Monitoring of Bird Abundance and Distribution at McKinley Bay and Hutchison Bay, Northwest Territories, 1981 to 1993

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ABSTRACT

McKinley Bay has been identified as a preferred site for a harbour to support oil and gas production in the Beaufort Sea. As the bay is a moulting area for several species of diving duck, this study was initiated to monitor the effect of harbour development on divers and other birds using the bay. Baseline information on the natural annual fluctuations in the number of birds were collected for nine years at McKinley Bay and eight years at nearby Hutchison Bay, the area chosen as the control. This is the final report of the predevelopment phase of the monitoring study. Results of the 1993 surveys and a summary of results of all years of surveys are presented.

Aerial surveys were conducted each year from 1981 to 1985 and 1990 to 1993 on the first day in early August when census conditions were satisfactory. A series of east-west transects 2 km apart was flown across each bay, and all birds within 180 m of the aircraft flight line were recorded.

An estimated 10 667 ± 2723 diving ducks were in McKinley Bay on August 1, 1993. As in other years, densities of Oldsquaws were highest in the area just south of Atkinson Point. At Hutchison Bay, there were an estimated 18 485 ± 969 diving ducks.

There were significantly more diving ducks in McKinley Bay in early August 1990 to 1993, on average, than from 1981 to 1985 ($p<0.05$). No statistically significant change in total diving ducks was noted at Hutchison Bay. Numbers of Oldsquaws and scoters, the most common divers, varied substantially between years at the two bays. However, numbers of the two species did not vary to the same degree. For example, in 1985, when ice covered much of the bays in early August, we counted less than one-tenth the number of scoters seen the previous year at McKinley Bay. Oldsquaw numbers in 1985, however, were similar to levels in previous years. Also, despite the close proximity of McKinley and Hutchison bays, the relative abundance of diving ducks did not always fluctuate in a similar way at both bays. For example, the number of scoters at McKinley Bay in 1993 was less than half the number seen the previous year, whereas over the same time period at Hutchison Bay, scoters increased in number.

Significantly more Pacific Loons, Red-throated Loons and Northern Pintails were recorded in the recent set of surveys (1990 to 1993) at McKinley Bay, than in the earlier surveys from 1981 to 1985 ($p<0.05$). Other species such as Brant, Greater White-fronted Geese and Tundra Swans fluctuated in number from year-to-year, but there were no significant changes in number between the first and the later set of surveys. At Hutchison Bay, there were more Red-breasted Mergansers in the recent set of surveys, but no other significant changes in numbers of birds.

Potential explanations for the large between-year fluctuations in diving duck numbers are discussed. The variations may be due to bird responses to changes in the physical environment, or related to the limitations of aerial surveys. Amount of cloud cover, height of waves, time of day, flock sizes and observer skill all affect the accuracy of surveys. We were able to reduce the effect of many of these factors by the survey method used. Ecological factors affecting numbers of divers in

the bays in early August include nesting chronology, nest success, ice cover in the bays when the birds arrive to moult, and availability of food. Measurement of these factors was beyond the scope of this study, but might have enhanced our ability to interpret the survey results.

Because of the large natural fluctuations in numbers of moulting diving ducks using these bays in early August, it will be difficult to detect future impacts of industrial disturbance, even when sources of survey bias are minimized. At McKinley Bay, the number of diving ducks would have to change by more than 82% before we could attribute the changes to human activity. Thus, we conclude that aerial surveys of moulting diving ducks in these bays are not suitable for monitoring the effects of industrial development.

RÉSUMÉ

La baie McKinley a été désignée comme étant le site idéal pour créer un port qui servira de soutien logistique à la production de produits pétroliers et gaziers dans la mer de Beaufort. Étant donné que la baie sert d'aire de mue à plusieurs espèces de canards plongeurs, la présente étude a été entreprise afin de contrôler les répercussions qu'aurait la création d'un port sur les plongeurs ainsi que sur les autres oiseaux qui fréquentent la baie. Pendant neuf ans, on a rassemblé des renseignements fondamentaux sur les fluctuations annuelles naturelles du nombre d'oiseaux fréquentant la baie McKinley. Les mêmes données ont été recueillies pendant huit ans dans une baie voisine, la baie Hutchinson, qui a d'ailleurs été choisie pour le contrôle. Le présent rapport est le dernier de l'étape préliminaire de l'étude de contrôle. On présente ici les résultats des enquêtes de 1993 ainsi qu'un résumé des résultats de toutes les enquêtes précédentes.

Des relevés aériens ont été effectués chaque année de 1981 à 1985, et de 1990 à 1993, le premier jour du début d'août où les conditions de recensement étaient satisfaisantes. On a effectué une série de vols au-dessus de chaque baie, suivant des bandes étroites d'est en ouest à 2 km d'intervalle, et tous les oiseaux qui se trouvaient à moins de 180 m de la ligne de vol ont éte enregistrés.

On estime que 10 667 ± 2 723 canards plongeurs se trouvaient dans la baie McKinley le 1er août 1993. Comme lors de relevés précédents, les densités de canards kakawis étaient le plus élevées dans la région située juste au sud de la pointe Atkinson. Dans la baie Hutchinson, on estime qu'il y avait 18 485 ± 969 canards plongeurs.

Dans la baie McKinley, il y avait en moyenne beaucoup plus de canards plongeurs de 1990 à 1993 que de 1981 à 1985 ($p<0,05$ p. 100). Dans la baie Hutchinson, on n'a pas remarqué de changement important dans les statistiques sur la totalité des canards plongeurs. Le nombre des canards kakawis et des macreuses, qui sont les plongeurs les plus communs, varie considérablement d'une année à l'autre dans les deux baies. Le nombre des deux espèces ne varie cependant pas dans les mêmes proportions. En 1985, par exemple, alors que la glace recouvrait la plus grande partie des baies au début d'août, nous avons dénombré moins de 10 p. 100 des macreuses qui se trouvaient l'année précédente dans la baie McKinley. En 1985, cependant, le nombre des canards kakawis était le même qu'en 1984. En outre, malgré la proximité des deux baies, le nombre relativement abondant des canards plongeurs n'a pas toujours subi les mêmes changements.

Dans la baie McKinley, on a enregistré bien plus de huarts du Pacifique, de huarts à gorge rousse et de canards pilets dans la dernière série de relevés (de 1990 à 1993) que lors des relevés datant de 1981 à 1985 ($p<0,05$ p.100). D'autres espèces comme la bernache cravant, l'oie rieuse et le cygne siffleur ont subi des fluctations d'année en année, mais on n'a pas constaté de changement important entre la première et la dernière série de relevés. Dans la baie Hutchinson, le nombre des becs-scies à poitrine rousse était plus élevé lors de la dernière série de relevés, mais aucun autre changement important n'a été noté en ce qui concerne le nombre d'oiseaux.

On avance des explications possibles aux grandes fluctuations qui ont lieu d'année en année dans le nombre des canards plongeurs. Les variations peuvent être dues à la réaction des oiseaux aux changements qui ont lieu dan l'environnement physique, ou elles peuvent être liées aux limites intrinsèques des relevés aériens. Les facteurs écologiques qui ont des répercussions sur le nombre des plongeurs dans les baies au début d'août comprennent la chronologie des couvées, le résultat de la couvée, l'épaisseur de glace encore présente dans les baies quand les oiseaux arrivent pour la période de la mue, et la quantité de nourriture qu'ils peuvent trouver. L'importance de la nébulosité, la hauteur des vagues, le moment de la journée et la taille des troupeaux influent tous sur l'exactitude des relevés. Nous avons cependant tenté de limiter les causes les plus importantes de biais.

À cause des grandes fluctuations naturelles du nombre des canards plongeurs fréquentant les baies au début d'août, au moment de la mue, les répercussions occasionnées par l'exploitation industrielle seront difficilement décelables à l'avenir, même lorsque les sources de biais sont minimisées. Nous en concluons que les relevés aériens des canards plongeurs présents dans ces baies au moment de la mue ne permettent pas de contrôler les répercussions de l'exploitation industrielle.

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1.0 INTRODUCTION

McKinley Bay is a shallow sheltered bay along the Tuktoyaktuk Peninsula in the eastern Beaufort Sea, NWT. Each year, tens of thousands of diving ducks migrate there to moult between mid-July and mid-August (Cornish and Allen 1983, Cornish and Dickson 1986, Scott-Brown et al 1981). During the wing-moult, the diving ducks become flightless and relatively sedentary for a period of about three weeks. Large concentrations of moulting diving ducks are particularly vulnerable to oil spills and other contaminants (Vermeer and Anweiler 1975).

The existence of moulting areas separate from the nesting grounds is an ecological adaptation that ultimately serves to increase brood survival (Salomonsen 1968). Breeding males, as well as non-breeders of both sexes (1-2 years), migrate to specific areas away from the nesting grounds to undergo the wing-moult, whereas many breeding females moult near the nesting areas (Palmer 1972). This segregation of age and sex classes during wing-moult reduces competition for food on the nesting grounds. For moulting diving ducks, the coastal bays provide protection from terrestrial predators (Stirling and Dzubin 1967), shelter from wind and rough seas, and a plentiful food supply at an accessible water depth (Johnson and Richardson 1981, Griffiths and Dillinger 1981).

Nesting areas may be adjacent to or distant from the moulting areas. Oldsquaws are common breeding birds in the arctic tundra, often nesting near shallow lakes and ponds (Johnson and Herter 1989), while scoters nest in the boreal forest and apparently not to any extent along the arctic coast (Arner et al 1985, Cornish and Allen 1983, Dickson 1985, Martel 1975, Salter et al 1980).

Since 1979, McKinley Bay has been the site of a winter harbour and support base for offshore oil drilling operations in the Beaufort Sea. Use of McKinley Bay peaked from 1982 to 1985 (Appendix A). Since then there has been very little offshore drilling activity in the Canadian Beaufort Sea, and a corresponding decrease in support activity in McKinley Bay.

In the future, the bay may become a year-round support base, leading to increased levels of industrial development and activity (Dome Petroleum Ltd. et al 1982). When development was originally proposed in the bay, the Canadian Wildlife Service was concerned that there was little quantitative data on which to assess the potential impacts of the harbour development. A preliminary environmental assessment of the proposed development was conducted in 1980 (Karasiuk and Boothroyd 1982). Subsequently, a bird monitoring study in McKinley Bay was initiated in 1981 (Scott-Brown et al 1981) and continued intermittently to 1993. The objective of the study was to collect baseline information on natural annual variability in numbers of birds, for use in detecting changes in bird numbers that might occur in the future due to industrial activity. Changes outside the limits of natural variation might be attributable to industrial disturbance. The surveys were also intended to provide details of bird distribution in the bay, and habitat use in surrounding areas, to facilitate development of oil spill protection programs.

The monitoring study was conducted in two phases. An initial 5-year set of surveys was carried out from 1981 to 1985. In order to determine whether diving duck numbers had changed significantly in the 5 years since the initial phase of the study, a second set of surveys was completed from 1990 to 1993. Starting in 1982, Hutchison Bay, an undeveloped bay of similar size 45 km to the west, was also surveyed. Emphasis throughout the study was on documenting numbers and distribution of moulting diving ducks, due to their abundance and vulnerability to oil pollution.

This is the final report of the pre-development baseline study. Herein are the detailed results of the 1993 surveys, a summary of the data gathered in all years of the study and an assessment of the effectiveness of the study as a monitoring tool for detecting potential impacts of industrial activity on bird usage of McKinley Bay.

2.0 METHODS

2.1 Aerial surveys

To allow comparisons between years, the same survey methods were used throughout the study. East-west transects were flown 2 km apart (Figs. 1 and 2) in a Cessna 185 with floats at an elevation of 30 m above ground level at an average speed of 145 km/h. One observer on each side of the aircraft counted all birds seen within 180 m of the flight line, so that the total transect width was 360 m. Observations were dictated into tape recorders so that observers never had to look away from the transect.

