THE RED-THROATED LOON AS AN INDICATOR OF ENVIRONMENTAL QUALITY IN THE BEAUFORT SEA REGION: FINAL REPORT ON PREDEVELOPMENT PHASE

by
D. Lynne Dickson

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EXECUTIVE SUMMARY

The objective of this project is to monitor the effect of future offshore oil and gas development on the birds that use the coastal areas of the Beaufort Sea. A preliminary investigation in 1984 indicated that the Red-throated Loon would be a suitable indicator species for monitoring due to its vulnerability to the proposed development, its abundance in the Beaufort Sea region and the conspicuous nature of its nests and chicks. The parameters chosen to be monitored each year were the abundance of Red-throated Loon pairs, their breeding effort and breeding success. This is a report on the five-year predevelopment phase of the study. These data will provide a benchmark for monitoring once full scale development has occurred.

Five study plots were selected: Atkinson Point and King Point where port development had been proposed (Dome, ESSO, Gulf 1982), Nuvorak Point where future shoreline development was unlikely (control for impact of shoreline development), Husky Lakes which would be unaffected by oil spills in the Beaufort Sea (control for impact of oil and other pollutants in the Beaufort Sea), and Toker Point which was relatively inexpensive to access from Tuktoyaktuk, hence suitable for a more intensive study of the Red-throated Loon. The combined total area of the five study plots was 276 km^2 with over 200 pairs of Red-throated Loons residing there each breeding season.

From 1985 to 1989, every wetland in each of the five study plots was searched to obtain total counts of Red-throated Loon pairs, nests, eggs and chicks. The surveys were conducted by helicopter, with the exception of several surveys at Toker Point which were done by foot.

A field camp was established at the Toker Point study plot from mid-June to early September each year to conduct a more intensive study intended to improve our ability to interpret the results of the basic monitoring program. Information was collected on the type of habitat used by nesting loons, the mortality rate of loon eggs and chicks, the timing of nest initiation, hatch and fledging, and the rate of development of the eggs and chicks. Information was also gathered on the various factors which might affect the productivity of the loon: weather; timing of break-up and freeze-up; water-levels in the wetlands; species and abundance of fish in loon feeding areas; frequency of feeding the chicks; abundance of predators; and abundance of prey other than loon eggs and chicks for the predators. The better our understanding of how various environmental and biological factors affect the indicator species under undisturbed conditions, the easier it will be to differentiate between man-caused and natural fluctuations in productivity during the post-development phase of the study.

The density of Red-throated Loon pairs occupying territories ranged from 0.5 to 1.9 pairs/km^2 with the highest densities occurring on the Tuktoyaktuk Peninsula and the lowest at King Point, Yukon. The number of pairs of loons at each study plot did not change significantly over the duration of the study, except at Nuvorak Point. There the number of pairs increased, with the largest influx occurring in 1987.

Productivity of the Red-throated Loons averaged 0.63 young near fledging per nesting pair from 1985 to 1989. In comparison, studies elsewhere have reported productivity ranging from 0.35 fledged young per pair on the Shetland Islands (Bundy 1978) to 1.15 fledged young per pair in Finland (Lokki and

Eklöf 1984).

As expected in an arctic environment, the breeding effort and success of the Red-throated Loon fluctuated from year to year. The percentage of resident pairs that attempted to nest varied from 58% in 1986 to 78% in 1988; similarly, the percentage of breeding pairs that were successful varied from 38% in 1989 to 63% in 1985.

The primary factor that affected breeding effort was the timing of thaw of the small ponds used by the Red-throated Loon for nesting. Although an early thaw had very little effect on breeding effort, the two-week late thaw in 1986 coincided with a much lower breeding effort. Only 58% of the Red-throated Loon pairs in the study area nested in 1986, compared to 73% to 78% in other years.

Predator pressure, particularly by arctic foxes, was the main influence on hatching success. The hatch at Toker Point was lowest in 1987 when the fox population peaked, and highest in 1985 and 1988 when there were very few foxes. To a lesser extent, hatching success was also influenced by the amount of food other than loon eggs and chicks available for the predators.

Chick survival to fledging was fairly constant at 62% to 67% during the first three years of the study, but dropped to < 39% in the last two years. The higher mortality rate of loon chicks in 1988 and 1989 was attributed primarily to heavier predation by avian predators. A four-day storm, low vole numbers and an early freeze-up were other factors contributing to the low survival of chicks in the later two years.

Red-throated Loons brought an average of 8.5 fish to each chick per day. There was no significant difference in the feeding rate from one year to the next; nor did the frequency of feedings change as the chicks got older.

The Red-throated Loon exhibited a strong tendency to use the same territory each year. At Toker Point 52% of the territories (n=65) were occupied in all five years of the study, while only 19% were used just one year. Breeding success had no effect on whether a territory was reused the following year.

In order to determine the optimum time to survey for incubating loons, two methods of establishing the date when the eggs were laid were tried: by floating the egg in water, and by weighing and measuring the size of the egg. Using the floatation method, one could estimate the age of the egg within 8 days, whereas the 95% Confidence Interval for the age derived from weighing and measuring the size of an egg was approximately ±7 days. Since neither method of aging eggs was very accurate and both involved disturbing the nest, it is recommended that the timing of the surveys for incubating loons be based on the timing of thaw of the nest ponds. The median number of days between the nest ponds thawing and egg-laying by the loons ranged from 16 to 21 days; the longer interval occurring in years when the thaw was early.

Very few chicks died after three weeks of age. Based on this, as well as the time of hatch and fledging, it was determined that most years the best time to conduct the aerial surveys for chicks near fledging would be from 18 to 22 August.

The Red-throated Loon arrives in the Beaufort Sea region in late May and early June. Most years its nesting ponds thaw at the same time and are occupied immediately by pairs of loons. With the exception of 1986 when spring was two weeks late, egg-laying began in mid-June and was completed by the first week in July with a median date of lay between 19 and 24 June. The eggs were laid 2 to 3 days apart (n=4), usually hatched 1 day apart (n=7), and were incubated 24 to

27 days (n=13). The chicks fledged from late August to mid-September following a development period of 43 to 52 days (n=10).

Lost clutches of eggs were replaced 18% to 42% of the time at Toker Point. No replacement clutches were laid by pairs that lost eggs after 13 July or lost chicks. An average of 11 days lapsed between loss of the first clutch and laying the replacement clutch (n=15). Breeding success from replacement clutches was low, ranging from none to 0.38 young per pair.

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TABLE OF CONTENTS

Table of Contents (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF FIGURES

LIST OF APPENDICES

1.0 INTRODUCTION

Exploration for oil and gas in the Canadian Beaufort Sea has resulted in the discovery of substantial quantities of fossil fuel. Although recent low market prices for oil have caused a slow-down in exploration activity in northern Canada, with favourable economics full scale extraction of oil and gas from the Beaufort Sea region may be expected.

Oil and gas production in the Beaufort Sea may have a significant impact on migratory bird populations. Since much of the oil reserves are offshore, a large portion of the associated development, including ports, airstrips, staging areas, accomodations, processing plants and communication towers, will likely occur along the coastline. Likewise, most of the bird species that inhabit the Beaufort Sea region concentrate in the coastal areas: notably the Brant, Greater White-fronted Goose, Oldsquaw, White-winged Scoter, Surf Scoter, scaup sp., Common Eider, Red-throated Loon, Arctic Tern, Glaucous Gull and several species of shorebirds. Potential impacts of oil and gas extraction on bird species in the Beaufort Sea region can be categorized as follows:

- mortality due to oil pollution from either catastrophic or chronic oil spills,
- habitat loss or degradation due to construction and operation of facilities such as ports, airstrips, roads, accomodations and pipelines, and
- disturbance from activities related to oil and gas extraction (for example, aircraft, ship and vehicular traffic, and recreational activity)

In view of the vulnerability of birds to offshore oil and gas extraction in the Beaufort Sea, the Canadian Wildlife Service decided to monitor the impact of the proposed development on the birds in the region. The results of a preliminary study conducted in 1984 showed that the Red-throated Loon would be a suitable "indicator species" for the proposed monitoring project. The Red-throated Loon occurs in relatively high densities on both the Tuktoyaktuk Peninsula and the coastal plain in northern Yukon, so that changes in numbers or productivity could be detected statistically. Red-throated Loons are present in the Beaufort Sea from June to September, nest near the coast and fish daily in the Beaufort Sea; hence, they are vulnerable to both oil spills and development along the coastline. The adults, young and nests are all conspicuous enough that they can be located from the air using a helicopter. Finally, Red-throated Loons tend to use the same nesting territory year after year (Davis 1972; Bergman and Derksen 1977; Gomersall 1986), which would facilitate locating the nests throughout the study.

To monitor the impact of development, the following parameters were measured each year:

a) number of resident pairs of Red-throated Loons,

b) breeding effort (the proportion of pairs that laid eggs), and

c) breeding success (the number of young just prior to fledging per active nesting territory).

These data were gathered for five years to determine the natural fluctuations in the breeding population size and productivity prior to development. Thereafter, the data will be collected once every five years, or following major development or an oil spill thought to be a threat to regional bird populations. The data collected later in the study will be statistically tested to see if the values fall within the range of those obtained during the predevelopment phase of the study.

For a monitoring study to be successful, it is vital to understand how various environmental and biological factors affect the indicator species under undisturbed conditions. This understanding is necessary in order to differentiate between man-caused and natural fluctuations that could occur during the post-development phase of the study. Thus, the monitoring study has a second objective which is to understand the factors that cause the natural annual fluctuations in productivity of the indicator species. Hence, information was gathered on each of the following: daily weather; timing of break-up and freeze-up; water-levels in the wetlands used by Red-throated Loons; location of the marine feeding areas; species and abundance of fish in the feeding areas; species and size of fish fed to the chicks; frequency of feeding the chicks; abundance of predators; and abundance of prey other than loon eggs and chicks for predators.

This study is intended to provide early warning of environmental changes that might occur due to oil and gas development. Because of the wide range of potential impacts, monitoring single abiotic factors, such as contaminants in the marine sediments, was considered inadequate. Subtle environmental changes affecting regional bird populations might go indetected, as well as the cumulative effect of several small impacts (Morrison 1986).

Should an impact be detected, the data from this monitoring program could also be used to measure the effectiveness of mitigative measures and the rate of recovery of the ecosystem from the impact. For example, loon abundance and productivity could be used as an indicator of recovery of an area from an oil spill.

2.0 METHODS

2.1 Aerial surveys

During a preliminary investigation in 1984, the following five study plots were selected based on loon densities, the likelihood of oil and gas related development at that location, and accessibility from Tuktoyaktuk:

- Atkinson Point (69°55'N; 131°20'W), the proposed site for a medium draft port to support future oil and gas activity (Dome, Esso, Gulf 1982),
- King Point (69°05'N; 138°00'W), the proposed site for a deep draft port (Dome, Esso, Gulf 1982),
- Nuvorak Point (70°03'N; 130°45'W), where future shoreline development was unlikely (control area for the impact of shoreline development),
- Husky Lakes (69°10'N; 132°55'W), which would be unaffected by a major oil spill in the Beaufort Sea (control for the impact of oil and other pollutants in the Beaufort Sea), and
- west of Toker Point (69°37'N; 132°44'W), which was relatively inexpensive to reach from Tuktoyaktuk and where no development had been proposed to date (site chosen for a more intensive study of the Red-throated Loon).

Figure 1 shows the location and extent of each of these five study plots.

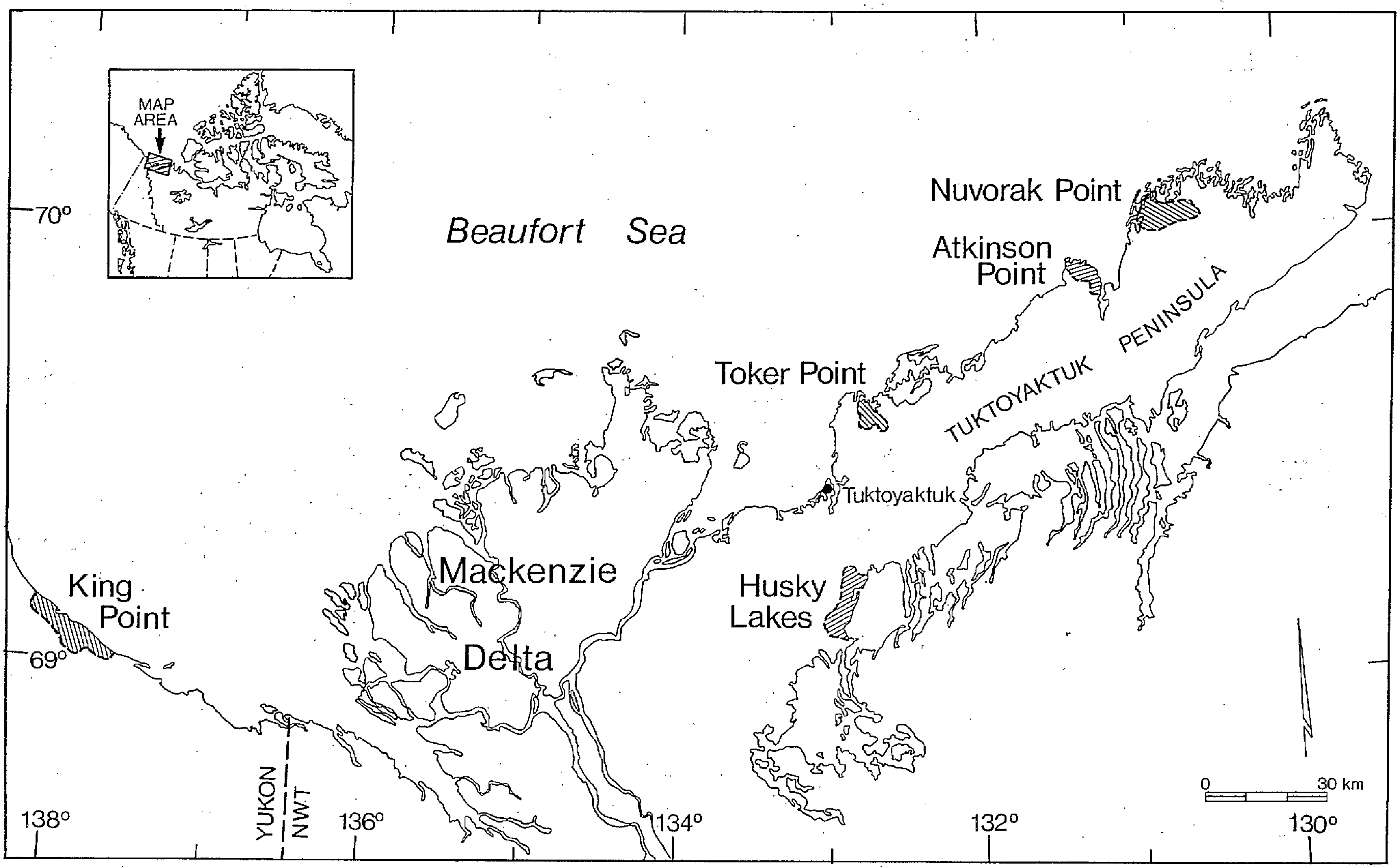

Figure 1. Location of the five study plots selected for monitoring the productivity of the Red-throated Loon in the Beaufort Sea region.

Each study plot was searched twice in 1985: once for Red-throated Loon nests during the incubation period, then once for chicks about four weeks after the median date of hatch. The surveys were repeated from 1986 to 1989, but instead of only one survey for eggs, two were conducted about 11 days apart. It became evident during the 1985 surveys that a second search for eggs was necessary, because of the three week spread in egg laying and because of egg predation.

The searches for nests were conducted by two observers in a Bell 206 Jet Ranger helicopter except at Toker Point from 1985 to 1987 when surveys were done by foot. In order to locate incubating loons, all wetlands within each study plot were checked by flying over the ponds at 70 to 90 ft above ground level (agl) at 30 to 60 mph. Wherever there were many small ponds or other complex but suitable habitat, the survey helicopter proceeded more slowly. When a loon was sighted, the shoreline of the pond was checked for a nest by hovering at about 25 ft agl and slowly moving sideways around the edge of the pond. If a loon was seen on a pond, the pond was considered an occupied territory unless there was evidence to the contrary: for example, if the loon had just flushed from a nearby occupied territory or if the habitat was deemed unsuitable.

Each territory was numbered and the location was marked on a 1:50 000 scale topographical map. The number of loons and number of eggs were recorded on a cassette tape recorder. The reaction of each loon to the helicopter (response and distance at which the loon responded) was also recorded. Photographs of the nest site and pond were taken using a camera with a 28 mm lens and shutter speed of 1/250 sec. Prior to each aerial survey, the date, time of day, pilot, observers, and weather (temperature, wind speed and direction, cloud cover, precipitation and visibility) were recorded. All data were transcribed onto a computer form later the same day.

The surveys for chicks near fledging were conducted from a helicopter at all but the Toker Point study plot which was surveyed by foot each year. For the plots checked from the air, every wetland was surveyed at approximately 30 mph and 100 ft agl. At each of the ponds known to be active nesting territories, if no young were seen, the helicopter passed over the pond again at about 10 mph and 10 ft agl to ensure the chicks were not hiding in the emergent vegetation during the first pass. If still no young were seen, the helicopter climbed to 300 ft and circled or hovered over the pond for about a minute to see if any young loons surfaced from underwater. If not, it was assumed that there were no survivors from that nest. At each nesting territory, we recorded the number of adults and chicks, the approximate size of each chick relative to adult size, and the reaction of each loon to the helicopter. A photograph of the pond was taken from the helicopter when directly above the pond. Any new nesting territory missed during the previous surveys was assigned a number, described and located on a 1:50 000 scale map.

In years when funds were available, additional aerial surveys were conducted in September to determine the approximate date when the young loons fledged. The number of adults and amount of ice on the ponds was also recorded during these surveys.

During a preliminary investigation in 1984, the aerial survey for incubating loons at the Atkinson Point study plot was repeated by two observers on foot to check the accuracy of the aerial surveys. Similarly in 1985, the August survey for chicks at Atkinson Point was repeated on the ground.

2.2 Ground surveys

Field studies were conducted at the Toker Point study plot from mid-June to early September from 1985 to 1989 (Fig. 2).

2.2.1 Nesting status of Red-throated Loon

Starting in mid-June, each wetland within the study area was searched for Red-throated Loons every three to five days. Any pond with a pair of Red-throated Loons was assigned a nesting territory number and marked on a 1:50 000 scale map. The loons were observed from a concealed place usually 200 to 300 m away for 15 to 30 min to determine whether they had begun to nest. If the loons were not nesting, they generally drifted on the pond and slept. Loons which had started to nest usually appeared more alert and resumed nest construction, egg laying or incubation within about 10 min of being disturbed.

In 1985 and 1986, once a loon had started to incubate, we approached the nest and recorded the number of eggs. If no eggs or only one was found, the nest was checked every day until there were two eggs (the normal clutch size) in order to establish laying dates. Once the clutch was complete, the nest was checked every five days until near the time of hatch. Then it was visited daily to establish the precise date of hatch. At each visit, the date, time of day, number of eggs, number of adults present and their reaction to the observer (response and distance when reacted) were recorded.

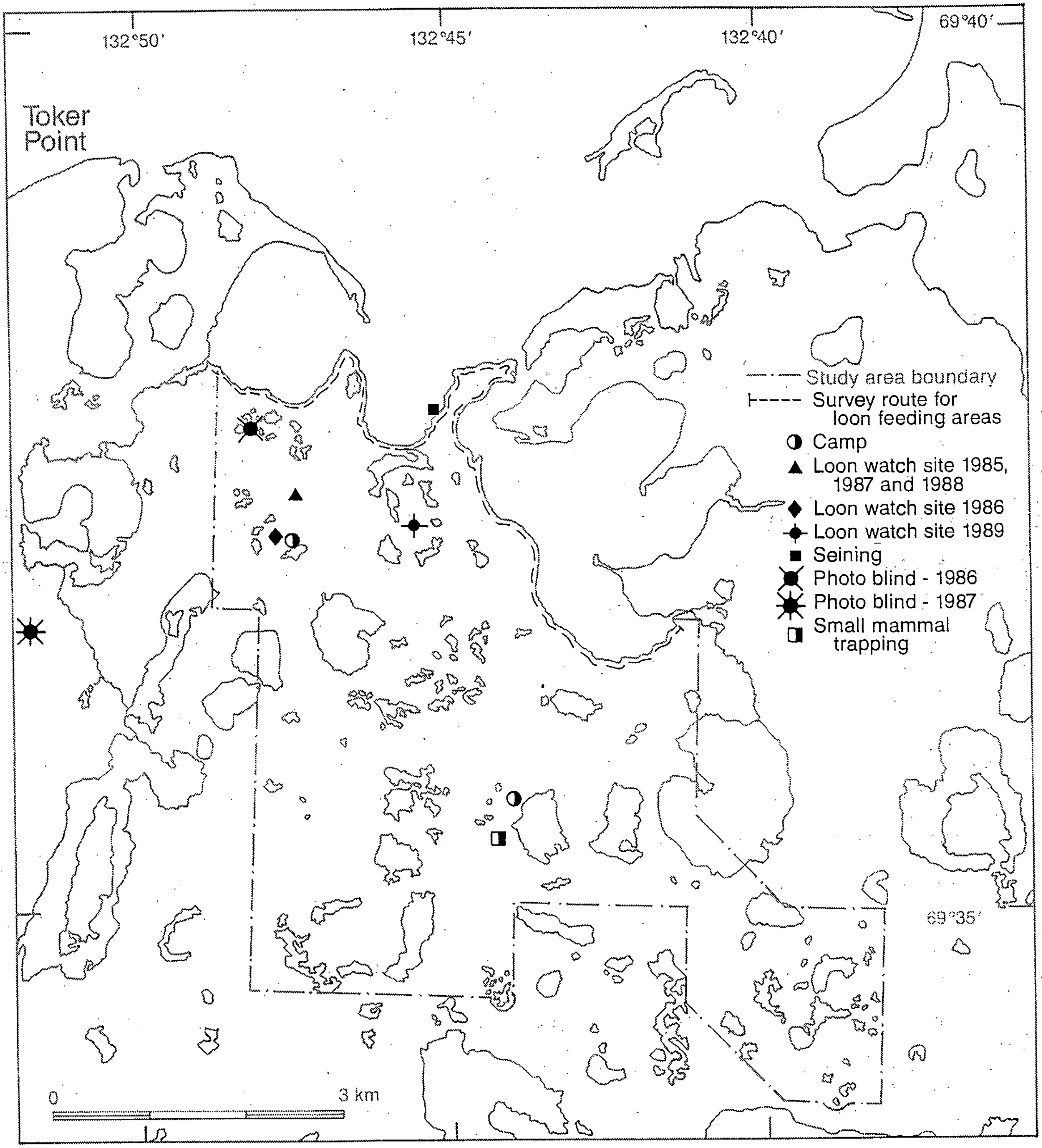

Figure 2. Toker Point study plot where ground surveys were conducted daily throughout the breeding season.

Nest checks were discontinued in 1987, since approaching the nests seemed to result in increased predation of the eggs and newly hatched chicks. Nesting and hatching data were still collected, but from a distance. In all five years, the location of the nest on the pond was sketched to facilitate locating the nest again and to establish whether the same nest site was used in future years.

If a nest had been preyed upon, any sign of what had happened was noted, as well as the date. The nest territory was then rechecked approximately every five days until early August to see if a second clutch had been laid.

Once the eggs hatched, each nesting pond was visited every five days until near the time of fledging. Then the pond was visited daily to establish the exact date when the young departed from the nesting territory.

At each visit after hatch the following information was recorded: the date, time of day, number of adults, number of young, response of the adults and young to the observer (reaction and distance at which they reacted) and the amount of ice on the pond. In addition, plumage development and the size of chicks of known age were described in order to devise a system for aging the chicks.

2.2.2 Aging eggs

In 1985 and 1986 and to a lesser extent in 1987, the density of eggs of a known age was determined so that a formula could be developed for calculating the age of an egg based on its density. Two methods for determining density were tried: measuring the weight, length and width of each egg; and floating each egg in water. A Pesola 100 gm scale was used to weigh the egg, then densities were calculated as described by Furness (1981): density = weight/0.507 x length x width^2

To determine the density of the eggs by floatation, a small clear plastic container filled with lukewarm water was used. During the first stages of egg development, the angle at which the egg rested on the bottom was recorded. To assist in estimating this angle, 22°, 45°, 68° and 90° angles were etched into the plastic container. During the latter stages of development, when the egg floated to the surface, the height the egg floated above the surface, as well as the approximate diameter of the egg protruding at the surface and the angle of the egg were recorded. Millimetres were etched along a vertical and a horizontal line on the container to facilitate taking these measurements. After floating the eggs, they were dried thoroughly with a cloth to minimize chilling, then returned to the nest.

2.2.3 Abundance of predators

Daily sightings of avian and mammalian predators (gulls, jaegers, ravens, cranes, owls, hawks, falcons, eagles, foxes) were plotted on 1:50 000 scale maps to determine the total number of predators with hunting territories in the Toker Point study plot during June and July. The location of nests and arctic fox dens were also recorded.

2.2.4 Abundance of prey other than loon eggs and chicks

A daily record was kept of the number of sightings of all bird species. Every nest and brood found within the study area was marked on a 1:50 000 scale map. The number of eggs or young was noted and the nest site was described. This report presents the relative abundance of birds, nests and young. See Sirois and Dickson (1989) and Dickson et. al (in prep) for a more detailed account of the bird species found at Toker Point.

From 1987 to 1989, small rodents (i.e. voles, mice, lemmings) were live-trapped to determine their relative abundance. In early July, a grid approximately 135 m square was established and 100 live-traps were set 15 m apart. The traps were checked twice a day for 10 days. The species and condition of captured animals were recorded, as well as the date, time, and trap number. The skin between the ears was then dyed with gentian violet so that recaptures could be identified.

2.2.5 Chick feedings

Each year, an observation tent was used to monitor the parental behavior of a pair of loons with a chick (Fig. 2). The loons were observed for two of every four hours over a 24-hour period (from 5-7:00; 9-11:00; 13-15:00; 17-19:00; 21-23:00; 1-3:00) about twice a week between time of hatch and fledging. The date, time of day, weather, visibility and number of loons at each nesting territory were noted prior to each watch. During the watch, the time and direction of all flights in and out of each nesting territory were noted, as well as whether the bird had a fish and the fate of the fish. The amount of time spent brooding the young was also recorded.

In order to determine the size and species of fish being fed to the chicks, photographs of adult loons feeding their young were taken from a blind placed at the edge of a pond in 1986 and 1987. The scale in the photographs was determined by using the distance from the anterior edge of the eye to the tip of the bill which had been measured on 22 Red-throated Loon specimens from the National Museums of Canada. A 500 mm lens and 1.5 x converter were used to photograph the fish.

Approximately 10 km of coastline were walked repeatedly between mid-July and early September from 1985 to 1987 to record the number and location of Red-throated Loons feeding in marine waters (Fig.2). In addition, in 1985 and 1987, we watched loons on several coastal lakes inhabited by fish to see if the loons ever fed in freshwater. It was assumed that fish inhabited any of the lakes that were connected to the ocean by a stream (Mike Lawrence, Fisheries Biologist, Department of Fisheries and Oceans, pers. comm.).

