# Monitoring the common loon population in Minnesota: assessment of the 1994 and 1995 survey results, the accuracy of volunteers and aerial surveys, and the power of detecting trends

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## PREFACE

The common loon (*Gavia immer*) has been designated as a "Species of Management Concern" by the U.S. Fish and Wildlife Service in Region 3 due to its susceptibility to decline from anthropogenic threats, including habitat loss and degradation (Titus and VanDruff 1981, McIntyre 1988a,b), direct human activity (e.g., recreational disturbance, drowning in commercial fish nets) (McIntyre 1988a,b, Robinson 1993, Stocek 1993, Titus and VanDruff 1981), and environmental contaminants (e.g., mercury deposition, acid precipitation, and lead) (Alvo et al. 1988, Barr 1986, Meyer and Daulton 1995, Ensor et al. 1992, Pokras et al. 1993, Swain and Helwig 1989). These threats have likely contributed to the decrease of the breeding range of the common loon over the past century along its southern periphery (Bohlen 1989, Dinsmore et al. 1984, Palmer 1962, Parker and Miller 1988, Roberts 1932, Sutcliffe 1981 as cited in McIntyre 1988a). Declines in the number of territorial loons and fledging rates have been observed in some regions of Minnesota over the past 10 to 20 years (McIntyre 1988b, P. Perry pers. comm.) and in the central and eastern Upper Peninsula of Michigan (Robinson 1993). (See "Literature Review" section at end of preface for more details.) Because of historical declines and current threats, state legislatures and natural resource agencies have listed the common loon as threatened in Michigan, New Hampshire, and Vermont and as a species of concern in Massachusetts and New York (McIntyre 1988a) .

To determine whether threats are increasing, monitoring programs, usually utilizing volunteers, have been established in most of the northern U.S. and some provinces in Canada by non-profit and governmental organizations (e.g., the Maine Audubon Society, Michigan Loon Preservation Society, Minnesota Department of Natural Resources, the Loon Preservation Committee in New Hampshire, Vermont Institute of Natural Science in Vermont, LoonWatch in Wisconsin, and the Canadian Lakes Loon Survey). In 1989, the Minnesota Department of Natural Resources (MN DNR) conducted a statewide survey and found that Minnesota provides over 50% of the loon breeding habitat in the 48 contiguous states. In 1994, the MN DNR initiated the development of a program that could detect changes in the adult loon population and reproductive success more rapidly than would a statewide population estimate and that could provide information about specific causes of a population decline, if a decline were detected.

In developing a statewide monitoring program, other loon monitoring activities in Minnesota were assessed. Most programs are lake or region specific (Table 1). The only on-going statewide program, the Minnesota Loon Survey (MLS), is a collection of data based on repeated surveys over the breeding season from lakes on which volunteers live. Because these data utilize repeated surveys, they may provide useful information on territory occupancy and changes in nesting and fledging success for this specific set of lakes, but many confounding variables likely exist (e.g., bias towards large lakes with homes and lakes with loons). However, conducting repeated surveys on a scale large enough to assess loon activity throughout Minnesota may not be logistically or economically feasible.

In addition to addressing the problems caused by the large number of lakes in Minnesota (approximately 12,000 $\geq$ 10 acres in surface area), many species-specific factors were considered in developing a monitoring program. Because the loon is long-lived and can utilize a variety of habitats and food sources, environmental stressors are likely to result in a slow change in adult loon populations (Strong 1990). Strong suggested that loon reproductive rates could serve as better indicators of habitat quality (e.g., suitable nesting habitat, adequate food supply, and tolerable levels of human activity). There is much year to year variability in survivorship of juveniles, thus long-term data are required to assess trends in productivity. However, the loon's relatively low juvenile survivorship may mean the adult population is the "driving force" in maintaining a demographically stable population (McIntyre 1988a). This points to the need to assess both the adult population and productivity.

To know whether anthropogenic threats may be affecting loon populations, changes in adult numbers, territorial pairs, and productivity need to be confirmed first; this is what monitoring programs throughout North America are attempting to accomplish and is the primary goal for the new monitoring program in Minnesota. If populations are changing, especially declining, then there is need to determine the underlying mechanisms of the detected changes (Krebs 1991).

To address these concerns, the MN DNR and I initiated the Minnesota Loon Monitoring Program (MLMP) in 1994 utilizing volunteers to census over 600 lakes within six regions of the state ("index areas") annually. The objective of the MLMP is to ensure rapid detection of changes in the number of adults and reproductive success in the loon populations within these areas.

Tracking the same set of lakes over time will provide a detailed record of changes in adult and juvenile numbers and densities and number of territories. The design of the MLMP surveys should provide insight into the causes of population and productivity declines, should either be detected. In Chapter 4,1 present the findings from the first two years of this monitoring program.