A preliminary assessment of seasonal and diurnal variations in diving duck numbers and distribution was carried out in the first two years of the study, in order to determine an optimal survey design for monitoring the birds. In 1981 and 1982, three sets of aerial surveys were flown at 10-day intervals in mid summer to measure seasonal variations in bird abundance. In July and August 1982, we also conducted surveys by boat and on foot, to identify any relationship between the distribution of waterfowl and tidal phase, time of day and weather. The techniques used for the boat and shoreline surveys on foot are summarized in an earlier report (Cornish and Allen 1983).

The same observers participated in all aerial surveys throughout the study, with the exception of one observer in 1981 and 1993. All observers had current experience in aerial surveys.

The terms "diving ducks" and "divers" refer to ducks belonging to both Aythyinae and Merginae. Appendix B lists the scientific and common names of species discussed in this report.

2.2 Analysis of data

For the purpose of data analysis of the aerial survey results, the study areas at McKinley Bay and Hutchison Bay were divided into three components: bay, terrestrial and outside components. At McKinley Bay, the bay component encompassed all saltwater areas within the bay, including exposed sand pits which were intermittently washed over by tides (Fig. 1). The terrestrial component covered all land areas including inland lakes and the lagoon system at the south end of the bay. The area north and west of Atkinson Point and the small bay at the west end of transects 4 to 6 were considered the outside component. The study area components at Hutchison Bay were similarly defined (Fig. 2).

Only those birds recorded on transect were used in density calculations. Bird population estimates were extrapolated from the mean densities by multiplying the observed densities by the total area of the survey component (Table 1). Estimates of the standard errors of these variables were calculated using the method by Kingsley and Smith (1980). These equations are summarized below.

Let: N = number of possible transects in the study area
n = number of transects sampled
f = n/N
y_i = number of observations recorded on the *i*th transect
x_i = area of the *i*th transect

Then:

(1) The standard ratio estimate $\hat{R}$ of the true mean density was given by:

$$\hat{R} = \frac{\sum_{i=1}^{n} y_i}{\sum_{i=1}^{n} x_i}$$

(2) The standard error of the mean density was estimated by the following:

Standard error = $\sqrt{s_1^2}$

$$s_1^2 = \frac{(1-f)\sum_{i=1}^{n-1} (d_i - d_{i+1})^2}{2 \cdot (n-1) \cdot n \cdot \bar{x}^2}$$

where $d = y_i - \hat{R}x_i$

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$$

(3) The standard error of the population estimate was found by multiplying $\sqrt{s_1^2}$ by the total area of the survey component (Table 1).

To determine if there had been a significant change in bird numbers in the bays, mean densities of birds observed in the second set of surveys, from 1990 to 1993, were compared to the results from 1981 to 1985. This was carried out using a t-test (Steel and Torrie 1980). Significant differences were accepted at $p<0.05$.

3.0 RESULTS

3.1 Survey conditions

Based on observations made in 1982, the peak period of moult for diving ducks in McKinley Bay was the first half of August (Cornish and Allen 1983). This was interpreted as the optimal range of dates for monitoring bird numbers in the bay. No relationship between tidal phase and bird distribution could be detected. However, bird behaviour and distribution did vary somewhat with time of day, since we saw more birds on surveys conducted later in the day. Therefore, in order to standardize these time variables, surveys in subsequent years were completed at approximately the same time of day each year, between late morning and mid-afternoon, and at the first possible date in early August.

In most years, two or three surveys were conducted, on days in early August when it appeared flying and surveying conditions would be good. However, because of travel time from our base to the study area, conditions had often changed by the time surveys were commenced. As a result, in some years several surveys were conducted on consecutive days under census conditions ranging from poor to excellent. This allowed us to compare numbers of birds counted under different weather conditions. Rough seas (especially waves with whitecaps), sun glare, thick overcast cloud cover and precipitation all seriously reduced the visibility of birds and thus numbers counted (Cornish et al 1991, Cornish et al 1992). Therefore, only data from surveys carried out under optimal conditions were used for the data analysis. Table 2 lists environmental variables and conditions during what were considered the 'best' aerial surveys. The year 1985 was unusual because ice remained covering about one third of both bays in early August.

3.2 Abundance and distribution of birds in 1993

Numbers and densities of birds observed at McKinley Bay and Hutchison Bay in 1993 are given in Appendices C to F. Based on observed densities, we estimated that 10 667 ± 2723 diving ducks were utilizing McKinley Bay to moult in early August 1993 (Table 3). An estimated 18 485 ± 969 diving ducks were in Hutchison Bay.

In 1993, more than half of the Oldsquaw counted were between Atkinson Point and the artificial island (Fig. 3). Scoters were more frequently observed southeast of the artificial island and towards the south end of the bay. Few diving ducks were observed on transects 1 and 2 at the north end of the bay. At Hutchison Bay, divers were scattered throughout much of the bay, but more diving ducks were in the northwest part of the bay than in other areas (Fig. 4).

Scoters occurred in large flocks more frequently than Oldsquaws during the 1993 surveys (Appendix G). One-half to two-thirds of observed scoters were in flocks of more than 50 birds. In contrast, most Oldsquaws at both bays were in small scattered groups.

3.3 Patterns of abundance and distribution: 1981-85 and 1990-93

3.3.1 Comparison of bird numbers

Diving ducks

The mean number of diving ducks using McKinley Bay to moult from 1990 to 1993 was significantly higher than during the first set of surveys from 1981 to 1985 ($p<0.05$; Table 4; Fig. 5). In contrast, no significant increase in total diving duck numbers was detected at Hutchison Bay over the same period (Table 5).

Over 90% of identified diving ducks were Oldsquaws or scoters (Appendix H). Numbers of Oldsquaws and scoters varied widely from year to year at both bays (Fig. 6). Mean numbers of both species at McKinley Bay from 1990 to 1993 were almost double the numbers observed during the first set of surveys from 1981 to 1985 (Table 4). However, this increase was not statistically significant for either species ($p>0.05$) due to the wide variation in counts among years. At Hutchison Bay, mean numbers of scoters were remarkably similar for the two sets of surveys (Table 5), but again there was a wide range in values for both scoters and Oldsquaws.

When counts from the bay and terrestrial components were combined for the purpose of comparison between survey sets, similar results were found. The increase in diving duck numbers was statistically significant only at McKinley Bay, where mean numbers of diving ducks almost doubled between the two sets of surveys (Table 6). A significant increase in Red-breasted Merganser numbers was recorded at Hutchison Bay ($p<0.05$), but no other significant changes in diving duck numbers at the species level could be detected (Table 7).

Other birds

Significantly more Pacific Loons, Red-throated Loons and Northern Pintails were observed in the recent set of surveys (1990-93) at McKinley Bay, compared to 1981 to 1985 surveys (Table 6, Fig. 7). Although other species fluctuated in number from year-to-year (Appendix I), there were no significant changes in number between the earlier and later sets of surveys. At Hutchison Bay, no species other than the Red-breasted Merganser showed a significant change in number (Table 7).

3.3.2 Bird distribution patterns

Diving ducks

During the surveys at McKinley Bay, some consistent patterns of diving duck distribution were evident. Diving ducks, particularly Oldsquaw, were consistently found in relatively high densities in the area southeast of Atkinson Point and west of the artificial island. Large numbers of both species were frequently noted just south of the artificial island, and scoters commonly occurred in greatest densities at the south end of the bay. Another area where diving ducks tended to concentrate was at the south end of the long spit in the northeast part of the bay. Mixed flocks of up to several hundred Oldsquaw and lesser numbers of scaup occurred frequently on some of the larger lakes. Mergansers were most commonly observed in the shallow lagoon at the south end of the bay.

Diving ducks at Hutchison Bay were observed in greatest densities in the northeast and northwest parts of the bay during most surveys. Large numbers of scoters frequently occurred near the long narrow spit in the northeast corner of the bay. Red-breasted Mergansers and scaup were most often observed in the shelter of small protected coves in the western part of the bay.

Generally, Oldsquaws tended to have a scattered distribution, utilizing many areas of both bays. Most Oldsquaws were recorded in small flocks of less than 50 birds. Compared to Oldsquaws, a higher proportion of scoters were in large flocks of greater than 50 or 100 birds, and flocks of several hundred were more frequently observed. In 1982, for example, a raft of 730 Surf Scoters accounted for over 65% of scoters observed in Hutchison Bay on that survey.

Other birds

At McKinley Bay, geese were most commonly noted on the tidal flats east of Louth Bay, in a small bay southwest of Atkinson Point and in the lagoon system at the south end of the bay. Geese at Hutchison Bay were consistently recorded in the small embayment in the southwest section of the bay, west of the long peninsula. Groups of up to 25 geese were also observed at various lakes in both study areas. Tundra Swans occurred in pairs, family groups, and large flocks of presumably non-breeding birds. They were found on lakes and ponds, as well as shallow lagoon areas.

Dabbling ducks, most of which were Northern Pintail, were commonly seen on tundra ponds throughout both study areas. Vegetated littoral flats were also frequented, especially areas east of Louth Bay and in lagoons at the south end of both McKinley and Hutchison bays.

Maps depicting the important areas for waterfowl in McKinley and Hutchison bays are presented in Cornish and Dickson (1986). Although the maps are based on surveys done from 1981 to 1985, they are a reasonable summary of patterns of distribution, since little change was detected in the more recent set of surveys.

4.0 DISCUSSION

Tens of thousands of diving ducks, primarily Oldsquaws and scoters, undergo the wing-moult in McKinley Bay and Hutchison Bay each year. However, there is wide variation in the numbers of divers using the bays in early August from year to year. We calculated the minimum detectable future change in diving duck numbers at a 90% level of significance (Table 8). Numbers of divers would have to change by more than 82% at McKinley Bay before we could attribute the changes to human activity.

Large fluctuations in diving duck numbers have also been recorded by other researchers. Estimates of numbers of Oldsquaw in Simpson Lagoon in Alaska in late July 1977-1979 were approximately 51 000, 13 000, and 23 000, respectively (Johnson and Richardson 1982). In Boundary Bay, British Columbia, Savard (1982) flew two aerial surveys, one right after the other, to count diving ducks on the wintering grounds. In the first survey, 25 347 birds were counted, compared to 31 271 shortly afterwards in the second survey. This represented almost a 20% difference. Stott and Olson (1972) also had extreme variation in diving duck counts during aerial surveys, despite the use of identical aircraft and observers during the surveys. The accuracy of 15 aerial surveys of scoters varied from 7 to 74%, compared to ground counts.

The number of diving ducks observed in McKinley and Hutchison bays in early August depends partly on the proportion of birds that have commenced the moult. The first 15 days of August represented the peak period of moult for Oldsquaws in McKinley Bay in 1982, based on daily shoreline surveys that recorded numbers of birds flushing (Cornish and Allen 1983). However, the timing of the moult for a species may vary between years, depending on timing of nest initiation (Salomonsen 1968). The timing of spring thaw affects nest commencement, which in turn affects when breeding males arrive in the moulting areas. At Simpson Lagoon in the Alaskan Beaufort Sea, Johnson and Richardson (1981) found that the moult for a large proportion of Oldsquaw began up to two weeks earlier in 1978 than in 1977, based on wing measurements. The nesting chronology of Oldsquaws in coastal Beaufort Sea regions between 1981 and 1993 is unknown. A preliminary examination of data on temperature and snowfall in May and June at Tuktoyaktuk showed no correlation between number of moulting birds in the bays and timing of spring thaw (weather data obtained from Atmospheric Environment Service).