2.2.6 Abundance of prey for loons

About once a week from mid-July until the end of August from 1987 t0 1989, a beach seine was used to catch fish in an area where Red-throated Loons frequently fed in order to determine the species and abundance of fish available to the loons (Fig. 2) Two people dragged a 10 m long net parallel to the beach for 25 m every 2 h over a 12 h period. Prior to each haul, the time, tidal phase, water temperature and weather conditions were recorded. The fish caught were identified, counted and measured for their fork length (total length for sculpins and flounders). All fish were returned to the sea immediately except some that were less than 50 mm long which we could not identify. These were placed in a 10% formalin solution and later identified in the Fisheries and Oceans laboratory in Tuktoyaktuk.

2.2.7 Weather

The weather was recorded daily at 18:00 h throughout the field season (temperature, wind speed and direction, cloud cover, cloud type, and precipitation). We also kept records of the timing of thaw of the marshes, ponds, lakes and nearshore ice in spring, and the occurrence of ice on the marshes and ponds in autumn.

2.2.8 Collection of reference samples

Samples of Red-throated Loon eggs, adults and young-of-the-year were collected outside the study plots on the Tuktoyaktuk Peninsula to be used as references for future environmental contaminants. The egg yolk and albumen were placed in a clean glass jar which had been rinsed with acetone. The lid of the jar was lined with aluminum foil to prevent contamination and the contents were frozen later the same day. The egg shells were placed in a non-crushable container and were frozen. Adults and young were collected with a .22 calibre rifle, placed in plastic bags and frozen the same day. The adults were taken prior to nest initiation, whereas the chicks were taken just before fledging.

Fish, the size used by the Red-throated Loon to feed their young, were also collected in 1986. They were obtained with a seine net, placed in plastic whirlpaks and frozen the same day.

2.2.9 Pond descriptions

Each active nesting territory in the Toker Point study plot was described in mid summer as follows:

- length, width and depth of pond;
- pond orientation, bottom type and turbidity;
- wetland type (basin complex, thermokarst, isolated pond, other);
- if a large pond, whether it was divided into distinct bays, hence had potential for several loon territories;
- number of nearby ponds (ponds within 200 m that could be used as alternate ponds);
- amount and species of emergent vegetation;
- amount of wet versus dry shoreline and the dominant species of vegetation along the shore;
- location of nest on pond (point, island {dimensions of island}, offshore, dry shoreline, wet shoreline);
- plant species beside nest;
- visibility from nest;
- distance from nest to edge of pond;
- distance from nest to dry shore;
- distance from nest to open water;
- nest material;
- dimensions of nest (length, width and height above water); and
- nest type (platform, built-up or depression).

Most of the ponds used by the Red-throated Loon for nesting were so small that their size could not be determined with accuracy from the aerial photographs available. Thus, photographs of the ponds were taken from the helicopter at a fixed height (300, 400 or 500 ft agl) directly above the pond using a camera with a 50 mm lens and 100 ASA print film. From the same height, a photograph was also taken of a marker of a known length on the ground to provide a scale for the photographs so that the area of each pond could later be calculated.

For comparison, 57 lakes and ponds within the Toker Point study plot were randomly selected and described using the same methods as above.

2.2.10 Water-levels

In addition to the pond depths measured during the pond descriptions, general descriptions and photographs of several wetlands were taken to compare water-levels from one year to the next.

2.2.11 Pacific Loon

The nesting territories of all Pacific Loons within the Toker Point study plot were assigned a number and marked on a 1:50 000 scale map. Although Pacific Loon territories were not systematically searched for nests, each territory was checked once a week and any evidence of nesting, such as a loon on a nest or the presence of a chick, was recorded.

3.0 RESULTS

3.1 Breeding success

3.1.1 All five study plots

Table 1 shows the dates when the surveys for incubating loons and young were conducted. Based on the results of these surveys, the density of occupied territories, active territories and nearly fledged chicks was

Table 1. Dates surveys were conducted for incubating Red-throated Loons and for chicks near fledging.

Year	Date of survey by study plot				
	Toker Point	Atkinson Point	Nuvorak Point	Husky Lakes	King Point
1985	1-9 July* 10-14 August* 3 September 10 September 17 September	9 July 13 August 3 September 10 September 17 September	1,9 July 12 August	3 July 11 August	8 July 14 August
1986	5-8 July* 17-20 July* 25-27 August* 9 September 17 September	8 July 20 July 26 August 9 September 17 September	7 July 20 July 26 August	6 July 18 July 27 August 9 September 17 September	5 July 17 July 25 August
1987	28 June-2 July* 10-15 July* 18-20 August* 6, 7 September*	1 July 14 July 19 August 9 September	30 June 13 July 19 August	2 July 12 July 18 August 9 September	29 June 11 July 20 August
1988	30 June 11 July 17, 18 August* 6, 7 September*	30 June 8 July 21 August	28 June 9 July 22 August	27 June 8 July 21 August	29 June 10, 11 July 24 August
1989	29 June 8 July 28, 29 August* 5 September	26 June 9 July 21 August	27 June 7 July 23 August	29 June 8 July 20 August	28 June 6 July 22 August

*Survey conducted by foot.

calculated for each study plot in each year (Table 2; Appendix A). A site was designated as occupied if a loon was present during at least one survey, it was suitable loon nesting habitat, and it was unlikely part of a nearby loon territory. An active territory was one where we found evidence of nesting (eggs, chicks, fresh egg remains or a dead chick). A resident pair was a pair of loons that occupied a territory; a breeding pair was one that laid eggs; and a successful pair was one with young near fledging. A fledged young was one that could fly well enough that it vacated the nesting territory.

The density of territories occupied by Red-throated Loons ranged from 0.5/km^2 to 1.9/km^2 at the five study plots during the period from 1985 to 1989 (Table 2; Appendix A). The study plots at Toker Point and Atkinson Point had the highest densities of loon pairs (five year averages of 1.7 and 1.3 pairs/km^2 respectively), whereas King Point on the Yukon coast had the lowest densities (five year average of 0.6 pairs/km^2). The number of occupied territories at each study plot did not change significantly over the duration of the study (X^2 tests, 4df, $p > 0.05$), except at Nuvorak Point. There the number of occupied territories increased ($X^2 = 9.37$, 4df, $p = 0.05$), with the largest influx of additional pairs of Red-throated Loons occurring in 1987 (Tables 3 and 4; Fig. 3).

The breeding effort of the Red-throated Loon was similar in all but one year (Table 3; Fig. 4). Nest attempts ranged from 73 to 78% of the pairs except in 1986 when only 58% of the loon pairs laid eggs. The decline in nesting attempts in 1986 was significant at Toker Point and Atkinson Point (X^2 tests, 4df, $p < 0.05$), approached significance at Nuvorak Point ($X^2 = 8.1$, 4df, $p = 0.09$), but was insignificant at Husky Lakes and

Table 2. Density of Red-throated Loon nesting territories and chicks near fledging from 1985 to 1989.

Study plot	Plot size (km^2)	Density by study plot (no. per km^2)					
		Occupied territories[1]		Active territories[2]		Young near fledging	
		Mean	Range	Mean	Range	Mean	Range
Toker Point	26	1.7	1.6–1.9	1.4	1.0–1.6	0.5	0.2–0.9
Atkinson Point	33	1.3	1.1–1.4	1.0	0.6–1.3	0.8	0.4–1.4
Nuvorak Point	65	0.9	0.7–1.1	0.6	0.4–0.8	0.3	0.1–0.6
Husky Lakes	56	0.7	0.6–0.8	0.5	0.4–0.6	0.4	0.2–0.5
King Point	96	0.6	0.5–0.7	0.4	0.3–0.5	0.3	0.2–0.4

[1]A territory was considered occupied if a loon was present during at least one survey, the site was suitable loon nesting habitat, and there was no evidence that the site was part of a nearby loon territory.

[2]A territory was considered active if there were eggs, young, fresh egg remains or dead chicks.

Table 3. Summary of the breeding statistics for the Red-throated Loon at all five study plots.

	Year				
	1985	1986	1987	1988	1989
No. of pairs occupying territories	206	216	265	274	261
No. of pairs that laid eggs	151	125	204	214	196
% of pairs that attempted to nest	73%	58%	77%	78%	76%
No. of young near fledging	123	64	141	136	94
No. of young near fledging per nesting pair	0.81	0.51	0.69	0.64	0.48
Percentage of breeding pairs that were successful	63%	45%	49%	51%	38%
Percentage of eggs that fledged	50%	31%	40%	38%	28%

Table 4. Breeding effort of the Red-throated Loon at each study plot from 1985 to 1989.

Study plot	Plot size (km^2)	Year	No. of occupied territories[1]	No. of active territories	Percentage of pairs that laid eggs[2]
Toker Point	26	1985	43	37	86
		1986	43	27	63
		1987	50	39	78
		1988	46	39	84
		1989	47	41	87
Atkinson Point	33	1985	35	26	74
		1986	40	21	52
		1987	48	38	79
		1988	47	42	89
		1989	44	33	75
Nuvorak Point	65	1985	44	28	64
		1986	50	28	56
		1987	69	53	77
		1988	70	53	76
		1989	65	46	71
Husky Lakes	56	1985	35	27	77
		1986	37	24	65
		1987	40	32	80
		1988	47	36	77
		1989	44	33	75
King Point	96	1985	49	33	67
		1986	46	25	54
		1987	58	42	72
		1988	64	44	69
		1989	61	43	70

[1]Difference between years not significant at Toker Point, Atkinson Point, Husky Lakes and King Point (X^2 tests, $p > 0.05$), but was significance at Nuvorak Point study plot ($X^2 = 9.37$, 4df, $p = 0.05$).

[2]Difference between years significant at Toker Point and Atkinson Point at $p < 0.05$ and at Nuvorak Point at $p < 0.10$ (X^2 tests).

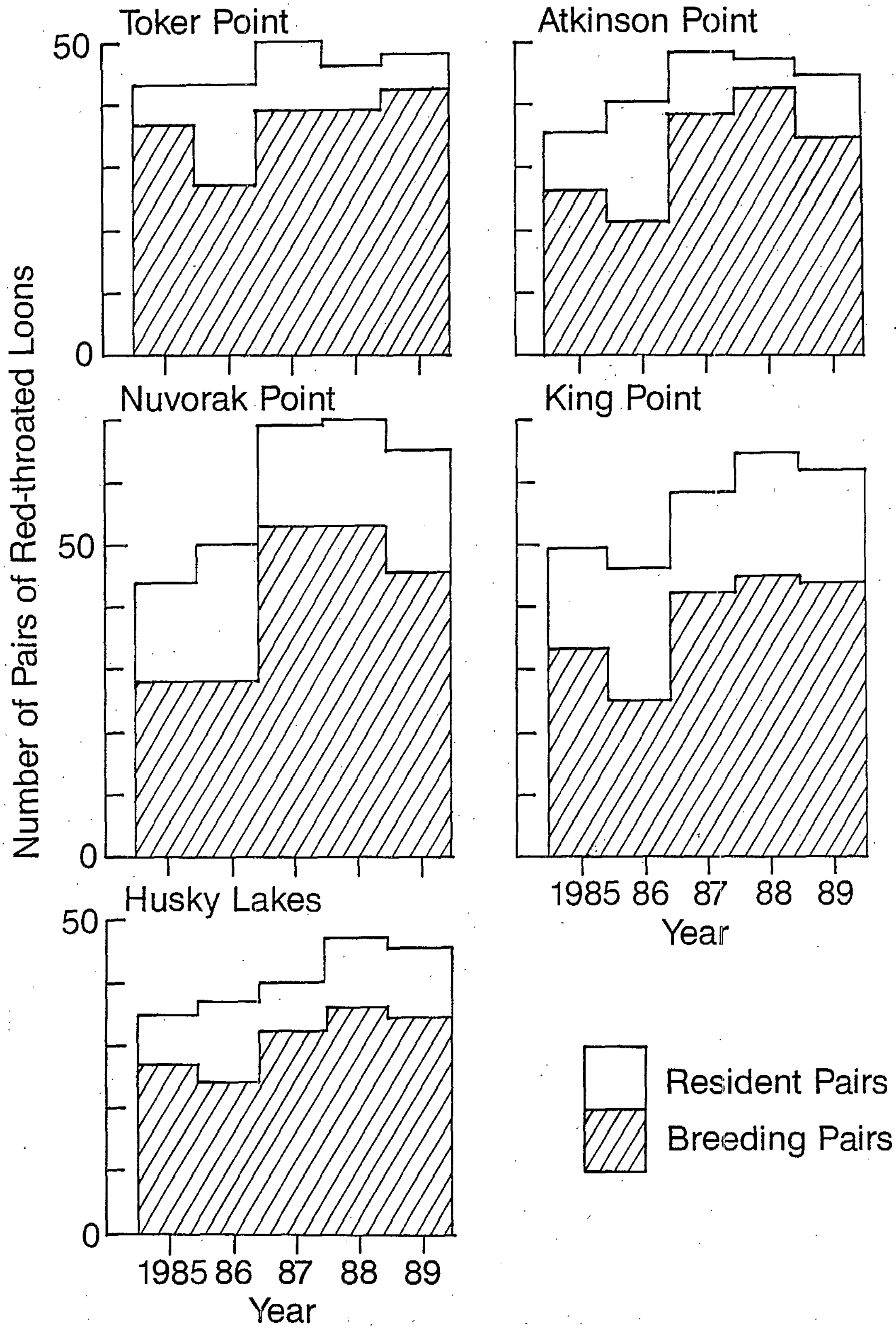

Figure 3. Number of pairs of Red-throated Loons that established nesting territories at each of the five study plots from 1985 to 1989.

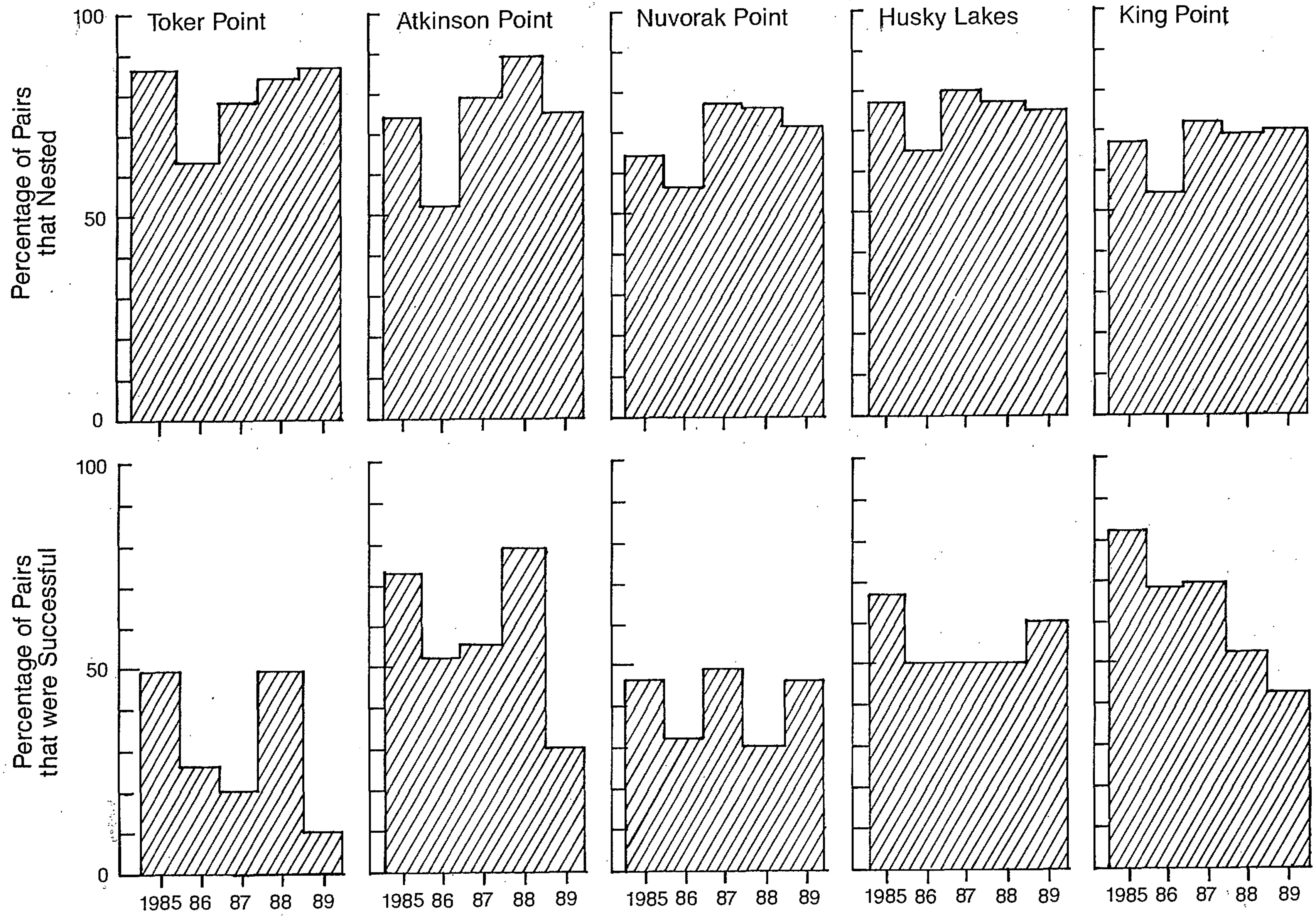

Figure 4. Breeding effort and success at five study plots in the Beaufort Sea region from 1985 to 1989.

King Point (X^2 tests, 4df, p >0.1). Throughout the study, the breeding effort was usually higher at Toker Point, Husky Lakes and Atkinson Point study plots than at the Nuvorak or King Point study plots (the five-year average percentage of pairs that attempted to nest was 80%, 75%, 74%, 69% and 66% respectively) (Fig. 4; Table 4).

Breeding success likewise varied between years and study plots (Tables 3 and 5; Fig. 4). The percentage of pairs that were successful was lowest in 1989 when an average of only 38% of the breeding pairs raised at least one young to near fledging, and highest in 1985 when 63% respectively were successful. The difference in breeding success between years was significant at the Toker, Atkinson and King Point study plots (X^2 tests, 4df, p <0.05). Breeding success was most consistent from year to year at Husky Lakes study plot.

Throughout the study period, breeding success was highest on average at King Point and Atkinson Point, and lowest at Toker Point and Nuvorak Point (Fig. 4; Table 5). The percentage successful pairs averaged 63% at King Point and 58% at Atkinson Point, compared to only 31% at Toker Point and 41% at Nuvorak Point. Similarly, the number of young fledged per active territory averaged 0.81 young/pair at King Point and 0.77 young/pair at Atkinson Point, but only 0.38 young/pair at Toker Point and 0.52 young/pair at Nuvorak Point.

3.1.2 Toker Point study plot

Four of the study plots were surveyed only three times each year, whereas the Toker Point study plot was surveyed every three to five days by foot throughout the breeding season from mid-June to the end of the

Table 5. Breeding success of the Red-throated Loon at each study plot from 1985 to 1989.

Study plot	Year	No. of eggs[1]	Ave. clutch size[2]	No. of young near fledging	Young near fledging per active territory	Successful pairs (%)[3]
Toker Point	1985	64	1.80 (n=30)	24	0.65	18 (49)
	1986	48	1.81 (n=26)	8	0.30	7 (26)
	1987	70	1.76 (n=38)	13	0.33	8 (20)
	1988	69	1.76 (n=38)	20	0.51	19 (49)
	1989	78	1.90 (n=41)	5	0.12	4 (10)
Atkinson Point	1985	44	1.89 (n=19)	21	0.81	19 (73)
	1986	36	1.79 (n=19)	14	0.67	11 (52)
	1987	65	1.74 (n=35)	32	0.84	21 (55)
	1988	77	1.87 (n=38)	46	1.10	33 (79)
	1989	61	1.85 (n=33)	15	0.45	10 (30)
Nuvorak Point	1985	43	1.70 (n=20)	15	0.54	13 (46)
	1986	45	1.65 (n=26)	9	0.32	9 (32)
	1987	91	1.74 (n=47)	37	0.70	26 (49)
	1988	89	1.69 (n=52)	20	0.38	16 (30)
	1989	77	1.63 (n=40)	31	0.67	21 (46)
Husky Lakes	1985	46	1.67 (n=15)	29	1.07	18 (67)
	1986	36	1.67 (n=18)	12	0.50	12 (50)
	1987	55	1.73 (n=30)	19	0.59	16 (50)
	1988	62	1.79 (n=33)	20	0.56	18 (50)
	1989	52	1.59 (n=32)	20	0.61	20 (61)
King Point	1985	48	1.62 (n=14)	34	1.03	27 (82)
	1986	42	1.71 (n=21)	21	0.84	17 (68)
	1987	76	1.87 (n=38)	40	0.95	29 (69)
	1988	71	1.68 (n=38)	30	0.68	23 (52)
	1989	70	1.72 (n=36)	23	0.53	18 (42)

[1] Includes eggs of chicks from nesting territories discovered after hatch.

[2] Difference between years is significant at Toker, Nuvorak and Atkinson at $p < 0.05$ and at King at $p < 0.10$ (X^2 tests).

[3] Percentage of proven breeding pairs that were successful. Difference between years is significant at Toker, Atkinson and King (X^2 tests, $p < 0.05$).

first week in September. Due to the frequency of visits, the breeding statistics for Toker Point study plot presented in Table 6 are more accurate than the similar data presented in Tables 4 and 5 which are based on only three visits a year.

The number of Red-throated Loons that established a territory in the Toker Point study plot ranged from 45 to 52 pairs between 1985 and 1989 which was not a significant change from year to year ($X^2 = 0.58$, 4df, p=0.96) (Table 6). However, the breeding effort did differ between years ($X^2 = 11.4$, 4df, p=0.023), especially in 1986 when 27% fewer pairs attempted to nest relative to other years. Clutch size was similar from year to year with an average of 1.86 eggs laid. There were never more than two eggs per clutch. Hatching success varied between years (X^2=51.9, 4df, p <0.001), ranging from as high as 66% in 1988 to possibly as low as 9% in 1989. Survival of young until near fledging was fairly constant at 62% to 67% from 1985 to 1987, but dropped to 38% or lower in 1988 and 1989. Overall, breeding success was low at Toker Point, ranging from 43% of the nesting pairs raising at least one young to near fledging in 1985 to only 2% successful pairs in 1989. Likewise, over the five years, an average of only 0.27 young fledged per breeding pair.

On average, 29% of the loons that lost their first clutch laid a replacement clutch (Table 7). Although the clutch size was similar to that of the first nesting attempt (1.78 eggs compared to 1.86 eggs in first clutches), breeding success was low. The number of young fledged per breeding pair ranged from none in three years to 0.38 young per pair in 1985.

Table 6. Breeding statistics for the Red-throated Loon obtained by continually monitoring the Toker Point study plot throughout the breeding season.[1]

	1985	1986	1987	1988	1989
Occupied territories	47	45	49	49	52
Active territories	42	32	43	44	48
% pairs that nested	89%	71%	88%	90%	92%
Eggs[2,3]	92	68	97	86-97	94-109
Average clutch size First clutch	1.87 (n=39)	1.81 (n=31)	1.84 (n=43)	1.83 (n=35)	1.95 (n=38)
Replacement clutch	1.88 (n=8)	1.83 (n=6)	1.70 (n=10)	1.83 (n=6)	1.67 (n=3)
Eggs hatched[2]	37	12	14	37-57	10-21
% eggs hatched	38%	17%	14%	38-66%	9-22%
Young fledged[4]	23	8	9	14	1
% young fledged	62%	67%	64%	25-38%	5-10%
% eggs fledged	25%	12%	9%	14-16%	1%
Young fledged/ breeding pair	0.55	0.25	0.21	0.32	0.02
Successful pairs	18	7	6	14	1
% successful pairs	43%	22%	14%	32%	2%

[1]Based on both first and second clutches.

[2]Includes eggs of chicks from nesting territories discovered after hatch.

[3]Includes 11 nests in 1988 and 15 nests in 1989 of unknown clutch size which we assumed had either 1 or 2 eggs.

[4]Assumed 2 chicks at nest site T-5 in 1985 did not fledge (36 to 39 days old at freeze-up on 19 September); assumed chick at T-6 and chick at T-22 in 1988 did not fledge (38 and 36 days old respectively at freeze-up on 23 September); assumed chick at T-20, 2 chicks at T-23 and chick at T-66 in 1989 did not fledge (36, 32, 33 and 35 days old respectively at freeze-up on 17 September).

Table 7. Replacement clutches laid by the Red-throated Loon at Toker Point study plot.

	Year				
	1985	1986	1987	1988	1989
No. of pairs that lost first clutch	23	23	40	19–22	40–45
No. of re-nests	8	6	11	8	8
% of loons with predated clutches that laid a second clutch[1]	35%	26%	28%	36–42%	18–20%
No. of eggs in second clutches[2]	15	11	18	13–15	10–15
Eggs hatched (%)	7 (47%)	0	8 (44%)	10–14 (66–100%)	4–6 (27–60%)
Young fledged[3] (%)	3 (43%)	0	4 (50%)	0	0
Young fledged per breeding pair	0.38	0.00	0.36	0.00	0.00
% successful pairs	38%	0	27%	0	0
Range in dates when first clutches were lost	25 June–10 July n = 8	30 June–6 July n = 4	27 June–13 July n = 11	27 June–10 July n = 7	27 June–7 July n = 8
Mean initiation date of replacement clutch (range)	10 July (4–17 July) n = 4	17 July (16–18 July) n= 3	9 July (1–12 July) n = 3	16 July (7–23 July) n = 4	15 July (4–21 July) n = 5
Mean no. of days between loss of first clutch and laying replacement clutch (range)[4]	10 days (8–13 days) n = 4	14 days (10–17 days) n = 2	9 days (6–11 days) n = 3	10 days n = 1	11 days (6–18) n = 5

[1]Difference among years not significant (X^2 tests, 4df, $p > 0.05$).

[2]Includes eggs of chicks from nesting territories not discovered until after hatch.

[3]Assumed chicks < 40 days when their nesting ponds froze died prior to fledging.

[4]Accuracy within 2 days.

3.2 Phenology

The following data on phenology were obtained at Toker Point from 1985 to 1989.

3.2.1 Egg laying

Most years, egg laying at Toker Point began around 12 June and was completed by the first week in July with a median date of lay occurring between 19 and 24 June (replacement clutches not included) (Table 8). In 1986, however, there was nearly a two week delay in nest initiation; egg laying did not begin until 26 June and the median date of egg laying was not until 3 July. The difference between years in the timing of nest initiation was significant (Median Test, $p < 0.001$), with observations from 1986 alone accounting for nearly half of the difference.

The two eggs within a clutch were usually laid two days apart, but sometimes three days apart (2 days apart for 3 pairs; 3 days apart for 1 pair). None were laid 1 day apart (n=26).

Replacement clutches were laid an average of 11 days after loosing the first clutch (range: 6 to 18 days, n=15) (Table 7). In all five years at Toker Point, no replacement clutches were laid after 23 July. Nor were any replacement clutches laid for nests where the eggs were lost after 13 July or where chicks were lost.

