D. Lynne Dickson

The Red-throated Loon as an indicator of environmental quality

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Cover photo: Pair of Red-throated Loons with chick (Chuck Gordon)

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Abstract

A monitoring study was initiated in the mid-1980s to determine the effects of future offshore oil and gas production on the birds that use the coastal areas of the Beaufort Sea. The primary objective of the five-year predevelopment phase of the study was to determine the natural annual fluctuations in the abundance, breeding effort, and breeding success of the study's indicator species, the Red-throated Loon *Gavia stellata*.

Four study plots were searched by helicopter to obtain total counts of Red-throated Loon pairs, nests, eggs, and chicks. The status of loon nesting territories was checked on foot every three to five days from mid-June to early September at a fifth study plot. Data were also collected on the abundance of fish, the abundance of predators, the abundance of alternative prey for the predators, and several weather-related factors.

Between 1985 and 1989, the number of loon pairs with nesting territories remained the same at all but one study plot. Breeding effort also tended to be constant among years. The percentage of resident pairs that nested ranged from 73 to 78%, except in 1986, when only 58% nested, possibly because of a late spring thaw. Breeding success averaged 0.63 young per nesting pair but was highly variable between years.

The abundance of arctic foxes was the single most influential factor affecting loon productivity. In comparison, avian predators had little effect. Other factors that affected breeding success were the abundance of northern red-backed voles, abundance of waterfowl nests, and, in 1988, a severe midsummer storm. Although the abundance of fish fluctuated among years, the frequency with which loons fed their chicks fish did not vary significantly.

The study concludes that the most suitable parameter for measuring the impact of offshore oil and gas activity is breeding success, as hatch and survival of young to fledging are primarily dependent on local conditions. However, only large changes in productivity (31–43%, for a 95% certainty) would be indicative of human impacts, because breeding success varied so much as a result of natural factors.

For the monitoring program to succeed, surveys during the development and postdevelopment phases of the study will have to span several years, or an unnatural upward or downward trend in productivity may go undetected. Furthermore, if a change is detected, a more intensive investigation will be needed to determine its cause.

1.0 Introduction

Recent oil and gas exploration in the Canadian Beaufort Sea (area between 69°N and 71°N and between 129°W and 139°W) has raised concerns about the impact of offshore production on bird populations in the region. Such development could affect birds in many ways, including destruction of nesting habitat, contamination or reduction of food supply, human disturbance, and direct mortality from oil spills. Because of the wide range of potential impacts, the monitoring of single abiotic factors—for example, contaminants in marine sediments—was considered inadequate for indicating possible effects. More subtle environmental changes affecting regional bird populations could go undetected, as could the cumulative effect of several minor impacts (Morrison 1986). Thus, the Canadian Wildlife Service initiated a monitoring program using the Red-throated Loon *Gavia stellata* as the indicator species. The loon was selected because of its vulnerability to offshore oil production, its ubiquitous distribution throughout the Beaufort Sea region, and its conspicuous nature, even when nesting.

The parameters chosen to be monitored were the abundance of Red-throated Loon pairs, their breeding effort, and their breeding success. The primary objective of the five-year predevelopment phase of the study was to determine the natural annual fluctuations in these parameters. The secondary objective was to understand how various environmental and biological factors affected the productivity of the loon under undisturbed conditions. This information would be needed during the postdevelopment phase of the monitoring study to help differentiate between human-caused and natural fluctuations in productivity.

The results of the five-year predevelopment phase of the monitoring program are presented here, including a discussion of the limitations of the program.

2.0 Methods

Five study plots were selected based on the amount of oil- and gas-related development proposed for each location. Two sites, King Point and Atkinson Point, had been identified by the oil companies as suitable for port development (Dome Petroleum Ltd. et al. 1982). Two other sites, Nuvorak Point and Toker Point, were chosen because there were no plans for shoreline development at those locations. The fifth site, Husky Lakes, was inland, where the loons would be less likely to be affected by oil pollution in the Beaufort Sea (Fig. 1). The combined total area of the five study plots was 276 km²; over 200 pairs of Red-throated Loons resided at the study plots 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 two observers in a Bell 206B Jet Ranger helicopter, except at the Toker Point study plot, where most of the surveys were done on foot. Each year, two surveys about 11 days apart were conducted during incubation, followed by a third survey for chicks four weeks after the median date of hatch. To locate incubating birds, the helicopter was flown at 20–25 m above ground and at 50–100 km/h. Wherever there were many small ponds or other complex but suitable habitat, the helicopter proceeded more slowly. If a loon was sighted on a water body, the shoreline was checked for a nest while the helicopter hovered at about 8 m above ground and slowly moved sideways around the edge of the pond. In the search for chicks, all wetlands were surveyed at approximately 50 km/h and at 30 m above ground. Ponds known to be active nesting territories were double-checked by observers as the helicopter made a slow, low-level pass then hovered at 90 m above the pond for about one minute to see if any young loons surfaced from underwater. The data were recorded on a cassette tape recorder, then transcribed onto forms later the same day.

Intensive field studies were done at the Toker Point study plot throughout the breeding season each year to assess the natural factors affecting the breeding effort and breeding success of the Red-throated Loon. The entire study plot was surveyed by foot every three to five days from mid-June to early September. During the first three years of the study, the observers approached the Red-throated Loon nests to record the number of eggs. During egg laying and just prior to hatch, the nests were checked daily. However, in the last two years, nest checks and visits more frequent than every third day were discontinued, as observer-induced predation of loon eggs and newly hatched chicks was suspected. Instead, the nesting status of each pair of loons was determined by observing the loons from a concealed place usually 200–300 m away and by checking for eggs during the two helicopter surveys. In addition to determining the nesting status of the Red-throated Loons, sightings of all birds and mammals, including their nests, eggs, and young, were recorded. Nests and fox dens were plotted on a 1:50 000-scale topographical map. Avian predator sightings were mapped for each day of surveys to determine the number of pairs with hunting territories within the study area during the nesting season.

Small rodents (voles, mice, lemmings) were live-trapped in early July from 1987 to 1989 to determine their relative abundance. One hundred live-traps were set 15 m apart in a square grid and checked twice a day for 10 days. Captured animals were marked so that recaptures could be identified.

