goose Population and the increase in population size and apparent shift in wintering pattern of the Western Arctic Population highlight the need for selective harvest management strategies (Hines et al. 1999a, 1999b, this volume; Kerbes et al. 1999, this volume). Our findings suggest that there is potential to manage Wrangel Island and Western Arctic Snow Geese as separate populations because they are segregated at a number of times and places during the fall and winter and are philopatric to wintering areas and migration routes.

Temporal segregation of Western Arctic and Wrangel Island populations was observed in the fall in eastern Oregon, where Wrangel Island Snow Geese arrived up to two weeks earlier in the fall than those from the Western Arctic (Appendix 3). Although these observations are not statistically significant (t -test, $P > 0.05$), this temporal segregation has been documented and used in management in the past. The opening of the hunting season in Klamath County was delayed until approximately 1 November from 1978 to 1983 in an attempt to reduce hunting pressure on Wrangel Island geese (Subcommittee on White Geese 1992; J.C. Bartonek, pers. commun.). In AB-SK, we found temporal

Figure 5

Major migration routes of Lesser Snow Geese neckbanded on Wrangel Island, 1988–1989, and observed from 1988–1989 to 1991–1992

**Table 2**

Estimated rates of philopatry to staging and wintering areas by neckbanded Lesser Snow Geese from the Western Canadian Arctic and Wrangel Island

Season	Western Canadian Arctic		Wrangel Island		G	df	P-value
	n ^a	%	n ^a	%			
Fall migration	1149	77.2	539	85.3	15.785	1	P < 0.001
Winter	708	97.3	407	95.8	1.788	1	P = 0.181
Spring migration	815	66.8	550	84.9	59.257	1	P < 0.001

^a Sample sizes (n) are the number of times geese were observed in consecutive years.**Table 3**

Estimated rates of philopatry to staging and wintering areas by neckbanded female and male Lesser Snow Geese from the Western Canadian Arctic and Wrangel Island

Season	Banding location	Female		Male		G	df	P-value
		n ^a	%	n ^a	%			
Fall	Western Arctic	698	76.1	451	78.9	1.283	1	P = 0.257
Fall	Wrangel Island	259	85.3	280	85.4	0.000	1	P = 0.992
Winter	Western Arctic	406	98.3	302	96.0	3.316	1	P = 0.069
Winter	Wrangel Island	209	95.7	198	96.0	0.108	1	P = 0.893
Spring	Western Arctic	524	65.5	291	69.1	1.107	1	P = 0.293
Spring	Wrangel Island	268	85.5	282	84.4	0.118	1	P = 0.731

^a Sample sizes (n) are the number of times geese were observed in consecutive years.

segregation of the two populations in the fall, when the few Wrangel Island birds migrating through the area arrived nine days later than their Western Arctic counterparts (t-test, $P < 0.05$) (Fig. 2; Appendix 3).

Geographical separation occurred in BC-WA, which supported only Wrangel Island geese; in AB-SK, where the majority of geese throughout the autumn staging period were from the Western Arctic; in Western Central Flyway wintering areas, where Wrangel Island birds were rare; and in the Imperial Valley of southern California, where the wintering population consisted entirely of Western Arctic geese.

Reducing the hunting pressure in BC-WA in winter would benefit the north-wintering component of the Wrangel Island Population. The south-wintering component might benefit from hunting restrictions in October in eastern Oregon, as noted above. Increased hunting pressure on Western Arctic Snow Geese in southern California throughout the winter would not affect the Wrangel Island Population. Increased harvest in the Western Central Flyway would affect Western Arctic and Central Canadian Arctic Snow Geese without having an impact on the Wrangel Island Population. Hines et al. (1999a, 1999b, this volume) offer further recommendations for harvest management.

We recommend further investigations using satellite tracking of radio-marked birds. Fall and spring migrations over the sparsely settled areas of northwestern Canada, Alaska, and northeastern Siberia are poorly understood for both Wrangel Island and Western Arctic geese. Further, in view of recent proposals for spring hunting (D. Duncan, pers. commun.), more information is needed on the spring routes and timing of Western Arctic geese returning from the Western Central Flyway. Experimental satellite tracking of Wrangel Island geese in fall 1991 and of Western Central Flyway geese in 1996–1997 was conducted by J. Takekawa (pers. commun.), but much more remains to be done.

5. Literature cited

- Alexander, S.A.; Ferguson, R.S.; McCormick, K.J. 1991. Key migratory bird terrestrial habitat sites in the Northwest Territories. 2nd ed. Can. Wildl. Serv. Occas. Pap. No. 71, Ottawa, Ontario. 182 pp.
- Anderson, M.G.; Rhymer, J.M.; Rohwer, F.C. 1992. Philopatry, dispersal, and the genetic structure of waterfowl populations. Pages 365–395 in B.D.J. Batt, A.D. Afton, M.G. Anderson, C.D. Ankney, D.H. Johnson, J.A. Kadlec, and G.L. Krapu (eds.), Ecology and management of breeding waterfowl. University of Minnesota Press, Minneapolis, Minnesota.
- Barry, T.W. 1967. Geese of the Anderson River Delta, Northwest Territories. Unpublished Ph.D. thesis, University of Alberta, Edmonton, Alberta.
- Bellrose, F.C. 1980. Ducks, geese and swans of North America. 3rd ed. Stackpole Books, Harrisburg, Pennsylvania.
- Cooke, F.; MacInnes, C.D.; Prevett, J.P. 1975. Gene flow between breeding populations of lesser snow geese. Auk 92:493–510.
- Greenwood, P.J. 1980. Mating systems, philopatry and dispersal in birds and mammals. Anim. Behav. 28:1140–1162.
- Hines, J.E.; Baranyuk, V.V.; Turner, B.; Boyd, W.S.; Silveira, J.G.; Taylor, J.P.; Barry, S.J.; Meeres, K.M.; Kerbes, R.H.; Armstrong, W.T. 1999a. Autumn and winter distributions of Lesser Snow Geese from the Western Canadian Arctic and Wrangel Island, Russia, 1953–1992. Pages 39–73 in R.H. Kerbes, K.M. Meeres, and J.E. Hines (eds.), Distribution, survival, and numbers of Lesser Snow Geese of the Western Canadian Arctic and Wrangel Island, Russia. Can. Wildl. Serv. Occas. Pap. No. 98, Ottawa, Ontario.
- Hines, J.E.; Wiebe, M.O.; Barry, S.J.; Baranyuk, V.V.; Taylor, J.P.; McKelvey, R.; Johnson, S.R.; Kerbes, R.H. 1999b. Survival rates of Lesser Snow Geese in the Pacific and Western Central flyways, 1953–1989. Pages 89–109 in R.H. Kerbes, K.M. Meeres, and J.E. Hines (eds.), Distribution, survival, and numbers of Lesser Snow Geese of the Western Canadian Arctic and Wrangel Island, Russia. Can. Wildl. Serv. Occas. Pap. No. 98, Ottawa, Ontario.
- Johnson, S.R. 1996. Staging and wintering areas of Snow Geese nesting on Howe Island, Alaska. Arctic 49:86–93.
- Kerbes, R.H.; Meeres, K.M. 1999. Project overview. Pages 15–24 in R.H. Kerbes, K.M. Meeres, and J.E. Hines (eds.), Distribution, survival, and numbers of Lesser Snow Geese of the Western Canadian Arctic and Wrangel Island, Russia. Can. Wildl. Serv. Occas. Pap. No. 98, Ottawa, Ontario.
- Kerbes, R.H.; Baranyuk, V.V.; Hines, J.E. 1999. Estimated size of the Western Canadian Arctic and Wrangel Island Lesser Snow Goose populations on their breeding and wintering grounds. Pages 25–38 in R.H. Kerbes, K.M. Meeres, and J.E. Hines (eds.), Distribution, survival, and numbers of Lesser Snow Geese of the Western Canadian Arctic and Wrangel Island, Russia. Can. Wildl. Serv. Occas. Pap. No. 98, Ottawa, Ontario.
- Kessel, B. 1984. Migration of Sandhill Cranes, *Grus canadensis*, in east-central Alaska, with routes through Alaska and western Canada. Can. Field-Nat. 98:279–292.
- Nagel, J.E. 1969. Migration patterns and general habits of the Snow Goose in Utah. Publ. No. 69-6, Utah State Division of Fish and Game. 74 pp.
- Raveling, D.G. 1979. Traditional use of migration and winter roost sites by Canada geese. J. Wildl. Manage. 43:229–235.
- Subcommittee on White Geese. 1992. Pacific Flyway management plan for the Wrangel Island Population of Lesser Snow Geese. Unpublished report, Pacific Flyway Study Committee, U.S. Fish and Wildlife Service, Portland, Oregon. 25 pp.
- Syroechkovsky, E.V.; Litvin, K.E. 1986. Investigation of the migration of the Snow Geese of Wrangel Island by the method of individual marking. Pages 5–20 in V.E. Sokolov and I.N. Dobrinina (eds.), The ringing and marking of birds in the USSR "Nauka," Moscow (in Russian). Translated by M.A. Bousfield.
- Turner, B.; Tomlinson, R.; Leyva, R.; Dominguez, P. 1994. Wintering populations of Lesser Snow Geese and Ross' Geese in the Northern Highlands of México, 1988–1990. Can. Wildl. Serv. Occas. Pap. No. 84, Ottawa, Ontario. 21 pp.

Appendix 1

Migration route connections of Lesser Snow Geese from the Western Canadian Arctic showing where geese came from (fall) and where they went (spring). Numbers represent the number of neckbanded geese observed in the area that were observed elsewhere in the same migration period (with percentage where sample size > 25). Data were combined for all years of the study.

Fall migration

OBSERVED IN:

	PREVIOUSLY RECORDED IN:													
	N.E. Alaska	N. Alberta	AB-SK	Montana	E. Oregon	Klamath	Central Valley	Imperial Valley	Nevada	W. NM	E. NM-CO-TX	N. Chihuahua	S. Chihuahua, Durango	Total
AB-SK	6	2												8
Montana			17											17
E. Oregon			3											3
Klamath			93 (81)	5 (4)	1 (1)		16 (14)							115
Central Valley	5 (1)	1 (-)	454 (56)	49 (6)	3 (-)	261 (32)		5 (1)	7(1)	13 (2)	2 (-)	13 (2)	5 (1)	818
Imperial Valley			22 (79)	1 (4)		1 (4)	4 (14)							28
Nevada			1	2			1							4
W. NM		1 (1)	52 (70)			4 (5)	7 (10)				6 (8)	2 (3)	2 (3)	74
E. NM-CO-TX			11				2							13
N. Chihuahua			41 (55)			3 (4)	20 (27)	2 (3)		8 (11)	1 (1)			75
S. Chihuahua, Durango			31 (70)	1 (2)		1 (2)	9 (20)			2 (4)				44

Spring migration

OBSERVED IN:

SUBSEQUENTLY RECORDED IN:															
	AB-SK	Montana	E. Oregon	Klamath	Central Valley	Imperial Valley	Nevada	Idaho	Utah	W. NM	E. NM-CO-TX	N. Chihuahua	S. Chihuahua, Durango	Nebraska	Total
Montana	131 (99)			1 (1)											132
E. Oregon	14	10													24
Klamath	107 (47)	77 (34)	15 (7)		24 (11)		1 (-)		2 (1)						226
Central Valley	204 (20)	265 (26)	56 (6)	444 (44)		1 (-)	11 (1)	1 (-)		2 (-)	1 (-)	8 (1)	6 (1)	1 (-)	1000
Imperial Valley	2 (4)	5 (9)		2 (4)	2 (4)				44 (79)			1 (2)			56
Nevada	4	8						1							13
Idaho		3													3
Utah	13 (21)	43 (70)	1 (2)	2 (3)				2 (3)							61
W. NM	20 (69)	1 (3)		1 (3)	3 (10)							2 (7)	2 (7)		29
E. NM-CO-TX	3				1										4
N. Chihuahua	25 (56)	1 (2)		4 (9)	11 (24)		1 (2)			3 (7)					45
S. Chihuahua, Durango	30 (70)	1 (2)		2 (5)	7 (16)				1 (2)	2 (5)					43

Appendix 2

Migration route connections of Lesser Snow Geese from Wrangel Island showing where geese came from (fall) and where they went (spring). Numbers represent the number of neckbanded geese observed in the area that were observed elsewhere in the same migration period (with percentage where sample size > 25). Data were combined for all years of the study.

Fall migration

PREVIOUSLY RECORDED IN:								
	AB-SK	Montana	BC-WA	Columbia River	E. Oregon	Klamath	Central Valley	Total
Montana	1							1
BC-WA	2 (5)			1 (3)	4 (11)	12 (32)	18 (49)	37
Columbia River			15					15
E. Oregon			9			1		10
Klamath	4 (9)	1 (2)	31 (67)		6 (13)		4 (9)	46
Central Valley	29 (11)	4 (2)	100 (37)		25 (9)	113 (42)		271
Nevada			1					1
N. Chihuahua			1					1
S. Chihuahua, Durango			1					1

Spring migration

SUBSEQUENTLY RECORDED IN:											
	S.E. Alaska	AB-SK	Montana	BC-WA	Columbia River	E. Oregon	Klamath	Central Valley	Nevada	Idaho	Total
AB-SK			1	3							4
Montana		55 (90)		5 (8)			1 (2)				61
BC-WA	106 (70)	21 (14)	5 (3)		2 (1)		11 (7)	7 (5)			152
Columbia River				27 (100)							27
E. Oregon		12 (44)	8 (30)	4 (15)			3 (11)				27
Klamath	1 (1)	32 (29)	32 (29)	13 (12)		12 (11)		21 (19)			111
Central Valley	1 (-)	70 (20)	97 (28)	23 (7)		37 (11)	120 (34)		2 (1)		350
Nevada			1							1	2
Idaho			2								2
Utah			1							1	2
W. NM		1									1
N. Chihuahua			1								1
S. Chihuahua, Durango		2									2

OBSERVED IN:

OBSERVED IN:

Appendix 3

(A) Date of first observation, (B) date of last observation, and (C) span of observations of neckbanded Lesser Snow Geese from the Western Canadian Arctic and Wrangel Island on fall staging areas, averaged across years. Sample sizes in A (n years of observations, total number of neckbands recorded in the area between 1 August and 31 December over n years) also apply to B and C.

Fall

	Banding location	
	Western Canadian Arctic	Wrangel Island
A. First observation ($\bar{x} \pm SE^a$)		
N.E. Alaska	27 Aug. (1, 15)	—
N. Alberta	20 Sep. ± 1.0 (2, 6)	—
AB-SK ^b	19 Sep. ± 2.6 (5, 1738)	28 Sep. ± 1.3 (4, 56)
Montana	27 Oct. ± 7.4 (4, 109)	31 Oct. ± 4.0 (2, 7)
E. Oregon	7 Nov. ± 4.0 (3, 8)	24 Oct. ± 8.4 (3, 52)
Nevada	18 Nov. ± 3.5 (2, 17)	15 Nov. (1, 3)
B. Last observation ($\bar{x} \pm SE^a$)		
N.E. Alaska	29 Aug.	—
N. Alberta	27 Sep. ± 8.0	—
AB-SK ^b	2 Nov. ± 2.9	24 Oct. ± 5.3
Montana	10 Nov. ± 5.8	10 Nov. ± 0.5
E. Oregon	14 Nov. ± 11.3	19 Nov. ± 9.2
Nevada	24 Nov. ± 2.0	26 Nov.
C. Span of observations (days)		
N.E. Alaska	2 ± 0.0	—
N. Alberta	7 ± 7.0	—
AB-SK ^b	44.6 ± 1.6	26.0 ± 5.4
Montana	14.2 ± 5.9	11.0 ± 4.5
E. Oregon	7.7 ± 7.7	26.0 ± 10.1
Nevada	5.5 ± 5.5	11.0

^a SE in days.

^b AB-SK = southeastern Alberta and southwestern Saskatchewan.

Appendix 4

(A) Date of first observation, (B) date of last observation, and (C) span of observations of neckbanded Lesser Snow Geese from the Western Canadian Arctic and Wrangel Island on wintering areas, averaged across years. Sample sizes in A (n years of observations, total number of neckbands recorded in the area between 1 August and 30 June over n years) also apply to B and C.

Winter

	Banding location	
	Western Canadian Arctic	Wrangel Island
A. First observation ($\bar{x} \pm SE^a$)		
BC-WA ^b	—	14 Oct. ± 1.6 (4, 5288)
Columbia River	—	27 Nov. ± 9.2 (4, 109)
Klamath Basin	29 Oct. ± 11.1 (5, 3281)	18 Oct. ± 19.2 (4, 1405)
Central Valley	24 Oct. ± 1.6 (5, 6330)	25 Oct. ± 4.1 (4, 2040)
Imperial Valley	31 Oct. ± 4.9 (5, 251)	—
E. NM, CO, TX ^b	7 Nov. ± 3.5 (5, 91)	—
W. NM ^b	8 Nov. ± 10.8 (5, 1671)	9 Nov. ± 4.5 (3, 52)
N. Chihuahua	6 Dec. ± 7.0 (5, 340)	29 Jan. (1, 1)
S. Chihuahua, Durango	27 Jan. ± 16.8 (4, 258)	17 Jan. ± 1.0 (2, 6)
B. Last observation ($\bar{x} \pm SE^a$)		
BC-WA ^b	—	18 Apr. ± 3.1
Columbia River	—	8 Feb. ± 16.0
Klamath Basin	1 Apr. ± 4.1	30 Mar. ± 4.9
Central Valley	17 Mar. ± 3.1	13 Mar. ± 3.4
Imperial Valley	4 Feb. ± 14.9	—
E. NM, CO, TX ^b	27 Jan. ± 16.7	—
W. NM ^b	21 Feb. ± 11.4	19 Feb. ± 2.9
N. Chihuahua	1 Feb. ± 9.5	29 Jan.
S. Chihuahua, Durango	19 Feb. ± 3.6	17 Jan. ± 0.5
C. Span of observations (days)		
BC-WA ^b	—	186.5 ± 1.7
Columbia River	—	72.5 ± 21.8
Klamath Basin	153.4 ± 14.8	162.5 ± 23.6
Central Valley	144.0 ± 3.2	139.5 ± 6.2
Imperial Valley	96.0 ± 17.6	—
E. NM, CO, TX ^b	81.0 ± 17.8	—
W. NM ^b	105.0 ± 22.1	102.0 ± 2.1
N. Chihuahua	56.8 ± 14.8	0.0
S. Chihuahua, Durango	23.2 ± 13.5	0.5 ± 0.5

^a SE in days.

^b BC-WA = Fraser-Skagit deltas (British Columbia–Washington); E. NM, CO, TX = New Mexico east of 105°W (including the Pecos River), Colorado, and Texas (including the Gulf Coast); W. NM = New Mexico west of 105°W (including the Rio Grande Valley).

Appendix 5

(A) Date of first observation, (B) date of last observation, and (C) span of observations of neckbanded Lesser Snow Geese from the Western Canadian Arctic and Wrangel Island on spring staging areas, averaged across years. Sample sizes in A (n years of observations, total number of neckbands recorded in the area between 1 August and 31 December over n years) also apply to B and C.