3.2.2 Incubation

The first egg laid in a clutch was incubated an average of 26 days (range: 25 to 27 days, n=7), whereas the second egg was incubated 25 days (range: 24 to 25 days, n=6).

Table 8. Comparative dates of egg laying for Red-throated Loons at Toker Point study plot from 1985 and to 1989.

Median date first egg of clutch laid (range)[1]				
1985	1986	1987	1988	1989
20 June	3 July	24 June	19 June	19 June
(10 June - 5 July)	(26 June - 12 July)	(17 June - 2 July)	(12 June - 8 July)	(13 June - 10 July)
n = 31	n = 22	n = 22	n = 37	n = 46

[1]Replacement clutches not included. If date of lay was unknown, it was estimated by back-dating from time of hatch assuming the first egg was incubated 26 days.

3.2.3 Hatch

The eggs within a clutch hatched 1 day apart in 4 clutches, 2 days apart in 2 clutches, and 3 days apart in 1 clutch.

3.2.4 Fledging

Most of the Red-throated Loon chicks at Toker Point fledged between late August and mid-September (Fig. 5). However, in 1986 the median date of fledging occurred over a week later than average (13 September in 1986, compared to 3 September in 1985, 1 September in 1988 and 31 August in 1987 - chicks from replacement clutches not included and 1989 data excluded due to small sample size).

The period between hatch and fledging averaged 47 days and ranged from 43 to 52 days (n=10). The number of days until fledging was known within a day for an additional 13 chicks. Based on the data for all 23 chicks, it took an average of 46 days for them to fledge.

3.3 Aging eggs

3.3.1 By weight and size

A total of 133 eggs at 77 nest sites at Toker Point were weighed every three to six days, and measured for their length and width. The decrease in the density of the eggs as they aged was then calculated. Whenever either the exact date of hatch or date of egg laying was unknown, we assumed that the eggs were laid two days apart and hatched one day apart (Sections 3.2.1 and 3.2.3; Davis 1972; Bundy 1976), and that the incubation period was 26 days for the first egg and 25 days for the second egg (Section 3.2.2). At sixteen nest sites where neither date of lay nor

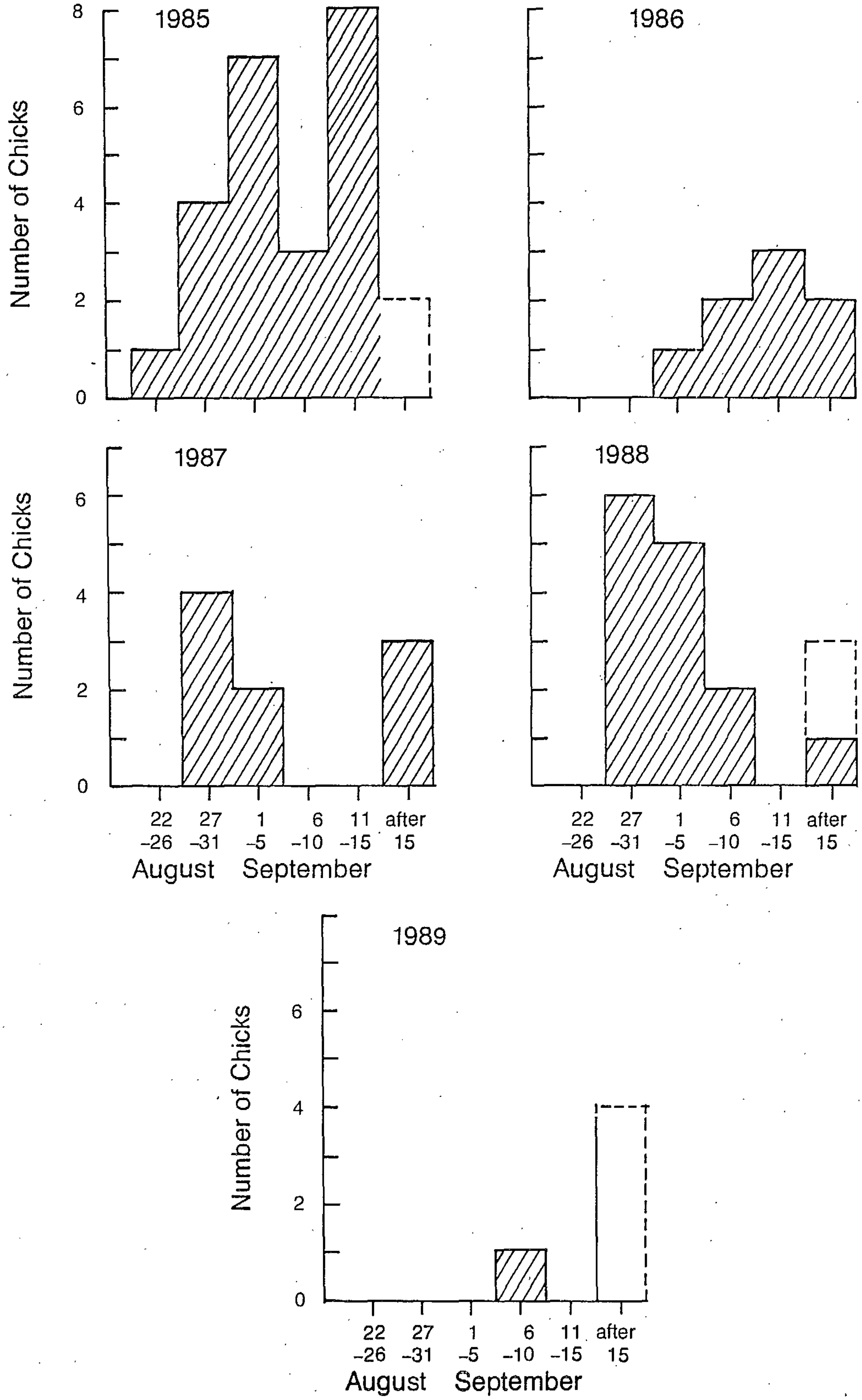

Figure 5. Fledging dates of Red-throated Loon chicks at the Toker Point study plot (dotted line indicates ponds froze before chicks were 40 days old, hence they may not have survived).

the date of hatch was known, the age of the egg was determined by floatation. Addled eggs were eliminated from the analysis.

The density of the eggs was regressed on age and the resulting linear equation was inverted to express days until hatch as a function of density:

$$\widehat{\text{days}} \text{ until hatch} = -133.297 + 144.663 \text{ (density)}$$

$$R^2 = 0.753$$

The estimated variance of days was:

$$S^2(\widehat{\text{days}}) = 11.886\left[1 + \frac{1}{546} + \frac{(\text{density} - 1.0359)^2}{0.9467}\right]$$

and the 95% Confidence Interval for $\widehat{\text{days}}$ was:

$$\widehat{\text{days}} \pm t_{1-\alpha/2,\ n-2}\sqrt{S^2(\widehat{\text{days}})}$$

$$t_{.975,544} = 1.964$$

Thus, if the egg weighed 69.0 gm, was 7.272 cm long and 4.204 cm wide:

density = 1.059 gm/cm^3

$\widehat{\text{days}}$ until hatch = 19.9

$S^2(\widehat{\text{days}}$ until hatch) = 11.9

95% Confidence Interval = ±6.78

Therefore, the egg would hatch in 20 ± 7 days.

3.3.2 By egg floatation

Eggs at 70 nests in the Toker Point study area were floated in a container of lukewarm water every 3 to 6 days. The changes in the way the eggs floated throughout incubation were summarized, then depicted graphically (Table 9; Fig. 6). Addled eggs, and eggs without either a

Table 9. Changes in egg floatation with incubation for the Red-throated Loon at the Toker Point study plot.

Days until hatch	Description	Percentage of observations that fit description	Bouoyancy		
			On bottom	Neutral	Floating
22-26	On bottom at 0° to 15°	97% (n = 98)	100%	0%	0%
18-21	On bottom at 16° to 40°	80% (n = 79)	100%	0%	0%
14-17	On bottom at 41° to 75°	57% (n = 68)	100%	0%	0%
10-13	On bottom at 76° to 90°	67% (n = 40)	78%	5%	17%
9	Transition between floating and resting on bottom; angle of egg 85° to 90°.	94% (n = 18)	39%	28%	33%
6-8	Floating at 85° to 90° with $\leq$0.5 cm above surface and <1.6 cm egg width at surface.	68% (n = 19)	5%	16%	79%
3-5	Floating at 85° to 90° with $\geq$0.5 cm above surface, and $\geq$1.6 cm egg width at surface	88% (n = 32)	0%	0%	100%
1-2	Floating at <85° with $\geq$0.7 cm above surface and $\geq$1.8 cm egg width at surface	75% (n = 8)	0%	0%	100%

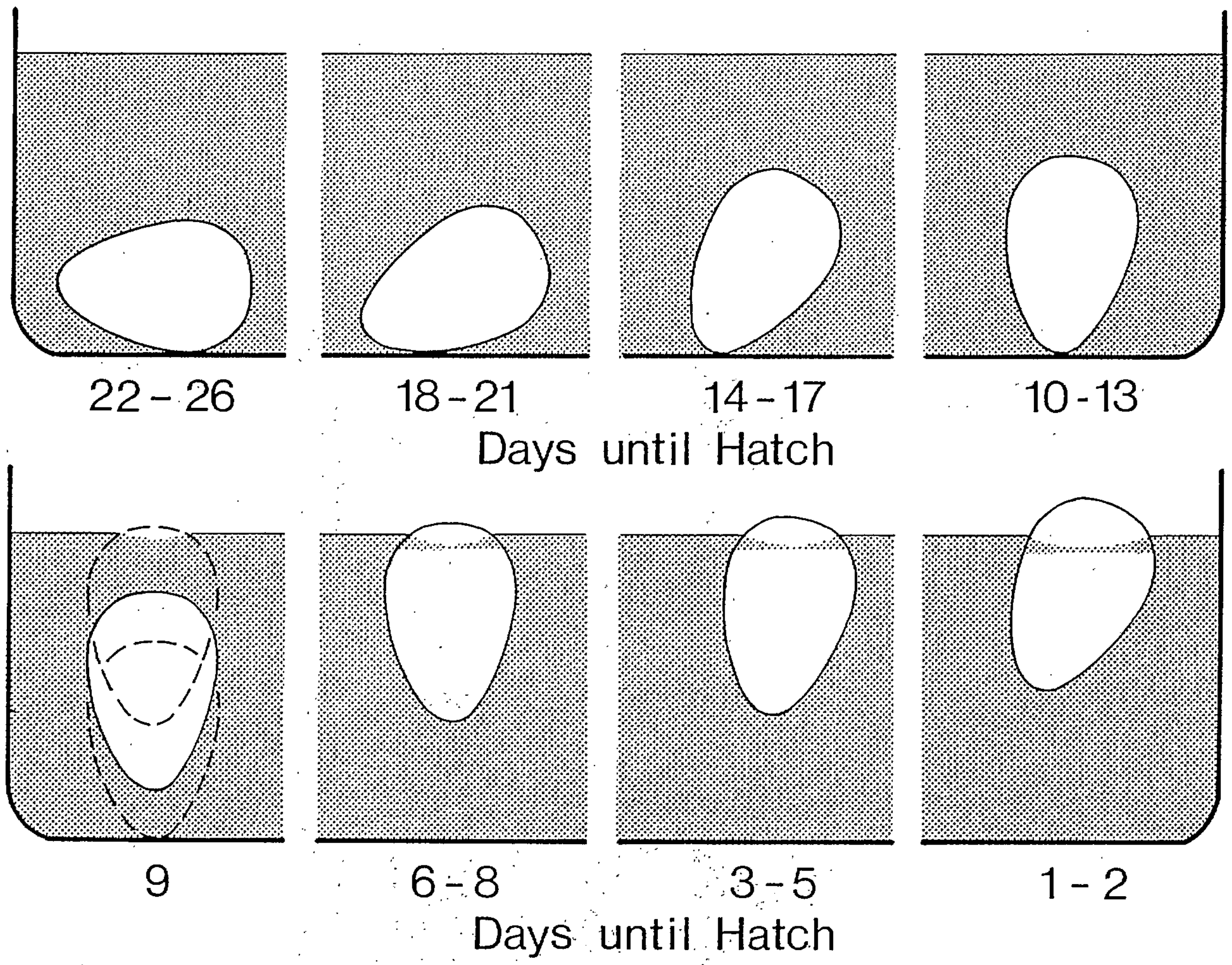

Figure 6. Changes in egg floatation with incubation for the Red-throated Loon at the Toker Point study plot.

known date of lay or hatch were excluded from the summary.

During the first five days of incubation, the eggs rested on the bottom of the container of water at an angle of 15° or less (Table 9; Fig. 6). Over the next eight days, the large end of the egg gradually lifted until by two weeks most of the eggs were standing upright on the bottom of container. The eggs floated to the surface 7 to 13 days before hatch, with the majority rising 8 to 10 days before hatch. In the last five days, the eggs emerged out of the water nearly a centimetre and tilted to an angle of about 80°.

3.4 Aging chicks

The size, shape and plumage of 30 loon chicks of a known age at Toker Point were recorded every five days until the chicks fledged. Using the information on size, an equation to estimate the age of a chick based on its size was developed following a technique described by Johnson <u>et al</u>. (1975). First, we determined the growth pattern of the chicks as a function of age (time) using the following model:

$$S\ (t) = (A^{1-m} + \beta e^{-kt})^{1/1-m}$$

Where $S(t)$ = size of chick at time t

A = asymptotic growth limit

β= a parameter related to time origin (i.e. size at hatch)

m = a shape parameter

t = time

K = growth rate

Using initial values of $m = 1.5$, $\beta = 1.0$ and $k = 1.5$, and setting $A = 100\%$, this model was fit to 210 size-age data points by Simplex and Quasi-Newton minimization methods (Wilkinson 1988). Both methods converged to:

Estimate	Asymptotic standard error	95% confidence interval
m = 2.222	0.314	1.603, 2.841
ß = 0.0612	0.048	-0.035, 0.155
K = 0.1558	0.016	0.125, 0.187

The resultant growth curve is depicted in Fig. 7.

So that age could be estimated from the size of the chick during the aerial surveys for chicks near fledging, the above model was inverted:

$$\text{Age} = \frac{\ln\{[(\text{size})^{1-m} - 100^{1-m}]/\beta\}}{-K}$$

It was not possible to determine the true estimates of the standard error due to the nonlinear nature of the growth curve. However, a lower bound for the variance was calculated by grouping the observed chick sizes into classes, then computing the variance of the ages in each size class (Johnson et al. 1975) (Table 10). Thus, for example, the minimum standard deviation of an age calculated for a chick 31 to 40% adult size would be 3.885 days, and the lower bound of variance for 95% confidence limits would be ± 2.348 using

$$\pm t_{1-\alpha/2,\, n-1} \cdot \frac{s}{\sqrt{n}}$$

The precision of the equation that estimates age was also assessed, primarily to determine the range of ages for which the equation was useful.

$$\text{Var (age)} \doteq \left[\frac{d \text{ age (size)}}{d \text{ size}}\right]^2 \text{Var (size)}$$

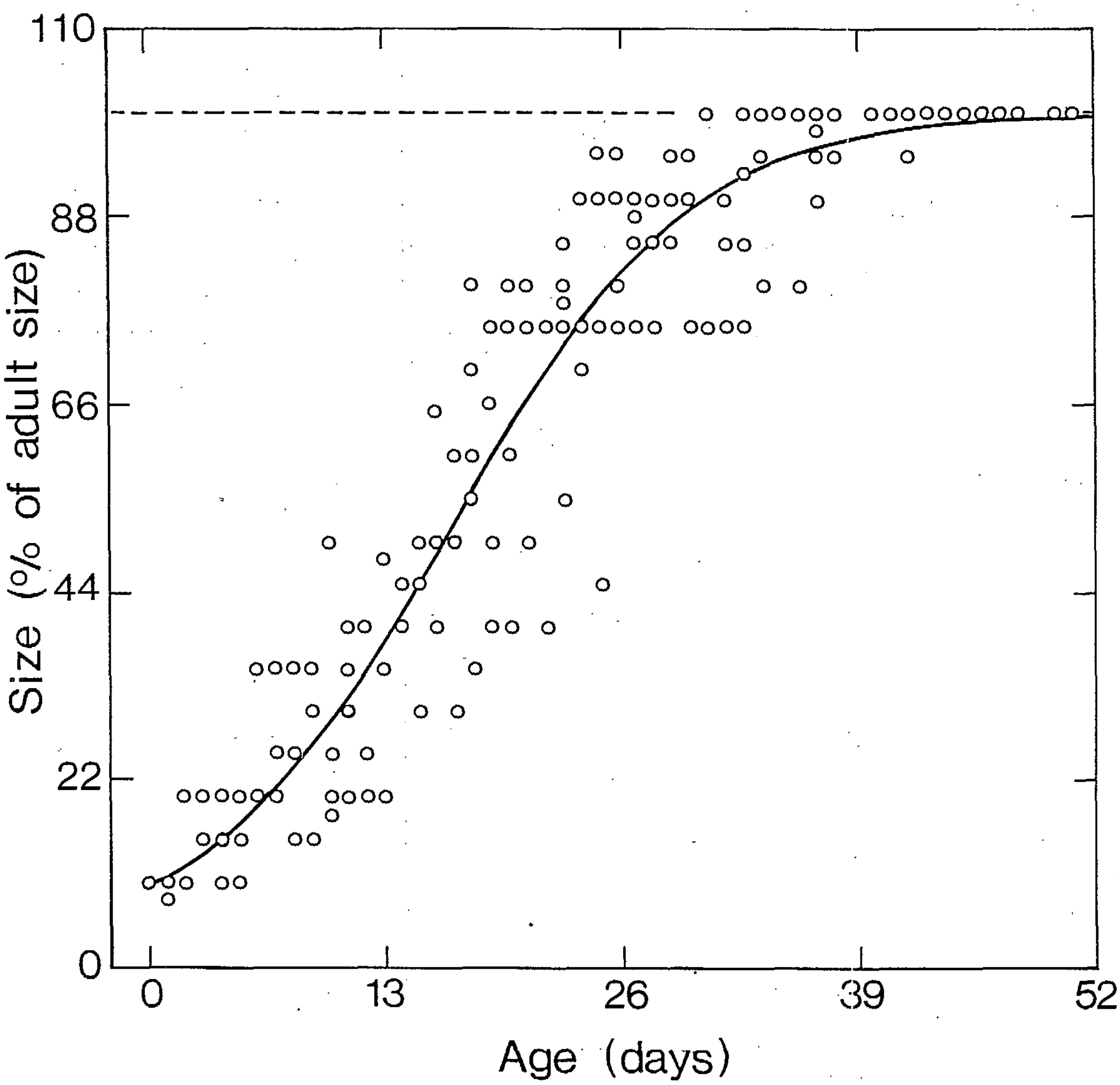

Figure 7. Rate of growth of Red-throated Loon chicks at the Toker Point study plot.

Table 10. Variance of the predicted age of the Red-throated Loon chicks at Toker Point study plot.

Percent of adult body size	Size class	Sample size	Age of chick (days) Mean	Standard deviation	Standard error
0-10	1	1			
11-20	2	31	2.935	2.792	0.501
21-30	3	19	7.737	3.177	0.729
31-40	4	13	11.385	3.885	1.077
41-50	5	14	15.571	4.327	1.157
51-60	6	12	17.083	3.204	0.925
61-70	7	6	18.333	1.633	0.667
71-80	8	24	24.375	4.528	0.924
81-100	9	90	35.267	7.849	0.827

Thus the derivative,

$$\frac{d\ age\ (size)}{d\ size} = (m-1)\ (\beta\kappa)^{-1} (size)^{-m}\ e^{k(age)}$$

governs the variance of age. The resultant graph of the derivative $\frac{d\ age}{d\ size}$ (Fig. 8) illustrates that age can be predicted from size with reasonable confidence up to about 37 days of age. After this point, the variance becomes too large.

An age classification system for chicks was developed using the growth curve and chick descriptions (Table 11). For the first nine days, the chicks were downy and ball-shaped. During the second week, the body elongated, and the head and neck became lighter in colour. By two weeks the chicks were about 40% of adult body size, and by three weeks they were two-thirds the size of an adult (Fig. 7). During the third and fourth week, feathers developed on the back, sides and the rump. By the end of the fifth week, the chick appeared nearly full grown (over 90% of adult body size), only small clumps of down remained, and a pale cheek patch became prominent. By 42 days, most chicks had no visible down, and had acquired an adult shape.

3.5 Mortality of eggs and chicks

Most years at Toker Point, the mortality rate was much higher for eggs than chicks (Fig. 9). The average weekly mortality rate for eggs was 31%, compared to 14% for chicks up to 21 days old in four of the five years. The exception was 1988 when the highest mortality occurred with freshly hatched chicks less than one week old (32% mortality). That year, the weekly mortality for eggs averaged only 15% compared to 23% for chicks up to 21 days old.

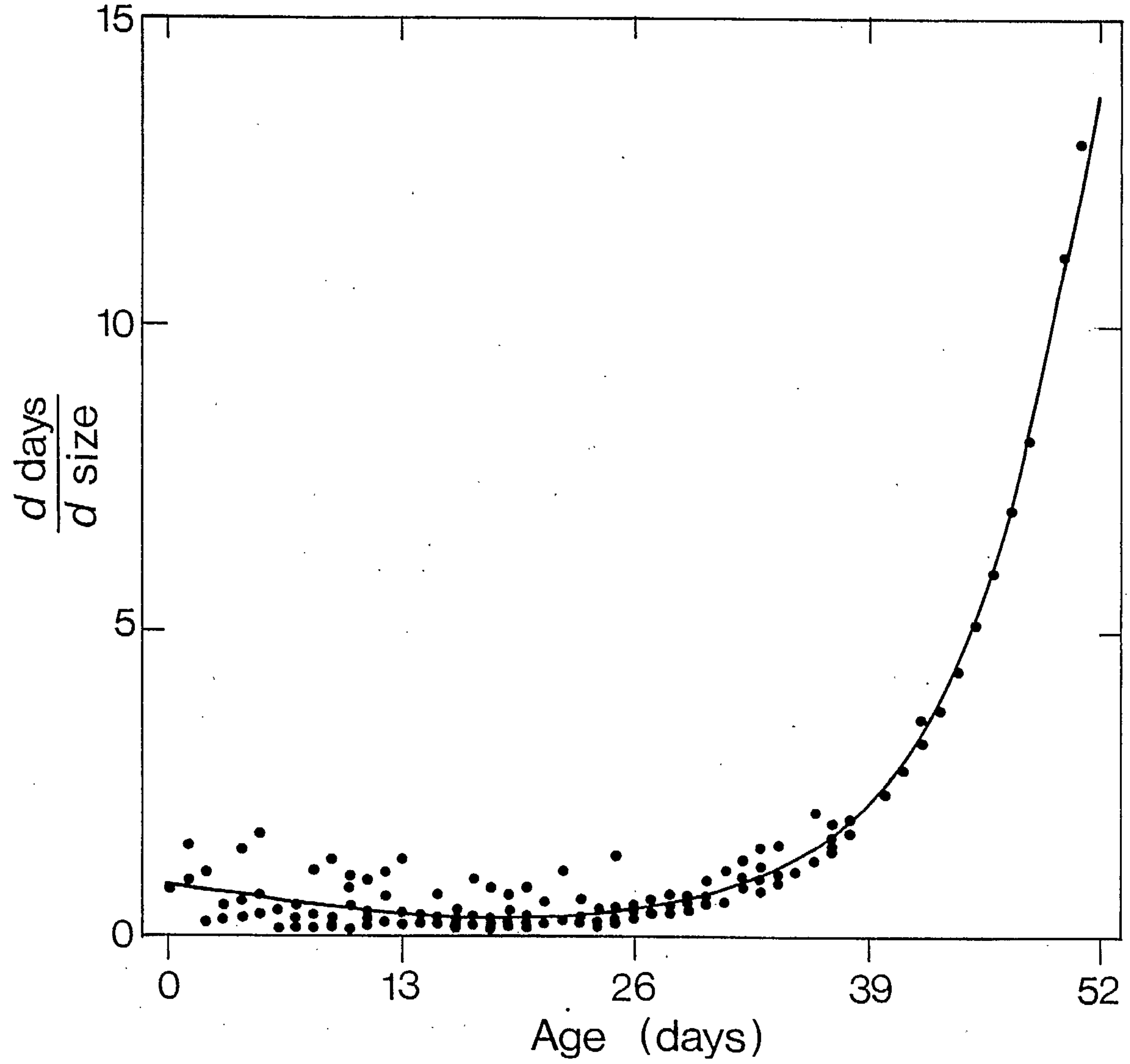

Figure 8. Precision of the equation for estimating the age of a Red-throated Loon chick from its size.

Table 11. Age classification of Red-throated Loon chicks according to plumage development, shape and size, based on chick descriptions at the Toker Point study plot.

	Class	Age in days	Description of plumage and shape	Size (% of adult size)
1	Downy	0-9	Downy with no feathers visible; ball-shaped; neck and tail not prominent.	10-25
2A	First Feathers	10-16	Head and neck appear lighter in colour and fuzzy*; back, sides and rump still dark and downy; body and neck elongated.	26-50
2B	Partly to Mostly Feathered	17-31	Head and neck light grey; back, sides and rump mixture of feathers and down; body elongated, but small head and short neck.	51-90
2C	Last Down	32-40	Clumps of down remain on sides, rump and back; underbody light; white cheek patches.	91-100
3	Fully Feathered	41-52	Completely feathered; adult-like; white cheek patches, white breast and belly, speckled back; grey bill; light coloured eye; fledges during this period.	100

*A second paler down plumage is acquired (Palmer 1962; Bundy 1976).

