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RESEARCH/RESOURCES MANAGEMENT REPORT MWR - 13

Effects of Regulated Lake Levels on the Reproductive Success, Distribution, and Abundance of the Aquatic Bird Community in Voyageurs National Park, Minnesota

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EFFECTS OF REGULATED LAKE LEVELS ON THE REPRODUCTIVE SUCCESS, DISTRIBUTION, AND ABUNDANCE OF THE AQUATIC BIRD COMMUNITY IN VOYAGEURS NATIONAL PARK, MINNESOTA

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ABSTRACT

The effects of regulated lake levels on the reproductive success, distribution and abundance of the aquatic and marsh bird community were studied in Voyageurs National Park, Minnesota. The park's four largest lakes have been regulated by dams since 1909. This regulation has caused less than natural (Rainy Lake), and greater than natural fluctuations in lake levels (Namakan Reservoir lakes); in addition, there are 26 small interior lakes which fluctuate naturally.

Park lake designation (by water levels) exerted a significant negative influence on the reproductive success of the Common Loon (Gavia immer) with Rainy Lake having a greater success rate than the Namakan Reservoir lakes. Reproductive success of Voyageurs National Park's Common Loon and Red-necked Grebe (Podiceps grisegena) populations were also significantly lower than populations occurring on other (non-park) naturally fluctuating lake systems.

The greatest nest loss on regulated lakes was due to rising water levels. Common Loon nest losses averaged 60% on Rainy Lake, 70.6% on the Namakan Reservoir lakes, and no losses due to flooding on the interior lakes. Red-necked Grebe nest losses averaged 47% on Rainy Lake, and 52% on the Namakan Reservoir lakes, while other marsh nesting species averaged 25.0% on Rainy Lake and 76% on the Namakan Reservoir lakes.

A significant proportion of the variation in Common Loon flooded-out nesting attempts could be explained by June lake level changes alone. Using computed natural lake levels for June 1983-1985, predicted percentages of loon nest losses on the Namakan Reservoir lakes would have declined from 37% to 27%, while on Rainy Lake percent nest loss under natural conditions would have increased slightly from actual losses, 20% to 25%. Lake-level change was also highly significant in explaining the percent of flooded Red-necked Grebe nests. Lake-level change was not significnat in explaining percentages of flooded-out nests for the other marsh nesting birds. If natural conditions prevailed, Red-necked Grebes on Rainy Lake would have experienced a 21% increase in percent of flooded nests and the other marsh nesting birds, a 58% increase. On the Namakan Reservoir lakes, however, Red-necked Grebes would have seen an 85% decline in the percent of flooded nests. Marsh nesting birds would have had virtually no losses following a 97% decline under computed natural conditions.

A modified lake regulation regime is proposed which should enhance the reproductive success of the aquatic avifauna community in Voyageurs National Park and thus increase park visitors' opportunity to enjoy the bird life.

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INTRODUCTION

In the United States and elsewhere, many of our lakes and rivers have been transformed from their original free-flowing state to a series of impoundments, reservoirs and stair-step ponds along rivers. These regulated waterways are commonly used for water supply, flood control and hydroelectric power. An important result of such artificially-controlled waters is that the level of the water often varies over a far greater range than is natural, or the "normal" annual pattern of change differs from the natural condition (Fisher and LaVoy 1972; Pearce et al. 1977).

Water level fluctuations inevitably affect different aquatic ecosystems (Koonz and Rakowski 1985; Kushlan 1987; Johnson and Carothers 1987; Proulx et al. 1987). Studies addressing the issue of water level fluctuations have dealt with a variety of aquatic organisms, such as fish (Sharp 1941; Forney 1968; Chevalier 1977; Kallemeyn 1987a and b), birds (Johnsgard 1956; Weller and Spatcher 1965), benthos (Hynes 1961; Grimås 1962; McLachlan 1970; Fisher and Lavoy 1972; Benson and Hudson 1975; Smock et al. 1981), and aquatic vegetation (Quennerstedt 1958; Robel 1962; Harris and Marshall 1963; Bishop et al. 1979).

Until recently, the effects of fluctuating water levels on aquatic birds has focused primarily on waterfowl productivity (Johnsgard 1956; Anderson and Glover 1967; Krapu et al. 1970; Swanson and Meyer 1977; Bishop et al. 1979). Many of these studies were concerned with declining water levels. Relatively few studies have investigated the effects of water fluctuations on nongame bird species. Broekhuysen and Frost (1968) found that 61.5% of all nesting attempts by Black-necked Grebes (<u>Podiceps nigricollis</u>) were destroyed by extreme variations in water level. The effects of water level changes have also been documented for the Western Grebe (<u>Aechmophorus occidentalis</u>) (Lindvall and Low 1982), the Common Loon (<u>Gavia immer</u>) (Titus and VanDruff 1981; Yonge 1981; Barr 1986; McIntyre 1988), and colonial nesting waterbirds (Koonz and Rakowski 1985; Kushlan 1987). Barr (1986) found significant differences in occupancy rates by loons of territories and hatching success between lakes with less than 1.5m and greater than 1.5m water fluctuations. McIntyre (1988) showed an increase in the number of possible loon territories as a reservoir reached full capacity. On a seasonal basis, however, fluctuating lake levels effected reproductive success with dropping water levels exerting a greater detrimental effect than rising water levels.

In an effort to assess the potential effects of manipulated water levels on a large lake system, I investigated the aquatic avifauna community in Voyageurs National Park (VNP), Minnesota. The objective of this study was to provide the

National Park Service with information upon which to determine the impacts, if any, to the aquatic bird community that the fluctuating lake levels impose. The project was designed to determine what impacts the present water management program has on the reproductive success, distributions and densities of aquatic and marsh birds within the park.

This research (1) measured the distributions, densities, and reproductive success of nesting and nonnesting bird species on study areas having natural and regulated water levels, (2) measured site specific physical attributes of nest sites, and habitat characteristics, and (3) monitored nonsite specific factors, such as water levels and climatological data.

Two aquatic nesting species were studied intensely, the Common Loon and Red-necked Grebe (Podiceps grisegena). Other species studied include the Pied-billed Grebe (Podilymbus podiceps), the Sora (Porzana carolina), the Black Tern (Chlidonias niger) and the Red-winged and Yellow-headed Blackbirds (Agelaius phoeniceus and Xanthocephalus xanthocephalus).

STUDY AREA

Voyageurs National Park, which was established in 1975, is located on the U.S.-Canadian border (Figure 1). Voyageurs' 88,628 ha contains 30 named lakes. The four largest lakes, Rainy, Kabetogama, Namakan and Sand Point (the Voyageurs lake system) comprise 39% of the total park area and 96% of the total water area. Twenty-six smaller lakes are scattered throughout the mainland and peninsular land areas (Appendix I). Numerous beaver ponds and bogs are also found throughout the park's land area.

The park lies within the southern range of boreal forest vegetation (Cole 1982, 1987), though Morley (1969), and Hosie (1975) place the region within the Great Lakes forest region. In Voyageurs, the Great Lakes forest type is characterized by eastern white and red pines (Pinus strobus and P. resinosa) and aspen (Populas tremuloides) on mineral soils. Intermixture with boreal forest species is considerable. The common tree species of the park's boreal forest are white spruce (Picea glauca), balsam fir (Abies balsamea), jack pine (Pinus banksiana), and white birch (Betula papyrifera) on mineral soils, and black spruce (P. mariana) on peat soils.

Marsh habitat is dominated by stands of common and narrow-leafed cattail (Typha latifolia and T. angustifolia). Hardstem bulrush (Scirpus acutus), burreed (Sparganium spp.), and water lilies (Nuphar spp. and Nymphaea spp.) are also present. The major lake edge emergent zone plant is hardstem bulrush. Some

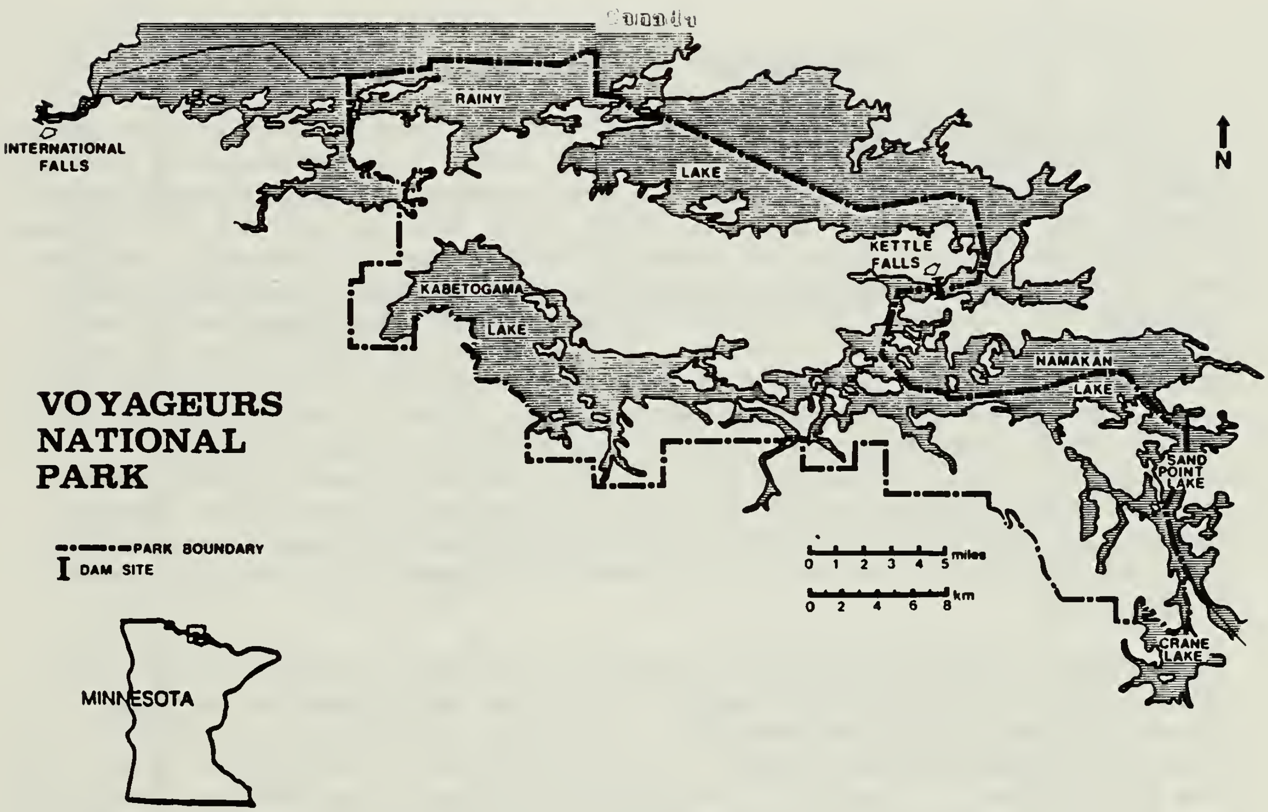

Figure 1. Voyageurs National Park, Minnesota. (From Kallemeyn et al. 1988)

offshore areas contain a mixture of common cattail, softstem bulrush (S. validus), sedges (Carex spp.) and Sagittaria spp. Common reed (Phragmites communis) is commonly found in thick stands along some shorelines. Floating marsh or bog edge vegetation consists primarily of common cattail or leather leaf (Chamaedaphne spp.). In some of the backwater coves and bays, stands of wild rice (Zizania aquatica), grasses (Glyceria spp.) and swamp horsetail (Equisetum fluviatile) appear by mid-summer (Morley 1969; Carlson and Moyle 1975).

BACKGROUND ON LAKE REGULATION

A single hydropower facility and two small regulatory dams govern the water levels of the four large interconnected lakes. Some regulation has occurred in the Voyageurs lake system since 1909. The hydropower dam is located at the outlet of Rainy Lake at International Falls, Minnesota/Fort Francis, Ontario, while both regulatory dams are located at the outlet of Namakan Lake (Figure 1). Water levels are regulated by the International Joint Commission (IJC), which is a governing body consisting of members from both the United States and Canada. Regulation of lake levels by the Commission is based upon a "rule curve" which takes into consideration power generation, flood control, navigation, fish spawning and pollution abatement. The "rule curve" establishes criteria for flow releases and lake levels. The rules of operation specify maximum and minimum lake levels, and the timing at which full reservoir levels can be achieved (Figure 2).

These impounded waters differ from the natural or pre-dam condition in three major ways: (1) the magnitude of annual fluctuations; (2) the pattern of annual fluctuations; and (3) the timing of peak water levels. The specific differences are: (1) The magnitude of annual fluctuations, under the current regulated condition, ranges from 1m on Rainy to 3m on the Namakan Reservoir lakes (Kabetogama, Namakan, Sand Point Lakes) vs. a 1.2-1.5m fluctuation range on all lakes if natural conditions prevailed; (2) The current pattern of lake level behavior is for higher summer and fall water levels and up to 100% greater overwinter drawdown on the Namakan Reservoir lakes (1.8m vs. 0.6-0.9m drawdown on all lakes under natural conditions); and (3) most importantly, for aquatic and marsh-nesting birds, the timing of peak water levels generally ranges from mid-June to early July, while under pre-dam conditions, the Namakan Reservoir lakes peaked from mid-May to early June, and Rainy Lake peaked late June to early July (Flug 1986) (Figure 2).

