The effects of human disturbance on common loon productivity in northwestern Montana

by Lynn Michelle Kelly

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Fish and Wildlife Management
Montana State University

Abstract:
Productivity and effects of human disturbance on common loons (Gavia immer)was studied from 1986-1991 in the Tobacco-Stillwater and Clearwater-Swan drainages in northwestern Montana. The adult loon population in these 2 drainages makes up approximately 30% of Montana's population. A density of 72.2 ha of lake surface area per loon was determined. Seventeen pairs exhibited territorial behavior and an average of 10 pairs were successful in raising at least one chick. Ninety percent of nests were located on islands situated in open water, along transitional swamp shorelines or within marshes. Fifty-two percent (n=23) of nests on islands in open water, 64% (n=l1) of nests along transitional swamp shorelines and 75% (n=4) of nests within marshes were successful. Successful nests had a significantly deeper water access than unsuccessful nests. Significant differences in vegetation surrounding nest sites were observed between the 2 drainages. Nest losses with known causes were attributed to flooding, wash-out by wave action, and infertility. Suspected causes of nest failures included human disturbance, dropping water levels and interactions with bald eagles. Reuse of a physiographic area for nesting occurred 94% (n=32) of the time. Nests were located within 50 m of a previously used nest bowl 50% of the time. Loons nesting successfully one year reused the area within 50 m of the previous successful nest over 60% of the time. A significant negative relationship was shown between the number of chicks produced per total nest attempt and the surface area disturbance ratio. A positive relationship was indicated between the number of fledged juveniles per nest attempt after protective signs were used and Skaar's disturbance rating. Human related disturbance, which included boats and shoreline activities accounted for 59% of the observed flushes and kept loons off their nests an average of 24 minutes per flush. Natural activities taking loons off the nest included territorial activities, nest building, heat stress and insect harassment. These activities accounted for 40% of the flushes and lasted an average of 8 minutes per flush. Average flushing distances due to approaching boats for the 4 weeks of incubation were 129,121, 91, 64 m respectively. Floating signs 137 m from nests formed a voluntary closure after which the number of nest departures attributed to human recreational activity were reduced from 32 to 13. The number of successful nests, number of chicks, and number of 2-chick broods were significantly increased after the use of protective floating signs. These data demonstrate that recreational activity on nesting territories was having a significant negative effect upon loon productivity which can be mitigated with the use of floating signs surrounding nest sites.

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Master of Science

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Fish and Wildlife Management

MONTANA STATE UNIVERSITY
Bozeman, Montana

July 1992

APPROVAL

of a thesis submitted by

Lynn Michelle Kelly

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ACKNOWLEDGMENTS

To the following, among others, I wish to express my sincere appreciation for their contributions to this study; Dr. Robert L. Eng, Montana State University, for project planning and guidance in the preparation of the manuscript; Dr. Lynn Irby, Dr. Harold Picton, and Dr. Robert White for critical reading of the manuscript; Dr. Richard Hauer, for assistance with the regression analyses; Don Skaar, Montana Loon Society, for project planning and guidance; Allen Elser, Montana Department of Fish, Wildlife and Parks, for the use of equipment; Dennis Johnson, Anne Zimmermann, Tom Puchlerz and William Boettcher, U. S. Forest Service, for logistical support and personnel for the construction and implementation of the floating signs; Dr. John Madsen D.D.S. for designing and constructing the buoy style of floating sign; Christie Ferruzzi (USFS), Amy Jacobs (USFS), Reed Kuennen (USFS), Tony Drahos (USFS), Dick Taylor (USFS), Gary (Woody) Baxter (MDFWP), and Fred King (MDFWP), for field assistance and data; Dan Gustafson, for the instruction needed for the operation of the digitizing board; landowners: Bill and Edna Gywnn, Phyllis Falconer, Ed and Gayle Hynes, Clarence and Mabel Stilwell, Ruth Bonnell, Bill and Ramona Holt, and Hilda Kritzberg for permitting access to their lands and their cooperation and assistance; Individual contributions of Fred King, Anne Zimmermann, Rolando (Rolly) Ortegon, Ken and Jody Wolff, Patricia Dolan, and Dan Casey were greatly appreciated. The study received partial financial support from the Montana Loon Society and the Lolo National Forest.

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ABSTRACT

Productivity and effects of human disturbance on common loons (Gavia immer) was studied from 1986-1991 in the Tobacco-Stillwater and Clearwater-Swan drainages in northwestern Montana. The adult loon population in these 2 drainages makes up approximately 30% of Montana's population. A density of 72.2 ha of lake surface area per loon was determined. Seventeen pairs exhibited territorial behavior and an average of 10 pairs were successful in raising at least one chick. Ninety percent of nests were located on islands situated in open water, along transitional swamp shorelines or within marshes. Fifty-two percent (n=23) of nests on islands in open water, 64% (n=11) of nests along transitional swamp shorelines and 75% (n=4) of nests within marshes were successful. Successful nests had a significantly deeper water access than unsuccessful nests. Significant differences in vegetation surrounding nest sites were observed between the 2 drainages. Nest losses with known causes were attributed to flooding, wash-out by wave action, and infertility. Suspected causes of nest failures included human disturbance, dropping water levels and interactions with bald eagles. Reuse of a physiographic area for nesting occurred 94% (n=32) of the time. Nests were located within 50 m of a previously used nest bowl 50% of the time. Loons nesting successfully one year reused the area within 50 m of the previous successful nest over 60% of the time. A significant negative relationship was shown between the number of chicks produced per total nest attempt and the surface area disturbance ratio. A positive relationship was indicated between the number of fledged juveniles per nest attempt after protective signs were used and Skaar's disturbance rating. Human related disturbance, which included boats and shoreline activities accounted for 59% of the observed flushes and kept loons off their nests an average of 24 minutes per flush. Natural activities taking loons off the nest included territorial activities, nest building, heat stress and insect harassment. These activities accounted for 40% of the flushes and lasted an average of 8 minutes per flush. Average flushing distances due to approaching boats for the 4 weeks of incubation were 129, 121, 91, 64 m respectively. Floating signs 137 m from nests formed a voluntary closure after which the number of nest departures attributed to human recreational activity were reduced from 32 to 13. The number of successful nests, number of chicks, and number of 2-chick broods were significantly increased after the use of protective floating signs. These data demonstrate that recreational activity on nesting territories was having a significant negative effect upon loon productivity which can be mitigated with the use of floating signs surrounding nest sites.

INTRODUCTION

The common loon (Gavia immer) is most often associated with the Great Lake states, Canada and Alaska. Few people associate loons with Montana, and most people are surprised to learn that Montana has the only significant loon population in the continental United States west of the Mississippi River. The loon has become increasingly visible in Montana and its presence on a territory is seen as an indicator of the pristine quality of the lakes found in northwest Montana.

Efforts to determine population estimates and breeding status of the common loon in the northeastern United State began when it became apparent that the use of pesticides was adversely affecting populations of fish-eating birds. While environmental pollutants have negatively affected loons, studies generally indicated that loon populations were declining due more to housing developments along shorelines of nesting lakes and increased human recreational activities than to losses associated with pesticides (McIntrye, 1989; Reum, 1976).

Regional efforts to assess common loon populations have only recently begun. Historically, the common loon was listed as a breeding species in California, Oregon and Washington. During the 1930's there was a major decline in the loon's breeding range, and by the 1950's, the bird had apparently been extirpated as a breeding species in these 3 states. Within the last few years very limited nesting success has been documented in Washington (Corkran 1988).

Pairs of loons and single birds were sighted in several portions of Idaho; however, only 1 nest has been documented on the Idaho-Wyoming border (Fitch and Trost, 1985). Ten pairs of nesting loons have been identified in Yellowstone National Park (McEneaney 1988). These 11 pairs probably constitute most of the population of loons in Wyoming.

British Columbia appears to have a healthy breeding population of several hundred nesting pairs with numbers increasing (Corkran 1988).

Efforts to determine the status of common loons in Montana began in 1982 when Skaar (1989) began a survey in northwestern Montana. Average values between 1982-1989 indicated that the summer population consisted of 160 loons and 44 territorial pairs. However, only an average of 24 pairs successfully raised 1-2 chicks each year. Successful breeding occurred mostly on lakes associated with glaciated valley floors. Loons did not utilize lakes which were less than 5.4 ha in size or above 1491 m in elevation.

Since the population of loons in Montana is located on the edge of loon distribution in North America, recreational development of lakes in this region has the potential to fragment this population creating "biological islands". These are areas of at least marginal habitat surrounded by habitats of unacceptable quality (Picton and Mackie, 1980). Gene flow between the "islands" is theoretically essential to the long term survival of the species. If excessive fragmentation due to loss of habitat continues between the Pacific Northwest and the Canadian provinces of British Columbia and Alberta, subpopulations of common loons in Montana could become vulnerable to local extinction.

The regulatory status of the common loon in Montana varies with the government agency involved. The U.S. Forest Service in Region 1 listed the loon as a "sensitive species" in September 1986. Region 6 of the U. S. Fish and Wildlife Service has not classified the loon as threatened or endangered, nor is the loon a candidate species for either of these classifications. The Montana Department of Fish, Wildlife and Parks has classified and protected the loon as a nongame species.

Skaar's (1986) work on common loons in Montana provided important information regarding general population size and habitat requirements. However, when the U. S. Forest Service designated the loon a "sensitive species", more specific information within major river drainages was necessary to more adequately manage these birds; thus, the specific goals of this study were to:

1) Establish a population data-base for lakes within the Clearwater-Swan and Tobacco-Stillwater River drainages.
2) Determine patterns of lake use as related to individual territorial requirements.
3) Identify the nest sites and nursery areas within the territories of loons in the study area.
4) Identify sources of disturbance and their affects on nesting and brood rearing success.
5) Analyze the habitat composition of nest sites and the degree to which these areas were reused from year to year.
6) Document nest chronology, nest success, chick development, and fledging success.

STUDY AREA

Clearwater-Swan Drainage

Two study areas were located in northwestern Montana (Fig.1). The first area included 11 lakes located between the towns of Condon and Seeley Lake in the Swan valley (Fig. 2).

The Swan valley lies between the Mission Mountains on the west and the Swan Mountains on the east. Both ranges are composed of Precambrian sedimentary formations which rose up as great slabs and then tilted down and eastward. All of the study area lakes originated due to glacial action (Alt and Hyndman 1986). There is a small divide between Lindbergh and Clearwater lakes. The water flowing south of the divide forms the Clearwater River while the drainages flowing north form the Swan River.

Eight of the lakes are located along the Clearwater River drainage. These lakes include Clearwater, Rainy, Alva, Inez, Seeley and Salmon. Placid Lake is in the Owl Creek drainage and and Marshall Lake is in the Marshall Creek drainage. Both of these streams flow into the Clearwater River.

Lindbergh, Holland and Loon Lakes are all in the Swan River drainage. Holland Lake is drained by Holland Creek, a tributary of the Swan River. Physical characteristics of all 11 lakes are presented in Table 1. General locations of each loon territory in this drainage are indicated in Figure 2.

Upland vegetation consists of mixed coniferous forests. Riparian areas along the 2 river drainages are dominated by thick stands of willow (Salix spp.).The climate of the Swan Valley is characterized by cool, wet springs and warm summers. Mean annual precipitation ranges between 102 - 152 cm. Precipitation for April, May and June in 1986 was 2.0, 6.2, 7.1 cm, respectively, and for the same months in 1987 was 1.9, 5.1 and 6.0 cm. Ice-out occurred in a northward progression beginning at Salmon Lake at the south end. Lakes typically became ice free between 1-15 April.

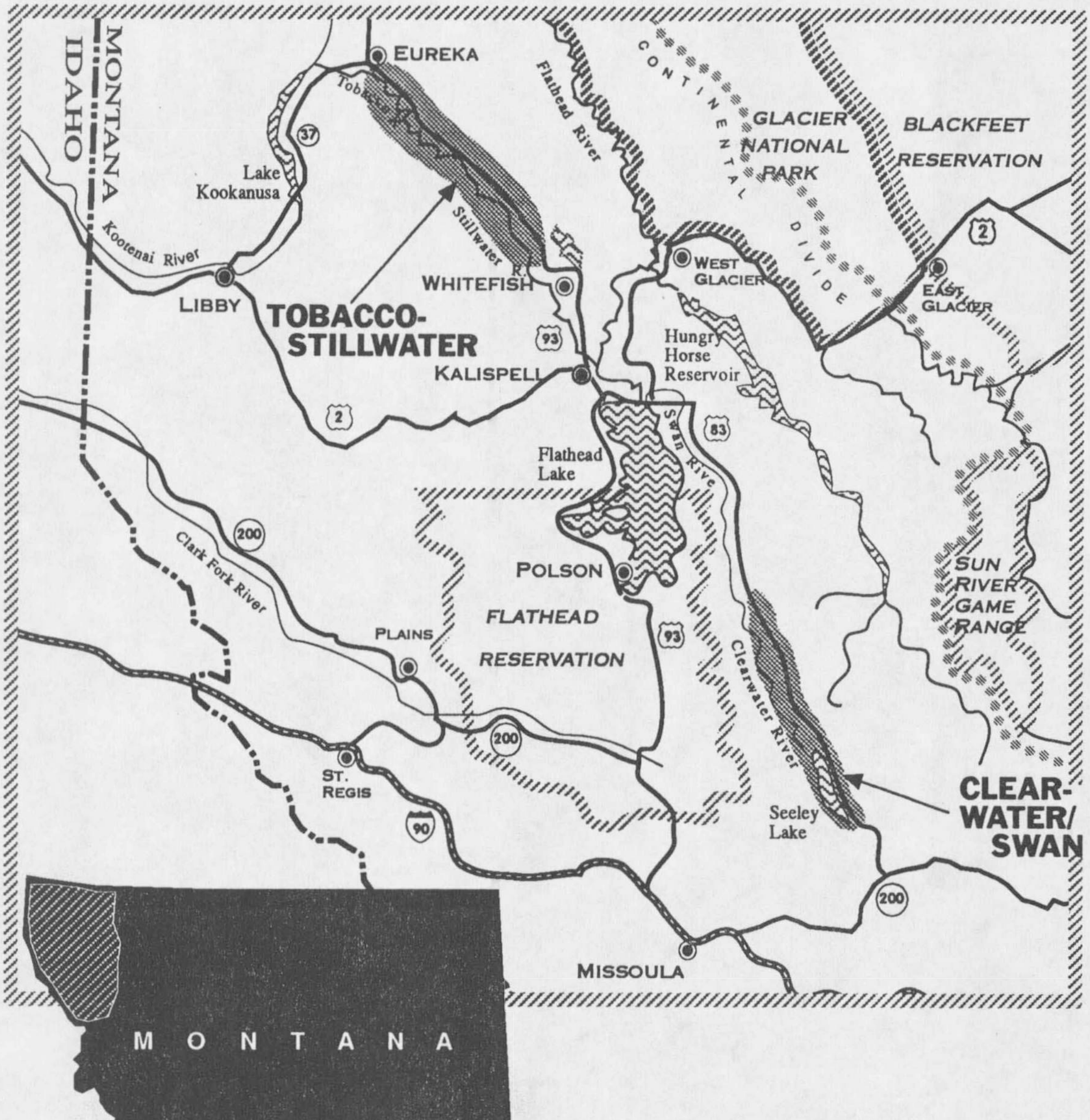

Figure 1. Map of northwestern Montana indicating the location of the Tobacco-Stillwater and Clearwater-Swan River drainage study areas.