Because the MLMP is based on complete censuses in six localities, there is no sampling error. However, other sources of error exist in the form of measurement error, which includes observer error, species-selection effects (e.g., loon movement), and other environmental effects (e.g., terrain, plot size) (Verner 1981). It is possible that the census results will be biased if there is substantial measurement error associated with the use of volunteer surveyors. Most loon monitoring programs throughout North America also utilize volunteers to conduct surveys. It is assumed volunteer observations are accurate, yet few studies have attempted to verify this assumption. In chapter 1, several studies are presented that assess the accuracy of volunteer surveys and other sources of variation in loon counts.

I applied the results of the volunteer accuracy studies to an analysis of the statistical power of detecting declines in the MLMP survey regions over time in Chapter 2. If no significant decline is observed after several years of data collection, it would be helpful for the MN DNR to know what rate of change is required and how long monitoring is necessary before a negative trend could be detected. I modeled adult loon population declines with randomized variable counts and statistically assessed the power of being able to detect various decline rates.

I also investigated the accuracy of aerial surveys to count loons in Chapter 3. Many monitoring programs utilize aerial surveys to count loons, including the MLMP. Studies on the accuracy of aerial surveys compared to ground counts have shown considerable variation. In addition, most of these studies have only reported single ratio estimates (Y_ aerial counts / Y_ ground counts) without assessing the variability around the ratio.

Each chapter is written to stand on its own, thus some information is repeated. Other chapters in the thesis are referenced as necessary.

The studies assessed in this thesis should provide useful information for the MN DNR and other loon monitoring programs about the use of volunteers, survey methodology, and the population dynamics of the common loon, especially rates of lake use and breeding success. In addition to providing needed information about the status of Minnesota's loons and survey methodology, hopefully this project reaches the lives of the citizens of the state through the volunteers and the stories they share. Because the loon is a species people care about and relate to, generating the support to maintain a healthy loon population and lake habitat is feasible.

## Literature review

### Environmental contaminants

Ensor et al. (1992) identified mercury contamination, lake acidification, and lead poisoning as three major concerns and reported that in Minnesota, juvenile loons who died from disease had significantly higher concentrations of mercury than live juveniles or juveniles dying from injury. Some adult loons had mercury levels high enough to impair reproduction (Barr 1986). In northeastern Minnesota, mean levels of mercury in juvenile loon feathers and in fish even in remote lakes are higher than in other regions of the state (Ensor et al. 1992, Swain and Helwig 1989). The majority of mercury found in fish enters from the atmosphere (Rada et al. 1989) and is likely related to fossil fuel combustion, municipal waste incineration, and industrial processes (Meyer et al. 1993). Mercury may damage the nervous system and impair motor coordination, reproduction, growth, and behavior (Eisler 1987 as cited in Ensor et al. 1992). Loons on lower pH lakes, common in northeastern Minnesota, may have elevated exposure to mercury (Meyer 1994). However, J. Pichner (pers. comm.) and Ensor et al. (1992) found high mercury concentrations in necropsied adult loons recovered in north-central and northwestern Minnesota, as well as some areas of northeastern Minnesota. Current research efforts are attempting to clarify the extent and mechanisms of mercury contamination. Lakes with low pH may also have low breeding success because of inadequate food supplies (Alvo et al. 1988). Parker and Miller (1988) observed no relationship between breeding success and low lake pH. Timm and McCall (1993) detected an insignificant trend relating lower reproductive success and acid-sensitive lakes, but both authors noted that feeding behavior was altered on these lakes. And finally, lead poisoning from the ingestion of lead sinkers has been linked to the mortality of 17 and 57% of recovered loons in Minnesota and New England, respectively (Ensor et al., 1992). High levels of lead sinkers are likely associated with high human use of the lakes.

Human Activity

Increased recreational use and lakeshore development may negatively affect loon populations (McIntyre 1988a,b, Olson and Marshall 1952, Strong 1985, Titus and VanDruff 1981, Valley 1985, Zimmer 1979), but these impacts are difficult to quantify. Loons are able to tolerate a fair amount of habitat loss and disturbance before reproductive success and lake occupancy by adults are negatively affected (Caron and Robinson 1994, McIntyre 1988a, Parker and Miller 1988, Stockwell and Jacobs 1993, Strong 1990). Alvo (1981) and Titus and VanDruff (1981) documented that when human habitation increased, loons switched nest locations from preferred island sites to more remote but less optimal mainland sites. Many studies have actually found . positive correlations with lakeshore development and loon presence and breeding success (Caron and Robinson 1994, McIntyre 1988a, Timm and McCall 1993). These observations are not surprising as optimal loon habitat includes lakes with deep, clear water and islands for nesting (Strong 1985, Blair 1989), which are the same types of lakes people utilize for homes and recreation (McIntyre 1988a). Direct human impacts from gunshots, fish-line entanglement, and boat propeller strikes accounted for 18% of collected dead loons in the study by Ensor et al. (1992). Drowning of loons in commercial fishery nets on the Great Lakes has caused significant mortality, especially for non-breeding loons and sub-adults (Robinson 1993). A threshold likely exists where human activity (e.g., recreational disturbance, degradation and loss of habitat) negatively affects loon activity, but this threshold may vary considerably.