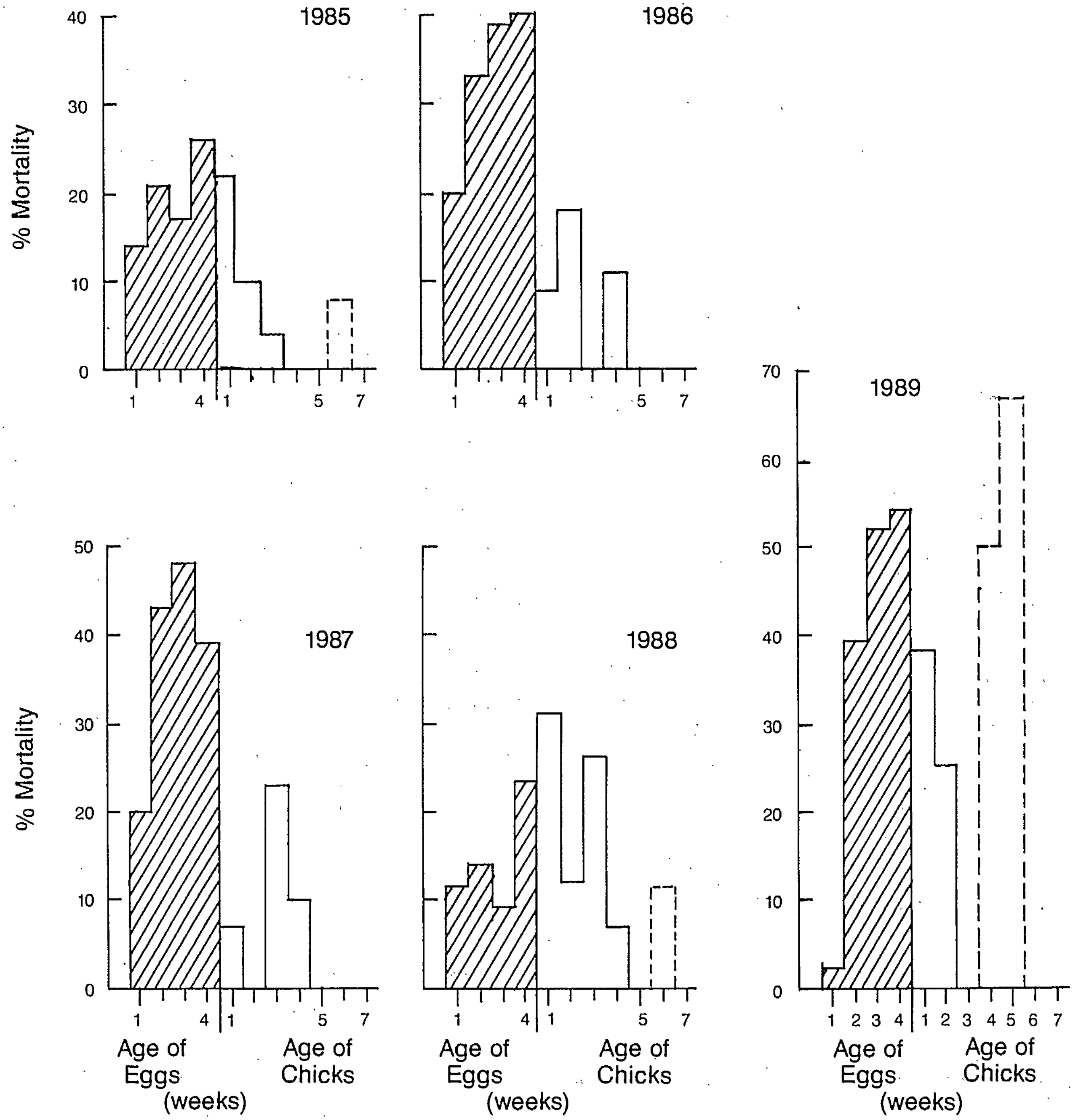

Figure 9. Red-throated Loon egg and chick mortality rates for Toker Point study plot (% mortality = no. lost during week/no. available at beginning of week (× 100%), addled or infertile eggs and eggs of unknown age were excluded from analysis; dotted line indicates death of chicks assumed since ponds froze when they were less than 40 days old).

Few chicks died after three weeks of age. Of the 53 chicks lost after hatch during the five years of study, all but 3 died in the first three weeks after hatch. This is excluding 8 chicks that may have died at 5 to 6 weeks old because their ponds froze over prior to the age when they normally fledge.

3.6 Abundance of predators

Throughout June and July each year, a daily record was kept of the number of predators of loon eggs and chicks seen in the Toker Point study plot (Table 12; Appendix B). The most common predator species were the Glaucous Gull, Parasitic Jaeger, Common Raven, Sandhill Crane and arctic fox. Total numbers of nesting pairs with hunting territories at least partly within the study area were tabulated (Table 13) and the core of their territory mapped each year (Appendix C). A pair of avian predators was recorded as nesting if either a nest was found or if the pair was seen repeatedly in the same location during the nesting period. Fox dens were mapped and their status noted. A natal den was one with pups; an active den was one in use by foxes, but not natal.

The arctic fox and Sandhill Crane were the only predators which differed significantly in numbers among years (Table 12; Appendix B). The arctic fox was more abundant in 1986 and 1987 than in the other three years (Quade Test, $T = 12.6$, $K_1 = 4$, $K_2 = 32$, $p < 0.05$). The Sandhill Crane was more abundant in 1989 than in any other year (Quade Test, $T = 6.8$, $K_1 = 4$, $K_2 = 32$, $p < 0.05$). The increase in cranes in 1989 was due to an influx of nonbreeding birds which occured only that year. They arrived during the last week of June, and remained in the study plot in small

Table 12. Changes among years in abundance of the most common predators of loon eggs and chicks at the Toker Point study plot.

	Mean daily count[1]				
Year	Arctic Fox	Sandhill Crane	Parasitic Jaeger	Glaucous Gull	Common Raven
1985	0.0	5.5	4.3	30.1	1.2
1986	0.3	6.1	2.6	30.5	0.7
1987	0.9	5.0	3.8	28.1	0.9
1988	0.1	6.3	3.5	22.5	0.5
1989	0.2	13.6	3.6	20.7	0.6
Quade test T value	12.6**	6.8**	1.6	1.8	2.4

[1]The daily count was initially calculated from observations recorded over 6-day intervals between 17 June and 9 August (Appendix B).

**Significant difference among years at $p < 0.05$ (Quade Test, $K_1 = 4$, $K_2 = 32$), calculated from daily counts recorded over 6-day intervals from 17 June to 9 August each year.

Table 13. Summary of the abundance of predatory birds with hunting territories in the Toker Point study plot.

Species	Number of pairs (number of young)[1] 1985	1986	1987	1988	1989
Glaucous Gull**	38 (30)	40 (14)	32 (22)	36 (42)	30 (27)
Sabine's Gull	0	0	1	0	0
Parasitic Jaeger	4 (1)	6 (0)	6 (2)	3 (3)	5 (2)
Long-tailed Jaeger	0	0	0	1	0
Sandhill Crane	5 (4)	12 (0)	8 (0)	10 (6)	14 (7)
Common Raven	0	2	1	1	1
Northern Harrier	1	0	0	1	1
Rough-legged Hawk	1	3 (6)	3 (4)	4 (7)	1

[1]Refer to Appendix C for location of nesting territories.

**Difference in the number of Glaucous Gull chicks among years was significant (X^2 = 15.8, 4df, p <0.05).

flocks of up to 12 birds until fall migration.

The number of nesting pairs of each of the common avian predators at Toker Point did not change significantly between years (X^2 tests, 4df, $p > 0.05$) (Table 13). However, Glaucous Gull chick production did vary between years ($X^2 = 15.8$, 4df, $p < 0.05$). Most of the variance was due to more chicks present in 1988 and fewer in 1986.

3.7 Abundance of prey other than loon eggs and chicks

Nests of all bird species found within the Toker Point study plot were recorded each year. With the exception of shorebirds, the number of nests found varied from year to year (X^2 test, 4df, $p < 0.05$), with the lowest number occurring in 1986 (Table 14; Appendix D). Likewise, fewer chicks of all species were found in 1986. Like the Red-throated Loon, although a relatively large number of waterfowl nested in 1987, few young were produced (Table 14).

The number of arctic ground squirrels seen was recorded daily from 17 June to 9 August (Table 15). No significant difference among years was detected (Quade Test, $T=2.1$, $K_1 = 4$, $K_2 = 24$, $p > 0.05$). However, the number of ground squirrels seen from one week to the next within each year was highly variable, so that differences among years would be hard to detect.

Small mammals were live-trapped for 10 days between 5 and 15 July from 1987 to 1989 (Appendix E). All were northern red-backed voles (*Clethrionomys rutilus*,), except one meadow vole (*Microtus pennsylvanicus*) caught in 1988. Vole numbers differed significantly among years (Kruskal-Wallis Test, $T=19.9$, 2df, $p < 0.05$), peaking in 1988 and crashing in 1989.

Table 14. Number of nests, eggs and young of species other than the Red-throated Loon found annually at Toker Point study plot.

	Waterfowl		Shorebirds		Passerine		All species	
Year	Nests[1]	Young[2]	Nests[1]	Young[2]	Nests[1]	Young[2]	Nests[1]	Young[2]
1985	21	226	9	25	18	16	97	382
1986	11	70	11	17	16	15	76	155
1987	33	33	20	8	35	78	157	164
1988	20	236	14	11	45	82	151	407
1989	23	241	13	13	26	55	129	441

[1]Differences among years in number of nests are significant except for shorebirds (X^2 tests, 4 df, $p < 0.05$).

[2]Differences among years in number of young are significant for all species groups (X^2 tests, 4 df, $p < 0.05$).

Table 15. Number of arctic ground squirrels seen daily at Toker Point.

6-day interval	Mean number of arctic ground squirrels seen per day[1]				
	1985	1986	1987	1988	1989
June 17-22	0.83	0.50	0.33	2.83	2.33
June 23-28	0.00	0.17	0.17	1.75	1.50
June 29-July 4	0.17	0.33	0.17	1.50	0.60
July 5-10	0.75	0.00	1.50	2.00	1.00
July 11-16	3.33	1.17	0.17	2.00	1.20
July 17-22	0.40	0.17	2.00	1.50	2.50
July 23-28	3.17	0.83	4.00	ND	2.33
July 29-Aug. 3	1.75	1.67	5.25	ND	2.50
Aug. 4-9	0.33	1.00	4.50	1.33	2.50
Mean	1.19	0.65	2.01	1.84	1.83
S.D.	±1.27	±0.56	±2.06	±0.50	±0.75

ND -no data

[1]No significant difference between years (Quade Test, $T=2.11$, $K_1=4$, $K_2=24$, $p>0.05$).

Excluding recaptured voles, 6.6 voles/100 trap-nights were caught in 1988, compared to only 1.8 voles/100 trap-nights in 1989. In 1987, vole numbers were moderate at 4.0/100 trap-nights.

3.8 Chick feeding frequency

The number of hours Red-throated Loons with chicks were systematically observed each year is presented in Table 16 and the locations of the bird-blinds are shown in Figure 2. The loons brought an average of 8.5 fish to each chick per day, based on all five years of data (Table 16). There was no relationship between the age of the chick and the feeding rate (R^2_{adj} = 0.016, F = 2.42, df = 1,86, p = 0.12). Nor was there a significant difference in the number of fish brought to the chicks from one year to the next (Kruskal-Wallis Test, T =8.5, 4 df, p >0.05), although the higher feeding rate in 1985 than in 1987 approached significance at p = 0.07. An average of 4% of the fish brought to the chicks were not eaten, either because the fish was too big or because the chick appeared not hungry. At one site in 1988, the chick refused 14% of the fish and died at about three weeks old.

3.9 Abundance of prey for loons

The coastal waters off the Toker Point study plot were surveyed from shore 6 times in 1985, 19 times in 1986 and 4 times in 1987 to determine where the Red-throated Loons were feeding (Fig. 2). Loons were seen throughout the three bays, usually within 200 m of shore (Fig. 10). On calm days they were farther offshore, including outside the bays. On windy days they tended to use a leeward shore. Overall, the loons

Table 16. Number of fish that Red-throated Loons brought to their chicks each day at the Toker Point study plot.

Year	Nest site	Number of chicks	Number of fish per chick per day[1] $\bar{X}$	SD	N	Percent of fish not eaten	Number of hours of observations
1985	T-35	2	9.8			5%	92
	T-36	1	10.0			8%	90
	T-72	1	10.1			4%	53
	Average		10.0	±4.8	24		
1986	T-43	1	7.7	±3.8	12	0%	123
1987	T-17	1	7.2			4%	81
	T-22B	1	9.8			0%	14
	Photoblind	2	5.5			4%	28
	Average		7.2	±4.3	15		
1988	T-7B	1	7.4			14%	66
	T-9	1	8.0			2%	128
	T-11	1	8.5			0%	32
	Average		7.9	±3.1	23		
1989	T-13	1	9.0	±4.3	14	10%	154
1985-89	All sites	13	8.5	±4.2	88	5%	861

[1]No significant difference between years in the number of fish brought to the chicks each day (Kruskal-Wallis Test, T=8.5, 4df, $p > 0.05$). Also, no significant relationship between age and feeding rate (R^2_{adj}= 0.016, $F = 2.42$, df = 1,86, p=0.123).

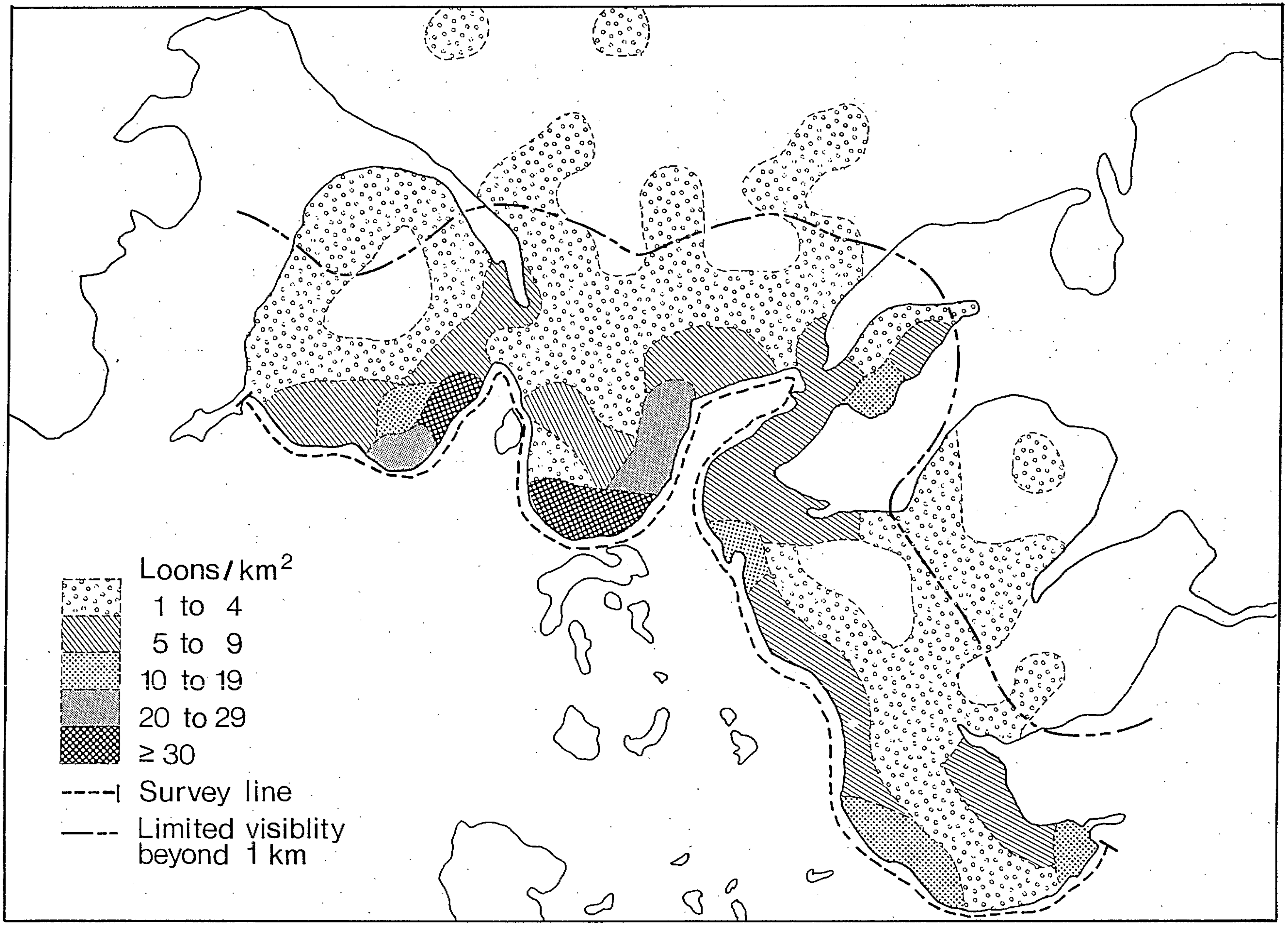

Figure 10. Feeding areas of the Red-throated Loon at the Toker Point study plot.

occurred most frequently along the southeast shore of the two bays nearest Toker Point.

In 1985 and 1987, the activities of Red-throated Loons on freshwater lakes were monitored for a total of 23 hours to see if they were taking fish for their young from fresh as well as salt water. Although there were as many as eight loons at a time on a lake, we saw a loon with a fish in its bill only once.

About once a week from mid-July to early September from 1987 to 1989, fish were caught with a beach seine to determine the relative abundance of prey for the Red-throated Loons (Fig. 2; Table 17; Appendix F). The fish caught varied in size from 2 to 47 cm, but only fish from 5 to 20 cm have been reported here since that is the size Red-throated Loons normally feed their chicks (Appendix G). Coregonids accounted for about 90% of the catch (5 to 20 cm along) over the three years: about 50% of the fish were least ciscos, 20% were arctic ciscos, 20% were broad whitefish and 1% were lake whitefish. The remaining 10% were mostly fourhorn sculpins, Pacific herring and rainbow smelt. Catch per unit effort (number of fish per 100 m of shoreline seined with a 10 m long net) differed among years, the low catch in 1987 contributing the most to this difference (Kruskal-Wallis Test, $T=27.5$, 2df, $p < 0.05$). The catch was low due to the greater number of hauls with no fish (30% of the hauls in 1987, compared to 8% in 1989 and 0% in 1988). When only hauls where fish were encountered were considered, the mean catch per unit effort was nearly the same each year (ranged from 40.9 to 41.9). Thus the density of fish in a school did not vary among years; only the frequency of times we encountered a school of fish.

Table 17. Comparison among years of the abundance of food for Red-throated Loons (fish with a fork length of 5 to 20 cm) at Toker Point based on a beach seining operation.

	Catch per unit effort[1]						% of hauls with no fish
	All hauls[2]			Excluding hauls with no fish			
Year	$\overline{X}$	SD	N	$\overline{X}$	SD	N	
1987	31.9	53.4	36	41.9	64.3	25	30
1988	40.9	21.9	42	40.9	21.9	42	0
1989	40.2	31.8	48	41.5	30.8	44	8

[1]Number of fish caught per 100 m of shoreline seined with a 10 m long net.

[2]Significant difference among years (Kruskal-Wallis Test, T=27.5, 2df, $p < 0.05$).

The amount of time fish-eating birds spend at the nest site might be an indication of the availability of fish to birds (Cairns 1987). The amount of time a pair of loons spent on the nesting pond was calculated using the data from the systematic 2-hour watches conducted each year at Toker Point study plot (Appendix H). Accordingly, during chick-rearing the loons were present on the nest pond significantly more in 1987 and less in 1988 than in any other year (Kruskal-Wallis Test, T =19.3, 4df, $p < 0.05$ with Multiple Comparisons). This suggests that fish were more abundant in 1987; thus contradicts the results of the beach seine operation which indicated that there were fewer fish available in 1987.

3.10 Weather

At Toker Point, a daily record of the temperature, wind speed and direction, precipitation and cloud cover was kept each year from mid-June to the end of the first week in September. In addition, weather records for Tuktoyaktuk were obtained from Atmospheric Environment Service (Appendix I). The following is a brief summary of the storms encountered each year.

In 1985, several snow storms occurred in July, but the mean temperature remained above freezing: on 5 and 6 July with 40 kph winds, on 17 July with 30 kph winds and on 19 July with 50 kph winds. From 15 to 18 September, there was a severe snow storm with snow and winds up to 70 kph. Of the ten ponds that had had Red-throated Loon chicks on 10 September at Atkinson Point and Toker Point, four had over 90% ice cover on 17 September.

In 1986, the only major storm during the breeding season at Toker

Point occurred on 22 to 24 August. The wind speed reached 40 kph and about 2 cm of snow accumulated on the ground. However, the snow melted within 24 hours and the small ponds remained open.

Similarly, in 1987 there was only one storm which occurred from 28 to 31 August. Winds gusted to 55 kph, accompanied by both rain and snow showers. However, it remained warm enough so that the snow did not accumulate on the ground. Nor did the small ponds freeze.

In 1988, a storm with high winds (50 kph gusting to 70 kph), rain and snow showers occurred from 1 to 4 August. The snow did not accumulate on the ground, but unusually high tides due to the strong northwest winds resulted in flooding of the coastal lowlands all along the northwest shore of the Tuktoyaktuk Peninsula. Two ponds with Red-throated Loon nests at Toker Point were flooded during this storm and one at Atkinson Point, as well as approximately 20% of the Nuvorak Point study plot.

No severe storms occurred during the breeding season in 1989.

3.11 Timing of break-up and freeze-up

The shallow ponds used by the Red-throated Loons for nesting thawed in late May and early June, except in 1986 when they did not thaw until 18 June (Table 18). The coastal waters where the loons fed were also slower to thaw in 1986. Based on weather data from Tuktoyaktuk airport 20 km from Toker Point, spring thaw was over a week earlier than normal in 1985, 1988 and 1989, near normal in 1987 and over a week late in 1986 (Fig. 11; Appendix J).

The ponds used by the Red-throated Loon for brood-rearing froze earliest in 1989 on 17 September and latest in 1987 on 26 September

Table 18. Timing of spring breakup and freeze-up at Toker Point study plot.

Year	Mean daily temperature goes above 0°C for >2 days[1]	Reach 30 thawing degree-days[1]	Snow cover <5%	Marshes open	Shallow ponds open	Deep ponds open	Lakes (>0.25 km^2) open	Coastal lead of >100 m	Shallow ponds freeze
1985	22 May	31 May	early June	early June	1 June	21 June	3 July	20 June	19 Sept
1986	6 June	18 June	16 June	16 June	15-18 June	25-27 June	13 July	1 July	24 Sept
1987	1 June	9 June	7 June	7 June	8 June	23-25 June	30 June	29 June	26 Sept
1988	25 May	4 June	late April	25 May	29 May	20 June	24 June	22 June	23 Sept
1989	27 May	31 May	1 June	30 May	1 June	19 June	24 June	22 June	17 Sept
27-year norm	29 May	10 June							

[1]From Atmospheric Environment Service

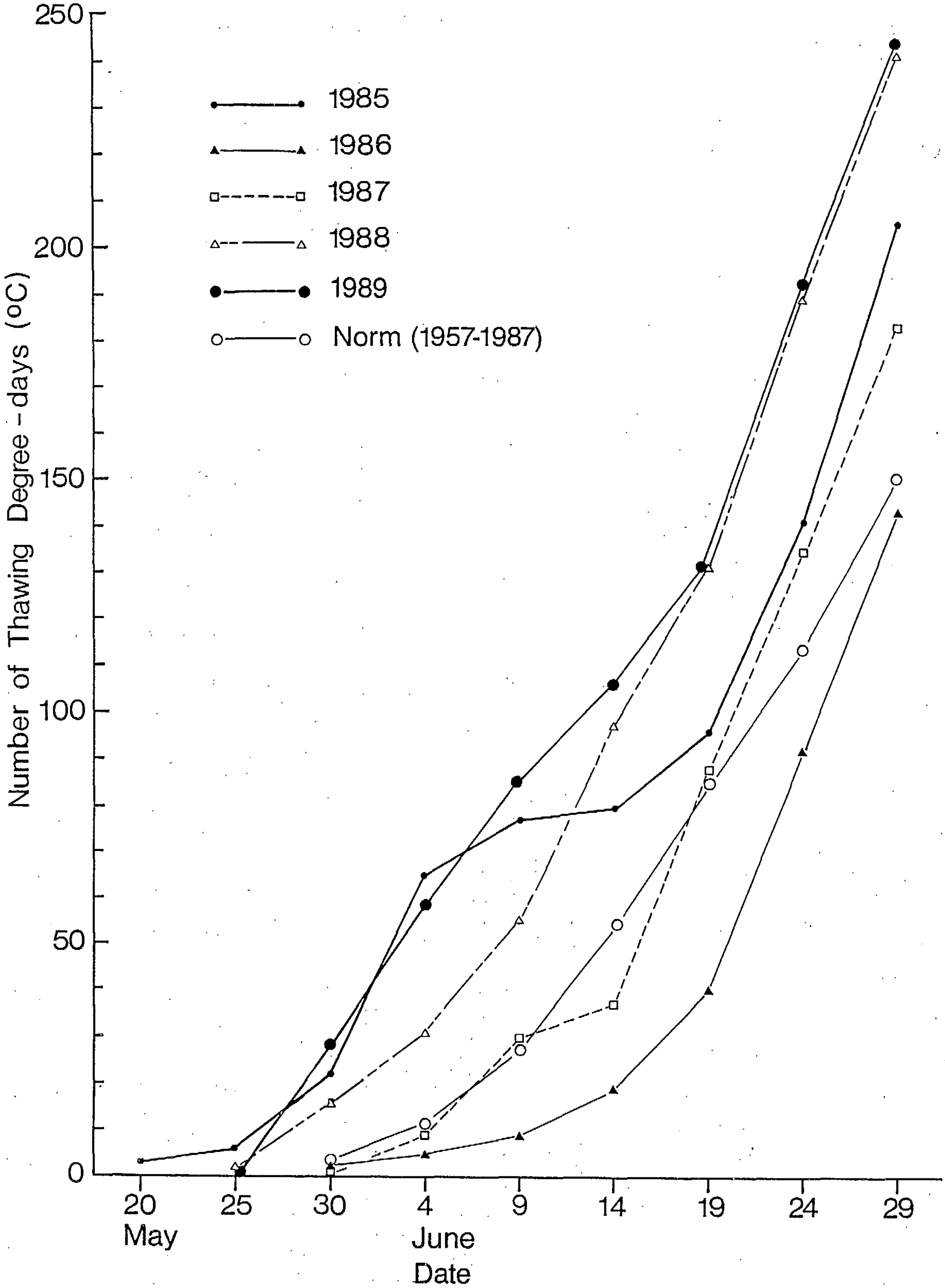

Figure 11. Cummulative number of thawing degree-days at Tuktoyaktuk airport (data provided by Atmospheric Environment Service).

(Table 18). These dates for freeze-up were likely a few days later than is typical, since temperatures in September were above normal in all five years (Appendix H).

3.12 Water-levels

Water-levels were measured in three wetlands at Toker Point in mid-July (1985, 1988 and 1989) and mid-August (1985 to 1989). Soil moisture and percent cover with standing water were recorded along transects in two of the wetlands, while the percent cover with water of a cluster of seven shallow ponds was recorded in the third wetland.

Water-levels in the wetlands at Toker Point were highest in 1986, following a winter of much higher than normal precipitation (73 mm more precipitation than normal at Tuktoyaktuk according to Atmospheric Environment Service) (Appendix I). Despite the high water-levels that year no nests were flooded, since rainfall in June and July was below normal.

The other four years had noticeably lower water-levels. In 1985 and 1988, the two driest years, several nests originally built in water became stranded on land several metres from the water's edge by mid-July. In all five years, the shallowest nesting ponds at Toker Point were partly dry by late July.

Ponds photographed from a helicopter in early July showed that water-levels at Husky Lakes, Atkinson Point and Nuvorak Point were also highest in 1986, and lowest in 1985 and 1988. Changes in water-levels at King Point could not be detected using photographs, because none of the ponds had exposed mudflats at lower water-levels.

3.13 Reference specimens collected

From 1986 to 1989, the following specimens were collected from the Beaufort Sea region, frozen and stored in the tissue bank at the National Wildlife Research Centre in Ottawa to be used as references for environmental contaminants: 9 adult Red-throated Loons collected shortly after arrival on the nesting ponds in mid-June; 10 eggs from separate clutches collected in the early stages of incubation (all <7 days old) in late June and early July; 11 young-of-the-year Red-throated Loons from different broods collected in late August (10 were live birds 3 to 6 weeks old and one was a dead bird about 18 days old); and 52 fish (fork length from 55 to 219 mm) collected in the middle bay north of the Toker Point study plot. See Appendix K for the exact dates and locations of the collections.