Spring

	Banding location	
	Western Canadian Arctic	Wrangel Island
A. First observation ($\bar{x} \pm SE^a$)		
S.E. Alaska	—	15 Apr. ± 1.0 (2, 187)
AB-SK ^b	1 Apr. ± 4.1 (5, 1173)	6 Apr. ± 2.8 (4, 347)
Montana	14 Mar. ± 6.0 (5, 919)	13 Mar. ± 1.7 (4, 339)
E. Oregon	7 Mar. ± 2.5 (5, 139)	10 Mar. ± 5.5 (3, 63)
Nevada	6 Mar. ± 9.5 (5, 31)	2 Mar. ± 6.8 (3, 5)
Utah	23 Feb. ± 1.3 (4, 286)	22 Feb. ± 2.5 (2, 8)
Nebraska	7 Mar. (1, 2)	—
B. Last observation ($\bar{x} \pm SE^a$)		
S.E. Alaska	—	1 May ± 4.0
AB-SK ^b	4 May ± 1.9	4 May ± 2.4
Montana	13 Apr. ± 1.9	16 Apr. ± 0.8
E. Oregon	9 Apr. ± 3.7	2 Apr. ± 6.6
Nevada	13 Mar. ± 7.4	2 Mar. ± 6.4
Utah	15 Mar. ± 4.0	26 Feb. ± 1.5
Nebraska	18 Mar.	—
C. Span of observations (days)		
S.E. Alaska	—	16.0 ± 3.0
AB-SK ^b	33.2 ± 4.8	28.0 ± 0.9
Montana	30.0 ± 7.0	33.5 ± 2.3
E. Oregon	33.4 ± 5.2	23.0 ± 4.7
Nevada	7.2 ± 3.3	0.3 ± 0.3
Utah	20.5 ± 4.7	4.0 ± 4.0
Nebraska	11.0	—

^a SE in days.

^b AB-SK = southeastern Alberta and southwestern Saskatchewan.

Survival rates of Lesser Snow Geese in the Pacific and Western Central flyways, 1953–1989

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Abstract

We evaluated neckband observations and legband recoveries to determine survival rates and their effects on the changing numbers and distribution of Lesser Snow Geese *Anser caerulescens caerulescens* (hereafter referred to as Snow Geese) in the Pacific and Western Central flyways over the past 40 years.

Survival estimates were determined, using the Jolly-Seber and related methods, for a sample of 4583 adult geese collared on the breeding grounds from 1987 to 1989 and 590 adults collared on wintering areas in 1986 and 1987. Neckband retention rates of male Snow Geese were low and highly variable; hence, we do not believe that the mark:resight survival estimates for males could be adequately corrected for neckband loss. Average annual neckband retention rates for females were higher (>0.869) and were used to adjust the average survival rates of female geese. Annual resighting rates of collared geese were high (about 75%), leading to relatively small standard errors (SE) and a good ability to detect survival or resighting differences among groups of collared geese.

Average survival rates of female geese marked in the Western Arctic ($0.802 \pm \text{SE } 0.024$) were higher than those for Wrangel Island geese (0.685 ± 0.033). Survival estimates for females collared on the wintering grounds in British Columbia (0.742 ± 0.036) and New Mexico (0.784 ± 0.037) were fairly consistent with those reported for Wrangel Island and the Western Arctic, respectively. We found no strong evidence that survival rates of the decreasing south-wintering (i.e., California) group of Wrangel Island birds (0.656 ± 0.056) were lower than those of the increasing north-wintering (i.e., British Columbia–Washington) stock (0.628 ± 0.045). In contrast, Western Arctic geese that shared wintering grounds with south-wintering Wrangel Island birds in California had significantly higher survival rates (0.844 ± 0.025). This suggests that differences in survival of the Western Arctic and Wrangel Island geese that occurred outside the wintering period might account for the overall differences in survival rates of the two populations. Survival of adult females from both populations was similar during the “winter” period (1 November – 1 February) of all years but lower for Wrangel Island geese during the “late winter – early fall period” (1 February – 1 November) of at least one year, lending further support to this interpretation.

Legband recoveries indicated that survival rates for adult geese from the Western Canadian Arctic were 0.935 ± 0.047 in 1960–1963, 0.832 ± 0.062 in 1973–1975, and 0.789 ± 0.069 in 1987–1989. Survival rates of adult geese from Wrangel Island were 0.668 ± 0.084 during 1975–1977. Comparison of these estimates as well as those from the neckband resighting data suggested that survival rates of Wrangel Island adults were 0.10–0.15 lower than for their Western Arctic counterparts during both the 1970s and 1980s, and among the lowest values reported for Snow Geese. The survival rates of Western Arctic adults may have declined from the 1960s to the 1980s. Although differences in rates of survival might in part explain why the Western Arctic Population has increased whereas the Wrangel Island Population has not, we found no evidence that regional variation in survival rates explained the recent changes in the winter distribution of either population.

Harvest rates, estimated using both legband recoveries and information on harvest and population size, for the combined Wrangel Island/Western Arctic populations were 15–20% in the 1960s and 1970s and $\leq 10\%$ in the late 1980s. Legband recoveries indicate that harvest rates were similar for both populations in recent years.

Unlike the situation with Snow Geese using the lowlands bordering Hudson Bay, there is little evidence that the Western Arctic geese are severely overgrazing their summer habitat. However, because of the current size and growth rate of the Western Arctic Population, we recommend returning the harvest rate to a 1960s and 1970s level. This would prevent the population from growing beyond the point where numbers can be successfully managed by hunting.

Résumé

Nous avons évalué les observations des colliers et analysé les bagues de patte récupérées pour déterminer les taux de survie et leurs effets sur les changements dans le nombre et la répartition des Petites Oies des neiges *Anser caerulescens caerulescens* (appelées ci-après Oies des neiges) des voies migratoires du Pacifique et du centre-ouest de 1953 à 1989.

Les estimations des taux de survie ont été déterminées, au moyen de la méthode Jolly-Seber et de méthodes connexes, auprès d'un échantillon de 4 583 oies adultes à qui on a posé un collier dans les aires de reproduction de 1987 à

1989 et de 590 oies adultes à qui on a posé un collier dans les aires d'hivernage en 1986 et en 1987. Le taux de rétention des colliers des Oies des neiges mâles était faible et très variable. Par conséquent, nous ne croyons pas que les estimations des taux de survie pour les mâles d'après les marquages-observations pourraient être adéquatement corrigés pour la perte des colliers. Les taux de rétention annuels moyens des colliers des femelles étaient plus élevés ($>0,869$) et étaient utilisés pour corriger les taux de survie annuels des oies femelles. Les taux d'observation annuels des oies à qui on a posé un collier étaient élevés (environ 75 p. 100), ce qui a donné lieu à un taux d'erreur-type (ET) relativement faible et à la capacité de bien déceler les différences des taux de survie ou d'observation entre les groupes d'oies portant un collier.

Les taux moyens de survie des oies femelles marquées dans l'ouest de l'Arctique ($0,802 \pm ES\ 0,024$) étaient plus élevés que ceux des oies de l'île Wrangel ($0,685 \pm 0,033$). Les estimations des taux de survie pour les femelles à qui on a posé un collier dans les aires d'hivernage de la Colombie-Britannique ($0,742 \pm 0,036$) et du Nouveau-Mexique ($0,784 \pm 0,037$) étaient assez conformes à celles rapportées pour l'île Wrangel et l'ouest de l'Arctique, respectivement. Nous n'avons constaté aucune preuve convaincante permettant de confirmer que les taux de survie du troupeau en régression de l'île Wrangel ($0,656 \pm 0,056$) hivernant dans le sud (c.-à-d., en Californie) était inférieur à ceux du troupeau en hausse ($0,628 \pm 0,045$) hivernant dans le nord (c.-à-d., en Colombie-Britannique et dans l'État de Washington). Par contraste, les oies de l'ouest de l'Arctique qui partageaient les aires d'hivernage des oiseaux de l'île Wrangel hivernant dans le sud (en Californie) avaient des taux de survie beaucoup plus élevés ($0,844 \pm 0,025$). Cette situation suggère que les différences des taux de survie entre les oies de l'ouest de l'Arctique et celles de l'île Wrangel, qui se produisaient en dehors de la période d'hivernage, pourrait expliquer les différences globales des taux de survie des deux populations. Les taux de survie des femelles adultes pour les deux populations étaient semblables pendant la période « d'hiver » (du 1^{er} novembre au 1^{er} février) de toutes les années, mais ils étaient inférieurs pour les oies de l'île Wrangel pendant la période « allant de la fin de l'hiver au début de l'automne » (du 1^{er} février au 1^{er} novembre) au cours d'au moins une année, ce qui appuie cette interprétation.

L'analyse des bagues récupérées a indiqué que les taux de survie des oies adultes provenant de l'ouest de l'Arctique canadien étaient de $0,935 \pm 0,047$ de 1960 à 1963, de $0,832 \pm 0,062$ de 1973 à 1975 et de $0,789 \pm 0,069$ de 1987 à 1989. Les taux de survie des oies adultes provenant de l'île Wrangel étaient de $0,668 \pm 0,084$ de 1975 à 1977. La comparaison de ces estimations, de même que de celles tirées des données de repérages des colliers suggèrent que les taux de survie des adultes de l'île Wrangel étaient inférieurs dans une proportion de 0,10 à 0,15 à ceux des oies de l'ouest de l'Arctique au cours des années 1970 et 1980, et se situaient parmi les valeurs les plus faibles rapportées pour l'Oie des neiges. Les taux de survie des adultes de l'ouest de l'Arctique peuvent avoir connu un déclin entre les années 1960 et 1980. Bien que les différences entre les taux de survie puissent expliquer en partie pourquoi la population de l'ouest de l'Arctique a augmenté et pas celle de l'île Wrangel, nous n'avons constaté aucune preuve indiquant que les variations régionales des taux de survie pouvaient

expliquer les changements récents de la distribution hivernale des deux populations.

Les niveaux de récolte, dont les estimations se fondent sur les bagues de patte récupérées ainsi que sur les renseignements relatifs à la récolte et à la taille de la population, étaient, dans les années 1960 et 1970, de 15 à 20 p. 100 pour l'ensemble des populations de l'île Wrangel et de l'ouest de l'Arctique, et de ≤ 10 p. 100 à la fin des années 1980. Les bagues de patte récupérées indiquent, qu'au cours des dernières années, les niveaux de récolte étaient semblables pour les deux populations.

Contrairement à la situation des Oies des neiges se nourrissant dans les basses terres bordant la baie d'Hudson, il existe peu de preuves confirmant un surpâturage important par les oies de l'ouest de l'Arctique dans leur habitat estival. Toutefois, en raison de la taille actuelle et du taux de croissance de la population de l'ouest de l'Arctique, nous recommandons de fixer les niveaux de récolte à ceux des années 1960 et 1970. Cette mesure empêcherait la croissance de la population au-delà du point où elle peut être contrôlée au moyen de la chasse.

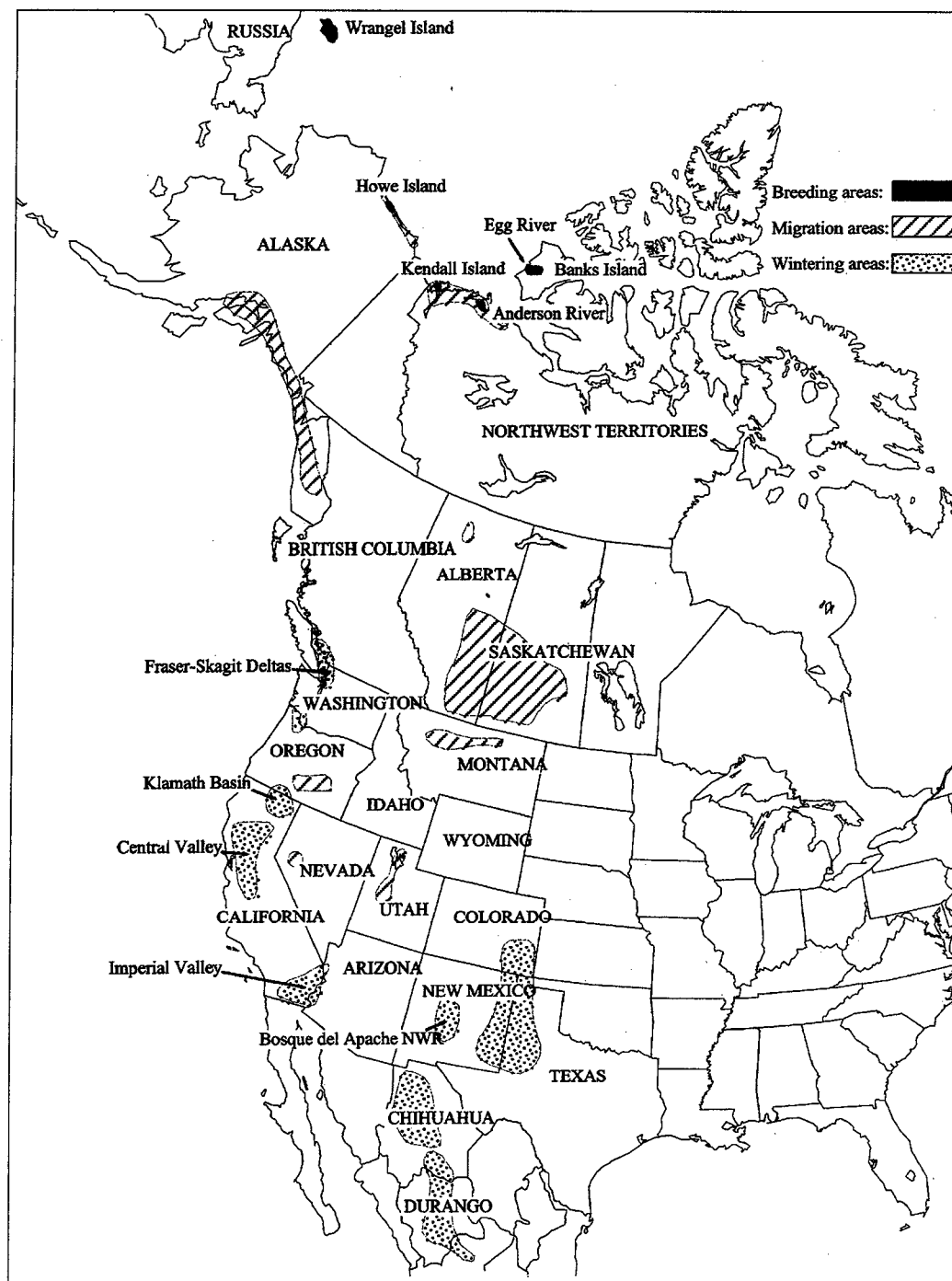
1. Introduction

Lesser Snow Geese *Anser caerulescens caerulescens* (hereafter referred to as Snow Geese) of the Pacific Flyway breed in the Western Canadian Arctic (mainly on Banks Island), on Wrangel Island, Russia, and at a small colony on the North Slope of Alaska (Fig. 1). Traditionally, most geese from Canada and Alaska wintered in the Central Valley of California, whereas those from Wrangel Island wintered at the Fraser Delta of British Columbia and the Skagit Delta in Washington as well as in the Central Valley. The winter distribution of Snow Geese in western North America seems to have changed during the past several decades (Dzubin 1979; Turner et al. 1994; Armstrong et al. 1999, this volume; Hines et al. 1999, this volume). Numbers of wintering birds have increased in the Western Central Flyway (i.e., the Northern Highlands of Durango and Chihuahua, New Mexico, and neighbouring parts of Colorado and Texas) and in British Columbia-Washington but have possibly declined in California (see Kerbes et al. 1999, this volume).

In addition to the dynamic nature of the winter distribution of Snow Geese, there have been significant changes in numbers at the breeding colonies (Kerbes et al. 1999, this volume). The Western Canadian Arctic Population has more than doubled since the late 1980s, and the small Alaskan colony is growing also (Johnson 1996). The Wrangel Island Population of Snow Geese is of special management concern because it declined greatly in the early 1970s and never returned to its former level (Bellrose 1976; Bousfield and Syroechkovsky 1985; Subcommittee on White Geese 1992a; Kerbes et al. 1999, this volume). Despite this overall decline, the number of Wrangel Island birds wintering in the Fraser-Skagit deltas has increased (Boyd 1995), possibly at the expense of the Central Valley component of the population.

The role that temporal and geographic differences in survival rates have played in altering the numbers and distributions of Snow Geese in western North America is not known, although there are now several sets of data that might shed light on this important problem. The observations of geese collared on the breeding and wintering grounds from 1986 to 1989 can be used to estimate survival rates by

Figure 1
Distribution of Lesser Snow Geese, showing breeding, migration, and wintering areas



capture-recapture (mark:resight) methods (Hestbeck et al. 1990; Pollock et al. 1990; Lebreton et al. 1992). Additionally, significant numbers of geese were banded in the Pacific Flyway from 1953 through the 1970s. Except for a report by Rienecker (1965), the legband recovery data have not previously been analyzed or widely reported.

In this report, we summarize the data on survival rates of geese collared at the different colonies and wintering areas from 1986 to 1989 and also review and analyze earlier banding and recovery data for Pacific and Western Central flyway Snow Geese. Our specific objectives were to 1) compute recent survival rates of adult Snow Geese from the

Western Canadian Arctic, Alaska, Wrangel Island, British Columbia, and New Mexico and document annual variations in survival for each site; 2) compare the survival of north-wintering (i.e., Fraser-Skagit deltas) and south-wintering (i.e., California) components of the Wrangel Island Population to determine if survival differences could account for recent changes in numbers of wintering geese at the two sites; and 3) derive survival and recovery rates from the 1950s–1980s banding and recovery data to determine if rates of survival or harvest have changed substantially over the past 35–40 years.

2. Methods

2.1 Marking and observing geese

During the summer flightless period, flocks of geese were herded into temporary capture pens by helicopter (Heyland 1970; Timm and Bromley 1976; Maltby 1977) or by crews working on foot (Cooch 1953). The sex and age of each captured goose were determined, and each bird was equipped with a standard metal legband. For analytical purposes, two age classes were recognized: adult (after hatch year) and young (hatch year). In addition to legbanding, in 1987–1989, many of the adult geese were marked with coloured plastic neckbands. Each neckband had a unique alpha-numeric code, making each collared goose individually identifiable.

Geese were also collared on two wintering areas in 1986 and 1987, the Fraser Delta in British Columbia (McKelvey et al. 1989) and the Bosque del Apache refuge in New Mexico (Taylor and Kirby 1990). In both areas, geese were captured with cannon nets as they fed in fields.

A large network of observers working at fall staging areas and wintering grounds used spotting scopes to scan flocks of feeding or resting geese and identify collared individuals (Kerbes and Meeres 1999, this volume). We used observations of collared geese made between November 1986 and February 1992 in our analyses.

2.2 Capture–recapture (mark:resight) analysis

The data from the observations of collared geese were suited for a capture–recapture (mark:resight) analysis for open populations (Pollock et al. 1990). By observing the gradual loss from the population of birds marked at specific times, survival rates were estimated (Hestbeck et al. 1990; Ebbinge et al. 1991). Current approaches to estimating survival rates by open population methods emphasize selecting a model that fits the data but requires the lowest number of estimable parameters (i.e., is parsimonious).

Data reported by Johnson et al. (1995) for geese collared at the Sagavanirktok River Delta in Alaska indicated that males and females had quite different rates of neckband loss, so we considered data sets for the two sexes separately. Because observer effort varied regionally and annually, most analyses were done separately for the different banding areas. We chose the Jolly-Seber model as a global model that was biologically realistic. It assumes that the two parameters of interest, survival rates and resighting rates, are time dependent (Jolly 1965; Seber 1965; Pollock et al. 1990).

In the analyses, a *survival rate* is defined as the probability that a goose alive at the midpoint of the neckband observation period of one year would live to the same date in the following year. A *resighting rate* (or the probability of capture) is the estimated probability that a collared goose alive during a given observation period was observed (i.e., its neckband code recorded) during that period.