Historic and current status of the common loon

The breeding range of the common loon has decreased over the past century along its southern periphery. Loons historically had summer ranges in southern Minnesota, northern Iowa, southern Wisconsin, Illinois, and Indiana (Bohlen 1989, Dinsmore et al. 1984, Palmer 1962, Roberts 1932). Populations in New Hampshire and New York have declined from 35 to 50% since the 1930's (Sutcliffe 1980 as cited in McIntyre 1988a, Parker and Miller 1988). Loon numbers have declined in the central and eastern Upper Peninsula of Michigan throughout the 1980's (Robinson 1993). On the Whitefish chain of lakes in central Minnesota, the number of occupied territories declined by about 25% since the early 1980's (P. Perry, pers. comm.). McIntyre (1988b) estimated that the number of territorial loons on 230 volunteer-monitored lakes in Minnesota decreased slightly between 1971 and 1986, and during the same time, shoreline development and recreational use increased. The majority of the lakes in McIntyre's study were located at the southern edge of the breeding range in Minnesota. Fledging rates have possibly declined in Wisconsin from 1986 to 1993 (Meyer and Daulton 1995) and Minnesota from 1971 to 1986 (McIntyre 1988b). Meyer and Daulton hypothesized that the observed reduction in productivity could be caused by increased predation, harsher weather conditions, a general decline in habitat quality (e.g., reduced prey base, loss of habitat, higher disturbance rates, environmental pollution), or density dependent factors from an increased number of adults.

Despite these historical declines, many local populations have apparently increased since the 1970's in Michigan, New Hampshire, and Wisconsin (Robinson 1993, Rimmer 1993, Strong 1988, Meyer and Daulton 1995) and remained relatively constant in New York (Parker and Miller 1988). Additionally, adults loons reestablished summer residence in Massachusetts in the 1970's as well (Blodget and Lyons 1988). Mooty (1993) reported that numbers of loon territories on Knife Lake in the Boundary Waters Canoe Area Wilderness (BWCA) declined from the 1950's through the late 1960's, but numbers have rebounded to 1950 levels over the last two decades. On Lake Vermillion in northeastern Minnesota, large increases in adult numbers were reported in the early 1990's (Sportsman's Club of Lake Vermillion 1994).

Changes in survey methodology, however, may have contributed to apparent increases in loon populations (Strong 1988, Robinson 1993). In Wisconsin, the mid-1980 ground surveys were compared to surveys conducted both from the ground and the air in the mid-1970's, but aerial surveys tend to underestimate loon numbers (see Hanson, Chapter 3). In Michigan, recent population estimates included lake resident surveys ("loon rangers") in addition to the original stratified sampling results, thus a potential bias toward lakes with known loon activity were included in the population estimate (Robinson 1993).

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Table 1. Loon monitoring activity in Minnesota since 1950. This list is probably not complete due to lack of published material

| Location | Sampling scheme | Survey type | Loon count objectives | Date initiated | Number of times conducted |
|---|---|---|---|---|---|
| Statewide [a] | random | single | adult and juvenile numbers | 1989 | 1 |
| Statewide - MN Loon Survey [b] | opportunistic | repeated - annual | territory, nesting and fledging rates | N.A. | N.A. |
| Chippewa National Forest [c] | random | single -aerial counts only | adult and juvenile numbers | N.A. | N.A. |
| Knife Lake [d] | selected | single - every 5 years | territory, nesting, and fledging rates | 1952 | 10 |
| Lake Vermillion [e] | selected | single - annual | adult and juvenile numbers | 1981 | 13 |
| Whitefish Chain [f] | selected | repeated - every 10 years | territory, nesting, and fledging rates | 1981 | 2 |
| Voyageurs National Park (Sections of Rainy, Namakan, and Kabetogema Lakes) [f] | selected | repeated - annual | territory, nesting rates | 1992 | 4 |

[a] Strong and Baker 1991
[b] P. Perry pers. comm.
[c] Mooty pers. comm.
[d] Mooty 1993
[e] Sportsman's Club of Lake Vermillion 1994
[f] Evers, pers. comm.

## Chapter 1: An evaluation of the accuracy of using volunteers to conduct common loon surveys.

### INTRODUCTION

Volunteers are widely used in counting the common loon (*Gavia immer*) for monitoring programs in Maine (the Maine Audubon Society), Michigan (Michigan Loon Preservation Society), Minnesota (Minnesota Department of Natural Resources), New Hampshire (the Loon Preservation Committee), Wisconsin (LoonWatch), and Canada (the Canadian Lakes Loon Survey). It is assumed that volunteer observations are accurate, yet except for two studies in Wisconsin (Daulton 1993, Meyer and Daulton 1995), few attempts have been made to verify this assumption.