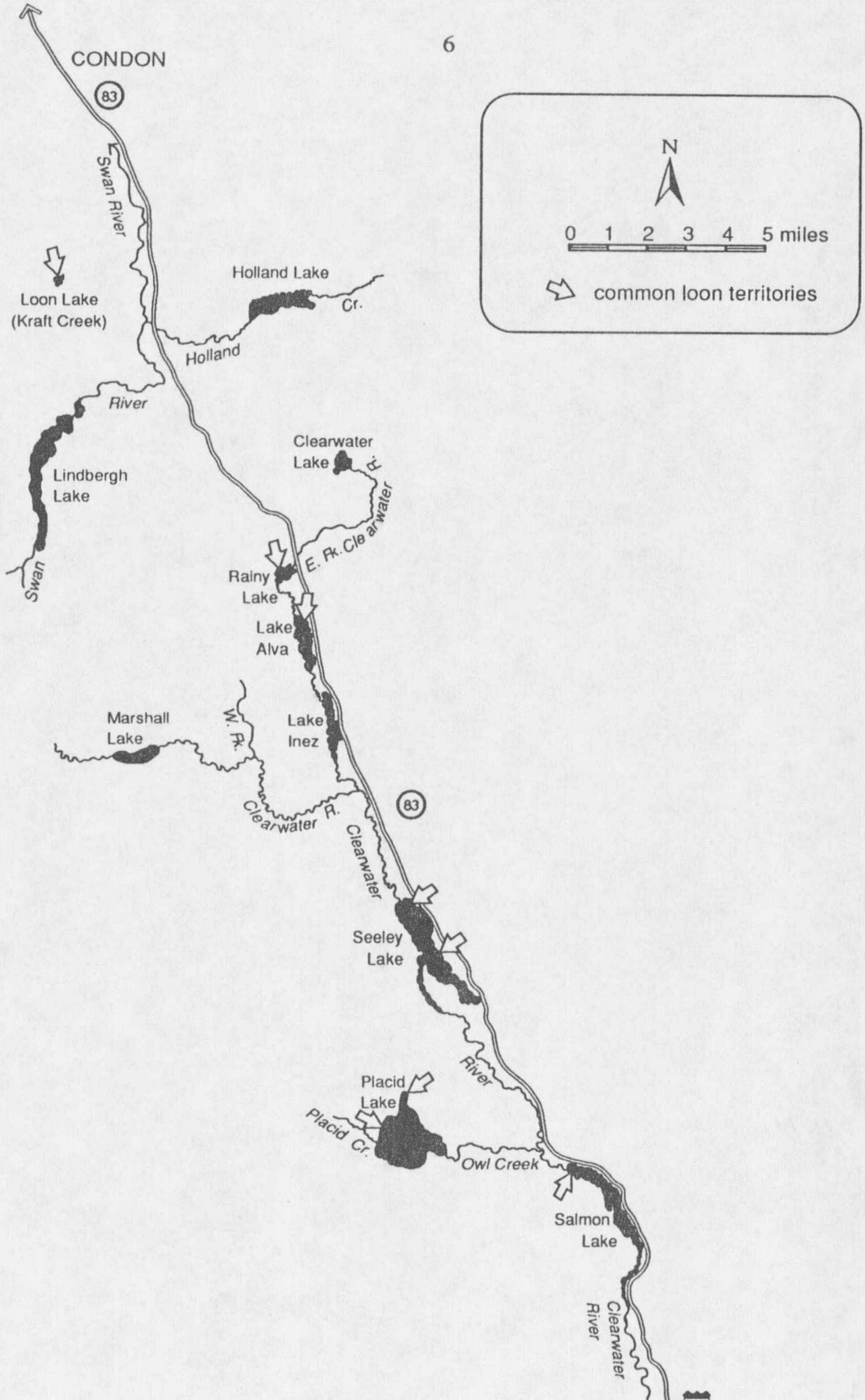

Figure 2. Map of the Clearwater-Swan River drainage study area.

Table 1. Physical characteristics of study lakes in the Clearwater-Swan River drainage.

Lake	Surface area (ha)	Shoreline length (m)	Maximum depth (m)	Mean depth (m)
Loon	10.4	1392	1.8	1.2
Holland	173.6	8608	47.2	18.2
Lindbergh	324.2	16604	36.6	20.8
Clearwater	43.5	**	12.2	*
Marshall	33.4	3017	16.8	*
Rainy	30.9	2551	9.5	6.8
Alva	121.6	6642	29.0	*
Inez	109.8	6995	21.0	11.3
Seeley	415.9	13899	41.0	*
Placid	483.0	10820	27.4	18.3
Salmon	242.0	15530	21.3	10.0

* Not available
** Not measured

Tobacco-Stillwater Drainage

The second study area, located in the Stillwater-Tobacco River valley between the towns of Whitefish and Eureka, included 12 lakes (Fig. 3). This valley lies west of the Whitefish Range and east of the Salish Mountains. The valley floor was the route of the great Rocky Mountain trench glacier which extended as far south as the Mission and southern Swan valleys (Alt and Hyndman 1986). Thus, all the study lakes have a glacial origin. There is a slight divide at Stryker, Montana. Most of the water south of the divide flows into the Stillwater River while the drainages north of the divide eventually join the Tobacco River.

Tally, Lower Stillwater, Upper Stillwater, Fish, Bull and Fishbull lakes are all part of the Stillwater River drainage. Upper Whitefish Lake is drained by Swift Creek which flows into Whitefish Lake. The Whitefish River flows out of Whitefish Lake and into the

Flathead River drainage. Dickey, Murphy and Marl Lakes are all within the Tobacco River drainage which flows into the Kootenai River and Lake Koocanusa. The physical characteristics of all 12 lakes are presented in Table 2. General locations of each loon territory in this drainage are indicated in Figure 3.

Upland areas are covered with mixed coniferous forests. Riparian areas support thick stands of willow (Salix spp.) and alder (Alnus spp.).

The climate of the Tobacco Valley is characterized by cold wet springs and warm summers. Mean annual precipitation ranges between 102 - 152 cm. Precipitation for April, May and June of 1986 was 2.5, 5.6, 7.1 cm respectively. Precipitation for these 3 months in 1987 was 2.6, 1.7, 7.7 cm respectively.. Ice-out in this drainage usually occurred between 1-15 April. Murphy was one of the first lakes to thaw, while Dickey and other smaller lakes typically thawed at least 2 weeks later.

Table 2. Physical characteristics of study lakes in the Tobacco-Stillwater River drainage.

Lake	Surface area (ha)	Shoreline length (m)	Maximum depth (m)	Mean depth (m)
Tally	501.0	13509	150.1	76.3
Upper Whitefish	32.9	2657	10.4	4.6
Lower Stillwater	100.5	6565	15.9	6.1
Upper Stillwater	243.2	16609	22.6	9.2
Dog	39.3	4292	7.6	3.1
Fish	12.8	3008	10.7	4.6
Bull	40.8	5480	21.4	*
Fishbull	5.9	1386	6.1	2.1
Dickey	240.8	7775	22.6	17.9
Murphy	57.7	3293	7.9	4.6
Loon	14.7	2185	7.6	*
Marl	41.6	2692	32.6	15.3

* Not available

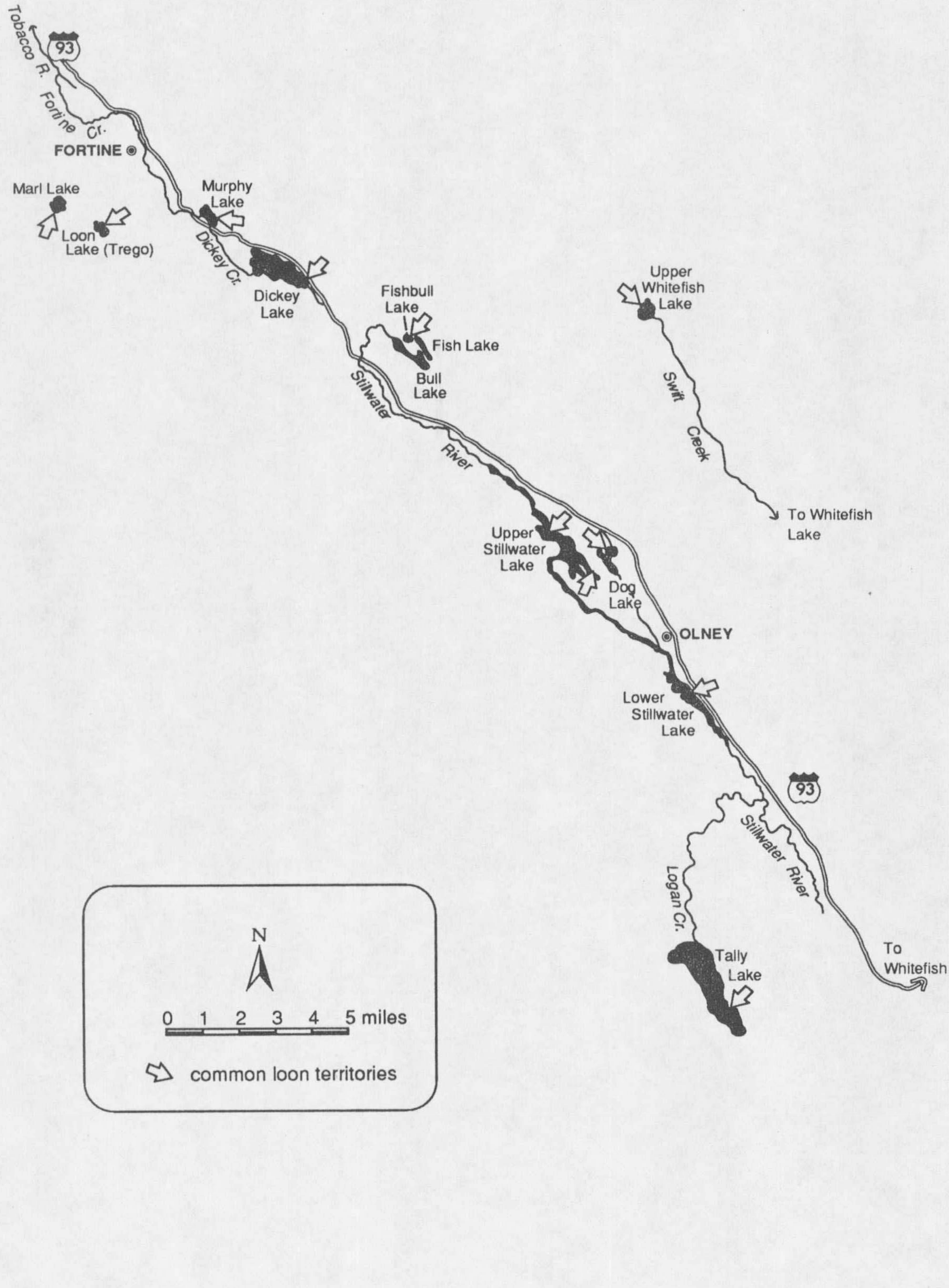

Figure 3. Map of the Tobacco-Stillwater River drainage study area.

METHODS

Field observations in 1986 began with weekend work from mid-May to Memorial Day and continued full time until early September. In 1987, data were collected on weekends between 1-15 May, full time between 13 June and the end of August, and again on weekends through 20 September. In 1988-91, data were gathered on weekends from 15 April until 7 June; and full time until 17 June. In 1989-92 weekend observations were confined mainly to the Clearwater-Swan drainage due to constraints imposed by time and distance. U. S. Forest Service personnel, in a cooperative effort with my study, monitored the study lakes in the Tobacco-Stillwater drainage. In 1986-87 distances between lakes within the two drainages resulted in approximately 20,000 miles of travel. Weekend travel between 1988-1991 averaged 300 miles.

Determination of Nest Locations, Measurements and Success

Nests were located by scanning shorelines and islands using a Bushnell 15-60 X spotting scope. Special attention was given to areas of emergent vegetation. Nest locations were recorded on prepared maps of each lake. Nest measurements were taken as described by Sutcliffe (1980). The degree to which nest sites were reused was determined as described by Strong (1987). A nest was considered to be successful if at least 1 chick hatched out of it.

Determination of Incubation Initiation

Dates of incubation initiation were determined by estimating age of chicks (Olson and Marshall, 1952) and backdating from date of hatch. Researchers have found varied lengths of incubation ranging from 26-31 days (McIntyre, 1975). Since Yonge (1981) reported that loons actually incubate any 1 egg for only 26 days, I used an incubation period of 26-28 days.

Determination of Lake Use

During the first summer, I obtained preliminary data on lake locations and presence or absence of loons. The second summer I narrowed my attentions to the lakes with pairs of loons, especially pairs with chicks. Lake use was determined by mapping the locations of resident loons on each lake. Adults and chicks were recorded as separate entries. Locations indicated on maps were combined into 2-week periods. Areas of use were then calculated using a computerized digitizer and the Jandel Scientific Graphics program. Total territory size was determined by combining all 2-week observations for each year onto 1 map. Maps for 1986, 1987 and 1988 were then combined to calculate the cumulative breeding territory.