Program RELEASE (Burnham et al. 1987), which can handle multiple data sets, was used to examine the goodness-of-fit to the Jolly-Seber model and to test for overall differences in survival or resighting rates among birds from different areas. We used Tests 2 and 3 of RELEASE to provide a cumulative χ^2 test for goodness-of-fit to the general Jolly-Seber model and Test 1 as an overall test for some

treatment effect (i.e., do survival rates or rates of observation of marked individuals differ among banding areas?). Program JOLLY (Pollock et al. 1990) was used to compute both annual and average survival rates (Model A) and to attempt to fit reduced parameter models to the data sets (e.g., ones in which survival probabilities [Model B] or both survival and capture probabilities [Model D] are constant among years). The model that best fit the individual data sets was deemed the “best model,” and the estimate from that model the “best estimate” of the average survival rate for a given group of geese. We then used the χ^2 test (Sauer and Williams 1989) to conduct pairwise comparisons of annual or “best estimates” of survival among areas if the Program RELEASE tests (mentioned above) indicated that such comparisons were warranted (Program CONTRAST; Hines and Sauer 1989). Unless otherwise indicated, statistical hypotheses were tested at the 0.05 level of significance.

Previous studies have shown that neckband loss is sometimes high for certain species of geese (Campbell and Becker 1991; Johnson et al. 1995). If rates of neckband retention can be measured, however, neckband loss can be accounted for when estimating population parameters (Arnason and Mills 1981; Hestbeck et al. 1990; Pollock et al. 1990; Nichols et al. 1992). In order to arrive at rates of neckband retention, we used the data reported by Johnson et al. (1995) for annual banding/collaring drives carried out from 1980 to 1989 at the Sagavanirktok River Delta, Alaska. Average neckband retention rates were calculated from these data according to the formula for a binomial distribution. We also estimated neckband retention rates by sending questionnaires to hunters who had shot banded birds, a method that had proven to be useful for Canada Geese *Branta canadensis* (Samuel et al. 1990a). The small sample of returns from the questionnaire was useful in checking the generality of the results from Alaska. Average retention rates were estimated from the questionnaire data using a modified form of the Mayfield estimator (Bart and Robson 1982). Mean survival rates and their standard errors were corrected for the effect of neckband loss using the formula described by Pollock (1981).

Although geese were marked in the Arctic during July or August of each year, we considered in our analyses of annual survival rates only the birds observed during November, December, and January of 1986–1987 to 1991–1992. This period was chosen because it contained the highest proportion (nearly 50%) of the annual neckband observations of any three-month period. For birds marked on the wintering grounds, the date of collaring was treated as an observation. Annual survival estimates refer to the midpoints of the consecutive sampling periods — i.e., from 15 December of one year to 15 December of the next.

We considered Wrangel Island geese that wintered in the Fraser–Skagit deltas and California separately in some analyses to find out if geographic differences in survival rates might account for the recent changes in the distribution of this population. For this purpose, geese sighted only in the Fraser–Skagit deltas or California between 1 November and 31 January were treated as being present on the wintering grounds, and geese sighted in more than one wintering area were eliminated from the analyses. From 1988 to 1992, 88% of the geese (730 of 830) sighted during November–January were observed in only the north (Fraser–Skagit) or the south (California) wintering area. Therefore, we believe that it was

valid to separate the overall population into north- and south-wintering stocks, and that eliminating the individuals that could not be clearly assigned to either stock would not severely bias the analyses. For comparative purposes, we also computed survival rates of Western Canadian Arctic geese that wintered in California.

To determine if survival rates differed seasonally for geese from different banding areas, we divided the observation data into two intervals per year, 11 October – 22 November and 11 January – 22 February, and computed survival rates for those periods. In this instance, the survival rates (from the midpoint of one sampling period to the midpoint of the next) are from 1 November to 1 February and from 1 February to 1 November, respectively. The intervals chosen for the analysis were dictated by the availability of data for different time periods and the need to shorten the sampling period relative to the time between samples (one of the assumptions of the Jolly-Seber method; Krebs 1989:43).

2.3 Band recovery analysis of earlier and present data sets (1960–1989)

Survival rates for Snow Geese banded in the 1960s through 1970s were estimated using legband recovery methods described by Brownie et al. (1985) and Conroy et al. (1989). Legband recoveries were also used to provide a statistically independent estimate of survival rates for the sample of geese collared from 1987 to 1989. The analyses used only legbands from hunter-killed birds that were reported to the Bird Banding Office of the Canadian Wildlife Service or the U.S. Fish and Wildlife Service. In these analyses, a *recovery rate* is defined as the estimated proportion of banded birds in the population that were killed by hunters during the subsequent hunting season and had their legbands reported (Brownie et al. 1985). A *direct recovery rate* is the recovery rate during the first hunting season after banding. *Survival rate* refers to the estimated proportion of birds (of a given sex or age class) that survived from the time of banding in one year to the time of banding in the following year.

The legband recovery approach involved selecting a multinomial model that best fit the data and then generating maximum likelihood estimates of survival and legband recovery estimates using the preferred model. We used the ESTIMATE procedure of the computer program MULT (Conroy et al. 1989) to determine survival rates of adult geese. This software tested for the fit of the legband recovery data to three models: M1 (both survival rates and recovery rates are year dependent), M2 (survival rates are constant from year to year, but recovery rates vary annually), and M3 (survival rates and recovery rates are constant each year). Adequate samples of banded juveniles were available for the Western Canadian Arctic and Wrangel Island for some years. In these instances, the BROWNIE procedure in program MULT was used to estimate survival for both adults and young. Specifically, we employed models H1, H02, and H01 of the BROWNIE procedure, which are two age class extensions of models M1, M2, and M3, respectively.

2.4 Harvest rates

Band recovery estimates are a useful index of the proportion of a waterfowl population that is killed by hunters each year. In the following analyses, we have assumed that legband reporting estimates have not changed over the years and that legbands from 30–40% of the marked birds shot by hunters are eventually “recovered” — that is, reported to one of the Wildlife Services (Martinson and McCann 1966; Conroy and Blandin 1984; Nichols et al. 1991). This assumption should produce a conservative estimate of the proportion of the population killed by hunters, because it does not take into account unretrieved kill or spring subsistence harvest of banded birds.

Analysis of legband recoveries might be further complicated by the collaring of geese. If hunters are more apt to report having shot a collared goose compared with one that was only legbanded (Samuel et al. 1990b), the collaring of adult geese during 1975–1977 on Wrangel Island and during 1987–1989 both on Wrangel Island and in the Western Canadian Arctic would inflate recovery estimates for those years relative to other periods. This form of bias was identified primarily for *direct* recovery estimates of collared geese and so might not greatly influence the *overall* recovery estimates (i.e., including direct plus indirect recoveries) for adult geese described here (Samuel et al. 1990b). In our analyses, we have assumed a reporting rate of 1/3. For the reasons outlined above, we believe this will lead to conservative estimates of harvest rates for legbanded birds and might somewhat inflate harvest rates for collared geese.

As a second measure of harvest rate, we considered annual estimates of harvest and population size. Because of the typically imprecise nature of both harvest and population estimates, the ratio of harvest to overall population size may be a less reliable estimator of harvest rate than legband recovery estimates. Nevertheless, the method provided a useful independent index to harvest rate. In most instances, the origin of harvested birds cannot be attributed to a specific breeding colony, so we calculated only an overall harvest rate for the entire flyway population.

3. Results

3.1 Neckbanding studies (1986–1989)

On the breeding grounds, 4583 adult Snow Geese were collared from 1987 to 1989, approximately 58% of these in the Western Canadian Arctic, 30% at Wrangel Island, and 13% at the Sagavanirktok Delta in Alaska (Table 1). Geese were banded in the Western Arctic and Alaska during all three years of study, but only during 1988 and 1989 on Wrangel Island. Sixty-one percent of the collared geese were sighted during the November–January period of at least one year, so the number of collared birds from the breeding grounds in the mark:resight survival analyses was 2814.

In the winters of 1986 and 1987, 345 adult geese were collared at the Fraser Delta, British Columbia, and 245 adults at the Bosque del Apache refuge in New Mexico (Table 1). Data from all of these geese were used in survival analyses.

Annual resighting probabilities for geese collared on the breeding grounds averaged nearly 0.75, and the average resighting rates for those collared during winter exceeded

Table 1
Number of adult Lesser Snow Geese neckbanded at five sites in the Pacific Flyway, 1986–1989 (F indicates females and M indicates males)

Year	Western Canadian Arctic			Alaska			Wrangel Island			British Columbia			New Mexico		
	F	M	Both	F	M	Both	F	M	Both	F	M	Both	F	M	Both
1986	0	0	0	0	0	0 ^a	0	0	0	96	74	170	117	90	225 ^b
1987	518	515	1033	87	113	200	0	0	0	98	76	175 ^b	14	4	20 ^b
1988	449	449	898	88	112	200	453	442	897 ^b	0	0	0	0	0	0
1989	391	322	713	90	92	182	207	253	460	0	0	0	0	0	0
Total	1358	1286	2644	265	317	582	660	695	1357 ^b	194	150	345 ^b	131	94	245 ^b

^a One hundred and ninety-nine geese were banded in Alaska in 1986, but these individuals were not used for survival analyses.

^b Totals include geese of undetermined sex.

Table 2
Minimum annual survival estimates (\pm standard errors) of neckbanded adult female Lesser Snow Geese from the Western Canadian Arctic, Alaska, and Wrangel Island, 1987–1989. The annual and average survival estimates are based on the Jolly-Seber model (Program JOLLY, Model A), and the overall survival estimates are based on the constant survival model (Model B). The survival estimate (average or overall) based on the best model (i.e., the simplest model that fit) is in bold type.

Banding area	Year	Survival \pm SE	Probability of resighting \pm SE
Western Canadian Arctic	1987	0.819 \pm 0.037	
	1988	0.769 \pm 0.028 ^a	0.678 \pm 0.042
	1989	0.544 \pm 0.030 ^b	0.839 \pm 0.028
	1990		0.727 \pm 0.037
	Average	0.711 \pm 0.016^c	0.748 \pm 0.031
Overall (1987–1989)		0.737 \pm 0.019 ^d	0.631 \pm 0.033
Alaska	1988	0.847 \pm 0.120	
	1989	0.539 \pm 0.112	0.703 \pm 0.116
	1990		0.549 \pm 0.118
	Average	0.693 \pm 0.074	0.626 \pm 0.166
	Overall (1988–1989)	0.758 \pm 0.094	0.488 \pm 0.095
Wrangel Island	1988	0.632 \pm 0.036	
	1989	0.576 \pm 0.046	0.841 \pm 0.040
	1990		0.738 \pm 0.054
	Average	0.604 \pm 0.027	0.789 \pm 0.067
	Overall (1988–1989)	0.612 \pm 0.027	0.722 \pm 0.058

^a Survival estimate is 0.742 \pm 0.038 if geese collared in 1987 are eliminated.

^b Survival estimate is 0.515 \pm 0.033 if geese collared in 1987 are eliminated (probability of resighting is 0.849 \pm 0.039).

^c Average survival estimate is **0.628 \pm 0.023** if geese collared in 1987 are eliminated (probability of resighting is 0.806 \pm 0.059).

^d Overall survival estimate is 0.644 \pm 0.030 if geese collared in 1987 are eliminated (probability of resighting is 0.687 \pm 0.049).

0.80. The high rates of resighting lead to good precision for many survival estimates (i.e., standard errors ≤ 0.05) and good statistical power to detect significant differences in survival rates (Tables 2–4).

Neckbands placed on geese in Alaska in 1987 were not glued, and birds collared in that year had much higher rates of neckband loss than birds collared in any other year (Johnson et al. 1995). Therefore, we omitted the birds collared in Alaska in 1987 from the analyses. We estimated survival rates for three years (1987–1989) for geese from the Western Canadian Arctic and for two years (1988–1989) for geese from Alaska and Wrangel Island (Tables 2 and 3).

Table 3
Minimum annual survival estimates (\pm standard errors) of neckbanded adult male Lesser Snow Geese from the Western Canadian Arctic, Alaska, and Wrangel Island, 1987–1989. The annual and average survival estimates are based on the Jolly-Seber model (Program JOLLY, Model A), and the overall survival estimates are based on the constant survival model (Model B). The survival estimate (average or overall) based on the best model (i.e., the simplest model that fit) is in bold type.

Banding area	Year	Survival \pm SE	Probability of resighting \pm SE
Western Canadian Arctic	1987	0.690 \pm 0.046	
	1988	0.640 \pm 0.031 ^a	0.622 \pm 0.051
	1989	0.445 \pm 0.046 ^b	0.909 \pm 0.030
	1990		0.700 \pm 0.069
	Average	0.592 \pm 0.022^c	0.743 \pm 0.046
Overall (1987–1989)		0.638 \pm 0.022 ^d	0.566 \pm 0.037
Alaska	1988	0.547 \pm 0.090	
	1989	0.397 \pm 0.113	0.878 \pm 0.110
	1990		0.633 \pm 0.170
	Average	0.472 \pm 0.070	0.756 \pm 0.203
	Overall (1988–1989)	0.519 \pm 0.077	0.560 \pm 0.114
Wrangel Island	1988	0.598 \pm 0.036	
	1989	0.624 \pm 0.057	0.873 \pm 0.039
	1990		0.649 \pm 0.061
	Average	0.611 \pm 0.032	0.761 \pm 0.072
	Overall (1988–1989)	0.608 \pm 0.029	0.685 \pm 0.055

^a Survival estimate is 0.666 \pm 0.041 if geese collared in 1987 are eliminated.

^b Survival estimate is 0.424 \pm 0.048 if geese collared in 1987 are eliminated (probability of resighting is 0.900 \pm 0.042).

^c Average survival estimate is **0.545 \pm 0.030** if geese collared in 1987 are eliminated (probability of resighting is 0.837 \pm 0.091).

^d Overall survival estimate is 0.625 \pm 0.038 if geese collared in 1987 are eliminated (probability of resighting is 0.547 \pm 0.043).

Data from female geese marked on the wintering grounds provided four annual estimates of survival (1986–1989), but only two or three annual estimates were calculated for males because of small sample sizes (Table 4). All estimates presented in Tables 2–4 are *minimum survival rates*, as they do not take neckband loss into account.

Table 5 summarizes Program RELEASE output concerning goodness-of-fit of the resighting data to the general Jolly-Seber model as well as the test results for differences in resighting or survival rates of geese from the three Arctic banding sites. In Table 6, Program JOLLY results describing the fit of the resighting data to the Jolly-Seber model (and its

Table 4

Minimum annual survival estimates (\pm standard errors) of adult Lesser Snow Geese neckbanded in winter in British Columbia and New Mexico, 1986–1989. The annual and average survival estimates are based on the Jolly-Seber model (Program JOLLY, Model A), and the overall survival estimates are based on the constant survival model (Model B). The survival estimate (average or overall) based on the best model (i.e., the simplest model that fit) is in bold type.

Sex	Year	British Columbia		New Mexico	
		Survival \pm SE	Probability of resighting \pm SE	Survival \pm SE	Probability of resighting \pm SE
Female	1986	0.673 \pm 0.051		0.731 \pm 0.046	
	1987	0.682 \pm 0.042	0.929 \pm 0.040	0.684 \pm 0.053	0.877 \pm 0.043
	1988	0.555 \pm 0.064	0.912 \pm 0.038	0.631 \pm 0.073	0.926 \pm 0.041
	1989	0.566 \pm 0.226	0.861 \pm 0.074	0.487 \pm 0.082	0.861 \pm 0.075
	1990		0.486 \pm 0.191		inadequate data ^a
	Average	0.619 \pm 0.059	0.797 \pm 0.071	0.633 \pm 0.029	0.888 \pm 0.048
	Overall (1986–1989)	0.657 \pm 0.029	0.650 \pm 0.071	0.695 \pm 0.030	0.674 \pm 0.075
Male	1986	0.582 \pm 0.072		0.747 \pm 0.057	
	1987	0.530 \pm 0.091	0.836 \pm 0.084	0.569 \pm 0.074	0.862 \pm 0.057
	1988	inadequate data ^a	0.729 \pm 0.117	0.476 \pm 0.121	0.886 \pm 0.076
	1989	inadequate data ^a		inadequate data ^a	0.825 \pm 0.162
	Average	0.556 \pm 0.055	0.783 \pm 0.144	0.597 \pm 0.046	0.858 \pm 0.094
	Overall (1986–1988)	0.568 \pm 0.057	0.633 \pm 0.099	0.672 \pm 0.044	0.644 \pm 0.106

^a Sample sizes too small to estimate values.

Table 5

The overall goodness-of-fit to the Jolly-Seber model (Program RELEASE, Tests 2 + 3) and test results for the regional differences in survival or resighting estimates (Test 1) for adult Lesser Snow Geese neckbanded on the breeding grounds, 1987–1989

Banding areas	Period	Sex	Goodness-of-fit to Jolly-Seber model			Regional differences in survival or resighting estimates		
			χ^2	df	P ^a	χ^2	df	P ^b
Western Canadian Arctic, Alaska, and Wrangel Island	1987–1989	F	23.697	15	0.070	18.743	10	0.044
Western Canadian Arctic, Alaska, and Wrangel Island	1988–1989	F	15.522	12	0.214	14.911	10	0.135
Western Canadian Arctic and Wrangel Island that wintered in all areas (seasonal rates)	1987–1989	F	123.515	72	0.000	43.401	13	0.000
Western Canadian Arctic and Wrangel Island that wintered in California (seasonal rates)	1987–1989	F	70.799	64	0.261	36.426	13	0.001
Wrangel Island (north- and south-wintering)	1988–1989	F	14.836	8	0.062	9.073	5	0.106
Western Canadian Arctic, Alaska, and Wrangel Island	1987–1989	M	18.873	15	0.220	36.804	9	0.000
Western Canadian Arctic, Alaska, and Wrangel Island	1988–1989	M	9.702	12	0.642	40.388	9	0.000
Western Canadian Arctic and Wrangel Island that wintered in all areas (seasonal rates)	1987–1989	M	100.345	57	0.000	46.372	13	0.000
Western Canadian Arctic and Wrangel Island that wintered in California (seasonal rates)	1987–1989	M	71.783	50	0.023	9.271	13	0.752
Wrangel Island (north- and south-wintering)	1988–1989	M	6.064	8	0.640	18.128	5	0.003

^a Nonsignificant χ^2 -values ($P > 0.05$) indicate adequate fit to the Jolly-Seber model.

^b Significant χ^2 -values ($P \leq 0.05$) indicate regional differences in survival or resighting estimates.

constant survival version) are presented for birds marked at each of the summer and winter banding sites.

3.2 Minimum survival rates of adult females

3.2.1 Females neckbanded on the breeding grounds

When only 1988 and 1989 bandings were considered (i.e., only the years when birds were collared at all three breeding areas), the observations of adult females showed good fit to the overall Jolly-Seber model. The data also showed adequate fit when the 1987 data for the Western Arctic were included (Tables 2 and 5).

The Test 1 results from RELEASE were ambiguous and did not provide clear evidence that survival or resighting rates differed among banding areas. When only the 1988–

1989 data were included, the overall test result was not statistically significant, suggesting that there was no difference in survival or resighting rates. When the 1987 Western Arctic data were included in the analysis, the overall test result was significant, suggesting that there were regional differences in either survival or resighting rates (Table 5).

The constant survival model (Model B) best fit the Wrangel Island and Alaska data sets (Table 6). The Jolly-Seber model (Model A) best fit the data for the Western Arctic.

Comparison of the estimates for the three Arctic banding sites using the method of Sauer and Williams (1989) indicated that several of the survival rates for the Western Arctic were significantly higher than the rates for Wrangel Island (Table 7). Alaska estimates had large standard errors,

Table 6

The goodness-of-fit of the Jolly-Seber model (Program JOLLY, Model A) and the constant survival model (Model B) for adult Lesser Snow Geese neckbanded on the breeding and wintering grounds, 1986–1989. The best model (i.e., the simplest model that fit) is indicated.