Nest success in a given year may also affect numbers of birds moulting in the bays. According to Palmer (1972), pre-breeding yearlings or non-breeding birds of both sexes would be the earliest of the diving ducks to become flightless in the moulting areas, followed by drakes of breeding pairs, then failed breeders. During our ground surveys in 1982, we recorded large numbers of Oldsquaw, probably females, arriving in both McKinley and Hutchison bays starting the first week of August. If these divers represent failed breeders, then the total number of Oldsquaw in the moulting areas in early August is related to both nesting chronology and nesting success. Numerous factors affect nesting success, including abundance of predators, timing of spring thaw, nutritional status of the female, age and experience of the female, weather at time of hatch, and abundance of alternate prey (Dickson 1992, Gaultier 1989, Pehrsson 1986, Alison 1975, Baillie and Milne 1982, Coulson 1984). Nesting success is unknown for any of the diving ducks moulting in our study.

According to Salomonsen (1968), the location of the moulting areas is largely determined by tradition, so that the same areas are used year after year. However, the site selected for the annual moult may shift, depending on the ice conditions in the bays and lagoons when the birds first arrive to moult in July (Barry et al 1981). Compared to other years, far fewer scoters were observed in early August 1985, a year when a substantial amount of ice remained in the bays in early August (Cornish and Dickson 1986). At the same time, Barry (pers. comm.) reported greater than usual numbers of diving ducks at nearby Liverpool Bay and Eskimo Lakes, which were ice-free in mid-summer. Many scoters that traditionally moult in McKinley Bay may have been displaced to other areas that year. Oldsquaw were apparently less affected by the ice than scoters, likely due to their more catholic diet. Whereas scoters are restricted to bottom dwelling marine invertebrates, Oldsquaws also feed on invertebrates associated with the ice edge (Divoky 1977, Johnson 1984, Sanger and Jones 1984, Vermeer and Bourne 1984).

Local prey distribution may fluctuate between years, affecting the numbers of birds that remain in the bays to moult. Densities of marine invertebrates are known to vary in both space and time within other coastal study areas (Johnson and Richardson 1981, Peterson and Elarson 1977), depending on such factors as ocean currents and prevailing winds. According to Griffiths and Dillinger (1981), mysids and amphipods, important prey for Oldsquaws in near shore Beaufort Sea waters, may move annually in and out of bays and lagoons, in response to prevailing ocean flows. There is little information on abundance or distribution of invertebrate organisms in McKinley Bay or Hutchison Bay. Further, we have no site-specific information on the diets of Oldsquaws and scoters off the Tuktoyaktuk Peninsula. It is also unknown to what extent moulting diving ducks move in and out of the bays in search of higher prey-density areas. Movement might more likely occur on calm days, which is when our surveys were conducted.

A portion of the between-year fluctuation in diving duck numbers in these bays in early August could also be an artifact of the survey technique. We found that height of waves and amount of cloud cover were two important factors determining potential accuracy of the counts (Cornish and Allen 1983). A choppy ocean surface, especially with whitecaps, hindered our ability to spot the diving ducks. This problem was worse in sunny conditions, when sunlight reflecting unevenly off wave tops made seaducks difficult to discern. Scoters in particular were easier to see on an overcast day, when the lighter appearance of the ocean surface allowed better contrast with the dark bodies of the birds. Stott and Olson (1972) similarly reported greatest accuracy when aerial counts of Oldsquaws and scoters occurred over a smooth ocean on a cloudy day. However, the thickness of the cloud cover is also important. During our surveys, a very thick, dark overcast cloud cover resulted in low lighting conditions, so that fewer diving ducks could be identified to species.

Many aspects of our survey design were based on these observations. We minimized the bias due to survey conditions by standardizing the variables that most obviously affected visibility of birds. We attempted to conduct surveys each year under similar weather and sea conditions, and for the statistical analysis we utilized only the data gathered during surveys with acceptable conditions.

All observers in this study had recent aerial survey experience. However, individual variation in aerial estimates of waterfowl numbers exists even between experienced observers, apparently because external factors influence observers differently (Savard 1982). During our study, this source of bias was reduced, since the same two observers took part in almost all surveys.

The accuracy of aerial survey results is also affected by the distribution of birds in flocks of different sizes. During our surveys, a greater proportion of scoters than Oldsquaws were observed in large flocks of over 50 birds. Savard (1982) found that estimates varied more for species that aggregated into flocks than for species with a more scattered distribution. According to Gaston and Smith (1984), as flock sizes increase, survey intensity must also increase to obtain the same level of accuracy. Thus, our population estimates were likely more accurate for Oldsquaw than for scoters.

At both study areas, diving ducks were often concentrated in certain regions of the bay. This uneven distribution of birds reduced the precision of our estimates. Precision of a density estimate is inversely related to the variability of density throughout the study area (Caughley 1977).

Studies of the behaviour of moulting diving duck populations have demonstrated that there are diurnal changes in distribution related to feeding behaviour (Ross 1983, Oring 1964). At McKinley Bay in 1983, we found that the number of Oldsquaw concentrated near and on shore increased in early evening (Cornish and Allen 1983). During helicopter surveys in protected bays at Herschel Island, Ward and Sharp (1974) saw more Oldsquaw and Surf Scoters per hour in the later afternoon and evening than during the rest of the day. We standardized this source of error by conducting all surveys at mid-day.

The McKinley Bay and Hutchison Bay study areas provide important habitat for many species of birds other than diving ducks. The lakes, ponds, lagoons, tidal mudflats and floodplain meadows, and sand and gravel beaches are used by a diversity of species. For example, both Glaucous Gulls and Arctic Terns nest near Warren Point and Atkinson Point (Cornish and Allen 1983, Arner et al 1985, Alexander et al 1988). Several nesting colonies of Brant are found south of Atkinson Point, as well as scattered nests of Greater White-fronted Geese (Arner et al 1985). These geese then gather in moulting and brood-rearing flocks in tidal marsh areas. Family groups and moulting flocks of swans utilize lakes, ponds and lagoons.

5.0 CONCLUSIONS

The results presented in this report indicate clearly that McKinley and Hutchison bays are important to vast numbers of diving ducks during the time of the wing-moult each year. Our data also provide a framework to aid in the analysis of future changes in populations of Oldsquaws and scoters in these Beaufort Sea areas. However, only massive changes in bird numbers will be detectable using aerial survey methods alone, due to the large natural annual fluctuations in the number of divers using the bays. The lack of information on natural factors affecting the timing and number of birds moulting in the study area inhibits our ability to interpret the results of the aerial surveys. Without an understanding of the natural causes of the annual fluctuations in numbers, it will be very difficult to decipher natural from man-induced changes in the future.

We established the control area (Hutchison Bay) near McKinley Bay to help differentiate changes due to industrial development. Because of their close proximity, we assumed that natural factors such as timing of spring thaw and abundance of prey would be similar at both bays. Thus, if after harbour development there were changes in the number of diving ducks at McKinley Bay, but not at Hutchison Bay, these changes could be attributed to man-induced factors. However, the study results show that despite their close proximity, changes in relative abundance in both bays were not always constant. From 1982 to 1985, the number of divers at each bay fluctuated in a similar way each year. However, in 1991, diving ducks increased in McKinley Bay, while they decreased dramatically at Hutchison Bay (Fig. 5). The reverse occurred in 1992 and 1993, when diving duck numbers decreased at McKinley Bay and increased at Hutchison Bay. These discrepancies may be due to differences between the two bays in the ecological factors affecting the moult, or they may be just due to chance. Although the broad location of moulting areas may be primarily traditional (Salomonsen 1968), if there is sufficient food, it may be immaterial to a duck whether it moults in Hutchison Bay or a few kilometres down the coast from there.

Local trends in bird abundance or distribution are the visible expression of behavioral responses to changes in the physical environment. Routine gathering of physical environmental data could improve our ability to interpret our data. However, due to the high degree of natural variability, as well as the complexity of factors causing the variability, the abundance of moulting seaducks is not a very sensitive measure of the effect of man-induced changes to the environment.

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Table 1. Aerial survey coverage of designated components of the McKinley Bay and Hutchison Bay study areas.

	McKinley Bay		Hutchison Bay	
Component	Total area (km^2)	Area surveyed (km^2)	Total area (km^2)	Area surveyed (km^2)
Marine	108.5	19.6	100.5	17.8
Terrestrial	158.5	28.3	91.0	16.3
Outside	38.0	6.9	31.5	5.8
TOTAL	305.0	54.8	223.0	39.9

Table 2. Date, time of day, environmental conditions and other variables affecting detectability of birds during aerial surveys at McKinley Bay (MB) and Hutchison Bay (HB) from 1981 to 1993.

			Time of	Wind		Sea	Cloud		% ice	Overall	Observer
Year	Bay	Date	survey	Speed[a]	Dir	cond.[a]	cover[a]	Precip.[a]	cover	rating	initials
1981	MB	Aug. 10	1715-1900	1	n.d.	1	1	1	0	Good	DLD, MS
	HB	(not surveyed in 1981)									
1982	MB	Aug. 10	1345-1635	1	N	2	1	1	0	Good	DLD, HLD
	HB	Aug. 10	1345-1635	1	N	2	1	1	0	Good	"
1983	MB	Aug. 5	1145-1410	1	NE	1	2	1	0	Good	"
	HB	Aug. 5	1145-1410	1	NE	1	2	1	0	Good	"
1984	MB	Aug. 3	1240-1610	1	N	2	1-2	1	0	Good	"
	HB	Aug. 3	1240-1610	1	N	2	1-2	1	0	Good	"
1985	MB	Aug. 4	1038-1330	1	SE	1	1	1	35	Excellent	"
	HB	Aug. 4	1038-1330	1	SE	1	1	1	35	Excellent	"
1990	MB	Aug. 5	1255-1419	1	n.d.	1	2	1	0	Good-Excellent	"
	HB	Aug. 5	1125-1230	1	n.d.	1	1	1	0	Excellent	"
1991	MB	Aug. 7	1530-1715	1	n.d.	1	1	1	0	Excellent	"
	HB	Aug. 7	1250-1353	1	n.d.	1	1	1	0	Good-Excellent	"
1992	MB	Aug. 3	1150-1310	1	SE	1	1	2	0	Good	"
	HB	Aug. 3	1320-1425	1	SE	1	1	1	0	Excellent	"
1993	MB	Aug. 1	1100-1156	1	SW	1	1	1	0	Good-Excellent	DLD, BC
	HB	Aug. 1	1216-1322	1	SW	1	1	1	0	Good-Excellent	"

[a] Code	Wind Speed	Sea conditions	Cloud cover	Precipitation
1	<10 kph	Calm	81-100% cloud	None or little
2	10-15 kph	Small waves, light swell	50-80% cloud, some glare	Light rain, drizzle
3	>15 kph	Large waves, whitecaps	<50% cloud, frequent glare	Moderate to heavy rain

n.d. no data

Table 3. Population estimates of diving ducks on the bay component at McKinley Bay and Hutchison Bay on August 1, 1993.

Species	Location	Adjusted number[a]	Density (birds/km^2)	Population estimate
Oldsquaw	McKinley Bay	910	46.43	5038
	Hutchison Bay	1314	73.82	7419
Scoter	McKinley Bay	984	50.20	5447
	Hutchison Bay	1364	76.63	7701
Scaup sp.	McKinley Bay	26	1.33	144
	Hutchison Bay	139	7.81	785
Merganser sp.	McKinley Bay	7	0.36	39
	Hutchison Bay	457	25.67	2580
TOTAL DIVERS	McKinley Bay	1927	98.32	10667 ± 2723 (S.E.)[b]
	Hutchison Bay	3274	183.93	18485 ± 969 (S.E.)

[a] From Appendix H

[b] S.E. = Standard Error. Not calculated for individual species since the adjusted number includes an uneven proportion of unidentified divers on each transect.

Table 4. Comparison of numbers of diving ducks on the bay component at McKinley Bay during two sets of aerial surveys, 1981 to 1985 and 1990 to 1993.