Pooled samples of the eggs collected in 1986 and 1987, as well as the livers of four adult Red-throated Loons collected in 1987 were analyzed for organochlorine residues by the National Wildlife Research Centre. Levels of all substances were low, indicating very little contamination (Appendix L).

3.14 Nesting territories

From 1985 to 1989, Red-throated Loons at the Toker Point study plot occupied a total of 65 different nesting territories (includes both occupied and active territories). The location of these territories is shown in Figure 12. Over half (57%) of the territories consisted of only 1 pond, 28% had 2 ponds and 15% had 3 or more ponds. In several cases, the nest platform changed location to a different pond within the

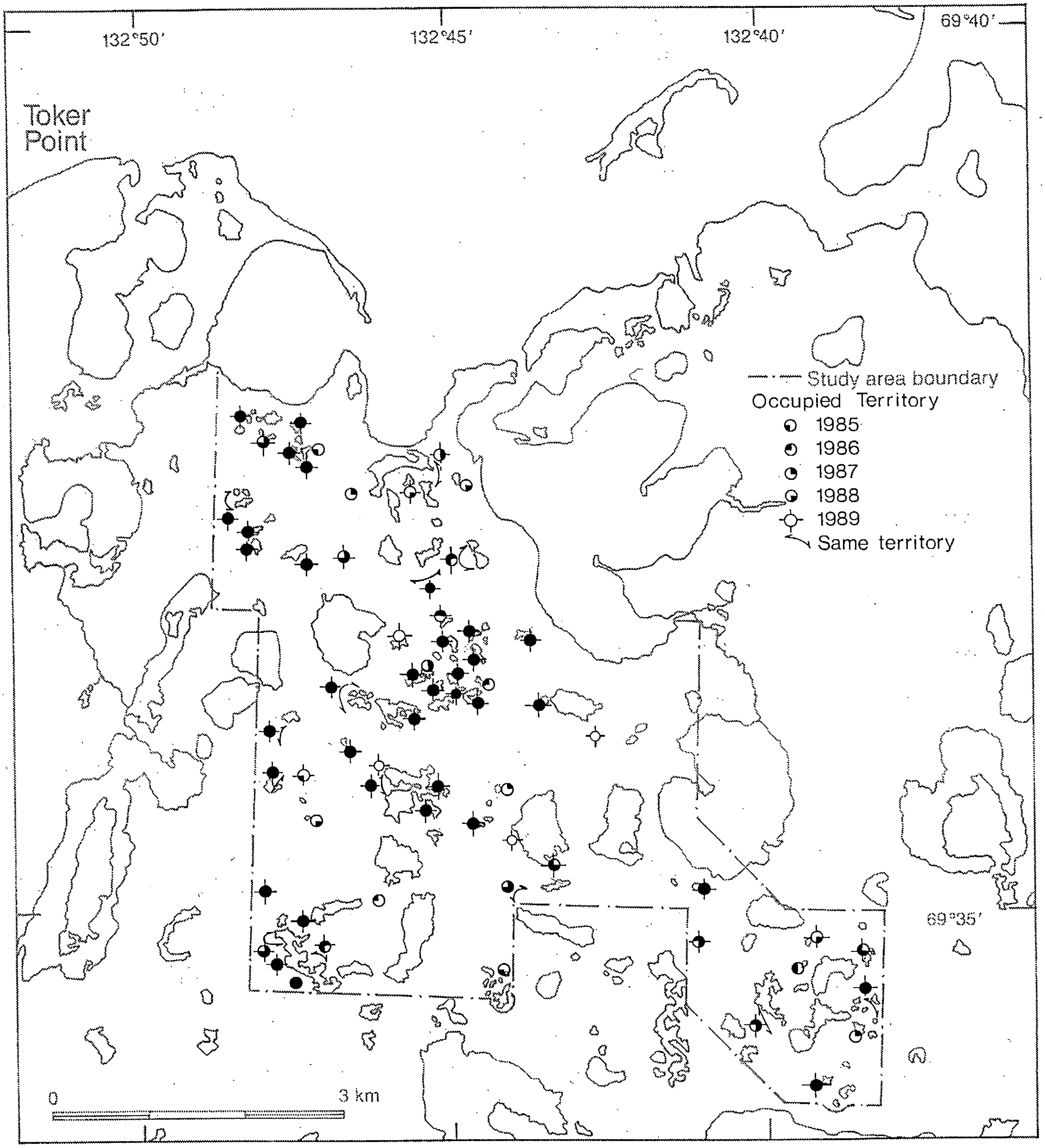

Figure 12. Location of Red-throated Loon nesting territories in the Toker Point study plot and their frequency of use.

territory, either from one year to the next or after the first clutch was lost. These changes have been indicated by arrows in Figure 12.

There was a strong tendency for the Red-throated Loons to use the same territories each year (Fig.12). About half of the territories at Toker Point (52%, n=65) were occupied in all five years of the study, while only 19% were used just one year.

Assuming the same pair returns to a pond each year, as banding evidence suggests (Furness 1983), neither hatching success nor fledging success affected whether the nesting territory was reoccupied the following year (X^2 tests, ldf, p >0.05). Ninety-six percent of the territories where at least one egg had hatched were reoccupied the following year (n=68), compared to an 88% reoccupancy following none hatching (n=93). Similarly, there was a 96% reoccupancy of territories where young had fledged (n=49), compared to 89% reoccupancy following an unsuccessful year (n=112).

Reuse rates for the nesting territories in the other study plots could not be determined, since it was not possible to assess which ponds were within the same territory in three brief visits by helicopter. Instead, frequency of use of ponds has been presented (Table 19). For all five study sites combined, just 13% of the ponds were occupied in all five years, while 39% of the ponds were used in only one year. Frequency of reuse was highest at Toker Point and lowest at Nuvorak Point (26% and 5% occupancy respectively in all five years). Breeding success effected whether a pond was reused the following year at Husky and Nuvorak, but had no effect at the other three study plots (X^2 tests, ldf, p=0.05) (Table 20).

Table 19. Frequency nesting ponds were occupied by Red-throated Loons between 1985 and 1989[1].

Study plot	One year # of ponds	(%)	Two years # of ponds	(%)	Three years # of ponds	(%)	Four years # of ponds	(%)	Five years # ponds	(%)
Toker Point	29	(33)	14	(16)	10	(11)	12	(14)	23	(26)
Atkinson Point	39	(44)	16	(18)	8	(9)	10	(11)	16	(18)
Nuvorak Point	60	(44)	31	(22)	23	(17)	17	(12)	7	(5)
Husky Lakes	32	(39)	17	(20)	11	(13)	17	(20)	6	(7)
King Point	41	(35)	24	(21)	23	(20)	16	(14)	11	(10)
All study plots	201	(39)	102	(20)	75	(14)	72	(14)	63	(13)

[1]Includes ponds that were Occupied, but not Active Territories.

Table 20. Effect of breeding success on reuse of the same pond the following year[1].

Study plot	Successful pairs Number	Successful pairs % that used same pond following year	Unsuccessful pairs Number	Unsuccessful pairs % that used same pond following year	Chi Square	P
Toker Point	48	85	113	74	2.38	0.12
Atkinson Pt.	84	75	43	67	0.81	0.37
Nuvorak Pt.	64	70	98	50	6.56	0.01
Husky Lakes	64	72	55	49	6.48	0.01
King Point	96	68	48	67	0.02	0.90

[1]Includes loon pairs that occupied a pond, but did not lay eggs.

Descriptions of the ponds, nest sites and nests were completed for 68 ponds used by Red-throated Loons for nesting in the Toker Point study plot. For comparison, 57 lakes and ponds in the study area were randomly selected and described. The two data sets were compared in order to characterize the habitat selected by the Red-throated Loon for nesting. These data are presented in a separate report (Dickson in prep.).

3.15 Breeding statistics for the Pacific Loon

The number of pairs of Pacific Loons occupying territories within the Toker Point study plot remained fairly constant between years, ranging from 39 to 44 pairs (Table 21; Fig. 13). In most cases, we did not search for their nests. Thus, whether or not a territory was active was based on either behaviour or sighting of a chick. Accordingly, we recorded the lowest number of active territories in 1986 and the highest number in 1987 (17 and 39 active territories respectively). Only 0.2 to 0.3 young/nesting pair survived to near fledging in four years. In the fifth year, 1985, fledging success was much higher at 0.7 young/nesting pair.

Table 21. Breeding statistics for the Pacific Loon at Toker Point.

Year	Occupied territories[1]		Active territories[2]		Young near fledging		Breeding success	Successful pairs	
	Number	Density (no./km^2)	Number	Density (no./km^2)	Number	Density (no./km^2)	(young/active territory)	Number	Percent
1985	44	1.7	26	1.0	18	0.7	0.7	14	54
1986	39	1.5	17	0.6	3	0.1	0.2	3	18
1987	43	1.6	39	1.5	9	0.3	0.2	7	18
1988	43	1.6	34	1.3	8	0.3	0.2	6	18
1989	44	1.7	36	1.4	11	0.4	0.3	8	23

[1]A territory was considered occupied if a pair of loons was present until at least mid-July.

[2]A territory was considered active if eggs or young were found or if nesting behavior was observed.

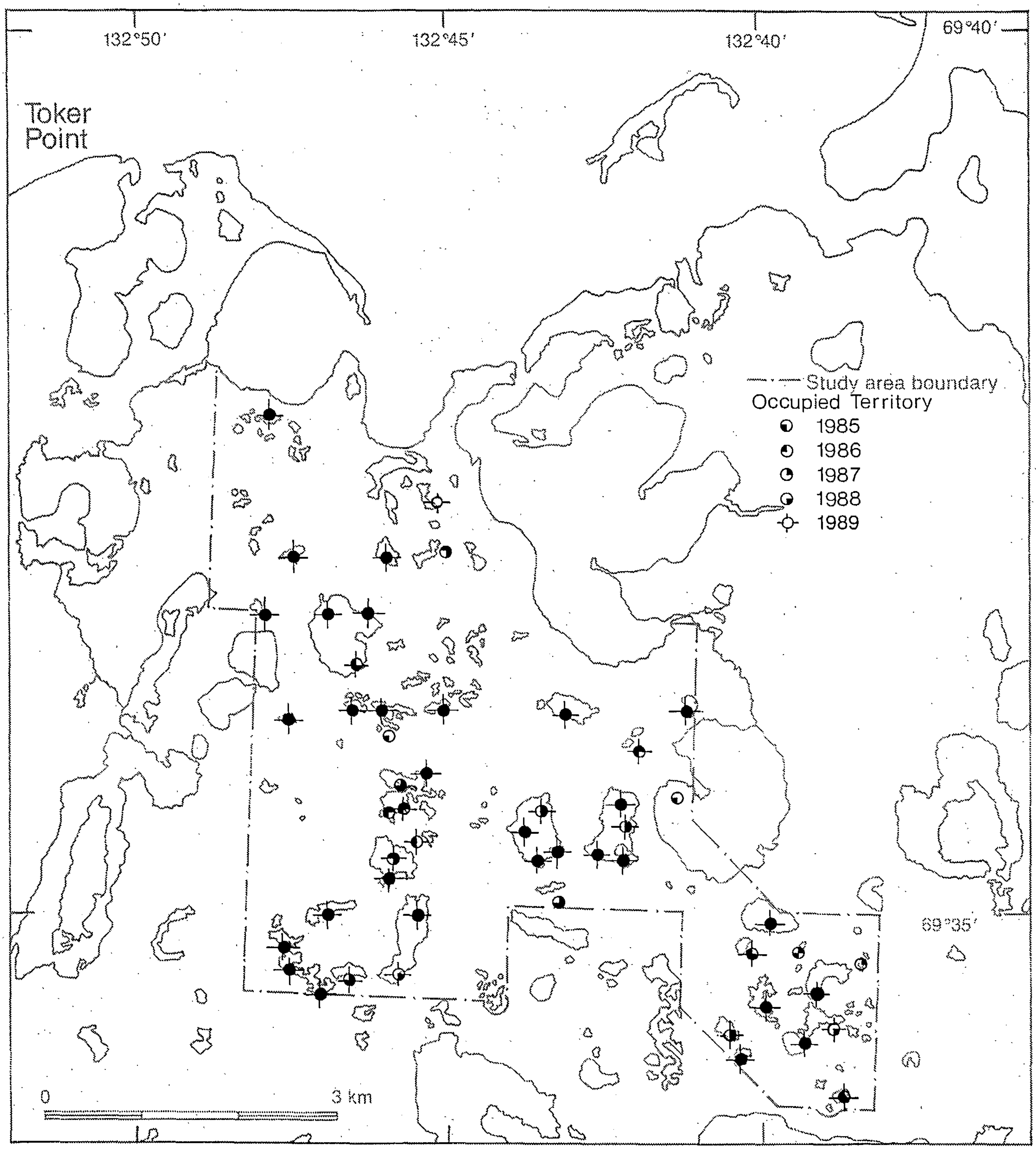

Figure 13. Location of Pacific Loon nesting territories in the Toker Point study plot and their frequency of use.

4.0 DISCUSSION

4.1 Density of resident loon pairs

The density of loon pairs varied within the study area with the highest densities occurring on the north side of the Tuktoyaktuk Peninsula (0.9 to 1.7 pairs/km^2), and lower densities occurring inland by Husky Lakes (0.7 pairs/km^2) and along the Yukon north coast (0.6 pairs/km^2). In comparison, Bergman and Derksen (1977) reported 0.6 to 0.8 pairs/km^2 at Storkersen Point on the Alaskan Beaufort Sea coast.

There were no flocks of non-breeding Red-throated Loons in the study area during the nesting season. All of the loons were in breeding plumage, paired and on territories. Bergman and Derksen (1977) likewise saw no flocks of non-breeders at Storkersen Point. Conversely, on the Queen Charlotte Islands at the southern limit of the breeding range of the Red-throated Loon, Reimchen and Douglas (1980) encountered mostly nonbreeding adults which formed loose flocks every evening on large lakes.

Each year about 10% of the Red-throated Loon pairs at Toker Point did not nest (Table 6). Some of these non-breeding pairs might have been immature birds establishing a territory, but not ready to breed. Immature pairs of several other bird species are known to attend the breeding grounds a year or more before first nesting, including the Northern Gannet (Nelson 1978), Black-legged Kittiwake (Coulson 1966) and Blue Goose (Cooch 1958). Davis (1972) provided circumstantial evidence that immature Red-throated Loons were selecting nesting territories a year in advance of breeding at Hudson Bay, as did Lehtonen (1965 in Davis 1972) for Arctic Loons in Finland. Coulson (1966) showed that Black-legged Kittiwakes breeding for the first time, nested an average of 7 days earlier if the female had been present at the colony the previous year. Given the short arctic breeding season, establishing a nesting territory the year before to reduce the pre-laying period would be advantageous to the Red-throated Loon.

4.2 Productivity

The productivity of the Red-throated Loon averaged 0.63 fledged young per nesting pair during the five years of study (Table 22). This value was very similar to the productivity found on Foula, Shetland Islands by Furness (1983), although studies elsewhere on the Shetland Islands have indicated lower productivity (0.35 to 0.45 young per nesting pair (Bundy 1976; Bundy 1978; Gomersall 1986)). On the other hand, a higher reproductive rate has been reported in Sweden and Finland (0.8 to 1.15 young per nesting pair) (Lokki and Eklöf 1984), on the Queen Charlotte Islands (0.86 young per nesting pair) (Douglas and Reimchen 1988) and on the Orkney Islands (0.79 young per nesting pair) (Booth 1982).

During the five-year study period, the number of resident pairs of Red-throated Loons at Nuvorak Point rose from 44 pairs in 1985 to a peak of 70 pairs in 1988. At the other four sites there were insignificant increases of 4 to 12 pairs recorded over the five years. Some of this was likely due to us finding additional territories which we had missed in previous years. Ground truthing of an aerial survey in the first year of the study indicated that we had missed 10% of the nests. Since the loons tend to renest in the same pond each year, fewer nests were likely missed in subsequent years. This would artificially raise the pair count,

Table 22. A comparison of the productivity of the Red-throated Loon in the Canadian Beaufort Sea region to other areas.

Region	Young fledged per nesting pair	Year	Source
Unst, Shetland Islands	0.41	1973-74	Bundy 1976
Shetland Islands	0.35	1976	Bundy 1978
Shetland Islands	0.45	1981-82	Gomersall 1986
Foula, Shetland	0.65	1956-81	Furness 1983
Orkney Islands	0.79	1973-80	Booth 1982
Sweden	0.8	1979-82	Arvidsson 1981 in Lokki & Eklöf 1984
Finland	1.15	1979-82	Lokki & Eklöf 1984
Queen Charlotte Islands	0.86	1976-86	Douglas & Reimchen 1988
Canadian Beaufort Sea	0.63	1985-89	This study

particularly during the first two or three years of the study. However, the near doubling of the number of pairs at Nuvorak Point between 1985 and 1988 must have also been due in part to a real growth in numbers.

Further evidence in support of a slight growth in population of Red-throated Loons was their productivity which ranged from 0.48 to 0.81 young per nesting pair from 1985 to 1989. Although the survival rate of the Red-throated Loon is unknown, Nilsson (1977) calculated that the Arctic Loon (Gavia arctica) in Sweden would maintain its population level if it produced 0.4 to 0.5 fledged young per pair each year. Assuming the mortality rate for the Red-throated Loon is similar, and that they return to their natal breeding grounds to nest as banding studies by Furness (1983) suggest, the reproductive rate measured during this study should result in a slight growth in the regional population.

Significant growth in the number of pairs occurred only at Nuvorak Point suggesting that the other study plots were already nearly full to capacity. Nuvorak may have less favourable nesting habitat, as is also suggested by the lower breeding success there most years compared to the other plots surveyed by helicopter. If the habitat at Nuvorak is suboptimal, in future it may provide the earliest indication of changes in the number of loons in the region.

4.3 Factors affecting productivity

As expected in an arctic environment, the breeding effort and success of the Red-throated Loon fluctuated from year to year. The percentage of resident pairs that attempted to nest varied from 58% in 1986 to 78% in 1988 (Table 3); similarly, the percentage of breeding pairs that were successful varied from 38% in 1989 to 63% in 1985 (Table 3). The following is a discussion of the primary factors which influenced productivity each year, with emphasis on the data from Toker Point, for which there is the most ecological information.

4.3.1 Breeding effort

The breeding effort of the Red-throated Loon was constant in every year except 1986. The lower number of pairs that nested that year coincided with a late spring thaw. The ponds used by Red-throated Loons to nest became ice-free 10 to 20 days later in 1986 than in the other four years of the study (Table 23). Subsequently, nest initiation was about two weeks later, and only 71% of the resident pairs at Toker Point laid eggs, compared to 88 to 92% in other years (Table 6; Fig. 14).

A diminished breeding effort in a late season has been reported previously for a number of bird species. Several species of arctic nesting geese respond to a late spring by either not nesting or laying smaller clutches (Barry 1962; Davies and Cooke 1983; Owen and Norderhaug 1977; Raveling and Lumsden 1977). Similarly, Herring Gulls (<u>Larus argentatus</u>) lay smaller clutches (Meathrel <u>et al</u>. 1987), while the Thick-billed Murre (<u>Uria lomvia</u>) which lays only one egg, lays a smaller egg in a late season (Gaston and Nettleship 1981).

It is unknown precisely what factors and mechanisms depress the reproductive effort of the Red-throated Loon in years when spring is late. For most temperate birds, day length determines whether the reproductive system is in an active or inactive state (Silver and Ball 1989; Loft and Murton 1968). However, for the final stages of ovarian recrudescence, the

Table 23. The timing of nest initiation by the Red-throated Loon at Toker Point in relation to spring thaw.

Year	Date reach 30 thawing degree days[1]	Date shallow ponds open	Date coastal lead of >100 m	Median date of nest initiation	Percentage of pairs that nested	Median days between arrival and egg laying	Synchrony of egg laying
1989	31 May	1 June	22 June	19 June	92	18	28
1988	4 June	29 May	22 June	19 June	90	21	27
1985	31 May	~ 1 June	20 June	20 June	89	~19	26
1987	9 June	8 June	29 June	24 June	88	16	16
1986	18 June	15–18 June	1 July	3 July	71	~17	17
27-year norm	10 June						

[1]Data for Tuktoyaktuk airport (Atmospheric Environment Service).

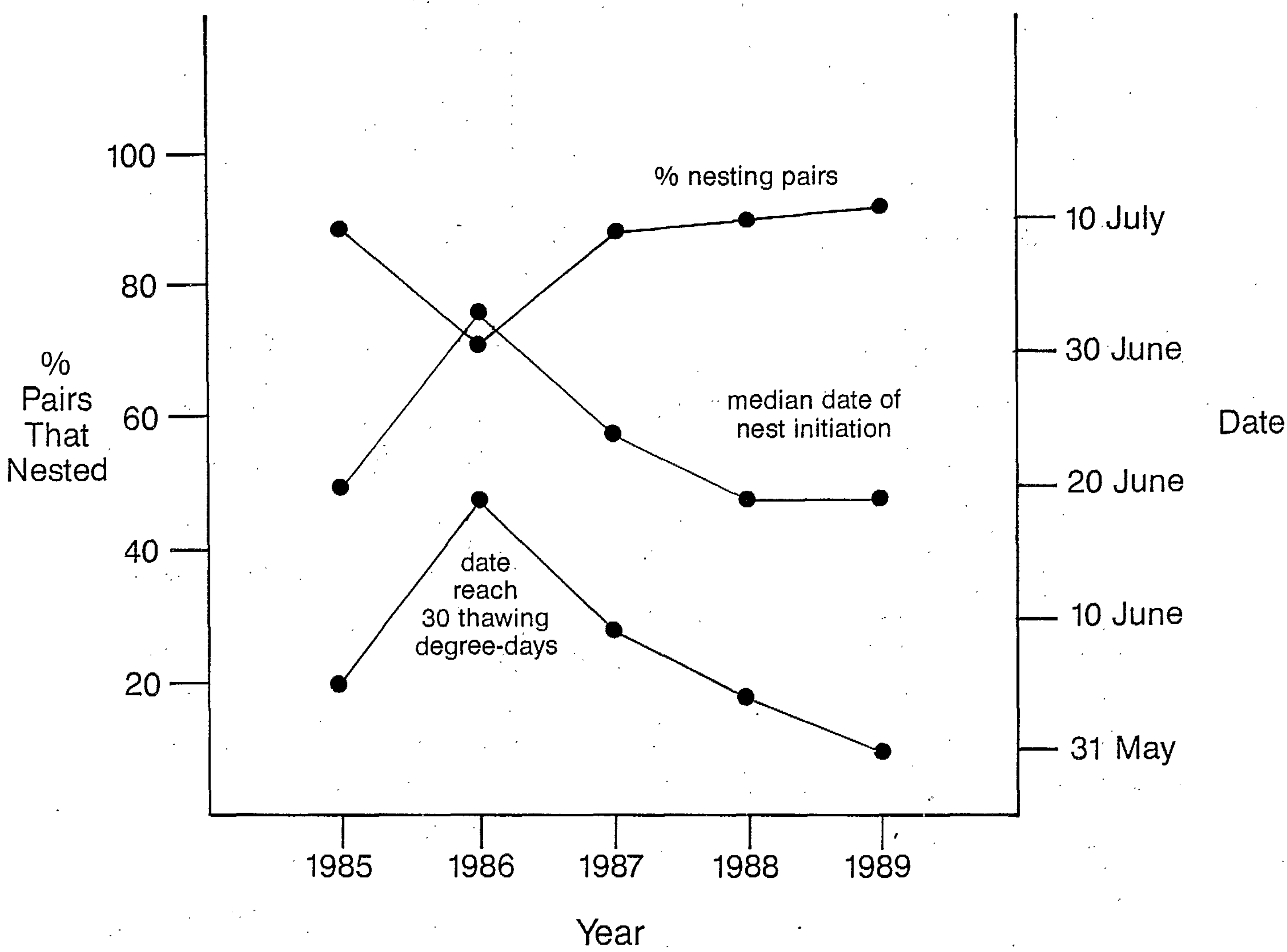

Figure 14. Relationship between timing of spring thaw, timing of nest initiation and the proportion of Red-throated Loon pairs that laid eggs.

female needs additional stimuli including territorial behavior, intra-pair behavior, a nest site and nest material. For loons, these final cues would likely not occur until the nesting pond was thawed (Yonge 1981). If the ponds stayed frozen long enough, gametogenesis in some individuals might terminate prior to the final stimulus required for egg development. Hence, the loon would not nest.

Alternatively, poor feeding conditions during the pre-laying period may be the primary reason why fewer loons nest in a late spring. In 1986, when open water leads in the Beaufort Sea were poorly developed, thousands of Red-throated and Pacific loons were seen staging on the lower Mackenzie River in early June (T. Barry, unpublished data). Feeding by the loons was likely hindered, because of the turbidity of the river. Thus, their energy reserves would be depleted while waiting for the offshore leads to develop.

In an attempt to determine if the Red-throated Loons were nutritionally stressed following the late spring breakup, egg sizes in 1986 were compared to other years. The mean weight of eggs weighed within two days of laying was 78.1 ± 5.8 gm ($n = 43$) in 1985, 75.6 ± 6.7 gm ($n = 40$) in 1986 and 77.8 ± 5.9 gm ($n=43$) in 1987. Although the eggs in 1986 tended to be lighter, thereby indicating nutritional stress (Elridge and Krapu 1988), the difference in egg weights was not significant (One-way ANOVA, $p = 0.13$).

Whatever the factors that inhibit the loons from nesting in a late spring, it is likely an adaptation to the short arctic season. The later nest initiation occurs, the lower the probability of successfully raising young to fledge prior to freeze-up. By not nesting, the pair would be in better condition by autumn, hence more likely to survive until the next nesting season.

4.3.2 Breeding success

The percentage of eggs that hatched at Toker Point varied from about 14% to possibly as high as 66% during the five-year study. Most of the eggs that did not hatch, disappeared from the nest with no sign of what happened, although they were presumably taken by predators. The major predators were the arctic fox, Parasitic Jaeger and Glaucous Gull, for which there was evidence of them taking loon eggs on 9, 10 and 10 occasions respectively. Although none were seen doing so, the Sandhill Crane likely also took loon eggs. It is a known predator of eggs (Reynolds 1985; Harvey et al. 1968), including Red-throated Loon eggs (Davis 1972), and was often seen feeding in the wetlands in the vicinity of loon nests at Toker Point. Although less abundant in the study area, the Common Raven may have also taken loon eggs (Marques and Booth 1986). Ravens were seen carrying off similar large birds eggs such as those of the Greater White-fronted Goose. None of the Red-throated Loon eggs at Toker Point were lost due to flooding of the nest, which has been identified as a source of mortality in other areas (Gomersall 1986; Lokki and Eklöf 1984; Douglas and Reimchen 1988). Only 11 eggs over the five years failed to hatch because they were addled or infertile. Two nests were abandoned, although more may have been abandoned, but not detected because the eggs were taken by predators before our next nest check. On one occasion we noted that the second egg in the clutch was abandoned when the first egg hatched. It is unknown how often this occurred, because the contents of the nests were usually not checked during hatch to minimize disturbance. Furness (1983) likewise noted that the Red-throated Loon sometimes abandoned the second egg.

