Habitat Characteristics and Population Estimate of Breeding Red-throated Loons, *Gavia stellata*, on the Queen Charlotte Islands, British Columbia

SHEILA D. DOUGLAS and T. E. REIMCHEN

Department of Zoology, University of Alberta, Edmonton, Alberta T6G 2E9

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Of 184 lakes and ponds surveyed on the Queen Charlotte Islands, British Columbia, 18.5% had breeding Red-throated Loons (*Gavia stellata*). The number of loons nesting in different regions (lowland, plateau and ranges) was primarily a function of the number of lakes in the region and was unrelated to water chemistry (pH, conductivity, calcium, spectral characteristics), geography (size of pond, distance from ocean, elevation) or presence of resident fish. The population of breeding Red-throated Loons on the entire Queen Charlotte Islands was estimated by two methods at 784 or 892 pairs, with the majority nesting in the lowlands, a broad expanse of bog terrain.

Key Words: Red-throated Loon, *Gavia stellata*, Common Loon, *Gavia immet*, Queen Charlotte Islands, population estimate, breeding, geographic distribution, habitat.

Red-throated Loons, *Gavia stellata*, commonly nest on small (< 1 ha) oligotrophic lakes and occupy diverse habitats such as northern forests and tundra over a wide latitudinal and elevation range (Palmer 1962; Bundy 1976; Bergman and Derksen 1977; Cramp and Simmons 1977; Merrie 1978; Furness 1983; Reimchen and Douglas 1984a). Habitat characteristics other than pond size (Bundy 1976; Bergman and Derksen 1977; Furness 1983) are rarely quantified, and thus the variables that determine the distribution, density and population of Red-throated Loons over their circumboreal breeding range are unspecified.

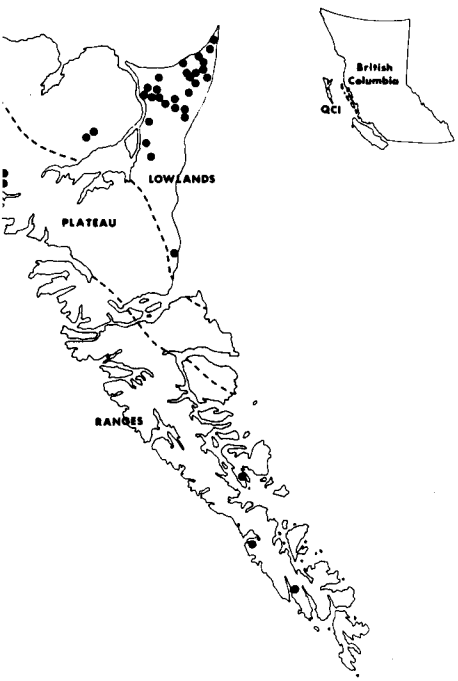
As part of a study on predator/prey relationships between piscivorous birds and freshwater fish (Reimchen 1983; Reimchen and Douglas 1984b), we surveyed lakes and ponds throughout the Queen Charlotte Islands, British Columbia, for breeding Red-throated Loons. For the majority of these waters, we are able to compare habitat characteristics in lakes with or without breeding Red-throated Loons. On the basis of this sample, we provide an estimate of the breeding population of the species on the Queen Charlotte Islands.

Study Area and Methods

The Queen Charlotte Islands have three distinct physiographic regions (Sutherland Brown 1968) [see Figure 1] that coincide with general water regimes and plant communities (Calder and Taylor 1968). The Queen Charlotte lowlands contain low elevation (< 150 m), poorly drained terrain characterized by extensive areas of *Sphagnum* bog and numerous small, shallow lakes. The Skidegate plateau consists of flat or sloping, heavily forested land mostly above 200 m. The Queen Charlotte ranges are primarily mountainous terrain with steep west-coast gradients; montane plant communities predominate on the west coast and forest communities on the east.

During the period 1975-1986, we surveyed 184 lakes and ponds (referred to hereafter as lakes) for Red-throated Loons (107 in the lowlands, 27 in the plateau and 50 in the ranges) during months (1 May to 1 September) in which Red-throated Loons are present in breeding territories. Red-throated Loons and nests were located by scanning with binoculars, and in the majority of small lakes, by walking the circumference of the lake. We defined breeding lakes by the presence of eggs, young or a territorial pair. Breeding pairs occupy nesting lakes as early as 27 March and frequent them during most of the day beginning at least in April (Reimchen and Douglas, *unpublished*). We do not consider non-breeding Red-throated Loons in this paper; these can be distinguished from territorial pairs because they occupy lakes only overnight (Reimchen and Douglas 1980). Common Loons, *Gavia immer*, also use lakes on the Queen Charlotte Islands during the summer (Reimchen and Douglas 1980) and are reported to nest in the lowlands (Godfrey 1966); we have kept records of Common Loon nests, chicks or territorial pairs.