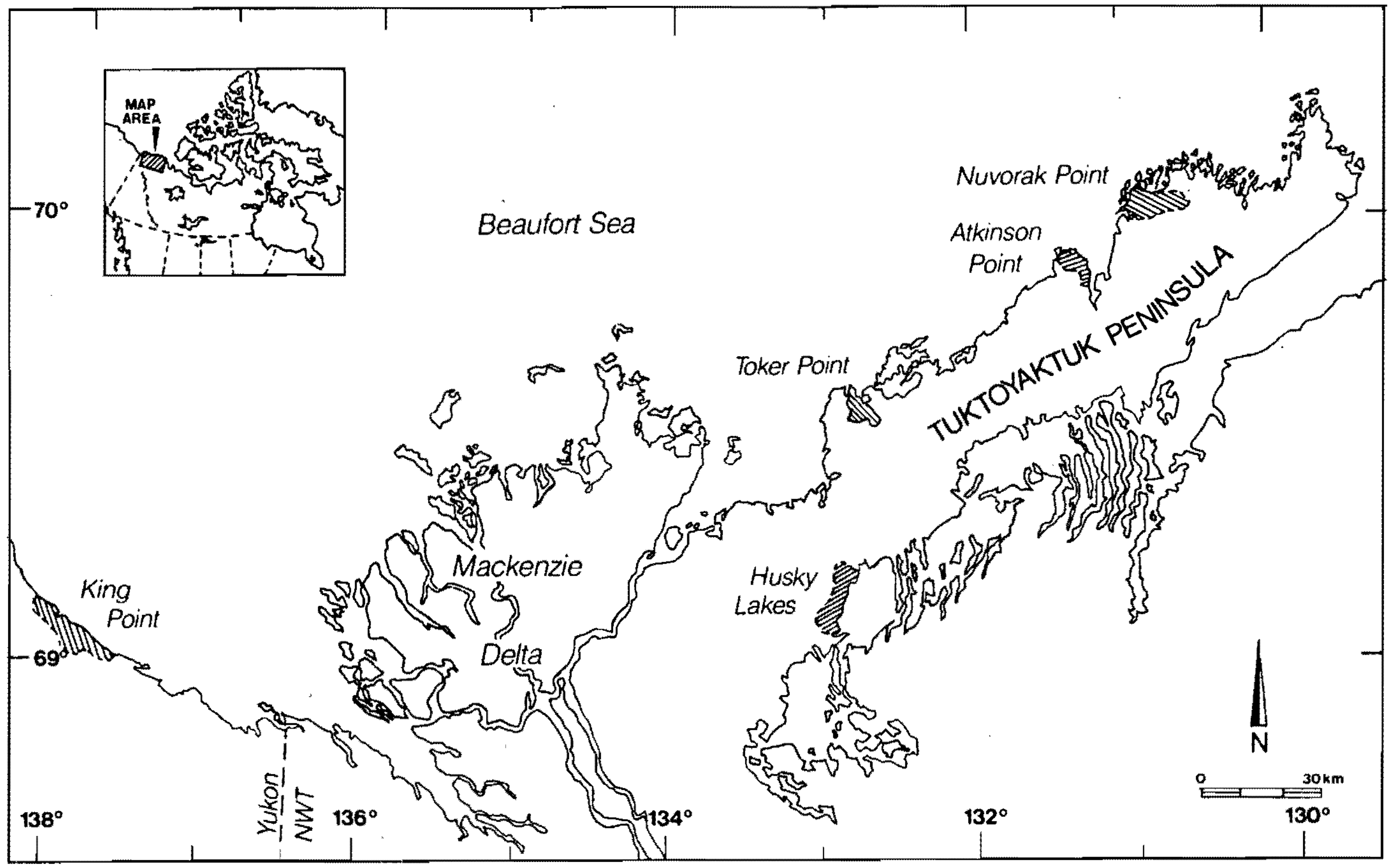
To assess the abundance of food available to the loons, fish were sampled with a beach seine at a location where loons frequently fed. Once a week from mid-July until the end of August from 1987 to 1989, a 10-m-long net was dragged parallel to the beach for 25 m every two hours for a 12-hour period. Fish caught were identified, counted, and measured for their fork length (total length for sculpins and flounders). Only fish 5–20 cm long were used for between-year comparisons of abundance, as that is the size range of fish that Red-throated Loons feed their chicks (Norberg and Norberg 1976; Reimchen and Douglas 1984; Eriksson et al. 1990).

The frequency with which loons brought fish to their chicks was monitored each year from an observation tent. The loons were observed for two of every four hours over a 24-hour period (5:00–7:00; 9:00–11:00; 13:00–15:00; 17:00–19:00; 21:00–23:00; 1:00–3:00) twice a week between time of hatch and fledging.

Several climate-related variables were also documented: the timing of breakup and freeze-up; the weather daily at 18:00; severe storms; and wetland water levels.

Loon nesting territories were classified as either occupied or active. A territory was *occupied* if a loon was present during at least one survey, if it was suitable loon nesting habitat, and if it was unlikely to be part of a nearby loon territory. An *active* territory was one where we found evidence of nesting (eggs, live 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.

Figure 1
Location of the five study plots selected for monitoring the abundance and productivity of the Red-throated Loon



3.0 Results

During a preliminary investigation in 1984, the results of an aerial survey for incubating loons at Atkinson Point were double-checked by resurveying the area from the ground to determine the accuracy of the survey method. The ground survey confirmed that 90% of the nests (n = 38) and 95% of the resident pairs (n = 42) had been located during the helicopter surveys. Ground-truthing of a helicopter survey for chicks at the Toker Point study plot in 1985 indicated that all of the chicks (n = 21) had been located.

3.1 Fluctuations in loon numbers and productivity

The number of pairs of Red-throated Loons that established nesting territories did not change significantly between 1985 and 1989 at four of the five study plots (χ^2 tests, 4 df, $p > 0.05$) (Table 1). At the fifth plot, the number of resident pairs increased ($\chi^2 = 9.37$, 4 df, $p = 0.05$), with an influx of 19 additional pairs in 1987 (38% rise) contributing the most to this increase.

The breeding efforts of the Red-throated Loon were similar in all but one year (Fig. 2). An average of 76% of the resident pairs laid eggs each year, except in 1986, when only about 58% nested.

Table 1
Range in breeding effort and breeding success of the Red-throated Loon at five study plots in the Beaufort Sea region, 1985–89

Study plot	No. of resident pairs	% of pairs that nested	No. of chicks near fledging	% successful pairs
Toker Point	43–50	63–87**	5–24**	10–49**
Atkinson Point	35–48	52–89**	14–46**	30–79**
Nuvorak Point	44–70**	56–77*	9–37**	30–49
Husky Lakes	35–47	65–80	12–29	50–67
King Point	46–64	54–72	21–40*	42–82**

** Difference among years significant at $p < 0.05$ (χ^2 test, 4 df).
* Difference among years significant at $p < 0.10$ (χ^2 test, 4 df).

Breeding success, which was based on the number of young near fledging, averaged 0.63 young per nesting pair over the five years of surveys (Fig. 3). Of the three parameters being monitored, this one varied the most (Table 1). The difference among years in the number of chicks near fledging was significant at three of the study plots (χ^2 tests, 4 df, $p < 0.05$) and approached significance at one plot ($\chi^2 = 9.49$, 4 df, $p = 0.085$). Productivity was most consistent from year to year at the inland study plot, Husky Lakes ($\chi^2 = 7.3$, 4 df, $p = 0.12$).