Year	Oldsquaw[a]	Scoters[a]	Total divers
1981	1046	705	2175
1982	1263	934	2246
1983	992	1207	2312
1984	1171	1880	3104
1985	1031	153	1258
$\bar{x}_{1981-85} \pm$ S.D.[b]	1101 ± 113	976 ± 637	2219 ± 655
1990	2397	2478	5040
1991	3666	1820	5707
1992	1419	2361	3906
1993	910	984	1927
$\bar{x}_{1990-93} \pm$ S.D.	2098 ± 1214	1911 ± 681	4145 ± 1655
Test for difference[c] ($\bar{x}_{1981-85}$ vs. $\bar{x}_{1990-93}$)	t = 1.86 ns	t = 2.12 ns	t = 2.41 *

[a] Adjusted number - from Appendix H
[b] S.D. = Standard Deviation
[c] Compare to: $t_{0.05} = 2.365$
* Significant difference, $p < 0.05$
ns Not significant

Table 5. Comparison of numbers of diving ducks on the bay component at Hutchison Bay during two sets of aerial surveys, 1982 to 1985 and 1990 to 1993.

Year	Oldsquaw[a]	Scoters[a]	Total divers
1982	838	1246	2385
1983	617	1678	2415
1984	1717	1161	3066
1985	884	796	1801
$\bar{x}_{1982-85} \pm$ S.D.[b]	1014 ± 438	1220 ± 362	2417 ± 517
1990	2733	1901	5064
1991	732	786	1968
1992	1516	875	3145
1993	1314	1364	3274
$\bar{x}_{1990-93} \pm$ S.D.	1574 ± 841	1232 ± 514	3363 ± 1277
Test for difference[c]	t = 1.15	t = 0.04	t = 1.37
($\bar{x}_{1982-85}$ vs. $\bar{x}_{1990-93}$)	ns	ns	ns

[a] Adjusted number - from Appendix H
[b] S.D. = Standard Deviation
[c] Compare to: $t_{0.05} = 2.447$
ns Not significant

Table 6. Mean numbers for the most common birds observed at McKinley Bay, 1981 to 1985, and 1990 to 1993, bay and terrestrial components combined.

	Mean number of birds[a]	
Species	1981 to 1985	1990 to 1993
Pacific Loon	10 ± 9	28 ± 4*
Red-throated Loon	24 ± 24	75 ± 26*
Loon sp.[b]	29 ± 17	15 ± 13
Total Loons	64 ± 11	118 ± 42*
Tundra Swan	55 ± 19	64 ± 16
Brant	61 ± 36	24 ± 47
G. White-fronted Goose	24 ± 26	55 ± 24
Dark Goose	50 ± 34	10 ± 7
Snow Goose	<1 ± <1	0 ± 0
Total Geese	136 ± 52	88 ± 25
Northern Pintail	113 ± 44	286 ± 186*
American Wigeon	12 ± 11	21 ± 35
Dabbling duck	43 ± 30	81 ± 101
Total Dabblers	168 ± 57	388 ± 198*
Scaup sp.	153 ± 134	140 ± 24
Eider sp.	4 ± 8	0 ± 0
Oldsquaw	1012 ± 100	1928 ± 915
White-winged Scoter	109 ± 131	166 ± 157
Surf Scoter	456 ± 364	365 ± 297
Scoter sp.	248 ± 177	875 ± 165*
Total Scoters	812 ± 477	1406 ± 417
Red-breasted Merganser	51 ± 31	110 ± 65
Diving duck[c]	414 ± 277	1304 ± 1015
Total Divers	2447 ± 684	4888 ± 1957*
Sandhill Crane	5 ± 4	8 ± 3
Shorebirds	123 ± 63	64 ± 78
Glaucous Gull	76 ± 24	112 ± 54
Sabine's Gull	8 ± 6	8 ± 6
Total Gulls	83 ± 19	120 ± 58
Arctic Tern	44 ± 39	17 ± 10

[a] ± standard deviation
[b] Includes Yellow-billed Loons and Common Loons
[c] Includes Common Merganser
* Significant difference between 1981-85 and 1990-93 (t test, $p<0.05$)

Table 7. Mean numbers for the most common birds observed at Hutchison Bay, 1982 to 1985, and 1990 to 1993, bay and terrestrial components combined.

	Mean number of birds[a]	
Species	1982 to 19 85	1990 to 1993
Pacific Loon	16 ± 10	22 ± 8
Red-throated Loon	24 ± 20	33 ± 13
Loon sp.[b]	26 ± 19	8 ± 7
Total Loons	65 ± 20	65 ± 13
Tundra Swan	44 ± 24	64 ± 28
Brant	51 ± 35	32 ± 40
G. White-fronted Goose	16 ± 18	63 ± 63
Dark Goose	30 ± 25	82 ± 88
Snow Goose	10 ± 10	0 ± 0
Total Geese	106 ± 49	177 ± 101
Northern Pintail	109 ± 115	124 ± 71
American Wigeon	2 ± 2	20 ± 25
Dabbling duck	26 ± 24	55 ± 39
Total Dabblers	136 ± 140	198 ± 123
Scaup sp.	156 ± 53	227 ± 165
Eider sp.	3 ± 6	0 ± 0
Oldsquaw	939 ± 390	1382 ± 792
White-winged Scoter	90 ± 89	44 ± 54
Surf Scoter	722 ± 226	374 ± 436
Scoter sp.	328 ± 192	660 ± 336
Total Scoters	1140 ± 326	1077 ± 515
Red-breasted Merganser	53 ± 72	374 ± 225*
Diving duck[c]	203 ± 158	476 ± 213
Total Divers	2495 ± 488	3536 ± 1342
Sandhill Crane	2 ± 3	7 ± 4
Shorebirds	42 ± 30	41 ± 25
Glaucous Gull	62 ± 16	104 ± 88
Sabine's Gull	0 ± 0	1 ± 1
Total Gulls	62 ± 16	105 ± 88
Arctic Tern	14 ± 9	3 ± 4

[a] ± standard deviation
[b] Includes Yellow-billed Loons and Common Loons
[c] Includes Common Merganser
* significant difference between 1981-85 and 1990-93 (t test, $p<0.05$)

Table 8. Minimum degree of change in diving duck numbers at McKinley and Hutchison bays necessary to detect a potential impact of human activities[a].

	McKinley Bay		Hutchison Bay	
	Mean numbers (90% confidence interval)	Min. detectable % change	Mean numbers (90% confidence interval)	Min. detectable % change
Oldsquaw	1608 ± 1810	113	1352 ± 1432	106
Scoters	1546 ± 1287	83	1287 ± 783	61
Total divers	3302 ± 2723	82	3045 ± 1964	64

[a] Based on aerial survey results from 1981 to 1993, but excluding 1985 due to extensive ice cover in the bays that year.

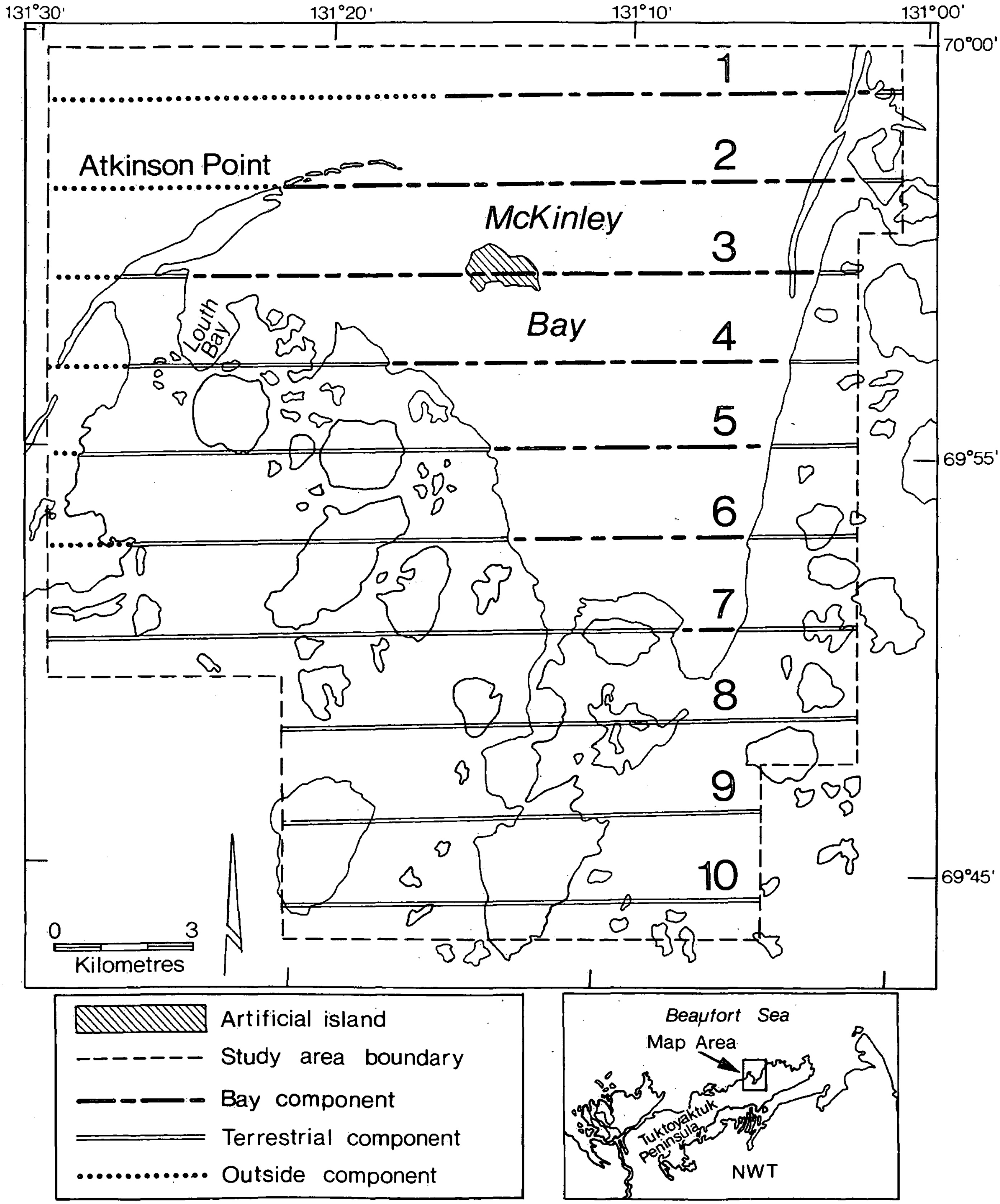

Figure 1. Aerial transects flown at McKinley Bay, 1981 to 1985 and 1990 to 1993, showing the bay, terrestrial and outside components of the study area.