For many lakes, water samples were taken for measurement of pH (N = 108 lakes), water colour



RE 1. Geographic distribution of lakes with breeding Red-throated Loons, *Gavia stellata*, on the Queen Charlotte Islands (QCI). Inset — British Columbia.

ght transmission at 400 nm, Beckman spectro-ometer; N = 105), conductivity and calcium entration (argon plasma spectrometer; N = 62 both). For all lakes (N = 184), presence or nce of fish was assessed using minnow traps in some lakes, seine nets. Elevation and ce area were obtained from topographical and aerial photographs (1 : 50 000 scale; eys and Mapping Branch, British Columbia stry of Environment); as Red-throated Loons o the ocean to obtain food for the young nchen and Douglas 1984a), the distance from entre of a lake to the nearest marine water was ured on maps. These eight variables, in ciation with region, were analyzed by stepwise iminant analysis [BMDP7] (Jenrich and pson 1983) for the two groups (Red-throated ns present or absent). Area, distance to ocean, tion, conductivity and calcium were log-formed. As well, discriminant analysis was rmed on the data excluding variables for h the data were not complete (pH, conductiv-alcium). We also analyzed the data sets for the lowland region separately, using the same statistical tests.

For each physiographic region, lakes with and without breeding Red-throated Loons were partitioned into lake-size classes (< = 1 ha, 2-5 ha, 6-10 ha, 11-20 ha, 21-50 ha, 51-100 ha, 101-200 ha, > 200 ha). To estimate the breeding population, all lakes were counted and recorded in the above lake-size classes; topographical maps were used for lakes > 1 ha and aerial photographs were used for ponds < 1 ha. Aerial photographs did not allow accurate resolution below 50 m (0.25 ha). A population estimate was made for the Queen Charlotte Islands as a whole and for each lake size category within each region based on the proportion of lakes in the survey that had breeding Red-throated Loons. The population estimate is based on one pair/lake. We found only one lake that had more than one breeding pair (Reimchen and Douglas 1984a); as one nest was in the lake and the other in an inlet to the lake 700 m from the first, they were treated as occurring in separate waters for analysis.

Results

On the 184 lakes surveyed, there were 34 pairs of breeding Red-throated Loons (14 with eggs or chicks, 20 with territories), representing occupancy of 18.5% of the lakes. The majority of lakes supporting breeding pairs (N = 29) occurred in the Queen Charlotte lowlands.

Stepwise discriminant analysis yielded a significant difference between lakes with or without breeding Red-throated Loons ($F = 4.51$; DF = 1, 41; $P < 0.05$), with region as the major predictor. Occupancy of lakes was 27% in the Queen Charlotte lowlands, 7% in the Skidegate plateau and 6% in the Queen Charlotte ranges (Figure 1). When the analysis was restricted to the variables of area, elevation, distance to ocean and region, the discrimination between the groups was comparable ($F = 11.4$; DF = 1, 170, $P < 0.001$). Multiple regression analysis showed that the total explained variance was only 7% ($F = 2.6$, $P = 0.03$). When the analysis was restricted to lakes in the lowlands (N = 107), no significant differences were found between lakes with or without breeding pairs.

It was evident that Red-throated Loons used a broad range of habitats, including bog and forested terrain, and geographically and chemically diverse lakes (Table 1). Although lakes which had nests varied greatly in size (0.27-373 ha), modal lake size was less than 1 ha. Fish, including Threespine Stickleback (*Gasterosteus aculeatus*), Dolly Varden (*Salvelinus malma*), Cutthroat Trout (*Salmo clarki*), Coho Salmon (*Onchorhynchus kisutch*) and

TABLE 1. Comparison of habitat characteristics for lakes with breeding Red-throated Loons and for total lakes surveyed on the Queen Charlotte Islands. None of the differences between the two groups was significant. T400 = light transmission at 400 nm.