Deviations from the natural conditions have directly affected the aquatic ecosystem, in particular, the littoral

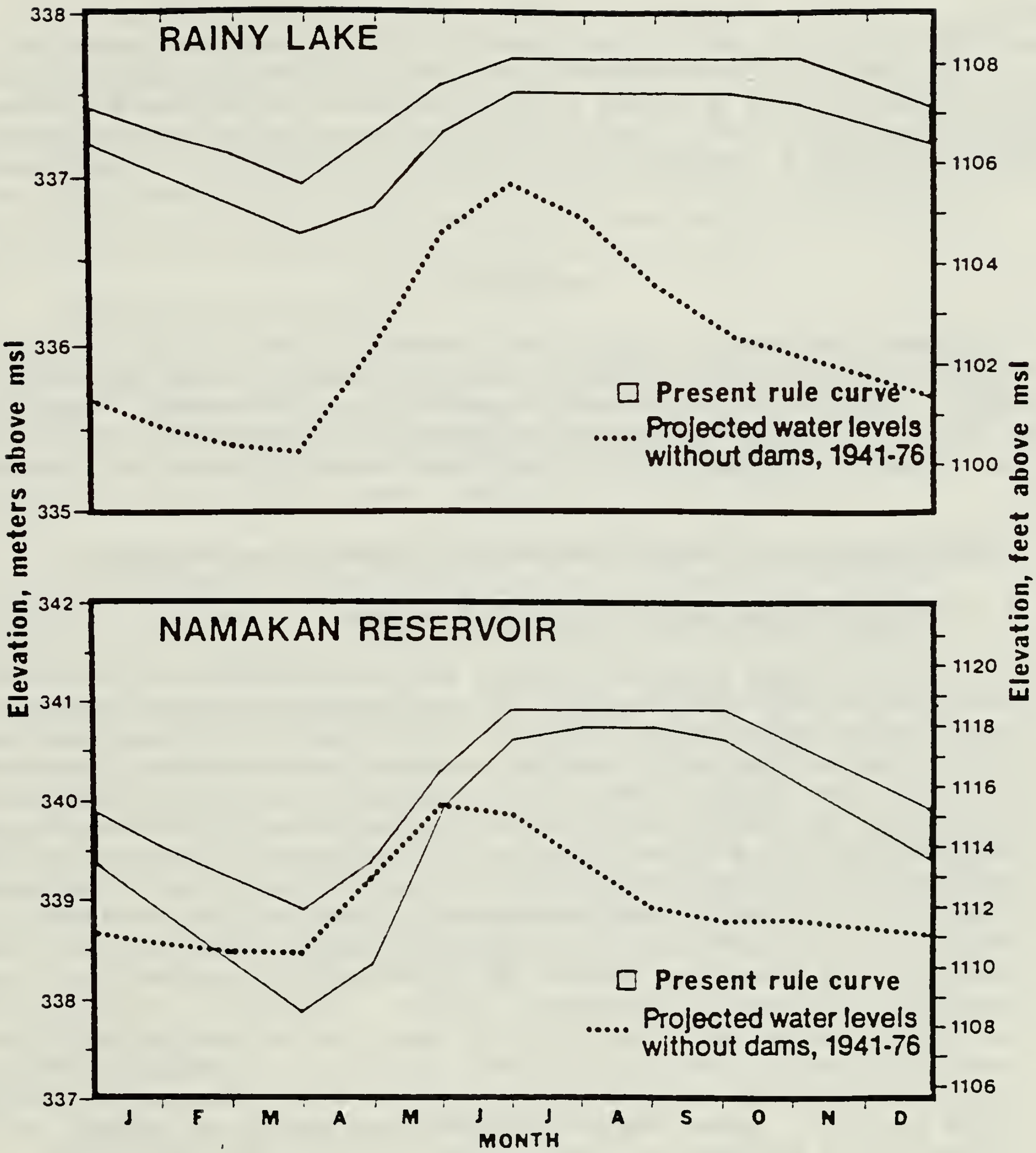

Figure 2. Present water management programs (rule curves) and computed natural lake levels for Rainy Lake and Namakan Reservoir, Minnesota and Ontario, Canada. Elevations given in meters and feet above mean seal level (msl). (From Kallemeyn et al. 1988)

community. Known effects include: (1) the disappearance of extensive wild rice beds from lakes with 3m fluctuations (Cole 1982); (2) reduced fish populations due to adverse impacts on spawning habitat and success (Chevalier 1977; Kallemeyn 1987a and 1987b; Kallemeyn et al. 1988); and (3) impacts on the aquatic avifauna community (Reiser 1984 and 1985; Kallemeyn et al. 1988).

METHODS

From May-September 1983-1986, survey crews of one to four individuals traveled throughout the four major lakes by motorboat and canoe. Aerial surveys were conducted on the small interior lakes from an average altitude of 250m. In addition, checks were made on interior lakes which were consistently occupied by loon pairs.

I. Determination of territories and population surveys.

A. Common Loon and Red-necked Grebe.

I reviewed past Voyageurs National Park survey records from 1979-1982 to identify all potential Common Loon and Red-necked Grebe territories. Potential loon territories were lake areas which had at least a 50% occupancy rate by a pair or lake areas with a 75% occupancy rate by a single bird plus at least one island and/or floating bog or marsh vegetation for a nest site and a sheltered area for brood-rearing. Loon territories are comparatively well-defined areas which are actively defended via displays and yodel calls. The constancy in occupying these areas for at least part of the breeding season is also typical pair behavior (Olson and Marshall 1952). Potential territories on large lakes were surveyed by boat at approximately two-week intervals from May through mid-July. Interior lakes were surveyed by air at one-to-three week intervals during this period. Lake areas regularly occupied by a pair of loons for a minimum of four weeks during the intensive survey period were considered active territories. Adult loons present as singles or in small groups on undefended lake areas were also included in the population surveys. Population estimates of adults and young were calculated only for the years 1979 through 1982, as not all park lake areas were surveyed. These estimates were based on the mean number of adults and young observed during the survey years (1983-1986) which covered the total water area for those particular lakes. During these survey years (1983-1986), absolute populations were determined.

Potential Red-necked Grebe territories were surveyed weekly from mid-May through early September by boat and canoe. Consistent occupancy of an area by a pair, defensive displays by the pair, and/or courtship behavior would categorize the area as an active territory. I also obtained absolute densities on the Red-necked Grebe in the park and in additional study sites on Rainy Lake which covered an area 4 to 9 km from the west end of the park.

B. Marsh bird community.

I estimated densities and distributions of the marsh avifaunal community on six to eight individual study sites on Rainy, Kabetogama and Namakan Lakes, and on five interior lakes. All the study sites had marsh, bog edge and/or emergent vegetation zones (Appendix II, Figure 3).

Surveys were conducted between sunrise and 1300 hours at approximately four-week intervals from May through August. Patches of emergent vegetation and small marsh areas were canoed or waded through in their entirety. In the only large marsh on the study areas, I established ten transect belts (25m wide) totalling approximately 2 ha which were canoed or walked. The observer moved along the transect following a compass bearing. Recordings of calls and sitings began 5m in from the beginning of each transect belt (station 1). After a five-minute wait at station 1, the observer(s) would slowly move along the transect noting sitings of birds. At every subsequent station, which were approximately 25m apart, the number and direction of calls were made during a five-minute period. Relative abundance was obtained on marsh-dwelling birds.

II. Locating nests.

A. Common Loon and Red-necked Grebe.

All mainland, island and bog shorelines in the established study sites were intensively searched for loon nests, as well as shorelines in occupied loon territories. Special attention was paid to shoreline areas where loons were in close proximity to one another and/or exhibited a Sneak or Hunched posture (McIntyre 1975). This display which sets the loon low in the water is considered a post-escape posture and serves as an indication of nearby nests (McIntyre 1975; Titus and VanDruff 1981). If no nest was found, but appropriate loon behavior was observed, additional searches were conducted on subsequent visits until the end of July.

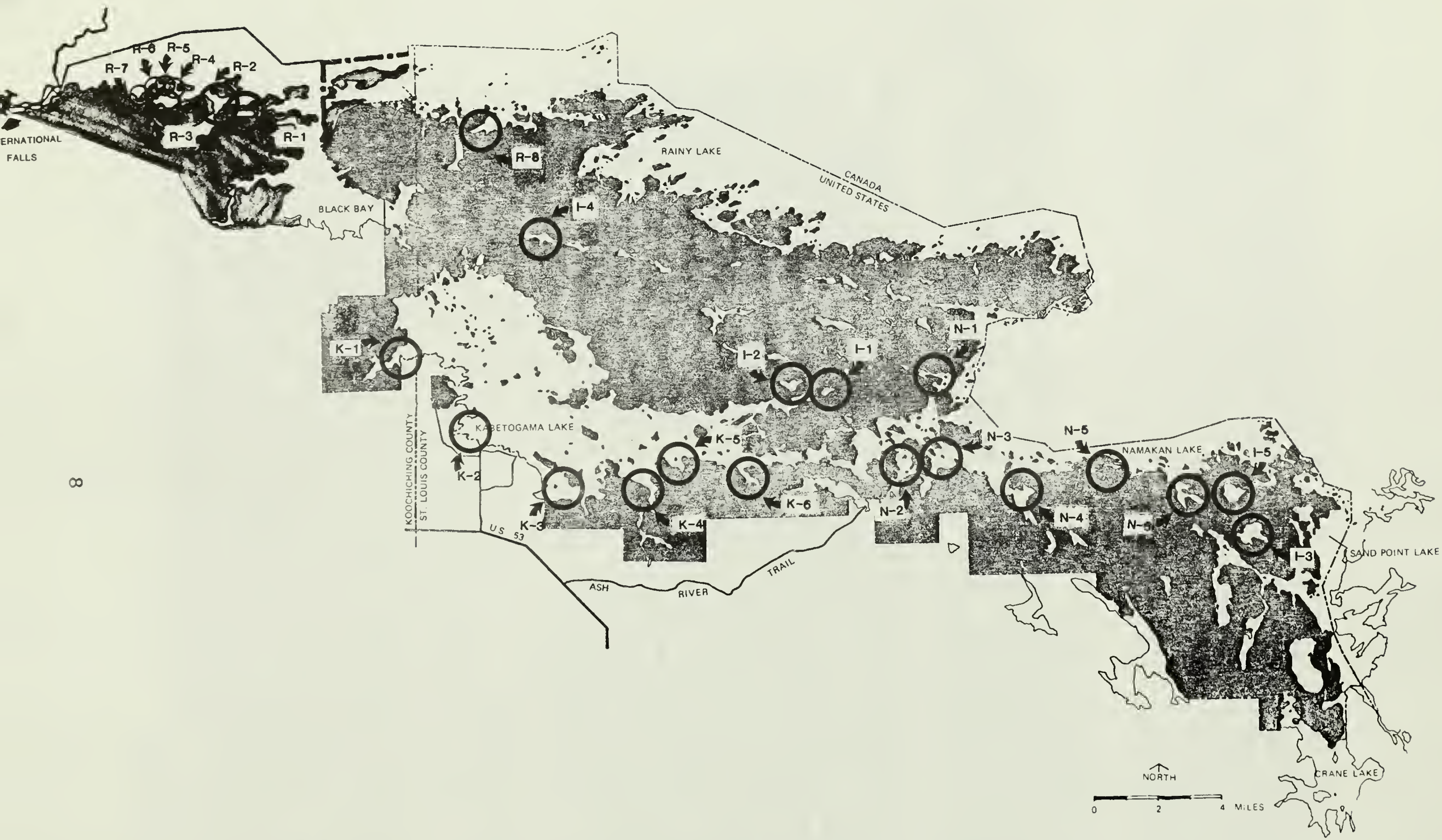

Figure 3. Locations of specific study areas and study sites in Voyageurs National Park, Minnesota. (Refer to Appendix II for location code legend.)

Red-necked grebes nest on open water at the edge of emergent vegetation or within stands of cattail and/or bulrush (Munro 1941; Eichhorst 1984; Reiser 1984 and 1985). These zones on the three major lakes were canoed in search of nests. Early in the breeding season prior to the emergence of vegetation, nests could be located from a boat anchored in the middle of the bay. Flagging tape was attached to cattail or bulrush stalks at the vegetation edge to facilitate the relocation of nest sites located in the interior portions of dense emergent vegetation or marshes. A nest site number was written on the tape. This number corresponded to the proper direction and distance to the actual nest site. I initiated weekly nest searches in mid-May and continued them until nesting activity ceased.

B. Other marsh nesting species.

Canoeing or wading through small patches of emergent vegetation enabled the crews to locate all nests of pied-billed grebes, black terns and red-winged blackbirds. In one large marsh area, nests were only searched for within a 25m belt along transect lines. In addition to the nesting birds found in patches of emergent vegetation, nests of soras and yellow-headed blackbirds were also located. These areas were, in general, extremely difficult to traverse due to the instability of the peat layer which accumulates over the lake bottoms and high density of vegetation during the summer. Located nests were appropriately identified as to species and marked with flagging tape 1-2m north of each nest. Only the edges of bog vegetation were surveyed for nesting activity, and bog areas or wet meadows that extended beyond marsh areas were not surveyed. However, sitings or calls of birds noted from these areas were only used to compile a list of birds in Voyaguers that utilized aquatic vegetation and/or wet habitats.

III. Checking nests.

Nests were checked weekly for all species except the Common Loon. Loons are susceptible to nest disturbance; thus, after initial discovery, nests were not rechecked until approximately three weeks into incubation. For example, detailed measurements of an active nest discovered the first week of June would not be taken until the third or fourth week of June. However, for nests that were initially located at the end of June or later, detailed measurements would be taken at the time of discovery unless a late nesting date had been established for that loon pair.

Nests of all species were monitored until a final outcome was determined. Nest fate was classified as follows: (1) nest flooded out - nests covered by water with or without eggs present in the nest or on the lake bottom; (2) successful nest - young seen with adult; (3) nest abandoned - documentation of incubating bird leaving nests and not returning due to a disturbance; (4) predation/scavenged nest - punctured or crushed eggs, tracks or scat found on or near the nest structure, destroyed nest or direct observation; and (5) unknown - failures of unknown origin. A renesting was recorded if a new nest was found in a territory which had a previously unsuccessful nest.

IV. Brood checks.

A. Common Loon and Red-necked Grebe.

A pair of loons was considered successful if young two weeks or older were present. Studies by Olson and Marshall (1952) and Titus and VanDruff (1981) revealed that only one out of 92 loon chicks was lost beyond the age of two weeks. Most chick mortality occurred before this age. Pairs with young were checked weekly until the young reached four weeks of age and then once every three to four weeks until I departed the park in late August to late September.

Red-necked Grebe broods were monitored weekly until fledging, which occurred 10 weeks post-hatching. A pair was considered successful if at least part of a brood survived to six weeks of age.

B. Marsh nesting species.

Nests containing nestlings were checked weekly. Number of eggs hatched, number with young in nest during pre-fledging checks and counts of juveniles in the vicinity of the nest site were recorded during the breeding season.

V. Nest site specific variables.

The site specific parameters measured at each nest site were: (1) nest cover index; (2) distance of nest above water; (3) distance of nest to nearest shore; (4) water depth at nest site; (5) water depth off nest @ 0.5m, 1.0m and 3m; (6) observability index; (7) nest site type; (8) nesting island size; (9) nest fate; (10) number of eggs laid; (11) number of eggs lost; (12) number of eggs hatched; and (13) number of young surviving. The cover index refers to the percent vegetation coverage in a $1m^2$ area around the nest. The 1m^2 frame was divided into 20 blocks in a 4x5 array. Each block was equal to 5% coverage. The percentage coverage corresponded to the number of blocks covered by vegetation within the frame. Categories were none (0%), sparse (1-5%), low (6-25%), moderate (26-50%), high (51-75%), dense (76-95%) and total (> 95%). Water depth was taken at distances of 0m, 0.5m, 1m, and 3m along a perpendicular line from the edge of the nest toward open water. An observability index was calculated only for loon nests. This index reflected the ease which passing boaters or fishermen could detect a loon nest from 10m out in open water. This distance was within the range that trolling occurs offshore. The categories ranged from obvious to not visible (Titus and VanDruff 1981).