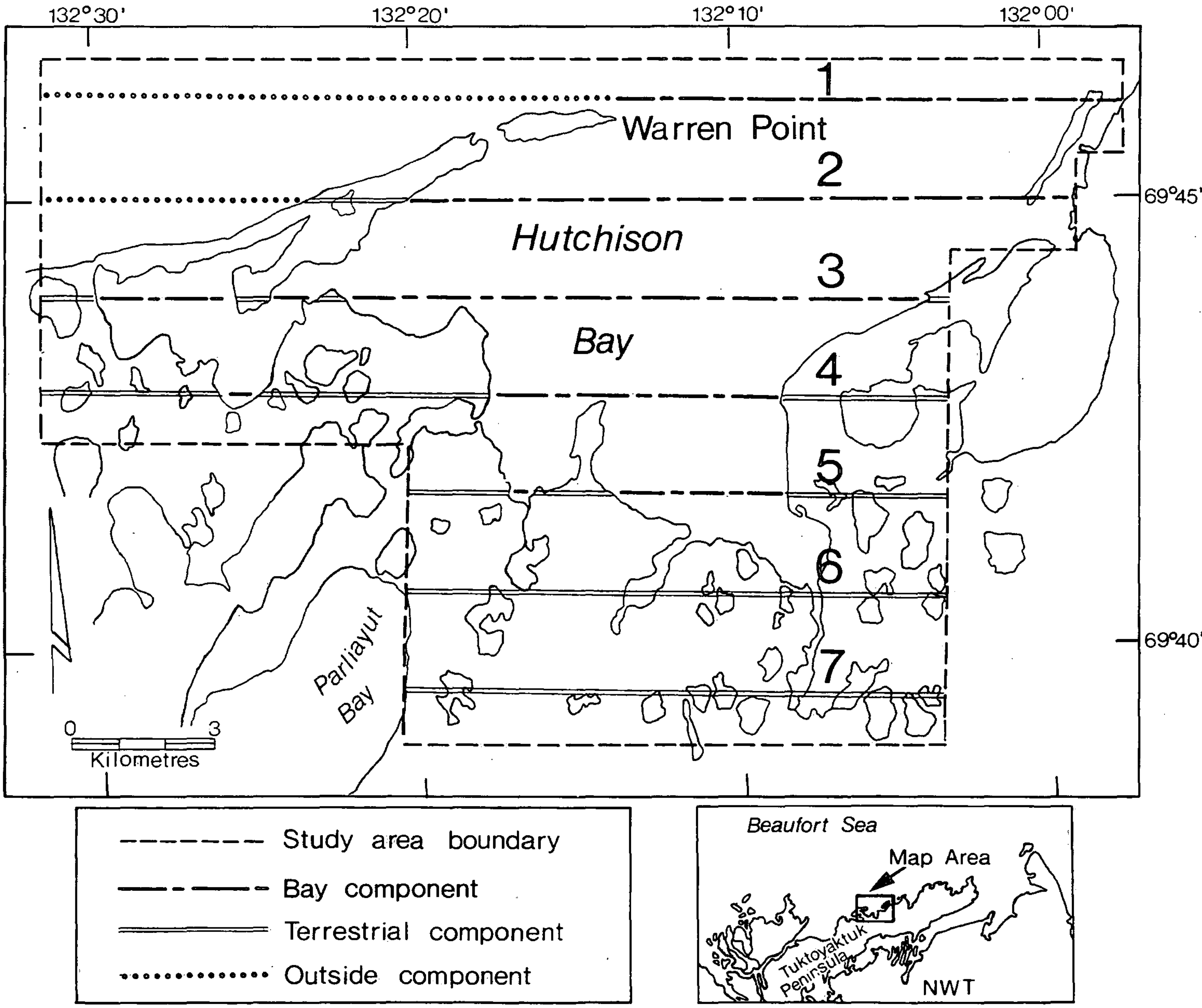

Figure 2. Aerial transects flown at Hutchison Bay, 1982 to 1985 and 1990 to 1993, showing the bay, terrestrial and outside components of the study area.

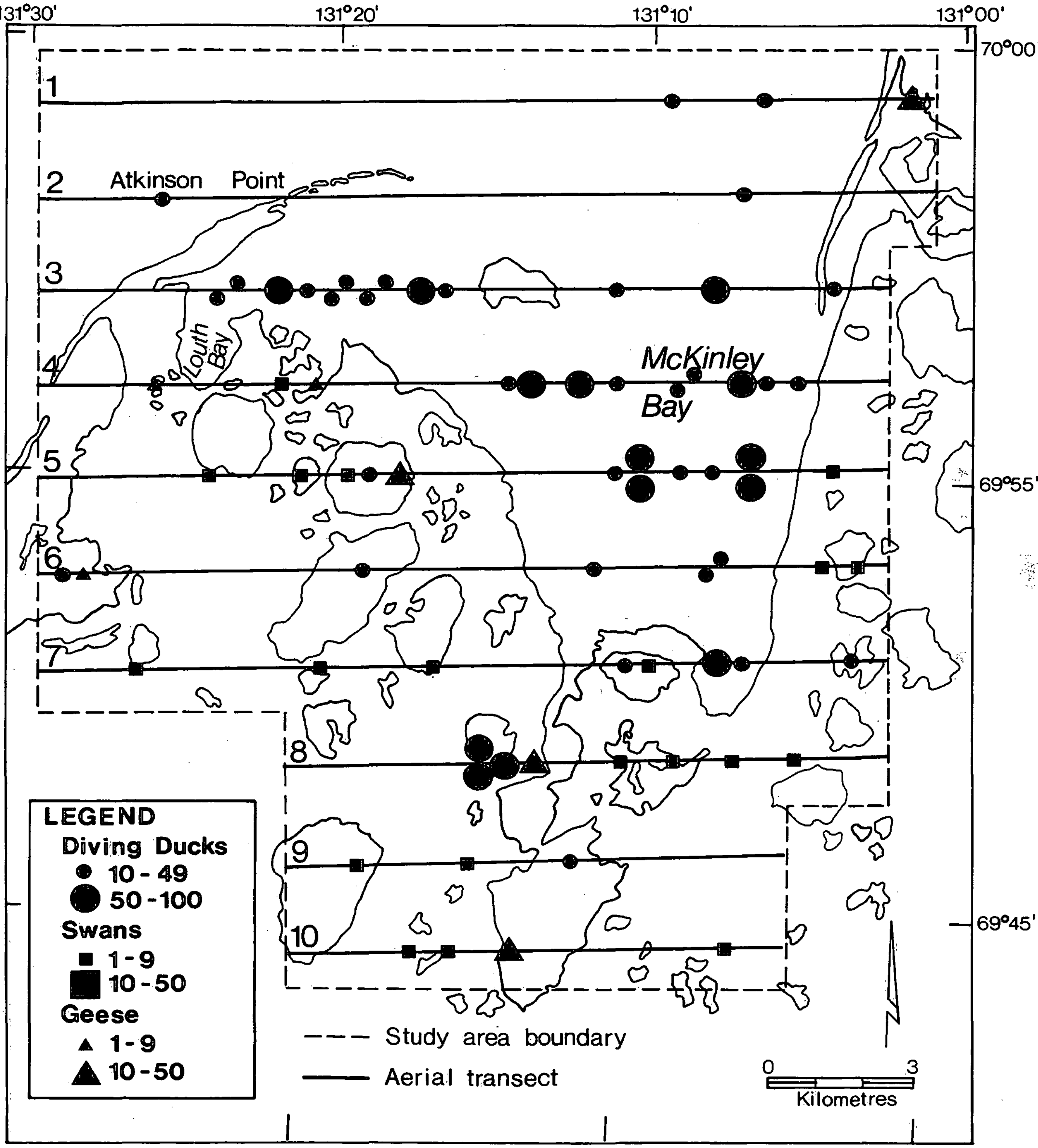

Figure 3. Distribution of waterfowl observed at McKinley Bay during aerial surveys on August 1, 1993.

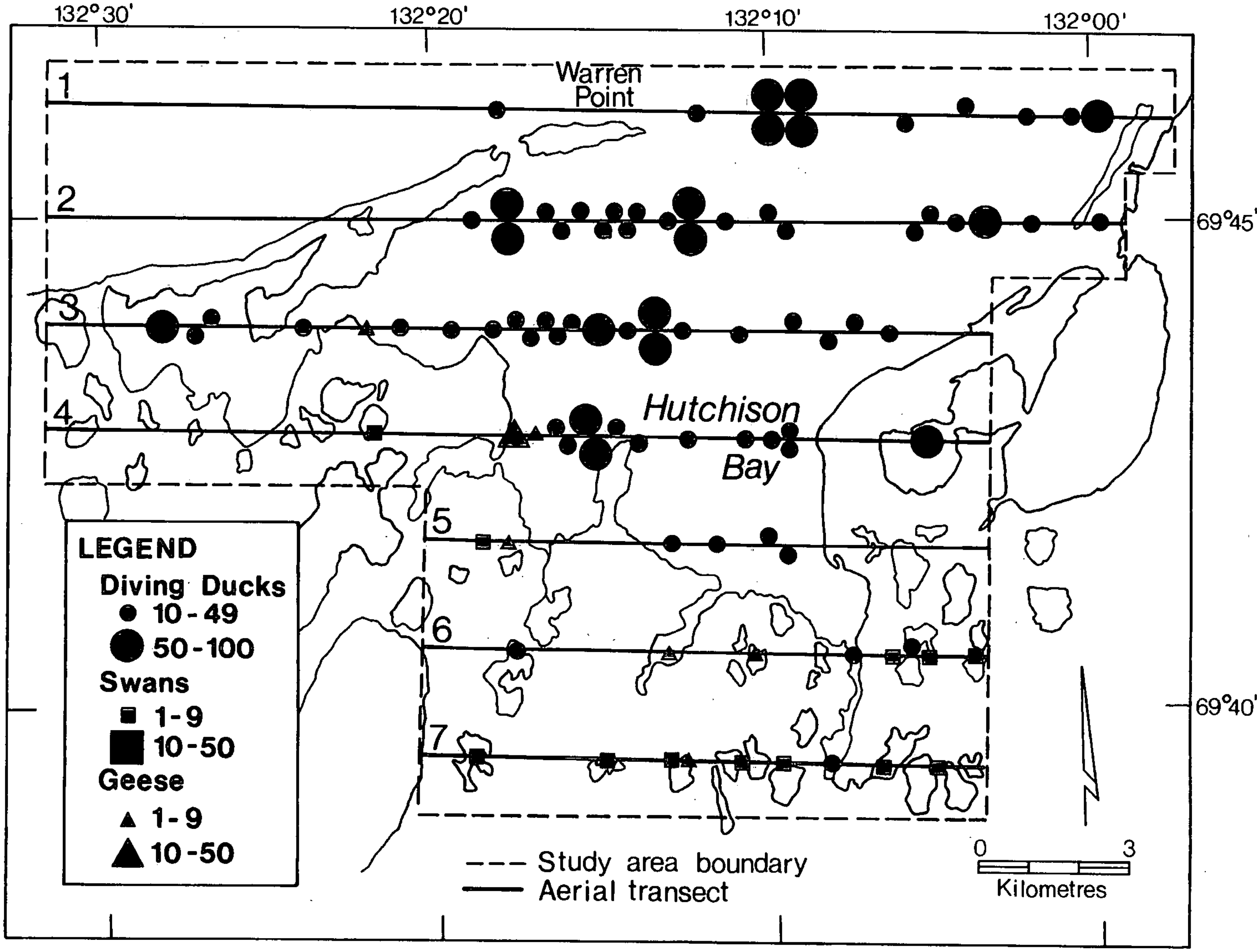

Figure 4. Distribution of waterfowl observed at Hutchison Bay during aerial surveys on August 1, 1993.