	Breeding lakes			All lakes surveyes		
Habitat variable	average	range	N	average	range	N
pH	4.70 ($\bar{x}$)	3.95 - 6.25	20	5.34 ($\bar{x}$)	3.95 - 7.40	108
Water color (T400)	70.4% ($\bar{x}$)	37.9% - 95.0%	23	75.9% ($\bar{x}$)	37.9% - 99.8%	106
Conductivity (μs/cm)[1]	7.50 ± 25.0 (mode)	39.5 - 2200.0	14	75.0 ± 25.0 (mode)	16.5 - 4150.0	62
Calcium (ppm)[2]	0.75 ± 0.25 (mode)	0.39 - 15.20	14	0.75 ± 0.25 (mode)	0.21 - 198.55	62
Distance to ocean (km)	4.1 ($\bar{x}$)	0.6 - 8.6	34	3.7 ($\bar{x}$)	0.2 - 15.8	184
Elevation (m)	52.4 ($\bar{x}$)	7.6 - 132.6	34	52.4 ($\bar{x}$)	4.6 - 228.6	184
Surface area (ha)[3]	< = 1 (mode)	0.27 - 373.0	34	< = 1 (mode)	0.27 - 545.0	184

[1]Partitioned into 50 μs/cm groups for mode; [2]Partitioned into 0.50 ppm groups for mode; [3]Partitioned into 1 ha groups for mode.

sculpins (*Cottus* sp.) were present in 72% of the lakes. However, presence or absence of fish was not a predictor of the presence of breeding Red-throated Loons (14 lakes with fish versus 20 lakes without fish).

The Queen Charlotte Islands contain over 3000 lakes and ponds, 82.5% of which are located in the Queen Charlotte lowlands (Table 2). In the lowlands and the plateau, the majority of these are less than 1 ha in size, while the Queen Charlotte ranges contain fewer and larger lakes. It appeared that none of the habitat characteristics that were measured, other than region, had an effect on the distribution of pairs. Thus, in calculating the total breeding population, lakes within regions, but not between regions, were considered to have equal potential for nests. Based on the proportion of lakes that had breeding pairs, a population estimate of 744 breeding pairs was obtained for the lowlands, 24 for the plateau and 16 for the ranges,

TABLE 2. Actual and estimated numbers of breeding pairs of Red-throated Loons on the Queen Charlotte Islands in relation to lake size and region. Population estimates are calculated for (a) lake-size classes within a region, (b) cumulative lake-size classes, and (c) total lake number in each region, independent of lake size.

	Size of lake (ha)								Population estimate (pairs)	
	< = 1	2-5	6-10	11-20	21-50	51-100	101-200	> 200	Total	lake size[b]	region[c]
Queen Charlotte Lowlands										
number of lakes in region	2534	151	21	18	11	6	1	3	2745		
number of lakes surveyed	27	45	11	10	7	6	0	1	107		
number of breeding pairs	7	12	2	1	3	3	0	1	29		
population estimate[a] (pairs)	657	40	4	2	5	3	0	3		714	744
Skidegate Plateau										
number of lakes in region	243	42	9	14	7	3	1	3	322		
number of lakes surveyed	3	8	4	7	2	2	0	1	27		
number of breeding pairs	2	0	0	0	0	0	0	0	2		
population estimate[a] (pairs)	162	0	0	0	0	0	0	0		162	24
Queen Charlotte Ranges										
number of lakes in region	78	100	23	27	20	7	5	1	261		
number of lakes surveyed	5	13	4	11	11	3	2	1	50		
number of breeding pairs	0	1	1	0	1	0	0	0	3		
population estimate[a] (pairs)	0	8	6	0	2	0	0	0		16	16
population estimate[a] (pairs)	819	48	10	2	7	3	0	3		892	784

yielding a total of 784 breeding pairs for the entire Queen Charlotte Islands. This represented a density of 0.23 pairs/km² in the lowlands, 0.007 pairs/km² in the plateau and 0.005 pairs/km² in the ranges (overall density, 0.079 pairs/km²). These densities primarily reflect densities of ponds in each region. A population estimate was also calculated for each lake-size class in each region (Table 2); this yielded a cumulative total of 892 breeding pairs for the Queen Charlotte Islands as a whole.

These estimates have several possible sources of error. Population estimates were heavily weighted by the preponderance of small ponds (< 1 ha) in the lowlands. Resolution in aerial photographs did not allow reliable identification of ponds less than 0.25 ha and, therefore, the number of these ponds may have been greatly underestimated. Although Red-throated Loons have been recorded nesting on ponds 15 m² (0.0015 ha) (Furness 1983), we have not observed them on ponds less than 0.27 ha despite extensive ground surveys. However, it remains possible, given the immense numbers of small ponds, that some are used by breeding Red-throated Loons; if so, our population estimates will be low.