Figure 2
Breeding effort of the Red-throated Loon at five study plots in the Beaufort Sea region, 1985–89

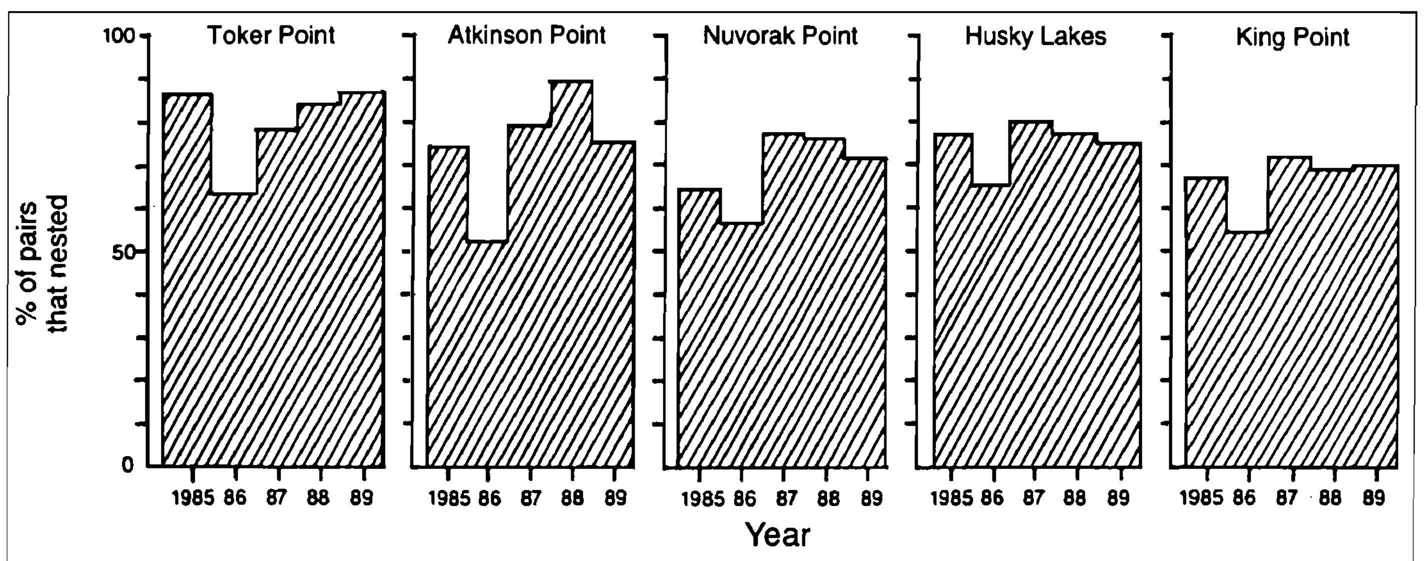
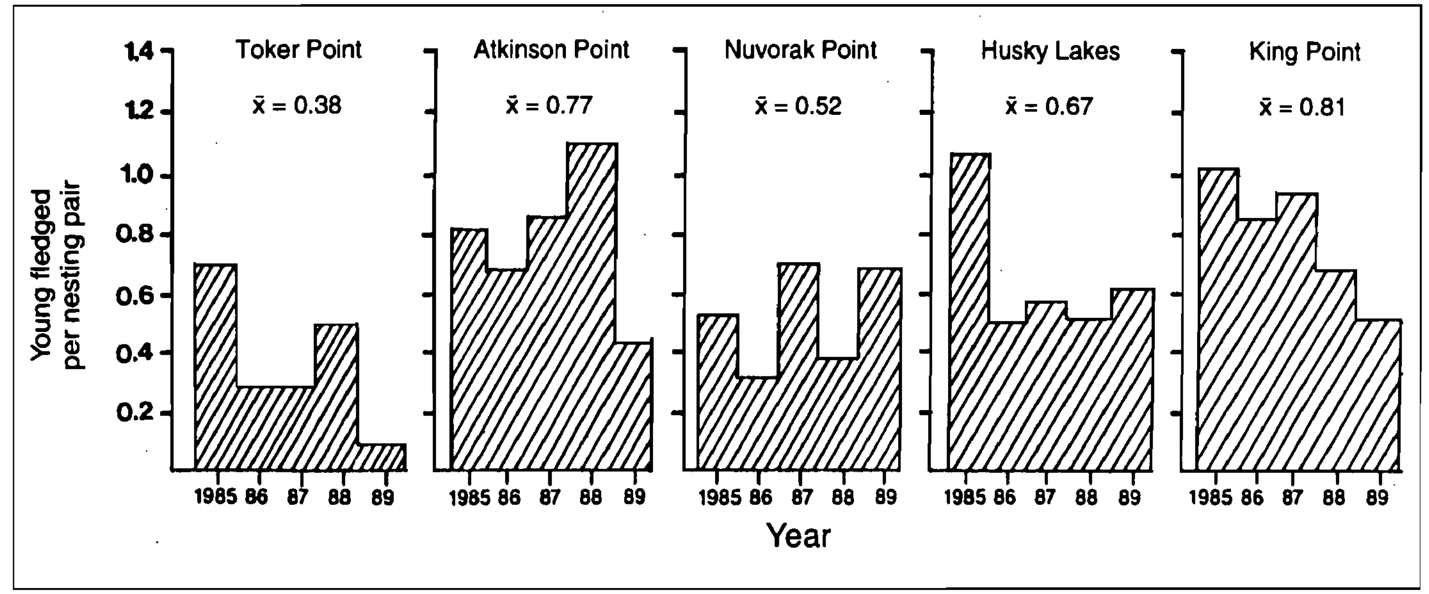


Figure 3
Breeding success of the Red-throated Loon at five study plots in the Beaufort Sea region, 1985–89



Because of the frequency of surveys, more accurate and detailed breeding statistics were obtained at Toker Point than at the other plots. Thus, egg and chick survival could be examined separately (Table 2). Hatching success at Toker Point differed significantly between years, the large proportion of eggs that hatched in 1988 attributing the most to this difference ($\chi^2 = 51.9$, 4 df, $p < 0.001$). The proportion of chicks that fledged also differed between years, the difference being primarily due to the low fledging success in 1989 and high success in 1985 ($\chi^2 = 13.2$, 4 df, $p = 0.01$).

3.2 Fluctuations in factors potentially affecting loon productivity

Most of the eggs and chicks that did not survive to fledging disappeared from the nest leaving no clues to their fate, although they were presumably taken by predators. The most common predator species at Toker Point were the arctic fox *Alopex lagopus*, Glaucous Gull *Larus hyperboreus*, Parasitic Jaeger *Stercorarius parasiticus*, and Sandhill Crane *Grus canadensis*. The first three species were seen taking loon eggs, whereas the Sandhill Crane was only suspected of doing so. However, Sandhill Cranes are known predators of eggs (Harvey et al. 1968; Reynolds 1985), including Red-throated Loon eggs (Davis 1972), and were often seen feeding in the wetlands in the vicinity of loon nests. Although less abundant in the study area, the Common Raven *Corvus corax* may have also taken loon eggs (Marquiss and Booth 1986).

For the first few days after hatch, loon chicks were easy prey for avian predators if left unattended, because they were unable to dive well enough to escape. The Glaucous Gull was the chief predator and the only species seen preying successfully on loon chicks. On one occasion, I saw a Sandhill Crane try unsuccessfully to catch a loon chick. Parasitic Jaegers took fish from adult loons that were carrying fish to the nesting pond, but none was seen taking loon chicks. Foxes were likely not a major threat because of the mobility of loon chicks on water within two to three days of hatch.