Banding area	Period ^a	Sex	Goodness-of-fit to Jolly-Seber model			Goodness-of-fit to constant survival model			Best model
			χ^2	df	P	χ^2	df	P	
Western Canadian Arctic	1987–1989	F	10.702	7	0.152	41.611	9	0.000	Jolly-Seber
Alaska	1988–1989	F	0.022	1	0.882	2.294	2	0.318	Constant survival
Wrangel Island	1988–1989	F	8.013	3	0.046	8.769	4	0.067	Constant survival
British Columbia	1986–1989	F	0.529	1	0.467	2.632	3	0.452	Constant survival
New Mexico	1986–1989	F	0.030	1	0.863	1.495	2	0.474	Constant survival
Wrangel Island (north-wintering)	1988–1989	F	1.288	1	0.257	5.969	2	0.051	Jolly-Seber ^b
Wrangel Island (south-wintering)	1988–1989	F	11.971	2	0.003	14.119	3	0.003	Unknown
Western Canadian Arctic	1987–1989	M	4.647	4	0.326	14.356	6	0.026	Jolly-Seber
Alaska	1988–1989	M	0.251	1	0.616	inadequate data ^c			Jolly-Seber
Wrangel Island	1988–1989	M	2.080	3	0.556	2.260	4	0.688	Constant survival
British Columbia	1986–1987	M	1.623	1	0.203	1.736	2	0.420	Constant survival
New Mexico	1986–1988	M	inadequate data ^c			inadequate data ^c			Unknown
Wrangel Island (north-wintering)	1988–1989	M	0.221	3	0.974	0.302	4	0.990	Constant survival
Wrangel Island (south-wintering)	1988–1989	M	1.089	2	0.580	3.156	3	0.368	Constant survival

^a Period refers to years for which survival estimates were determined.

^b The fit of the Jolly-Seber model was significantly better than that of the constant survival model ($\chi^2 = 4.681$, df = 1, P = 0.031).

^c Sample sizes too small to test the goodness-of-fit.

so none of the comparisons with the Wrangel Island or the Western Arctic estimates was statistically significant.

3.2.2 Females neckbanded on the wintering grounds

Data for adult female Snow Geese collared in New Mexico showed good fit to the Jolly-Seber model and showed best fit to the constant survival model (Tables 4 and 6). About half of the geese wintering in the Western Central Flyway (Turner et al. 1994) are from the Western Arctic, so comparisons with this stock were most meaningful. Some of the annual survival rates for Western Arctic samples were significantly higher than those for New Mexico birds, but there were no significant differences in survival rates for the two sites when the best overall model was used (Table 7).

The observations of geese collared on the Fraser Delta showed adequate fit to the Jolly-Seber model (Table 6), with the constant survival model showing best fit to the data. This group of birds is part of the Wrangel Island Population, so perhaps it was not surprising that the survival rates for geese marked on the Fraser Delta and on Wrangel Island were similar (Table 7).

3.3 Minimum survival rates of adult males

3.3.1 Males neckbanded on the breeding grounds

The observations of males fit the Jolly-Seber model for the 1988–1989 data for the Western Arctic, Wrangel Island, and Alaska (Tables 3 and 5). When the data for the Western Arctic geese collared in 1987 were included, the fit to the Jolly-Seber model remained adequate. The overall test for regional differences in either male survival or resighting rates (Test 1) was highly significant for both the 1988–1989 and the 1987–1989 data sets (Table 5).

The generalized Jolly-Seber model (Model A) provided best fit for the Western Arctic and Alaska data, and the constant survival model (Model B) best fit the Wrangel

Island data (Table 6). Pairwise comparisons did not indicate any significant difference in average or “best model” survival estimates of male geese from the three regions (Table 8).

3.3.2 Males neckbanded on the wintering grounds

The data on adult male geese collared at the Bosque del Apache refuge in New Mexico did not fit either the Jolly-Seber model (Model A) or its reduced parameter version, the constant survival model (Table 6). As noted by Carothers (1973, 1979) and Pollock et al. (1990), the Jolly-Seber survival estimator seems robust to heterogeneity of capture and survival probabilities, especially when recapture or resighting rates are high (e.g., >0.5). Therefore, we felt it was valid to compare annual, average, or “best model” survival estimates of the New Mexico and Western Arctic geese. None of the comparisons revealed significant differences (Table 8).

Observations of adult male geese collared in the Fraser Delta of British Columbia fit the Jolly-Seber model and showed best fit to the constant survival model (Table 6). Comparisons with the sample of geese marked on Wrangel Island revealed no significant differences in overall or average survival rates for the two banding areas (Table 8).

3.4 Survival of north- and south-wintering stocks of the Wrangel Island Population

Survival rates of north-wintering and south-wintering stocks of Wrangel Island Snow Geese are presented in Table 9. The data for females had borderline fit to the Jolly-Seber model, and Test 1 suggested that neither survival nor resighting rates differed between the two wintering areas (Table 5).

The Jolly-Seber survival estimate proved to be best for the north-wintering females, but neither the Jolly-Seber nor the constant survival model fit the data set for the

Table 7

Statistical comparisons of estimated survival estimates for neckbanded adult female Lesser Snow Geese (Sauer and Williams 1989). Significant χ^2 -values ($P \leq 0.05$) indicate differences in survival estimates.

Comparisons	Year	df	χ^2	P	Group with higher survival estimate
Western Canadian Arctic (1987–1989), Alaska, and Wrangel Island	Average	2	11.381	0.003	See comparisons below
	Best model ^a	2	10.116	0.006	See comparisons below
Western Canadian Arctic (1987–1989) and Alaska	Average	1	0.055	0.814	–
	Best model	1	0.244	0.621	–
Western Canadian Arctic (1987–1989) and Wrangel Island	Average	1	11.362	0.001	Western Canadian Arctic
	Best model	1	9.526	0.002	Western Canadian Arctic
Wrangel Island and Alaska	Average	1	1.258	0.262	–
	Best model	1	2.224	0.136	–
Western Canadian Arctic (1988–1989), Alaska, and Wrangel Island	1988	2	6.140	0.046	–
	1989	2	1.154	0.562	–
	Average	2	1.419	0.492	–
	Best model	2	2.241	0.326	–
Western Canadian Arctic (1988–1989) and Alaska	1988	1	0.701	0.402	–
Western Canadian Arctic (1988–1989) and Wrangel Island	1988	1	4.393	0.036	Western Canadian Arctic
Alaska and Wrangel Island	1988	1	2.944	0.086	–
Western Canadian Arctic wintering in California (1988–1989) and south-wintering Wrangel Island	1988	1	16.396	0.000	Western Canadian Arctic
	1989	1	0.361	0.548	–
	Average ^b	1	3.776	0.052	–
Western Canadian Arctic (1987–1989) and New Mexico	1987	1	4.329	0.038	Western Canadian Arctic
	1988	1	3.117	0.078	–
	1989	1	0.440	0.507	–
	Average	1	5.542	0.019	Western Canadian Arctic
	Best model	1	0.214	0.644	–
North- and south-wintering Wrangel Island	1988	1	3.878	0.049	North-wintering
	1989	1	3.983	0.046	South-wintering
	Average ^b	1	0.159	0.690	–
British Columbia and Wrangel Island	1988	1	1.116	0.291	–
	1989	1	0.002	1.000	–
	Average	1	0.052	0.820	–
	Best model	1	1.261	0.262	–
British Columbia and north-wintering Wrangel Island	1988	1	1.911	0.167	–
	1989	1	0.264	0.607	–
	Average	1	0.659	0.417	–
	Best model	1	3.844	0.050	British Columbia

^a Comparison using the simplest models that fit.

^b Average is the best model.

south-wintering birds (Table 6). The resighting rates for the south-wintering geese were high (Table 9); thus, despite the inadequate model fit, we felt it was valid to make cautious use of the average survival rates for this group (Carothers 1973, 1979; Pollock et al. 1990). A comparison of the survival rates of the north- and south-wintering females suggested that average survival rates were similar for both stocks, although there may have been some annual differences in survival estimates (Tables 7 and 9).

The data sets on north-wintering and south-wintering males together showed good fit to the Jolly-Seber model (Table 5), and there was strong evidence of regional differences in survival and/or resighting rates. The constant survival model showed best fit to each of the individual data sets for males (Table 6). Subsequent comparisons of the constant survival estimates of north- and south-wintering males indicated no significant difference among the two groups of birds (Table 8).

The collaring done at the Fraser Delta in 1986 and 1987 offered an independent estimate of the survival of the north-wintering stock of Wrangel Island geese (Tables 4 and 9). The annual and average survival rates for females marked at the Fraser Delta were similar to the estimates for the north-wintering females collared on Wrangel Island. However, use of the “best estimates” suggested that birds marked at the Fraser Delta had higher survival (Table 7). Average or “best estimate” survival values did not differ for male geese collared on Wrangel Island or in British Columbia (Tables 8 and 9).

Female geese from the Western Arctic that wintered in California had significantly higher survival rates than Wrangel Island geese sharing the same wintering area during at least one year and perhaps overall (Tables 7 and 9). There was no evidence that this relationship held for male geese, however (Tables 8 and 9).

Table 8
Statistical comparisons of estimated survival estimates for neckbanded adult male Lesser Snow Geese (Sauer and Williams 1989). Significant χ^2 -values ($P \leq 0.05$) indicate differences in survival estimates.

Comparisons	Year	df	χ^2	P	Group with higher survival estimate
Western Canadian Arctic (1987–1989), Alaska, and Wrangel Island	Average	2	3.284	0.194	–
	Best model ^a	2	1.170	0.557	–
Western Canadian Arctic (1988–1989), Alaska, and Wrangel Island	1988	2	2.296	0.317	–
	1989	2	8.103	0.017	See comparisons below
	Average	2	4.245	0.120	–
	Best model	2	2.777	0.250	–
Western Canadian Arctic (1988–1989) and Alaska	1988	1	0.048	0.827	–
Western Canadian Arctic (1988–1989) and Wrangel Island	1988	1	7.226	0.007	Wrangel Island
	1988	1	3.236	0.072	–
Alaska and Wrangel Island	1988	1	2.041	0.153	–
	1989	1	5.957	0.015	Wrangel Island
	Average	1	1.215	0.270	–
	Best model	1	2.588	0.108	–
Western Canadian Arctic wintering in California (1988–1989) and south-wintering Wrangel Island	1987	1	1.926	0.165	–
	1988	1	1.745	0.187	–
	Average	1	0.013	0.910	–
	Best model	1	2.626	0.105	–
Western Canadian Arctic (1987–1989) and New Mexico	1988	1	0.011	0.915	–
	1989	1	1.655	0.198	–
	Average	1	1.130	0.288	–
	Best model	1	0.476	0.490	–
North- and south-wintering Wrangel Island	Average	1	0.750	0.384	–
	Best model	1	0.378	0.539	–
British Columbia and Wrangel Island	Average	1	0.056	0.814	–
	Best model	1	0.039	0.844	–

^a Comparison using the simplest models that fit.

Table 9
Minimum annual survival estimates (\pm standard errors) of neckbanded adult Lesser Snow Geese from Wrangel Island that wintered in the north (Fraser–Skagit region) and the south (California), and geese from the Western Canadian Arctic that wintered in California, 1987–1989. The annual and average survival estimates are based on the Jolly-Seber model (Program JOLLY, Model A), and the overall survival estimates are based on the constant survival model (Model B). The estimate (average or overall) based on the best model (i.e., the simplest model that fit) is in bold type.

Sex	Year	Wrangel Island (north-wintering)		Wrangel Island (south-wintering)		Western Canadian Arctic wintering in California	
		Survival \pm SE	Probability of resighting \pm SE	Survival \pm SE	Probability of resighting \pm SE	Survival \pm SE	Probability of resighting \pm SE
Female	1987					0.835 \pm 0.039	
	1988	0.677 \pm 0.062		0.516 \pm 0.054		0.805 \pm 0.029	0.686 \pm 0.046
	1989	0.446 \pm 0.064	0.790 \pm 0.069	0.657 \pm 0.085	0.894 \pm 0.057	0.604 \pm 0.032	0.861 \pm 0.028
	1990		0.766 \pm 0.092		0.689 \pm 0.091		0.762 \pm 0.038
	Average	0.562 \pm 0.039	0.778 \pm 0.114	0.586 \pm 0.049 ^a	0.791 \pm 0.108	0.748 \pm 0.017	0.769 \pm 0.033
	Overall	0.608 \pm 0.049	0.625 \pm 0.089	0.570 \pm 0.042 ^a	0.765 \pm 0.096	0.768 \pm 0.020	0.663 \pm 0.037
Male	1987					0.813 \pm 0.053	
	1988	0.562 \pm 0.066		0.553 \pm 0.049		0.635 \pm 0.035	0.633 \pm 0.056
	1989	0.512 \pm 0.102	0.809 \pm 0.083	0.674 \pm 0.074	0.944 \pm 0.038	0.495 \pm 0.049	0.930 \pm 0.030
	1990		0.516 \pm 0.107		0.752 \pm 0.081		0.721 \pm 0.068
	Average	0.537 \pm 0.057	0.662 \pm 0.135	0.613 \pm 0.044	0.848 \pm 0.090	0.648 \pm 0.024	0.761 \pm 0.047
	Overall	0.553 \pm 0.054	0.587 \pm 0.096	0.598 \pm 0.037	0.781 \pm 0.078	0.670 \pm 0.026	0.607 \pm 0.043

^a Neither the Jolly-Seber model nor the constant survival model fit the data (goodness-of-fit tests: Jolly-Seber, $\chi^2 = 11.97$, $P = 0.003$; constant survival model, $\chi^2 = 14.12$, $P = 0.003$), so the model of best fit is unknown.

Table 10

Minimum seasonal survival estimates (\pm standard errors) of neckbanded adult female Lesser Snow Geese from the Western Canadian Arctic and Wrangel Island, 1987–1992

Period	Western Canadian Arctic		Wrangel Island		Pairwise comparison ^a	
	Survival \pm SE	Probability of resighting \pm SE	Survival \pm SE	Probability of resighting \pm SE	χ^2	P
Wintering in all areas						
Nov 1/87 – Feb 1/88	0.813 \pm 0.050					
Feb 1/88 – Nov 1/88	0.898 \pm 0.043	0.441 \pm 0.052				
Nov 1/88 – Feb 1/89	0.901 \pm 0.035	0.487 \pm 0.041	0.823 \pm 0.052		1.580	0.209
Feb 1/89 – Nov 1/89	0.840 \pm 0.037	0.476 \pm 0.030	0.684 \pm 0.044	0.585 \pm 0.052	7.344	0.007
Nov 1/89 – Feb 1/90	0.867 \pm 0.042	0.532 \pm 0.030	0.803 \pm 0.050	0.667 \pm 0.044	0.973	0.324
Feb 1/90 – Nov 1/90	0.676 \pm 0.047	0.509 \pm 0.030	0.754 \pm 0.070	0.573 \pm 0.044	0.871	0.351
Nov 1/90 – Feb 1/91	0.826 \pm 0.094	0.479 \pm 0.035	0.795 \pm 0.116	0.464 \pm 0.050	0.045	0.833
Feb 1/91 – Nov 1/91	0.693 \pm 0.145	0.317 \pm 0.040	0.930 \pm 0.408	0.506 \pm 0.073	0.300	0.584
Nov 1/91 – Feb 1/92		0.402 \pm 0.078		0.207 \pm 0.092		
Average	0.814 \pm 0.018	0.456 \pm 0.018	0.798 \pm 0.067	0.500 \pm 0.030	0.055	0.814
Average (Nov 1 – Feb 1)	0.852	0.499	0.807	0.566		
Average (Feb 1 – Nov 1) ^b	0.804	0.476	0.719	0.579		
Wintering in California						
Nov 1/87 – Feb 1/88	0.902 \pm 0.045					
Feb 1/88 – Nov 1/88	0.946 \pm 0.040	0.505 \pm 0.058				
Nov 1/88 – Feb 1/89	0.935 \pm 0.036	0.558 \pm 0.046	0.872 \pm 0.074		0.579	0.447
Feb 1/89 – Nov 1/89	0.879 \pm 0.039	0.455 \pm 0.033	0.709 \pm 0.065	0.531 \pm 0.071	4.968	0.026
Nov 1/89 – Feb 1/90	0.903 \pm 0.043	0.570 \pm 0.033	0.757 \pm 0.097	0.707 \pm 0.063	1.872	0.171
Feb 1/90 – Nov 1/90	0.731 \pm 0.051	0.519 \pm 0.033	0.784 \pm 0.187	0.534 \pm 0.079	0.074	0.786
Nov 1/90 – Feb 1/91	0.824 \pm 0.090	0.495 \pm 0.038	0.559 \pm 0.255	0.408 \pm 0.103	0.962	0.327
Feb 1/91 – Nov 1/91	0.801 \pm 0.161	0.361 \pm 0.044	inadequate data ^c	0.475 \pm 0.191		
Nov 1/91 – Feb 1/92		0.415 \pm 0.079		inadequate data ^c		
Average	0.865 \pm 0.019	0.485 \pm 0.019	0.736 \pm 0.050	0.531 \pm 0.062	5.860	0.016
Average (Nov 1 – Feb 1)	0.891	0.510	0.729	0.557		
Average (Feb 1 – Nov 1) ^b	0.852	0.493	0.747	0.532		

^a Pairwise comparison of survival estimates (Sauer and Williams 1989). Significant χ^2 -values ($P \leq 0.05$) indicate regional differences in survival.

^b Average does not include Feb 1/91 – Nov 1/91 because of the small sample size for this period.

^c Sample sizes too small to calculate values.

3.5 Seasonal differences in survival rates of Wrangel Island and Western Canadian Arctic Snow Geese

Survival rates for the periods 1 November – 1 February and 1 February – 1 November were compared to determine whether seasonal differences in survival occurred between the Wrangel Island and Western Canadian Arctic populations (Tables 10 and 11). We carried out two separate analyses for males and females from each area: 1) birds that wintered in any area; and 2) birds that wintered in California.

The overall data set for females did not fit the Jolly-Seber model, whereas the California data set did (Table 5). Test 1 results for both data sets suggested that either survival or resighting rates differed between the two regions. Subsequent pairwise comparisons indicated only one significant difference: female geese from the Western Arctic had higher survival than Wrangel Island geese during the spring and summer of 1989 (Table 10). This result held for both the complete and California data sets.

Neither data set for males adequately fit the Jolly-Seber model (Table 5). Test 1 results suggested that

there may have been geographic differences in survival or resighting rates for the overall data set, and pairwise comparisons suggested one or two significant differences in survival rates (Table 11). There was no consistent pattern to these differences, and, given the lack of model fit and the problem with neckband loss for males (described in Section 4.1.1), we do not attach any specific biological significance to these differences.

3.6 Rates of neckband retention and adjusted estimates of survival

Average annual neckband retention rates were derived from the data collected by Johnson et al. (1995) at the Sagavanirktok River Delta, Alaska. We excluded the neckband retention data for 1987 from the analyses, as did Johnson et al. (1995), because no adhesive was used on the neckbands that year.