Our estimates do not take into account the patchiness of pond distribution. Where ponds occur very densely, numbers of pairs may be limited by spacing between nests; in such areas, there may be fewer pairs than estimated by average occupancy rate. To assess the importance of this effect, we analyzed separately the area where ponds occurred at exceptionally high density. This area, in the central lowlands, is 30.75 km² and has 373 lakes. At the calculated occupancy rate for the lowlands, there should be 101 pairs or 3.3 pairs/km². If we assume a minimum distance between nests of 700 m (*see* Study Area and Methods), the area would support only 62 pairs; this would reduce the total population estimate by 39 pairs (5%).

Common Loons with chicks were observed in two lakes, both in the lowlands; territorial pairs were found in two lakes, one in the plateau and one in the ranges. Lake size ranged from 13-53 ha; breeding Red-throated Loons were not present on these lakes.

Discussion

On the Queen Charlotte Islands, lakes which had nesting Red-throated Loons showed variation in water colour, pH, conductivity, calcium, lake size, elevation, distance to the ocean and presence of resident fish. Breeding pairs appeared to occupy lakes according to their availability rather than to any of these measured parameters.

In other geographic areas, competition with Pacific Loons (*Gavia pacifica*) for breeding territories is considered to restrict the distribution of breeding Red-throated Loons. Where the two species are sympatric, they partition the habitat, with Red-throated Loons occupying smaller lakes (Davis 1972; Bergman and Derksen 1977; Merrie 1978). Although occasional summer migrants have been observed on the Queen Charlotte Islands (Reimchen and Douglas 1984b), breeding Pacific Loons are absent.

Breeding Common Loons are infrequent on the Queen Charlotte Islands (4 territories/184 lakes) and are thus unlikely to have a major influence on the distribution of breeding Red-throated Loons. However, non-breeding Common Loons use large lakes on the islands for foraging (Reimchen and Douglas 1980), and where they overlap with breeding Red-throated Loons, aggressive encounters occur (Reimchen and Douglas 1985). Common Loons are limited in the size of fishing lakes they use on the Queen Charlotte Islands by a minimum distance (approximately 300 m) for taking-off and gaining altitude sufficient for leaving the lake. There is, therefore, a potential for interactions between the two loon species on lakes down to about 2 ha (a size on which we have observed Common Loons). If Common Loons are restricting the breeding distribution of Red-throated Loons, Red-throated Loons should be less common on those lakes greater than 2 ha that have fish than on those where fish are absent. Yet our data showed that there was no significant difference in occupancy (13.2% occupancy of lakes ≥ 2 ha with no fish (N = 53) and 18.8% with fish (N = 96); G test, G = 0.42, DF = 1, NS), suggesting that non-breeding Common Loons were not restricting the distribution of Red-throated Loons.

Red-throated Loons use smaller nesting lakes than any of the other loon species (Palmer 1962; Cramp and Simmons 1977; Bergman and Derksen 1977; Merrie 1978). Norberg and Norberg (1971) reported a take-off distance of 15-40 m for Red-throated Loons; this may be a lower limit for size of most breeding ponds, although, on Foula, pairs nested on ponds less than 15 m long and successfully raised young (Furness 1983). In Alaska, nesting ponds of Red-throated Loons ranged from 0.1-0.8 ha ($\bar{x}$ = 0.4 ha); their distribution is probably influenced by nesting Pacific Loons who occupied larger ponds ($\bar{x}$ = 3.0 ha, range = 0.7 - 12.1 ha) (Bergman and Derksen 1977). Bundy (1976) suggested that breeding Red-

throated Loons on Unst, Shetland Islands, had a preference for lakes less than 1 ha. We have re-examined his data and found that, rather than exhibiting a preference for small tarns, Red-throated Loons were nesting according to the availability of size classes of lakes: of 96 lakes < 1 ha, 19.8% were occupied, of 14 lakes 1 - 5 ha, 21% were occupied and of 10 lakes > 5 ha, 20% were occupied. As in our study, the preponderance of pairs nesting on small lakes reflected the abundance of lakes of that size; it did not imply a habitat preference.

Red-throated Loons are exceptional among the Gaviidae in that they do not feed their young with food from the nesting lake, but fly to marine water or to larger lakes to obtain fish (Norberg and Norberg 1971; Bundy 1976; Bergman and Derksen 1977; Merrie 1978; Furness 1983; Reimchen and Douglas 1984a). Thus, it is not unexpected that the use of lakes for breeding is independent of the presence of fish or of limnological characteristics which may relate to productivity (conductivity, calcium and pH).