Errors associated with observer accuracy may be considered "measurement" or "observer error" and are often thought to be small in relation to "sampling error" (Raitt 1981). However, several recent studies and discussions of observer accuracy of passerines have found that measurement errors can be substantial (Davis 1981, Faanes and Bystrak 1981, Kepler and Scott 1981, McDonald 1981, Raitt 1981, Verner and Milne 1990). Factors contributing to observer error include observer effects (e.g., previous experience, hearing ability, attentiveness, physical condition), species-selection effects (variation in detectability, behavior, and habitat), and site selection effects (e.g., vegetation, terrain, plot size) (Verner 1981). For loon counts, the major observer effects likely consist of previous experience, sighting ability (especially at a distance), and the ability to keep track of loons already counted. Species-specific and site-specific effects may include loon movement (e.g., diving behavior, flying from lake to lake), the size, color, and behavior of chicks, seasonal effects (e.g., changes in territory fidelity), the effect of nonbreeding "floaters," time of day, lake size and shape, and weather conditions (e.g., wind, lighting).

Observer error has been difficult to quantify. For many taxa, such as passerines and amphibians, temporal and spatial variation have complicated attempts to obtain reliable count data and measure various sources of bias. Most monitoring programs employed study designs that control the numerous sources of bias (Verner 1981). Study design is discussed in detail in many sampling texts (Cochran 1977, Seber 1982, Norton-Griffiths 1978). Faanes and Bystrak (1981) and Kepler and Scott (1981) conducted training programs in an attempt to minimize observer error in passerine counts. They reported that training reduced, but did not eliminate observer error. Kepler and Scott (1981) intensively trained a few observers over a three-week period. However, for largescale monitoring programs involving hundreds of observers, this type of training would be impractical. Faanes and Bystrak (1981) concluded that observer variability would cause an insignificant bias in large-scale census work involving many observers as long as observer skills were adequate for the species or taxa being counted. However, observer variability may be significant for small-scale studies. Davis (1981) recommended that the optimal survey method should be determined based on each species' characteristics, behavior, and preferences (e.g., vocal, secretive, habitat type) as bias will vary by species or related taxa.

Studies of observer error in loon surveys indicate that accuracy of volunteers and trained professionals are comparable (Daulton 1993, Meyer and Daulton 1995); thus "measurement error" may be minimal for volunteer loon monitoring programs. The biases caused by observers, species-specific effects, and site selection factors discussed above for passerines may be of less concern in loon surveys because of the high visibility of loons and their use of open water habitats. Furthermore, because of the high profile of the loon in Minnesota and its familiarity even to nonbirders, specific training of volunteers may not be necessary to obtain accurate adult and juvenile counts of this distinctive species.

Numerous common loon programs have been initiated throughout North America over the past few decades as concern for the loon's welfare has risen. Anthropogenic threats, including habitat loss and degradation (Titus and VanDruff 1981, McIntyre 1988a,b), direct human activity (e.g., recreational disturbance, drowning in commercial fish nets) (McIntyre 1988a,b, Robinson 1993, Stocek 1993, Titus and VanDruff 1981), and environmental contaminants, including mercury deposition, acid precipitation, and lead (Alvo et al. 1988, Barr 1986, Daulton and Meyer 1995; Ensor et al. 1992, Pokras et al. 1992, Swain and Helwig 1989) have been documented throughout the loon's breeding range. Loons historically had summer ranges in southern Minnesota, northern Iowa, southern Wisconsin, Illinois, and Indiana (Bohlen 1989, Dinsmore et al. 1984, Palmer 1962, Roberts 1932). Recently loons reestablished summer residence in Massachusetts (Blodget and Lyons 1988). Because of historical declines and current threats, the common loon currently is, considered threatened in Michigan, New Hampshire, and Vermont.

To address these concerns, the Minnesota Department of Natural Resources (MN DNR) attempted a scientifically valid survey of Minnesota's adult common loon population in 1989 utilizing over 700 volunteers. Because lakes were randomly sampled, observer error was essentially lumped into the sampling error around the estimate. In 1994, the MN DNR initiated the Minnesota Loon Monitoring Program (MLMP) to annually assess the adult common loon population and its reproductive success. The MLMP is a large-scale project requiring hundreds of volunteers to survey lakes for adult and juvenile loons. In 1994 and 1995, complete censuses were conducted on over 600 lakes that were $\geq$ 10 acres in surface area, within six regions of the state ("index areas"). The MLMP was established because Minnesota provides habitat for over 50°10 of the breeding common loon population in the lower 48 contiguous states (Strong and Baker 1991), the existence of significant anthropogenic threats, and concern over the decline of the breeding range over the past century. The objective of the MLMP is to census 600 lakes annually within the six index areas in order to ensure rapid detection of changes in the number of adults and reproductive success. Because the MLMP is based on complete censuses in six localities, however, there is no sampling error. It is possible that the census results will be biased if there is substantial measurement error associated with the use of volunteers. Therefore, I conducted three studies to assess the accuracy and variability of volunteer loon counts in the MN DNR's long-term Loon Monitoring Program with a focus on the effect of observers and lake size.