There was an inverse relationship between the hatching success of the loon eggs and the number of foxes in the study area (Fig. 15). Hatching success was highest in 1985 and 1988 when there were very few foxes, whereas it was lowest in 1987 when foxes were most abundant (Tables 6 and 12). Studies in Alaska likewise noted heavier losses of loon eggs in years when fox activity was high (Bergman and Derksen 1977; Schamel and Tracy 1985).

Avian predator numbers at Toker Point remained stable throughout the five-year study, except for the influx of nonbreeding Sandhill Cranes in 1989. Although the abundance of cranes likely contributed to the greater loss of eggs that year, overall, avian predators had little influence compared to the fox on the difference among years in the percentage of eggs that hatched. Bergman and Derksen (1977) likewise found that jaeger and Glaucous Gull numbers did not change during a five-year study in northern Alaska, suggesting that the fox had a greater influence on loon productivity.

Egg predation was unexpectedly high in 1989 given the moderate number of foxes in the study area. However, vole numbers were low that year which might have contributed to the high rate of predation of loon eggs (Fig. 6). The arctic fox, whose main prey are small rodents, shifts to alternate prey such as eggs when small rodents are not as abundant (Larson 1960; Macpherson 1969). Thus, although there was only a moderate number of foxes in the study area in 1989, they likely put more effort

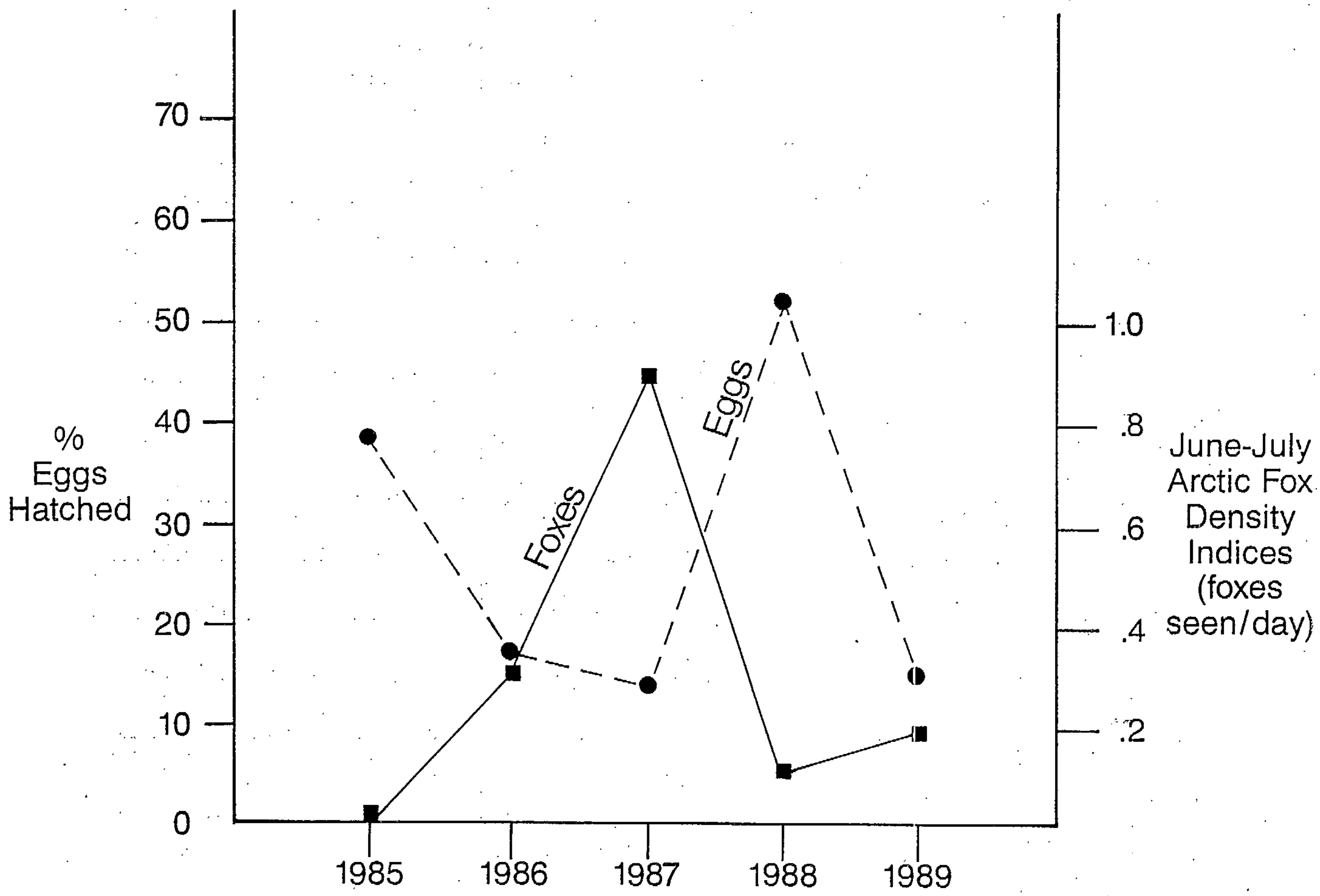

Figure 15. Relationship between arctic fox abundance and the proportion of Red-throated Loon eggs that hatched.

into searching for loon eggs. Low vole numbers may have also influenced the number of eggs taken by the Glaucous Gull, Sandhill Crane and Common Raven. All of these species eat both small rodents and eggs, and tend to take each food item in proportion too its abundance (Barry and Barry 1990; Herter 1982; Marquis and Booth 1986).

A relationship between productivity and small rodent cycles has been observed in a number of other bird species. Pehrsson (1986) found that the production of Oldsquaw ducklings doubled in rodent peak years. Likewise, the abundance of small rodents has been linked to the breeding success of the Brent Goose, Branta b. bernicla (Dhondt 1987), the Curlew Sandpiper, Calidris ferruginea (Roselaar 1979), the Willow Ptarmigan, Lagopus lagopus (Myrberget 1972), Black Grouse, Tetrao tetrix (Angelstam et al. 1985) and Pacific Loon, Gavia pacifica (Petersen 1979). All stated that the best explanation for this link was that predators switched from eating small rodents to eggs and young birds in years when small rodents were less abundant.

Hatching success was also unexpectedly low in 1986, given the moderate numbers of foxes in the study area that year. This may have again been linked to predators shifting to loon eggs when other prey items were less abundant. Fewer waterfowl laid eggs in 1986 due to the late spring thaw, so that predator pressure on loon eggs was likely heavier. Similarly, Petersen (1979) and Davis (1972) both attributed an increase in predation of Pacific and Red-throated loon eggs to a decline in the availability of eggs from a nearby goose colony. This occurred each year just before hatch of the goose eggs when the geese became more protective of their eggs.

Evidence suggests that small rodents were less abundant in 1986. Although not trapped that year, our casual observations, as well as the three to four-year small rodent cycle reported elsewhere (Pehrsson 1986; Summers 1986; Larson 1960; Angelstam et al. 1985) would suggest that the voles were in the low part of their cycle in 1986. This would further contribute to predator pressure on loon eggs.

Like the eggs, most of the Red-throated Loon chicks that did not fledge disappeared without any sign of what happened to them. Many of the deaths of the youngest chick in the brood may have been due to starvation (Furness 1983; Davis 1972; Braun et al 1968). Davis (1972) found that because the eggs of the Red-throated Loon hatched asynchronously, one chick had an advantage over the other in competing for the fish brought to them. Thus, the youngest chick of most broods starved to death.

Predation was another factor causing chick mortality. The chicks were particularly vulnerable during the first few days after hatch when they were unable to dive well enough to escape avian predators. On five occasions, a Glaucous Gull was seen picking up a newly hatched loon chick from a pond. The gull was successful in carrying away the chick in two incidents, but the other three attempts failed when a close pass by an adult loon resulted in the Glaucous Gull dropping the chick. Although we never saw a Parasitic Jaeger take a loon chick, on several occasions we did see them try to take fish from adult loons that were carrying the fish to the nesting pond. On one occasion, a Sandhill Crane was observed unsuccessfully trying to catch a loon chick. Northern Harriers and Rough-legged Hawks may prey on loon chicks in years when small rodents are scarce. Other potential predators of loon chicks were the Common Raven, Bald Eagle (Douglas and Reimchen 1988), and Peregrine Falcon (White and Cade 1971), although the latter two species were only occasional visitors at Toker Point.

The percentage of chicks that fledged was a consistent 62 to 67% for the first three years of the study, but dropped to 25 to 38% in 1988 and only 5 to 10% in 1989. Evidence suggests that there was heavier predation on loon chicks in the latter two years. The greater chick loss in 1988 coincided with a significantly larger number of Glaucous Gull chicks in the study area than in other years. Although Glaucous Gulls are not major egg predators, they do consume significant numbers of newly hatched birds, particularly if there is human disturbance (Barry and Barry 1990). The heavier loss of chicks in 1989 coincided with an influx of nonbreeding Sandhill Cranes which occurred only that year. The low vole numbers in 1989 likely further contributed to loon chick losses that year, as predators switched from eating voles to alternate prey species.

There was very little evidence that the high mortality rate of chicks in 1988 and 1989 was caused by a decline in their food supply. The results of the fish-netting operation indicated that there were actually more fish the size used by the Red-throated Loons during the chick-rearing period in 1988 and 1989 than in 1987. Furthermore, feeding rates of loon chicks did not differ significantly between years, indicating that food availability had not changed. The only indication that fish were less available to the loons in 1988 was the greater amount of time that loons with chicks spent on the marine fishing areas that year. Assuming the amount of time spent on the fishing areas is an indication of fish availability to the loons (Cairns 1987), there were less fish in 1988.

However, data were collected on only one to three pairs of loons each year (Table 16). Thus, the differences among years in the amount of time spent away from the nesting pond could have been due to individual differences in behavior rather than the availability of fish.

The large percentage of eggs that hatched in 1988 (Table 6) may have caused a temporary depletion of fish due to greater competition for a limited food source. Pehrsson and Nyström (1988) found that Oldsquaw duckling mortality was higher in years when duckling production was high, and attributed this to the ducklings depleting their major food source, the fairy shrimp. The impact on fish abundance of more intensive fishing by loons during the 1 to 2 week period when there were lots of newly hatched chicks would likely only be temporary because the fish along the Beaufort Sea coast are so mobile (Bill Bond, Department of Fisheries and Oceans, pers. comm.). Because the beach seining operation and the loon watches, occurred only once or twice a week, neither operation would likely have detected such a short-term decline in fish abundance.

The severe storm from 1 to 4 August in 1988 seemed to have only a minor immediate affect on the survival of the Red-throated Loon chicks. The mortality rate during the storm was actually lower than either before or after that period. Only one chick death was linked directly to the storm: a five-day old chick which likely drowned when its nesting pond was inundated by high surf caused by winds over 50 kph. However, the four chicks that disappeared during the week following the storm may have also died as a result of the four-day storm. Dunn (1975) reported many tern chicks slowly starved to death following a three-day storm despite a return to favorable foraging conditions. He attributed the deaths to the chicks being so weak from food reduction during the storm that they were unable to beg vigorously enough for food to elicit the appropriate response from their parents. The four-day storm at Toker Point may have had a similar effect on the loons, although such an occurrence has not been documented for loons.

Another factor which contributed to the low fledging success in 1989 was the early freeze-up that year. The nesting ponds used by the Red-throated Loons froze 10 days prior to any of the chicks from replacement clutches reaching the age when fledging normally occurs.

Flooding which has been identified as a cause of hatching failure for Red-throated Loons in several other areas (Douglas and Reimchen 1988; Gomersall 1986; Lokki and Eklöf 1984; Cyrus 1975) did not occur at Toker Point during the study period. However, at Nuvorak Point study plot the stormtide in early August of 1988 flooded about 20% of the ponds that had active Red-throated Loon territories. This flooding seemed to have a positive effect on breeding success. The 17 nesting pairs on flooded ponds produced 0.59 young per active territory, compared to a reproductive rate of 0.38 for the entire study plot. In other years, that portion of the Nuvorak study plot always had a lower breeding success than the rest of the study plot. Given the shallowness of these ponds (<1 m), the flooding may have enhanced the survival of the loon chicks by making it easier for them to escape predation.

The data from Nuvorak Point study plot would suggest that low water-levels contributed to lower productivity. However, at Toker Point, drought conditions seemed to have very little effect on breeding success. Water-levels dropped the most in 1985 and 1988, two of the most productive years at Toker Point, and remained most stable in 1986 when productivity was very poor. In the dry years several nests initially surrounded by water became isolated from the pond by as much as 12 m making the nests more accessible to foxes and making escape for the adult bird difficult. Yet the loons continued to incubate despite having to crawl several metres through the mud to reach the nest. In 1988, a chick was successfully reared to fledging on a pond that by August was covered less than 10% with water (an area of about 200 m^2). At another nest pond, that was covered only about 10% with water at hatch (25 m^2 of pond had water), the loon lead its chicks 30 m across the wetland to a deeper pond. At yet another pond, a chick was successfully hatched despite the fact that all but about 6 m^2 of the pond had dried up. Gomersall (1986) likewise noted that drought conditions seemed to have no affect on egg losses of Red-throated Loons on the Shetland Islands. The apparent tolerance of this loon species to low water-levels may be due to its ability to take-off from land (Godfrey 1966).

The intensive monitoring of the loons by observers on the ground at Toker Point had a marked effect on breeding success. During the preliminary investigation in 1984, the search for incubating loons at Toker Point was conducted by helicopter. That year, Toker Point had the highest breeding success of all five study plots, indicating that when undisturbed Toker Point is one of the most productive areas of the region for loons. In the following five years, when Toker Point was checked every three to five days by observers on foot, it had the lowest productivity in the study area (only one exception: Nuvorak Point in 1985) (Fig. 4). The loons usually reacted to an observer on foot by getting off the nest and not returning until the observer was out of site. Given that most of the vegetation at Toker Point was less than half a metre high, an observer was often within view of a loon for several kilometers. Thus, loons would remain off their nests for extended periods of time, leaving their eggs vulnerable to predation. Increased loss of eggs to predators due to human disturbances near nests in the arctic has been previously reported by numerous researchers (Barry and Barry 1990; Enquist 1983; MacInnes and Misra 1972; Strang 1980; Harvey 1971).

The five-year pattern of annual fluctuations in breeding success at Atkinson Point was very similar to that at Toker Point (Fig. 4). However, the patterns for the other three study plots were all different. For example, unlike the other areas, King Point maintained a relatively high success rate in 1986, the year when spring thaw was late. At Husky Lakes, breeding success was much more consistent from year to year than it was at the other study plots. The reason for these differences between study plots in the pattern of annual fluctuations in breeding success are beyond the scope of this study, but the fact that they do differ must be taken into consideration in the post-development phase of the monitoring study.

Most years at Toker Point, the annual fluctuations in both breeding effort and hatching success of waterfowl were similar to those of the Red-throated Loon (Table 14). Like the loon, waterfowl nests were least abundant in 1986 when spring break-up was delayed about two weeks. Also like the loon, few young were seen in 1987 despite the large number of nest attempts. However, in 1989 when loon hatching success was low, chick production appeared normal for waterfowl. It is not known whether the waterfowl experienced high mortality of their young like the Red-throated Loons did in 1988, since waterfowl usually lead their young away from the nesting area, thus making it difficult to assess annual production. One of the reasons why the loon is the preferred species for the monitoring program is that the young remain on the breeding pond until they can fly; hence more accurate data on annual production can be obtained. However, caution should be used when extrapolating from the indicator species to waterfowl, since the pattern of annual change in breeding success does differ in some years.

4.4 Breeding site tenacity

The degree of reoccupancy of the same nesting ponds by Red-throated Loons each year may be an indication of the amount of additional nesting habitat there is available for the Red-throated Loons. Toker Point had the highest frequency of reoccupancy of ponds (Table 19), thus likely had the least amount of suitable habitat for additional breeding pairs. Nuvorak Point and Husky Lakes, conversely, had the lowest rate of reoccupancy of ponds. Further evidence that Nuvorak Point and Husky Lakes had more unused nesting habitat was that they were the only study plots where breeding success affected whether a pond was reoccupied the following year. Only in areas with vacant nesting habitat would loons be able to switch ponds following nesting failure. Should development occur along the coast in the Beaufort Sea region, the impact on loons would likely be less severe if it was located in an area where nesting habitat was not full to capacity.

The effect of breeding success on reuse of the same pond the following year has also been investigated by Davis (1972) at Hudson Bay and by Gomersall (1986) on the Shetland Islands. The former found a trend towards greater re-use of a pond following a successful year, but the difference was not statistically significant. However, on the Shetland Islands the effect of hatching success on reoccupancy of the lochs the following year was significant.

Only the pond site tenacity and not the territorial site tenacity could be determined for the study plots surveyed by helicopter. An analysis of territory site tenacity like that which was done for Toker Point (Section 3.14), would likely show that there is much less unused nesting habitat than the data on pond site tenacity suggests. This may be particularly true of Atkinson Point where the ponds are numerous but clustered close together.

On the Shetland Islands, 65% of known breeding lochs (n=157) were used in three consecutive years (Gomersall 1986), compared to our study area where 41% of the ponds were used three or more consecutive years. The frequency of reuse of lochs in Shetland was more closely comparable to the 65% reuse of occupied territories in the first three years at Toker (n=57). At McConnell River on the Hudson Bay coast, Davis (1972) reported that 77% of the nesting territories (n=39) were used three years in a row.

4.5 Phenology

The Red-throated Loon arrives in the Beaufort Sea region in late May and early June (Koski and Tull 1981). Before their nesting ponds thaw, they occupy the offshore leads of open water, particularly west of Tuktoyaktuk (Alexander et al. 1988; Barry and Barry 1982; Barry et al.

1981), as well as any near shore open water such as the Kugaluk River mouth (P. Voudrach, pers comm.). In 1974 and 1986, two years when there was very little open water in the Beaufort Sea during spring migration, T. Barry (pers comm.) found thousands of Red-throated and Pacific loons on the Mackenzie River over 200 km upstream from the coast (between the mouth of the Travaillant River and the Ontaratue River).

In the two years that we arrived on the study area before the loon nesting ponds thawed (during the preliminary study in 1984 and in 1986), nearly all of the loons occupied the ponds within a day of thawing. Bergman and Derksen (1977) likewise noted that the loons arrived at Storkersen Point, Alaska concurrently with thawing of their nesting ponds.

The median number of days between arrival on the nest ponds and laying the first egg ranged from 16 to 21 days (assuming the loons arrived on the nesting ponds within a day of thaw each year). The later the nesting ponds thawed, the later the date for nest initiation (Fig. 14). These data suggest that the stimulus for the final stages of ovarian development does not occur for the Red-throated Loon until its nesting pond is thawed. Yonge (1981) likewise observed that the date of nest initiation of the Common Loon (Gavia immer) in northern Manitoba was dependent on when the lakes thawed.

On average, 90% of Red-throated Loon nests were initiated within 15 days of eachother (ranged from 10 to 22 days over the five years). The later the nesting ponds thawed, the more synchronous egg laying was (Table 23).

Delays in nest initiation due to social behaviour associated with pair formation, and finding and defending a nesting territory would be minimal for the Red-throated Loon since it likely pairs for life (Cramp et al. 1977) and usually returns to the same nesting territory each year (Davis 1972; Furness 1983). By minimizing the length of time required to lay their eggs, the Red-throated Loon is better adapted to nesting in areas such as the Beaufort Sea region where the nesting ponds are ice-free for only a short period of time.

In regions where the open-water season is much longer, the period between arrival and nest initiation is also longer. Schamel and Tracy (1985) reported a 30 day delay at Cape Espenberg in western Alaska, compared to the 18 day period in our study area. Similarly, on the Queen Charlotte Islands, although the loons arrived in mid-April, they did not lay eggs until 10 May to 20 July (Douglas and Reimchen 1988). In Shetland, loon pairs arrived in the breeding area at least two months before clutch initiation (Bundy 1976).

Eggs within a clutch were laid 2 to 3 days apart at Toker Point (n=4). In comparison, eggs on the Shetland Islands and Hudson Bay were laid 2 days apart (Bundy 1976 - sample size not reported; Davis 1972 - n=4), and eggs on the Queen Charlotte Islands were laid 1 day apart (Douglas and Reimchen 1988 - n=4). The length of time between eggs might be dependent on the nutritional status of the female: the higher the energy reserves, the shorter the length of period between eggs.

At Toker Point, the eggs hatched 1 to 3 days apart (n=7), whereas Davis (1972) found that the eggs within a clutch always hatched 1 day apart (n=22).

Length of incubation varied from 24 to 27 days (n=13) in our study area, compared to 24 to 29 days (n=19) on the Shetland Islands (Bundy

1976), and 24 to 31 days (n=11) on the Queen Charlotte Islands (Douglas and Reimchen 1988). It appears that the minimum length of time required for Red-throated Loon eggs to hatch is 24 days, although they may take up to a week longer. The presence of observers may have contributed to the variation in the length of incubation. Incubation was sometimes interrupted for an extended period of time while an observer was investigating other nesting territories in the area. The subsequent cooling of the eggs would slow their development. Extended incubation periods due to disturbance which interrupted incubation has been reported previously in Tufted Puffins (Pierce and Simons 1986).

The number of days required for chicks to fledge at Toker Point ranged from 43 to 52 days (n=10), compared to 38 to 48 days (n=25) on the island of Unst, Shetland (Bundy 1976), and 46 to 50 days (n=5) on the Queen Charlotte Islands (Douglas and Reimchen 1988). The variation in the number of days required for development of the loon chicks may be partly due to the amount of food each chick received. Slower growth rates in Red-throated Loon chicks not receiving adequate food have been reported by Davis (1972).

Chicks at Toker Point took an average of four days longer to fledge in 1988 than in the previous three years: 50 days in 1988 (n=3) compared to 46 days from 1985 to 1987 (n=7). The systematic observations from a blind twice a week indicated that chicks were fed the same number of fish per day in 1988 as in other years, so that one would expect a normal rate of development for nutritional reasons. However, the four-day storm in mid summer of 1988 which had offshore winds of 50 to 70 kph and heavy surf, likely hindered adult loons from catching and carrying fish inland to feed their chicks. This interruption in feeding for several days would slow the rate of development of the chicks. The reduction of growth during strong winds and rain has been noted in Common Terns (Dunn 1975).

Chicks at Toker Point fledged between 24 August and freeze-up of the nesting ponds which occurred in mid to late September. Assuming unfledged chicks survived freeze-up by moving to larger lakes when their nesting ponds froze, fledging occurred as late as 4 October.

The average period of time from egg-laying to fledging of the young was nearly the same at Toker Point as it was for areas with much longer ice-free periods. Young Red-throated Loons fledged an average of 75 days after the onset of clutch initiation on the Queen Charlotte Islands where the lakes are ice-free at least 170 days, compared to 74 days for the young to fledge at Toker Point where there are only about 108 ice-free days (n=5, range: 100 in 1986 to 118 in 1988).

4.6 Determining when to survey for incubating loons

During the first two years of the study, methods of determining the timing of clutch initiation were investigated in order to establish the optimum time to survey for incubating loons in future years of the monitoring program. The date of clutch initiation can be calculated by back-dating if one knows the age of the egg. Thus, two techniques for aging eggs were tried at Toker Point, both of which measured the change in density of the egg as it developed.

The floatation method of aging eggs proved most accurate. By placing an egg in a container of water, one could estimate its age to within 8 days (Table 9), whereas the 95% Confidence Interval for the age derived from weighing and measuring the size of an egg was approximately ± 7 days. Aging eggs by measuring their weight, length and width was so imprecise because loon eggs vary in shape so much. The same constant (k=0.507) was used to calculate the volume of each egg regardless of its shape, so that the volume was inaccurate for certain egg shapes. As a result, the variance in the density of eggs of a given age was very large. In order to improve the accuracy of this method of aging eggs, one could develop different constants for several classes of egg shapes in order to calculate the volume, or one could obtain a more accurate estimate of the volume by measuring the amount of water displaced by the egg.

As was discussed in Section 4.3.2, visiting the Red-throated Loon nests to either weigh or float the eggs caused a notable increase in predation. Since this study is intended to monitor impacts of industrial development, it is essential to minimize the effect of the researcher on the indicator species. Thus, it is recommended that for the duration of the monitoring study, the timing of the aerial surveys for incubating loons be determined by when the nesting ponds thaw each year rather than by aging the eggs. See Section 4.5 for details.

4.7 Determining when to survey for chicks near fledging

The timing of chick mortality and fledging was examined to determine the optimum time to collect data on breeding success. Ideally, the surveys should be conducted when the chicks are old enough that they will all survive to fledging. At Toker Point, 72% of the losses occurred prior to the chicks reaching 15 days of age, while another 18% of the losses occurred when the chicks were in their third week (excluding chicks that may have died at freeze-up). Due to the substantial number of chicks lost during their third week in some years at Toker Point, the surveys for chicks near fledging should not be conducted until the majority of chicks are over three weeks old. At Toker Point, surveys conducted after 17 August fulfilled this requirement in all years except 1986 when nest initiation was two weeks late. The other limitation on the timing of the census of chicks is the date when they start to fledge. The earliest record of fledging at Toker Point was 24 August in 1985. Thus, in a typical year, the aerial survey for chicks should be conducted from 18 to 22 August.

4.8 Estimation of chick losses at freeze-up

In order to estimate the number of chicks lost due to their nesting ponds freezing prior to the chicks fledging, the size of each chick was estimated. Their age was then calculated based on the formula derived from the ground surveys at Toker Point (Section 3.4). For example, a chick two-thirds adult size would be 21 ± 2 days old. The number of potential chick deaths due to the nesting ponds freezing was then calculated, based on the date of freeze-up and assuming the chicks fledged at 46 days (Table 24). These estimates were factored into the calculations of breeding success based on the intensive ground surveys at Toker Point (Table 6). However, they were excluded from the calculations of breeding success for the basic monitoring program (Table 5), due to the potential error in estimating the size of the loon chicks from the helicopter, particularly when there were no adult loons on the pond.

Table 24. Estimation of the number of chicks which may have died because their nesting ponds froze prior to fledging.

Study plot	Number of chicks <46 days old at freeze-up				
	1985[1]	1986	1987	1988	1989
Toker Point	2	0	0	2	4
Atkinson Point	1	2	0	1	4
Nuvorak Point	1	0	1	1	6
Husky Lakes	1+	0	1	0	2
King Point	5+	1	3	1	6
ALL	10+	3	5	5	22

[1]In 1985, the size of some chicks at Husky Lakes and King Point was not recorded, so that the number of unfledged chicks at freeze-up is a minimum estimate.

Also, it is unknown how unfledged chicks react when their nesting ponds freeze. Some chicks may survive by moving to open water on a lake or bay on the coast. On several occasions during this study, chicks moved up to 300 m across land to another waterbody, usually due to low water-levels on the nesting pond, and at least once due to disturbance. Movement by Red-throated Loon chicks to another waterbody has also been reported by Furness (1983), Bergman and Derksen (1977) and S. MacDonald (pers. comm.). Thus, provided there are larger waterbodies nearby, freezing of the shallow nesting ponds may have little effect on the survival of Red-throated Loon chicks.