Specific habitat variables measured around the nest site were types of plant species and numbers, mean height of each species and lake bottom composition. These same measurements were also taken from 10-20 randomly-placed quadrants in each study site.

VI. Nonsite specific variables.

Climatological data were obtained from the U.S. Weather Service, International Falls, Minnesota and the Voyageurs National Park fire weather station, Ash River Trail Ranger Station, Kabetogama Lake (approximately 64 kilometers southeast of International Falls).

VII. Lake-level fluctuations.

I measured water depth at each nest during each survey with a meter stick placed at the 0m distance along the perpendicular line from the edge of the nest toward open water. If the water depth at a nest site was greater than 1m, a calibrated nylon rope weighted at one end was used to determine lake depth. Water depth was also monitored on a calibrated reference stake attached to a dock located near the Ash River Trail Ranger Station on Kabetogama Lake. In addition, daily records from 1950-1986 were obtained from monitoring stations associated with the two dam sites within the Voyageurs lake system (Site 1, Namakan Lake above Kettle Falls Dam, 48°30'00"N, 92°38'00"W; Site 2, Rainy Lake near Fort Francis, Ontario, Canada, 48°38'30"N, 93°20'00"W) (Figure 1). Computed natural lake levels from 1950-1985 were provided by the U.S. Army Corps of Engineers, Water Control Section, St. Paul, Minnesota.

VIII. Statistical Analysis

The data were analyzed with programs drawn from the Biomedical Computer Programs (BMDP) Statistical Software (Dixon et al. 1983). The following BMDP statistical programs were used on the data: (1) analysis of variance and covariance, including repeated measures (subprogram 2V); (2) description of groups (strata) with histograms and analysis of variance (subprogram 7D); (3) bivariate (scatter) plots (subprogram 6D); (4) stepwise regression (subprogram 2R); and (5) stepwise discriminant function analysis (subprogram 7M) (Dixon et al. 1983).

Many statistical tests were used in the analysis of the data. Univariate statistical procedures that were applied for simple comparisons included Chi-square tests, the Kolmogorov-Smirnov Goodness of Fit test, Student-Newman-Keuls test, and Sheffe's test (Zar 1974; Snedecor and Cochran 1980). In order to clarify the significance of the observed variations, the term "significance" means the observed difference was not likely to be a matter of chance at the stated level of probability. Probability levels greater than $p = 0.05$ were not statistically significant, unless otherwise noted.

RESULTS

Results will be presented in sections covering (1) the Common Loon, (2) the Red-necked Grebe, (3) the effects of water-level fluctuations on the aquatic avifauna community in Voyageurs National Park, and (4) the distribution of aquatic and marsh bird species.

I. Common Loon.

A. Population characteristics.

Common Loons were found throughout most of the park's water areas. From 1979-1986 surveys, populations of both adults and young were relatively stable. The actual observed and estimated (see Methods) mean number of adult loons in Voyageurs was 182 ± 16.5 and 195 ± 13.0 per year, respectively, and the actual and estimated mean number of fledged young was 31 ± 3.5 and 32 ± 3.8 per year, respectively (Figure 4). Only 13.8% of the actual total population is comprised of fledged young on the regulated lakes versus 16.3% on Voyageurs' naturally fluctuating interior lakes (Table 1).

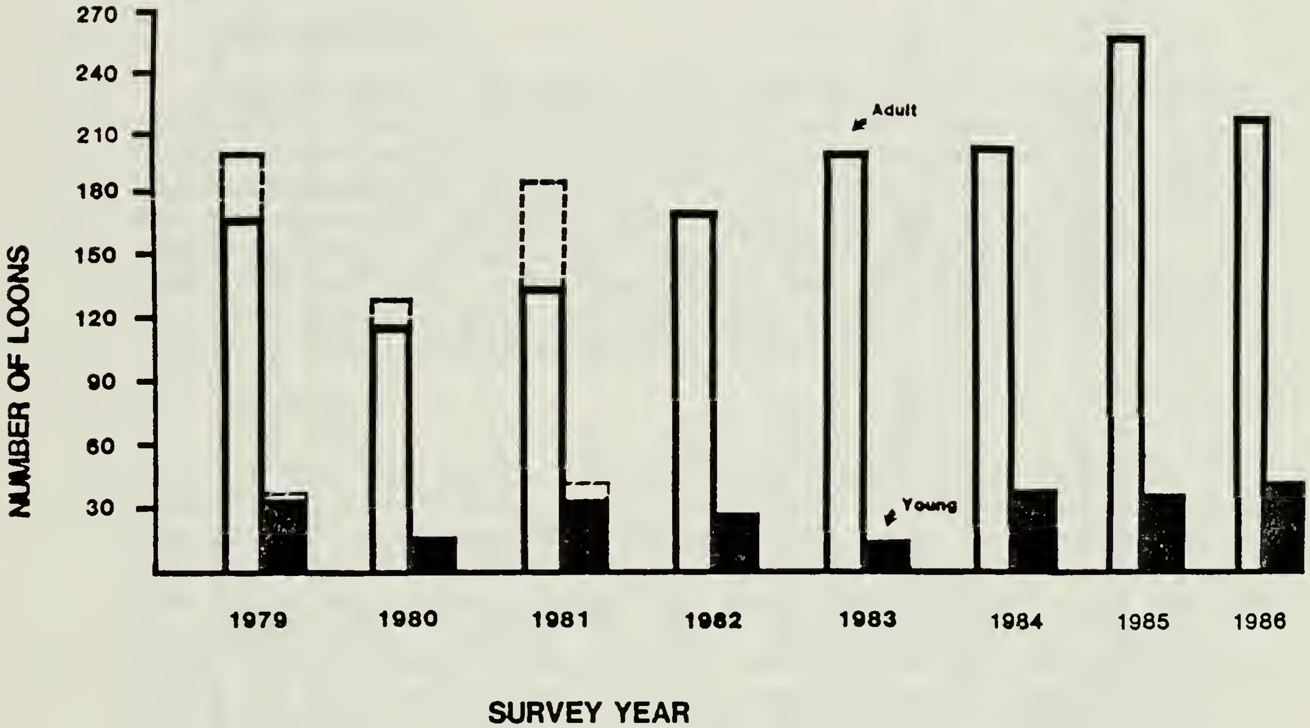

Figure 4. The number of adult and fledged young Common Loons in Voyageurs National Park, 1979 - 1986. Solid bar lines represent the actual observed population levels, and the dashed bar lines represent the estimated population levels.

Table 1. Number of adult and fledged young common loons by lake in Voyageurs National Park, 1979 - 1986. (A = adult, Y = young, ND = no data, * = incomplete survey of the interior lakes, or portions of Rainy Lake).

Lake	1979		1980		1981		1982		1983		1984		1985		1986	
	A	Y	A	Y	A	Y	A	Y	A	Y	A	Y	A	Y	A	Y
Rainy	61	11	29*	5	69	21	39*	9	52*	8	77	19	89	19	67	20
Kabetogama	46	2	31	0	33	5	48	8	60	3	35	2	56	3	49	4
Namakan	29	7	16	1	28	5	24	4	31	0	32	3	43	4	36	4
Sand Point	ND	ND	6	0	ND	ND	9	3	8	2	14	1	15	1	8	4
Interior Lakes	22*	12	28*	11	ND	ND	48	3	44	2	40	7	47	5	48	9
Total	158	32	110	17	130	31	168	27	195	15	198	32	250	32	208	41

The actual adult densities among the large regulated lakes was similar, 0.46 loons/100 ha of water area, while the interior lake density was 3.55 adult loons/100 ha of water area.

The overall mean loon pair occupancy rate of 83 potential territories, identified from the 1979-1982 park surveys, and 39 additional territories identified from the 1983-1986 surveys, was 75.5% (Table 2). Pairs on Kabetogama Lake had the lowest occupancy rate, 61.9%. Nine (10.8%) of the original 83 identified territories were not utilized during 1983-1986.

B. Reproduction.

Reproductive success in Voyageurs' loons was variable (Table 3). Lake classification based on water level fluctuations exerted a significant influence over the 1979-1986 reproductive output ($F = 6.11$, $DF = 4{,}101$, $p < 0.0002$), but there was no significant year alone or year/lake interactions. Rainy Lake had a significantly higher reproductive rate than Kabetogama and Namakan Lakes (Table 3). The overall mean reproductive rate in Voyageurs was 0.39 ± 0.066 fledged yg/pr/yr (Table 4).

C. Nesting.

Of the 155 known loon nesting attempts in the 122 potential territories from 1983-1986, 54.8% were successful. The highest success rate was on Rainy Lake (70.2%) where water levels fluctuated less than naturally (Table 5). On the large regulated lakes, the most common nest loss was due to rising water levels (63.6%, $n = 28/44$ losses). Desertion, due to human disturbance, and predation accounted for 27.3% ($n = 12/44$ losses) of the nest losses. The interior lakes had a 35% success rate and suffered greater losses from predation and desertion (61.6%, $n = 16/26$ losses) ($X^2 = 3.44$, $DF = 1$, $p < 0.10$) than did nest attempts on the large regulated lakes (Table 5). Only one predation event was observed in the four years of the study, a raven removed two eggs from a nest and cached them in a nearby red pine.

On the large regulated lakes, 62.6% ($n = 62$) of all nesting attempts on known substrates were on islands, while 29.7% ($n = 11$) of all nesting attempts on known substrates on the interior lakes were on islands. The number of island nesting attempts was significantly different between Rainy

Table 2. The number and percentages of common loon territories occuppied by pairs in Voyageurs National Park, 1979 - 1986. (N = number of potential territories, Occ(%) = occupancy rate(%) of territories checked, ND = no data, Total ± S.E.).

Lake area	1979		1980		1981		1982		1983		1984		1985		1986		Total	
	N	Occ(%)	N	Occ(%)	N	Occ(%)	N	Occ(%)	N	Occ(%)	N	Occ(%)	N	Occ(%)	N	Occ(%)	N	Occ(%)
Rainy	23	70.6	23	78.6	23	88.2	23	78.6	27	80.0	36	88.6	38	83.3	40	77.8	40	80.7 ± 2.09
Kabetogama	19	43.8	19	50.0	19	68.8	19	79.0	26	83.3	26	41.7	28	60.7	28	68.2	28	61.9 ± 5.54
Namakan	15	88.9	15	87.5	15	53.9	15	72.7	17	80.0	18	75.0	20	70.0	21	76.2	21	75.5 ± 3.89
Sand Point	ND	ND	3	66.7	ND	ND	3	66.7	4	75.0	6	83.3	6	83.3	6	83.3	6	73.6 ± 3.33
Interior Lakes	23	100	23	92.9	ND	ND	23	91.3	25	75.0	25	76.0	27	80.8	27	85.2	27	85.9 ± 3.52
Total	80	75.8 ± 12.28	83	75.1 ± 7.69	57	70.3 ± 9.93	83	77.7 ± 4.08	99	78.7 ± 1.61	111	72.9 ± 8.19	119	75.6 ± 4.47	122	74.8 ± 3.38	122	75.5 ± 4.02

Table 3. Number of young per adult common loon observed in Voyageurs National Park, 1979 - 1986.

Year	Rainy	Kabeto-gama	Namakan	Sand Point	Interior Lakes	VNP overall ratio
1979	0.18	0.04	0.24	ND	0.55	0.20
1980	0.17	0.00	0.06	0.00	0.39	0.16
1981	0.30	0.15	0.18	ND	ND	0.24
1982	0.23	0.17	0.17	0.33	0.06	0.23
1983	0.15	0.05	0.00	0.25	0.05	0.08
1984	0.25	0.06	0.09	0.07	0.17	0.16
1985	0.21	0.05	0.09	0.07	0.10	0.13
1986	0.30	0.08	0.11	0.50	0.18	0.20
Average (1979-86):	0.22^{a}	0.08^{b}	0.12^{b}	0.20	0.21	0.18

ND = no data collected

a is significantly different from b ($S = 2.99$, $DF = 4,101$, $\alpha = 0.05$)

Table 4. Number of fledged young per pair in North American populations of the common loon.

Region[1]	Years	No. of pairs	No. of fledged young	Fledged young per pair and year	Reference
VNP	1979-86	582	227	0.39	(this study)
Rainy	1979-86	198	112	0.57	(this study)
K,N,SP	1979-86	256	64	0.25	(this study)
Inter.	1979-86	128	49	0.38	(this study)
BWCA	1950-84	224	115	0.51	Mooty & Goodermote (1985)
Chippewa National Forest	1970-74	25	20	0.80	McIntyre (1975)
Saskat-chewan	1973-74	198	106	0.54	Yonge (1981)

[1]Rainy L. fluctuates less than natural conditions. Kabetogama K), Namakan (N), and Sand Point (SP) Lakes fluctuate more than under natural conditions. The interior lakes (Inter.) fluctuate under natural conditions.

VNP = Voyageurs National Park, Minnesota

BWCA = Boundary Waters Canoe Area, northeastern Minnesota.

Table 5. Outcome of common loon nesting attempts in Voyageurs National Park, 1983 - 1986. Percentages in ( ) are based on the total number of nesting attempts by lake, and percentages in [ ] are based on the total number of nest losses per lake.

Nest outcome	Rainy (n=67) [n=20] N	(%)	Kabetogama (n=16) [n= 7] N	(%)	Namakan (n=20) [n=11] N	(%)	Sand Point (n=12) [n= 6] N	(%)	Interior Lakes (n=40) [n=26] N	(%)	Total (n=155) [n= 70] N	(%)
Successful	47	(70.2)	9	(56.3)	9	(45.0)	6	(50.0)	14	(35.0)	85	(54.8)
Flooded out	12	(17.9) [60.0]	4	(25.0) [57.1]	6	(30.0) [54.6]	6	(50.0) [100.0]	0	(00.0) [00.0]	28	(18.1) [40.0]
Predation	4	(6.0) [20.1]	1	(6.3) [14.3]	2	(10.0) [18.2]	0	(00.0) [00.0]	13	(32.5) [50.0]	20	(12.9) [28.6]
Abandoned	1	(1.5) [5.0]	1	(6.3) [14.3]	3	(15.0) [27.3]	0	(00.0) [00.0]	3	(7.5) [11.5]	8	(5.2) [11.4]
Storm loss	1	(1.5) [5.0]	1	(6.3) [14.3]	0	(00.0) [00.0]	0	(00.0) [00.0]	0	(00.0) [00.0]	2	(1.3) [2.9]
Unknown	2	(3.0) [10.0]	0	(00.0) [00.0]	0	(00.0) [00.0]	0	(00.0) [00.0]	10	(25.0) [38.5]	12	(7.7) [17.1]

Lake and the Namakan Reservoir lakes ($X^2 = 5.23$, DF = 1, $p < 0.01$). The second major nesting substrate was bog vegetation which comprised 27.3% (n = 27) of all attempts on the large regulated lakes, and 46.0% (n = 17) of attempts on the interior lakes. There was no significant difference in the number of bog nesting attempts between Rainy Lake and the Namakan Reservoir lakes. Other nest-site types were mainland, open water and other (i.e., on a log). Nesting substrate was unknown for 12.3% of the nesting attempts in the park.