In the primary study, I compared the adult and juvenile common loon counts of volunteers who had attended a training session ("trained volunteers") to counts of volunteers who had not attended training sessions ("untrained volunteers") on different sized lakes. The objective of this study was to evaluate the effectiveness of a volunteer training program in reducing variability in the loon counts on lakes of three size classes. The secondary study assessed loon counts of paired volunteers on 139 lakes. Volunteers were arbitrarily assigned to one of two groups, and the adult and juvenile loon count differences between the two groups were compared. The objective of this study was to assess the magnitude of variation of the count differences between the pairs of volunteers and whether the variation differed on lakes of four size classes. The third study assessed the residual learning effect of "returning" volunteers from the previous year of the MLMP compared to "new" volunteers. These studies will complement those done in Wisconsin by addressing the effectiveness of an economically and logistically feasible training program and the effects of lake size on observer variability.

## METHODS

Study Site

Loon surveys were conducted within six index areas located in southwest Aitkin/east-central Crow Wing Counties, north-central Becker County, west Cook/east Lake Counties, central Itasca County, north Kandiyohi County, and central Otter Tail County (Fig. 1). Each index area included about 100 lakes z 10 acres in surface area. The six index areas were chosen to be indicators of the major anthropogenic threats (i.e., habitat loss, recreational disturbance, lake acidification and associated mercury contamination) that may occur in different regions of Minnesota. The following criteria were used as measures of the potential threats to loons from pollutants, human activity, and habitat loss: 1) lake sensitivity to acidification, 2) human population density, 3) road density, 4) projected human population growth, and 5) land ownership. Regions with relatively low, moderate, and high levels of potential threats were identified using these criteria. Current human population density and road density were used simultaneously as indicators of current human activity levels. I assumed that recreational disturbance and development would tend to be less of a threat on public lands than on private lands, because human activity and development would be less restricted on private lands. At least two index area were located in regions with higher levels of threats and two in regions with lower levels compared to the other index areas. Suitable index area locations were identified using map overlays and geographic information system (GIS) data. The results are summarized in Table 1. (See Hanson Chapter 4 for complete description of site selection.)

The Aitkin/Crow Wing index area is located within the northern coniferous forest biome (Coffin and Pfannmuller 1988). Local vegetation varies from stands of conifers including red (*Pinus resinosa)* and white pine *(Pinus strobus)* to areas of mixed aspen (*Populus* sp.), white birch *(Betula papyrifera),* maples *(Acer* sp.), and basswoods *(Tilia americana).* Most lakes were formed by ice blocks left in glacial till associated with the St. Croix moraine (MN DNR 1968). Shoreline of most lakes is primarily privately owned. Both seasonal and permanent homes are common in the area, but only 10 lakes have public access.

The Becker index area overlays sections of both the northern coniferous and eastern deciduous forest biomes (Coffin and Pfannmuller 1988). Most lakes in the index area are located in till in the

Alexandria moraine, but some are found in glacial outwash plains (MN DNR 1968) resulting in a mix of shallow to deep lakes. Many lakes surveyed in the Becker index area are located within or near the Tamarack National Wildlife Refuge where there is little or no shoreline development. A few of the larger lakes surrounding the refuge have moderate to high levels of development where shoreline ownership is either private, county, state, or part of the White Earth Indian Reservation (MN DNR 1991).

The Cook/Lake index area is located within the northern coniferous forest biome (Coffin and Pfannmuller 1988). Lakes were formed primarily from three processes: ice left in glacial till in the Highland moraine, glacial erosion, and glacial drift damming valleys (MN DNR 1968). Most lakes are located within the Superior National Forest and Pat Bayle Minnesota State Forest. A few lakes are located along the southern edge of the Boundary Waters Canoe Area Wilderness. Shoreline on some of the larger lakes is privately owned, but most small and medium-sized lakes have little or no development (MN DNR 1991).

The Itasca index area lies in the northern coniferous forest biome (Coffin and Pfannmuller 1988). Local vegetation consists of a mixture of conifers and hardwoods. Lakes in the Itasca index area were formed primarily by ice left in glacial till (MN DNR 1968). The majority of lakes are found within the Chippewa National Forest, but shoreline sections of many lakes are privately owned. Development varies from moderate to none. A few lakes are bordered by county and state lands (MN DNR 1991).

The Kandiyohi area is located on the border of the tallgrass prairie and eastern deciduous forest biomes (Coffin and Pfannmuller 1988). Lakes tend to be shallow with shorelines supporting dense growths of aquatic vegetation. A few large areas of maple, basswood, and oak forests still exist around some lakes. Most of the index area lakes are in a terminal moraine. Two water bodies, Mongalahia and Crow River, were greatly enlarged by the damming of the Crow River (MN DNR 1968). Almost all lakes are located on private lands. Five lakes are located in Sibley State Park (MN DNR 1991).