The maximum distance from Red-throated Loon breeding lakes to the nearest marine water on the Queen Charlotte Islands was 8.6 km. For 85 pairs of breeding Red-throated Loons in Scotland, the majority of feeding flights were within 8 km of the nest site (Merrie 1978). As increased distance to the foraging grounds will limit the number of return flights per day and thus the number of fish fed to the young, as well as expose the young to increased periods without parental guarding (Reimchen and Douglas 1985), survivorship of the young could be reduced on lakes at increasing distances from the ocean. We found no reduction in occupancy over the short distances to feeding grounds on the Queen Charlotte Islands; however, fledging success at differing distances to the ocean is unknown. On the Shetland Islands, Gomersall (1986) compared pairs that nested less than 1 km from the ocean to pairs nesting more than 1 km and found no significant difference in hatching or fledging success.

Physiographic region was the only significant predictor of the presence or absence of breeding pairs of Red-throated Loons on the Queen Charlotte Islands, with lakes in the lowlands having a higher occupancy than those in the plateau or ranges. Several characteristics that are correlated with region — plant communities, lake density and proximity to fishing areas — may explain this distribution. The lowlands are dominated by extensive areas of *Sphagnum* bog; lakes and bog pools often have convoluted *Sphagnum*-covered shorelines and low islets which are typical nest substrates for Red-throated Loons (Cramp and Simmons 1977; Dement'ev and Gladkov 1969; Davis 1972). Ponds in this region usually have short vegetation on their shores which may facilitate landing and take-off; in small ponds that have forested shores, Red-throated Loons must do tight aerial turns to gain altitude during take-off (Norberg and Norberg 1971; personal observation). Red-throated Loons in Alaska nested on shallow ponds with emergent shoreline vegetation (Derksen et al. 1981) and, in comparison to Pacific Loons, occupied those with greater vegetative cover (Bergman and Derksen 1977). Aquatic vegetation was not quantified in our survey and as such, presence or absence of breeding Red-throated Loons according to percentage coverage cannot be assessed. In general, however, ponds and lakes in the lowlands are dystrophic, with low diversity and abundance of plants, while those in the plateau and ranges are oligotrophic, with comparatively higher diversity but similar low abundance (Calder and Taylor 1968).

The lowlands have a higher density of lakes than the other two regions. In the Northwest Territories, the availability of alternate lakes was found to be important for predator escape (Davis 1972); as well, chicks incubated on small ponds may be able to move to larger lakes for fledging (Bergman and Derksen 1977; Furness 1983). Thus, successful fledging of young may depend on a certain density of ponds and a territory larger than the nesting pond.

Merrie (1978) postulated that the distribution of breeding Red-throated Loons on lakes in Scotland was based on the availability of shallow fishing areas. The higher occupancy of lakes in the lowlands may similarly relate to the proximity of broad littoral marine feeding areas to the north and east (see Figure 1). Conversely, for most of the plateau and ranges, the nearest marine water lies on the Islands' west coast, where the continental shelf is very narrow and even nearshore water is deep.

On the Queen Charlotte Islands, occupancy of lakes (27% in the lowlands, 18.5% overall) appears low, yet comparable numbers are found on the Shetland Islands, Scotland (Unst: 20% to 33%, N = 120, Bundy 1976; Foula: 82%, N = 17, Furness 1983). Although the habitat characteristics we investigated did not appear to affect the suitability of lakes for breeding, there may be other constraints limiting occupancy. Competition does not seem important, since apart from occasional

Common Loons, Red-throated Loons are the only large divers observed nesting on these lakes. If absolute numbers of Red-throated Loons are limited in their winter distribution, low occupancy may represent deficiencies in numbers of breeding birds. This appears unlikely, as there is a relatively large number of non-breeding adult Red-throated Loons utilizing marine waters in the day and overnighting on large lakes throughout the breeding season (Reimchen and Douglas 1980).

In contrast, low occupancy rate may be a result of spacing of nesting territories, which is maintained by territorial displays and vocalizations. We suspect this is also unlikely, as maximum density in the lowlands (0.23 pairs/km) is substantially lower than that observed in Scotland (0.84 pairs/km^2: Merrie 1978), Alaska (0.40 pairs/km^2: Bergman and Derksen 1977) and the Northwest Territories (1.7 pairs/km^2: L. Dickson, Canadian Wildlife Service, personal communication).

Occupancy may be limited by foraging success in the marine habitat. The major diet of the young during the 50-day prefledging period, during which adult birds bring prey of particular taxa and size depending on the age of the chick, is obtained from marine foraging areas (Reimchen and Douglas 1984a). It is possible that the ability to maintain suitable marine feeding territories can influence the establishment and maintenance of their breeding territories and, therefore, limit the number of occupied lakes.

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