Determination of Human Disturbance

Several strategies were used for determining human disturbance. The first, employed during both summers, was to observe the loons for either 1 or 4-hr.periods, during which time I mapped locations of loons and all water craft, and noted loon vocalizations and behavior at 5 minute intervals.

The second strategy involved determining disturbance of nesting loons. Observations occurred on weekends between 1 May-15 June and each lake was monitored on Saturday (day 1) and Sunday (day 2). Six lakes in the Seeley-Swan drainage which normally receive moderate to heavy fishing pressure were selected as "disturbed" lakes. One lake, in the same drainage, with no access and no game fish, was selected as a control lake. On each lake I observed the loons during 2 or 4-hr. time periods and at 5 minute intervals, recorded behavior, postures of the incubating bird, and vocalizations. The amount of time the loon spent off the nest (for any reason) was determined with the use of a Micronta Digital LCD stopwatch.

The critical disturbance distance was determined using a range finder with a 914 m capability. At the beginning of each observation period I used the range finder to measure the distance between myself and the incubating bird. A compass reading between myself and the bird was also taken at this time. If the loon lowered its head or left the nest because of an approaching boat, the range finder and compass were used to determine the distance and location of the watercraft. This data was used in the Law of Cosines (McKee, 1969) to determine the distance between the boat and the nesting bird.

Three methods were used to give an indication of the degree to which a lake was being affected by human activities. Two involved calculating ratios developed by Vermeer (1973). The ratios were calculated by assigning 10 points for each resort or government campground, 5 points for unmaintained public access sites and 1 point for each home or cabin around the lake. These points were totaled and divided by surface area (hectares/acres) or shoreline length (meters) and then used in regression analysis with chick production and fledging data. The surface area disturbance ratio gives general comparisons between lakes regarding human activities which occur on the lake. The shoreline disturbance ratio was included because slow moving boats trolling near the shoreline and shoreline development impact nesting loons more directly than boats in the middle of the lake.

The third method was developed by Skaar (1989). This method included a priority rating which enables managers to quantitatively determine which lakes should have priority management considerations. I used 3 categories from his system: shoreline disturbance, fishing pressure and public access rated on a scale of 1 to 3 with a 1 indicating minimum levels of disturbance. Ratings for each lake were added together for a total Skaar disturbance rating and used in regression analysis with chick production and fledging data .

Determination of Shoreline Composition

Shoreline composition was determined by canoeing the perimeter of each study lake in August. Shoreline was classified into the following groups: Bare (no shoreline vegetation); Debris (logs or other obstacles along the shoreline); Grass (forbs and terrestrial grasses); Understory (vegetation less than 3 m tall); Overstory (vegetation greater than 3 m tall); Emergents (sedges, rushes, cattails or other emergent plants). The percentage of the shoreline covered by each of these classifications was computed using a digitizing board and the Jandel Scientific Graphics program.

Placement of Protective Floating Signs

Protective floating signs were constructed by personnel in the U.S. Forest Service and Montana Department of Fish, Wildlife and Parks using the diagrams in Figures 6-7. These signs were placed 137 m (150 yds) in a semi-circle around loon nests as soon as the nests were located. They were removed approximately 2 weeks after hatching.

Statistical Analysis

Statistical analyzes were undertaken using the MSUSTAT Statistical Analysis Package, Microcomputer Version 4.10 which was developed by Dr. Richard E. Lund, Montana State University, Bozeman, Mt. 59717. The acceptable level of statistical significance is 0.10.

RESULTS AND DISCUSSION

Nest Chronology

Arrival on territories occurred immediately after ice-out which agrees with observations of others (McIntyre 1975, Sutcliffe 1980). All pairs had established territories by 22 April. Earliest and latest arrivals were 2 April-22 April, respectively, with over 68% of the loons arriving between 14 April-21 April.

The earliest that incubation was initiated was between 26-29 April with the latest between 21-26 May. This late nesting attempt appeared to be a response to disturbance by logging activities on the shoreline of the small lake used by this pair.

Fifty-three percent of 45 nesting pairs were incubating by 7 May during 1986-1990. A significant difference was observed between drainages since 69% (18 of 26) of the nesting pairs in the Clearwater-Swan drainage were incubating by 7 May while only 27% (5 of 19) in the Tobacco-Stillwater were incubating by that date (Chi-square = 8.091; df=1, P=0.04). Most of the nesting pairs (73%, 14 of 19) in the Tobacco-Stillwater initiated incubation between 8-20 May.

Yonge (1981) and Heimberger et al. (1983) found that early nesting efforts tended to be more successful. In this study, all nests initiated between 26 April-1 May were successful (5 of 5) while 83% (20 of 24) initiated between 26 April-7 May and 71% (15 of 21) initiated between 8 May-26 May were successful. Loons in the Tobacco-Stillwater drainage experienced a lower rate of reproductive success in terms of the number of territorial, nesting, and successfully nesting pairs. Since a significant number of pairs in this drainage nested after 8 May, a larger number of nests may have been predisposed to failure.

Only 2 renest attempts were confirmed. Two others were suspected based upon late hatch dates and extended periods when only a single bird was observed on a territory before a late hatch. However renesting was difficult to discern because observations were made only on weekends and a brief nest attempt made during the week would have been overlooked. Various authors (Olson and Marshall 1952; Sutcliffe 1980; McIntyre 1975; Evers 1990) have indicated that renesting usually occurs within 2 weeks of the original nesting attempt. This is in agreement with my observations where the original nest on Salmon Lake was abandoned after 8 May and the bird was observed renesting on 22 May. In 1991, the pair on Murphy Lake renested within 1 week of loss of the first nest. It has also been observed that loons are more likely to renest if the nest is lost early in the incubation period. Since over half of the pairs were incubating by 7 May, a failed nest attempt during the first week of May could be followed by a renesting attempt around 15 May. If all nests initiated after 15 May were renests, then renesting attempts could have been as high as 13% (6 of 45) with a success rate of 83% (5 of 6).

The earliest hatch date observed was 24 May while the latest was 2 July and probably represented a renesting effort. Sixty-eight percent (24 of 35) of chicks hatched between 24 May and 7 June while 97% hatched by 14 June.

Population Characteristics

Six years of observations suggest an adult loon population in the 2 drainages of 48 birds or approximately 30% of the population reported for Montana (Skaar 1989). Individually, the Tobacco-Stillwater and Clearwater-Swan drainages accounted for 17% and 13% of the state population, respectively. A density of 1 adult loon per 72.2 ha of lake surface area was determined for the entire study area. The Tobacco-Stillwater and Clearwater-Swan drainages had densities of 51.2 and 99.4 ha per loon, respectively.

Seventeen individual territories averaged 70.4 ha (range, 3.5-146.5 ha). Lakes less than 125 ha (n=9) and greater than 240 ha (n=8) had territories averaging 36.0 ha (range, 3.5-98.1 ha) and 109.1 ha (range 47.1-146.5 ha) respectively. Territories on these small and large lakes encompassed, on average, 75% (range, 54-92%) and 33% (19-61%) of the total surface area, respectively.

For the purpose of the discussion on productivity, the following definitions will be used: A territorial pair refers to a pair of loons observed defending a territory between 15 April - 1 July. Nesting pairs refers to a pair which was observed incubating, or a nest site which was discovered upon searching the shoreline of the territory. A successful pair hatched at least one chick. Nest attempts refer to original nesting attempts plus any additional renesting the pair may have attempted.

<u>Nest Success</u>

Nest success was measured by comparing successful pairs to total pairs, territorial pairs, nesting pairs and nest attempts (Table 3). Corresponding proportions are summarized in Table 4.

When successful pairs were compared with territorial pairs in the 2 drainages, significantly fewer territorial pairs successfully nested in the Tobacco-Stillwater drainage (P=0.0863; df = 1; Chi- square = 2.941). When successful pairs were compared to nesting pairs for the 2 drainages, the Tobacco-Stillwater drainage also had fewer nesting pairs which produced chicks. These results probably are the result of repeated nest failures on four territories within the Tobacco-Stillwater drainage. Two territories in this drainage, Dog and Mid-Upper Stillwater, have been occupied since 1986, but have failed to produce chicks. Two other territories, Lower Stillwater and South Upper Stillwater, have experienced only limited success despite the use of floating signs to reduce human disturbance since 1990. Other factors such as flooding have been a problem with these nests. Although there were fewer territorial pairs in the Clearwater-Swan (Table 3), a higher proportion was consistently successful (Table 4). Extensive mitigative measures to reduce human disturbance have occurred in this drainage since 1989.

Table 3. Summary of adult loons for the Tobacco-Stillwater (TS) and Clearwater-Swan (CS) drainages 1986-1991.

Year	Total adults TS	Total adults CS	Total pairs TS	Total pairs CS	Territorial pairs TS	Territorial pairs CS	Nesting pairs TS	Nesting pairs CS	Successful pairs TS	Successful pairs CS
1986	25	20	11	8	11	7	6	5	3	5
1987	30	16	12	8	9	7	7	5	6	4
1988	26	20	13	9	10	7	8	6	3	3
1989	24	18	12	8	8	7	6	5	4	4
1990	25	26	12	12	12	8	10	7	6	5
1991	31	26	13	11	10	8	9	8	6	7
Ave *	27	21	12	9	10	7	8	6	5	5

* Rounded to the nearest whole number.

Table 4. Comparison of successful pairs to total pairs, territorial pairs, nesting pairs and nest attempts as an indication of nest success in Tobacco-Stillwater (TS) and Clearwater-Swan (CS) drainages 1986-1991.

	Successful pairs per							
Year	Total pairs		Territorial pairs		Nesting pairs		Nest attempts	
	TS	CS	TS	CS	TS	CS	TS	CS
1986	0.27	0.63	0.27	0.71	0.50	1.00	0.50	1.00
1987	0.50	0.50	0.67	0.57	0.86	0.80	0.75	0.80
1988	0.23	0.33	0.30	0.43	0.38	0.50	0.38	0.43
1989	0.33	0.50	0.50	0.57	0.67	0.80	0.67	0.80
1990	0.50	0.42	0.50	0.63	0.60	0.71	0.55	0.71
1991	0.46	0.64	0.60	0.88	0.67	0.88	0.60	0.78
Average:	0.38	0.50	0.47	0.63	0.61	0.78	0.58	0.75
Combined average:	0.44		0.55		0.70		0.67	

Loons in the Clearwater-Swan drainage were reproductively more successful in each of the 4 categories (Table 4). When data for the 2 drainages were combined, 55% of the territorial pairs in this study were successful compared to 54% for all of northwest Montana (Skaar 1989), and others which ranged from 30% in the Eastern Upper Peninsula in Michigan (Evers 1990) to 50% in Maine (Christenson 1981). Combined data also indicated that 70% of the nesting pairs were successful, a higher success rate than the 55% reported by Skaar (1989) for all of northwestern Montana. Data from other states indicate a range from 50% in Minnesota (Titus and VanDruff 1981) to 80% in Wisconsin (Zimmer 1982).

Chick production

The presence of chicks was usually ascertained by the 7th day after hatching, but mortality was very likely to have occurred during the first week. Therefore, the number of chicks in these data (Table 5) represent the minimum number hatched.

I compared the number of chicks to the total number of adults, territorial pairs, nesting pairs and successful pairs (Table 5). Due to the weekend observation schedule, breeding attempts which began and ended during the week were missed. As a result, some breeding pairs may have been designated only as territorial pairs.

Table 5. Chick production in the Tobacco-Stillwater (TS) and Clearwater-Swan (CS) drainages between 1986-1991.

	Chicks per									
	Total adults		Territorial pair		Nest pair		Nest attempt		Successful pairs	
Year	TS	CS	TS	CS	TS	CS	TS	CS	TS	CS
1986	0.20	0.30	0.45	0.86	0.83	1.20	0.83	1.20	1.67	1.20
1987	0.30	0.31	1.11	0.71	1.43	1.00	1.25	1.00	1.67	1.25
1988	0.19	0.20	0.50	0.57	0.63	0.67	0.63	0.57	1.67	1.30
1989	0.33	0.39	1.00	1.00	1.30	1.40	1.33	1.40	2.00	1.75
1990	0.36	0.23	0.75	0.75	0.90	0.86	0.82	0.86	1.50	1.20
1991	0.39	0.38	1.20	1.25	1.33	1.25	1.20	1.11	2.00	1.43
Average:	0.30	0.30	0.84	0.86	1.07	1.06	1.01	1.02	1.75	1.36
Combined average:	0.30		0.85		1.07		1.02		1.56	

The average number of chicks produced per adults (0.30) was identical for the Clearwater-Swan and the Tobacco-Stillwater and similar to Skaar's data for northwestern Montana which indicated 0.25 chicks per adult (Skaar 1989). Other studies reported slightly lower values ranging from 0.22 (Sutcliffe 1975) to 0.27 (Yonge 1981).

Chicks per territorial pair provides a comparison with the potential production if all the birds defending territories had produced 2 young. Results for the 2 drainages were similar and were higher than the 0.69 reported by Skaar (1989) for northwestern Montana. Skaar's results may be influenced by the fact that he only had 2 years data for the number of territorial pairs, much of which was collected in mid-July when the territorial urge of nonbreeding or unsuccessful pairs had waned. My data was similar to that obtained by both Rimmer (1988) and Christenson (1981) while Titus and VanDruff (1981) reported 0.42.

The number of chicks produced per nesting pair or nest attempt was essentially equal (1.07) for the Tobacco-Stillwater and Clearwater-Swan. Skaar's data indicate that there were 1.11 chicks per nesting pair for northwestern Montana. Olson and Marshall (1952) reported 0.50 in Minnesota and Rimmer (1988) reported 1.22 chicks per nesting pair in Vermont. Sutcliffe (1980) indicated that a loon population could be sustained or increased at production levels of 0.50 - 0.79 chicks per nesting pair. If this is true, the populations in these 2 drainages should be increasing.

There were 1.37 and 1.75 chicks produced per successful pair in the Clearwater-Swan and Tobacco-Stillwater drainages, respectively, which resulted in an overall production of 1.56 compared to 1.39 from northwestern Montana (Skaar 1989). A greater number of 2-chick broods may be the explanation for the higher number of chicks per successful pair in the Tobacco-Stillwater despite fewer numbers of nesting and successful pairs (Table 3). Data from other states revealed that the number of chicks per successful pair ranged from

1.05 in Minnesota (Olson and Marshall 1952) to 1.58 in New Hampshire (McCoy 1988) and 1.60 in Maine (Christenson 1981).