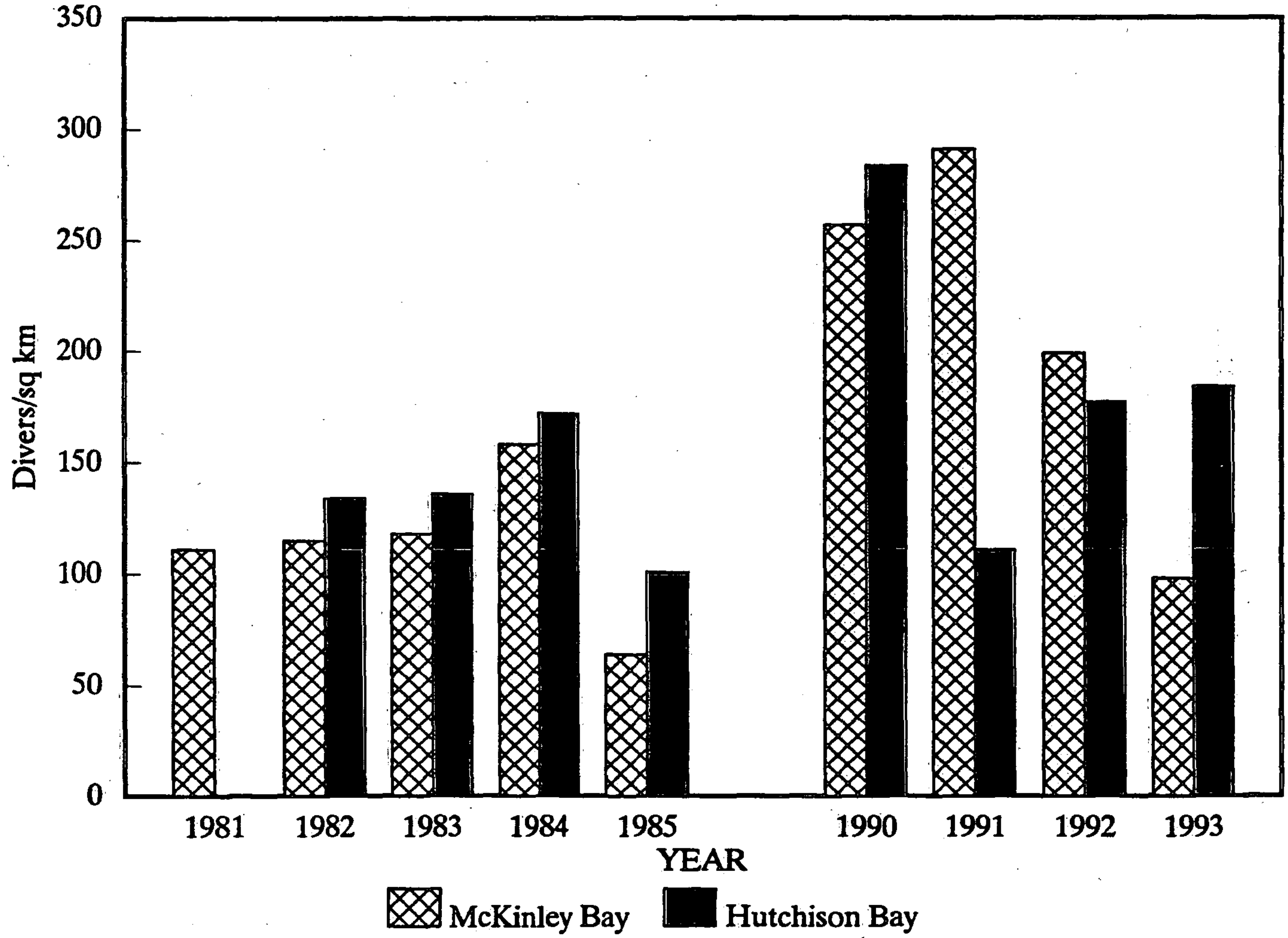

Figure 5. Trends in abundance of total diving ducks at McKinley Bay and Hutchison Bay between 1981 and 1993.

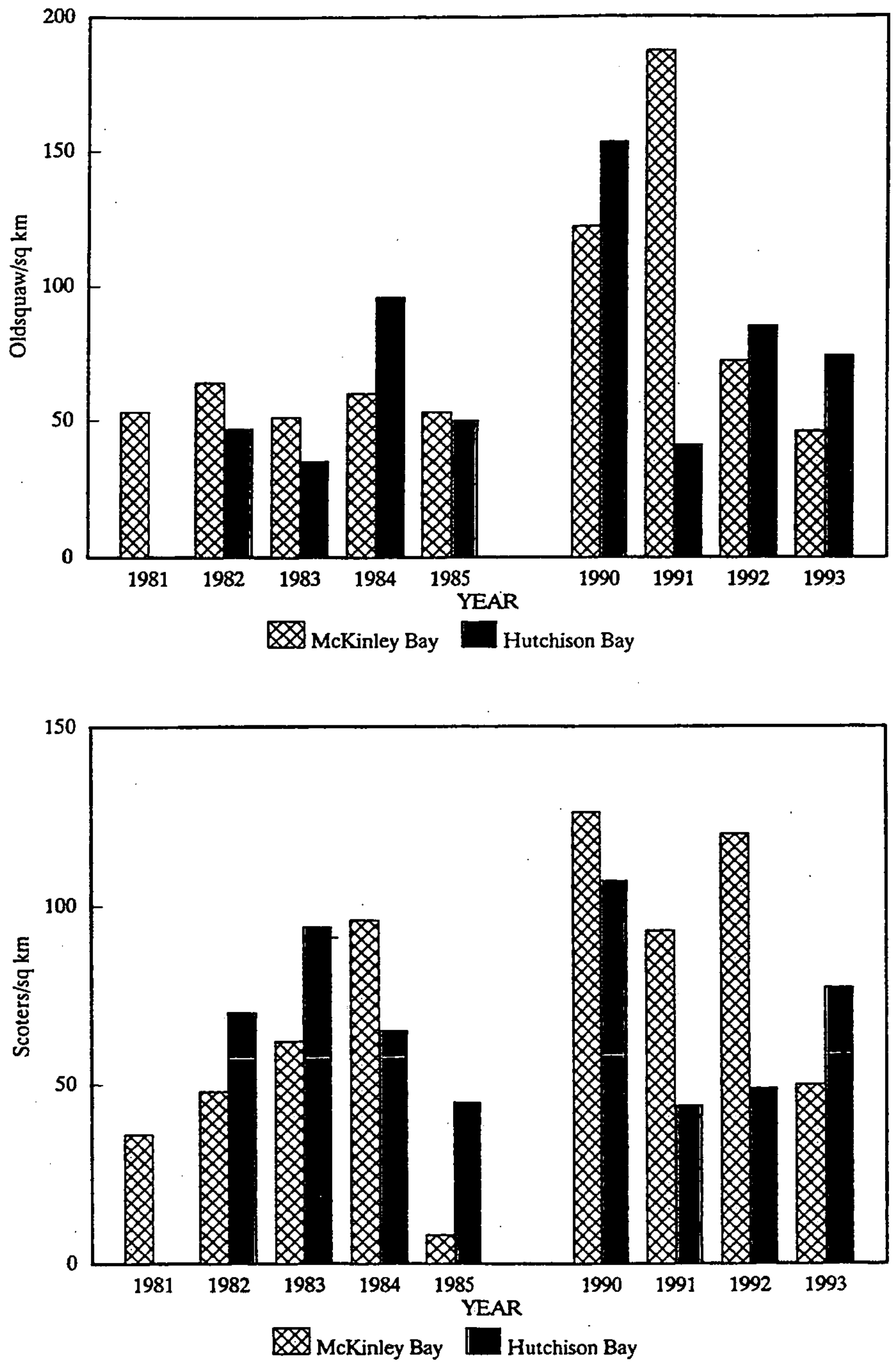

Figure 6. Trends in abundance of Oldsquaws and scoters at McKinley Bay and Hutchison Bay between 1981 and 1993.

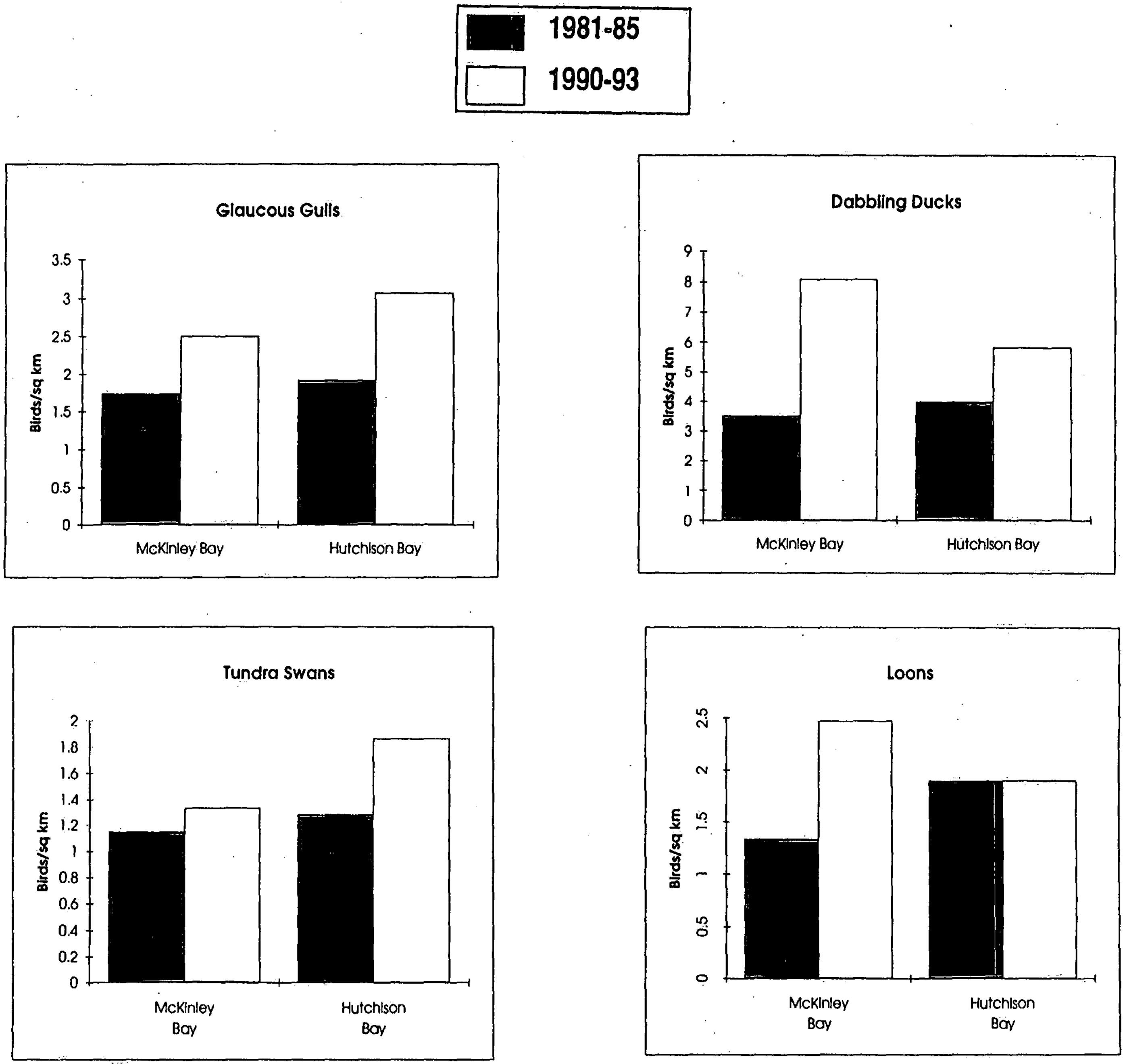

Figure 7. Mean densities of selected bird species observed at McKinley and Hutchison bays during the two sets of surveys.

APPENDIX A. Industrial Activity in McKinley Bay and Hutchison Bay, 1979-1993.

In response to the need for a winter harbour to support offshore oil and gas exploration in the Canadian Beaufort Sea, an entrance channel and mooring basin were dredged in the northeast section of McKinley Bay in September of 1979. This was followed in 1980 by construction of a more sheltered mooring area, southwest of the original location. An artificial island was created to the north of the new location with the dredged spoils, to further protect the moored ships from storms and ice movement. In 1981, docking facilities were constructed, and the artificial island and mooring basin were expanded. In 1982 and 1983, an airstrip and accommodation for 130 people were put on the island. The island also became a storage area for fuel and materials to support the offshore drilling operation.

Use of McKinley Bay as a harbour peaked from 1982 to 1985. Since then there has been very little offshore drilling activity in the Canadian Beaufort Sea. Appendix A1 summarizes the activities associated with industrial use of McKinley Bay from 1979 to 1993.