Lakes the in Otter Tail index area are located within the eastern deciduous forest biome. Most treeless areas are dominated by agriculture (Coffin and Pfannmuller 1988). Local vegetation includes maple *(Acer* sp.) and basswood *(Tilia americana)* forests, aspens (*Populus* sp.), and oaks *(Quercus* sp.). Lakes were formed by both ice block basins in glacial till and in till-filled preglacial valleys (MN DNR 1968). All lakes are located on private lands (MN DNR 1991).

Many of the shallow lakes in Becker, Kandiyohi and Otter Tail index areas have extensive tracts of emergent aquatic vegetation. Lakes in open areas in Kandiyohi and Otter Tail index area are highly influenced by agriculture activities along their borders.

**Effect of training on volunteer accuracy, after controlling for possible (confounding) effects of lake size and date of survey**

This study was conducted in the Aitkin/Crow Wing index area because of the overall ease of access to lakes and the proximity to a large pool of volunteers. Lakes > 700 acres were not included in the study.

The study was conducted during the first three days (15-17 July) of the 1994 statewide MLMP. MLMP volunteers were assigned five days (15-19 July) to conduct their surveys. The survey dates were selected to best assess the adult common loon population, territorial occupancy, and reproductive success from a single annual survey. Factors considered in selecting the survey dates included juvenile mortality and seasonal movement. Most juvenile mortality occurs during the first two weeks posthatching (McIntyre 1988a). In mid-July in Minnesota, most juvenile loons should be between two and four weeks of age, and therefore very likely to fledge (McIntyre 1988a). Alvo et al. (1988) and Dulin (1988) reported that a second period of increased juvenile mortality may occur in highly acidic lakes at four to five weeks of age, possibly caused by food shortages. Thus, Belant et al. (1993) recommended that surveys should be conducted when juveniles are greater than six to seven weeks of age (early August in Minnesota). However, I decided to conduct the surveys in July rather than early August, so as to avoid the increasing movement of adult loons away from their territorial lakes which occurs as the breeding season progresses (Croskery 1988, McIntyre 1988a, D. Evers pers. comm.).

Twenty-five volunteers were recruited from the larger pool of volunteers in the MLMP, four volunteers from the Aitkin County Coalition of Lake Associations, and one from the Minnesota Loon Fest in Nisswa, MN, for a total of 30 volunteers.

Study Design

The effect of training on volunteer accuracy was assessed by comparing the differences in adult and juvenile loon counts between 15 randomly paired volunteers who surveyed the same lake at the same time. One member of each pair was randomly selected to attend a pre-study training session on how to conduct common loon surveys and the other volunteer did not attend. All volunteers received the same written instructions. Fifteen lakes were surveyed on each of three consecutive days, i.e., three replications resulting in a total of 45 comparisons. Lakes were blocked by surface area: small (10-149 acres), medium (150-399 acres), and large (400-700 acres). Only those lakes accessible by road were considered, yielding stratum sizes of 35, 25, and 7 lakes, respectively. From these, five lakes were randomly selected to represent each size class in the experiment. Each lake was surveyed once per day by a pair of volunteers, thus each lake was surveyed six times.

The paired difference in loon counts on each lake was the response variable, and training/no training was the dichotomous treatment. The trained and untrained volunteers may be regarded as two types of measuring devices. The effects of training were tested across three lake size strata, over a three-day period. Lake size was modeled as a treatment effect modifier and day as a repeated time factor. Each lake was considered a subject (observational unit) and was modeled as a random effect. Under the null hypothesis of no significant treatment effect, the expected mean response is zero (i.e., no difference between trained and untrained observers' loon counts). This hypothesis was evaluated for all combinations of lake size and day of survey. In addition, a test for a trend over days was applied to evaluate a learning effect on the part of the volunteers.

Because the response variable was assessed across potentially confounding factors, lake size and day, a randomized latin square with repeated measures was used (Table 2) (see the statistical analysis section for details). This was accomplished by randomly assigning the 15 matched pairs to one of three groups (A, B, and C). Because there were many possible random assignments of the 15 pairs to 3 groups of 5, "group" was modeled as a random blocking factor. Each group was assigned to a different lake size class on different days in a Latin square to ensure that each group of volunteers surveyed lakes from every size category (Table 2). The five trained and untrained volunteers within each group were then randomly assigned to lakes.

All surveys were scheduled to commence at 1000 h. Volunteers were explicitly instructed not to discuss the loon count with anyone on the lake to ensure independence of counts by each member of the matched pairs. Volunteers were encouraged but not required to use a boat or canoe on larger lakes. Observations from the shoreline were made from multiple vantage points to ensure that all surface water areas were observed. Instructions for boat surveys varied on the size and shape of the lake. For small and medium-sized lakes, volunteers were to stay about 100 m from shore while systematically circling the lake. All islands were to be completely circled. For large, round lakes, in addition to the procedures described above, observers systematically surveyed open water regions by boating out into the lake and back to the shore every 400 to 800 m. For large, convoluted lakes, observers surveyed narrow sections and bays completely before moving on to other parts of the lake. Boat surveyors were asked to stop the boat and scan the entire water surface every 400 m for loons.