A successful or failed nesting attempt was not independent of nest site type ($X^2 = 11.28$, DF = 1, $p < 0.005$). Island nesting attempts were successful 49.3% of the time compared to 63.6% of bog nesting attempts on all lakes. On Voyageurs' major lakes, 54.8% of island nest attempts succeeded while 77.8% of bog attempts were successful. There was no significant difference between Rainy Lake and the Namakan Reservoir lakes regarding success rates on islands and bogs.

Cover densities around the nest site did not differ significantly between lake types, but did differ signficantly between bog and island sites ($X^2 = 21.28$, DF = 6, $p < 0.005$). Overall, the most prevalent cover densities used were moderate (26-50%) and high (51-75%). Twenty-four percent of known nesting attempts were found in moderate cover and 22% were found in high-density cover (Table 6). Bog and island nest sites did differ signfiicantly in the observability index ($X^2 = 8.42$, DF = 3, $p < 0.05$). Overall, more loon nests were categorized as noticeable (30.4%) (Table 7).

D. Brood-rearing.

In this study, a brood was considered successfully reared when at least one young reached the age of two weeks. During four breeding seasons, only five of 125 known young within Voyageurs were lost before two weeks of age, and only one was lost past two weeks of age. Probable causes of brood losses, at any age, included exhaustion or exposure related to weather conditions, predation by fish (e.g., northern pike (*Esox lucius*)) or snapping turtles (*Chelydra sepentina*), starvation, and human-caused (e.g., run over by power boats).

Table 6. Cover density for common loon nest sites, Voyageurs National Park, 1983 - 1986. (R = Rainy Lake, NR = Namakan Reservoir lakes, I = interior lakes).

Cover density index (%)	Nest Substrate: Bog			Island			Other			Total		
	R	NR	I	R	NR	I	R	NR	I	R	NR	I
1 (0)	0	0	0	4	2	2	0	2	0	4	4	2
2 (1-5)	0	0	6	5	8	0	0	2	3	5	10	9
3 (6-25)	1	1	3	9	4	0	1	4	3	11	9	6
4 (26-50)	4	3	1	13	3	6	0	0	2	17	6	9
5 (51-75)	7	3	4	8	4	3	0	0	0	15	7	7
6 (76-95)	4	2	3	1	1	0	0	0	1	5	3	4
7 (>95)	1	1	0	0	0	0	0	0	0	1	1	0
Total	17	10	17	40	22	11	1	8	9		135	

Table 7. Observability index for common loon nests, Voyageurs National Park, 1983 - 1986.

Observability index	Nest Substrate			Total
	Bog	Island	Other	
1 (Not visible)	16	13	2	31
2 (Look hard)	14	21	2	37
3 (Noticeable)	9	26	6	41
4 (Obvious)	5	13	8	26
Total	44	73	18	135

II. Red-necked Grebe.

A. Population characteristics.

Red-necked Grebes in Voyageurs are on the southeastern edge of their distributional range (Palmer 1962). From 1983-1986, the mean number of adult red-necked grebes in the park and areas 4 to 9 km from the western edge of the park was 67.3 (Figure 5). The Rainy Lake Study Area adult grebe population declined by 31.5% from 1983-1986. The decline occurred primarily in one bay, Jackfish Bay, where eight pairs did not return from the 1983 breeding season. During this same period, the adult red-necked grebe population on the Kabetogama Lake Study Area increased by 60.0% (Table 8).

The highest concentration of Red-necked Grebes was found on the Rainy Lake Study Area. Red-necked Grebes were also found in low numbers on the Kabetogama Lake Study Area. Habitat evaluation on Namakan and Sand Point Lakes indicated few suitable nesting locations, with the exception of localized habitat in Namakan(n =7 sites) and Sand Point (n = 3). Red-necked grebes were not observed on the interior lakes. Marginal to suitable grebe nesting habitat was found on 34% (n = 9) of the interior lakes.

B. Reproduction.

Reproductive success in the Red-necked Grebe population was relatively stable during 1983-1986, $x = 0.15 \pm 0.032$ fledged young/adult. Mean reproductive rates were not significantly different between Rainy and Kabetogama Lakes (0.15 and 0.14 fledged young/adult, respectively) (Tables 9 and 10).

C. Nesting.

Red-necked Grebe nests were primarily located within a 10m band of emergent vegetation, measured from the vegetation - open-water edge back toward the shoreline. Only four nests were exceptions to the above. There was no difference in nest site location between Rainy and Kabetogama Lake Study Areas. Overall, most nest sites were located in pure common cattail stands (43.1%, n = 69), while another 36.9% (n = 59) were located in mixed stands of cattail and hardstem bulrush. About 46% (n = 73) of all nests were found in cover density of 6-25%. The second most prevalent cover density around a nest site was the 26-50% class (25.6%, n = 41) (Table 11). Nesting attempts were not evenly distributed among the available cover density categories ($D = 0.3598$, $n = 160$, $p < 0.001$), and, again,

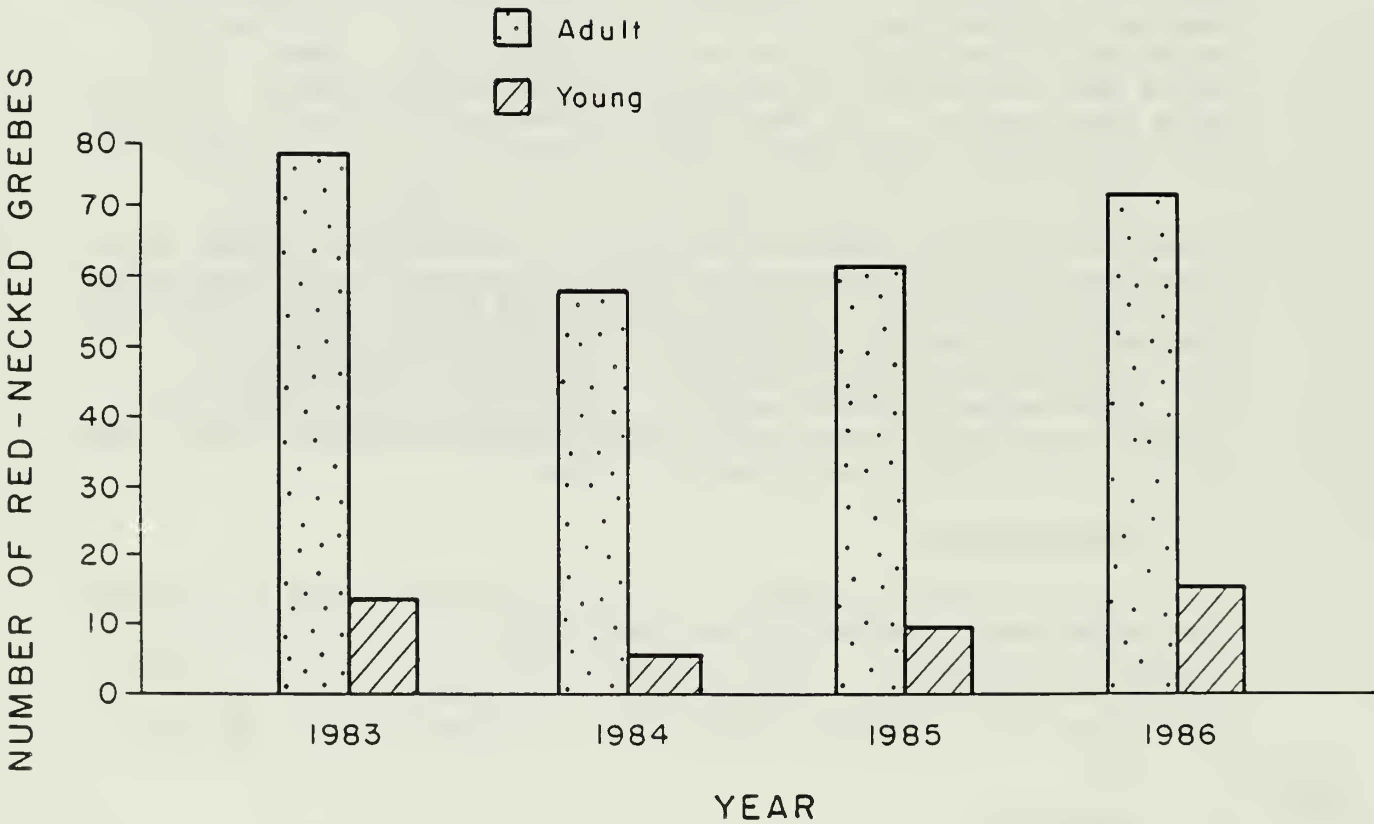

Figure 5. Number of adult and fledged young Red-necked Grebes in Voyageurs National Park and adjacent areas, 1983-1986.

Table 8. Number of adult and fledged young red-necked grebes in Voyageurs National Park and adjacent areas west of the park, by study area, 1983 - 1986. (A = adult, Y = young).

Study area	1983		1984		1985		1986	
	A	Y	A	Y	A	Y	A	Y
Rainy	54	11	43	5	38	3	37	7
Kabetogama	24	2	14	0	24	6	35	8
Total	78	13	57	5	62	9	72	15

Table 9. Number of young per adult red-necked grebe observed in Voyageurs National Park and adjacent areas, 1983 - 1986.

Year	Rainy	Kabeto-gama	VNP overall ratio
1983	0.20	0.08	0.14
1984	0.12	0.00	0.06
1985	0.08	0.25	0.17
1986	0.19	0.23	0.21
Mean	0.15	0.14	0.15

Table 10. Number of fledged young per pair in North American populations of the red-necked grebe.

Region[1]	Years	No. of adults	No. of fledged young	Fledged yg. per ad. and year	Reference
VNP	1983-86	269	42	0.16	this study
Rainy	1983-86	172	26	0.15	this study
K,N,SP	1983-86	97	16	0.17	this study
Interior	1983-86	0	0	0.00	this study
Central Minn.	1978-83	312	174	0.56	Perry & Bloch (1983)
British Columbia	1936-41	150	106	0.71	Munro(1941)

[1]Rainy L. fluctuates less than natural conditions. Kabetogama (K), Namakan (N), and Sand Point (SP) Lakes fluctuate more than natural conditions. The interior lakes fluctuate under natural conditions.

VNP = Voyageurs National Park, Minnesota

Table 11. Cover density for red-necked grebe nest sites in Voyageurs National Park, 1983 - 1986.

Cover density index (%)	N	Relative frequency
1 (0)	6	3.8
2 (1-5)	29	18.1
3 (6-25)	73	45.6
4 (26-50)	41	25.6
5 (51-75)	11	6.9
6 (76-95)	0	0.0
7 (>95)	0	0.0

there was no difference in cover densities of nest sites between Rainy and Kabetogama Lake Study Areas.

From 1983-1986, 13.8% (n = 22) of 160 known nesting attempts were successful. Nesting success was independent of lake type. Other nesting outcomes, flooded-out nests, predation, and desertion were also independent of lake type. Flooded nests due to rising lake levels caused the greatest number of nest losses (53.3%, n = 73/137 losses) (Table 12).

Mink were the primary predators on Red-necked Grebe eggs. Two owl-killed adults were noted during this study. An additional predator on adult Red-necked Grebes was the Common Loon. One adult was found dead with a piercing wound which entered dorsally through the abdomen.

D. Brood-rearing.

During this study, four out of 52 Red-necked Grebe chicks disappeared prior to two weeks of age, and six losses occurred in young older than two weeks. Possible causes of brood losses included predation by northern pike or snapping turtles, and exposure related to inclement weather. One known cause of brood loss was starvation. In this case, the adults aggressively kept the chick away from the remainder of the brood, and also were not feeding the chick.

III. Effects of fluctuating lake levels.

A. Common Loon.

Annual lake-level fluctuation ranged from < 1m to > 3m on the Voyageurs' major lakes, and the timing of peak summer levels varied from year to year (Table 13). Rainy Lake generally reached peak levels in late June through early July, while the Namakan Reservoir lakes peaked approximately two weeks later. A major exception to this pattern, in the past eight years, was 1980 which was an extremely dry year. Productivity by Common Loons on the major lakes in 1980 was also the lowest deserved (0.06 fledged young/adult). Interior lake levels peaked soon after ice-out and spring snow melt. Some increases may have occurred during times of local rainfall, but as no flooded nests were found on the interior lakes in four years, these fluctuations were probably minor.

The range in variation in lake levels (Figure 6) was also much greater on the park's major lakes than on the naturally fluctuating interior lakes. During the breeding seasons, May-July 1979-1986, Rainy Lake ranged between 3-69

Table 12. Nest outcomes for red-necked grebes in Rainy (R) and Kabetogama (K) Lake Study Areas in Voyageurs National Park, 1983 - 1986. Percentages in ( ) are based on the total number of nesting attempts per lake, and percentages in [ ] are based on the total number of nest losses per lake.

Nest outcome	1983 R	1983 K	1984 R	1984 K	1985 R	1985 K	1986 R	1986 K	Total (n=160) [n=137]
Successful	8	0	3	0	2	3	3	3	22 (13.8)
Flooded out	35	4	17	4	5	4	2	2	73 (45.3) [53.3]
Predation	4	0	9	0	6	1	11	2	33 (20.6) [24.1]
Abandoned	1	0	5	0	2	0	1	2	11 (6.9) [8.0]
Unknown	3	0	8	1	3	0	3	3	21 (13.1) [15.3]
Total	51	4	42	5	18	8	20	12	160

Table 13. Date peak water levels reached in Voyageurs National Park's major lakes, 1979 - 1986.