4.9 Replacement clutches

The proportion of renests after failed clutches is likely partly dependent on how early the loons are able to lay eggs. At Toker Point, an average of 29% of the pairs that lost their first clutch laid a second clutch (ranged from 18% to 42% over the five years). In comparison, on the Shetland Islands where egg-laying starts a month earlier, much higher rates of renesting have been reported: 64% on Unst (n=22) (Bundy 1976) and 48% on Foula (n=31) (Furness 1983).

The length of time between loss of the original clutch and laying eggs of the replacement clutch averaged 11 days (range 6 to 18 days, n=15) at Toker Point. Most pairs (86%, n=36) built or renovated another nest for the second clutch, rather than using the same platform. They usually renested on the same pond (76% of the pairs, n=41) and always within the same nesting territory. Schamel and Tracy (1985) reported a 12 to 15 day period for three pairs of Red-throated Loons in Alaska and confirmed by colour marking each bird that replacement clutches were laid by the same pair of loons on their original nesting territory.

The eggs from replacement clutches had a greater probability of hatching than the eggs from orginal clutches. An average of 44% of the eggs from replacement clutches hatched compared to only 27% of the first clutch eggs. The high hatching success may have been due to the lower density of nests with eggs at that time of year. Given the lower probability of finding eggs, predators likely switch to hunting other prey species. Contrarily, Gomersall (1986) reported a reduced hatching success of replacement clutches on the Shetland Islands.

Fledging success from replacement clutches at Toker Point was low most years, assuming unfledged chicks died when their nesting ponds froze. About one quarter of the chicks from replacement clutches were likely too young to fledge at freeze-up. However, if the chicks survived by moving to larger waterbodies which froze later, fledging success of replacement clutches was similar to that of the first clutches (43 to 52% compared to 42 to 59% for first clutch chicks).

4.10 Pacific Loon

The breeding success of the Pacific Loon at Toker Point tended to be low. Although 0.7 young fledged per nesting pair in the first year of the study, only 0.2 to 0.3 young fledged per nesting pair in the last four years. In comparison, Eriksson (1987) reported 0.4 young per breeding pair in southwest Sweden, although Sharrock (1976 in Nilsson 1977) observed only 0.25 young per pond in Scotland. The low breeding success at Toker Point may have been partly due to disturbance. The Pacific Loon was more sensitive than the Red-throated Loon to our presence on the study area. During incubation, the Pacific Loon left the nest at a greater distance from the observers than the Red-throated Loon, and took much longer to return to the nest. When we hid from view, the Red-throated Loon usually returned to the nest within 5 to 10 minutes, whereas the Pacific Loon remained in the centre of the pond preening, diving and mock-sleeping often 30 to 45 minutes. This difference in reaction to our presence likely resulted in a greater proportion of Pacific Loon eggs being taken by avian predators or becoming addled from exposure.

The late spring thaw in 1986 had a greater effect on the productivity of the Pacific Loon than the Red-throated Loon. Half as many Pacific Loons nested in 1986 compared to other years (Table 21), whereas the breeding effort by the Red-throated Loon dropped by only a quarter (Table 6). Likewise, only a quarter of the usual number of Pacific Loon chicks fledged in 1986 (3 young fledged in 1986 compared to an average of 12 in the other four years), whereas half the usual number of Red-throated Loon chicks fledged (8 young fledged in 1986 compared to an average of 12 in the other four years). The Red-throated Loon is better adapted to a short ice-free season than the Pacific Loon, as their more northerly distribution would suggest. The Red-throated Loon nests on small shallow ponds that thaw earlier than the larger ponds and lakes used by the Pacific Loon (this study; Davis 1972). Thus, they are able to occupy a nesting territory and lay eggs earlier than the Pacific Loon. Furthermore, Red-throated Loon chicks fledge about two weeks earlier than Pacific Loon chicks (Cramp _et al_. 1977).

Despite the tendency for Red-throated Loons to select smaller more shallow ponds for nesting, there was some competition with the Pacific Loon for the same ponds at Toker Point. Four ponds alternated from year to year between being occupied by Red-throated and Pacific loons. At eight other sites (five Red-throated Loon territories and three Pacific Loon territories), we observed frequent interspecific territorial encounters, but no switching of species occupying the territory. Davis (1972) likewise reported interspecific territorial encounters at Hudson Bay.

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Appendix A. Density of Red-throated Loon nesting territories and chicks near fledging at five study plots in the Beaufort Sea region from 1985 to 1989.

		Density by area (no. per km^2)				
	Year	Toker Point	Atkinson Point	Nuvorak Point	Husky Lakes	King Point
Occupied territories[1]	1985	1.65	1.06	0.68	0.62	0.51
	1986	1.65	1.21	0.77	0.66	0.48
	1987	1.92	1.45	1.06	0.71	0.60
	1988	1.77	1.42	1.08	0.84	0.67
	1989	1.81	1.33	1.00	0.79	0.64
Active territories[2]	1985	1.42	0.79	0.43	0.48	0.34
	1986	1.04	0.64	0.43	0.43	0.26
	1987	1.50	1.15	0.82	0.57	0.44
	1988	1.50	1.27	0.82	0.64	0.46
	1989	1.58	1.00	0.71	0.59	0.45
Young near fledging	1985	0.92	0.64	0.23	0.52	0.35
	1986	0.31	0.42	0.14	0.21	0.22
	1987	0.50	0.97	0.57	0.34	0.42
	1988	0.77	1.39	0.31	0.36	0.31
	1989	0.19	0.45	0.48	0.36	0.24
Area surveyed (km^2)		26	33	65	56	96

[1]Occupied territory - A territory was considered occupied if a loon was present during at least one survey, the site was suitable loon nesting habitat, and there was no evidence that the site was part of a nearby loon territory.

[2]Active territory - A territory was considered active if there were eggs or young, or fresh egg remains or dead chicks.

Appendix B. Mean daily counts of predators at Toker Point during the breeding season from 1985 to 1989.

Appendix B1. Mean daily counts of predators in 1985.

Species	June 17-22	June 23-28	June 29 -July 4	July 5-10	July 11-16	July 17-22	July 23-28	July 29 -Aug. 3	Aug. 4-9
	Mean number observed per day by 6-day intervals								
Northern Harrier	0.50	0.33	0.67	0.25	0.67	0.20	0.17	1.50	0.67
Rough-legged Hawk	1.67	0.17	2.17	1.50	0.33	0.60	0.50	0.25	0.33
Eagle species				0.25			0.17		
Peregrine Falcon		0.17		0.25	0.33				
Gyrfalcon	0.17								
Sandhill Crane	8.33	8.17	5.83	6.50	5.00	3.80	4.50	4.75	2.67
Parasitic Jaeger	4.50	5.50	4.50	4.00	8.67	3.60	3.00	3.00	2.33
Long-tailed Jaeger	2.00	1.50	1.67	0.75	5.00	0.80			
Glaucous Gull	46.17	31.17	15.50	42.50	32.33	26.20	22.33	30.00	25.00
Sabine's Gull	3.67	0.33	1.00	0.50	2.67	1.60	0.17		
Snowy Owl				0.25					
Short-eared Owl					0.33				
Common Raven	3.17	1.17	0.83	1.00		0.40	0.17	2.00	2.33
Red Fox		0.17							
All species	70.17	48.67	32.17	57.75	55.33	37.20	31.00	41.50	33.33

*Blank indicates 0.00

Appendix B2. Mean daily counts of predators in 1986.

	Mean number observed per day by 6-day intervals								
Species	June 17-22	June 23-28	June 29 -July 4	July 5-10	July 11-16	July 17-22	July 23-28	July 29 -Aug. 3	Aug. 4-9
Northern Harrier	1.00	0.83		0.17		0.17	0.50		0.33
Rough-legged Hawk	1.33	1.00	1.00	2.00	0.67	1.50	1.83	1.17	0.50
Peregrine Falcon		0.17	0.17		0.17				
Sandhill Crane	11.17	6.67	3.50	6.67	8.17	5.00	4.50	5.00	4.50
Pomarine Jaeger	0.33								
Parasitic Jaeger	2.83	4.33	2.67	2.17	4.00	3.17	1.17	1.83	1.67
Long-tailed Jaeger	2.00	1.17	0.83	1.33	1.00	1.00			
Jaeger species					0.83				0.33
Glaucous Gull	19.67	26.33	26.17	19.67	47.50	23.17	52.83	28.00	31.00
Sabine's Gull	2.67	1.17	0.83			0.33	0.17		
Snowy Owl			0.17						
Short-eared Owl	0.50			0.17	0.33		0.17		
Common Raven	0.33	0.50	1.50	0.83	0.50	0.33	0.50	0.33	1.33
Arctic Fox	0.83		0.17	0.33	0.33	0.67	0.17	0.17	0.17
All species	42.67	42.17	37.00	33.33	63.50	35.33	61.83	36.50	39.83

*Blank indicates 0.00

Appendix B3. Mean daily counts of predators in 1987.

Species	June 17-22	June 23-28	June 29 -July 4	July 5-10	July 11-16	July 17-22	July 23-28	July 29 -Aug. 3	Aug. 4-9
	Mean number observed per day by 6-day intervals								
Northern Harrier	0.17								
Rough-legged Hawk	1.83	2.00	1.50	1.00	1.33	1.20	2.00	1.50	3.50
Gyrfalcon	0.17								
Sandhill Crane	5.33	4.17	4.67	4.50	3.00	4.80	4.50	3.50	10.50
Parasitic Jaeger	3.17	4.17	3.83	5.67	7.00	3.80	0.50	4.25	1.50
Long-tailed Jaeger	1.50	1.50	1.67	1.33	1.17		0.50		
Glaucous Gull	26.67	17.83	30.50	26.83	31.17	21.40	32.50	39.75	26.50
Sabine's Gull	1.33	1.00		0.50	0.67	1.00	0.50	2.75	
Snowy Owl				0.17		0.20		0.25	
Short-eared Owl		0.17	0.17						
Common Raven	1.33	0.83	0.50	0.50	0.33		0.50	1.25	2.50
Arctic Fox	1.00	1.33	0.83	0.33	0.17	0.80		0.75	3.00
Arctic Wolf							0.50		
All species	42.50	33.00	43.67	40.83	44.83	33.20	41.50	54.00	47.50

*Blank indicates 0.00

Appendix B4. Mean daily counts of predators in 1988.

Species	Mean number observed per day by 6-day intervals								
	June 17-22	June 23-28	June 29 -July 4	July 5-10	July 11-16	July 17-22	July 23-28	July 29 -Aug. 3	Aug. 4-9
Northern Harrier	1.17	0.25	0.50		0.20	0.25	0.25	0.50	
Rough-legged Hawk	1.67	3.50	1.83	2.50	1.80	1.75	1.50	1.00	1.00
Golden Eagle		0.50							
Merlin		0.25							
Peregrine Falcon								0.50	
Falcon species	0.17		0.17						
Sandhill Crane	3.67	9.50	5.83	6.33	3.60	7.25	7.75	5.50	7.33
Pomarine Jaeger	0.17								
Parasitic Jaeger	3.50	2.50	1.83	3.33	2.40	3.75	2.00	6.00	6.00
Long-tailed Jaeger	0.83		0.33	0.17		1.00			2.67
Glaucous Gull	23.50	15.75	19.67	10.17	7.40	31.75	19.75	31.50	42.67
Sabine's Gull	0.17								
Short-eared Owl	0.83		0.33		0.20			0.50	0.33
Common Raven	1.00	0.75	0.67	0.17	0.20	0.50		1.00	
Arctic Fox	0.50				0.20				
All species	37.17	33.00	31.17	22.67	16.00	46.25	31.25	46.50	60.00

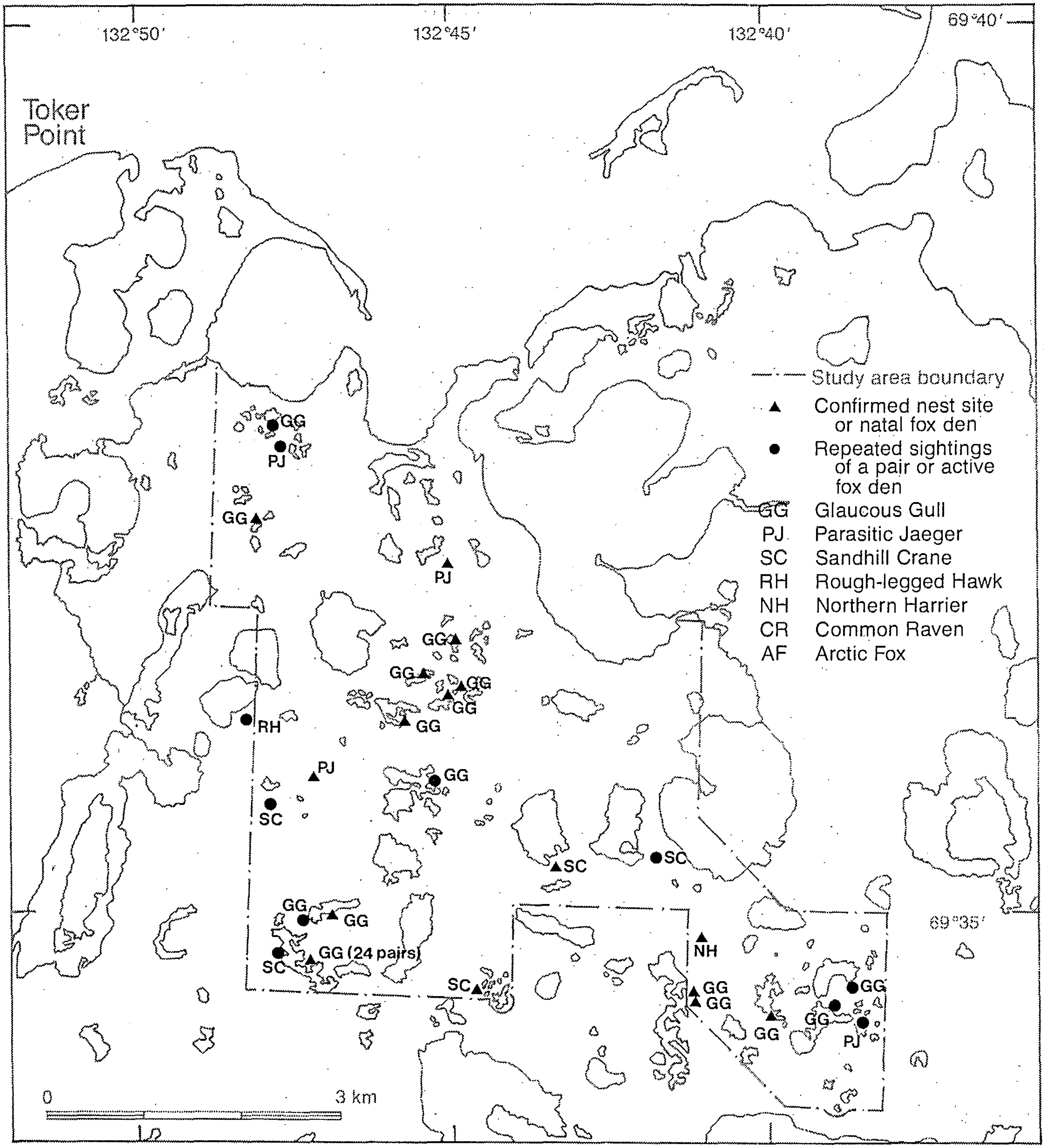
*Blank indicates 0.00

Appendix B5. Mean daily counts of predators in 1989.

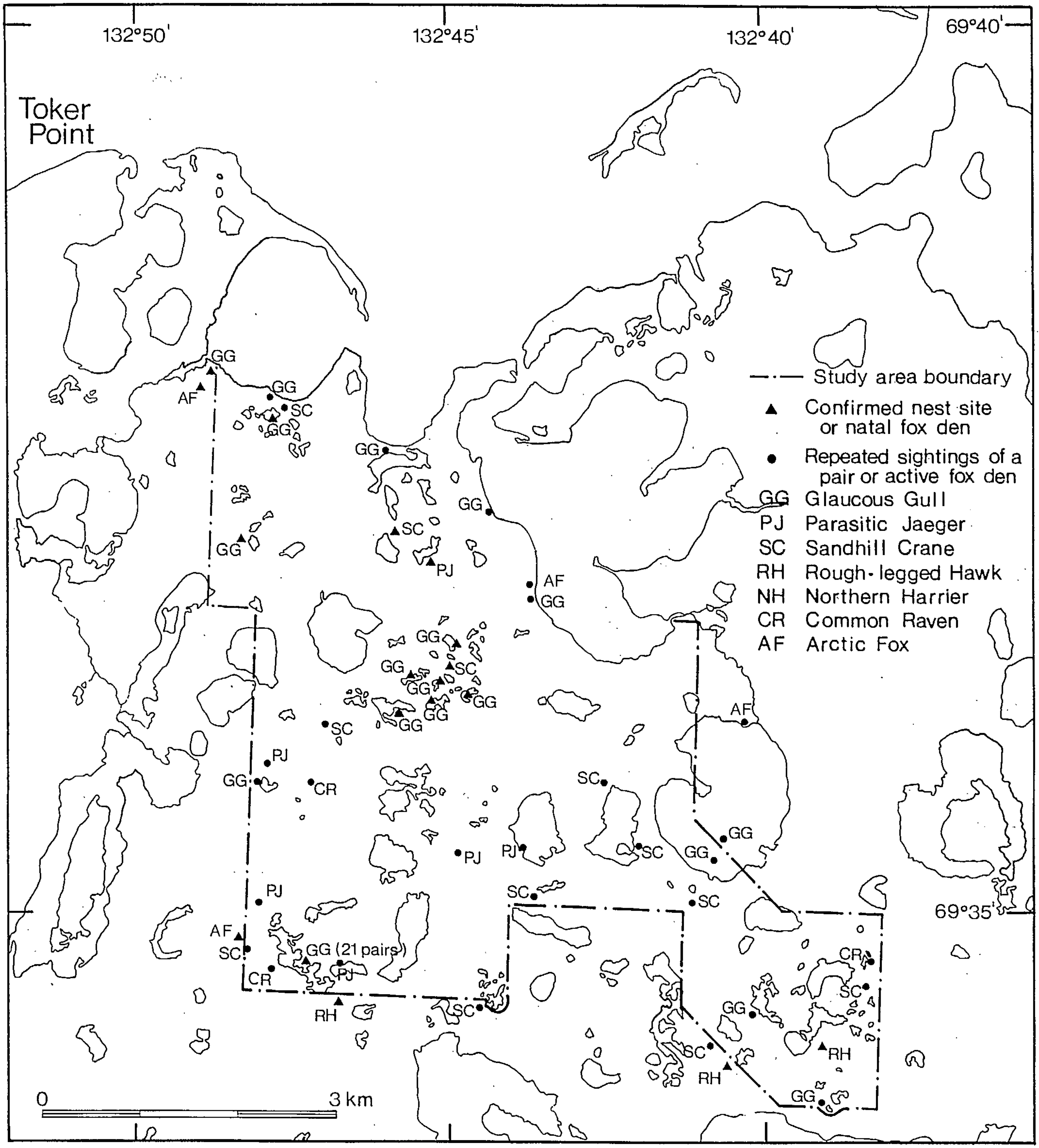
Species	Mean number observed per day by 6-day intervals								
	June 17-22	June 23-28	June 29 -July 4	July 5-10	July 11-16	July 17-22	July 23-28	July 29 -Aug. 3	Aug. 4-9
Northern Harrier	0.67		1.20	1.40	0.40		0.25		
Rough-legged Hawk	0.50	0.17			0.20				
Bald Eagle			0.20						
Peregrine Falcon		0.17	0.20						
Sandhill Crane	9.00	15.33	15.60	12.20	12.80	11.33	9.75	8.00	28.00
Pomarine Jaeger	1.17	0.17							
Parasitic Jaeger	3.83	3.67	3.60	5.20	4.60	3.33	2.50	1.33	4.00
Long-tailed Jaeger	0.17	0.17	0.60	0.60		0.33			
Glaucous Gull	23.83	17.83	18.20	21.60	18.60	20.67	13.50	16.33	35.50
Snowy Owl	0.17		0.20						
Common Raven	0.67	0.67	0.60	0.80		1.00	0.75		1.00
Arctic Fox	0.17	0.50					0.50	0.33	
Red Fox	0.17								
All species	40.33	38.67	40.40	41.80	36.60	36.67	27.25	26.00	68.50

*Blank indicates 0.00

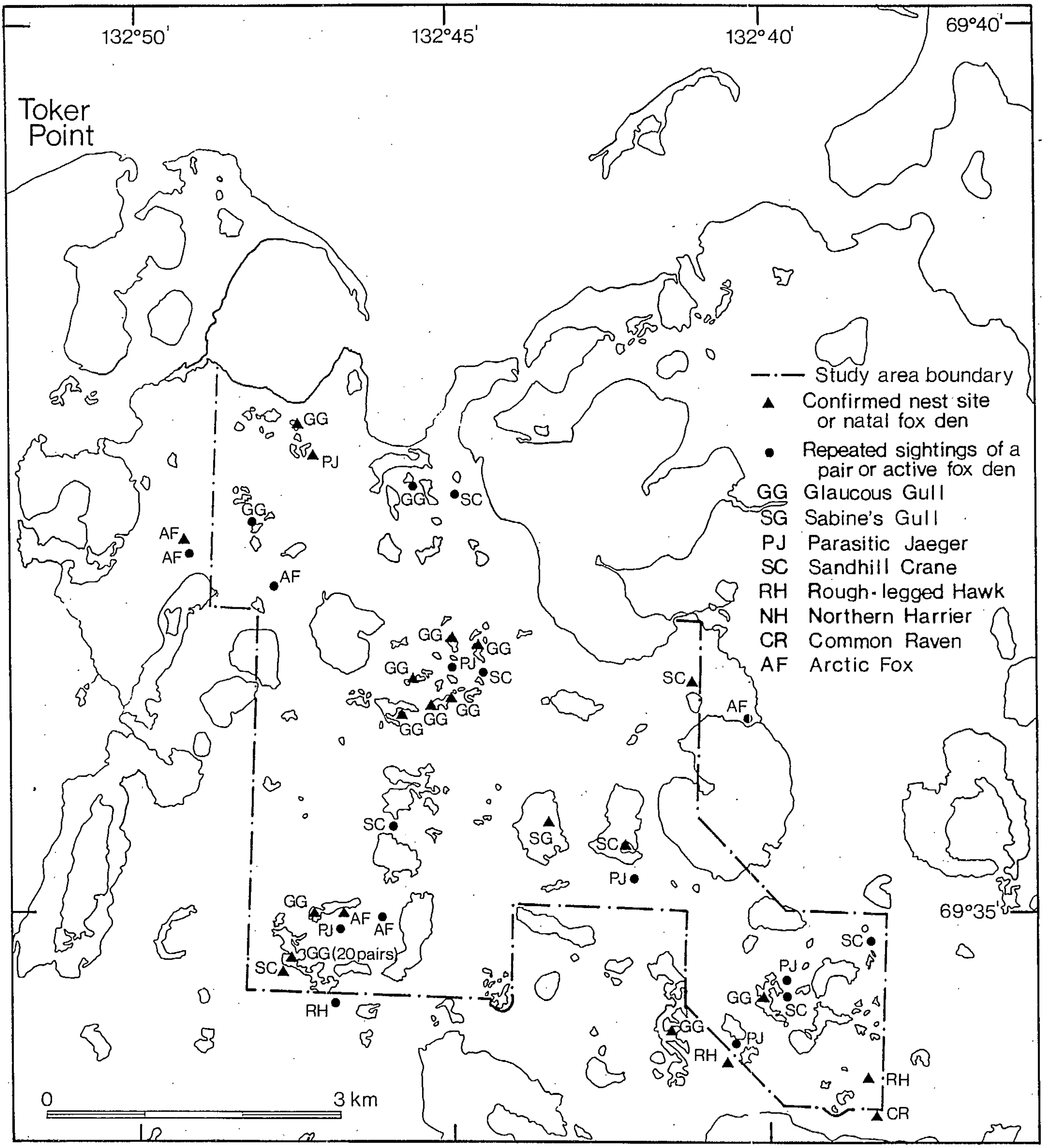
Appendix C. Location of dens and nesting territories of predators with hunting territories in the Toker Point study plot.



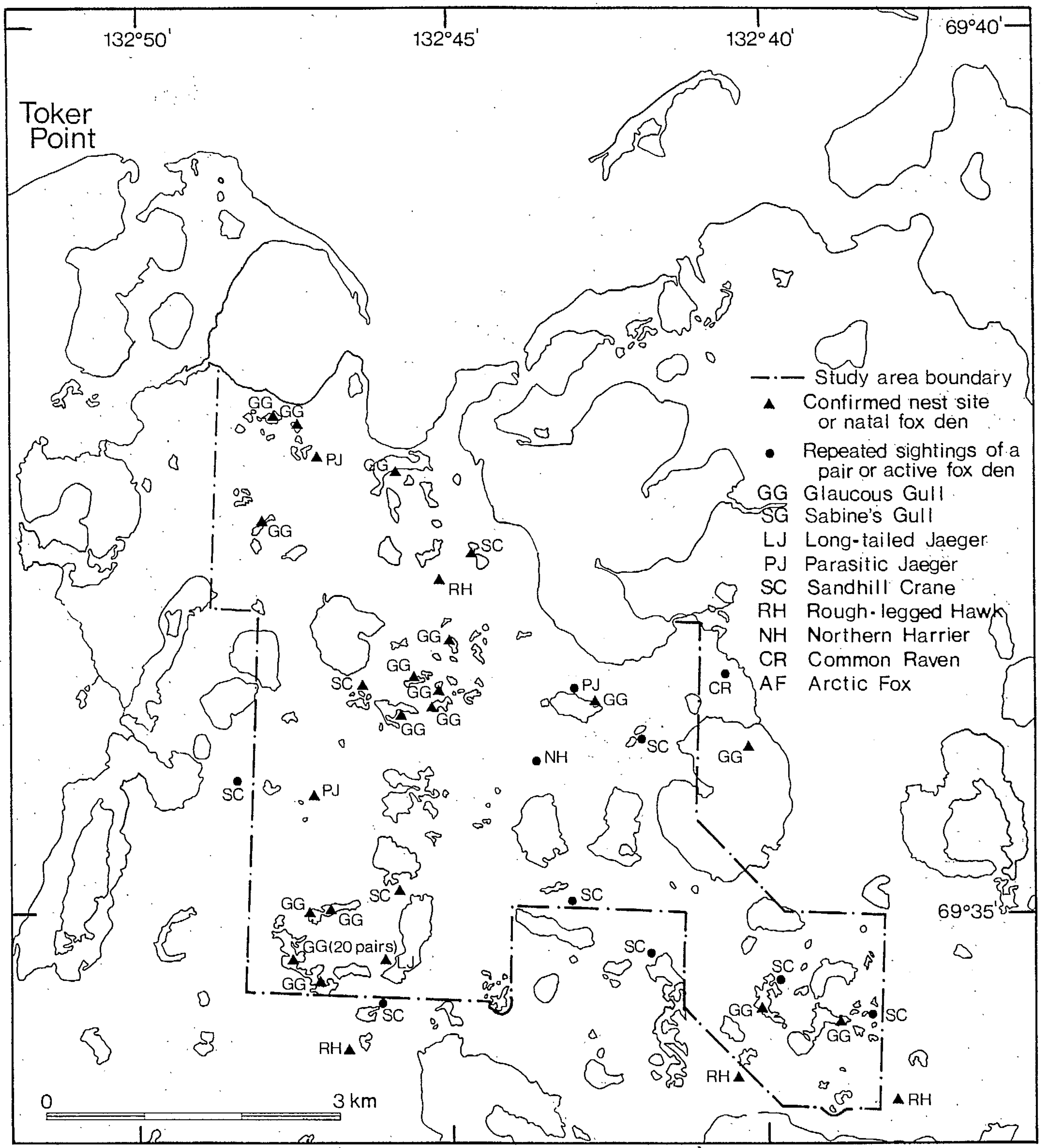
Appendix C1. Location of predators in the Toker Point study plot in June and July of 1985.