For females, the overall annual retention rates declined gradually in the years following banding. Average

Table 11
Minimum seasonal survival estimates (\pm standard errors) of neckbanded adult male Lesser Snow Geese from the Western Canadian Arctic and Wrangel Island, 1987–1992

Period	Western Canadian Arctic		Wrangel Island		Pairwise comparison ^a	
	Survival \pm SE	Probability of resighting \pm SE	Survival \pm SE	Probability of resighting \pm SE	χ^2	P
Wintering in all areas						
Nov 1/87 – Feb 1/88	0.750 \pm 0.063					
Feb 1/88 – Nov 1/88	0.754 \pm 0.050	0.420 \pm 0.058				
Nov 1/88 – Feb 1/89	0.952 \pm 0.050	0.585 \pm 0.048	0.809 \pm 0.053		3.815	0.051
Feb 1/89 – Nov 1/89	0.723 \pm 0.048	0.443 \pm 0.035	0.698 \pm 0.047	0.561 \pm 0.052	0.137	0.711
Nov 1/89 – Feb 1/90	0.833 \pm 0.060	0.491 \pm 0.036	0.836 \pm 0.048	0.639 \pm 0.046	0.001	1.000
Feb 1/90 – Nov 1/90	0.534 \pm 0.057	0.499 \pm 0.040	0.731 \pm 0.066	0.607 \pm 0.043	5.133	0.024
Nov 1/90 – Feb 1/91	0.779 \pm 0.185	0.509 \pm 0.053	0.858 \pm 0.135	0.479 \pm 0.049	0.120	0.730
Feb 1/91 – Nov 1/91	0.254 \pm 0.087	0.322 \pm 0.078	0.470 \pm 0.139	0.449 \pm 0.073	1.730	0.189
Nov 1/91 – Feb 1/92		0.443 \pm 0.122		0.412 \pm 0.114		
Average	0.697 \pm 0.020	0.464 \pm 0.026	0.734 \pm 0.025	0.525 \pm 0.033	1.298	0.255
Average (Nov 1 – Feb 1)	0.828	0.528	0.834	0.559		
Average (Feb 1 – Nov 1) ^b	0.670	0.454	0.715	0.584		
Wintering in California						
Nov 1/87 – Feb 1/88	0.896 \pm 0.059					
Feb 1/88 – Nov 1/88	0.896 \pm 0.051	0.441 \pm 0.064				
Nov 1/88 – Feb 1/89	0.933 \pm 0.054	0.625 \pm 0.052	0.819 \pm 0.077			
Feb 1/89 – Nov 1/89	0.764 \pm 0.056	0.465 \pm 0.041	0.788 \pm 0.080	0.564 \pm 0.079	1.510	0.219
Nov 1/89 – Feb 1/90	0.900 \pm 0.075	0.537 \pm 0.044	0.928 \pm 0.126	0.584 \pm 0.073	0.061	0.805
Feb 1/90 – Nov 1/90	0.552 \pm 0.070	0.471 \pm 0.046	0.760 \pm 0.194	0.496 \pm 0.083	0.036	0.850
Nov 1/90 – Feb 1/91	0.749 \pm 0.171	0.491 \pm 0.060	0.779 \pm 0.458	0.362 \pm 0.099	1.014	0.314
Feb 1/91 – Nov 1/91	0.339 \pm 0.106	0.354 \pm 0.082	inadequate data ^c	0.352 \pm 0.191	0.004	0.951
Nov 1/91 – Feb 1/92		0.511 \pm 0.125		inadequate data ^c		
Average	0.754 \pm 0.018	0.487 \pm 0.028	0.815 \pm 0.088	0.472 \pm 0.064	0.464	0.496
Average (Nov 1 – Feb 1)	0.870	0.551	0.842	0.473		
Average (Feb 1 – Nov 1) ^b	0.737	0.459	0.774	0.530		

^a Pairwise comparison of survival estimates (Sauer and Williams 1989). Significant χ^2 -values ($P \leq 0.05$) indicate regional differences in survival.

^b Average does not include Feb 1/91 – Nov 1/91 because of the small sample size for this period.

^c Sample sizes too small to calculate values.

annual retention rates for one, two, three, four, five, and six years after banding were 0.952 ± 0.016 , 0.940 ± 0.015 , 0.915 ± 0.016 , 0.894 ± 0.017 , 0.886 ± 0.017 , and 0.869 ± 0.017 , respectively.

The smaller data set from the hunter questionnaire provided an independent assessment of neckband loss rates for females from the Western Canadian Arctic and Wrangel Island. Eighteen of 20 females retained their neckbands into the first hunting season, nine of nine retained their neckbands into the second hunting season, and six of seven retained their neckbands into the third season. The annualized neckband retention rate was 0.920 ± 0.045 for the first 2.5 years after collaring. This result was consistent with the short-term retention rates calculated from the Alaska data of Johnson et al. (1995).

Annual neckband retention rates for adult male geese collared and recaptured at the Sagavanirktok Delta averaged 0.696 ± 0.039 after one year, 0.634 ± 0.036 after two years, 0.615 ± 0.036 after three years, and 0.611 ± 0.017 in the four years after marking. Neckband loss from males increased

with the age of the neckbands, to the point where no recaptured geese retained neckbands five years after marking (Johnson et al. 1995). Although the sample was small, it was clearly evident that neckband retention rates for males derived from the hunter questionnaires were higher than those we calculated from the recapture data of Johnson et al. (1995). Thirty-three of 36 geese retained neckbands into the first hunting season, eight of 13 retained neckbands into the second hunting season, and five of five geese retained their neckbands into the third hunting season. The annualized neckband retention rate based on the questionnaires was 0.820 ± 0.058 for the first 2.5 years after marking.

Average minimum survival rates for females were adjusted for neckband loss by dividing the survival rate by the appropriate neckband retention rate (Pollock 1981). For example, the average survival estimate for females from the Western Arctic (0.711 ± 0.016 ; Table 2) based on five years of observations (1987–1988 to 1991–1992) was divided by 0.886 ± 0.017 (the average annual neckband retention rate over five years) to produce a corrected survival estimate of

Table 12

Survival estimates adjusted for neckband loss (\pm standard errors) for female Lesser Snow Geese neckbanded on breeding or wintering areas, 1986–1989. The survival estimates from the models of best fit are presented.

Banding area	Years	Minimum survival estimate	Mean annual neckband retention rate \pm SE ^a	Adjusted survival estimate \pm SE
Western Canadian Arctic	1987–1989	0.711 \pm 0.016	0.886 \pm 0.017	0.802 \pm 0.024
Western Canadian Arctic wintering in California	1987–1989	0.748 \pm 0.017	0.886 \pm 0.017	0.844 \pm 0.025
Western Canadian Arctic neckbanded on the mainland	1987–1989	0.722 \pm 0.020	0.886 \pm 0.017	0.814 \pm 0.027
Western Canadian Arctic neckbanded on the mainland in 1987	1987–1989	0.812 \pm 0.028	0.886 \pm 0.017	0.917 \pm 0.036
Western Canadian Arctic neckbanded on Banks Island in 1987	1987–1989	0.767 \pm 0.039	0.886 \pm 0.017	0.865 \pm 0.047
Alaska	1988–1989	0.758 \pm 0.095	0.894 \pm 0.017	0.848 \pm 0.108
New Mexico	1986–1989	0.695 \pm 0.030	0.886 \pm 0.017	0.784 \pm 0.037
Wrangel Island	1988–1989	0.612 \pm 0.027	0.894 \pm 0.017	0.685 \pm 0.033
Wrangel Island (north-wintering)	1988–1989	0.562 \pm 0.039	0.894 \pm 0.017	0.628 \pm 0.045
Wrangel Island (south-wintering)	1988–1989	0.586 \pm 0.049	0.894 \pm 0.017	0.656 \pm 0.056
British Columbia	1986–1989	0.657 \pm 0.029	0.886 \pm 0.017	0.742 \pm 0.036

^a Mean annual rate of neckband retention is dependent on the number of years of observations for a given group of geese.

0.802 \pm 0.024 (Table 12). The correction for neckband loss raised survival estimates by 0.07–0.11 and increased the size of standard errors by 0.006–0.013 (Table 12). The adjusted survival estimates for Western Arctic females were about 0.11 higher than those for Wrangel Island females. Similarly, the adjusted survival estimate for female geese from Alaska was comparable to that for Western Arctic birds and high relative to the estimate for Wrangel Island. In general, statistical comparisons of the adjusted survival rates indicated similar patterns to that reported previously for the minimum survival estimates (Table 13).

3.7 Survival rates based on legband recoveries

The numbers of geese banded in the Western Canadian Arctic and on Wrangel Island from 1953 to 1989 are summarized in Table 14, and survival and legband recovery estimates for geese from these locations are presented in Tables 15 and 16. (The summary does not include results of banding studies carried out on Wrangel Island in the 1950s and 1960s, many of the records of which were destroyed in a fire.) Samples of adults were large enough for calculating survival estimates for three periods for the Western Arctic (1960–1963, 1973–1975, and 1987–1989) and one period for Wrangel Island (1975–1977). Constant survival models best fit all data sets for adults except for the 1988–1989 Wrangel data, which were very sparse (Table 15).

Survival estimates derived for the 1953–1963 banding study carried out in northern California are presented in Table 17 (Rienecker 1965). This area is an important stopping point for geese of both the Wrangel Island and Western Arctic stocks as they move southward, and the banded sample of geese was composed of birds from both populations. Given the size of the two populations in the 1950s and 1960s (Kerbes et al. 1999, this volume), the banded sample would have consisted of about half Wrangel Island and half Western Arctic geese during that period. We reanalyzed the data for adults using the methods described by Brownie et al. (1985), which were not available when Rienecker (1965) carried out his analyses. None of the models showed good fit to the data set for adults (Table 17).

We were able to calculate survival rates of young (hatch year) geese for three periods (1960–1963, 1973–1975, and 1987–1989) for the Western Arctic and for one period for Wrangel Island (1975–1977). A constant survival model (BROWNIE H02) best fit the 1987–1989 data for the Western Arctic, but none of the models showed good fit to the other data sets (Table 16).

The best information on historic changes in survival rates of Snow Geese in western North America comes from the legbanded samples of adults from the Western Arctic. Statistical comparisons from these data indicated no significant long-term changes in survival rates in the 1960–1963, 1973–1975, or 1987–1989 periods (Table 18). If, however, the survival estimate from the neckband resighting data was used instead of that for the legband recoveries for 1987–1989, the difference among periods was significant. Specifically, pairwise contrasts indicated that the 1960–1963 estimate (0.935) was significantly higher than that for 1987–1989 (0.802). The mean survival rate for adult geese from 1960 to 1989 was 0.852 based on legband recoveries or 0.856 if the 1987–1989 resighting estimate is used.

A comparison between the 1973–1975 Western Arctic adult survival rate and that for Wrangel Island geese for 1975–1977 revealed no statistical significance despite the relatively large difference between estimates.

Survival rates of young geese banded in the Western Arctic differed significantly among the three time periods (Table 18). The only significant pairwise comparison involved the 1987–1989 estimate, which was greater than both the 1960–1963 and 1973–1975 estimates. The survival estimate for young Wrangel Island geese banded during 1975–1977 was not significantly different from that for young geese marked in the Western Arctic during 1973–1975.

3.8 Legband recovery and harvest rates (1953–1989)

Legband recovery rates for both adult and young geese from the Western Arctic varied among time periods, increasing from 1960–1963 to 1973–1975 and then declining in 1987–1989 (Tables 15 and 16). As has been reported in

Table 13

Statistical comparisons of survival estimates (adjusted for neckband loss) for adult female Lesser Snow Geese (Sauer and Williams 1989). Significant χ^2 -values ($P \leq 0.05$) indicate differences in survival estimates.

Comparisons	df	χ^2	P	Group with higher estimate
Western Canadian Arctic, Alaska, and Wrangel Island	2	8.846	0.012	See comparisons below
Western Canadian Arctic and Alaska	1	0.170	0.680	—
Western Canadian Arctic and Wrangel Island	1	8.240	0.004	Western Canadian Arctic
Alaska and Wrangel Island	1	2.082	0.149	—
New Mexico and Wrangel Island	1	3.991	0.046	New Mexico
Western Canadian Arctic wintering in California and south-wintering Wrangel Island	1	9.428	0.002	Western Canadian Arctic
Western Canadian Arctic and New Mexico	1	0.175	0.676	—
North- and south-wintering Wrangel Island	1	0.150	0.699	—
British Columbia and Wrangel Island	1	1.355	0.244	—
British Columbia and north-wintering Wrangel Island	1	3.873	0.049	British Columbia

Table 14

Number of Lesser Snow Geese banded in the Western Canadian Arctic, on Wrangel Island, and in the Klamath Basin, California, 1953–1989

Year	Banding area	Number banded		
		Adult	Young	Total
1953	Western Canadian Arctic	79	0	79
	California	485	269	754
1954	California	970	592	1562
1955	Western Canadian Arctic	177	122	299
	California	706	357	1063
1956	California	461	434	895
1957	California	372	270	642
1958	California	753	251	1004
1959	Western Canadian Arctic	134	96	230
	California	475	579	1054
1960	Western Canadian Arctic	614	1056	1670
	California	503	325	828
1961	Western Canadian Arctic	762	1050	1812
	California	238	270	508
1962	Western Canadian Arctic	371	647	1018
	California	482	452	934
1963	Western Canadian Arctic	190	976	1166
	California	563	497	1060
1964	Western Canadian Arctic	0	0	1 ^a
1966	Western Canadian Arctic	103	121	224
1973	Western Canadian Arctic	688	749	1438 ^a
1974	Western Canadian Arctic	269	205	474
	Wrangel Island	1	0	1
1975	Western Canadian Arctic	383	546	930 ^a
	Wrangel Island	224	372	596
1976	Western Canadian Arctic	71	126	197
	Wrangel Island	265	231	496
1977	Wrangel Island	489	231	720
1979	Western Canadian Arctic	1	0	1
	Wrangel Island	49	0	49
1987	Western Canadian Arctic	1279	887	2172 ^a
1988	Western Canadian Arctic	888	835	1723
	Wrangel Island	1240	0	1243 ^a
1989	Western Canadian Arctic	732	311	1043
	Wrangel Island	460	0	460

^a Total includes individuals of unknown age.

Table 15

Annual survival and recovery estimates (\pm standard errors) determined from legband recoveries of adult Lesser Snow Geese from the Western Canadian Arctic and Wrangel Island, 1960–1989. The annual and average survival estimates are based on the estimate model M1, and the overall survival estimates are based on the constant survival model (M2). The survival estimate (average or overall) based on the best model (i.e., the simplest model that fit) is in bold type.

Banding area	Year	Survival \pm SE	Recovery estimate \pm SE
Western Canadian Arctic	1960	0.952 \pm 0.096	0.055 \pm 0.009
	1961	0.946 \pm 0.124	0.050 \pm 0.006
	1962	0.836 \pm 0.156	0.024 \pm 0.004
	1963		0.032 \pm 0.006
	Average	0.911 \pm 0.050	0.041 \pm 0.003
Overall (1960–1963)		0.935 \pm 0.047	0.026 \pm 0.002
Western Canadian Arctic	1973	0.882 \pm 0.131	0.055 \pm 0.009
	1974	0.749 \pm 0.133	0.070 \pm 0.011
	1975		0.041 \pm 0.007
	Average	0.816 \pm 0.061	0.056 \pm 0.005
	Overall (1973–1975)	0.832 \pm 0.062	0.032 \pm 0.003
Western Canadian Arctic	1987	0.753 \pm 0.119	0.043 \pm 0.006
	1988	0.809 \pm 0.146	0.020 \pm 0.004
	1989		0.026 \pm 0.004
	Average	0.781 \pm 0.070	0.030 \pm 0.003
	Overall (1987–1989)	0.789 \pm 0.069	0.021 \pm 0.002
Wrangel Island	1975	0.497 \pm 0.115	0.094 \pm 0.020
	1976	0.850 \pm 0.177	0.103 \pm 0.017
	1977		0.041 \pm 0.008
	Average	0.673 \pm 0.090	0.079 \pm 0.009
	Overall (1975–1977)	0.668 \pm 0.084	0.074 \pm 0.013
Wrangel Island	1988	1.076 \pm 0.286	0.036 \pm 0.005
	1989		0.013 \pm 0.004
	Average	1.076 \pm 0.286 ^a	0.024 \pm 0.003
	Overall (1988–1989)	1.134 \pm 0.302^a	0.008 \pm 0.001

^a Neither Model M1 nor Model M2 fit the data (goodness-of-fit tests, $\chi^2 = 22.7$, $P < 0.0001$ for both models), so the model of best fit is unknown.

Table 16

Annual survival and recovery estimates (\pm standard errors) determined from legband recoveries of adult and young Lesser Snow Geese from the Western Canadian Arctic and Wrangel Island, 1960–1989. The annual and average survival estimates are based on the BROWNIE Model H1, and the overall survival estimates are based on the constant survival model (BROWNIE Model H02). The survival estimate (average or overall) based on the best model (i.e., the simplest model that fit) is in bold type.

Banding area and year	Adults		Young	
	Survival \pm SE	Recovery estimate \pm SE	Survival \pm SE	Recovery estimate \pm SE
Western Canadian Arctic				
1960	0.952 \pm 0.096	0.055 \pm 0.009	0.186 \pm 0.030	0.056 \pm 0.007
1961	0.921 \pm 0.121	0.055 \pm 0.006	0.390 \pm 0.060	0.081 \pm 0.008
1962	0.828 \pm 0.154	0.026 \pm 0.004	0.415 \pm 0.083	0.045 \pm 0.008
1963		0.036 \pm 0.006		0.075 \pm 0.008
Average	0.900 \pm 0.049	0.043 \pm 0.003	0.330 \pm 0.036	0.064 \pm 0.004
Overall (1960–1963)	inadequate data	inadequate data	inadequate data	inadequate data
Western Canadian Arctic				
1973	0.882 \pm 0.131	0.055 \pm 0.009	0.314 \pm 0.059	0.079 \pm 0.010
1974	0.732 \pm 0.129	0.073 \pm 0.011	0.144 \pm 0.066	0.112 \pm 0.022
1975		0.043 \pm 0.007		0.099 \pm 0.013
Average	0.807 \pm 0.059	0.057 \pm 0.005	0.229 \pm 0.044	0.097 \pm 0.009
Overall (1973–1975)	inadequate data ^a	inadequate data ^a	inadequate data ^a	inadequate data ^a
Western Canadian Arctic				
1987	0.753 \pm 0.119	0.043 \pm 0.006	0.418 \pm 0.089	0.038 \pm 0.006
1988	0.831 \pm 0.149	0.019 \pm 0.003	0.553 \pm 0.118	0.038 \pm 0.007
1989		0.025 \pm 0.004		0.051 \pm 0.013
Average	0.792 \pm 0.071	0.029 \pm 0.003	0.485 \pm 0.074	0.043 \pm 0.005
Overall (1987–1989)	0.833 \pm 0.060	0.019 \pm 0.002	0.527 \pm 0.071	0.043 \pm 0.005
Wrangel Island				
1975	0.497 \pm 0.115	0.094 \pm 0.020	0.156 \pm 0.048	0.065 \pm 0.013
1976	0.870 \pm 0.177	0.101 \pm 0.017	0.549 \pm 0.153	0.091 \pm 0.019
1977		0.037 \pm 0.007		0.030 \pm 0.011
Average	0.684 \pm 0.089	0.077 \pm 0.009	0.352 \pm 0.080	0.062 \pm 0.009
Overall (1975–1977)	inadequate data ^a	inadequate data ^a	inadequate data ^a	inadequate data ^a

^a Sample sizes too small to estimate values.

many studies of waterfowl (Brownie et al. 1985), recovery rates for young birds were higher than those for adults.

Recovery rates for adult Snow Geese banded in California averaged 0.045 for the 1953–1963 banding period (Table 17) and were somewhat higher than the rates for adult geese marked in the Western Arctic in the 1960s (0.026–0.032; Table 15). During the 1970s, recovery rates were greater for Wrangel Island adults than for Western Arctic adults. The difference possibly reflected heavier hunting pressure on the Wrangel Island stock, but the data are difficult to interpret because the years of banding do not entirely correspond and because most Wrangel Island geese were collared whereas the Western Arctic birds were only legbanded. In contrast to the situation for adults, the recovery rates of young (which were legbanded only) were in fact higher for the Western Arctic than for Wrangel Island in the 1970s. This result suggested that the high recovery rate for Wrangel Island adults in the 1970s may have been, in part, an artifact of collaring (see Samuel et al. 1990b). During

1987–1989, overall recovery rates for Wrangel Island adults were not significantly different from the rates for Western Arctic geese.