Year	Rainy Lake	Namakan Reservoir Lakes
1979	June 6	July 15
1980	November 20	October 6
1981	June 26	July 3
1982	July 10	July 26
1983	July 4	July 11
1984	July 3	August 5
1985	July 7	June 25
1986	May 24	July 6

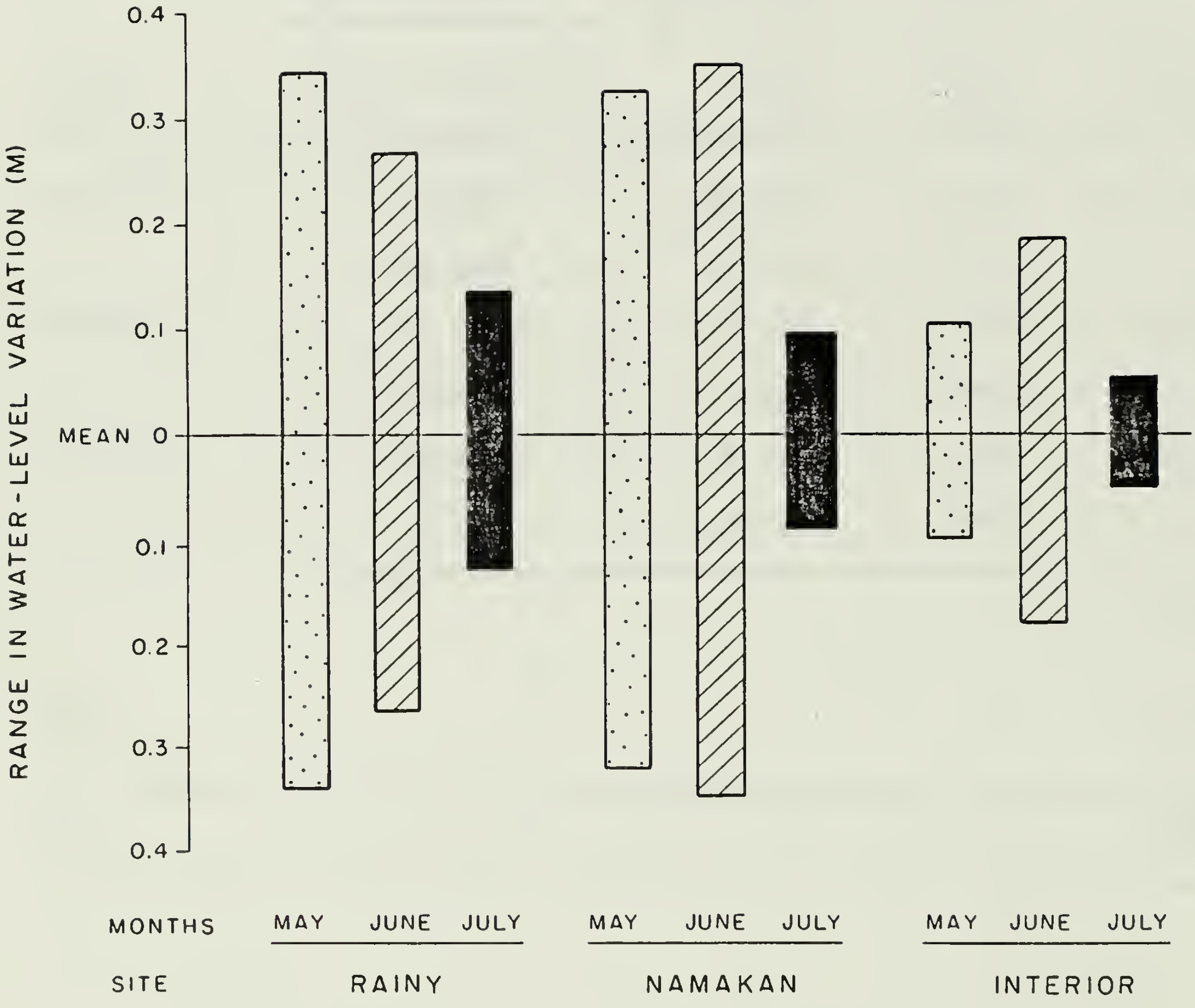

Figure 6. The range in variation in monthly lake levels for Rainy Lake, the Namakan Reservoir lakes (1979-1986), and the interior lakes (1983-1986).

cm, and the Namakan Reservoir lakes fluctuated between 8-129 cm. Interior lakes generally underwent gradual declines of 5-22 cm. (1983-1985).

Local precipitation was not a significant predictor of lake level changes for both Rainy ($r^2 = 0.151$, $n = 23$, $p = 0.066$) and the Namakan Reservoir lakes ($r^2 = 0.000$, $n = 23$, $p = 0.953$).

Loon pairs occupied territories at approximately the same rate between regulated lakes fluctuating < 1m, and park lakes experiencing natural fluctuations, (80.7% and 85.9%, respectively). Loon pairs on regulated lakes which fluctuated > 3m, however, had a significantly lower ($\alpha = 0.05$, Bonferroni probability level) occupancy rate (70.3%) (Table 14).

Productivity (fledged young/adult) on park lakes was also effected by lake type ($F = 6.11$, $DF = 4,101$, $p < 0.0002$). Analysis of all pair-wise comparisons among the lake groupings, Rainy Lake, Namakan Reservoir lakes, and the interior lakes, showed that the productivity on Rainy (< 1m fluctuation) differed significantly ($\alpha = 0.05$, Bonferroni probability level) from those lakes fluctuating > 3m, but not from the naturally fluctuating interior lakes.

Did water level changes also effect nesting outcomes? Most nest flooding occurred in June, so June values of the variables precipitation and lake level changes were utilized in the analysis. These two covariates were significant ($F = 36.11$, $DF = 2,4$, $p < 0.003$) in explaining the proportion of flooded common loon nests between Rainy Lake and the Namakan Reservoir lakes. However, when flooded-out nest attempts were only analyzed between years (1983-1986) and across the park's major lakes, there was a highly significant effect between years ($F = 5.16$, $DF = 3,153$, $p = 0.002$). The year effect also followed a significant quadratic pattern ($F = 15.80$, $DF = 1,51$, $p = 0.000$). The proportion of flooded nests also showed a significant interaction effect between years and across the major regulated lakes ($F = 2.39$, $DF = 9,153$, $p = 0.02$). The years 1984 and 1985 had a significantly higher percentage of flooded nests than 1986 ($q = 4.428$, $DF = 220$, $\alpha = 0.05$), and 1983 was similar to 1986. I was unable to analyze together the effects of the two covariates, precipitation and lake-level changes along with years on flooded-out nests due to the lack of degrees of freedom. The covariates are at least partial causes of the year-to-year variation.

Table 14. Effects of water-level fluctuations on the occupation and nesting success rates (%) of loon territories in Voyageurs National Park, 1979 - 1986.

	Regulated Lakes		Unregulated Lakes
Water-level fluctuations	Rainy Lake < 1m	Namakan Reservoir Lakes > 1m	Interior Lakes < 1m
Territories potential n =	40	55	27
% occupied =	80.7	70.3	85.9
% success rate of occupied territories =	46.3	28.1	36.4

In order to be able to predict percentages of flooded loon nests, a stepwise multiple regression analysis was also conducted on the June values of the variables (1983-1986). A significant proportion of the variation in flooded-out nests could be explained by lake level changes alone ($F = 16.52$, $DF= 1,6$, $p < 0.02$, $r^2 = 73.4\%$) (Table 15). The ability to predict the number of nests lost to flooding was moderate, but not significant (Table 16). When the computednatural lake-level change for the month of June, 1983-1985, was used in the regression equations, predicted percentages of nest losses due to flooding decreased on the Namakan Reservoir lakes. The mean loss under actual conditions for 1983-1985 was 47.1%, while under computed natural conditions (1983-1985), the mean loss would have declined to a 27.1% nest loss. On Rainy Lake, current mean losses to flooding (1983-1985) was 26.9% and under natural conditions, the mean remained similar at 25.4% (Figure 7). The number of young Common Loons potentially lost from flooded-out nests would decline by 34% on Rainy Lake, and by 70% on the Namakan Reservoir lakes (Table 17). Since there was no significant relationship between the predictor variables and the number of flooded nests (Table 16), the specific percent declines should be viewed with caution.

Under regulated lake conditions from 1950-1985, only eight years have followed "ideal" timings of peak water levels, and/or patterns of fluctuations. Under computed natural conditions during this period, 14 nesting seasons would have followed "ideal" timings of peak water levels and/or patterns of fluctuations. Natural water fluctuation regimes would result in one of every 2.5 years being highly productive versus only one of every 4.4 years being highly productive under regulated conditions. "Ideal" conditions are defined as peak lake levels achieved by the 10th of June and/or water level changes (declines or rises) of not more than 15 cm during the month of June. Common Loon nests on the major park lakes were an average 10.7 cm above the water surface. Loons do add nest material if water levels rise and can maintain the nest if water rises slowly (Strong, pers. comm.).

In addition to individual nests flooding out, small rock islands were completely flooded during June which eliminated previously-used nest sites. The protracted rising water levels in June and July inhibited other loon pairs from nesting or delayed initiation of nesting until early July. Though delayed or late renesting attempts were frequently successful (91%, n=23), these young had four to six weeks less time to mature or increase fat reserves prior to migration, which begins in mid-September. However, no data was collected on weight or fat reserve differences

Table 15. Results of a stepwise multiple linear regression of the variables June lake level change (LLEV), June precipitation (PREC), and lake type (LATY) on the percent of flooded common loon nests in June. The $R^2_{(adj)}$ is adjusted for degrees of freedom.

Equation	F	DF	p<	$R^2_{(adj)}$
y = -38.91 + 0.359(LLEV) + 2.582(PREC) + 11.300(LATY)	15.54	3,4	0.02	86.2 %

Step	Independent variable entered	Multiple R	Multiple R^2	Change in R^2	F to enter
1	LLEV	0.857	0.734	0.734	16.52
2	PREC	0.924	0.854	0.120	4.14
3	LATY	0.960	0.921	0.067	3.37

Table 16. Results of a stepwise multiple linear regression of the variables June lake level change (LLEV), June precipitation (PREC), and lake type (LATY) on the number of flooded common loon nests in June. The $R^2_{(adj)}$ is adjusted for degrees of freedom.

Equation	F	DF	p<	$R^2_{(adj)}$
y = -1.55 + 1.186(LATY) + 0.069(LLEV)	4.16	2.4	0.20	54.2 %

Step	Independent variable entered	Multiple R	Multiple R^2	Change in R^2	F to enter
1	LATY	0.640	0.409	0.409	5.93
2	LLEV	0.752	0.631	0.222	1.25

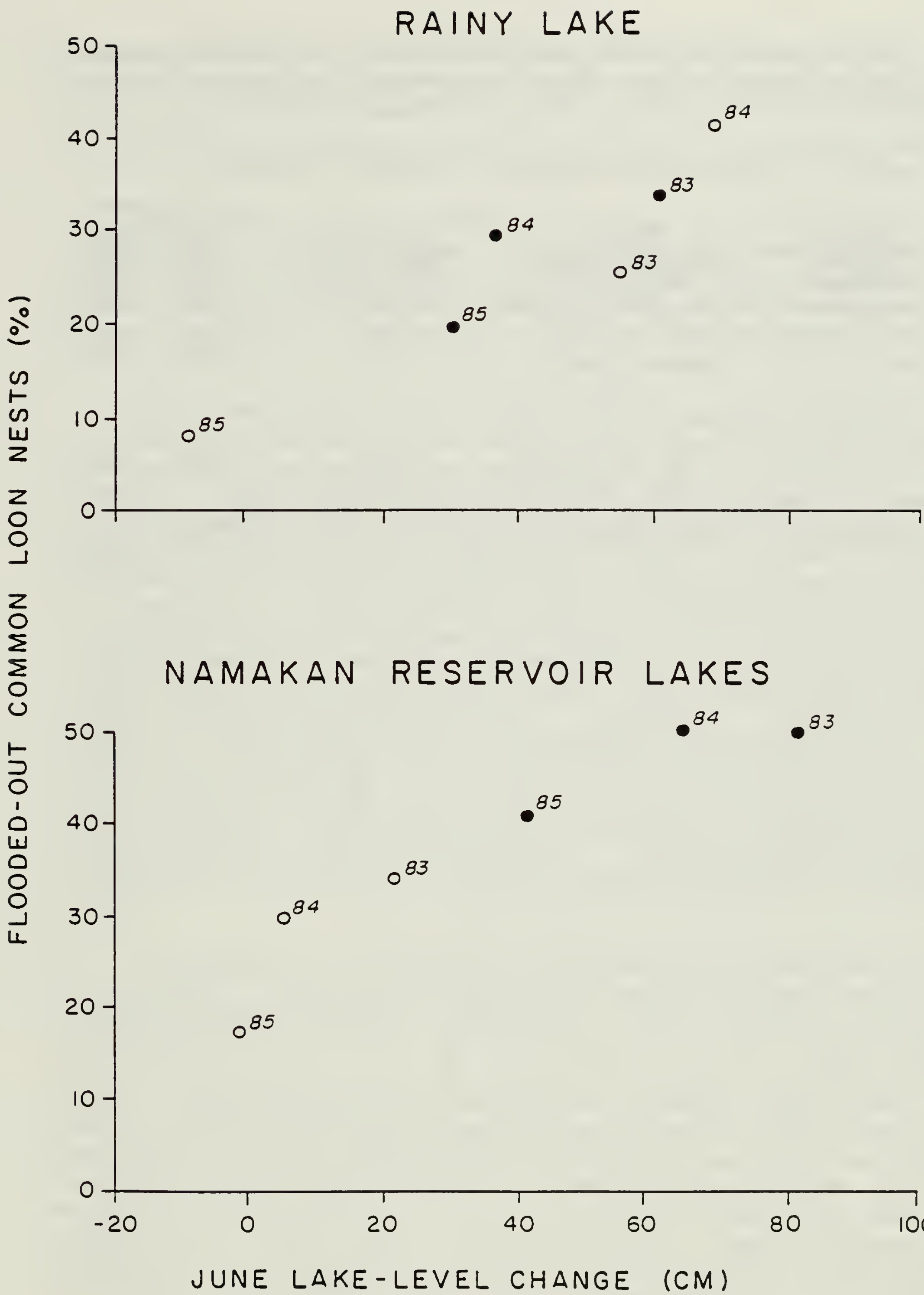

Figure 7. The percent Common Loon nest loss from flooding compared to actual (regulated) and computed natural June lake level changes on Rainy Lake, and on the Namakan Reservoir lakes, 1983 - 1985. (● = actual, ○ = natural).

Table 17. Actual (1983-1985) and estimated natural (1983-1985) common loon nest losses, and potential chick losses from flooding on Rainy Lake and the Namakan Reservoir lakes. Mean percent nest loss in ( ).

Lake	No. of nesting attempts	No. of nests lost(%)		$\bar{x}$ no. of fledged young per nest	No. of young lost from flooded nests	
		Act	Nat		Act	Nat
Rainy	46	12 (26.9)	8.0 (25.4)	1.0	12.0	8.0
Namakan Reservoir	33	15 (47.1)	4.4 (27.1)	0.58	8.7	2.6

between early or late hatchings, and no research to date has studied first-year survival rates of young with widely varying hatching times.

B. Red-necked Grebe and other marsh-nesting birds.

The period of greatest nest loss for Red-necked and Pied-billed Grebes, Sora, Black Tern, and Red-winged and Yellow-headed Blackbirds from flooding also occurred in June (Table 18). Since weekly nest checks were conducted on these species, I was able to look at the effects of June precipitation and lake-level changes on a weekly basis.