Trained and untrained volunteers received identical written instructions covering protocol relating to finding back-up observers, checking lakes before the survey, obtaining access to the lake, when to survey, weather conditions under which to survey and not to survey, minimum length of survey, what to count, loon movement and other potential problem areas, and pictures and descriptions of potentially confusing avifauna (See App. II).

Eight, 90-minute training sessions were held throughout the state in conjunction with the MLMP. The training program covered many of the same topics presented in the written instructions but in more depth and with visual and verbal explanations (See App. III). The critical training material covered bird and age class identification, photos of loons at various distances, long-distance loon detection, how to keep track of loons already observed, methods for surveying different sized and shaped lakes, and appropriate observation rates. The training also explained the MLMP's purpose and how it was designed giving volunteers a better understanding of the program.

Volunteers recorded the location and number of adult and juvenile common loons observed, the beginning and end time of observation, observation method (e.g., by boat/canoe or from shore), equipment used (e.g., binoculars, spotting scope), weather and surface water conditions, a qualitative assessment of the percent of disturbed/developed shoreline, and level of confidence in completing an accurate survey (See App. lI).

Statistical Analysis

To accommodate both the layout of the study and the problem caused by taking measurements on the same observational unit over time, I employed a mixed models latin square ANOVA with repeated measures. Lake size class and the day of the survey were modeled as fixed discrete effects. The lakes themselves were modeled as random "subject" effects. The response was the difference in loon counts as measured by paired volunteers who had been randomly blocked into three groups.

Mixed linear models have recently been extended to the case of repeated-measures ANOVA (Ware 1985), wherein subjects (i.e., lakes) are modeled as a random effect. The procedure involves two steps in which the within-subjects correlation structure (Jennrich and Schlucter 1986, Wolfinger 1993) is modeled, first. The treatment effects are then estimated from the fitted correlation structure. This technique circumvents the usual independence assumption by explicitly accounting for the non-independence among the repeated measures, thus yielding unbiased estimates of the residual variance. Although neither the time-effect or lake size effect were the principle factors of interest, their inclusion in the model made it possible to obtain an unconfounded estimate of the effects of the training. The null hypothesis of no training effect was evaluated by testing if the mean of the matched difference in counts equaled zero, within and across lake size classes and time.

I fit the mixed model using restricted maximum likelihood (REMLs) estimators (SAS Proc Mixed, SAS 1996). Seven covariance structures were evaluated including autoregressive (AR), heterogeneous AR, autoregressive-moving average (ARMA), compound symmetry (CS), heterogeneous CS, Huynh-Feldt, and unstructured. The covariance structure with the largest Akaike's Information Criterion (AIC) values was chosen (Wolfinger and Chang 1995).

I also assessed the variability of the six loon counts on the same lake by calculating the coefficient of variation (C.V.) for each lake. Adult loon presence on individual lakes may vary depending on whether a territory is present, the status of the territory, and habitat suitability.

**Assessment of the differences between paired observers' adult and juvenile loon counts.**

One hundred thirty-nine lakes were surveyed by two different observers from 14-18 July 1995. The first person assigned to the lake was arbitrarily designated as "observer 1." This person was usually the returning volunteer from the 1994 survey. The second observer assigned to the lake was designated "observer 2." The paired loon counts were conducted on lakes in all six index areas, including 36 lakes in Aitkin/Crow Wing, 12 in Becker, 22 in Cook/Lake, 29 in Itasca, 25 in Kandiyohi, and 15 in Otter Tail. All surveys were conducted between 0500 and 1200 h. Survey methods, instructions, and data collected were nearly identical to those described for the study on the effect of training.

The purpose of this study was to verify the assumption, implicit in the design of the first study, that the expected distribution of the paired differences was normal with $p = 0$. The two groups of observers were arbitrarily chosen from the same population of volunteers, thus I would expect that the mean of the paired differences to be zero. With this study, I can assess the magnitude of variation of the count differences between the pairs of volunteers and whether the variation differed on lakes of four size classes.

Statistical Analysis

The differences between the two observers' adult and juvenile loon counts were assessed by using a one-sample t-test on the adult and juvenile loon count differences of matched observations (observer 1 count minus observer 2 count) and plotting the frequency distribution of the differences. To check for normality, a Wilk-Shapiro test was applied and normal probability plots of the paired differences were constructed.

Differences in the frequency distributions were assessed among four lake size-classes: small (10-149 acres), medium (15-399 acres), large (400-699 acres), and very large (>700 acres). The small, medium, large, and very large size classes each contained 89, 29, 8, and 13 lakes, respectively. A Kruskal-Wallis test was used to assess the effect of lake size, and a one-sample t-test was used to determine if count differences were equal to zero for each lake size, separately. I assessed any trends in the median count differences among lake sizes using a rank-ANOVA test, followed by a linear contrast.