Harvest rates, calculated from the legband recovery data, suggested that about 11% of the adult and 19% of the young geese in the overall Wrangel Island/Western Arctic population were harvested each year in the 1950s and 1960s (Table 19). Harvest rates increased to about 15% for adults and 26% for young geese in the 1970s and dropped to <7% for adults and 13% for young in the late 1980s.

Harvest rates computed using estimates of population size and reported harvest were higher than those calculated from legband recoveries (Table 19), but general trends corresponded to that determined from the legband recovery data. Considering both methods of harvest rate calculation together suggested that overall harvest rates for the combined Wrangel Island/Western Arctic population were about 15–20% in the 1960s and 1970s and \leq 10% in the late 1980s.

Table 17

Annual survival and recovery estimates (\pm standard errors) determined from legband recoveries of adult Lesser Snow Geese banded at the Klamath Basin, California, 1953–1963 (data from Rienecker 1965). The annual and average survival estimates are based on the estimate model M1, and the overall survival estimates are based on the constant survival model (M2).

Year	Survival \pm SE	Recovery estimate \pm SE
1953	0.837 \pm 0.106	0.083 \pm 0.013
1954	0.760 \pm 0.084	0.043 \pm 0.006
1955	0.659 \pm 0.082	0.042 \pm 0.005
1956	1.095 \pm 0.179	0.061 \pm 0.008
1957	0.598 \pm 0.097	0.042 \pm 0.007
1958	0.716 \pm 0.099	0.037 \pm 0.005
1959	1.344 \pm 0.235	0.031 \pm 0.005
1960	0.514 \pm 0.121	0.037 \pm 0.006
1961	0.753 \pm 0.189	0.050 \pm 0.010
1962	1.205 \pm 0.309	0.021 \pm 0.004
1963		0.044 \pm 0.009
Average	0.848 \pm 0.033 ^a	0.045 \pm 0.002
Overall (1953–1963)	0.802 \pm 0.013 ^a	0.046 \pm 0.002

^a Neither model fit the data (goodness-of-fit tests: Jolly-Seber, $\chi^2 = 78.1$, $P = 0.0008$; constant survival model, $\chi^2 = 95.2$, $P = 0.0003$), so the model of best fit is unknown.

4. Discussion

Both the numbers (Kerbes et al. 1999, this volume) and fall–winter distribution (Armstrong et al. 1999, this volume; Hines et al. 1999, this volume) of Snow Geese have changed greatly in the Pacific Flyway and neighbouring parts of the Western Central Flyway over the past 35–40 years. The Egg River breeding colony on Banks Island, which comprises >95% of the Western Arctic Population, has more than quadrupled in size since the 1960s. In contrast, the

Wrangel Island Population declined rapidly in the early 1970s and has since fluctuated around a level half its former size. Smaller proportions of both populations winter in the Central Valley of California than previously. High adult survival rates (>85%) are associated with the increasing Midcontinent Snow Goose Population that breeds in the Central and Eastern Arctic (Francis and Cooke 1992). Elsewhere, relatively low survival rates (<70%) were associated with decreasing populations of Atlantic Flyway Canada Geese (Hestbeck 1994, 1995) and Pacific Flyway Greater White-fronted Geese *Anser albifrons* (Timm and Dau 1979). We wished to evaluate the effect that regional and historic differences in survival might have on changes in distribution and numbers of Snow Geese in the Pacific and Western Central flyways. Before we can do that, however, we must first consider the general reliability of the results.

4.1 Reliability of results and possible biases

Survival analyses can provide an overwhelming array of rates, standard errors, χ^2 statistics, and P-values that are difficult to interpret and sometimes conflicting. The biological significance that can be attributed to these values depends on the assumptions that it is safe to make about the data set. As discussed below, both neckband loss and the nature of the marking and observation efforts placed constraints on the representativeness of the recent (1987–1989) collaring observation data.

4.1.1 Neckband loss

Minimum survival rates of male geese for most locations and years were lower than survival rates for females from the same banding areas or years. Undoubtedly,

Table 18

Statistical comparisons of average survival estimates and recovery estimates determined from legband recoveries from Lesser Snow Geese (Sauer and Williams 1989). Significant χ^2 -values ($P \leq 0.05$) indicate differences in survival. Comparisons were done with estimates from the models of best fit.

Comparisons	df	χ^2	P	Group with higher estimate
Survival estimates from legband recoveries				
Western Canadian Arctic 1960–1963, 1973–1975, and 1987–1989 — adults	2	3.633	0.163	—
Western Canadian Arctic 1960–1963, 1973–1975, and 1987–1989 — young	2	12.814	0.002	See comparisons below
1960–1963 and 1973–1975	1	3.188	0.074	—
1960–1963 and 1987–1989	1	6.131	0.013	1987–1989
1973–1975 and 1987–1989	1	12.686	0.000	1987–1989
Western Canadian Arctic 1973–1975 and Wrangel Island 1975–1977 — adults	1	2.489	0.115	—
Western Canadian Arctic 1973–1975 and Wrangel Island 1975–1977 — young	1	1.811	0.178	—
Western Canadian Arctic 1987–1989 and Wrangel Island 1988–1989 — adults	1	0.948	0.330	—
Wrangel Island 1975–1977 and 1988–1989 — adults	1	1.874	0.171	—
Recovery estimates from legband recoveries				
Western Canadian Arctic 1960–1963, 1973–1975, and 1987–1989 — adults	2	12.213	0.002	See comparisons below
1960–1963 and 1973–1975	1	3.818	0.051	—
1960–1963 and 1987–1989	1	3.883	0.049	1960–1963
1973–1975 and 1987–1989	1	11.834	0.001	1973–1975
Western Canadian Arctic 1960–1963, 1973–1975, and 1987–1989 — young	2	28.133	0.000	See comparisons below
1960–1963 and 1973–1975	1	10.690	0.001	1973–1975
1960–1963 and 1987–1989	1	10.541	0.001	1960–1963
1973–1975 and 1987–1989	1	26.349	0.000	1973–1975
Western Canadian Arctic 1973–1975 and Wrangel Island 1975–1977 — adults	1	11.168	0.001	Wrangel Island
Western Canadian Arctic 1973–1975 and Wrangel Island 1975–1977 — young	1	7.765	0.005	Western Canadian Arctic
Western Canadian Arctic 1987–1989 and Wrangel Island 1988–1989 — adults	1	0.641	0.424	—
Wrangel Island 1975–1977 and 1988–1989	1	15.076	0.000	1975–1977

Table 19

Changes in harvest estimates for Lesser Snow Geese, 1953–1989, determined by using recovery estimates from banded birds and by using the estimated population size and reported harvest for Pacific Flyway Snow Geese. The recovery estimates from the models of best fit are presented.

Year	Banding area	Age	Recovery estimate	Harvest rate
1953–1963	California	Adult	0.045	0.135
1960–1963	Western Canadian Arctic	Adult	0.026	0.078
		Young	0.064	0.192
1973–1975	Western Canadian Arctic	Adult	0.032	0.096
		Young	0.097	0.291
1987–1989	Western Canadian Arctic	Adult	0.021	0.063
		Young	0.043	0.129
1975–1977	Wrangel Island	Adult	0.074	0.222
		Young	0.062	0.186
1988–1989	Wrangel Island	Adult	0.024	0.072

Year	Fall population size ^a	Reported harvest ^b	Harvest rate
1961–1970	408 400	84 718 ^c	0.207
1971–1979	403 800	74 242	0.184
1981–1989	473 800	47 138	0.099

^a Summer population estimates from breeding grounds (Kerbes et al. 1999, this volume) adjusted for 19% young in the autumn population from Wrangel Island (Boyd 1995) and for 30% young in the remainder of the population (Subcommittee on White Geese 1992b). Assumed that 20% of the Western Canadian Arctic population were nonbreeders.

^b Reported harvest from Sharp (1996). Includes both adult and young geese.

^c Reported harvest is for 1962–1970.

much of this indicated difference was a function of the differences in neckband loss rates, which averaged >10% per annum for females and possibly 40% or more for males. Therefore, despite substantial differences between minimum survival estimates for males and females for several samples, there was not a valid reason to conclude that survival rates of the two sexes were different. Two independent sources of information — geese recaptured in Alaska (Johnson et al. 1995) and questionnaires sent to hunters who reported shooting banded geese from the Western Arctic or Wrangel Island — suggested that the neckband retention rates for males might have been influenced by a number of factors, including year and geographic location of collaring, method of estimating neckband retention, and the age of the neckband. Given the low, highly variable, and uncertain rates of neckband retention for male geese, we believe it is difficult to adjust the data to provide unbiased estimates of survival rates for males.

Other studies suggest that survival rates of male and female geese might differ at least under some circumstances. For example, nesting females might be more susceptible to starvation or more vulnerable to predation than males, and males may be more sensitive to avian cholera than females (McLandress 1983). Given the suspected impact of arctic fox *Alopex lagopus* predation on Wrangel Island Snow Geese (Bousfield and Syroechkovsky 1985) and the prevalence of avian cholera among Pacific Flyway Snow Geese (Friend et al. 1987), there is a need to know more about the relative survival rates of the two sexes. For such studies to be successful, improved methods for marking male geese and better ways of estimating neckband loss may be required. We echo the sentiments of Hestbeck et al. (1990), Nichols et al. (1992), and others — evaluating neckband loss should be an important component of any capture–recapture study of collared waterfowl.

The two sources of information on neckband loss provided high and very similar estimates of average neckband retention for female Snow Geese for the different areas, so we have taken the approach of adjusting the average or overall estimates of survival rates using the average neckband retention rate. To check further on the reliability of this approach, we compared survival estimates derived from legband recoveries and neckband observations for the only banding area and time period for which adequate data were available (i.e., the Western Arctic data for 1987–1989). The estimates, 0.802 ± 0.024 using the mark:resight approach and 0.789 ± 0.069 from legband recoveries, were similar. Therefore, the adjusted survival estimates for females seem reasonable.

4.1.2 Marking and observing geese

An important source of bias that needs to be considered in any mark:resight study is how well the marked or resighted samples represent the populations from which they were taken. The large flocks of flightless geese captured on the breeding grounds are certainly not random samples from the populations (Sulzbach and Cooke 1978), and the same is likely true of the cannon-netted samples from the wintering grounds as well (Raveling 1966). The comparisons between banding areas reported here are based on the assumption that these sorts of biases were not severe or, if they occurred, acted similarly on the different marked samples.

A particular problem might be noted for the sample of geese banded in the Western Canadian Arctic. For logistical reasons, collaring was carried out on the mainland (mainly at Anderson River) during all three years (1987–1989) but at Banks Island, which comprises most of the population, only during 1987. Both the fall–winter distribution (Hines et al. 1999, this volume) and survival rates (Table 12) of the Banks Island and mainland samples were similar over the 1987–1989 period, so it seemed reasonable to consider the mainland geese as representative of the Western Arctic Population.

The neckband observation data were gathered over a four- or five-year period through a large but geographically diverse and temporally variable observation effort. The network of observers had as a main goal determining the fall–winter distribution of Snow Geese from different regions (Kerbes and Meeres 1999, this volume); for this reason, the study design was not optimal for a survival study. Ideally, such a study would be carried out over an even greater number of years, with more intensive observations over narrow and rigorously defined observation periods each year.

Most samples indicated a relative decrease in survival rates throughout time. Undoubtedly, neckband loss was a major factor influencing this pattern, a goose that lost its neckband being effectively the same as a dead goose from an analytical viewpoint. If neckband loss were the only factor involved here, the correction for neckband loss should have helped overcome this bias. The reduced observation effort in the later years of study might also possibly influence survival estimates. This may have been especially true in Mexico, where it was logistically much more difficult to observe collared geese at the same level of intensity as at some of the other sites.

Errors in reading neckband codes are frequent in studies of collared geese, especially for inexperienced observers (Raveling et al. 1990; Kerbes and Meeres 1999,

this volume). As a check on the effect that such errors might have on the reliability of our survival estimates, we repeated the analyses for the Western Arctic sample, treating only geese that were sighted two or more times as alive in a given sampling period. The mean minimum survival estimate from this analysis (0.697 ± 0.028) was very similar to that obtained using single observations (0.711 ± 0.016), so we concluded that errors in reading neckband codes did not alter survival estimates. Weiss et al. (1991) reached a similar conclusion for Canada Geese.

Despite the possible shortcomings in our data set mentioned above, the fit to the Jolly-Seber model was good for most samples, resighting rates were very high, and most survival and resighting rates were precise for the data from collared females. Given the robust nature of the Jolly-Seber survival estimator (Carothers 1973, 1979; Pollock et al. 1990), we believe that a number of generalizations and conclusions can be drawn from the data on female geese collared from 1986 to 1989 and for geese of both sexes banded in earlier years. The implications of these results are discussed below.

4.2 Regional and seasonal differences in survival

Collared adult female Snow Geese from the Western Canadian Arctic had significantly higher survival rates than females from Wrangel Island in the late 1980s. Legband recoveries suggested that a similar pattern may also have existed in the 1970s (Fig. 2), although the results were not statistically significant, possibly because of small sample sizes. The available data indicate that average survival rates for Western Arctic adults may have been 0.10 or more greater than those of the Wrangel Island adults during the late 1980s.

The actual causes of the differences in survival rates in recent years are open to speculation. During the late 1980s, both direct legband recovery rates (0.034 ± 0.004 for Wrangel Island adults, 0.035 ± 0.003 for Western Arctic adults) and overall annual recovery rates (0.024 ± 0.003 for Wrangel Island, 0.021 ± 0.002 for the Western Arctic) were similar for geese from the two populations. Therefore, differences in harvest rates for the two populations did not seem to account for the recent differences in adult survival. In the 1970s, however, recovery rates of Wrangel Island adults were higher than for Western Arctic adults, although the opposite was true for young birds. The difference in adult recovery rates in the 1970s might be caused by a factor other than differential hunting pressure on the two populations. Specifically, the Wrangel Island geese were collared, and legband reporting rates are sometimes higher for neckbanded than for legbanded-only birds (Samuel et al. 1990b).

Two additional lines of evidence suggested that nonhunting mortality outside the wintering period might account for survival differences between Wrangel Island and Western Arctic geese. First, Snow Geese of the two populations sharing common wintering grounds in California (and presumably subjected to similar sources and levels of mortality during winter) had highly different survival rates. Second, calculations of seasonal rates indicated no significant difference in survival rates of Wrangel Island and Western Arctic females during winter (1 November – 1 February) but lower survival rates for Wrangel Island

females during the spring–summer–early fall period (1 February – 1 November) of at least one year.

A variety of biotic and environmental factors might operate differently on Wrangel Island and Western Arctic Snow Geese during the spring and summer. Migrating Wrangel Island geese follow a longer and possibly more arduous route than Western Arctic geese and, once they arrive on the breeding grounds, usually face harsher and more unpredictable weather conditions than the Western Arctic birds. High rates of predation by arctic foxes have been observed on Wrangel Island and might also be the cause of lower survival rates of Wrangel Island geese (Bousfield and Syroechkovsky 1985). Similarly, avian cholera might differentially impact the Wrangel Island and Western Arctic stocks of geese (M.D. Samuel, pers. commun.).

The neckband data provide no strong evidence that north-wintering geese from Wrangel Island survived better than those wintering farther south in California over the 1988–1989 period. If this is a generalization that can be extended to other years, the recent change in abundance of the two stocks must be explained by factors other than differential mortality of north- and south-wintering stocks. Recent changes in movement patterns or differences in productivity of the two stocks are alternative explanations that need to be evaluated. Elsewhere in this volume, we have suggested that changes in movement patterns rather than regional differences in survival or productivity are the most likely cause of changes in the distribution of Snow Geese in the Pacific and Western Central flyways (Hines et al. 1999). We note, however, that survival rates from the present data set refer only to adult geese, and there is also a need for a detailed evaluation of the survival of young geese from this and other stocks.

4.3 Management implications

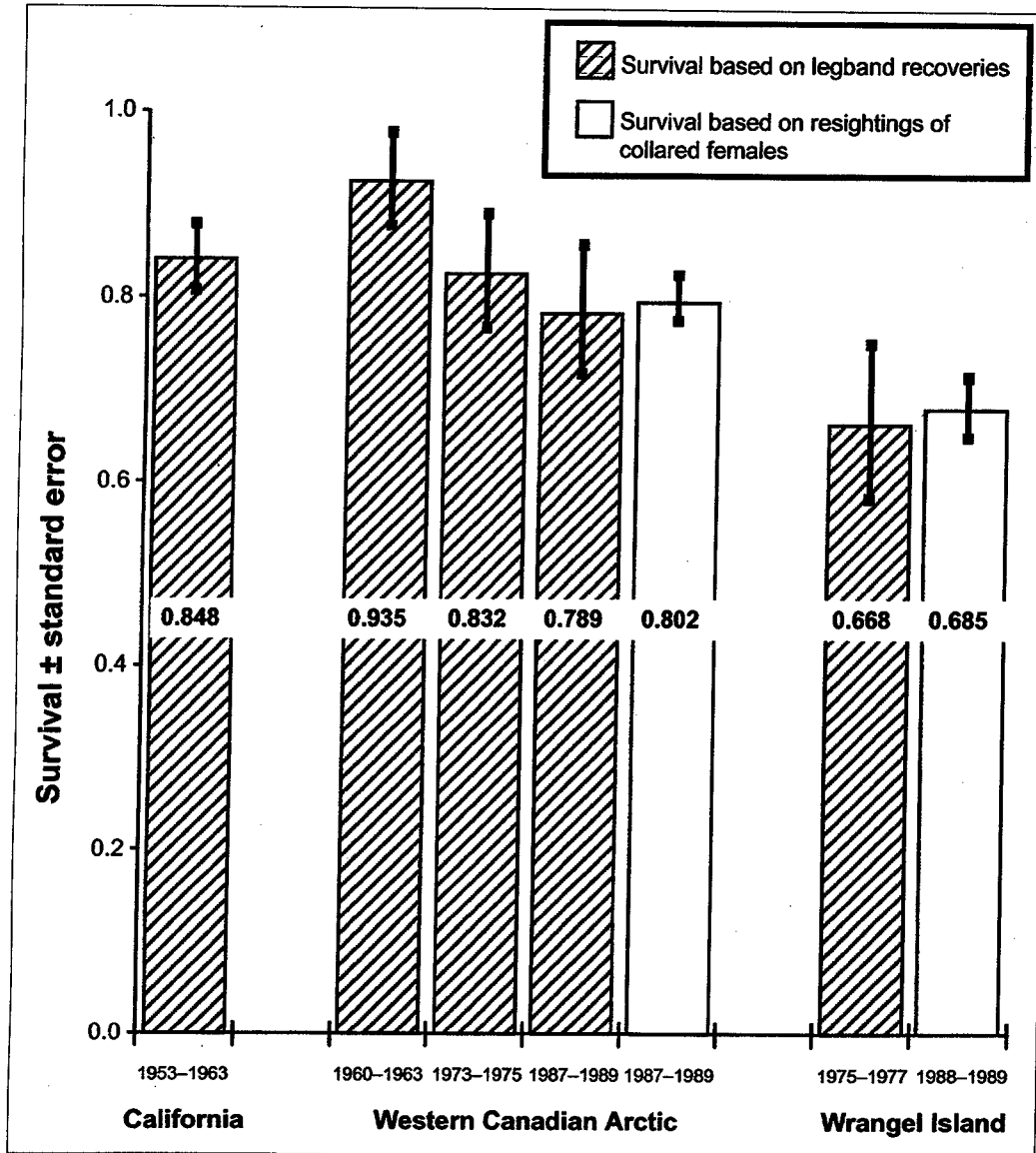
The Western Arctic Population of Snow Geese has grown over the past several decades, and the survival rates of adult geese are high. Thus, a larger harvest of this population seems warranted. The geese do not seem to have increased to the level where they are seriously damaging habitat on the breeding grounds, as witnessed in the Hudson Bay area (Kerbes et al. 1990; Abraham and Jefferies 1997), but it would be prudent to take measures to reduce the rate of population growth before the number of geese becomes too large to be readily influenced by traditional forms of harvest management (liberalizing seasons and bag limits).