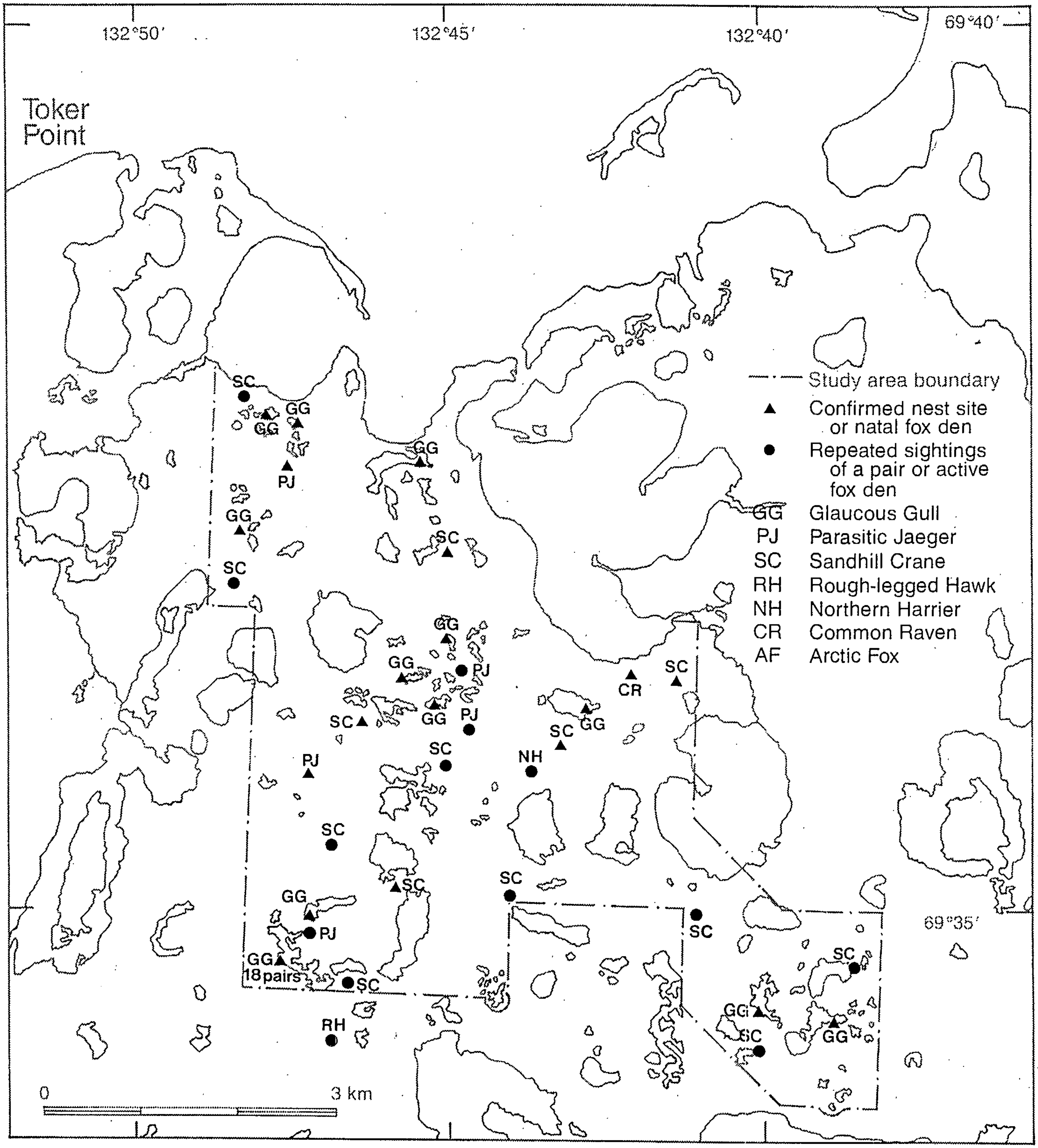
Appendix C2. Location of predators in the Toker Point study plot in June and July of 1986.



Appendix C3. Location of predators in the Toker Point study plot in June and July of 1987.



Appendix C4. Location of predators in the Toker Point study plot in June and July of 1988.



Appendix C5. Location of predators in the Toker Point study plot in June and July of 1989.

Appendix D. Number of nests and young of all birds species other than the Red-throated Loon found at Toker Point from 1985 to 1989.

Species	Number of nests[1]					Number of young				
	1985	1986	1987	1988	1989	1985	1986	1987	1988	1989
Pacific Loon	26	17	39	34	36	22	3	14	15	15
Tundra Swan	3		5	4	6	24		5	31	31
Brant	2	1	11	2	1	33		3		
Greater White-fronted Goose	6	3	8	7	8	6	9	4	10	42
Northern Pintail	3	3	1	3		23	3	8	17	15
Green-winged Teal	1	1	1	2	1	19	19	7	39	30
Lesser Scaup	3			1		6				22
Scaup sp.			1		2	2			12	3
Oldsquaw	3	3	6		4	113	39	16	122	88
Duck sp.				1					5	10
Rough-legged Hawk	1	3	3	4			6	4	7	
Northern Harrier	1									
Willow Ptarmigan	3	6	4	4	13	59	29		3	81
Sandhill Crane	3	1	3	3	2	3			6	7
Lesser Golden-Plover				1		1				7
Semipalmated Plover						3				
Stilt Sandpiper	1	5	2		3	3	8		2	6
Long-billed Dowitcher			1	1						
Red-necked Phalarope	3	1	5	6	5	5	1	1	8	
Common Snipe	1				1					
Pectoral Sandpiper			4	1		2		3	1	
Semipalmated Sandpiper	4	5	8	5	3	11	8	4		
Whimbrel					1					
Parasitic Jaeger	2	1	1	2	2	1		2	3	2
Long-tailed Jaeger				1						
Glaucous Gull[2]	11	10	11	17	11	30	14	22	42	27
Sabine's Gull			1					2		
Arctic Tern	2		6	7	4		1	1	2	
Common Raven			1							
Water Pipit			1					3		
Savannah Sparrow	3	2	18	10	7	5	1	42	17	10
American Tree Sparrow			3					3		
White-crowned Sparrow				2					9	
Lapland Longspur	15	14	13	18	17	11	14	30	34	37
Redpoll sp.				15	2				22	8
Total	97	76	157	151	129	382	155	164	407	441

[1]Includes nests with eggs or young, and inaccessible nests where adults were seen incubating. For Pacific Loons, the number of active territories was used.

[2]Glaucous Gull colony in southwest lowland was counted as one nest each year since number of nests in colony unknown.

Appendix E. Number of small mammals trapped on the Toker Point study plot between 5 and 15 July from 1987 and 1989.

Date	Number trapped by year[1] 1987	1988	1989
July 5	1	–	0
	3	–	0
6	2	7	1
	3	3	0
7	4	3	1
	2	4	1
8	5	3	0
	3	5	2
9	1	4	1
	1	4	1
10	1	6	2
	1	2	2
11	1	2	0
	3	2	0
12	3	4	1
	2	5	1
13	2	1	2
	0	0	1
14	2	5	2
	0	0	0
15	–	4	–
	–	2	–
Total	40	66	18
No./100 trapnights	4.0	6.6	1.8

[1] Traps checked at 9:00 and 21:00 hours. Recaptured animals excluded. Significant difference between years in number trapped (Kruskal-Wallis Test, T=19.9, 2df, $p < 0.05$).

Appendix F. Catch per unit effort (fish/100 m) of fish 5 to 20 cm long at Toker Point from 1987 to 1989.

Appendix F1. Catch per unit effort (fish/100 m) of fish 5 to 20 cm long at Toker Point in 1987.

	Species[1]														
Date	PCHA	LSCS	ARCS	BDWT	LKWT	CO	RNSM	NOPI	NSSB	FHSC	ARFL	STFL	UNID	All CO	All species
July 19		0.7		5.3		18.7				1.3				24.7	26.0
July 28						1.3								1.3	1.3
Aug. 6		109.4	30.0			0.7								140.1	140.1
Aug. 12		1.3	1.3	0.7										3.3	3.3
Aug. 21		1.3	3.3	3.3										8.0	8.0
Aug. 29		3.3	2.7							5.3	1.3			6.0	12.6
Mean	0	19.3	6.2	1.6	0	3.4	0	0	0	1.1	0.2	0	0	30.6	31.9
SD	0	43.9	11.7	2.2	0	7.4	0	0	0	2.1	0.5	0	0	54.1	53.4
% of catch		61	20	5		11				3	<1			97	

[1]Key to abbreviations

PCHA pacific herring
LSCS least cisco
ARCS Arctic cisco
BDWT broad whitefish
LKWT lake whitefish
CO coregonid
RNSM rainbow smelt
NOPI northern pike
NSSB ninespine stickleback
FHSC fourhorn sculpin
ARFL Arctic flounder
STFL starry flounder
UNID unidentified fish

Appendix F2. Catch per unit effort (fish/100 m) of fish 5 to 20 cm long at Toker Point in 1988.

	Species[1]														
Date	PCHA	LSCS	ARCS	BDWT	LKWT	CO	RNSM	NOPI	NSSB	FHSC	ARFL	STFL	UNID	All CO	All species
July 17, 1988		4.7	2.0	4.7			0.7			4.0	4.7			11.3	20.7
July 24	1.3	1.3		2.7						6.0				5.3	11.3
July 30	2.0	3.3		26.7			1.3	0.7		6.7	0.7			32.0	41.4
Aug. 6	2.0	48.0	1.3	14.7	4.7				0.7	2.7	0.7			70.7	74.7
Aug. 14		33.4	1.3	6.0	1.3				0.7	2.7	0.7			42.0	46.0
Aug. 28		20.7	4.0							6.7	0.7			24.7	32.0
Sept. 3		16.0	27.3	8.7						8.0				52.0	60.0
Mean	0.8	18.2	5.1	9.1	0.8	0	0.3	0.1	0.2	5.2	1.1	0	0	34.0	40.9
SD	1.0	17.4	9.8	9.1	1.7	0	0.5	0.2	0.3	2.2	1.6	0	0	23.0	21.9
% of catch	2	44	12	22	2		<1	<1	<1	13	2			80	

[1]Key to abbreviations

PCHA	pacific herring
LSCS	least cisco
ARCS	Arctic cisco
BDWT	broad whitefish
LKWT	lake whitefish
CO	coregonid
RNSM	rainbow smelt
NOPI	northern pike
NSSB	ninespine stickleback
FHSC	fourhorn sculpin
ARFL	Arctic flounder
STFL	starry flounder
UNID	unidentified fish

Appendix I. Monthly mean temperature and precipitation at Tuktoyaktuk from 1985 to 1989 (data provided by Atmospheric Environment Service).

Month	Temperature (°C)						Precipitation (mm)					
	1985	1986	1987	1988	1989	27-year mean[1]	1985	1986	1987	1988	1989	27-year mean[1]
January	-25.4	-31.4	-23.6	-26.7	-31.5	-27.7	14.0	11.0	15.1	6.6	7.6	5.6
February		-24.0	-27.5	-25.9	-14.8	-28.5		19.9	5.0	8.6	27.6	5.4
March	-22.7	-28.7	-24.9	-21.4	-26.1	-26.3	6.2	3.4	2.8	11.6	6.2	4.4
April	-20.9	-20.6	-22.4	-12.9	-13.6	-16.9	9.9	22.8	4.8	3.5	1.0	7.0
May	-2.0	-6.8	-8.0	-4.3	-5.5	-4.7	9.4	24.5	5.8	11.2	6.6	5.8
June	5.9	4.5	6.4	7.9	7.1	5.1	11.3	TR	TR	1.6	8.3	12.0
July	6.0	8.7	11.3	13.8	13.9	10.6	25.2	8.4	31.4	12.0	24.0	20.4
August	7.2	8.3	8.9	8.9	14.3	9.0	16.7	27.4	45.1	38.6	20.5	27.6
September	2.7	5.0	4.0	3.1	4.1	2.6	27.0	21.1	11.4	8.3	53.3	16.0
October	-9.8	-7.8	-3.2	-9.3		-7.8	33.8	30.2	13.7	29.3		18.4
November	-20.0	-24.7	-20.0	-27.5		-19.8	6.6	7.4	18.8	10.5		8.8
December	-22.7	-23.4	-19.8	-21.5		-25.2	12.7	14.8	21.5	11.8		7.2

[1] 27-year mean is based on records from 1957 to 1984 from the Tuktoyaktuk airport

Appendix G. Determination of size of fish Red-throated Loons fed their chicks.

Methods

Slides of adult Red-throated Loons feeding fish to their young were taken from a blind at the edge of a nest pond between 9 and 17:00 h each day from 16 to 21 August in 1986 and from 12 to 21 August in 1987. A 35 mm SLR camera with a 500 m lens and 1.5x converter was used to photograph the feedings.

The scale in the photographs was obtained by using the distance from the tip of the bill to the front of the eye of the Red-throated Loon as a reference (Reimchen and Douglas 1984). This distance averaged 7.51 cm (SD ± 0.43 cm) based on measurements made on 22 Red-throated Loon specimens from the National Museums in Ottawa.

Results

Table G1. Length of fish fed to Red-throated Loon chicks at Toker Point

Year	Mean (cm)	Range (cm)	Sample size	Age of chicks (days)
1986	12.6	7.1-17.6	18	18-23
1987	12.9	10.2-17.5	13	23-32
Both years	12.7	7.1-17.6	31	18-32

Fish fed to the loon chicks ranged in size from 7.1 to 17.6 cm which concurs with other studies. Reimchen and Douglas (1984) reported fish sizes ranging from 5.0 to 14.7 cm (n=60). Norberg and Norberg (1976) reported fish ranged in size from 9 to 20 cm (n=11). Eriksson *et al.*

(1990) noted that most fish were <14 cm, but ranged up to 20 cm.

The quality of the photographs and similarity in appearance of several species of fish made it difficult to determine what species were being fed to the chicks. All fish were slender, dark on the back and silvery on the sides and belly. None of them were flounders, sticklebacks or sculpins which can be easily recognized. Thus, the species being used by the Red-throated Loons were the least cisco, arctic cisco, broad whitefish, lake whitefish, rainbow smelt and Pacific herring.

Appendix H. Among year comparisons of the amount of time a pair of Red-throated Loons spent on its nesting territory during brood-rearing.

	Number of loon-minutes per 120 min watch[1]				
Date	1985	1986	1987	1988	1989
July 21	183				
~					
27			184		188
28	149				166
29				116	
30					
31			188		
Aug. 1					208
2					174
3					186
4	162				
5		186	203	121	
6					
7				126	162
8	174	169			165
9					
10			206	104	
11	167	146			
12				128	
13					136
14		186	177		147
15	187		227	139	105
16				114	
17		167			
18					
X ±SD	170 ±14	171 ±16	198 ±18	121 ±11	164 ±29

[1]Mean value for each 24h set of loon watches
Significant difference among years (Kruskal-Wallis Test, T=19.3, 4df, $p < 0.05$). Attendance significantly greater in 1987 and less in 1988 than in any other year (Multiple Comparisons).

Appendix F3. Catch per unit effort (fish/100 m) of fish 5 to 20 cm long at Toker Point in 1989.

Date	Species[1]														All CO	All species
	PCHA	LSCS	ARCS	BDWT	LKWT	CO	RNSM	NOPI	LNSK	NSSB	FHSC	ARFL	STFL	UNID		
July 18		5.3	2.7	5.3	0.7	0.7	0.7				6.0				14.7	21.3
July 23		12.7	3.3	22.0		8.0	4.7		0.7		6.0	0.7			46.0	58.0
July 30		37.3		22.7			1.3	0.7							60.0	62.0
Aug. 5		14.7		12.0	3.3						1.3				30.0	31.3
Aug. 10		0.7	0.7	3.3							0.7	0.7			4.7	6.0
Aug. 18	0.7	2.0	1.3	6.7			0.7				0.7				10.0	12.0
Aug. 25	16.0	47.3	34.0	3.3			0.7								84.7	101.3
Aug. 30		8.0	17.3	3.3			0.7								28.7	29.3
Mean	2.1	16.0	7.4	9.8	0.5	1.1	1.1	0.1	0.1	0	1.8	0.2	0	0	34.9	40.2
SD	5.6	17.1	12.2	8.3	1.2	2.8	1.5	0.2	0.3		2.6	0.3			27.4	31.7
% of catch	5	40	18	24	1	3	3	<1	<1	0	5	<1	0	0	86	

[1]Key to abbreviations

PCHA	pacific herring	NOPI	northern pike
LSCS	least cisco	NSSB	ninespine stickleback
ARCS	Arctic cisco	FHSC	fourhorn sculpin
BDWT	broad whitefish	ARFL	Arctic flounder
LKWT	lake whitefish	STFL	starry flounder
CO	coregonid	UNID	unidentified fish
RNSM	rainbow smelt	LNSK	longnose sucker

Appendix J. Mean daily temperature at Tuktoyaktuk during spring thaw (data provided by Atmospheric Environment Service).

Date	1985	1986	1987	1988	1989	27-year mean
May 11-15	-6.1	-7.4	-11.4	-5.4	-8.8	-6.9
16-20	0.0	-10.1	-9.0	-2.8	-6.5	-3.9
21-25	0.1	-5.8	-7.1	-0.3	-5.7	-2.6
26-30	1.8	-3.9	-1.1	2.8	5.0	0.1
31-Jun. 4	8.6	-0.5	1.1	2.7	6.4	2.0
June 5-9	2.2	0.6	4.2	4.7	5.8	3.2
10-14	0.4	1.2	1.4	8.3	3.4	5.4
15-19	3.3	4.3	10.2	6.8	5.6	5.1
20-24	8.9	10.4	9.4	9.6	12.2	6.0
25-29	12.8	10.1	9.6	12.4	9.9	7.2

Appendix K. Specimens collected and stored in the tissue bank at the National Wildlife Research Centre in Ottawa to be used as references for environmental contaminants.

Specimen number	Units in specimen	Tissue	Species	Collection date	Location
1	1	egg	Red-throated Loon	7 July 1986	69°54'N; 131°25'W
2	1	egg	Red-throated Loon	7 July 1986	69°52'N; 131°33'W
3	1	egg	Red-throated Loon	7 July 1986	69°51'N; 131°35'W
4	1	egg	Red-throated Loon	7 July 1986	69°37'N; 132°37'W
5	1	egg	Red-throated Loon	7 July 1986	69°37'N; 132°53'W
86-F1	5	whole fish	Least cisco	24 August 1986	69°37'N; 132°45'W
86-F2	12	whole fish	Least cisco	24 August 1986	69°37'N; 132°45'W
86-F3	7	whole fish	Arctic cisco	24 August 1986	69°37'N; 132°45'W
86-F4	4	whole fish	Arctic cisco	24 August 1986	69°37'N; 132°45'W
86-F5	12	whole fish	Least cisco	24 August 1986	69°37'N; 132°45'W
86-F6	9	whole fish	Least cisco	24 August 1986	69°37'N; 132°45'W
86-F7	3	whole fish	Broad whitefish	24 August 1986	69°37'N; 132°45'W
87-1	1	whole adult	Red-throated Loon	13 June 1987	69°35'N; 132°28'W
87-2	1	whole adult	Red-throated Loon	13 June 1987	69°35'N; 132°28'W
87-3	1	whole adult	Red-throated Loon	13 June 1987	69°35'N; 132°28'W
87-4	1	whole adult	Red-throated Loon	13 June 1987	69°35'N; 132°28'W
87-5	1	whole egg	Red-throated Loon	30 June 1987	69°42'N; 132°00'W
87-6	1	whole egg	Red-throated Loon	30 June 1987	69°37'N; 132°22'W
87-7	1	whole egg	Red-throated Loon	30 June 1987	69°42'N; 132°00'W
87-8	1	whole egg	Red-throated Loon	30 June 1987	69°42'N; 132°00'W
87-9	1	whole egg	Red-throated Loon	30 June 1987	69°42'N; 132°04'W
87-10	1	whole young of year	Red-throated Loon	5 September 1987	69°37'N; 132°45'W
88-1	1	whole adult	Red-throated Loon	14 June 1987	69°35'N; 132°29'W
88-2	1	whole adult	Red-throated Loon	14 June 1987	69°35'N; 132°29'W
88-3	1	whole adult	Red-throated Loon	14 June 1987	69°35'N; 132°29'W
88-4	1	whole adult	Red-throated Loon	14 June 1987	69°35'N; 132°29'W
88-5	1	whole adult	Red-throated Loon	14 June 1987	69°35'N; 132°29'W
88-6	1	whole young of year	Red-throated Loon	25 August 1988	69°37'N; 132°27'W
88-7	1	whole young of year	Red-throated Loon	25 August 1988	69°37'N; 132°35'W
88-8	1	whole young of year	Red-throated Loon	25 August 1988	69°37'N; 132°35'W
88-9	1	whole young of year	Red-throated Loon	25 August 1988	69°38'N; 132°37'W
88-10	1	whole young of year	Red-throated Loon	25 August 1988	69°38'N; 132°37'W
89-1	1	whole young of year	Red-throated Loon	24 August 1989	69°42'N; 132°33'W
89-2	1	whole young of year	Red-throated Loon	24 August 1989	69°43'N; 132°33'W
89-3	1	whole young of year	Red-throated Loon	24 August 1989	69°43'N; 132°21'W
89-4	1	whole young of year	Red-throated Loon	24 August 1989	69°43'N; 132°21'W
89-5	1	whole young of year	Red-throated Loon	24 August 1989	69°43'N; 132°21'W

Appendix L. Organochlorine residues in Red-throated Loon eggs and livers collected in the Beaufort Sea region in 1986 and 1987.

	Organochlorine residues (wet weight basis) in ppm[1]			
Pooled samples	DDE	Dieldrin	Total PCBs[2]	Mirex[3]
Five eggs collected in 1986	0.582	0.037	1.62	<0.001
Control Egg (1986)	4.75	0.280	22.4	0.149
Five eggs collected in 1987	0.5036	0.0291	1.416	0.0108
Four livers of adults collected in 1987	0.1531	0.0151	0.5655	0.0024
Control egg (1987)	4.953	0.2644	10.36	0.2098
Control egg (1987)	5.218	0.2670	10.71	0.2112

[1]Data from Won (1986) and Won (1987).
[2]PCB47 excluded from results in all except eggs collected in 1986.
[3]Mirex = p Mirex + Mirex.

Appendix M. English and scientific names of bird species that occurred in the study area.

English Name	Scientific Name
Red-throated Loon	Gavia stellata
Pacific Loon	Gavia pacifica
Common Loon	Gavia immer
Yellow-billed Loon	Gavia adamsii
Tundra Swan	Cygnus columbianus
Greater White-fronted Goose	Anser albifrons
Lesser Snow Goose	Chen caerulescens
Brandt	Branta bernicla
Canada Goose	Branta canadensis
Green-winged Teal	Anas crecca
Mallard	Anas platyrhynchos
Northern Pintail	Anas acuta
Northern Shoveler	Spatula clypeata
American Wigeon	Anas americana
Canvasback	Aythya valisineria
Greater Scaup	Aythya marila
Lesser Scaup	Aythya affinis
Common Eider	Somateria mollissima
King Eider	Somateria spectabilis
Oldsquaw	Clangula hyemalis
Surf Scoter	Melanitta perspicillata
White-winged Scoter	Melanitta fusca
Common Goldeneye	Bucephala clangula
Common Merganser	Mergus merganser
Red-breasted Merganser	Mergus serrator
Bald Eagle	Haliaeetus leucocephalus
Northern Harrier	Circus cyaneus
Rough-legged Hawk	Buteo lagopus
Golden Eagle	Aquila chrysaetas
Merlin	Falco columbarius
Peregrine Falcon	Falco peregrinus
Gyrfalcon	Falco rusticolus
Willow Ptarmigan	Lagopus lagopus
Rock Ptarmigan	Lagopus mutus
Sandhill Crane	Grus canadensis
Black-bellied Plover	Pluvialis squatarola
Lesser Golden-Plover	Pluvialis dominica
Semipalmated Plover	Charadrius semipalmatus
Lesser Yellowlegs	Tringa flavipes
Whimbrel	Numenius phaeopus
Hudsonian Godwit	Limosa haemastica
Ruddy Turnstone	Arenaria interpres
Sanderling	Calidris alba
Semipalmated Sandpiper	Calidris pusilla

Appendix M. Continued.

English Name	Scientific Name
Least Sandpiper	_Calidris minutilla_
White-rumped Sandpiper	_Calidris fuscicollis_
Baird's Sandpiper	_Calidris bairdii_
Pectoral Sandpiper	_Calidris melanotos_
Stilt Sandpiper	_Calidris himantopus_
Buff-breasted Sandpiper	_Tryngites subruficollis_
Long-billed Dowitcher	_Limnodromus scolopaceus_
Common Snipe	_Gallinago gallinago_
Red-necked Phalarope	_Phalaropus lobatus_
Red Phalarope	_Phalaropus fulicaria_
Pomarine Jaeger	_Stercorarius pomarinus_
Parasitic Jaeger	_Stercorarius parasiticus_
Long-tailed Jaeger	_Stercorarius longicaudus_
Thayer's Gull	_Larus thayeri_
Glaucous Gull	_Larus hyperboreus_
Sabine's Gull	_Xema sabini_
Arctic Tern	_Sterna paradisaea_
Snowy Owl	_Nyctea scandiaca_
Short-eared Owl	_Asio flammeus_
Horned Lark	_Eremophila alpestris_
Tree Swallow	_Tachycineta bicolor_
Common Raven	_Corvus corax_
American Robin	_Turdus migratorius_
Water Pipit	_Anthus spinoletta_
Yellow Warbler	_Dendroica petechia_
American Tree Sparrow	_Spizella arborea_
Savannah Sparrow	_Passerculus sandwichensis_
White-crowned Sparrow	_Zonotrichia leucophrys_
Dark-eyed Junco	_Junco hyemalis_
Lapland Longspur	_Calcarius lapponicus_
Snow Bunting	_Plectrophenax hyperboreus_
Common Redpoll	_Carduelis flammea_
Hoary Redpoll	_Carduelis hornemanni_