Table 2
Breeding statistics for the Red-throated Loon obtained by continuous monitoring of the Toker Point study plot throughout the breeding season

Year	No. of resident pairs	No. (%) of resident pairs that nested**	No. of eggs[a]	No. (%) of eggs that hatched**[b]	No. (%)[c] of chicks that fledged**[d]	No. (%) of successful pairs**
1985	47	42 (89)	92	37 (38)	23 (62)	18 (43)
1986	45	32 (71)	68	12 (17)	8 (67)	7 (22)
1987	49	43 (88)	97	14 (14)	9 (64)	6 (14)
1988	49	44 (90)	95	37–57 (39–60)	14 (25–38)	14 (32)
1989	52	48 (92)	107	10–21 (9–20)	1 (5–10)	1 (2)

** Difference among years significant at $p < 0.05$ (χ^2 test, 4 df).
[a] Includes replacement clutches. Clutch size was unknown for 11 nests in 1988 and 15 nests in 1989. For these nests, the number of eggs was estimated based on the annual average clutch size.
[b] Confirmed number of eggs hatched in 1988 was 37, with 20 additional eggs possibly hatching. In 1989, 10 eggs hatched and 11 more may have hatched.
[c] Proportion of hatchlings that fledged.
[d] Assumed chicks <40 days old at freeze-up did not survive.

Table 3
Changes in abundance of the most common predators of loon eggs and chicks at the Toker Point study plot, 1985–89

	Mean daily count[a]				
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

** Difference among years significant at $p < 0.05$ (Quade Test, $K_1 = 4$, $K_2 = 32$).

[a] Calculated from daily counts recorded over six-day intervals from 17 June to 9 August each year.

Table 4
Changes in the number of predatory bird species nesting in the Toker Point study plot, 1985–89

	No. of pairs (no. of young)			
Year	Sandhill Crane	Parasitic Jaeger	Glaucous Gull**	Common Raven
1985	5 (4)	4 (1)	38 (30)	0
1986	12 (0)	6 (0)	40 (14)	2
1987	8 (0)	6 (2)	32 (22)	1
1988	10 (6)	3 (3)	36 (42)	1
1989	14 (7)	5 (2)	30 (27)	1

** Difference among years in number of young significant at $p < 0.05$ (χ^2 test, 4 df).

The arctic fox and Sandhill Crane were the only predators that differed significantly in numbers among years (Table 3). 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, $T = 6.8$, $K_1 = 4$, $K_2 = 32$, $p < 0.05$), because of an influx of nonbreeding birds that occurred only that year. They arrived during the last week of June and remained in the study plot in small flocks of 3–12 birds until fall migration.

The number of nesting pairs of each of the common avian predators at Toker Point did not change significantly among years (χ^2 tests, 4 df, $p > 0.05$) (Table 4). However, Glaucous Gull chick production did vary ($\chi^2 = 15.8$, 4 df, $p < 0.05$), being highest in 1988 and lowest in 1986.

The abundance of alternative prey for the chief predators of loon eggs and chicks could affect predator pressure on the loons (Lack 1954). Thus, the abundances of small rodents and waterfowl nests, eggs, and young were monitored each year. The number of waterfowl nests found in the Toker Point study plot differed among years ($\chi^2 = 11.7$, 4 df, $p < 0.05$), with fewer waterfowl nesting in 1986 and more nesting in 1987 (Table 5). Likewise, the number of waterfowl chicks seen differed among years ($\chi^2 = 254.1$, 4 df, $p < 0.05$). The lowest productivity occurred in 1986 and 1987. Productivity was low in the latter year despite a strong breeding effort.

The small mammals captured in live-traps were all northern red-backed voles *Clethrionomys rutilus*, except for one meadow vole *Microtus pennsylvanicus*. The number of voles captured differed significantly among years (Kruskal-Wallis Test, $T = 19.9$, 2 df, $p < 0.05$), peaking in numbers in 1988 and crashing in 1989 (Table 5). Although no trapping

Table 5
Changes in the abundance of prey other than loon eggs and chicks at the Toker Point study plot, 1985–89

	Waterfowl		Voles	Ground squirrels
Year	No. of nests**[a]	No. of young**[a]	(no. per 100 trap-nights)**[b]	(mean daily count)[c]
1985	21	226	No data	1.2
1986	11	70	No data	0.6
1987	33	33	4.0	2.0
1988	20	236	6.6	1.8
1989	23	241	1.8	1.8

** Significant difference among years at $p < 0.05$.

[a] χ^2 test, 4 df.
[b] Kruskal-Wallis test, 2 df.
[c] Quade test, $K_1 = 4$, $K_2 = 24$.

Table 6
Factors indicating the relative abundance of fish available to Red-throated Loons at the Toker Point study plot, 1985–89

	Beach seining**						
	Fish caught per unit effort[a]			% of hauls with no fish	Chick feedings* (no. of fish/chick/day)[b]		
Year	$\bar{x}$	SD	n		$\bar{x}$	SD	n
1985	—	No data	—	No data	10.0	4.8	24
1986	—	No data	—	No data	7.7	3.8	12
1987	31.9	53.4	36	30	7.2	4.3	15
1988	40.9	21.9	42	0	7.9	3.1	23
1989	40.2	31.8	48	8	9.0	4.3	14

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

* Significant difference among years at $p = 0.07$ (Kruskal-Wallis Test, $T = 8.5$, 4 df). Multiple comparisons indicated that the feeding rate in 1985 was higher than in 1987 or 1988.

[a] Number of fish 5–20 cm long caught per 100 m of shoreline seined with a 10-m-long net.

[b] Each sample consisted of a 24-hour period of two-hour watches conducted every four hours.

occurred in the first two years of the study, casual observations indicated that there were more voles in 1985 than in 1986. Daily sightings of arctic ground squirrels *Spermophilus parryi* indicated no significant change in their numbers during the study period (Quade Test, $T = 2.1$, $K_1 = 4$, $K_2 = 24$, $p > 0.05$) (Table 5).

The relative abundance of fish available to the loons was determined both by netting fish and by recording the frequency of chick feedings. There was no significant difference between years in the number of fish that Red-throated Loons brought to their chicks (Kruskal-Wallis Test, $T = 8.5$, 4 df, $p > 0.05$) (Table 6), although the higher feeding rate in 1985 than in 1987 or 1988 approached significance at $p = 0.07$. However, beach seining, which was carried out only in the last three years of the study, did indicate a difference in fish abundance among years. Fewer fish 5–20 cm long were netted in 1987 than in 1988 or 1989 (Kruskal-Wallis Test, $T = 27.5$, 2 df, $p < 0.05$) (Table 6).