The covariate, June lake level changes provided a significant contribution in explaining the proportion of flooded Red-necked Grebe nests ($F = 12.49$, $DF = 1,25$, $p = 0.002$). Red-necked Grebes nest on the surface of the water, but the nests are anchored to submerged detritus and living aquatic plants so that rapid increases in lake levels during incubation can have a significant effect on nest losses due to flooding. The covariate June precipitation had no effect on percentages of flooded out nests. There were also no significant differences between lakes or weeks regarding the percentages of flooded out nests. The other marsh nesting birds were analyzed together. Lake-level change had a weak effect on the proportion of flooded-out nests of the other marsh nesting birds ($F = 3.55$, $DF = 1,25$, $p = 0.071$). As this group includes both surface-water nesters and above-water nesters, the magnitude of lake-level changes would differentially effect the birds. Lake and week were not significant grouping variables with regards to flooded nests.

Analysis of flooded-out red-necked grebe nests between lake types, weeks, and years, but with no hydrological or climatological factors included, again showed a significant year effect ($F = 7.00$, $DF = 3,9$, $p < 0.02$). Lake type ($F = 5.08$, $DF = 1,9$, $p < 0.10$) and week ($F = 4.70$, $DF = 3,9$, $p < 0.10$) both had a slight effect on flooded Red-necked Grebe nests. When the flooded-out nest data was analyzed for the remainder of the marsh nesting birds, week was the only time variable that significantly effected proportions of flooded nests ($F = 5.85$, $DF = 3,9$, $p < 0.05$). Lake type had a minor effect ($F = 5.51$, $DF = 1,9$, $p < 0.10$). Again, there was no satisfactory method of analysis that jointly considered time variables and hydrological and climatological factors.

Stepwise multiple regression analysis was also conducted on the June values of lake-level change and precipitation, and lake type as predictors of the percent of flooded-out Red-necked Grebe nests and the other marsh

Table 18. Nest fate of "on water" nesters (aquatic birds), and "over water" nesters (marsh birds), in Voyageurs National Park, 1983 - 1986. (R = Rainy Lake, NR = Namakan Reservoir lakes[1], A = aquatic, M = marsh, NO = no birds observed or heard).

Species[2]	Nest type	Total no. nest attempts		Successful(%)		Flooded out(%)		Other/ unknown[3]	
		R	NR	R	NR	R	NR	R	NR
RNGR	A	131	29	16 (12.2)	6 (20.7)	59 (45.0)	14 (48.3)	56 (42.8)	9 (31.0)
PBGR	A	19	4	10 (52.6)	0 (00.0)	6 (31.6)	4 (100)	3 (15.8)	0 (00.0)
BLTE[4]	A	111	2	66 (59.5)	0 (00.0)	19 (17.1)	2 (100)	26 (23.4)	0 (00.0)
SORA[5]	M	2	0	1 (50.0)	NO --	1 (50.0)	NO --	0 (00.0)	NO --
RWBL	M	138	64	103 (74.6)	33 (51.6)	17 (12.3)	18 (28.1)	18 (13.0)	13 (20.3)
YHBL[6]	M	66	0	43 (65.2)	0 (00.0)	8 (12.1)	0 (00.0)	15 (22.7)	0 (00.0)

1/ Only 10 RWBL nests were found in study sites on Namakan Lake, the remainder of the nesting attemps were all found on Kabetogama Lake study sites. No marsh-dwelling bird survey was conducted on NR during 1983.

2/ RNGR=red-necked grebe, PBGR=pied-billed grebe, BLTE=black tern, SORA=sora, RWBL=red-winged blackbird, YHBL=yellow-headed blackbird.

3/ This category includes nest losses from predation, desertion, and unknown.

4/ The major black tern colony did not return to its primary nest site on Rainy Lake in 1985 or 1986.

5/ Only 2 nests were found in 1983. Some eggs hatched from each nest, but the remainder of the clutch was flooded out. Each nest was scored ½ successful and ½ flooded out.

6/ An occassional male was spotted on Kabetogama Lake Study Area sites, but no evidence of breeding was found in the 1984 - 1986 surveys.

nesting birds (Tables 19 and 20). As with the Common Loon, the number of flooded Red-necked Grebe nests predicted from the above three variables was moderate, but not significant. The number of flooded marsh nesting birds' nests was significantly explained by lake-level change and lake type (Tables 21 and 22).

If computed natural lake-level changes from 1983-1985 were used to predict proportions of flooded nests of Red-necked Grebes and other marsh birds, increases in percent nest losses from regulated levels (1983-1985) would occur on Rainy Lake (8.6% and 44.0%, respectively). Namakan Reservoir lakes would show significant decreases in percent nest losses, 87.6% decline for Red-necked Grebes, and a 97.6% decline for the other marsh nesting birds (Figures 8 and 9). The number of young Red-necked Grebes potentially lost from flooded-out nests would decline slightly on Rainy Lake by 3.0%, and no young would potentially be lost from nests on Kabetogama Lake (Table 23).

IV. **Distribution and status of other marsh birds.**

The greatest diversity of nesting species occurred on the Rainy Lake Study Area, while the least number of nesting species was found consistently on the Namakan Lake Study Area (Tables 24 and 25). Both the interior lakes and the Namakan Lake Study Area had poorer quality marsh habitat in that the coverage was less extensive, fewer species of aquatic emergents were present, and the densities in the $1m^2$ quadrats were lower than on the Rainy Lake Study Area. Four species were found on all study areas for all years (1983-1986). Only the Common loon, and the Red-winged Blackbird actually nested. Two potential nesting species were unique to a particular marsh/bog habitat, the Virginia Rail (Rallus limicola) on one Namakan Lake study site, and the Yellow Rail (Coturnicops noveboracensis) on one site on Rainy Lake.

The habitat data from the random quadrants and nest-site quadrants were compared to levels of bird use on the four study areas. From the variable primary plant species, and two location variables, study area and study site, high-use bird areas were correctly classified as such, 85.7% of the time, and 68.6% of the low-use bird areas were classified into the proper group. The specific lake a marsh area was located on was most important in helping to explain bird use levels.

Table 19. Results of a stepwise multiple linear regression of the variables June lake level change (LLEV), June precipitation (PREC), and lake type (LATY) on the percent flooded red-necked grebe nests in June. The $R^2_{(adj)}$ is adjusted for degrees of freedom.

Equation	F	DF	p <	$R^2_{(adj)}$
y = -2.90 + 1.227(LLEV)	58.83	1,6	0.001	89.2 %

Step	Independent variable entered	Multiple R	Multiple R^2	Change in R^2	F to enter
1	LLEV	0.953	0.907	0.953	58.83

Table 20. Results of a stepwise multiple linear regression of the variables June lake level change (LLEV), June precipitation (PREC), nad lake type (LATY) on the percent of flooded out nests for the other marsh and aquatic birds in June. The $R^2_{(adj)}$ is adjusted for degrees of freedom.

Equation	F	DF	p <	$R^2_{(adj)}$
y = -27.07 + 1.497(LLEV)	7.04	1,5	0.10	50.2 %

Step	Independent variable entered	Multiple R	Multiple R^2	Change in R^2	F to enter
1	LLEV	0.765	0.585	0.585	7.04

Table 21. Results of a stepwise multiple linear regression of the variables June lake level change (LLEV), June precipitation (PREC), and lake type (LATY) on the number of flooded out red-necked grebe nests in June. The $R^2_{(adj)}$ is adjusted for degrees of freedom.

Equation	F	DF	p<	$R^2_{(adj)}$
y = 36.69 - 21.375(LATY) + 0.494(LLEV) - 1.303(PREC)	3.45	3,4	0.50	51.2 %

Step	Independent variable entered	Multiple R	R^2	Change in R^2	F to enter
1	LATY	0.545	0.297	0.297	2.54
2	LLEV	0.770	0.593	0.296	3.64
3	PREC	0.849	0.721	0.128	1.83

Table 22. Results of a stepwise multiple linear regression of the variables June lake level change (LLEV), June precipitation (PREC), and lake type (LATY) on the number of flooded out nests for the other marsh and aquatic birds in June. The $R^2_{(adj)}$ is adjusted for degrees of freedom.

Equation	F	DF	p<	$R^2_{(adj)}$
y = -27.07 + 0.596(LLEV) - 10.909(LATY)	10.83	2,4	0.05	76.6 %

Step	Independent variable entered	Multiple R	R^2	Change in R^2	F to enter
1	LLEV	0.772	0.596	0.596	7.36
2	LATY	0.919	0.844	0.248	6.38

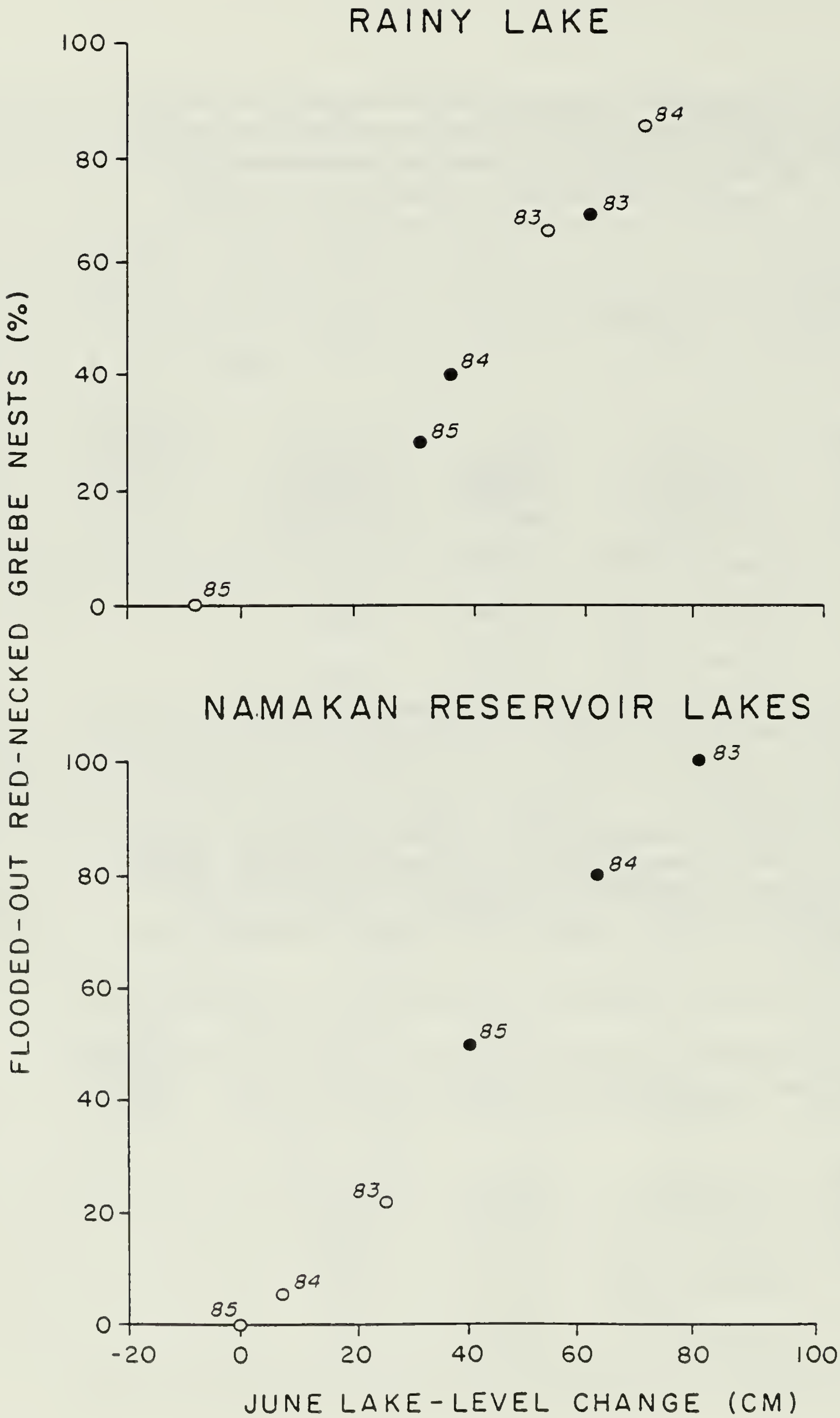

Figure 8. The percentage of Red-necked Grebe nest losses from flooding compared to actual (regulated), and computed natural June lake level changes on Rainy Lake, and on Kabetogama Lake, 1983 - 1985. (● = actual, ○ = natural).

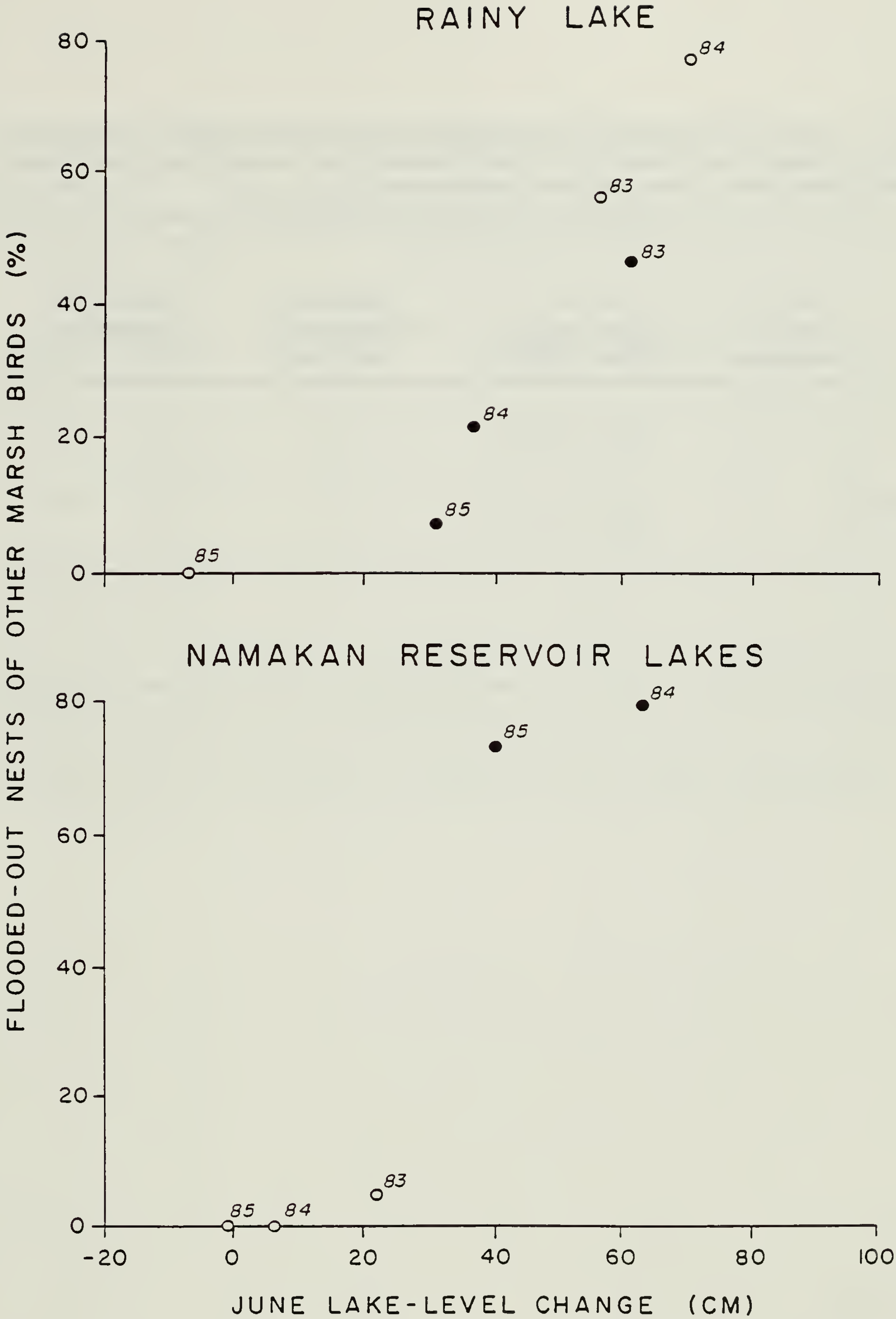

Figure 9. The percent nest loss from flooding of the other marsh birds compared to actual (regulated), and computed natural June lake level changes on Rainy Lake, and on the Namakan Reservoir lakes, 1983 - 1985. ● = actual, ○ = natural). No marsh-dwelling bird survey was conducted on the Namakan Reservoir lakes in 1983.