Fledging

Juveniles were considered to be fledged if they were present in mid-August. At this time, most were 10-11 weeks old and beginning to fly. The number of fledged juveniles was compared to the same parameters as the number of chicks produced (Table 6). These data reflected mortality since June when the chicks were first observed.

Table 6. Fledging success in the Tobacco-Stillwater (TS) and Clearwater-Swan (CS) drainages between 1986-1991.

	Fledged juveniles per									
	Total adults		**Territorial pair**		**Nest pair**		**Nest attempt**		**Successful pairs**	
Year	**TS**	**CS**	**TS**	**CS**	**TS**	**CS**	**TS**	**CS**	**TS**	**CS**
1986	0.20	0.30	0.45	0.86	0.83	1.20	0.83	1.20	1.67	1.20
1987	0.30	0.31	1.00	0.71	1.29	1.00	1.13	1.00	1.50	1.25
1988	0.19	0.20	0.50	0.57	0.63	0.67	0.63	0.57	1.67	1.33
1989	0.29	0.33	0.88	0.86	1.17	1.20	1.17	1.20	1.75	1.50
1990	0.24	0.23	0.50	0.75	0.60	0.86	0.55	0.86	1.00	1.20
1991	0.39	0.27	1.20	0.88	1.33	0.88	1.20	0.78	2.00	1.00
Average:	0.27	0.27	0.76	0.77	0.98	0.97	0.92	0.94	1.60	1.25
Combined average:	0.27		0.77		0.98		0.93		1.43	

The number of juveniles fledged per adult (0.27) was similar in the 2 study drainages. These data compare favorably with those reported by Titus and VanDruff (1981), Yonge (1981), Sutcliffe (1980) and Reiser (1988) which ranged from 0.15 to 0.28 juveniles fledged per adult.

Values for juveniles fledged per territorial pair (0.77) on the Tobacco-Stillwater and Clearwater-Swan drainages were considerably higher than those reported by McIntyre (1975), 0.27-0.31, in Minnesota. Sutcliffe (1980) reported values of 0.44-0.58 as did Yonge (1981) and Titus and VanDruff (1981). McCoy (1988) in New Hampshire and Sawyer (1979) in Maine reported comparable numbers of 0.71 and 0.65 fledged per adult respectively while Trivelpiece et al. (1979) reported the highest values of 0.83 and 0.84 in New York.

The average number of fledged juveniles per nesting pair for both drainages (0.98) was higher than the 0.50 reported by Olson and Marshall (1952) and Sutcliffe (1980). McCoy (1988) of New Hampshire recorded 0.79 and Rimmer's (1988) Vermont data indicated the highest value, 0.92, in the literature. It is possible that some territorial pairs nested but were not observed doing so. As a result, the number of nesting pairs may be underestimated, resulting in the high mean value of 0.98 for my study areas.

The number of fledged juveniles per successful pair averaged 1.43 for both drainages. Other reported values ranged from 0.84 in Maine (Christenson 1981) to 1.26 in New Hampshire (Sutcliffe 1980).

Chick Survival

The number of chicks fledged was essentially the same for both drainages (Chi square = 0.2396E-02; df=1, P=0.9610) (Table 7). Survival rates were very high as revealed by the overall averages of 90.8% and 92.7%. However, the percent survival dropped somewhat in 1989 corresponding to a simultaneous increase in bald eagles in both drainages (Flath pers. commun.). Adult and subadult eagles were observed swooping in after 1-4 day old chicks, and these birds were suspected to have killed at least 5 chicks 4 weeks old or less. In 1 case, campers observed the eagle's attack on a family unit with a 2-chick brood. After the attack, 1 chick remained. This is the only case where eagles were actually observed preying upon loon chicks. Eagles have coexisted with loons on several of the study lakes for the duration of the study. Though eagle predation of chicks was suspected in 1988-1989, 1990 was the first year that loons were observed being negatively impacted by their presence.

Table 7. Total number of chicks produced and fledged in the Tobacco-Stillwater (TS) and Clearwater-Swan (CS) drainages between 1986-1991.

Year	Number of chicks produced		Number of chicks fledged		Percent survival	
	TS	CS	TS	CS	TS	CS
1986	5	6	5	6	100	100
1987	10	5	9	5	90	100
1988	5	4	5	4	100	100
1989	8	7	7	6	88	86
1990	9	6	6	6	67	100
1991	12	10	12	7	100	70
Average:	8.2	6.3	7.3	5.6	90.8	92.7
Combined average:	7.3		6.5		91.8	

Nest Sites

Strong (1987) emphasized the importance of locating and protecting nesting and nursery area habitats from development and disturbance. Many Montana lakes are experiencing rapid development. A discussion of nest site characteristics may enable others to identify and protect the more secure sites for use by existing pairs or future recruits to a lake.

A total of 50 nests were observed between 1986-1990. Twenty-seven were successful. Four nests, 2 of which were successful, could not be located to ascertain island type and other site specific analysis due to washout or receding water levels which occurred after incubation. Four other nests were on artificial platforms. These were not included in the analysis since they were not natural sites. Forty-six successful and unsuccessful nest locations are summarized in Table 8.

Table 8. Summary of combined data for successful and unsuccessful nest location (n=46) between 1986-1990.

Nest Location	Successful nest site	Unsuccessful nest site	Total
Peat island	15	11	26
Solid island	7	5	12
Artificial platform	2	2	4
Mainland	1	3	4

Nest Island Locations

Thirty-eight of 42 nests were on islands. Sixty-one percent (23 of 38) of the nests were located on islands in open water while 29% were found along a transitional swamp shoreline and 10% were within a marsh.

Nesting islands in open water were 1-275 m from the mainland. Fifty-two percent (12 of 23) had a foundation of peat and would sink under the weight of the observer. The remaining were "solid" islands which had a rock or gravel foundation. Vegetation on solid islands varied from grasses to conifers while vegetation on peat islands usually consisted of sedges. Twelve of the 23 nests located on an island in open water were successful.

Transitional swamp shoreline was identified as a maze of very small peat islands surrounded by water ranging in depths from 10-107 cm during high flows of May and June. By late June or July, the islands either were connected to the mainland or were surrounded by water less then 10 cm. Identification of a swamp shoreline required close inspection during the spring since this habitat appeared as mainland when viewed from the opposite side of the lake. Riparian vegetation such as willow (Salix spp.), alder (Alnus spp.), red-osier dogwood (Cornus stolonifera) and sedges (Carex sp.) usually surrounded and sheltered nest sites. This plant community forms a dense thicket which discourages travel and may limit access by some predators. Seven of 11 nests located along a swamp shoreline were successful.

Marsh nest sites were associated with extensive backwater areas, 30.5 m to more than 137 m from the main body of the lake. The loons accessed the lake using channels ranging from 51 cm to 6.1 m wide. All islands used for nesting within a marsh were peat masses which were generally larger than the peat islands used in the transitional swamp shoreline. Cattails and various aquatic or semi-aquatic forbs constituted most of the vegetation surrounding the nests. Three of 4 nests located within a marsh were successful.

Other researchers have reported that loons nest in a variety of locations ranging from sedge mats, floating muskeg, brush in water and logs to banks of earth, gravel bars, mud flats, and rock ledges (Munro 1945; Olson and Marshall 1952; Skaar 1989). The importance of islands to nest success of the common loon has been emphasized in numerous studies (Olson and Marshall 1952; Sutcliffe 1980; Strong 1985). In McIntrye's (1975) study, 50% of all nesting occurred on islands. When artificial nesting platforms were added to lakes lacking islands, 88% of all nests were on islands. Olson and Marshall (1952) found that 93% of 54 nests were on islands while, Vermeer (1973) found 96% of 26 nests on islands. Yonge (1981) noted that since young loons were produced from sites other than islands, islands were not a territorial requirement but undoubtedly enhanced the potential of an area as a territory.

Twenty-two of 38 islands supported nests which were successful (at least one egg hatched). Fifteen of 26 sedge islands and 7 of 12 solid islands supported successful nests, a 58% success rate for both. McIntyre (1975) indicated that increased success on solid islands should occur when compared to sedge mats, perhaps due to greater security from predation. My data did not support this hypothesis.

Sizes of Nesting Islands

Of 32 islands measured, 19 were 11 m^2 or smaller. The mean size of islands was 219.3 m^2 while the median was 9.0 m^2. Considering the large number of small islands, the median more accurately portrays nesting island size.

Differences in island size existed between the 2 study areas. Fifteen of 18 nest islands in the Clearwater-Swan were 5.5 m^2 or less while only 4 of 14 islands in the Tobacco-Stillwater were 11 m^2 or less. Mean sizes of nesting islands were 71.8 m^2 and 394 m^2 for the Clearwater-Swan and Tobacco-Stillwater, respectively. Corresponding median values for the 2 areas were 2.9 m^2 and 69 m^2 respectively.

The size difference in nest islands between study areas was a result of use of 2 different types of natural islands by loons. Twenty-two of 32 measured island sites were sedge/peat masses, either solidly anchored or floating muskeg. The habitat type for 12 of the 22 sedgepeat masses was the transitional swamp shoreline or marshes as described above. Islands in these habitats were small, ranging from 0.7-27.0 m^2 with a median size of 2.3 m^2. Ten of the masses of floating muskeg were located in open water sites in shallow backbays and were generally larger than sedge islands along swamp shorelines or in marshes. These islands ranged in size from 1.7-469.0 m^2 with a median size of 10 m^2. Sixteen of 18 nests in the Clearwater-Swan drainage and 6 of 14 in the Tobacco-Stillwater drainage were located on sedgepeat islands. The median and mean sizes of sedge islands in the Tobacco-Stillwater drainage were generally much larger than those in the Clearwater-Swan drainage.

Ten of 32 islands were solid islands as described above. There were distinct differences between the two drainages regarding use of these islands. Both drainages had approximately the same number of solid islands. Two of 18 nests in the Clearwater-Swan and 8 of 14 nests in the Tobacco-Stillwater were on solid islands, respectively. These islands were much larger than the sedge islands, ranging in size from 30.3-1335.0 m^2 with a median of 452.5 m^2.

Vermeer (1973) did not find a statistically significant preference by loons for islands smaller than 0.8 ha (2 acres), but he noted that 19 of 25 nests were on islands less than 0.8 ha. Reum (1976), Olson and Marshall (1952), and Sutcliffe (1980) all reported a preference for small islands for nest sites. My data agreed with these results.

No clear-cut preference was shown for sedge or solid islands. On the 5 nesting lakes where both types occurred, loons on 3 (Salmon, Upper Stillwater, and Fishbull) nested on both types of islands sometime during the study. On Lake Alva a sedge island was used as a nest site during 4 nesting seasons despite the presence of a large solid island which was further from a public boat ramp. Loon lake (Trego), a small private lake, has a solid island which, in past years was the traditional nest site. However, a reduced water level apparently made this island unacceptable to the loons because it became too accessible to the mainland. An artificial nest platform, placed on the lake in 1988, was used by loons but no chicks hatched. In 1989, loons hatched 2 chicks from the artificial platform. In 1990, depth of the lake increased, and the pair successfully hatched chicks from the solid island, despite the availability of the artificial platform. In 1991, the artificial nest platform was selected as the nest site and 2 chicks hatched from this site.

Loons probably used islands of either type opportunistically. Vermeer (1973) found 4 of 26 nest sites on muskeg while 22 were on firmer substrates like sand, clay or rock boulders. Other factors such as wind and wave protection, location in a shallow backwater, productivity of the lake and lack of human disturbance probably dictate which type of island will be used.

Large solid islands are sites where human recreational activities often occur. While I did not observe activity occurring on the larger islands in my study area, I received reports of its occurrence. Other studies have documented the disruption of nesting loons by recreational island use (Titus and VanDruff 1981). Reum (1976) felt that the use of nesting islands for lunch stops or campsites may be a key factor limiting loon reproduction in the Knife Lake area of the Superior National Forest in Minnesota. She indicated that although people did not usually destroy eggs or even locate nests, their presence kept the loons off the nests. Alvo (1981) suggested that loons were beginning to select marsh nest sites over favored open water island sites in response to increased human use of the islands. He postulated that if this is true, the number of sheltered marsh bays may limit the number of breeding pairs on a lake. Munro (1945) noted that when open water islands were not present loons usually nested in marshes.

Nest Measurements

There were no significant differences in sizes of successful and unsuccessful nests regarding inside and outside nest diameters (Chi square=0.1026E-01, df=1,P=0.9192) or height and depth (Chi square=0.5333, df = 1, P=0.4653) (Table 9). Sutcliffe (1980) and McIntyre (1975) also found no relationship between nest measurements and the outcome of nesting attempts.

Table 9. Mean measurements of common loon nests in northwestern Montana 1986-1989.

	Outside diameter (cm)	Inside diameter (cm)	Height (cm)	Depth (cm)
All Nests	64.7	32.5	15.2	5.1
Successful Nests	62.5	32.3	14.3	5.9
Unsuccessful Nests	66.5	32.6	16.3	4.1

Inner and outer diameters and depths of nests in Montana were greater, but not significantly, than those reported by McIntrye (1975) for Minnesota loon nests (Chi square

=0.2075, df=1,P=0.6488). Close agreement can be seen between measurements of Montana and New Hampshire nests (Table 10).

Table 10. Comparisons of sizes of common loon nests in northwestern Montana, Minnesota, and New Hampshire.

Location/researcher	Average outer diameter (cm)	Average inner diameter (cm)
N.W. Montana/This Study	64.7	32.5
Minnesota/ McIntyre (1975)	57.0	24.6
Minnesota/ Olson/Marshall (1952)	56.4	33.3
New Hampshire/ Sutcliffe (1975)	66.0	32.3

Distance to Water

The distance to water, measured from the outer rim of the nest to the closest open water on 32 nests, averaged 7.9 cm (range 0-51 cm). Twenty-three (72%) nests had the outer rim in contact with the water. All nests in my study areas were within 0.5 m from water, which is a small range when compared to other states. Titus and VanDruff (1981) found that 63.6% of nests in Minnesota were less than 0.5 m from water. Sutcliffe (1980) found that most New Hampshire nests were within 91 cm of water with an average distance of 39.9 cm. However, several nests were 3 m from water late in the incubation period. Olson and Marshall (1952) and Vermeer (1973) both indicated that most nests they observed were as close to the water as possible.