The shallow ponds used by the Red-throated Loons for nesting thawed in late May and early June, with the exception of 1986, when they did not thaw until 18 June (Table 7). 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 and over a week

Table 7
Changes in nesting habitat conditions for Red-throated Loons at the Toker Point study plot, 1985–89

	Breakup		Freeze-up		
Year	Reach 30 thawing degree-days[a,b]	Shallow ponds open	Shallow ponds frozen	Mean temperature for Sept. (°C)[a,c]	Water levels
1985	31 May	Early June	19 Sept.	2.7	Low
1986	18 June	18 June	24 Sept.	5.0	High
1987	9 June	8 June	26 Sept.	4.0	Medium
1988	4 June	29 May	23 Sept.	3.1	Low
1989	31 May	1 June	17 Sept.	4.1	Medium

[a] Data for Tuktoyaktuk airport (Atmospheric Environment Service).
[b] 27-year norm, 10 June.
[c] 27-year norm, 2.6°C.

late in 1986. The nesting ponds froze earliest in 1989, on 17 September, and latest in 1987, on 26 September.

Only one major storm occurred during the breeding season over the five-year study period. From 1 to 4 August 1988, strong northwesterly winds (50 km/h gusting to 70 km/h) with rain and snow showers created unusually high surf and high tides, which flooded coastal lowlands all along the northwestern shore of Tuktoyaktuk Peninsula. All other storms that occurred either had winds less than 50 km/h or lasted no more than a day (storms at freeze-up excluded).

Water levels on the shallow ponds used by the Red-throated Loons during breeding season were high in 1986 and low in 1985 and 1988 (Table 7). When water levels were low, many of the ponds partially dried up, and several nests originally built in water became stranded on land several metres from the water's edge by mid-July. Flooding of nests during incubation did not occur during the study.

4.0 Discussion

4.1 Abundance of loon pairs

During the five-year study period, the number of pairs of Red-throated Loons at the Nuvorak Point study plot increased markedly from 44 pairs in 1985 to a peak of 70 pairs in 1988. At each of the other study plots, there was a smaller increase of 7–18 pairs during the first three to four years of the study. Some of this increase was likely due to the discovery of additional territories that had been 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. As 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, 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.

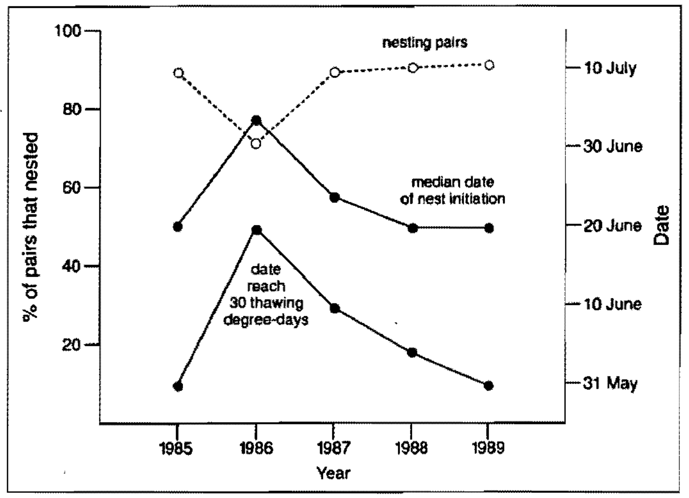
Further evidence in support of a slight growth in the regional population of Red-throated Loons was their productivity, which averaged 0.63 young per nesting pair over the five years of the study. Although the survival rate of the Red-throated Loon is unknown, Nilsson (1977) calculated that the Arctic Loon *Gavia arctica* in Sweden would maintain its population level if it produced 0.4–0.5 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 Point may have less favourable nesting habitat, as is also suggested by the lower breeding success there most years compared with the other plots surveyed by helicopter. If the habitat at Nuvorak Point is suboptimal, in future it may provide the earliest indication of changes in the number of loons in the region.

4.2 Factors affecting loon productivity

In the following discussion of the primary factors that influenced productivity each year, emphasis has been placed

Figure 4
Effect of the timing of spring thaw on the timing of nest initiation and proportion of Red-throated Loon pairs that nested at Toker Point



on data from the Toker Point study plot, for which there is the most ecological information.

4.2.1 Breeding effort

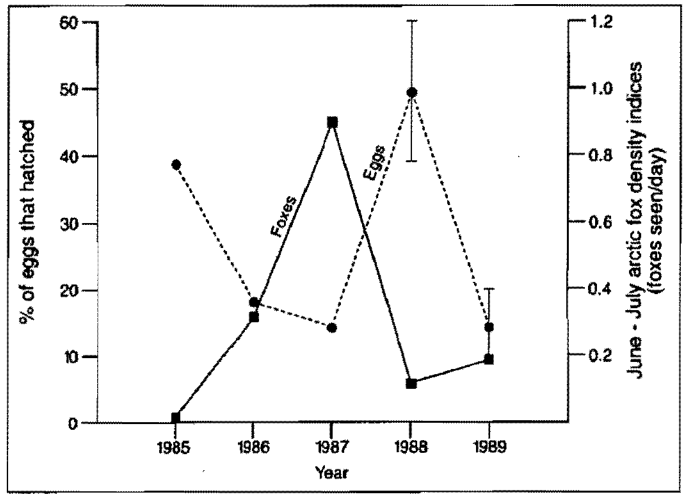
The breeding effort of the Red-throated Loon was constant in every year except 1986. The lower number of pairs that nested that year coincided with a late spring thaw. The ponds used by Red-throated Loons to nest became ice-free 10–20 days later in 1986 than in the other four years of the study (see Table 7). Subsequently, nest initiation was about two weeks late, and only 71% of the resident pairs at Toker Point laid eggs, compared with 88–92% in other years (Fig. 4).

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; Owen and Norderhaug 1977; Raveling and Lumsden 1977; Davies and Cooke 1983). Similarly, Herring Gulls *Larus argentatus* lay smaller clutches (Meathrel et al. 1987). The Thick-billed Murre *Uria lomvia,* 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 (Loft and Murton 1968; Silver and Ball 1989). However, for the final stages of ovarian recrudescence, the female needs additional stimuli, including territorial behaviour, intrapair behaviour, 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. However, the fact that Red-throated Loons at Toker Point renested as late as 23 July suggests that the reproductive system of most loons would still be in an active state on 18 June, which was when most of the nesting ponds melted in 1986.

Alternatively, poor feeding conditions during the prelaying period may be the primary reason why fewer loons

Figure 5
Relationship between arctic fox abundance and the proportion of Red-throated Loon eggs that hatched at Toker Point



nest in a late spring. Most years, the loons arrive in the offshore leads of open water in the Beaufort Sea within a few days of the thawing of the nesting ponds (Alexander et al. 1988; Johnson and Herter 1989). However, in 1986, the ponds thawed two to three weeks after their arrival. During the interim period, T. Barry (pers. commun.) saw thousands of Red-throated Loons and Pacific Loons *Gavia pacifica* staging on the lower Mackenzie River. The river may be suboptimal feeding habitat for loons, as, according to T. Barry (pers. commun.), such large numbers have been seen there only in years when there was very little open water in the Beaufort Sea. Thus, their energy reserves would be depleted while waiting for their nesting ponds to thaw.