Most of the oil spills at McKinley Bay occurred between 1979 and 1984 (Appendix A2). The two largest spills which were 500 gal in 1980 and 1100 gal in 1982 both occurred after freeze-up. There was another large spill of 7000 gal at Atkinson Point in February in 1983, but the oil did not enter the water. Since 1985, there have been only two small spills of less than 25 gal within McKinley Bay.

Two oil spill clean-up experiments were permitted in McKinley Bay under the Ocean Dumping Control Act (Seakem Group Ltd. 1991). The first experiment involved dumping about 4000 gal of crude oil under the ice in three releases from December 1979 to April 1980. In the second experiment, which occurred in February 1982, about 75 gal of emulsified crude oil were released under the ice.

There have been no oil spills or industrial development in Hutchison Bay from 1979 to present.

Appendix A1. Level of industrial activity at McKinley Bay, 1979-1993.

Year	Dredging activity (m^3)[1]	No. of ships in January[2]	No. of ships mobilized[2]	Annual no. of person-days[3]	No. of flights June-Sept.	No. of offshore drilling operations[5]
1979	3 427 000			21 900	?	3-4
1980	5 860 015	16	16	48 300	?	3-4
1981	3 486 400	16	16	41 250	?	3-4
1982	43 669	19	19	45 700	?	3
1983	0	20	20	42 750	?	4
1984	0	20	20	42 750	2/day	6
1985	0	17	17	27 750	daily	5
1986	0	17	13	14 550	daily	1
1987	0	11	7	14 550	3/wk	0
1988	0	8	6	14 550	3/wk	0
1989	0	11	5	14 550	daily	1
1990	0	9	4	14 500	3/wk	0
1991[4]	0	7	6	2 850	daily	0
1992[4]	0	8	2	300	1-2/wk	0
1993[4]	0	7	3	400	daily	0

[1]from: Sackmann et al 1991
[2]from: N. Vanderkooy, Canadian Marine Drilling Ltd., pers comm; John Ward, AMOCO, pers. comm; and Seakem Group Ltd. 1991
[3]from: Seakem Group Ltd. 1991
[4]from: N. Vanderkooy, pers. comm.
[5]from: Scott Edwards, Indian and Northern Affairs, Yellowknife, pers. comm.

Appendix A2. Oil spills reported in McKinley Bay, 1979-1993.[1]

Year	No. of oil spills	Oil spill size (gallons)			
		<50	51-200	201-400	>400
1979	2		2		
1980	16	13	2		1
1981	3	1	1	1	
1982	10	5	2	2	1
1983	2		2		
1984	1		1		
1985	0				
1986	1	1			
1987	1	1			
1988	0				
1989	1	1			
1990	0				
1991	0				
1992	0				
1993	0				

[1] Data from NWT Spill Reports, Government of NWT.
No oil spills occurred in Hutchison Bay from 1979 to 1993.
Spill of 6995 gal of fuel oil on land at Atkinson Point on 9 February, 1983 and two spills <1 gal at McKinley Bay not included in above.

Appendix B. Scientific names of species of birds observed at McKinley Bay and Hutchison Bay.

Common name	Scientific name
Yellow-billed Loon	*Gavia adamsii*
Red-throated Loon	*Gavia stellata*
Pacific Loon	*Gavia pacifica*
Common Loon	*Gavia immer*
Tundra Swan	*Cygnus columbianus*
Greater White-fronted Goose	*Anser albifrons*
Brant	*Branta bernicla*
Canada Goose	*Branta canadensis*
Snow Goose	*Chen caerulescens*
Mallard	*Anas platyrhynchos*
Northern Pintail	*Anas acuta*
American Wigeon	*Anas americana*
Canvasback	*Aythya valisineria*
Scaup sp.	*Aythya sp.*
King Eider	*Somateria spectabilis*
Common Eider	*Somateria mollissima*
Oldsquaw	*Clangula hyemalis*
Surf Scoter	*Melanitta perspicillata*
White-winged Scoter	*Melanitta fusca*
Red-breasted Merganser	*Mergus serrator*
Common Merganser	*Mergus merganser*
Bald Eagle	*Haliaeetus leucocephalus*
Northern Harrier	*Circus cyaneus*
Rough-legged Hawk	*Buteo lagopus*
Gyrfalcon	*Falco rusticolus*
Willow Ptarmigan	*Lagopus lagopus*
Ptarmigan sp.	*Lagopus sp.*
Sandhill Crane	*Grus canadensis*
Whimbrel	*Numenius phaeopus*
Stilt Sandpiper	*Calidris himantopus*
Red-necked Phalarope	*Phalaropus lobatus*
Phalarope sp.	*Phalaropus sp.*
Pectoral Sandpiper	*Calidris melanotos*
Semi-palmated Sandpiper	*Calidris pusilla*
Parasitic Jaeger	*Stercorarius parasiticus*
Jaeger sp.	*Stercorarius sp.*
Glaucous Gull	*Larus hyperboreus*
Sabine's Gull	*Xema sabini*
Arctic Tern	*Sterna paradisaea*
Black Guillemot	*Cepphus grylle*
Short-eared Owl	*Asio flammeus*
Snowy Owl	*Nyctea scandiaca*
Common Raven	*Corvus corax*

Appendix C1. Birds observed on the bay component of aerial surveys at McKinley Bay on August 1, 1993[a].

	Transect number							Total on all
Species	1	2	3	4	5	6	7	transects
Pacific Loon				3				3
Red-throated Loon			4	3	2		2	11
Loon sp.								
Tundra Swan								
Brant								
Gr. White-fronted Goose								
Dark Goose								
Mallard								
Northern Pintail								
American Wigeon								
Dabbling duck								
Scaup sp.		3	7				16	26
King Eider								
Common Eider								
Eider sp.								
Oldsquaw			520	256	67	15	40	898
White-winged Scoter		5	16	15	152	4		192
Surf Scoter			37	30				67
Scoter sp.	21	16	71	217	246	81	60	712
Red-breasted Merganser			7					7
Diving duck	25							25
Unidentified duck								
Northern Harrier								
Rough-legged Hawk								
Gyrfalcon								
Willow Ptarmigan								
Ptarmigan sp.								
Sandhill Crane								
Whimbrel								
Stilt Sandpiper								
Red-necked Phalarope								
Phalarope sp.								
Pectoral Sandpiper								
Shorebird		15						15
Parasitic Jaeger								
Jaeger sp.								
Glaucous Gull	13	80	3	5	4	3	7	115
Herring Gull		1						1
Sabine's Gull		12						12
Arctic Tern	1	7				3		11
Short-eared Owl								
Passerine								
Black Guillemot	1							1
All species	61	139	665	529	471	106	125	2096
Km surveyed	8.5	12.0	13.2	8.5	5.8	5.0	1.5	

[a] Blank denotes no birds seen

Appendix C2. Birds observed on the terrestrial component of aerial surveys at McKinley Bay on August 1, 1993.[a]

	Transect number										Total on all
Species	1	2	3	4	5	6	7	8	9	10	trans.
Pacific Loon	2	2		2	3	1	9	3	4		26
Red-throated Loon				1	14	2	16		9		42
Common Loon											
Loon sp.						1	7				8
Tundra Swan				2	10	6	14	8	4	10	54
Brant											
Gr. Wh.-fronted Goose	25			12	28					10	75
Dark Goose								18			18
Mallard											
Northern Pintail		3		45	23	10	15	6	7	3	112
American Wigeon											
Dabbling duck											
Scaup sp.			5	8	13	10	25	70	7		138
King Eider											
Common Eider											
Eider sp.											
Oldsquaw				6	12	16	23	190			247
White-winged Scoter											
Surf Scoter											
Scoter sp.	6					24					30
Red-breasted Merganser									8		8
Diving duck					3						3
Unidentified duck											
Northern Harrier											
Rough-legged Hawk											
Gyrfalcon											
Willow Ptarmigan											
Ptarmigan sp.					1						1
Sandhill Crane					2			5	2		9
Whimbrel											
Stilt Sandpiper											
Red-necked Phalarope											
Phalarope sp.											
Pectoral Sandpiper											
Shorebird		1	2	22	5		7		3	3	43
Parasitic Jaeger							1				1
Jaeger sp.											
Glaucous Gull	1	2	7	2	11	14	19	2	5	1	64
Sabine's Gull				3							3
Arctic Tern				3			3		2		8
Short-eared Owl											
Snowy Owl									1		1
Passerine	1							2		2	5
All species	35	8	14	106	125	84	139	304	52	29	896
Km surveyed	0.2	1.0	2.2	6.8	10.8	10.2	15.5	12.0	10.0	10.0	

[a] Blank denotes no birds seen

Appendix C3. Birds observed on the outside component of aerial surveys at McKinley Bay on August 1, 1993.[a]

Species	Transect number 1	2	3	4	5	6	Total on all trans.
Pacific Loon							
Red-throated Loon	2	2					4
Common Loon							
Loon sp.						1	1
Tundra Swan							
Brant						4	4
Gr. White-fronted Goose							
Dark Goose							
Mallard							
Northern Pintail				9			9
American Wigeon							
Dabbling duck							
Scaup sp.							
King Eider							
Common Eider							
Eider sp.							
Oldsquaw				5			5
White-winged Scoter							
Surf Scoter							
Scoter sp.		25		1			26
Red-breasted Merganser						10	10
Diving duck							
Unidentified duck							
Northern Harrier							
Rough-legged Hawk							
Gyrfalcon							
Willow Ptarmigan							
Ptarmigan sp.							
Sandhill Crane							
Whimbrel							
Stilt Sandpiper							
Red-necked Phalarope							
Phalarope sp.							
Pectoral Sandpiper							
Shorebird				8		10	18
Parasitic Jaeger							
Jaeger sp.							
Glaucous Gull	12	6	2	19		1	40
Sabine's Gull				2			2
Arctic Tern							
Short-eared Owl							
Passerine							
All species	14	33	2	44	0	26	119
Km surveyed	9.2	5.0	1.5	1.8	0.5	1.8	

[a] Blank denotes no birds seen

Appendix D1. Birds observed on the bay component of aerial surveys at Hutchison Bay on August 1, 1993[a].

Species	Transect number 1	2	3	4	5	Total on all trans.
Yellow-billed Loon		2			1	3
Pacific Loon			1			1
Red-throated Loon	2	2	5		1	10
Common Loon						
Loon sp.		1				1
Tundra Swan						
Brant			4	23		27
Gr. White-fronted Goose						
Dark Goose						
Mallard			3			3
Northern Pintail	2					2
American Wigeon						
Dabbling duck						
Scaup sp.		27	65	40		132
King Eider						
Common Eider						
Eider sp.						
Oldsquaw	30	442	557	163	57	1249
White-winged Scoter	49	61		6		116
Surf Scoter	23	8	1	7		39
Scoter sp.	506	203	181	177	75	1142
Red-breasted Merganser		231	171	31	1	434
Diving duck			40	77	45	162
Unidentified duck						
Northern Harrier						
Rough-legged Hawk						
Gyrfalcon						
Willow Ptarmigan						
Ptarmigan sp.						
Sandhill Crane						
Whimbrel						
Stilt Sandpiper						
Red-necked Phalarope						
Phalarope sp.						
Pectoral Sandpiper						
Shorebird						
Parasitic Jaeger						
Jaeger sp.						
Glaucous Gull	20	6	40	57	10	133
Sabine's Gull						
Arctic Tern			1			1
Short-eared Owl						
Passerine						
All species	632	983	1069	581	190	3455
Km surveyed	10.5	13.5	15.5	6.5	3.5	

[a] Blank denotes no birds seen

Appendix D2. Birds observed on the terrestrial component of aerial surveys at Hutchison Bay on August 1, 1993[a].