There were only slight differences regarding distance to water between successful and unsuccessful nests in my study. Successful nests in Montana ranged from 0-31 cm from water while unsuccessful nests ranged from 0-51 cm. Sutcliffe (1980) noted that loon nests within 0.3 m of water were significantly more successful than those at greater distances. However, 75% of successful nests and 67% of unsuccessful nests were immediately adjacent to the water's edge which suggests that other factors were responsible for nest losses.

Depth of Water at Nest Sites

Depth of water at nest sites was measured at the edge of the island where the nest was located. Average depth was 25.8 cm (n=30, range 5-120 cm). These data are comparable to Olson and Marshall (1952) who reported that water depths at the nest edge in Minnesota averaged 15.4 cm (6 in) and ranged between 0-0.9 m (0-3 ft). A summary of water depths between nest edge and 3 m out into the lake is presented on Table 11.

Table 11. Comparison of water depths between successful and unsuccessful nests.

Distance from nest	Successful (cm)	Unsuccessful (cm)	Total nests (cm)
Nest Edge	28.2	21.5	25.8
0.3 meter	28.9	38.6	34.9
1.5 meter	88.0	42.6	63.3
3.0 meter	89.7	60.4	73.4

Successful nests had a significantly greater depth than unsuccessful nests (Chi square=11.37, df=3, P= 0.0099). My study lakes appeared to have a more gradual slope from shoreline than those reported by Olson and Marshall (1952) where water depths at 3 m (10 feet) ranged between 0.3-6.1 m (1-20 ft) and averaged 1.7 m (5.5 ft).

Olson and Marshall (1952), Vermeer (1973) and McIntyre (1975) indicated that a deep water access point was very important to loon nesting sites because birds were able to slip onto and off the nest with as little obvious activity as possible. Using Sutcliffe's data indicating that 30 cm of water is sufficient depth for a loon to dive, 75% of the nest sites in my study areas had at least 30 cm of water within 1 m of the nest.

Aerial Cover at Nest Sites

Aerial cover generally consisted of willow or alder understory 1.5 m or less in the immediate area of the nest. Of 40 nests analyzed for this component, 25 (63%) lacked aerial cover of any kind. When present, aerial cover usually consisted of a single small tree on one side of the nest. In my study, there appeared to be a slight advantage, though not significant (Chi square=0.8031, df=1, P=0.3702), to nesting at sites without aerial cover since 71% of successful nests were without cover compared to 58% of unsuccessful nests. In contrast, Olson and Marshall (1952) found preference for some degree of overhead cover. They rated overhead cover as dense, medium, sparse or none. Out of 54 nest sites, 11 were rated as having dense cover, 19 had medium, 14 had sparse and 10 had no overhead cover. Vermeer (1973) found that 22 out of 25 nesting islands were wooded while only 3 lacked woody (overhead) cover.

Vegetation Surrounding Nest Sites

Immediate vicinities of 39 nest sites were analyzed for general types of vegetation. Twelve were bare in early May when selected as nest sites. Twenty-seven (73%) were surrounded by some type of vegetation during nest site selection. At the onset of incubation, sedges or grasses surrounded 14 (52%) nests, small trees with or without a grass/sedge/forb understory were immediately adjacent to 10 (37%) nests and cattails surrounded 3. High percentages of nests were located on vegetated sites suggesting a preference for this type of habitat over bare sites.

There were no significant differences in nest success associated with surrounding vegetation (Table 12; Chi square = 2.870, df=2, P=0.2387). However, there were highly significant differences in nest site vegetation between the two drainages within the study area (Table 13; Chi square = 5.304, df=2, P=0.0707). Two-thirds of the nests in the Clearwater were surrounded by taller vegetative types like cattails and small trees. In the

Tobacco-Stillwater drainage, only one-third were found next to small trees. Cattail habitats were not utilized in the Tobacco-Stillwater drainage (Table 13). This differential use of cover types may be a factor in the higher nest success which occurred within the Clearwater-Swan drainage compared with that in the Tobacco-Stillwater. Since the grass/sedge vegetative type is commonly found along the shoreline in both drainages, its presence probably reflects the selection of a site immediately adjacent to water.

Table 12. Comparison of successful and unsuccessful nests with regard to vegetative types adjacent to the nest site.

Vegetative type	Successful nests (n=15)	Unsuccessful nests (n=12)
Cattails	20%	0%
Small trees with sedge/grass/forb understory	33%	50%
Grasses/sedges	47%	50%

Table 13. Comparison of the Clearwater-Swan drainage and the Tobacco-Stillwater drainage with regard to use of 3 vegetative types.

Vegetative type	Clearwater-Swan drainage (n=12)	Tobacco-Stillwater drainage (n=15)	Combined drainages (n=27)
Cattails	25%	0%	11%
Small trees with sedge/grass/forb understory	42%	33%	37%
Grasses/sedge	33%	67%	52%

Vermeer (1973) found that the most frequent plant species bordering loon nests in Alberta, Canada were sedges, willow and balsam poplars. Olson and Marshall (1952) identified 6 major cover types including sedges and grasses, willow-alder, cattails/bulrush, and no cover. Titus and VanDruff (1981) reported that less visible nests in the Boundary Waters Canoe Area in northeastern Minnesota were significantly more successful than more visible nests.

Composition of Nest Materials

All of the 35 nests examined in my study were composed of submergent vegetation which the loons had piled on the nest site. Seventeen percent had additional materials such as grasses or cattails placed on top. Considerable differences existed in the amount of submergent vegetation used within a particular nest. Two nests located on peat islands on North Seeley were large structures measuring 92 x 97 x 21 cm and 87 x 87 x 23 cm. They were composed entirely of submergent vegetation pulled from the lake. In contrast, 1 nest on a solid island consisted only of a thin base of submergent vegetation with cattail stems piled on top. Two nests were built on artificial platforms using materials which were provided for nesting. In these cases, the loons did not appear to utilize any material from the lake.

Loon nests are often composed of materials found in the immediate vicinity of the nest (McIntyre, 1975). McIntyre (1975) noted that loon nests on her study area were remarkably similar to one another. Most contained "much wet rotting vegetation" and were generally composed of clumps of roots, rhizomes, and decayed vegetation. Stems and sticks added rigidity. She felt that differences in size and bulk of nests such as those noted in my study may be explained by the fact that nesting materials are more available on sedge mats which have an abundance of aquatic vegetation near the nest. Nests on solid islands with gravel beaches and shallow access to water typically have fewer materials with which to build a nest. She also hypothesized that the size of the final nest structure may be determined by the degree of firmness since a substantial substrate is required to support the weight of the nest, 1 or both adults and still keep the eggs from being submerged.

Sutcliffe (1980) and McIntyre (1975) both noted that loons are opportunistic in obtaining nest construction materials. Nests were composed of any available material and loons did not demonstrate a specific vegetative preference. My data from loon nests in northwestern Montana is in agreement with their findings.

Nest Location as Affected by Wind and Wave Action

Fifty-four percent (25 of 46) of the nests were located at the north end of a lake while 20% were found at the south end. Nests located on the east side, west side and middle of the lakes represented 15%, 2%, and 9% of the locations, respectively. Successful (n=25) and unsuccessful nests (n=21) were located at the north end of a lake 60% and 48% of the time, respectively. The predominance of nests at the north end of a lake may reflect the fact that the prevailing winds come from a northwesterly direction and wave action on such nests would be less devastating. However, since nest success was quite similar at various directional locations on a lake, factors other than wind may be involved (Table 14).

Table 14. Comparison of successful and unsuccessful nests in relation to directional locations along lake shorelines.

Nests	North	South	East	West	Middle
Successful nests (n=25)	60%	20%	12%	0%	8%
Unsuccessful nests (n=21)	48%	19%	19%	4%	10%
Total nests (n=46)	54%	20%	15%	2%	9%

McIntyre (1975) found that most nests in her study area in Minnesota were located on the north and/or west sides of a lake. As in Montana, the prevailing winds from the northwest created strong wave action on the south and east sides of a lake. She indicated that while prevailing winds shape the shoreline and that while loons place nests to minimize flooding, the proximate cause of selection for north and west sides appeared to be choice of substrate.

Ninety-one percent of nests (39 of 43) in my study area were protected from wave action by a nearby shoreline, a small point, an island or by its location in a northwest backbay. Similar findings were reported by Vermeer (1973) and Olson and Marshall (1952). Sutcliffe (1980) also found that 91% of nests in New Hampshire were sheltered from an "expansive fetch of wind" and felt that degree of shelter from waves was a major determining factor in positioning of loon nests.

Wind Direction and Orientation Faced while Incubating

Prevailing winds in northwestern Montana are typically from the north or west. This was reflected in the fact that 90% (39 of 43) of observations at nest sites recorded winds coming from these directions. The directional orientation of 23 incubating loons was observed. Twenty-one consistently faced either south or east while setting on the nest. Nine birds were observed facing either north or west. The fact that directional orientation of incubating loons is opposite the prevailing wind direction may be coincidental. Other researchers have reported that loons tend to face the open water of their nesting lake so the direction a loon faces while incubating is probably more a function of the nest location on the lake than the direction of prevailing winds in the area (Yonge, 1981). In this study, 17 of the 23 incubating loons faced the open lake.

Reuse of Nests

Strong et al. (1987) defined reuse as either nesting within the same nest bowl used in a previous year or nesting within 50 m of a previously used nest. Reuse of the same physiographic area (cove, marsh, backwater or island) of a territory was also important to determine since management plans should attempt to reduce or prevent shoreline development within these areas. I observed nest sites on 13 breeding territories for 2 or more years. This allowed determination of the amount of reuse of a nest site. Forty-five nests were located during this time which allowed 32 year to year comparisons. Combined data revealed that reuse of a physiographic area occurred 94% of the time indicating a high fidelity to a particular nesting area. Nest sites were within 50 m of a previously used nest bowl 50% (16 of 32) of the time while nests located within a previously used nest bowl occurred in only 4 of 32 comparisons. There were no differences in reuse between the 2 study areas (Table 15).

Table 15. Comparison of reuse of nest sites and physiographic areas used for nesting in the Tobacco-Stillwater drainage and the Clearwater-Swan drainage.

Drainage	**Reuse of physiographic area (n=19)**	**Reuse of nest within 50 m. of previous nest (n=18)**	**Reuse of old nest bowl (n=19)**
Clearwater/ Swan (n=17)	94%	47%	12%
Tobacco/ Stillwater (n=15)	93%	53%	13%
Combined data (n=32)	94%	50%	13%

In order to determine how success affected reuse, year to year comparisons were classified into four categories as follows: 1) a successful nest was followed the next year by another successful nest (+/+); 2) a successful nest was followed by an unsuccessful nest (+/-); 3) An unsuccessful nest was followed by a successful nest (-/+); 4) An unsuccessful nest was followed by another unsuccessful nest (-/-) (Table 16). Loons nesting successfully one year renested within 50 m of the previous nest over 60% of the time. However, loons which experienced successive nest failures usually did not reuse the area the following year. These observations agree with Strong et al. (1987) who postulated that since loons are long-lived birds, experience may supplement instinct with regard to nest site selection.

Table 16. Comparison of reuse of nest sites and physiographic areas for 4 categories of successful and unsuccessful nests.

Success categories	Reuse of physiographic area	Reuse of nest within 50 m. of previous nest	Reuse of old nest bowl
+/+ (n=12)	100%	58%	0%
+/- (n=6)	83%	67%	33%
-/+ (n=7)	100%	43%	29%
-/- (n=7)	86%	29%	14%

Nest Failure

Twenty-two of 48 nests were unsuccessful for a variety of reasons. Thirteen were lost for unknown reasons while 7 (32%) were flooded by rising water due to heavy and prolonged precipitation or beaver (Castor canadensis) activity. A mammalian predator and an infertile egg were each responsible for 1 nest loss.

Losses due to unknown reasons (n=13) were categorized into suspected causes of failure which included human disturbance (54%), dropping water levels (8%), interactions with bald eagles (Haliaeetus leucocephalus) (8%), wash out by wave action (8%) and unknown losses with no probable or suspected cause (23%). It is possible that nest failures due to predation in northwestern Montana could be as high as 64% if known mammalian predation is combined with losses for unknown reasons.

Human disturbance was suspected in 7 of 13 unknown losses because of the high frequency of recreational activity seen in the nest area. It probably affected success indirectly by influencing vulnerability of eggs to predation. Ravens (Corvus corax) were probably the predator responsible for most losses as they were present on both study areas and were frequently seen flying over nesting loons. In 1 case, a fishing boat forced a loon from the nest at Lake Alva. Two ravens were flying over the nest as this occurred and 1 spiraled towards the nest. The loon was close enough to mount the nest in time to protect the eggs. Ravens were also seen swooping down over nesting loons on Seeley Lake as if trying to intimidate them into leaving the nests. One loon lowered its head as the raven passed, however, I never observed a loon leaving the nest due to these activities.

Interactions with a pair of bald eagles was the suspected reason for the loss of 1 nest on Salmon Lake. Bald eagles were responsible for keeping 5 different pairs of loons off their respective nests for at least 25 minutes.

An infertile egg was the reason for nest failure at Loon Lake (Trego). This particular lake experienced repeated unsuccessful nesting attempts due to dropping water levels which caused the only island to be accessible to land predators. An artificial nest platform was placed on the lake for use by the loons but became the site of a Canada goose (Branta canadensis) nest on 22 April. However, on 2 May the loon was incubating on the platform. Nesting materials were lost through the wire mesh on the bottom of the platform throughout May. On 4 June the loon rearranged the nest and continued to incubate 1 loon egg and 1 goose egg until sometime between 5 August and 10 August when she was observed off the nest. This prolonged incubation lasted approximately 95 days. Sutcliffe (1975) reported an incident of prolonged incubation of up to 74 days in New Hampshire.

In New Hampshire 57% of the nests failed. Raccoon (Procyon lotor) predation was the major reason and was responsible for 37% of the nest failures (Sutcliffe 1980). McIntrye (1975) found that predation was responsible for 75% of the nest failures in Minnesota but only 46% of failures of nests located on islands. However, losses of nests located on sedge mats were always the result of predation. The raccoon was also the principle predator in Minnesota (McIntrye 1975). She also indicated that while most losses occurred at night, diurnal loon activity associated with nest relief, not the nest and eggs per se, may draw attention to the nest, especially from avian predators. This would underscore the importance of a deep water access to the nest site.