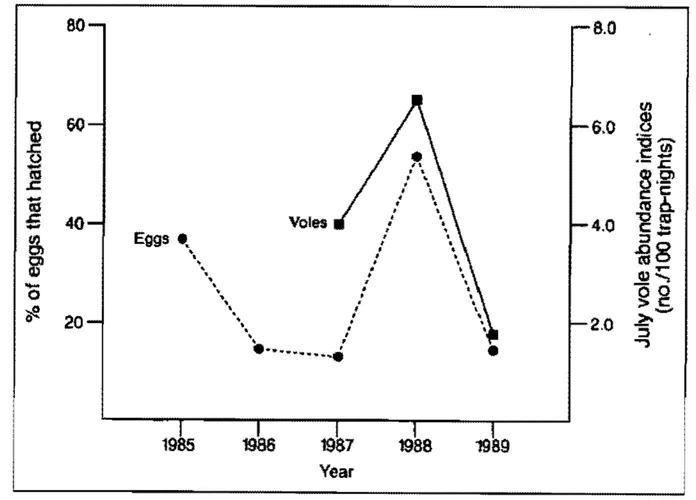
In an attempt to determine if the Red-throated Loons were nutritionally stressed following the late spring breakup, egg sizes in 1986 were compared with those in other years. The mean weights of eggs weighed within two days of laying were 78.1 ± 5.8 g (n = 43) in 1985, 75.6 ± 6.7 g (n = 40) in 1986, and 77.8 ± 5.9 g (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.

4.2.2 Hatching success

The annual fluctuations in hatching success at Toker Point (estimated 14–50% from 1985 to 1989) were governed by many interrelated factors, so that the degree of influence of a single factor was often difficult to determine. However, one obvious major influence was predation by arctic foxes. There was an inverse relationship between the hatching success of the loon eggs and the number of foxes in the study area (Fig. 5). 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 (see Tables 2 and 3). Studies in Alaska likewise noted heavier losses of

Figure 6
Relationship between vole abundance and the proportion of Red-throated Loon eggs that hatched at Toker Point



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 an influx of nonbreeding Sandhill Cranes in 1989. Although the abundance of cranes likely contributed to the greater loss of eggs that year, avian predators generally had less influence than the fox on the percentage of eggs that hatched in different years. 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 the annual fluctuations in loon productivity.

Egg predation was unexpectedly high in 1989 given the moderate number of foxes in the study area that year. However, vole numbers were low in 1989, 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 alternative prey such as eggs when small rodents are not abundant (Larson 1960; Macpherson 1969). Thus, although there was only a moderate number of foxes on the study area in 1989, they likely put more effort 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 to its abundance (Herter 1982; Marquiss and Booth 1986; Barry and Barry 1990).

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 *Clangula hyemalis* ducklings doubled in peak rodent years. Likewise, the abundance of small rodents has been linked to the breeding success of the Brant *Branta b. bernicla* (Dhondt 1987), Curlew Sandpiper *Calidris ferruginea* (Roselaar 1979), Willow Ptarmigan *Lagopus lagopus* (Myrberget 1972), Rock Ptarmigan *Lagopus mutus* (Jarvinen 1990), Black Grouse *Tetrao tetrix* (Angelstam et al. 1985), and Pacific Loon (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, Davis (1972) and Petersen (1979) 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.

The intensive monitoring of the loons by observers on the ground at Toker Point had a marked effect on hatching success. During a 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 (except for Nuvorak Point in 1985). The loons usually reacted to an observer on foot by getting off the nest and not returning until the observer was out of sight. 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 kilometres. 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 (Harvey 1971; MacInnes and Misra 1972; Strang 1980; Enquist 1983; Barry and Barry 1990).

4.2.3 Fledging success

Most (78%) losses of Red-throated Loon chicks occurred within three weeks of hatch, whereas an additional 13% presumably died at freeze-up because they were still too young to fledge. Many of the earlier deaths may have been due to starvation of the youngest chick in the brood. Von Braun et al. (1968), Davis (1972), and Bergman and Derksen (1977) all found that the youngest chick usually died within two weeks of hatch. Davis (1972) noted that because the eggs hatched a day apart, the oldest chick had an advantage over the other chicks in competing for fish brought to them. He found that the youngest chick generally did not get fed until the oldest was satiated, hence it usually starved to death.

The percentage of hatchlings that fledged was a consistent 62–67% from 1985 to 1987, but dropped to 25–38% in 1988 and only 5–10% in 1989. Evidence suggests that there was heavier predation on loon chicks in 1988 and 1989. 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 that 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 alternative prey species.

There was no 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 of the size taken by the Red-throated Loons in 1988 and 1989 than in 1987. Furthermore, feeding rates of loon chicks did not differ significantly among years, indicating that food availability had not changed.

Another factor that may have contributed to the high chick mortality in 1988 was a severe storm that occurred from 1 to 4 August. Although only one chick death was linked directly to the storm, the four chicks that disappeared during the following week may have also died as a result of the four-day storm. Dunn (1975) reported that rain and wind lasting several consecutive days weakened tern chicks sufficiently that they were unable to beg vigorously enough to elicit the appropriate feeding response from their parents. The chicks subsequently starved to death. 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.

The early freeze-up in 1989 might have contributed to the low fledging success that year. The nesting ponds used by the Red-throated Loons froze 10 days prior to the date when any of the chicks from replacement clutches would have fledged. However, because we left the study area before freeze-up each year, it is unknown how unfledged chicks react when their ponds freeze. Although I assumed chicks less than 40 days old at the time of freeze-up died, some may have survived by moving to open water on a nearby lake. On four occasions during this study, chicks moved up to 300 m across land to another water body as a result of either low water levels on their nesting ponds or disturbance. Similar movements have been reported by Von Braun et al. (1968), Bergman and Derksen (1977), and Furness (1983). Thus, given their ability to traverse land, some of the Red-throated Loon chicks might have survived an early freeze-up.

4.3 Effectiveness of the Red-throated Loon as a bioindicator

For a bird species to be an effective indicator of environmental change, the bird must be sensitive to the change, it must be possible to obtain reliable information on the population size and productivity of the bird, and it must be possible to establish a link between a change in the indicator and the cause of that change.

Of all the bird species in the Beaufort Sea region, the Red-throated Loon is probably the most vulnerable to the types of environmental change that could occur as a result of offshore oil and gas development. The Red-throated Loon feeds daily on fish in marine nearshore waters. Thus, it is highly vulnerable to oil pollution. Because of its position in the food chain, the loon is sensitive to environmental contaminants that bioaccumulate, as well as any environmental change that affects the abundance of fish. Furthermore, because it nests near shore, the loon is vulnerable to the loss or degradation of terrestrial habitat that will occur when support facilities (e.g., docks, staging areas, roads, pipelines) for offshore oil and gas production are constructed.

Reliable data on the abundance and productivity of the Red-throated Loon can be obtained rapidly by helicopter with little effect on the loons. All of the chicks, 95% of the resident pairs, and 90% of the nests were located. The reaction of the loons to the helicopter was mild and short in duration. When approached by helicopter, most loons slipped off the nest within 100 m or less, remained on the pond, and returned to the nest as soon as the helicopter left. Thus, accurate data could be collected with only minor disturbance to the loons.