Although the Western Arctic Population has grown rapidly, the Wrangel Island stock of geese is not doing as well, and the average adult survival rate for this population is among the lowest reported for Snow Geese (Francis and Cooke 1992). An optimum harvest strategy should involve directing the harvest towards the growing Western Arctic stock while minimizing the harvest on the declining southern stock of Wrangel Island geese. Implementing such a strategy would not be simple.

Harvest rates of Western Arctic geese were nearly twice as high in the 1960s and 1970s (15–20%) as they were in the late 1980s (<10%), but the population still grew slowly. Returning the harvest rate to the 1960s and 1970s level, seemingly a safe harvest strategy, would amount to a doubling of the recent kill of Snow Geese in western North

Figure 2

Change in survival (\pm standard errors) of adult Lesser Snow Geese legbanded or neckbanded in California, the Western Canadian Arctic, and Wrangel Island, 1953–1989. The survival estimates from the models of best fit are presented.



America, from about 50 000 geese to 100 000 geese (Table 19).

Traditionally, over 80% of the Snow Goose harvest in the Pacific Flyway has occurred in Oregon and California, and the greatest potential for increasing the harvest on Western Arctic geese is there. However, the number of Western Arctic birds wintering in Oregon and California does not seem to have increased in recent years (Hines et al. 1999, this volume; Kerbes et al. 1999, this volume), and a greater harvest of this population segment might not be sustainable. In any event, increasing the harvest of Snow Geese in this region might further jeopardize the south-wintering stock of Wrangel Island geese, which overlaps both spatially and temporally with the Western Arctic Population throughout much of the late fall and winter. A safer approach would be to increase the fall harvest of Snow Geese in Alberta, Saskatchewan, and Montana, the winter harvest in the Western Central Flyway, or the spring subsistence harvest in the western Northwest Territories. The number of hunters and

the demand for more Snow Goose hunting opportunities in these areas are limited, however, and the total take of geese there would have to be increased by a factor of about four to reach a harvest objective of 100 000 geese. In addition, any increase in harvest in the Western Arctic would need to be focused on geese returning to Banks Island (where the vast majority of the Western Arctic Population nests) and avoid geese from the small and less secure colonies at Anderson River and Kendall Island.

5. Acknowledgements

The information reported here is truly the result of a large cooperative effort by banders, observers, and resource management agencies. The numerous people providing observations of collared geese are outlined in detail elsewhere in this volume. In addition, we especially acknowledge the banding efforts carried out on Wrangel Island in the 1960s and 1970s by E.V. Syroechkovsky and

associates and in the Western Canadian Arctic from the 1960s through 1980s by T.W. Barry (Canadian Wildlife Service). The funding procured through the Inuvialuit Final Land Claim Agreement and administered by the Wildlife Management Advisory Council of the Inuvialuit Settlement Region was instrumental in getting the Western Arctic banding program, and ultimately the International Snow Goose Neckbanding Project, up and running in 1987. We also thank S. Boyd, S. Slattery, D. Duncan, and K. Meeres for reviewing the manuscript and K. Meeres and O. Daku for their efforts in inputting, proofing, and managing the data.

6. Literature cited

- Abraham, K.F.; Jefferies, R.L. 1997.** High goose populations: causes, impacts, and implications. Pages 7–72 in B.D.J. Batt (ed.), Arctic ecosystems in peril: report of the Arctic Goose Habitat Working Group. Arctic Goose Joint Venture Special Publication, U.S. Fish and Wildlife Service, Washington, D.C., and Canadian Wildlife Service, Ottawa, Ontario. 120 pp.
- Armstrong, W.T.; Meeres, K.M.; Kerbes, R.H.; Boyd, W.S.; Silveira, J.G.; Taylor, J.P.; Turner, B. 1999.** Routes and timing of migration of Lesser Snow Geese from the Western Canadian Arctic and Wrangel Island, Russia, 1987–1992. Pages 75–88 in R.H. Kerbes, K.M. Meeres, and J.E. Hines (eds.), Distribution, survival, and numbers of Lesser Snow Geese of the Western Canadian Arctic and Wrangel Island, Russia. Can. Wildl. Serv. Occas. Pap. No. 98, Ottawa, Ontario.
- Arnason, A.N.; Mills, K.H. 1981.** Bias and loss of precision due to tag loss in Jolly-Seber estimates for mark-recapture experiments. Can. J. Fish. Aquat. Sci. 38:1077–1095.
- Bart, J.; Robson, D.S. 1982.** Estimating survivorship when the subjects are visited periodically. Ecology 63:1078–1090.
- Bellrose, F.C. 1976.** The ducks, geese, and swans of North America. 2nd ed. Stackpole Books, Harrisburg, Pennsylvania. 544 pp.
- Bousfield, M.A.; Syroechkovsky, E.V. 1985.** A review of Soviet research on the Lesser Snow Goose on Wrangel Island, USSR. Wildfowl 36:13–20.
- Boyd, W.S. 1995.** Lesser Snow Geese (*Anser c. caerulescens*) and American three-square bulrush (*Scirpus americanus*) on the Fraser and Skagit river deltas. Unpublished Ph.D. thesis, Department of Biological Sciences, Simon Fraser University, North Burnaby, B.C. 154 pp.
- Brownie, C.; Anderson, D.R.; Burnham, K.P.; Robson, D.S. 1985.** Statistical inference from band-recovery data: a handbook. 2nd ed. U.S. Fish Wildl. Serv. Resour. Publ. 156, Washington, D.C.
- Burnham, K.P.; Anderson, D.R.; White, G.C.; Brownie, C.; Pollock, K.H. 1987.** Design and analysis methods for fish survival experiments based on release-recapture. Am. Fish. Soc. Monogr. No. 5, Bethesda, Maryland.
- Campbell, B.H.; Becker, E.F. 1991.** Neck collar retention in dusky Canada Geese. J. Field Ornithol. 62:521–527.
- Carothers, A.D. 1973.** The effects of unequal catchability on Jolly-Seber estimates. Biometrics 29:79–100.
- Carothers, A.D. 1979.** Quantifying unequal catchability and its effect on survival estimates in actual population. J. Anim. Ecol. 48:863–869.
- Conroy, M.J.; Blandin, W.W. 1984.** Geographic and temporal differences in band reporting rates for American Black Ducks. J. Wildl. Manage. 48:23–36.
- Conroy, M.J.; Hines, J.E.; Williams, B.K. 1989.** Procedures for the analysis of band-recovery data and user instructions for program MULT. U.S. Fish Wildl. Resour. Publ. 175, Washington, D.C. 61 pp.
- Cooch, F.G. 1953.** Techniques for mass capture of blue and Lesser Snow Geese. J. Wildl. Manage. 17:460–465.
- Dzubin, A. 1979.** Recent increases of blue geese in western North America. Pages 141–175 in R.L. Jarvis and J.C. Bartonek (eds.), Management and biology of Pacific Flyway geese. Oregon State University Book Stores, Corvallis, Oregon.
- Ebbinge, B.S.; van Biezen, J.B.; van de Voet, H. 1991.** Estimation of annual adult survival rates of Barnacle Goose *Branta leucopsis* using multiple resightings of marked individuals. Ardea 79:73–112.
- Francis, C.M.; Cooke, F. 1992.** Sexual differences in survival and recovery rates of Lesser Snow Geese. J. Wildl. Manage. 56:287–296.
- Friend, M.; Laitman, C.J.; Kampen, R.S. 1987.** Field guide to wildlife diseases. Vol. 1. General field procedures and diseases of migratory birds. U.S. Fish Wildl. Serv. Resour. Publ. 167, Washington, D.C. 225 pp.
- Hestbeck, J.B. 1994.** Survival of Canada Geese banded in winter in the Atlantic Flyway. J. Wildl. Manage. 58:748–756.
- Hestbeck, J.B. 1995.** Population study and management of Atlantic Flyway Canada Geese. J. Appl. Stat. 22:877–890.
- Hestbeck, J.B.; Rusch, D.H.; Malecki, R.A. 1990.** Estimating population parameters for geese from band-recovery and mark-recapture data. Trans. North Am. Wildl. Nat. Resour. Conf. 55:350–373.
- Heyland, J.D. 1970.** Aircraft-supported Canada Goose banding operations in arctic Quebec. Trans. North East Fish Wildl. Conf. 27:187–198.
- Hines, J.E.; Sauer, J.R. 1989.** Program CONTRAST — a general program for the analysis of several survival or recovery rate estimates. U.S. Fish Wildl. Serv. Tech. Rep. 24, Washington, D.C. 7 pp.
- Hines, J.E.; Baranyuk, V.V.; Turner, B.; Boyd, W.S.; Silveira, J.G.; Taylor, J.P.; Barry, S.J.; Meeres, K.M.; Kerbes, R.H.; Armstrong, W.T. 1999.** Autumn and winter distributions of Lesser Snow Geese from the Western Canadian Arctic and Wrangel Island, Russia, 1953–1992. Pages 39–73 in R.H. Kerbes, K.M. Meeres, and J.E. Hines (eds.), Distribution, survival, and numbers of Lesser Snow Geese of the Western Canadian Arctic and Wrangel Island, Russia. Can. Wildl. Serv. Occas. Pap. No. 98, Ottawa, Ontario.
- Johnson, S.R. 1996.** Immigration in a small population of Snow Geese. Auk 112:731–736.
- Johnson, S.R.; Schieck, J.O.; Searing, G.F. 1995.** Neck band loss rates in Lesser Snow Geese. J. Wildl. Manage. 59:747–752.
- Jolly, G.M. 1965.** Explicit estimates from capture-recapture data with both death and immigration — stochastic model. Biometrika 52:225–247.
- Kerbes, R.H.; Meeres, K.M. 1999.** Project overview. Pages 15–24 in R.H. Kerbes, K.M. Meeres, and J.E. Hines (eds.), Distribution, survival, and numbers of Lesser Snow Geese of the Western Canadian Arctic and Wrangel Island, Russia. Can. Wildl. Serv. Occas. Pap. No. 98, Ottawa, Ontario.
- Kerbes, R.H.; Kotanen, P.M.; Jefferies, R.L. 1990.** Destruction of wetland habitats by Lesser Snow Geese: a keystone species on the west coast of Hudson Bay. J. Appl. Ecol. 27:242–258.
- Kerbes, R.H.; Baranyuk, V.V.; Hines, J.E. 1999.** Estimated size of the Western Arctic and Wrangel Island Lesser Snow Goose populations on their breeding and wintering grounds. Pages 25–38 in R.H. Kerbes, K.M. Meeres, and J.E. Hines (eds.), Distribution, survival, and numbers of Lesser Snow Geese of the Western Canadian Arctic and Wrangel Island, Russia. Can. Wildl. Serv. Occas. Pap. No. 98, Ottawa, Ontario.
- Krebs, C.J. 1989.** Ecological methodology. Harper and Row Publishers, New York, N.Y.
- Lebreton, J.D.; Burnham K.P.; Clobert, J.; Anderson, D.R. 1992.** Modeling survival and testing biological hypotheses using marked animals: a unified approach with case studies. Ecol. Monogr. 62:67–118.
- Maltby, L. 1977.** Techniques used for the capture, handling and marking of Brant in the Canadian High Arctic. Can. Wildl. Serv. Prog. Notes No. 72, Ottawa, Ontario. 6 pp.

- Martinson, R.K.; McCann, J.A. 1966.** Proportion of recovered goose and brant bands that are reported. *J. Wildl. Manage.* 30:856–858.
- McKelvey, R.; Bousfield, M.; Reed, A.; Baranyuk, V.V.; Canniff, R. 1989.** Preliminary results of the Lesser Snow Goose collaring program on the Alaksen National Wildlife Area, 1986 and 1987. *Can. Wildl. Serv. Prog. Notes* No. 183, Ottawa, Ontario. 5 pp.
- McLandress, M.R. 1983.** Sex, age and species differences in disease mortality of Ross' and Lesser Snow geese in California: implications for avian cholera research. *Calif. Fish Game* 69:196–206.
- Nichols, J.D.; Blohm, R.J.; Reynolds, R.E.; Trost, R.E.; Hines, J.E.; Bladen, J.P. 1991.** Band reporting rates for mallards and reward bands of different dollar values. *J. Wildl. Manage.* 55:119–126.
- Nichols, J.D.; Bart, J.; Limpert, R.J.; Sladen, W.J.L.; Hines, J.E. 1992.** Annual survival rates of adult and immature eastern population Tundra Swans. *J. Wildl. Manage.* 56:485–494.
- Pollock, K.H. 1981.** Capture–recapture models: a review of current methods, assumptions, and experimental design. Pages 426–435 in C.J. Ralph and J.M. Scott (eds.), *Estimating the numbers of terrestrial birds. Proceedings of an International Symposium at Asilomar, California, 26–31 October 1980. Studies in Avian Biology* 6, Cooper Ornithological Society.
- Pollock, K.H.; Nichols, J.D.; Brownie, C.; Hines, J.E. 1990.** Statistical inference for capture–recapture experiments. *Wildl. Monogr.* 107: 1–97.
- Raveling, D.G. 1966.** Factors affecting age ratios of samples of Canada Geese caught with cannon-nets. *J. Wildl. Manage.* 30:682–691.
- Raveling, D.G.; Zezulak, D.S.; Silveira, J.G.; Weldon, J.A. 1990.** Accuracy in recording neck-band codes of cackling Canada Geese. *Calif. Fish Game* 76:205–210.
- Rienecker, W.C. 1965.** A summary of band returns from Lesser Snow Geese (*Chen hyperborea*) of the Pacific Flyway. *Calif. Fish Game* 51:132–146.
- Samuel, M.D.; Weiss, N.T.; Rusch, D.H.; Craven, S.R.; Trost, R.E.; Caswell, F.D. 1990a.** Neck-band retention for Canada Geese in the Mississippi Flyway. *J. Wildl. Manage.* 54:612–621.
- Samuel, M.D.; Weiss, N.T.; Rusch, D.H.; Craven, S.R. 1990b.** Influence of neck bands on recovery and survival rates of Canada Geese. *J. Wildl. Manage.* 54(1):45–54.
- Sauer, J.R.; Williams, B.K. 1989.** Generalized procedures for testing hypotheses about survival or recovery rates. *J. Wildl. Manage.* 53:137–142.
- Seber, G.A.F. 1965.** A note on the multiple–recapture census. *Biometrika* 52:249–259.
- Sharp, D.E. (compiler). 1996.** Central Flyway harvest and population survey data book 1996. Unpublished report, U.S. Fish and Wildlife Service, Golden, Colorado. 113 pp.
- Subcommittee on White Geese. 1992a.** Pacific Flyway management plan for the Wrangel Island Population of Lesser Snow Geese. Unpublished report, Pacific Flyway Study Committee, U.S. Fish and Wildlife Service, Portland, Oregon. 25 pp.
- Subcommittee on White Geese. 1992b.** Pacific Flyway Management Plan for the Western Arctic Population of Lesser Snow Geese. Unpublished report, Pacific Flyway Study Committee, U.S. Fish and Wildlife Service, Portland, Oregon. 30 pp.
- Sulzbach, D.; Cooke, F. 1978.** Elements of nonrandomness in mass-captured samples of snow geese. *J. Wildl. Manage.* 42:437–441.
- Taylor, J.P.; Kirby, R.E. 1990.** Experimental dispersal of wintering Snow and Ross' geese. *Wildl. Soc. Bull.* 18:312–319.
- Timm, D.E.; Bromley, R.G. 1976.** Driving Canada Geese by helicopter. *Wildl. Soc. Bull.* 4:180–181.
- Timm, D.E.; Dau, C.P. 1979.** Productivity, mortality, distribution, and population status of Pacific Flyway White-fronted Geese. Pages 280–298 in R.L. Jarvis and J.C. Bartonek (eds.), *Management and biology of Pacific Flyway geese: a symposium. Oregon State University Book Stores, Corvallis, Oregon.*
- Turner, B.; Tomlinson, R.; Leyva, R.; Dominguez, P. 1994.** Wintering populations of Lesser Snow Geese and Ross' Geese in the Northern Highlands of México, 1988–1990. *Can. Wildl. Serv. Occas. Pap.* No. 84, Ottawa, Ontario. 21 pp.
- Weiss, N.T.; Samuel, M.D.; Rusch, D.H.; Caswell, F.D. 1991.** Effects of resighting errors on capture–resight estimates for neck-banded Canada Geese. *J. Field Ornithol.* 62:464–473.

Mineral staining of facial plumage as an indicator of the wintering ground affinities of Wrangel Island Lesser Snow Geese

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Abstract

Lesser Snow Geese *Anser caerulescens caerulescens* (hereafter referred to as Snow Geese) from Wrangel Island, Russia, can be divided into two different groups based on their wintering ground affinities. A northern group winters at the Fraser and Skagit river deltas of British Columbia and Washington, whereas a southern group, after stopping in the Fraser-Skagit area during fall migration, continues on to winter in the Central Valley of California. It was previously shown that the north-wintering birds, because they fed extensively by grubbing in tidal marshes, tended to have reddish-coloured faces from mineral staining. In contrast, the south-wintering geese fed in agricultural fields and tended to retain their white facial plumage. Face colour scores could be used to identify the wintering ground affiliations of 86–90% of the Wrangel Island geese in the late 1970s and the early 1980s. We evaluated the continued reliability of face staining as an indicator of the wintering grounds of Snow Geese neckbanded during 1988 and 1989 on Wrangel Island. The face colour of 1357 geese neckbanded on Wrangel Island was scored using a subjective scale of 0 (no staining) to 10 (maximum staining) in 1988 and 0 to 9 in 1989. Neckband observations indicated that 86% of the geese in the lower three classes ($n = 226$) individually identified during winter were in California and 90% of the geese in the upper three classes ($n = 209$) wintered in the Fraser-Skagit area. Geese with intermediate scores (3–7 in 1988, 3–6 in 1989) made up 35% of the captured sample but could not be closely associated with wintering areas based on face staining. Although face staining is not now as broadly applicable as a natural marker as it had been previously, it still should be useful in studies comparing the productivity, survival, or migration patterns of the two different stocks of geese, while acknowledging that samples obtained by face staining scores may be missing a significant proportion of the population. An additional variable (size and wear of feathers on the head) might be used to enhance the reliability of the technique.