Human Disturbance

Several studies have documented that human activities can have negative impacts upon nesting success and brood survival of common loons. Titus and VanDruff (1981) noted that loons were reproductively more successful on lakes where motors were not allowed. Vermeer (1973) felt that the loon's intolerance to human disturbance may leave fewer or no young to return to breed on lakes where such disturbances occur. Using disturbance ratios also utilized in this study, he concluded that loons prefer to nest on lakes where there is a minimum of human disturbance. Heimberger (1983) reported that loons which initiated incubation early in the breeding season were more likely to be successful than those which nested later when the risk of human disturbance was greater. She found that hatching success declined as the number of cottages within 150 m of the nest increased. However, once eggs had hatched, chick survival appeared to be independent of cottage development. Heimberger further indicated that loons can cope with a relatively low level of recreational pressure from humans and that some loons nesting on developed lakes had become habituated to human disturbances. Reum (1976) indicated that the main factor limiting reproduction appeared to be disturbance of nest sites by canoeists during spring breeding season.

In this study I attempted to identify specific human activities which may negatively impact nesting and rearing success of common loons. I also wanted to determine if mitigative measures such as posted floating signs forming voluntary closures around nest sites would effectively reduce human disturbance.

Disturbance Ratios

There were no significant differences between the Clearwater-Swan and Tobacco-Stillwater drainages with regard to the surface area disturbance ratio indicating that the lakes in the 2 drainages had about the same level of human disturbance. However, when lakes with a disturbance ratio of 0 were excluded to allow exclusive comparisons of lakes experiencing recreational development, the Clearwater-Swan had a higher average shoreline disturbance ratio than the Tobacco-Stillwater (Mann-Whitney test, P=0.2390) (Table 17). This difference, although not statistically significant, does agree with field observations that the Clearwater-Swan drainage was more impacted by human activity than the Tobacco-Stillwater.

Skaar's disturbance ratings are summarized in Table 18. Mann-Whitney tests revealed that the drainages had similar shoreline disturbance ratings (P=0.9431). Fishing pressure (P=0.5677) and public access (P=0.3531) also were not significantly different between the 2 drainages.

Simple regressions compared the 2 disturbance ratios and Skaar's ratings to chick production, fledging and percent survival before and after the protective signs were used. In most cases there were no significant relationships. However, a significant negative relationship was revealed between the number of chicks produced per total nest attempt and the surface area disturbance ratio (r=0.6586; P=0.0104) (Fig.4) indicating that increasing human disturbance does negatively impact chick production. A positive relationship (Fig.5) was discovered between the number of fledged juveniles per nest attempt after use of protective signs and Skaar's disturbance ratings (r=0,405; P= 0.1503). While not statistically significant, this may indicate that mitigative measures are helping to overcome the disturbance created by recreational activities. However, protective signs are removed by mid-July and should not affect fledging success. It is possible that signs do reduce some mortality which occurs during the first 2 weeks after hatching by limiting the amount of activity occurring in nursery areas used by newly hatched chicks.

Table 17. Calculated surface area and shoreline disturbance ratios of study lakes in the Clearwater-Swan and Tobacco-Stillwater drainages; number government campgrounds/resorts (#G C/R), number of unmaintained public access sites (#U PAS), number of homes/cabins (#H/C, total disturbance units (Total DU). Disturbance ratio modified after Vermeer (1973).

Lake	#G C/R	#U PAS	#H/C	Total DU	Size ha (acres)	Disturbance ratio units/ha (acres)	Shoreline length (m)	Disturbance ratio unit/length
Clearwater-Swan drainage								
Loon (KC)	0	0	0	0	25.7 (10.4)	0.0000 (0.0000)	1392	0.0000
Holland	2	0	16	36	428.8 (173.6)	0.0840 (0.2074)	8608	0.0040
Lindbergh	1	0	50	60	800.0 (324.2)	0.0749 (0.1851)	16604	0.0040
Clearwater	1	0	0	10	107.4 (43.5)	0.0931 (0.2300)	-	-
Marshall	1	0	0	10	82.5 (33.4)	0.1212 (0.2994)	3017	0.003
Rainy	1	0	0	10	76.3 (30.9)	0.1311 (0.3240)	2551	0.004
Alva	2	0	0	20	300.4 (121.6)	0.0666 (0.1644)	6642	0.003
Inez	2	0	31	51	271.2 (109.8)	0.1881 (0.4645)	6995	0.007
Seeley	8	0	88	168	1027.3 (415.9)	0.1587 (0.4039)	13899	0.012
Placid	2	1	69	94	1193.0 (483)	0.0788 (0.1946)	10820	0.009
Salmon	3	1	11	46	597.7 (242)	0.0770 (0.1901)	15530	0.003
Tobacco-Stillwater drainage								
Tally	1	0	0	10	1237.5 (501)	0.0081 (0.020)	13509	0.0007
Upper Whitefish Lake	1	0	0	10	81.3 (32.9)	0.1230 (0.304)	2657	0.0040
Lower Stillwater	2	1	19	44	248.3 (100.5)	0.1772 (0.438)	6565	0.0070
Upper Stillwater	1	0	0	10	600.7 (243.2)	0.0166 (0.0411)	16609	0.0006
Dog	1	2	1	21	97.1 (39.3)	0.1133 (0.5344)	4292	0.0049
Fish	0	1	1	6	31.6 (12.8)	0.1899 (0.4690)	3008	0.0020
Bull	0	2	1	11	100.8 (40.8)	0.1091 (0.2700)	5480	0.0020
Fishbull	0	0	1	1	14.6 (5.9)	0.0685 (0.1690)	1386	0.0007
Dickey	3	0	9	39	594.8 (240.8)	0.0656 (0.1620)	7775	0.0050
Murphy	1	1	4	19	142.5 (57.7)	0.1333 (0.329)	3293	0.0060
Loon (Trego)	0	0	0	0	36.3 (14.7)	0.0000 (0.0000)	2185	0.0000
Marl	0	2	1	11	102.8 (41.6)	0.0584 (0.2644)	2692	0.0041

Table 18. Summary of the Skaar disturbance rating for individual study lakes in the Tobacco-Stillwater and Clearwater-Swan drainages.

	Shoreline disturbance	Fishing pressure	Public lake access	Total
<u>Clearwater-Swan drainage</u>				
Loon (KC)	1	1	2	4
Rainy	1	2	2	5
Alva	2	3	3	8
Seeley	3	3	3	9
Salmon	3	1	3	7
<u>Tobacco-Stillwater drainage</u>				
Tally	2	1	3	6
Lower Stillwater	2	2	2	6
Upper Stillwater	2	1	3	6
Fishbull	3	2	1	6
Murphy	2	3	3	8
Marl	3	2	2	7
Loon (Tr)	1	2	1	4

<u>Shoreline Disturbance Ratings</u>: (1) <= 15.1% disturbed; (2) 17.3-38.4% disturbed; (3) >= 38.7% disturbed; (Disturbance = percent of shoreline within 200 feet of a road, campground, house or boat ramp). <u>Fishing Pressure Ratings</u>: (1) <=82.7 angler days/yr/km shoreline; (2) 95.1-181.4 angler days/yr/km shoreline; (3) >= 183.7 angler days/yr/km shoreline. <u>Public Access:</u> (1) No road within 200 feet of lake or no public access permitted. (2) Road within 200 feet of lake, public access allowed, no public boat access site exists. (3) Public boat access site exists.

Data reported by the Minnesota and New York Project Loon Watch programs indicated no significant differences in loon productivity on lakes divided into 9 human use categories ranging from no use to heavy motorized boat traffic (McIntyre, 1989). Smith (1981) found that productivity was essentially identical for Alaskan lakes on a canoe route and lakes receiving little or no human use. On the Boundary Waters Canoe Area, Titus and Van Druff (1981) reported that during 1 year of research productivity on heavily used lakes was the same as that observed on low-use lakes. However, the following year, the low-use lakes fledged 80% more young per pair than high-use lakes.

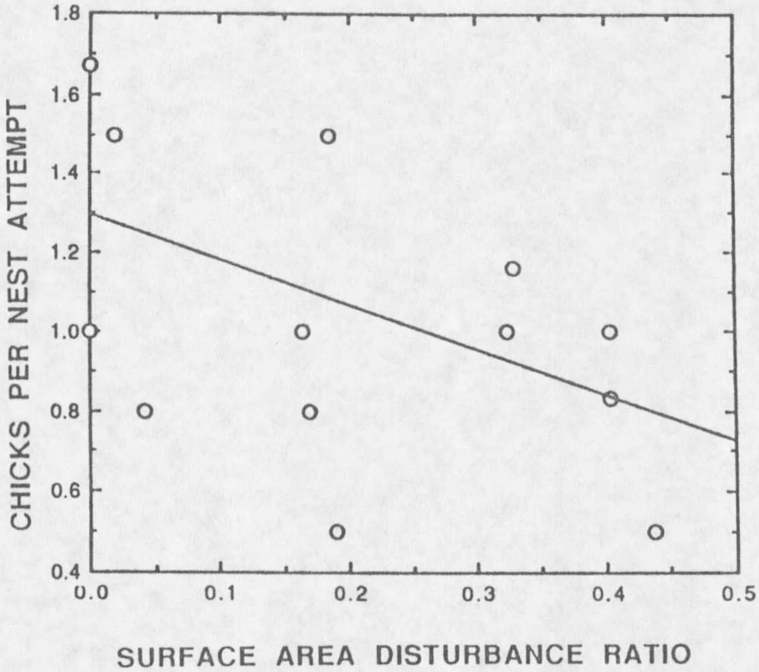

Figure 4. The relationship between the number of chicks produced per total nest attempt and the surface area disturbance ratio.

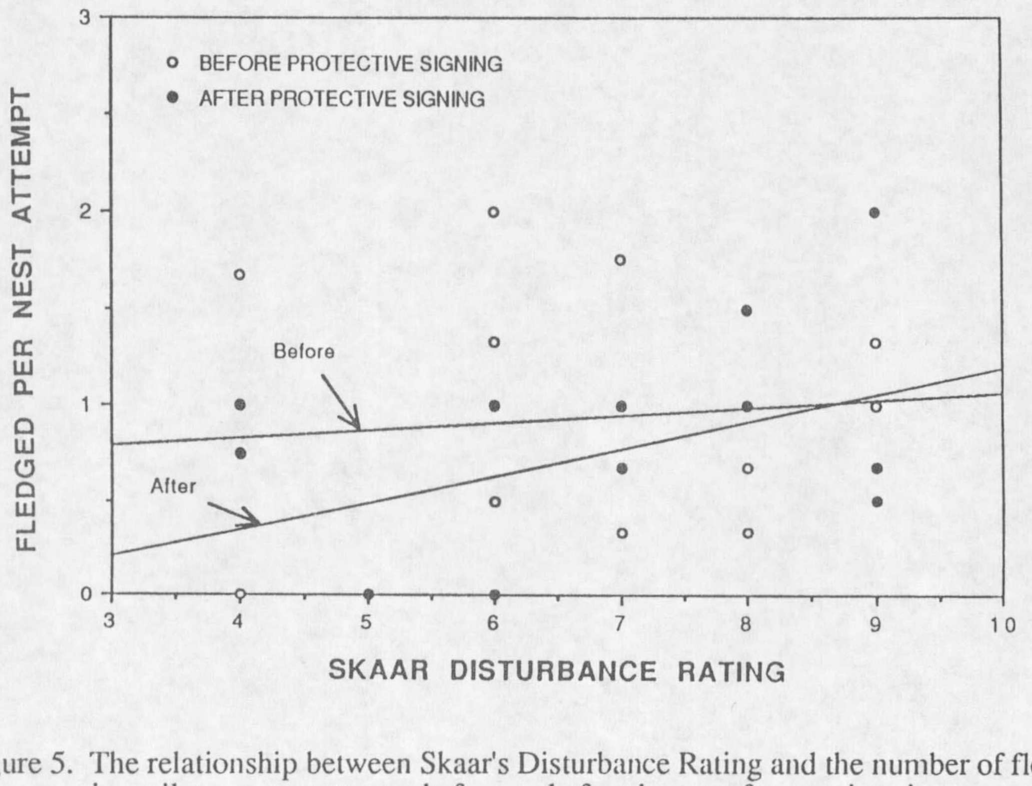

Figure 5. The relationship between Skaar's Disturbance Rating and the number of fledged juveniles per nest attempt before and after the use of protective signs.

Apparent Causes of leaving Nest Sites

Average time off the nest due to natural causes was significantly shorter then for human related disturbances (Mann-Whitney; P=0.0369) which included boats, shoreline disturbance and human activity occurring after the loon flushed for unknown reasons (Table 19). These activities accounted for 59% of the observed flushes from nests and resulted in loons staying off their nests an average of 24 minutes per flush. Twelve (52%) of the 23 boats involved in flushing loons were fishing boats. Three canoes (13%), 1 kayak (4%), 4 rowboats (17%) and 3 (13%) unspecified boats made up the balance of the boats causing temporary abandonment of nests.

Table 19. Reasons for loon nest departures and average time away from the nest in the Clearwater-Swan drainage in the Lolo National Forest, 1988-89 (n=45).

Apparent cause of flushing	Percent	Average time off nest (min)
Natural causes of leaving the nest		
Territoriality	9%	10.6
Nest building	11%	4.1
Insects/heat stress	7%	10.6
Changing incubators	4%	4.9
Unknown cause/no human disturbance after entering water	9%	10.0
Human related causes for flushing		
Boats	51%	21.8
Shoreline disturbance	4%	26.3
Unknown cause/human disturbance occurred after entering water	4%	24.0

On 2 occasions, activity on the shoreline caused the incubating bird to leave the nest. One of these cases involved people loudly conversing at a boat dock 277 yards south of the nest. The other was an unknown disturbance occurring on the mainland directly behind the nest. These 2 disturbances occurred near the same nest which was in its first week of incubation. This loon appeared to be more sensitive to disturbance than it would have been later in incubation.