Table 23. Actual (1983-1985) and estimated natural (1983-1985) red-necked grebe nest losses, and potential chick losses from flooding on Rainy Lake and Kabetogama Lake. Mean percent nest loss in ( ).

Lake	No. of nesting attempts	No. of nests lost(%)		$\bar{x}$ no. of fledged young per nest	No. of young lost from flooded nests	
		Act	Nat		Act	Nat
Rainy	111	57 (45.6)	55.0 (49.9)	0.17	9.7	9.4
Kabetogama	17	12 (76.7)	0.0 (9.5)	0.47	5.6	0.0

Table 24. Number of bird species utilizing open water, marsh, and bog edge vegetation for reproductive activities on study areas in Voyageurs National Park, 1983 - 1986. (A = nests potentially affected by water fluctuations, U = nests unaffected by water fluctuations).

Area[1]	Known nesters A	Known nesters U	Unknown breeding status	Brood-rearing (excl. nesters)	Total no. species
RLSA	7	3[2]	4	2	13
KLSA	5	2[2]	5	2	11
NLSA	2	1[2]	3	1	5
ILSA	0	4	1	0	5

1/ RLSA=Rainy Lake Sudy Area, KLSA=Kabetogama Lake Study Area, NLSA=Namakan Lake Study Area, ILSA=Interior Lakes Study Area.

2/ Red-winged blackbirds nested in both affected marsh areas and unaffected bog edge vegetation. This species is counted in both 'nester' categories.

Table 25. Bird species occurrence and status list on study areas in Voyageurs National Park, 1983 - 1986.

Species[1]	Study Areas[2] Rainy	Kab.	Nam.	Int.	Status
COLO	X	X	X	X	Breeding - A[3]
RNGR	X	X			Breeding - A
PBGR	X	X			Breeding - A
AMBI	X	X			Unknown
MALL	X	X	X	X	Cover, Breeding - ?, Brood-rearing
BLWT	X	X			Cover, Breeding - ?, Brood-rearing
VIRA			X		Unknown
SORA	X				Breeding - A
YERA	X				Unknown
BLTE	X	X			Breeding - A
MAWR	X	X	X	X	Breeding - A,U[4]
SWSP	X	X		X	Breeding - U(?)
YHBL	X	X			Breeding - A(R)
RWBL	X	X	X	X	Breeding - A,U

[1]COLO = Common Loon, RNGR = Red-necked Grebe, PBGR - Pied-billed Grebe, AMBI = American Bittern, MALL = mallard, BLWT = Blue-winged Teal, VIRA = Virginia Rail, SORA = Sora, YERA = Yellow Rail, BLTE = Black Tern, MAWR = Marsh Wren, SWSP = Swamp Sparrow, YHBL = Yellow-headed Blackbird, RWBL = Red-winged Blackbird

[2]R = Rainy Lake, Kab. = Kabetogama Lake, Nam. = Namakan Lake, Int. = the interior lakes

[3]A = nesting in areas affected by water level fluctuations

[4]U = nesting in areas unaffected by water level fluctuations

DISCUSSION

Regulated water levels have had a negative impact on territory establishment and the reproductive success of selected members of the aquatic and marsh nesting avifauna community in Voyageurs National Park. This man-induced problem prevents the park from fulfilling its legislative mandate to conserve and protect its natural resources and to provide opportunities for the public to enjoy the park's wildlife (U.S. Code 1971). These general mandates are related to the directives of the National Park Service (U.S. Code 1916). Additionally, the overall park management strategy concerning water and land areas is to promote understanding and appreciation of the park's natural ecosystems and to "enhance recovery of park lands to their natural condition" (Voyageurs National Park 1980).

One member of the aquatic and marsh avifauna community, the Common Loon, is of particular concern. The Common Loon is Minnesota's state bird, and it has been listed as a "special concern" species by the Minnesota Department of Natural Resources. All the native aquatic plant life, and the aquatic and marsh-dwelling birds that depend on it for nesting habitat, brood-rearing, cover, and food are adapted to a natural water cycle. Evolutionarily, the aquatic and marsh nesting birds have adapted to the water cycles of natural boreal forest lakes and, accordingly, nest site selection and nesting occurs within the period of greatest lake-level stability. This condition is generally absent in Voyageurs National Park.

I. **Common Loon.**

The natural water-level fluctuations occurring on the interior lakes did not flood any nests. Barr (1986) also found no nest losses due to flooding on an unregulated lake system. On the interior lakes in the park, water levels peak soon after ice-out and spring run-off. High water levels are reached prior to nest initiation by loons, and more importantly, the timing of high water levels and the pattern of fluctuation throughout the breeding season are relatively consistent year to year.

Interior lake loons experienced lower than expected reproductive rates from reproductive rates seen on other naturally fluctuating lake systems (Table 4). Higher predation and desertion rates were responsible for the low nesting success rate on the park's interior lakes. Nest losses from known causes on the interior lakes showed an 81.3% loss from predation compared to a mean of a 17.4% on the large regulated lakes. McIntyre (1977) and Sutcliffe (1978) found predation rates by raccoons (Procycon lotor) on Common Loon nests to range from 63 to 80%. Common crows (Corvus brachyrhynchos) were also an egg predator in the above studies, but only gained access to a nest after prior human disturbance. The only instance of egg predation (by a common raven) in this study occurred after park visitors caused an incubating loon to leave a nest which was located on an islet. Other suspected or known loon nest predators and scavengers were the Herring Gull (Larus argentatus), and the mink (Mustela vison). Potential nest disturbers were muskrat (Ondata zibethicus), beaver (Castor canadensis), and otter (Lutra canadensis) (Ream 1976). An influx of visitor use can also be linked to higher densities of scavengers and egg predators. Food scraps and other garbage left on the shorelines by visitors were probably responsible for higher densities of raccoons (McIntyre 1975). Ream (1976) found that fish entrails thrown on shore by fisherman or left by campers attracted numerous ravens and crows. Similar garbage problems exist at some campsites on the interior lakes and at numerous undesignated island campsites on the park's large regulated lakes. However, measurement of potential predator and scavenger populations was beyond the scope of this study.

As interior lakes are relatively small (mean = 49.9 ha), there are few to no areas on the lakes free from potential human disturbance. All interior lakes are accessible either by hiking, canoes, motorized boats, or float planes, so nest islands and all shoreline can potentially be utilized by park visitors. This accessibility may be responsible for the higher desertion rate (18.8%) on the interior lakes compared to 11.2% of known nest losses from desertion on the park's major regulated lakes.

In contrast to the interior lakes, the single greatest cause of known nest losses on the park's artificially regulated lakes was rising water levels. Sixty percent of all nest losses on Rainy Lake were due to rising water, while over 70% of all nest losses on the Namakan Reservoir lakes were attributable to rising lake levels (Table 5). Loons are able to compensate for minimal and gradual rises in water levels, but June lake level increases of 31 - 81 cm caused an 18 - 50% loss of nesting attempts due to rising water. Barr (1986) found that water-level increases of only 15 cm during incubation was sufficient to cause nest flooding. Lake fluctuation regimes for Rainy Lake in survey years 1981, 1982, and 1986 met the "ideal" criterion under the current regulated conditions. For those years, the mean rise in June water level was 12.0 cm, and the mean reproductive rate was 0.28 fledged young/adult. The mean water level rise for the remaining years surveyed (1979, 1980, 1983, 1984, and 1985) was 30.7 cm. The mean rises to 35.7 cm if the drought year 1980 is excluded. Mean productivity level for these years was 0.19 fledged young/adult, and again, excluding the drought year, the reproductive rate was 0.20 fledged young/adult. This rate is almost 30% lower than the reproductive success seen in "ideal" years.

For the Namakan Reservoir lakes, "ideal" conditicns prevailed in 1979, 1982 and 1986. The mean rise in lake levels for those three years was 19.5 cm, and the mean reproductive rate was 0.20 fledged young/adult. The remaining survey years had a mean June water level rise of 50.1 cm, or 53.1 cm when the 1980 drought year was excluded. Reproductive success for the "non-ideal" survey years was 0.09 fledged young/adult, or 0.10 fledged young/adult when the drought year was excluded. The rate is a 50% decrease in productivity from the reproductive success rate under "ideal" conditions.

In 1986, there were no Common Loon nests lost to rising water in June on either Rainy Lake or the Namakan Reservoir lakes. Rainy Lake's water level rose 13.2 cm in June, 1986, while on the Namakan Reservoir lakes, the water level rose 33.6 cm. Water levels were relatively stable or slowing increasing until June 16.

Common Loons have shown a strong affinity to territories, previously-used nest sites and nursery areas (McIntyre 1974; Titus and VanDruff 1981; Strong 1987). Loons will delay nesting until lake levels recede, thus allowing specific nest sites to become available (Yonge 1981; Strong 1985; Barr 1986), or the birds will delay nesting until water levels rise, allowing access to traditionally-used nest sites. Yonge (1981) found that for loons residing on naturally fluctuating lakes, nest site selection and nesting were synchronized with the annual peak rise in lake levels. Fifty percent of the nests in his study also had successful egg hatches during this period of greatest lake level stability.

As water level fluctuations become greater and more unpredictable, access to a preferred nest site becomes less certain. The low spring water levels in Voyageurs following ice-out do not allow loons to establish nests on island sites or on bog marshes because extensive mud flats separate the bogs from open water. By late May or early June, bog and island sites are generally accessible. In years of drought, however, excessively low water levels make both islands and bogs unuseable as nest sites. The low productivity on Voyageurs regulated lakes during the 1980 breeding season (0.06 fledged young/adult) was at least partially due to severe drought conditions (Table 3). McIntyre (1978) found a similarly poor reproductive rate (0.13 fledged young/adult) during a drought year in Itasca State Park, Minnesota.

The range of water level increases through early to mid-July and the inconsistency in water level changes during the breeding season, however, make island and mainland sites unpredictable substrates. Floating bog sites, however, are unaffected by increases in water level, and consequently are more successful.

In territories with only a single appropriate nest site, inconsistent and unpredictable lake level changes could cause pairs to forego nesting in most years. Their strong affinity for particular nest sites would mean some loon pairs might never be successful in a nesting attempt. As replacement birds enter into the park's loon population, their inability to utilize appropriate nest sites for nesting attempts, or the subsequent low success rate of their nesting attempts could cause decreased territory and/or nest site fidelity, thus, perpetuating a high turnover rate and depressed reproductive success.

II. Red-necked Grebe and other marsh birds.

Red-necked Grebes are faced with similar effects of regulated lake-level fluctuations as are Common Loons. The extremely low spring water levels due to over-winter draw-down delays the timing of the emergence of aquatic macrophytes (Quennerstedt 1958; Anderson and Glover 1967). Stands of cattails and bulrushes provide ideal nesting cover and protection from predators. When water levels are low at the beginning of the nesting season in mid-May, Red-necked Grebes are forced to nest in very open conditions. These early open water nests are more vulnerable to storms and predation. Earlier, higher spring water levels can enhance the growth of emergent vegetation (Anderson and Glover 1967), increase seed production in <u>Scirpus</u> (Lieffers and Shay 1981), and in Voyageurs, it would allow emergent vegetation to grow at lower lake elevations (Kallemeyn 1987a).

In addition to lower spring water levels under regulated conditions, lake levels tend to be higher throughout the summer. Holding water levels high through the summer growing season (which does occur in Voyageurs) has been found to limit the distribution and variety of emergent vegetation (Quennerstedt 1958; Harris and Marshall 1963; Kallemeyn 1987a). If distribution of aquatic macrophytes is limited, nesting habitat for the marsh-dwelling birds is reduced.

Birds which nest in June are faced with protracted and steep rises in water levels. Water level increases of 9 cm/week have caused weekly Red-necked Grebe nest losses of 13 - 100% from 1983-1986. Though Red-necked Grebe nest records only cover the years 1983-1986, comparisons between "good" and "bad" years can still be made. In the one "ideal" year, 1986, the reproductive rate on Rainy Lake was 0.19 fledged young/adult, and 0.23 fledged young/adult on Kabetogama Lake. June lake levels rose 13.2 cm on Rainy Lake during 1986, and 33.8 cm on Kabetogama Lake. The steepest rise in the June water level on Kabetogama Lake occurred during the first two weeks, thus allowing ample time for Red-necked Grebes to initiate nesting or to renest. For "non-ideal" years, 1983-1985, mean reproductive rates on Rainy and Kabetogama

Lakes were 0.13 and 0.11 fledged young/adult, respectively. The mean June lake-level rises for those remaining years were 43.1 cm on Rainy Lake, and 61.3 cm on Kabetogama Lake.