Analyses of the natural factors affecting breeding effort and success proved to be much more difficult because there were so many factors affecting productivity and they were often interrelated. It was not possible to adequately measure all of the key factors, partly because of project funding, but also because of the disturbance effect of such a comprehensive study. For example, it is doubtful that the data obtained by beach seining were sufficient to be a reliable indicator of fish abundance. Furthermore, although the effects of some factors such as late spring thaw or egg predation by foxes have been well documented, the role of other factors, such as disease and parasites, is poorly understood. Such gaps in knowledge lend uncertainty to any analysis of the chief factors affecting productivity. Consequently, it might be difficult to differentiate between natural and human-induced changes in Red-throated Loon productivity in the postdevelopment phase of the monitoring study.

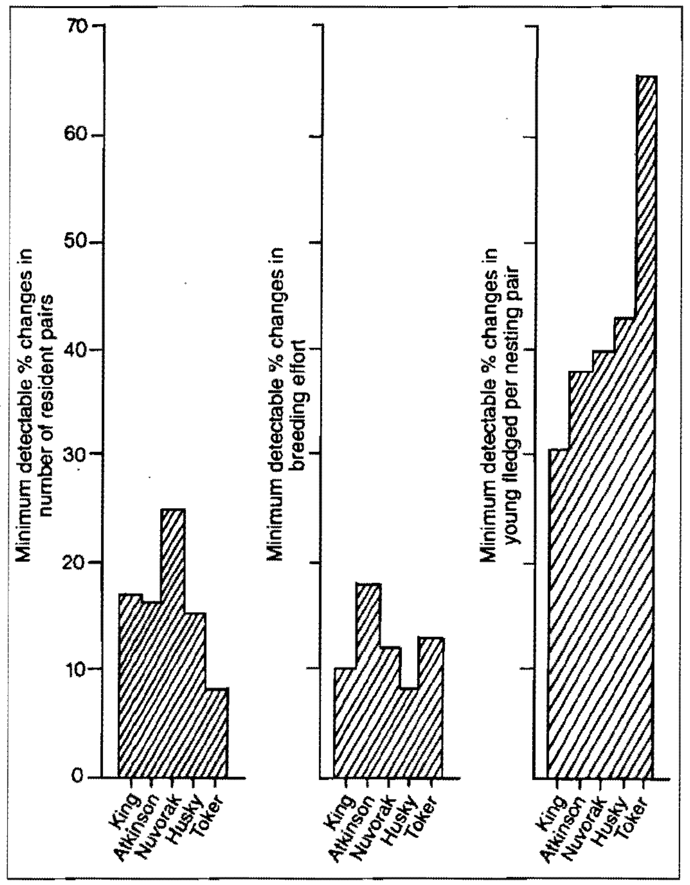
Of the three parameters being monitored, breeding success will be the most effective indicator of environmental change in the Beaufort Sea region. Hatch and survival of young to fledging are primarily dependent on local conditions, whereas changes in the number of resident pairs of loons and their breeding effort could also be due to conditions on the wintering and staging grounds.

Although breeding success is the most appropriate parameter, only large changes in breeding success will be detectable, because of the wide natural annual fluctuations in chick production. Based on this five-year study, the minimum future change in the number of young fledged per pair that will be detectable with 95% certainty will be 31–43% (Toker Point data excluded because of the impact of the ground observers on breeding success) (Fig. 7). Any change less than that could simply be a natural fluctuation in breeding success.

Breeding effort each year was more consistent than breeding success, so that future human-induced changes should be easier to detect. A minimum change of 8–18% in the proportion of resident pairs that nest will be detectable (Fig. 7). Also, the effect of a late spring thaw on breeding effort has been clearly documented. However, there are other factors that might affect breeding effort, including poor nutrient status of the female, for reasons other than a late season, and the age structure of the breeding population (Baillie and Milne 1982; Davies and Cooke 1983; Anderson 1989). Should the breeding effort change, such factors would have to be investigated.

The number of resident pairs of loons was fairly stable, with the exception of one study plot. Thus, a minimum change of 8–17% in the number of resident pairs will be detectable with 95% certainty at four of the study plots, although only a change of 25% or more would alert us to potential human impacts at the fifth plot (Fig. 7). A disadvantage of monitoring population size is the time lag that might occur between impact and detection. Changes that affect chick production will not show in the adult population until the chicks return to the nesting ground several years later. The time lag will make it more difficult to decipher which underlying event caused a change in population size (Temple and Wiens 1989). The subsequent delay in

Figure 7
Minimum level of change in the parameters being monitored that would indicate a human-induced environmental change had occurred



correcting the problem might also result in a longer recovery period.

The Red-throated Loon should not be regarded as an indicator of a broad spectrum of environmental changes. Although it is relatively sensitive to changes that might occur as a result of oil and gas activity, such as marine pollution, human disturbance, or degradation of wetland habitat near the coast, it may not be a suitable indicator of other human-induced changes. For example, as the loon is not a preferred species for local hunters, it would probably not reflect a change in hunting pressure. Similarly, because the loon does not depend on seeds, berries, or insects for food, it would likely not alert us to changes that affect those aspects of the environment.

The annual productivity of the Red-throated Loon will not necessarily represent the breeding effort and breeding success of other bird species. The waterfowl and Red-throated Loons at Toker Point followed a similar pattern of breeding effort and breeding success for the first four years of the study. However, in the last year, waterfowl productivity was high, whereas loon productivity was low. The reasons for this are beyond the scope of the present study, but its occurrence shows that one should use caution when extrapolating from the indicator species to other bird species.

5.0 Conclusions

The Red-throated Loon is a suitable species for monitoring environmental changes caused by offshore oil and gas development in the Beaufort Sea. It is vulnerable to the potential environmental impacts of the development, and accurate data on its population size and productivity can be obtained with little effect on the indicator species itself. Breeding success will be the best indicator of environmental change occurring within the Beaufort Sea region. However, only large changes of 31–43% in productivity will be detectable with 95% certainty because of the natural large annual fluctuations in breeding success. Furthermore, human-induced changes in productivity of the loon may be difficult to identify because the cause-and-effect relationship between natural fluctuations in the environment and loon productivity is difficult to measure and interpret. Thus, for the monitoring program to succeed, surveys during the development and postdevelopment phases of the study will have to span several years. Otherwise, an unnatural upward or downward trend in productivity may go undetected. Furthermore, if a change is detected, an intensive study will have to be conducted to determine the cause of the change.

Literature cited

Alexander, S.A.; Ealey, D.M.; Barry, S.J. 1988. Spring migration of Eiders, Oldsquaw and Glaucous Gulls along offshore leads of the Canadian Beaufort Sea. Tech. Rep. Ser. No. 56, Can. Wildl. Serv., Edmonton.

Anderson, D.J. 1989. Differential responses of boobies and other seabirds in the Galapagos to the 1986–87 El Niño Southern Oscillation event. Mar. Ecol. Prog. Ser. 52:209–216.

Angelstam, P.; Lindström, E.; Widén, P. 1985. Synchronous short-term population fluctuations of some birds and mammals in Fennoscandia—occurrence and distribution. Holarct. Ecol. 8:285–298.