Natural activities which resulted in loons leaving the nest included territorial activities, nest building, heat stress and harassment of the nesting loon by insects. These activities accounted for 40% of the flushes from nests which lasted an average of 8 minutes. Observed territorial behavior included raised necks, displacement peering, displacement diving, mutual or individual splash dives, chasing, penguin dances or the utterance of yodels as described by Rummel and Goetzinger (1975). Actual observance of an intruder was made in only 1 of 4 territorial disruptions. In 2 cases the cause of the territorial behavior could not be identified. In the fourth case, territorial aggression was directed at a female ring-necked duck (Aythya collaris) that apparently swam too close to the nest site. Typically, territorial displays from the non-incubating bird would cause the incubating bird to leave the nest.

Nest building activities occurred when birds pulled vegetative materials out of the lake and threw it onto the nest. This activity was most commonly observed during the first week of incubation. Times off the nest were generally very short.

Harassment by insects was evident during observations on hot spring days when incubating birds vigorously shook or rubbed their heads before leaving the nest and entering the water. Heat stress was suspected when the birds were seen panting or sitting with wings slightly opened before entering the water.

Changing incubating duties was observed 4 times. On 2 occasions, the incubating bird left the nest and the non-incubating bird took over setting on the eggs a short time later. The loons on Loon Lake on Kraft Creek road were also observed changing incubators twice. However, in both of these instances, the non-incubating bird mounted the nest and moved next to the setting bird. The loon on the nest then slipped off while the second moved over onto the nest, turned the eggs and resumed incubation. During this procedure, the eggs were never left unattended and actual departure from the nest did not occur.

Flushes resulting from unknown causes, in which loons left the nest for apparently no reason, accounted for 13% of 45 departures. In 4 of 6 cases no disruption from humans occurred during the time they were off the nest.

In 1988, the nests on all lakes were unprotected from human activity and 56% of the 32 nest departures occurred because of boating activities. During that year only 2 chicks hatched on the Lolo National Forest prompting implementation of voluntary closure areas around nests on Salmon, Mid-Seeley, North Seeley, and Alva. Placid was not involved because no National Forest land adjoins the lake. In 1989, signs mounted on floating platforms were placed approximately 91 m (100 yds) from the nest sites. Mid-Seeley also had a buoyed rope barrier placed at 48 m from the nest because of the high level of recreational boating in the vicinity of this nest site. Comparison of data on nest disturbance for 1988 and 1989 (Table 20) revealed that the total number of nest departures for all causes was reduced from 32 to 13 (Mann-Whitney; P=0.1939). This reduction, while not statistically significant, indicates the effectiveness of the voluntary closures. While number of natural causes for leaving a nest remained at about the same level for both years, the number of flushings resulting from human activity (especially approaching boats) was reduced significantly (Chi Square = 3.534, df=1, P=0.0604). Anchored or approaching boats still caused 38.5% of 13 nest departures, 3 of these 5 cases occurred before floating signs were set. Only 2 disturbances occurred after the signs were in place.

Table 20. A comparison of the number of times loons were observed leaving a nest due to natural activities and human disturbances during 1988 (before voluntary closures) and 1989 (after voluntary closures) on the Clearwater-Swan Drainage.

Lake	Human related activity causing an incubating loon to flush from a nest	Natural activities causing an incubating loon to leave the nest	Total
North Seeley:			
1988	8	3	11
1989	2	0	2
Total	10	3	13
Mid-Seeley:			
1988	6	1	7
1989	2	5	7
Total	8	6	14
Alva:			
1988	7	5	12
1989	*	*	*
Total	7	5	12
Salmon:			
1988	**	**	**
1989	1	1	2
Total	1	1	2
Loon: (Control lake)			
1988	1	1	2
1989	0	2	2
Total	1	3	4
Total 1988:	22	10	32
Total 1989:	5	8	13
Combined total :	27	18	45

* Failed to initiate a nest.
** Nest failed.

Percent Time Spent off the Nest

The percent of time spent off the nest in 1988 (before voluntary closures) was reduced to levels comparable to the control lake in 1989 after floating signs limited human activity (Table 21). Both daily and weekly averages were presented because weekly averages did not reveal the severity of some of the daily disturbances. I felt that 1 extreme disturbance on any particular day is more likely to result in nest loss than a series of minor disturbances

Table 21. Percent time off the nest related to the week of incubation for 1988 (before voluntary closures) and 1989 (after voluntary closures) on the Clearwater-Swan drainage.

Lake	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Yearly average**	**# Chicks hatched**
North Seeley						
1988:						
Day 1	0%	0%	22%	11%		
Day 2	20%	40%	25%	2%		
Average	10%	20%	24%	7%	15.3%	1
1989:						
Day 1	0%	27%	0%	nf		
Day 2	0%	14%	0%	nf		
Average	0%	20%	0%	nf	6.7%	0
Mid-Seeley:						
1988:						
Day 1	16%	5%	nf	nf		
Day 2	57%	73%	nf	nf		
Average	37%	39%	nf	nf	38.0%	0
1989:						
Day 1	0%	13%	0%	0%		
Day 2	0%	16%	0%	0%		
Average	0%	15%	0%	0%	3.8%	1
Salmon:						
1988:*	nf	nf	nf	nf	-	0
1989:						
Day 1	0%	0%	0%	0%		
Day 2	0%	8%	0%	-		
Average	0%	4%	0%	0%	1.0%	2
Alva:						
1988:						
Day 1	5%	-	0%	10%		
Day 2	1%	12%	49%	13%		
Average	3%	12%	25%	12%	13.0%	0
1989:**	nf	nf	nf	nf	-	0
Loon: (control lake)						
1988						
Day 1	-	-	-	-		
Day 2	0%	0%	9%	12%		
Average:	0%	0%	9%	12%	5.3%	2
1989						
Day 1	12%	-	-	-		
Day 2	0%	0%	9%	0%		
Average	6%	0%	9%	0%	3.8%	2

*Nest failed in 1988. 1989 data is comparable to other lakes for that year.

** Failed to initiate nest in 1989 but 1988 data is comparable to other lakes for that year.

occurring throughout the weekend. Typically an "extreme disturbance" results when a fishing boat anchors near a loon nest and stays in that spot for an extended period of time. Loons on the control lake (Loon Lake) spent an average of 5.3% of their time off the nest in 1988. Loons on Alva lost their nest after being off the nest 13% while North Seeley hatched 1 chick after being off the nest 15% of the time. The North Seeley pair seemed to be somewhat habituated to humans which may be a contributing factor to a successful nesting attempt at this level of disturbance.

Results from 1989 data show that loons on the control lake were off the nest 3.8% of the time. All successful nests compared favorably to this figure. It's important to note that all these nests were protected by either floating signs, buoyed ropes or both. A disturbance during the second week on North Seeley kept the bird off the nest 27% of the observation period. This occurred before signs were in place. This was the only protected nest which was lost due to unknown circumstances.

Flushing Distances

Flushing distance was defined as that distance at which a loon leaves its nest due to an approaching boat. Average flushing distances for the 4 weeks of incubation were 129, 121, 91 and 64 m, respectively (Table 22). These data indicate that loons exhibit increased fidelity to nests as incubation progresses in that flushing distances appear to be proportional to the amount of investment the loon has in the eggs. Olson and Marshall (1952) also noted this among nesting loons in Minnesota.

It is difficult to compare my data with those of Titus and VanDruff (1981) or Smith (1981) because they compared flushing distances of high and low use recreational areas. Loon Lake was not useful as a control lake for flushing distances because there was no boating pressure on this lake and there was no other "low use" lake available in the Clearwater-Swan drainage. Although Titus and Van Druff (1981) and Smith (1981) did

Table 22. Average boat distances (meters) at which departure from nests occurred related to the week of incubation.

	Week 1	Week 2	Week 3	Week 4
North Seeley:				
1988	144	117	-	46
1989	-	123	-	nf
Average	144	120	-	46
Mid Seeley:				
1988	254	110	nf	nf
1989	128	128	114	-
Average	191	119	114	-
Alva:				
1988	-	125	68	83
1989	nf	nf	nf	nf
Average	-	125	68	83
Salmon:				
1988	nf	nf	nf	nf
1989	118	-	-	-
Average	118	-	-	-
Placid:				
1988	-	-	-	-
1989	-		-	64
Average:	-	-	-	64
Combined average:	129	121	91	64

not specifically report flushing distances in relation to week of incubation, Titus (1979) reported flushing distances which were much shorter than those I calculated. Birds on heavily used lakes flushed at 41.6 m and birds on his remote lakes flushed at 23.1 m. Smith (1981) reported that the mean flushing distance on high use lakes within a canoe system was 8.5 m with a range of 0-55 m. On the low use control lakes the mean flushing distance was 112.6 m with a range of 7-273 m. The data for the low use lakes compare more favorably to the flushing distances I found on lakes in the Clearwater-Swan drainage.

Heimberger (1983) indicated that hatching success declined as the number of cottages within 150 m increased. While this is a different type of disturbance, it indicates that loons are sensitive to various kinds of disturbances at this distance which is comparable to my flushing distance for the first week of incubation.

The calculated flushing distances for 1988 were used as a guideline in 1989 for placement of floating signs around nest sites. Signs were placed at about 91 m (100 yds) from the nest. Boats tended to stay some distance from the signs so that incubating loons actually were more than 91 m from boats in the area. Signs were initially placed at 91 m to minimize the impact on recreational fishing and still protect the nest sites. After combining the data for 1988 and 1989, the average flushing distances were greater than 91 m during the first 2 weeks of incubation indicating that the floating signs should have been placed further from the nest in order to give adequate protection during the first half of the incubation period. In future years, 5-6 signs will be placed at 137 m (150 yds) since compliance with the voluntary closures was high and the loons need more distance at the beginning of the incubation period.

Results of Voluntary Closures on Reproductive Success

The effect of voluntary closures on reproductive success was quantified by calculating ratios consisting of reproductive parameters compared to the number of lake years. This was necessary because not all of the lakes were involved in mitigative efforts the same year. Nine lakes chosen for this analysis had at least 2 years of both "pre" and "post" data. Mann-Whitney tests revealed that the number of successful nests increased significantly (P=0.0576) after the use of the signs. The same was true for the number of chicks produced (P=0.0171), and the number of 2-chick broods (P=0.0341). The number of chicks produced was obviously influenced by the increased number of 2-chick broods. The number of 1-chick broods remained at the same level before and after the use of signs. Signs were put into position after the nest was discovered (after the nest attempt was made) so the "pre" and "post" data for this parameter are not comparable (Table 23).

Table 23. Summary of various parameters of reproductive success per lake year before and after the use of voluntary closures around nest sites.

Reproductive parameter	Before voluntary closures number	Before voluntary closures percent	After voluntary closures number	After voluntary closures percent
Lake year	32		22	
# Successful nests	13	42	16	72
# Chicks produced	17	54	25	115
# Nest attempts	20	67	22	100
# 1 Chick broods	9	30	7	30
# 2 Chick broods	4	12	9	43

These data demonstrate that recreational activity on nesting territories during the nesting season is having a significant negative effect upon the reproductive success of loons on the study area. The data also demonstrate that the effects of this recreational activity can be mitigated with management of the spring fishing/recreational activities by the use of floating signs surrounding the nest sites. The increase in the number of 2-chick broods is especially significant since McIntyre (1975) stated that 2-chick broods represent the maximum breeding potential of common loons. Yonge (1981) demonstrated that the second egg and chick are expendable. Thus it appears that the floating signs are providing the security needed to allow the loon to stay on the nest the extra time necessary to bring off the second chick.

When the 9 lakes involved in the above analysis were categorized into small (< 250 ha) and large (>250 ha) lakes the number of 2-chick broods significantly increased on small lakes after the use of voluntary closures (Chi Square = 5.6, df = 1, P= 0.0180) (Table 24). The numbers of 1 and 2 chick broods were essentially the same before and after the voluntary closures on large lakes. There were more 1-chick broods found on large lakes which was a tendency also noted by Jung (1987).

Table 24. Effects of voluntary closures (VC) on the production of 1 and 2 chick broods on small and large lakes.

Size	1 chick broods #broods before VC	 # broods after VC	2 chick broods # broods before VC	 # broods after VC
Small lakes (<250 ha) (n=5)	4	1	0	7
Large Lakes (>250 ha) (n=3)	5	6	3	2

Since loons are thought to benefit from longer shorelines, especially associated with higher shoreline development factors, Chi-square tests were run to see if more 2-chick broods would be associated with longer shorelines (Table 25). The division of lakes between categories was similar to that in Table 24 since smaller lakes tend to have shorter shorelines. Salmon Lake, classified as a small lake (242 ha) in Table 24, was placed in the long shoreline category (15.3 km) for the purposes of Table 25. Nevertheless, production of 1 and 2-chick broods were exactly the same on lakes with longer shorelines before and after use of voluntary closures. There were no significant differences between lakes with short and long shorelines and the number of 1-chick broods. However, there were significantly more 2-chick broods produced on lakes with shorter shorelines after voluntary closures were in effect (Chi-square = 4.0; df=1; P= 0.0455).

Table 25. Effects of voluntary closures (VC) on the production of 1 and 2 chick broods on lakes with shoreline lengths less than 8 km and greater than 8 km.

Shoreline length	1 chick broods # broods before VC	 # broods after VC	2 chick broods # broods before VC	 # broods after VC
< 8 km (n=4)	3	1	0	6
> 8 km (n=4)	6	6	3	3

These data indicate that mitigative measures such as voluntary closures created by floating protective signs will benefit smaller lakes more than larger bodies of water. The effects of human recreational activities on large lakes are more dispersed than on smaller lakes. As a result, when time, money and/or personnel are limited, smaller lakes with a breeding pair will benefit more from these management efforts than larger lakes.

MANAGEMENT RECOMMENDATIONS

Successful common loon management depends upon: 1) identification of and protection of nesting and nursery areas from shoreline development and other factors (Strong, 1987; McIntrye, 1983); 2) identification of and protection of individual nesting loons using floating signs on lakes where moderate to high levels of human recreational activities occur. Loon nests in Montana are often located in bass or pike habitat which may experience significant early spring disturbance associated with fishing activity. Three to 6 signs should be placed at approximately 137 m (150 yards) in a semicircle around the nest site. The number of signs will be determined by location of the nest site. If the signs are placed too far out, their effectiveness diminishes as people may not see the signs and inadvertently enter the nesting area. Despite excellent compliance, signs which close off too large of an area may be ignored, removed or vandalized.