The sharp rises in lake levels not only affect species nesting on the ground or on the water, but also marsh species whose nests are attached to a fixed substrate, such as cattail stalks. Red-winged Blackbirds can construct nests in habitat with little to no water below the nests (Weller and Spatcher 1965; Orians 1980). In most years, Red-winged Blackbirds initiate nest construction under low lake-level conditions from early to mid-June. The nests are built approximately 18 cm above the water surface, while the average increase in lake levels during nest building and incubation is 27.8 cm. Yellow-headed Blackbirds require deeper water before nest building begins, thus nesting is usually delayed until late June and early July. These birds are less susceptible to rising water levels flooding nests. Johnsgard (1956) found that Soras are particularly adapted to undisturbed marsh areas, and this species is one of the first to show population reductions through increased water levels. The absence of Soras, in particular on the Kabetogama Lake Study Area and evidence of only two nesting pairs on the Rainy Lake Study Area over the four years of this study, may be a reflection of the Sora's sensitivity to water fluctuations. Johnsgard (1956) also noted direct nest loss from flooding of Red-winged Blackbird nests and potential population reductions in Black Terns, Yellow-headed Blackbirds, and Pied-billed Grebes due to loss of breeding habitat and nesting cover. The depauperate marsh nesting avifauna community that exists on Voyageurs' regulated lakes may be the result of a combination of nest flooding, low spring lake levels and artificially-maintained high summer levels affecting the diversity and distribution of marsh vegetation.

MANAGEMENT RECOMMENDATIONS

In order to improve the reproductive success and population stability in Voyageurs National Park's aquatic and marsh nesting bird community, regulated water levels should peak by the first week of June and remain relatively stable through the second week of July (Figure 10). The majority of the known nesting species are incubating clutches by the second week of June. Thus, a direct benefit to the aquatic avifauna will be the elimination or significant reduction in nest losses directly due to flooding. The timing of peak lake levels and the period of lake stability should encompass the Common Loon's incubation period, which is the longest (26-29 days). Ensuring proper timing of peak water levels and stability in water levels through the loon's incubation period should afford significant improvement in the nesting success of all the other aquatic and marsh birds in Voyageurs

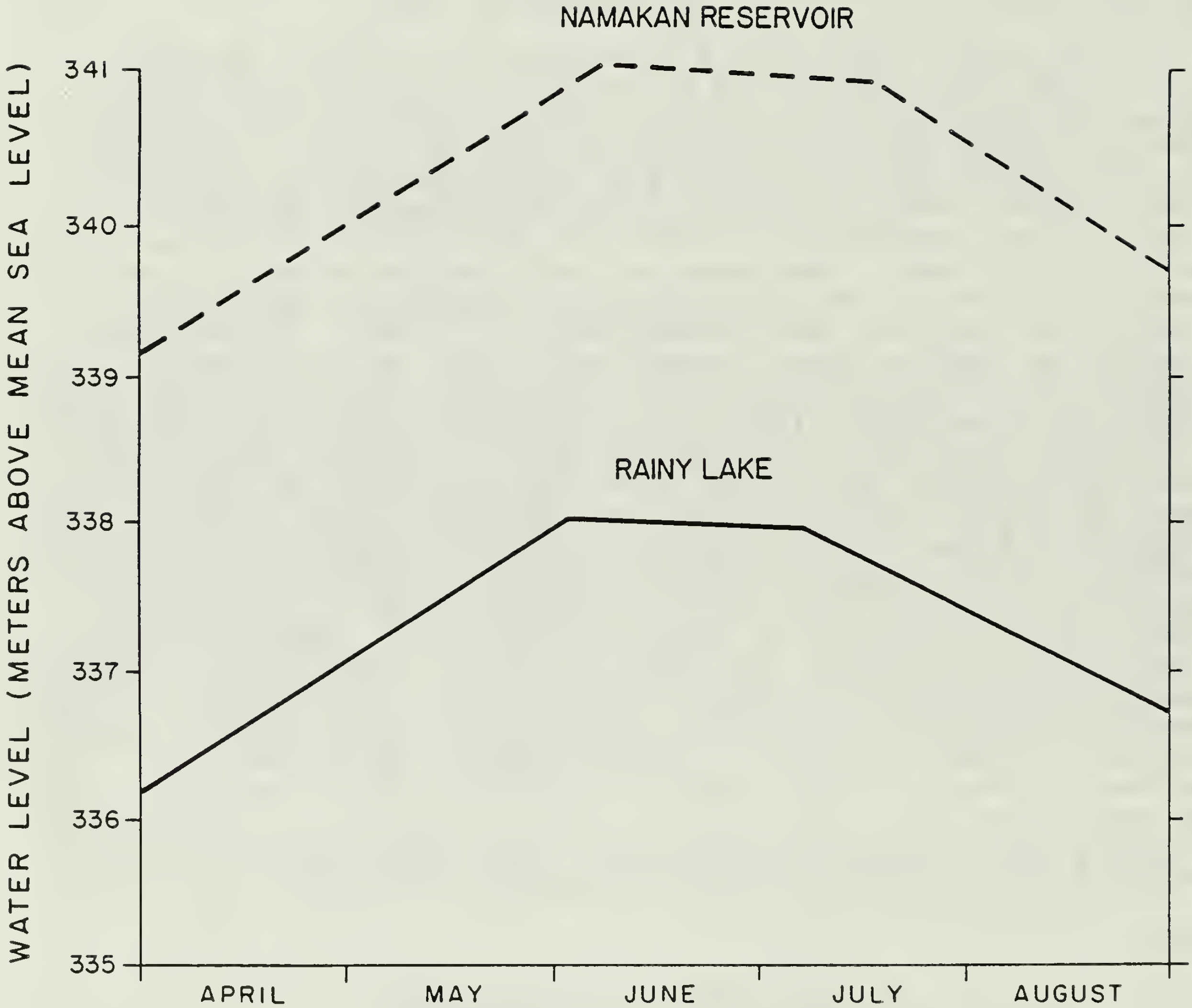

Figure 10. Proposed alternate water management regime to improve the reproductive success of the nesting aquatic avifauna in Voyageurs National Park. The regulation regime covers the months of April through August. (Solid line = Rainy Lake water levels, dashed line = the Namakan Reservoir lakes' water level).

National Park. Additionally, for over-the-water nesters, such as a Red-winged and Yellow-headed Blackbirds, nestling drownings should also be eliminated. A third benefit of more natural timings of peak lake levels and stability during June might be a reduction of mink predation on aquatic and marsh birds. Low water levels can persist until mid-June in the park. Low water levels allow mink to travel deep into marsh areas where they prey on aquatic birds (Proulx et al. 1987).

Declining summer water levels, particularly after the majority of nesting is completed (at the beginning of July), might benefit the aquatic vegetation which, in the future, would improve conditions for marsh-dwelling birds. If the distribution and diversity of the emergent plants can be increased, then the distribution and diversity of the aquatic and marsh avifauna might increase as well. Quennerstedt (1958) found that persistent high water level conditions also damaged or destroyed epilithic vegetation, including diatoms. Not only can emergent vegetation be harmed by high water levels, but submergent vegetation, as well, which could play a role in reducing populations and diversity of aquatic invertebrates, a food source for many aquatic and marsh birds.

A modified lake-level management program will provide more favorable conditions to the aquatic and marsh avifauna. Reductions in nest losses directly due to flooding should be evident within a few breeding seasons of fluctuations following a more natural course. If the aquatic vegetation responded to a modified regulation regime, long-term improvements in the aquatic and marsh bird community might include population increases and expanded distributions through the park. Along with improved breeding conditions, visitors to the park would have increased opportunities to enjoy the bird life. The sight of young Common Loons and Red-necked Grebes swimming beside their parents might shift from being an infrequent and rare observation to being commonplace.

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APPENDIX I. Surface areas of interior lakes and major lakes located in Voyageurs National Park.

A. Interior Lakes

Interior Lakes	Area(ha)
Agnes	12.95
Beast	32.78
Brown	30.76
Cruiser	46.54
Ek	36.02
Fishmouth	12.95
Jorgens	24.69
Little Shoepack	22.66
Little Trout	96.72
Locator	56.66
Loiten	36.62
Lucille	53.02
McDevitt	12.14
Mukooda	304.98
Net	43.71
O'Leary	78.51
Oslo	42.49
Peary	45.33
Quarterline	8.30
Quill	34.40
Ryan	14.16
Shoepack	123.84
Tooth	23.47
War Club	36.83
Weir	26.83
Wiyapka	20.24
Total:	1,277.58

B. Major Lakes

Major Lakes	Area(ha)
Rainy	14,916
Kabetogama	10,425
Namakan	5,686
Sand Point	2,299
Total	33,326
Grand Total	34,603.58

APPENDIX II. Study areas in Voyageurs National Park and adjacent areas. (Refer to Figure 3 for specific study area and study site locations.)

Study Area	Study Site	Map Location Code
Rainy Lake	Frank's Bay	R-1
	Tilson Bay	R-2
	Jackfish Bay	R-3
	M - 2 Bay	R-4
	M - 4 Bay	R-5
	Elk's Bay	R-6
	Crystal Bay	R-7
	Cranberry Bay	R-8
Kabetogama Lake	Tom Cod Bay	K-1
	Peterson Bay	K-2
	Irwin Bay/ South Moxie Island	K-3
	Daley Brook Bay	K-4
	Nebraska Bay	K-5
	Blind Ash Bay	K-6
Namakan Lake	Johnson Bay	N-1
	Moose Bay	N-2
	Hoist Bay	N-3
	Junction Bay	N-4
	Deep Slough	N-5
	Grassy Portage Bay	N-6
Interior Lakes	Agnes	I-1
	Ek	I-2
	Little Trout	I-3
	Locator	I-4
	O'Leary	I-5

APPENDIX III. <u>Park Supplement</u>. Common loon territories in Voyageurs National Park, 1979 - 1986.

<u>Interior Lake Territories</u>
Agnes
Beast
Brown
Cruiser
Ek
Fishmouth
Jorgens
Little Trout
Locator
Loiten
Lucille
McDevitt
Mukooda - North
Mukooda - South
Net (lost in 1984 when beaver dam collapsed)
O'Leary
Oslo
Peary
Quill
Ryan
Shoepack
Tooth (added 1983 - 1986)
War Club (added 1983 - 1986)
Weir
Wiyapka
Junction Bay Falls Beaver Pond (added 1983)
Lake west of Wiyapka (added 1986)

<u>Rainy Lake Territories</u>
Tilson Bay/Creek (added 1983 - 1986)
Thunderbird Resort Bay (added 1983 - 1986)
Island View Resort
Black Bay/Skunk Island (added 1983 - 1986)
Krause Bay (added 1983 - 1986)
Tango Bay
Harrison Bay
North Dryweed Island
Bushyhead Island South Cove
Dove Bay - Proper (added 1983 - 1986)
Mid Dove Bay (added 1983 - 1986)
Far East Dove Bay
Diamond Island/Horseshoe Island (added 1983 - 1986)
Arden Island/Olsen Island (added 1983 - 1986)
Outer Cranberry Bay
APPENDIX III. (continued)

Ovison's Fish Camp
Lower Cranberry Bay
Lower Alder Creek (added 1983 - 1986)
Outer Lost Bay
Mid Lost Bay
Lower Lost Bay (added 1983 - 1986)
Harbor Island
The Brule - West End
The Brule Bay (added 1983 - 1986)
Bay Northwest of Payson Island - Saginaw Bay
Saginaw Bay Campsite
Marion Bay (added 1983 - 1986)
Finlander Island/Bay
Hitchcock Bay
Kawawia Island (added 1983 - 1986)
East Kempton Channel/Bear Slide
Idle Hour Island Bay (added 1983 - 1986)
Blueberry Island (lost 1983 - 1986)
Brown's Bay
Anderson Bay
Smith Island/Sand Bay Island
Rabbit Island/Virgin Island (added 1983 - 1986)
Surveyors Island/Bay (added 1983 - 1986)
Emerald Island (lost 1983 - 1986)
Three Sisters Island/Shelland Island

Kabetogama Lake Territories
State Point/Echo Island
Peterson Bay (lost 1983 - 1986)
Sphunge Island/Duck Bay
South Moxie Island/Irwin Bay
Bowman Bay (lost 1983 - 1986)
Deer Point Islands/Richie Island
Daley Brook Bay
Mud Bay
Nebraska Bay
Blind Ash Bay
Kabetogama Narrows
Rudder Bay
Green/Twin/Larkin Islands (added 1983 - 1986)
Lost Bay - Rock Buoy
Lost Bay - Ek's Bay (added 1983 - 1986)
Blue Fin Bay
North Central Sugarbush Island (lost 1983 - 1986)
Harris/West Sugarbush Island (lost 1983 - 1986)
Northeastern Cutover Island (added 1983 - 1986)
Northwestern Cutover Channel
APPENDIX III. (continued)

Moose Bay (added 1983 - 1986)
Rottenwood Island (added 1983 - 1986)

Upper Tom Cod Bay
Mid Tom Cod Bay
Grassy Island Complex
Bittersweet Island (added 1983 - 1986)
Sullivan Bay
Pine/Chase Islands (added 1983 - 1986)

<u>Namakan Lake Territories</u>
Old Dutch Bay (lost 1983 - 1986)
Inlet South of Blind Indian Narrows (added 1983 - 1986)
Kohler Bay/Tar Point
Cemetary /Sweetnose Islands
Wigwam/Sexton Islands (added 1983 - 1986)
Kubel/Bivo Islands (added 1983 - 1986)
Johnson Bay
Moose Bay
Hoist Bay
East Williams Island
Junction Bay - Proper
Mouth of Junction Bay/Postage Island
Sheen Point/McManus Island
Sheen/Wolf Pack Islands
Randolph Bay
Cameron Bay
Grassy Portage Bay
Whiskey Point (added 1983 - 1986)
Hammer Bay/Owl Island
My/Your Islands
Side Y Bay East of Hammer Bay (added 1983 - 1986)

<u>Sand Point Lake Territories</u>
Duffy's Bay (added 1983 - 1986)
Swanson's Bay (lost 1983 - 1986)
North Cove of Grassy Bay Entrance (added 1983 - 1986)
Grassy Bay - Entrance to Staeges Bay
Staeges Bay (added 1983 - 1986)
Brown's Bay

The National Park Service's Midwest Region covers 33 park units located in 10 states in the Great Plains and Great Lakes area (Nebraska, Kansas, Missouri, Iowa, Minnesota, Wisconsin, Michigan, Illinois, Indiana, and Ohio). The physical and biological diversity of the Region is reflected in the variety of research conducted in the parks. Current research subjects range from a survey of prairie vegetation in several small parks to the ecology of boreal forests at Voyageurs; from threatened plants in a number of parks to endangered wolves at Isle Royale; from hydrology of springs at Ozark to air pollution at Indiana Dunes; and from recreational boating use patterns on the Lower Saint Croix to hiking and campground use at Isle Royale. For more information on the National Park Service's Midwest Regional science program, please write:

Regional Chief Scientist
National Park Service
Midwest Regional Office
1709 Jackson Street
Omaha, Nebraska 68102

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