Baillie, S.R.; Milne, H. 1982. The influence of female age on breeding in the Eider *Somateria mollissima*. Bird Study 29:55–66.

Barry, S.J.; Barry, T.W. 1990. Food habits of Glaucous Gulls in the Beaufort Sea. Arctic 43:43–49.

Barry, T.W. 1962. Effect of late seasons on Atlantic Brant reproduction. J. Wildl. Manage. 26:19–26.

Bergman, R.D.; Derksen, D.V. 1977. Observations on Arctic and Red-throated Loons at Storkersen Point, Alaska. Arctic 30:41–51.

Davies, J.C.; Cooke, F. 1983. Annual nesting productivity in Snow Geese: prairie droughts and arctic springs. J. Wildl. Manage. 47:291–296.

Davis, R.A. 1972. A comparative study of the use of habitat by Arctic Loons and Red-throated Loons. Ph.D. thesis, Univ. of Western Ontario, London.

Dhondt, A.A. 1987. Cycles of lemmings and Brent Geese *Branta b. bernicla*: a comment on the hypothesis of Roselaar and Summers. Bird Study 34:151–154.

Dome Petroleum Ltd.; ESSO Resources Canada Ltd; Gulf Canada Resources Inc. 1982. Environmental impact statement for hydrocarbon development in the Beaufort Sea – Mackenzie Delta region. Vol. 2. Development systems. Calgary.

Dunn, E.K. 1975. The role of environmental factors in the growth of tern chicks. J. Anim. Ecol. 44:743–754.

Elridge, J.L.; Krapu, G.L. 1988. The influence of diet quality on clutch size and laying pattern in Mallards. Auk 105:102–110.

Enquist, M. 1983. How do Arctic Skuas *Stercorarius parasiticus* search for diver eggs? Ornis Fenn. 60:83–85.

Eriksson, M.O.G.; Blomqvist, D.; Hake, M.; Johansson, O.C. 1990. Parental feeding in the Red-throated Diver *Gavia stellata*. Ibis 132:1–13.

Furness, R.W. 1983. Foula, Shetland. Vol. 4. The birds of Foula. The Brathay Hall Trust, Ambleside, Cumbria.

Gaston, A.J.; Nettleship, D.N. 1981. The Thick-billed Murres of Prince Leopold Island — a study of the breeding ecology of a colonial high arctic seabird. Can. Wildl. Serv. Monogr. Ser. No. 6.

Harvey, J.M. 1971. Factors affecting blue goose nesting success. Can. J. Zool. 49:223–234.

Harvey, J.M.; Lieff, B.C.; MacInnes, C.D.; Prevett, J.P. 1968. Observations on behavior of Sandhill Cranes. Wilson Bull. 80:421–425.

Herter, D.R. 1982. Habitat use and harassment of Sandhill Cranes staging on the eastern Copper River Delta, Alaska. M.Sc. thesis, Univ. of Alaska, Fairbanks.

Jarvinen, A. 1990. Changes in the abundance of birds in relation to small rodent density and predation rate in Finnish Lapland. Bird Study 37:36–39.

Johnson, S.R.; Herter, D.R. 1989. The birds of the Beaufort Sea. BP Exploration (Alaska) Inc., Anchorage.

Lack, D. 1954. The natural regulation of animal numbers. Clarendon Press, Oxford.

Larson, S. 1960. On the influence of the arctic fox *Alopex lagopus* on the distribution of arctic birds. Oikos 11:276–305.

Loft, B.; Murton, R.K. 1968. Photoperiodic and physiological adaptations regulating avian breeding cycles and their ecological significance. J. Zool. 155:327–394.

MacInnes, C.D.; Misra, R.K. 1972. Predation on Canada Goose nests at McConnell River, Northwest Territories. J. Wildl. Manage. 36(2):414–422.

Macpherson, A.H. 1969. The dynamics of Canadian arctic fox populations. Can. Wildl. Serv. Rep. Ser. 8.

Marquiss, M.; Booth, C.J. 1986. The diet of Ravens, *Corvus corax* in Orkney. Bird Study 33:190–195.

Meathrel, C.E.; Ryder, J.P.; Termaat, B.M. 1987. Size and composition of Herring Gull eggs: relationship to position on the laying sequence and the body condition of females. Colonial Waterbirds 10:55–63.

Morrison, M.L. 1986. Bird populations as indicators of environmental change. Pages 429–451 *in* R.F. Johnson (ed.), Current ornithology. Plenum, New York.

Myrberget, S. 1972. Fluctuations in a North Norwegian population of Willow Grouse. Pages 107–120 *in* Proc. XVth Int. Ornithol. Congr., The Hague.

Nilsson, S.G. 1977. Adult survival rate of the Black-throated Diver, *Gavia arctica*. Ornis Scand. 8:193–195.

Norberg, R.A.; Norberg, U.M. 1976. Size of fish carried by flying Red-throated Divers, *Gavia stellata* (Pont.) to nearby fledged young in nesting tarn. Ornis Fenn. 53:92–95.

Owen, M.; Norderhaug, M. 1977. Population dynamics of Barnacle Geese, *Branta leucopsis* breeding in Svalbard, 1948–1976. Ornis Scand. 8:161–174.

Pehrsson, O. 1986. Duckling production of the Oldsquaw in relation to spring weather and small-rodent fluctuations. Can. J. Zool. 64:1835–1841.

Petersen, M.R. 1979. Nesting ecology of Arctic Loons. Wilson Bull. 91:608–617.

Raveling, D.G.; Lumsden, H.G. 1977. Nesting ecology of Canada Geese in the Hudson Bay lowland of Ontario: evolution and population regulation. Ont. Minist. Nat. Resour., Fish and Wildl. Res. Rep. 98.

Reimchem, T.E.; Douglas, S. 1984. Feeding schedule and daily food consumption in Red-throated Loons (*Gavia stellata*) over the prefledging period. Auk 101:593–599.

Reynolds, J.D. 1985. Sandhill Crane use of nest markers as cues for predation. Wilson Bull. 97:106–108.

Roselaar, C.S. 1979. Fluctuaties in aantallen Krombekstrandlopers *Calidris ferruginea*. Watervogels 4:202–210.

Schamel, D.; Tracy, D.M. 1985. Replacement clutches in the Red-throated Loon. J. Field Ornithol. 56:282–283.

Silver, R.; Ball, G.F. 1989. Brain, hormone and behavior interactions in avian reproduction: status and prospectus. Condor 91:966–978.

Strang, C.A. 1980. Incidence of avian predators near people searching for waterfowl nests. J. Wildl. Manage. 44(1):220–224.

Temple, S.A.; Wiens, J.A. 1989. Bird populations and environmental changes: can birds be bio-indicators? Am. Birds 43:260–270.

Von Braun, C.; Hessle, A.C.; Sjolander, S. 1968. Smalommen (*Gavia stellata* L.) beteende under ungvarnadstiden. Zool. Revy 30:94–95.

Yonge, K.S. 1981. The breeding cycle and annual production of the Common Loon (*Gavia immer*) in the boreal forest region. M.Sc. thesis, Univ. of Manitoba, Winnipeg.

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