	Transect number						Total on all trans.
Species	2	3	4	5	6	7	
Pacific Loon			1		1	14	16
Red-throated Loon	5		1	5		1	12
Common Loon							
Loon sp.					3		3
Tundra Swan			2	2	9	20	33
Brant							
Gr. White-fronted Goose			4	2	2	4	12
Dark Goose					8		8
Mallard							
Northern Pintail	1			25	25	5	56
American Wigeon							
Dabbling duck							
Scaup sp.				6	26	2	34
King Eider							
Common Eider							
Eider sp.							
Oldsquaw					4		4
White-winged Scoter							
Surf Scoter							
Scoter sp.							
Red-breasted Merganser			70	4	46	16	136
Diving duck							
Unidentified duck					44		44
Northern Harrier							
Rough-legged Hawk							
Gyrfalcon							
Willow Ptarmigan							
Ptarmigan sp.							
Sandhill Crane			1	4	2	4	11
Whimbrel							
Stilt Sandpiper							
Red-necked Phalarope							
Phalarope sp.							
Pectoral Sandpiper							
Shorebird	2	3		4		3	12
Parasitic Jaeger							
Jaeger sp.					1		1
Glaucous Gull	41		5	18	16	17	97
Sabine's Gull							
Arctic Tern	2	1				5	8
Short-eared Owl							
Common Raven					1		1
Passerine						2	2
All species	51	4	84	70	188	93	490
Km surveyed	1.8	2.5	11.5	7.5	11.0	11.0	

[a] Blank denotes no birds seen

[b] Includes young

Appendix D3. Birds observed on the outside component of aerial surveys at Hutchison Bay on August 1, 1993[a]

	Transect number		
Species	1	2	Total on all transects
Pacific Loon	1		1
Red-throated Loon	1		1
Common Loon			
Loon sp.			
Tundra Swan			
Brant			
Gr. White-fronted Goose			
Dark Goose			
Mallard			
Northern Pintail			
American Wigeon			
Dabbling duck			
Scaup sp.			
King Eider			
Common Eider			
Eider sp.		5	5
Oldsquaw	43		43
White-winged Scoter	1		1
Surf Scoter	2	2	4
Scoter sp.			
Red-breasted Merganser			
Diving duck			
Unidentified duck			
Northern Harrier			
Rough-legged Hawk			
Gyrfalcon			
Willow Ptarmigan			
Ptarmigan sp.			
Sandhill Crane			
Whimbrel			
Stilt Sandpiper			
Red-necked Phalarope			
Phalarope sp.			
Pectoral Sandpiper			
Shorebird			
Parasitic Jaeger			
Jaeger sp.			
Glaucous Gull		3	3
Sabine's Gull			
Arctic Tern			
Short-eared Owl			
Passerine			
All species	48	10	58
Km surveyed	11.0	5.2	

Appendix E. Total number and density of birds observed on the bay component at McKinley Bay and Hutchison Bay on August 1, 1993[a]

	McKinley Bay		Hutchison Bay	
Species group	Number	Density (birds/km^2)	Number	Density (birds/km^2)
Loons	14	0.71	15	0.84
Geese			27	1.52
Dabbling ducks			5	0.28
Diving ducks	1927	98.32	3274	183.93
Shorebirds	15	0.76		
Gulls	128	6.53	133	7.47
Terns	11	0.56	1	0.06
Other	1[b]	0.05		
Total birds	2096	106.94	3455	194.10

[a] Area surveyed: McKinley Bay - 19.6 km^2
Hutchison Bay - 17.8 km^2

[b] 1 Black Guillemot

Blank denotes no birds seen

Appendix F. Total number and density of birds observed on the terrestrial component at McKinley Bay and Hutchison Bay on August 1, 1993[a].

	McKinley Bay		Hutchison Bay	
Species group	Number	Density (birds/km^2)	Number	Density (birds/km^2)
Loons	76	2.68	31	1.90
Swans	54	1.91	33	2.02
Geese	93	3.29	20	1.23
Dabbling ducks	112	3.96	56	3.44
Diving ducks	426	15.05	174	10.67
Unidentified ducks			44	2.70
Ptarmigan	1	0.04		
Sandhill Cranes	9	0.32	11	0.67
Shorebirds	43	1.52	12	0.74
Jaegers	1	0.04	1	0.06
Gulls	67	2.37	97	5.95
Terns	8	0.28	8	0.49
Owls	1	0.04		
Passerines	5	0.18	3	0.18
Total birds	896	31.66	490	30.06

[a] Area surveyed: McKinley Bay - 28.3 km^2
Hutchison Bay - 16.3 km^2

Blanks denote no birds seen

Appendix G. Distribution of diving ducks in flocks of different sizes on the bay component at McKinley Bay and Hutchison Bay, August 1, 1993.

	Percent of total observed					
	Oldsquaw		Scoters		All divers[c]	
Flock size	MB[a]	HB[b]	MB	HB	MB	HB
< 50 birds	65	80	35	54	51	65
50-99 birds	35	20	36	19	34	18
100-199 birds			29	12	15	10
≥ 200 birds				15		6
Total observed	898	1249	971	1297	1927	3274

[a] McKinley Bay
[b] Hutchison Bay
[c] Includes scaup and mergansers

Appendix H1. Adjusted number of each species of diving duck seen on the bay component at McKinley Bay each year based on the species composition of the identified divers[a].

	Oldsquaw			Scoter			Scaup			Red-breasted Merganser			Eider			Identified divers			
Year	No.	%	Adj. no.	No.	%	Adj no.	No.	%	Adj. no.	No.	%	Adj. no.	No.	%	Adj. no.	Total	%	Unidentified divers	Total divers
1981	910	48	1046	613	32	705	369	20	424	0	0	0	0	0	0	1892	87	283	2175
1982	1063	56	1263	785	41	934	34	2	40	8	<1	9	0	0	0	1890	84	356	2246
1983	814	43	992	990	52	1207	93	5	113	0	0	0	0	0	0	1897	82	415	2312
1984	913	38	1171	1466	61	1880	20	<1	26	20	<1	26	1	<1	1	2420	77	684	3104
1985	996	82	1031	148	12	153	70	6	72	0	0	0	1	<1	1	1215	96	43	1258
1990	1713	48	2397	1771	49	2478	87	2	122	31	1	43	0	0	0	3602	71	1438	5040
1991	2179	64	3666	1082	32	1820	30	1	51	101	3	170	0	0	0	3392	59	2315	5707
1992	1049	36	1419	1746	60	2361	71	2	96	22[b]	1	30	0	0	0	2888	74	1018	3906
1993	898	47	910	971	51	984	26	1	26	7	<1	7	0	0	0	1902	99	25	1927

[a] From best survey each year

Appendix H2. Adjusted number of each species of diving duck seen on the bay component at Hutchison Bay each year based on the species composition of the identified divers[a]

	Oldsquaw			Scoter			Scaup			Red-breasted Merganser			Eider			Identified divers			
Year	No.	%	Adj. no.	No.	%	Adj. no.	No.	%	Adj. no.	No.	%	Adj. no.	No.	%	Adj. no.	Total	%	Unidentified divers	Total divers
1981	not surveyed																		
1982	778	35	838	1156	52	1246	122	5	132	157	7	169	0	0	0	2213	93	172	2385
1983	578	26	617	1571	69	1678	99	4	106	13	<1	14	0	0	0	2261	94	154	2415
1984	1488	56	1717	1006	38	1161	159	6	183	4	<1	5	0	0	0	2657	87	409	3066
1985	872	49	884	785	44	796	102	6	104	6	<1	6	11	1	11	1776	99	25	1801
1990	2436	54	2733	1694	38	1901	252	6	283	131	3	147	0	0	0	4513	89	551	5064
1991	541	37	732	581	40	786	109	7	147	224	15	303	0	0	0	1455	74	513	1968
1992	1262	48	1516	728	28	875	65	2	78	563	22	676	0	0	0	2168	83	527	3145
1993	1249	40	1314	1297	42	1364	132	4	139	434	14	457	0	0	0	3112	95	162	3274

[a] From best survey each year

Appendix II. Total numbers of birds observed on the bay and terrestrial components at McKinley Bay from 1981 to 1985 and 1990 to 1993[a].

Species	1981	1982	1983	1984	1985	1990	1991	1992	1993
Pacific Loon	9		24	10	9	25	34	25	29
Red-throated Loon	4	2	18	42	56	80	110	56	53
Loon sp.	49	44	29	13	11	11	34	8	8
Total Loons	62	46	71	65	76	116	178	89	90
Tundra Swans	33	73	37	71	61	58	88	56	54
Brant	97	100	22	47	38	95			
Gr. White-fronted Goose			30	61	31	23	72	50	75
Dark Goose	95	45		47	65	4	4	15	18
Snow Goose	1								
Total Geese	193	145	52	155	134	122	76	65	93
Northern Pintail	127	130	40	110	158	536	184	311	112
American Wigeon	3	30	6	7	15	11	72		
Dabbling Duck	93	43	33	33	13	23	224	78	
Total Dabblers	223	203	79	150	186	570	480	389	112
Scaup sp.	391	120	95	71	87	151	109	135	164
Eider sp.	19			1	1				
Oldsquaw	1023	1120	877	950	1092	2153	3127	1286	1145
White-winged Scoter	338	83	69	46	8	370		102	192
Surf Scoter	171	382	753	907	65	673	158	562	67
Scoter sp.	121	340	168	515	95	742	934	1082	742
Red-breasted Merganser	25	25	100	60	46	133	131	162	15
Diving Duck	410	356	416	833	57	1498	2493	1198	28
Total Diving Ducks	2498	2426	2478	3383	1451	5720	6952	4527	2353
Glaucous Gull	83	81	101	77	36	95	124	49	179
Sabine's Gull	8		4	9	17	9		7	15
Total Gulls[b]	91	81	105	86	53	104	124	56	195
Date of Survey	Aug 10	Aug 10	Aug 5	Aug 3	Aug 4	Aug 5	Aug 7	Aug 3	Aug 1

[a] Blanks denote no birds seen

[b] Includes 1 Herring Gull

Appendix I2. Total numbers of birds observed on the bay and terrestrial components at Hutchison Bay from 1982 to 1985 and 1990 to 1993[a].

Species	1982	1983	1984	1985	1990	1991	1992	1993
Pacific Loon	4	11	25	22	15	31	27	17
Red-throated Loon	2	17	24	51	48	24	41	22
Loon sp.	54	14	17	18	8	18	2	4
Total Loons	60	42	66	91	71	73	70	43
Tundra Swans	35	17	75	48	100	58	63	33
Brant	78		60	65	89	7	3	27
Gr. White-fronted Goose	32			31	26	153	62	12
Dark Goose		35	61	25	33	82	205	8
Snow Goose	6		8	24			1	
Total Geese	116	35	129	145	148	242	271	47
Northern Pintail	61	9	92	273	210	75	152	58
American Wigeon	1			5	16	6	56	
Dabbling Duck	5	12	26	59	85	47	85	3
Total Dabblers	67	21	118	337	311	128	293	61
Scaup sp.	122	231	159	114	454	224	65	166
Eider sp.				11				
Oldsquaw	780	586	1491	898	2453	541	1280	1253
White-winged Scoter	4	59	214	84	55	5		116
Surf Scoter	904	908	632	443	1005	134	316	39
Scoter sp.	271	605	160	278	637	448	412	1142
Red-breasted Merganser	160	13	4	36	138	224	563	570
Diving Duck	177	202	409	25	629	586	527	162
Total Diving Ducks	2418	2604	3069	1889	5371	2162	3163	3448
Glaucous Gull	85	71	49	56	54	99	34	230
Sabine's Gull					2		1	
Total Gulls	85	71	49	56	56	99	35	230
Date of Survey	Aug 10	Aug 5	Aug 3	Aug 4	Aug 5	Aug 7	Aug 3	Aug 1

[a] Blanks denote no birds seen.