Résumé

Les Petites Oies des neiges *Anser caerulescens caerulescens* (appelées ci-après Oies des neiges) provenant de l'île Wrangel, en Russie, peuvent être divisées en deux groupes différents en fonction de leurs affinités aux aires d'hivernage. Un groupe du nord hiverne dans les deltas du fleuve Fraser et

de la rivière Skagit de la Colombie-Britannique et de l'État de Washington, tandis qu'un groupe du sud, après une halte dans la région Fraser-Skagit pendant la migration d'automne, poursuit sa route pour hiverner dans la vallée centrale de la Californie. On avait déjà démontré que la face des oiseaux hivernant dans le nord était souvent d'une couleur rougeâtre qui était attribuable aux minéraux se trouvant dans le sol des marais maritimes où les oiseaux se nourrissaient principalement. Par contraste, les oies hivernant dans le sud se nourrissaient dans les champs agricoles et avaient tendance à conserver leur plumage facial blanc. Vers la fin des années 1970 et au début des années 1980, on pouvait se servir d'un système d'attribution de points pour la couleur faciale afin d'identifier les affinités vis-à-vis des aires d'hivernage de 86 à 90 p. 100 des oies de l'île Wrangel. Nous avons évalué la fiabilité continue des taches faciales pour indiquer les aires d'hivernage des Oies des neiges baguées au cou en 1988 et en 1989 sur l'île Wrangel. On a attribué des points pour la couleur faciale de 1 357 oies baguées au cou à l'île Wrangel en utilisant une échelle subjective de 0 (aucune tache) à 10 (beaucoup de taches) en 1988 et de 0 à 9 en 1989. Les observations des bagues de cou ont indiqué que 86 p. 100 des oies des trois classes inférieures ($n = 226$) qui avaient été individuellement identifiées passaient l'hiver en Californie, tandis que 90 p. 100 des oies des trois classes supérieures ($n = 209$) hivernaient dans la région Fraser-Skagit. Les oies qui obtenaient des évaluations intermédiaires (3 à 7 en 1988, 3 à 6 en 1989) représentaient 35 p. 100 des échantillons capturés, mais on ne pouvait pas établir un lien étroit avec les aires d'hivernage en fonction des taches faciales. Bien que l'utilisation des taches faciales à titre d'indicateur naturel ne soit pas aujourd'hui aussi généralisée qu'auparavant, elle devrait toutefois s'avérer encore utile dans le cadre d'études comparant la productivité, la survie ou le comportement migratoire des deux troupeaux différents, tout en reconnaissant le fait que les échantillons obtenus au moyen de l'évaluation des taches faciales pourraient ne pas inclure une partie importante de la population. On pourrait utiliser une variable supplémentaire (taille et usure des plumes de la tête) pour accroître la fiabilité de la technique.

1. Introduction

Lesser Snow Geese *Anser caerulescens caerulescens* (hereafter referred to as Snow Geese) breeding on Wrangel Island, Russia, winter in two distinct areas. A south-wintering group mixes with geese from the Western Arctic in the Central Valley of California, and a north-wintering group uses the deltas of the Fraser and Skagit rivers in British Columbia–Washington (Subcommittee on White Geese 1992a, 1992b). Geese of the south-wintering group feed mainly in agricultural fields, whereas geese of the north-wintering group, in addition to feeding in agricultural fields, forage extensively in tidal marshes, where they grub for bulrush (*Scirpus americanus*) rhizomes (Boyd 1995).

As a result of frequent grubbing in salt marshes, the white facial plumage takes on a heavy red staining from iron oxides in the substrate. Using a three-class scoring system, Baranyuk and Syroechkovsky (1994) recorded the degree of mineral staining on the faces of Snow Geese breeding on Wrangel Island in the late 1970s and early 1980s. They demonstrated, with information on marked birds from known wintering locations, that 90% of the redder-faced geese wintered in the north and that 86% of the whiter-faced birds wintered in the south.

Conditions that lead to the differences in face colours between north- and south-wintering geese seem to have changed since the late 1970s and early 1980s, when Baranyuk and Syroechkovsky (1994) carried out their work. Particularly, the geese in the Fraser Delta now spend much more of their time feeding in upland areas than they did previously (W.S. Boyd, pers. commun.).

We ranked face staining for Snow Geese neckbanded on Wrangel Island in 1988 and 1989. Our objective was to determine if face stain scores remained a reliable indicator of wintering ground affinities of Wrangel Island Snow Geese. The continued existence of such a marker would be valuable for linking specific demographic variables to the wintering ground affinities of the geese and for understanding what effect events on the wintering ground might be having on the population.

2. Methods

Adult geese were captured during banding drives in 1988 and 1989 on Wrangel Island. The face colour of captured adult geese was scored on a subjective scale ranging from 0 (white or no staining) to 10 (reddish or maximum staining) in 1988, and from 0 to 9 in 1989. The data were recorded only by the senior author to standardize the technique as much as possible. The age and sex of captured geese were recorded, and 1357 adult geese (898 in 1988, 459 in 1989) were equipped with red plastic neckbands with white alpha-numeric codes.

Neckbanded geese were individually identified on the wintering grounds by observers using spotting scopes. Birds sighted from 1 December to 1 February were treated as being present on the wintering grounds, as most migration is completed at this time (Bellrose 1976; Armstrong et al. 1999, this volume). The percentage of the geese by face colour score that wintered in each major wintering area was used to determine how reliable the scores were for indicating wintering ground affinities. For this purpose, we recognized

Table 1

The number of male and female Lesser Snow Geese (n) in each face score class that wintered in each location.^a

Year	Face score	North		South		Central		Both (North and South)	
		n	(%)	n	(%)	n	(%)	n	(%)
1988	0	9	(13.8)	53	(81.5)	0	(0.0)	3	(4.6)
	1	4	(8.0)	41	(82.0)	1	(0.0)	4	(8.0)
	2	5	(8.8)	50	(87.7)	0	(0.0)	2	(3.5)
	3	5	(33.3)	10	(66.7)	0	(0.0)	0	(0.0)
	4	29	(29.0)	61	(61.0)	1	(1.0)	9	(9.0)
	5	11	(45.8)	10	(41.7)	2	(8.3)	1	(4.2)
	6	11	(61.1)	7	(38.9)	0	(0.0)	0	(0.0)
	7	42	(61.8)	21	(30.9)	1	(1.5)	4	(5.9)
	8	15	(88.2)	1	(5.9)	0	(0.0)	1	(5.9)
	9	24	(85.7)	3	(10.7)	1	(3.6)	0	(0.0)
	10	90	(90.9)	7	(7.1)	1	(1.0)	1	(1.0)
Total (1988)		245	(45.3)	264	(48.8)	7	(1.3)	25	(4.6)
1989	0	2	(4.5)	42	(95.5)	0	(0.0)	0	(0.0)
	1	1	(25.0)	3	(75.0)	0	(0.0)	0	(0.0)
	2	0	(0.0)	6	(100.0)	0	(0.0)	0	(0.0)
	3	1	(16.7)	4	(66.7)	1	(16.7)	0	(0.0)
	4	5	(35.7)	7	(50.0)	1	(7.1)	1	(7.1)
	5	2	(20.0)	8	(80.0)	0	(0.0)	0	(0.0)
	6	5	(50.0)	3	(30.0)	1	(10.0)	1	(10.0)
	7	2	(100.0)	0	(0.0)	0	(0.0)	0	(0.0)
	8	10	(83.3)	0	(0.0)	1	(8.3)	1	(8.3)
	9	48	(94.1)	2	(3.9)	1	(2.0)	0	(0.0)
Total (1989)		76	(47.8)	75	(47.2)	5	(3.1)	3	(1.9)

^a North = Fraser and Skagit river deltas; South = California; Central = southern Washington and northern Oregon; Both = sighted in both North and South regions during winter.

three broad wintering areas: 1) the Fraser and Skagit river deltas of British Columbia–Washington (referred to as the North area); 2) California (the South area); and 3) southern Washington and northern Oregon (the Central area). In addition, a few birds were sighted in both the North and South areas during the wintering period. We designated geese in this category as wintering in “both” areas. Only “direct” sightings of collared geese (those made during the winter following banding) were used in the analyses.

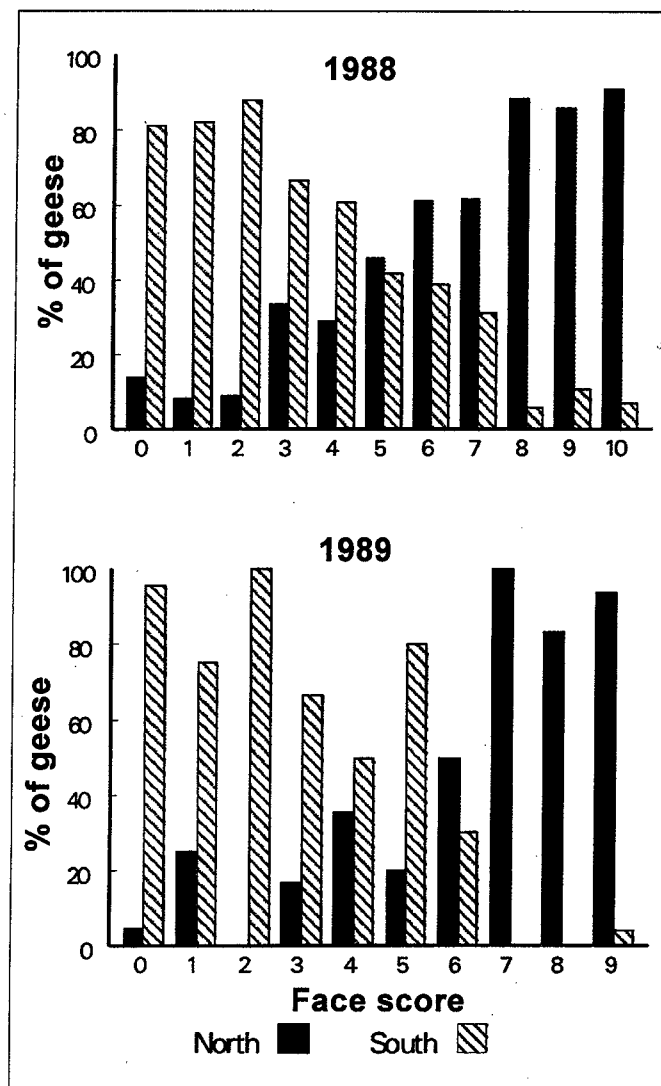
3. Results and discussion

At least 75% of the geese marked in a given year were resighted within the seven months after banding (see Kerbes and Meeres 1999, this volume, for details of observer effort and success). More than half (52%, or 700 of 1357) of the geese neckbanded and scored for face colour on Wrangel Island were resighted during the “wintering” period.

High or low (but not intermediate) face colour scores proved to be good indicators of wintering area. Observations on the wintering grounds revealed that 86% (195 of 226) of the neckbanded geese in the three lowest classes wintered in California, and 90% (189 of 209) of those in the upper three classes wintered in British Columbia or Washington (Table 1). We therefore believe it was valid to treat these two categories of individuals as samples of the south- and north-wintering components of the population, respectively. The middle grouping of face colour scores (scores 3–7 in

Figure 1

The percentage of Wrangel Island Lesser Snow Geese by face colour scores that wintered in the Fraser-Skagit area (North) or California (South). Data shown here are for both males and females.



1988, 3–6 in 1989) proved to be ambiguous as an indicator of wintering area (Table 1; Fig. 1).

Using only the upper three and lower three face colour classes, 86% of the females ($n = 205$) and 91% of the males ($n = 228$) could be correctly classified to wintering area (Tables 2 and 3). The difference between sexes was not statistically significant ($\chi^2 = 2.575$, 1 df, $P = 0.1086$), possibly owing to small sample sizes.

About 33% of the 1357 geese marked on Wrangel Island in 1988 and 1989 were placed in the lower three colour classes, and 32% of the geese were placed in the upper three (red) classes. Therefore, it would have been reasonable to try to predict the wintering areas for 65% of the population marked from 1988 to 1989. The remaining 35% of the geese were in the intermediate face colour classes, and their wintering ground affinities could not be determined from feather staining. In contrast, face colour was an accurate predictor of the wintering grounds of most (86–90%) of the Wrangel Island geese in the late 1970s and early 1980s (Baranyuk and Syroechkovsky 1994). Changes in the foraging behaviour of the geese in the Fraser Delta

Table 2

The number of female Lesser Snow Geese (n) in each face score class that wintered in each location^a

Year	Face score	North		South		Central		Both (North and South)	
		n	(%)	n	(%)	n	(%)	n	(%)
1988	0	3	(9.1)	27	(81.8)	0	(0.0)	3	(9.1)
	1	3	(11.1)	20	(74.1)	0	(0.0)	4	(14.8)
	2	2	(8.7)	20	(87.0)	0	(0.0)	1	(4.3)
	3	1	(16.7)	5	(83.3)	0	(0.0)	0	(0.0)
	4	14	(26.4)	34	(64.2)	1	(1.9)	4	(7.5)
	5	9	(60.0)	5	(33.3)	1	(6.7)	0	(0.0)
	6	5	(55.6)	4	(44.4)	0	(0.0)	0	(0.0)
	7	26	(68.4)	10	(26.3)	1	(2.6)	1	(2.6)
	8	6	(85.7)	0	(0.0)	0	(0.0)	1	(14.3)
	9	16	(88.9)	2	(11.1)	0	(0.0)	0	(0.0)
	10	41	(87.2)	5	(10.6)	0	(0.0)	1	(2.1)
Total (1988)		126	(45.7)	132	(47.8)	3	(1.1)	15	(5.4)
1989	0	1	(5.3)	18	(94.7)	0	(0.0)	0	(0.0)
	1	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
	2	0	(0.0)	3	(100.0)	0	(0.0)	0	(0.0)
	3	0	(0.0)	2	(66.7)	1	(33.3)	0	(0.0)
	4	2	(40.0)	2	(40.0)	0	(0.0)	1	(20.0)
	5	0	(0.0)	4	(100.0)	0	(0.0)	0	(0.0)
	6	3	(60.0)	1	(20.0)	1	(20.0)	0	(0.0)
	7	2	(100.0)	0	(0.0)	0	(0.0)	0	(0.0)
	8	6	(75.0)	0	(0.0)	1	(12.5)	1	(12.5)
	9	17	(94.4)	1	(5.6)	0	(0.0)	0	(0.0)
Total (1989)		31	(46.3)	31	(46.3)	3	(4.5)	2	(3.0)

^a North = Fraser and Skagit river deltas; South = California; Central = southern Washington and northern Oregon; Both = sighted in both North and South regions during winter.

likely account for this difference. In the 1970s, Snow Geese using the Fraser Delta fed almost exclusively in salt-marsh habitats (Jeffrey and Kaiser 1979); now, however, they feed extensively in fields as well (Boyd 1995).

Despite the changes noted above, our results suggest that face colour can still be used to indicate the wintering ground affiliations of a significant proportion of the Wrangel Island Snow Goose Population. It has the advantage that large samples of geese of known wintering ground affiliation can be observed without any effort, expense, or disturbance to the geese required for "marking." Previously, this natural marker has been used to assess the relative productivity and brood sizes of north- and south-wintering geese (V.V. Baranyuk, unpubl. data), as well as to determine the relative dates of arrival and nesting of the two different stocks of geese on Wrangel Island (Baranyuk and Syroechkovsky 1994).

In studies involving actual capturing of geese, face colour scores may allow researchers to accurately predict where geese will winter and thereby to allocate neckbanding, radio-tagging, or other sampling efforts effectively. We caution that such studies still need to be carefully thought out, as one-third of the population, which might have different patterns of habitat use and demography, would be eliminated from the sample because of intermediate face colour score.

Finally, we note one other variable that might be used to enhance the reliability of the technique. The geese wintering in California feed in grain stubble, and this seems

Table 3

The number of male Lesser Snow Geese (n) in each face score class that wintered in each location^a

Year	Face score	North		South		Central		Both (North and South)	
		n	(%)	n	(%)	n	(%)	n	(%)
1988	0	6	(18.8)	26	(81.3)	0	(0.0)	0	(0.0)
	1	1	(4.3)	21	(91.3)	1	(0.0)	0	(0.0)
	2	3	(8.8)	30	(88.2)	0	(0.0)	1	(2.9)
	3	4	(44.4)	5	(55.6)	0	(0.0)	0	(0.0)
	4	15	(31.9)	27	(57.4)	0	(0.0)	5	(10.6)
	5	2	(22.2)	5	(55.6)	1	(11.1)	1	(11.1)
	6	6	(66.7)	3	(33.3)	0	(0.0)	0	(0.0)
	7	16	(53.3)	11	(36.7)	0	(0.0)	3	(10.0)
	8	9	(90.0)	1	(10.0)	0	(0.0)	0	(0.0)
	9	8	(80.0)	1	(10.0)	1	(10.0)	0	(0.0)
	10	48	(96.0)	1	(2.0)	1	(2.0)	0	(0.0)
Total (1988)		118	(44.9)	131	(49.8)	4	(1.5)	10	(3.8)
1989	0	1	(4.0)	24	(96.0)	0	(0.0)	0	(0.0)
	1	1	(25.0)	3	(75.0)	0	(0.0)	0	(0.0)
	2	0	(0.0)	3	(100.0)	0	(0.0)	0	(0.0)
	3	1	(33.3)	2	(66.7)	0	(0.0)	0	(0.0)
	4	3	(33.3)	5	(55.6)	1	(11.1)	0	(0.0)
	5	2	(33.3)	4	(66.7)	0	(0.0)	0	(0.0)
	6	2	(40.0)	2	(40.0)	0	(0.0)	1	(20.0)
	7	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
	8	4	(100.0)	0	(0.0)	0	(0.0)	0	(0.0)
	9	31	(93.9)	1	(3.0)	1	(3.0)	0	(0.0)
Total (1989)		45	(48.9)	44	(47.8)	2	(2.2)	1	(1.1)

^a North = Fraser and Skagit river deltas; South = California; Central = southern Washington and northern Oregon; Both = sighted in both North and South regions during winter.

to cause greater feather wear and reduced feather size on the faces of many geese (V.V. Baranyuk, pers. obs.). Consideration of this variable when birds are being scored might further enhance the predictive value of the face stain scores.

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5. Literature cited

- Armstrong, W.T.; Meeres, K.M.; Kerbes, R.H.; Boyd, W.S.; Silveira, J.G.; Taylor, J.P.; Turner, B. 1999. Routes and timing of migration of Snow Geese from the Western Canadian Arctic and Wrangel Island, Russia, 1987–1992. Pages 75–88 in R.H. Kerbes, K.M. Meeres, and J.E. Hines (eds.), Distribution, survival, and numbers of Lesser Snow Geese of the Western Canadian Arctic and Wrangel Island, Russia. Can. Wildl. Serv. Occas. Pap. No. 98, Ottawa, Ontario.
- Baranyuk, V.V.; Syroechkovsky, E.V. 1994. The usage of the natural marks in Wrangel Island Snow Geese for the population studies. Ornithologica 26:45–49 (in Russian).
- Bellrose, F.C. 1976. The ducks, geese, and swans of North America. 2nd ed. Stackpole Books, Harrisburg, Pennsylvania. 544 pp.
- Boyd, W.S. 1995. Lesser Snow Geese (*Anser c. caerulescens*) and American three-square bulrush (*Scirpus americanus*) on the Fraser and Skagit river deltas. Unpublished Ph.D. thesis, Department of Biological Sciences, Simon Fraser University, North Burnaby, B.C. 154 pp.
- Jeffrey, R.; Kaiser, G. 1979. The Snow Goose flock of the Fraser and Skagit deltas. Pages 266–279 in R.L. Jarvis and J.C. Bartonek (eds.), Management and biology of Pacific Flyway geese. Oregon State University Book Stores, Corvallis, Oregon.
- Kerbes, R.H.; Meeres, K.M. 1999. Project overview. Pages 15–24 in R.H. Kerbes, K.M. Meeres, and J.E. Hines (eds.), Distribution, survival, and numbers of Lesser Snow Geese of the Western Canadian Arctic and Wrangel Island, Russia. Can. Wildl. Serv. Occas. Pap. No. 98, Ottawa, Ontario.
- Subcommittee on White Geese. 1992a. Pacific Flyway management plan for the Wrangel Island Population of Lesser Snow Geese. Unpublished report, Pacific Flyway Study Committee, U.S. Fish and Wildlife Service, Portland, Oregon. 25 pp.
- Subcommittee on White Geese. 1992b. Pacific Flyway management plan for the Western Arctic Population of Lesser Snow Geese. Unpublished report, Pacific Flyway Study Committee, U.S. Fish and Wildlife Service, Portland, Oregon. 30 pp.

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