Once the voluntary closures are in place, public education about the signs and their purpose will greatly improve public compliance. The most effective way to do this is to have an individual talking to the public at the public access sites as they are putting boats into the water. A spotting scope set up at the boat ramp which enables people to see the nesting loon further enhances public knowledge and compliance with the voluntary closures. Newspaper articles, radio, TV and educational talks given to various sporting groups are important components in the public education efforts.

The signs are left in the water for 1-2 weeks after hatching to allow the chicks to become strong enough to leave the protected nursery area. However, signs can be removed immediately if the adults move the chicks out of the voluntary closure soon after hatching. It is important to remove the signs within this period of time because if they are left in place, they will gradually be ignored by the recreating public. This may encourage noncompliance during the next nesting season.

SUMMARY

Arrival on territories occurred immediately after ice-out with over 68% of the loons arriving on their territories between 14 April - 21 April. Fifty-three percent of nesting pairs were incubating by 7 May during 1986-90, although a significant difference was observed between drainages. Most of the nesting pairs in the Clearwater-Swan drainage were incubating by 7 May while most in the Tobacco-Stillwater initiated incubation between 8-20 May.

All nests initiated between 26 April - 1 May were successful (n=5) while 83% (n=24) initiated between 26-7 May and 71% (n=21) initiated between 8 May-26 May were successful. Loons in the Tobacco-Stillwater drainage experienced a lower rate of reproductive success in terms of the number of territorial, nesting and successfully nesting pairs. A significant number of pairs in this drainage nested after 8 May. Sixty-eight percent (n=35) of chicks hatched between 24 May-7 June while 97% hatched by 14 June.

The adult loon population in the two drainages between 1986-1991 was 48 birds or approximately 30% of the population reported for Montana by Skaar (1989). A density of 72.2 hectares of lake surface area per adult loon was determined for the entire study area.

Seventeen pairs exhibited territorial or pair-bonding behaviors. Fourteen pairs were either observed incubating or nest sites were discovered upon searching the shoreline of the territory.

An average of 10 pairs hatched at least 1 chick and were considered successful pairs. Combined data revealed that there were 0.30 chicks and 0.26 juveniles fledged per adult between 1986-1991.

Chick survival between 1986-91 was very high and averaged 91.8 percent. The survival rates dropped somewhat between 1989-91 corresponding with a simultaneous increase of bald eagles in both drainages. Bald eagle predation was observed and suspected in the disappearance of at least 5 chicks four weeks old or less.

Thirty-eight of 42 nests were located on islands. Sixty-one percent (23 of 38) of the loon nests were located on islands in open water, 29% along a transitional swamp shoreline and 10% within a marsh. Twelve of 23 nests on islands in open water, 7 of 11 island nests along the transitional swamp shoreline and 3 of 4 nests within marshes were successful.

Sixty-three percent (n=40) of the nests lacked aerial cover of any kind. Twenty-seven nests were surrounded by some type of vegetation during the nest site selection. Sedges and grasses surrounded 52% (n=14) while small trees with or without a grass/sedge/forb understory were adjacent to 37% of nests. Cattails surrounded 3 nests and 12 were found on bare sites. There were significant differences in vegetation surrounding nest sites between the two drainages within the study area. Successful nests had a significantly greater depth of water than unsuccessful nests between the nest edge and 3.0 m out into the lake.

Twenty-two nests were unsuccessful. Thirteen were lost for unknown reasons. Seven were flooded by rising water due to either heavy and prolonged precipitation or beaver activity, 1 was lost due to wave action and 1 to infertility. Thirteen, which were lost to unknown reasons, were categorized into suspected causes of failure which included human disturbance, dropping water levels, interactions with bald eagles and those with no probable or suspected cause. Human disturbance was suspected in 7 of 13 unknown losses because of the high frequency of recreational activity seen in the area of the nests. It is probable that predation was actually the cause of the nest failures, but human presence forced the incubating bird to leave the nest, exposing the eggs to predators, especially ravens. It is possible that nest failures due to predation could be as high as 64% if known mammalian predation is combined with losses for unknown reasons.

Combined data revealed that reuse of a physiographic area occurred 94% of the time indicating high fidelity to a particular nesting area. Nest sites were within 50 m of a previously used nest bowl 50% (16 of 32) of the time. Loons nesting successfully one year reused the area within 50 m of the previous successful nest over 60% of the time. However, loons which experienced successive nest failures reused the area within 50 m of the unsuccessful nest only 29% of the time.

Disturbance ratios revealed that there were no significant differences between the Clearwater-Swan and Tobacco-Stillwater drainages with regard to surface area disturbances. However, the Clearwater-Swan drainage did have a higher average shoreline disturbance ratio then the Tobacco-Stillwater. Though not statistically significant this difference does agree with field observations that the Clearwater-Swan drainage was more impacted by human activity then the Tobacco-Stillwater drainage. A rating developed by Skaar (1990) was used to determine differences between the 2 drainages with regard to shoreline disturbance, fishing pressure and public access.

A significant negative relationship was shown between the number of chicks produced per total nest attempts and the surface area disturbance ratio indicating that human activity was negatively affecting chick production. A positive relationship was discovered between the number of fledged juveniles per nest attempt after protective signs were used and Skaar's disturbance ratings suggesting that voluntary closures did help to overcome the disturbance created by recreational activities. Protective signs removed by mid-June should not affect fledging success. However, it is possible that signs may reduce some mortality occurring during the first 2 weeks after hatching by limiting the amount of activity occurring in the nursery areas.

Human related disturbance included boats, shoreline disturbance and human activity occurring after the loon had flushed from the nest for unknown reasons. These activities accounted for 59% of the observed flushes from nests and resulted in loons staying off their nests an average of 24 minutes per flush.

Natural activities which resulted in loons leaving the nest included territorial activities, nest building, heat stress or harassment of the nesting loon by insects. These activities accounted for 40% of the flushes from nests which lasted an average of 8 minutes. In 1988 nests on all lakes were unprotected from human activity and only 2 chicks were hatched on the Lolo National Forest. After voluntary closure areas were placed around the nests on Salmon, Mid-Seeley, North Seeley and Alva in 1989, the total number of nest departures for all causes was reduced from 32 to 13. While the number of natural causes for leaving a nest remained at about the same level for both years, the number of flushes resulting from human activity (especially approaching boats) was reduced significantly.

Average flushing distances for the 4 weeks of incubation were 129, 121, 91, 64 meters respectively. These data clearly indicate that loons exhibit increasing fidelity to nest sites as incubation progresses. The number of successful nests increased significantly after the use of the signs. The same was true for the number of chicks produced, and the number of 2-chick broods although the number of 1-chick broods remained at the same levels before and after the use of signs. These data demonstrate that recreational activity on nesting territories during the nesting season was having a significant negative effect upon the reproductive success of loons on the study area. The data also demonstrated that the effects of this recreational activity can be mitigated with management of the spring fishing/recreational activities by the use of floating signs surrounding the nest sites.

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APPENDIX

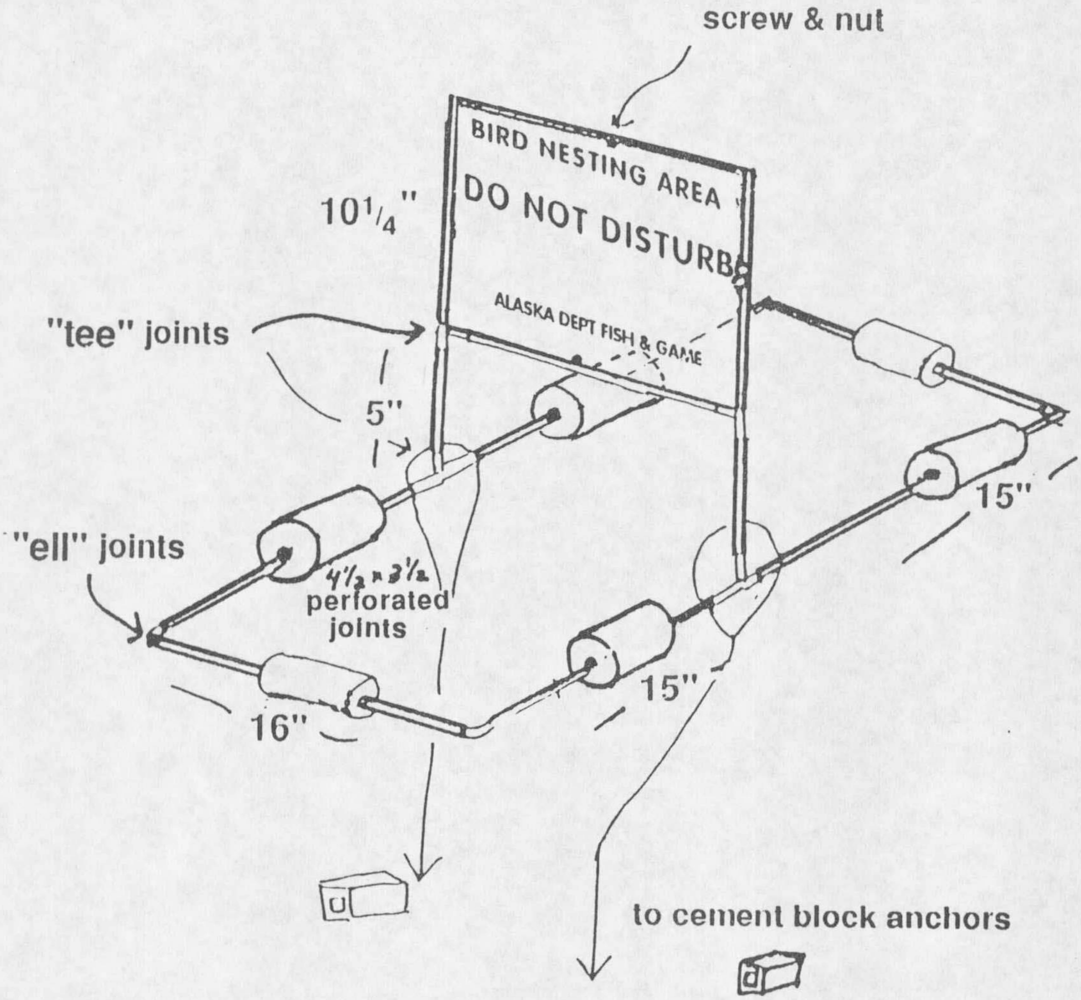

Figure 6. Floating sign designed in Alaska (Tankersley, 1988) and used to protect nesting loons in the Clearwater-Swan drainage.

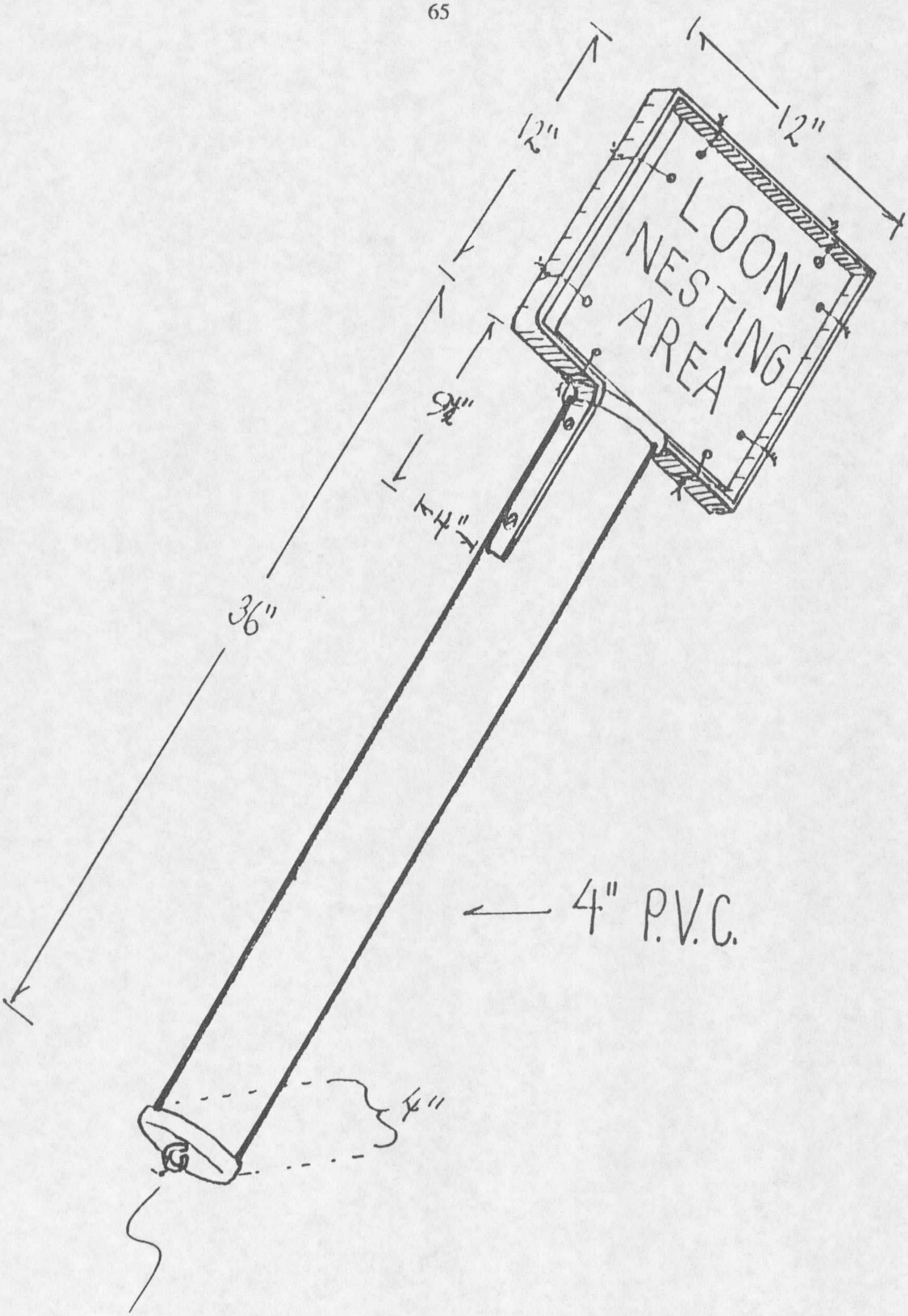

Figure 7. Floating buoy sign designed by Dr. John Madsen, D.D.S.. and used to protect nesting loons in the Clearwater-Swan drainage.