**A comparison of first time (new)** vs. **returning volunteers' adult and juvenile loon counts over a two year period.**

As observers become more experienced, there may be a learning effect that will influence the accuracy of adult and juvenile loon counts. The assumption is that new observers are less experienced and thus, are more likely to undercount adult and juvenile loons. With experience, detection rates will increase. However, overcounting may occur, especially on large lakes.

To test whether returning volunteers tended to count more loons than new volunteers, I compared the frequency distribution of the differences between the 1995 and 1994 adult and juvenile loon counts on the same lakes for two groups: 1) first year (new) volunteers in both 1994 and 1995 and 2) first year volunteers in 1994 and returning volunteers in 1995. The study sites, survey methods, instructions, and data collected are identical to those described in the previous two sections.

<u>Statistical Analysis</u>

I tested the similarity of the distributions of loon counts statistically using a Wilcoxon rank sum test. The hypothesis of equal location of loon count distributions of new and returning volunteers would be verified if distributions of the count differences between 1994 and 1995 were normal with a mean zero, resulting in a non-significant Wilcoxon test.

## RESULTS

### Effect of training on accuracy, after controlling for possible (confounding) effects of lake size and date of survey

Fifteen pairs of trained and untrained observers censused one lake/day, on three different days, for a total of 45 paired counts. Trained observers counted a total of 92 adult and 19 juvenile common loons. Untrained observers counted a total of 86 adult and 16 juvenile common loons. Volunteers observed adult loons at least one time on all 15 lakes except one, which was in the small size class.

Based on Akaike's Information Criterion (AIC), a first order autoregressive (AR) covariance structure with heterogenous variances was optimal for the repeated measures model. The likelihood ratio test ($x2=12.52$, 4 df, $p=0.0139$) verified that the fitted covariance model improved the overall model fit. Modelbased estimates of the mean and standard errors of the differences in loon counts are presented in Table 3 for each group, lake size, and day of survey. The mean difference between trained and untrained observer adult loon counts did not vary significantly by lake size ($F2,,2=0.70$, $p=0.5137$) or over days ($F2,28=2.06$, $p=0.1465$). In addition, groups of volunteers as apportioned for the latin square design, did not exhibit a significant trend in loon counts with lake size ($F1,12=1.41$, $p=.2587$) or over time ($F,,28=1.14$, $p=0.2955$), the latter indicating that there was no learning effect.

Model-based estimates of the means of the paired adult loon count differences between trained and untrained observers were not significantly different from zero for any lake size class (Table 4). However, the count difference on day three was marginally significant (Table 4). The trained observers counted nine more adult loons than the untrained observers on this day resulting in a mean difference of 0.6 (Table 3). The variability (SE) among the count differences increased on large lakes (Table 3), an indication that it is more difficult to obtain reliable counts on larger lakes regardless of the amount of prior training.

The paired differences in adult loon counts ranged from -7 to 4. The frequency distribution of differences by lake size class and for the overall study are presented in Fig. 2. For the small and medium size class, all but three differences ranged between 0 and 1. For the large size class, there were four differences $\geq$ two.

Although the variability of the count differences increased with lake size, when considering the six repeated loon counts for each lake, the largest C.V.'s were observed on small lakes (Table 5). Changes of one or two loons between observations increased the C.V.'s more on small lakes than on medium-sized or large lakes.

Juvenile loons were only observed consistently on three of the five lakes in the large size class. Because juvenile loons usually cannot leave their natal lake until they are 11 to 12 weeks of age, the actual number of juveniles on a lake will remain constant. It could be determined with high confidence that two juveniles were present on each of these three lakes. Trained observers both undercounted and overcounted the number of juveniles once. Untrained observers undercounted three times, misidentified adult loons as juveniles on one lake, and had no overcounts.

Trained observers spent an average of 58, 72, and 101 minutes surveying small, medium, and large lakes, respectively, and untrained observers spent 59, 100, and 116 minutes. For the large and medium-sized lakes, untrained observers spent more time surveying than the trained observers, but the difference was only significant for medium lakes using a two-sample t-test ($t=2.09$, $df=14$, $p=0.0455$).

Despite instructions to survey all lakes at 1000 h, 6 of the 45 paired observers failed to survey their lakes within one hour of each other. Three of these paired observations were greater than two hours apart. The count differences for the comparisons made between one and two hours apart were -2, -1, and 1, and for the paired observations greater than two hours apart, the differences were -1, 0, and 1.

**Assessment of the differences between paired observers' adult and juvenile loon counts.**

The overall total adult and juvenile loon counts conducted over a five day period (July 14-18) for the pair of observers were similar (Table 6). Using a one-sample t-test, the differences between the two observers' adult and juvenile loon counts were not significantly different from zero for adult ($t=1.289$, $df=138$, $p=0.200$) or juvenile ($t=0.450$, $df=138$, $p=0.654$) loons. As expected, by arbitrarily selecting two groups of volunteers from the same population, similar results were obtained.

The frequency distributions of the differences in adult and juvenile loon counts are presented in Fig. 3. Visual assessment of the distributions of loon count differences and the Wilk-Shapiro normal probability plot indicated that they were distributed normally with means of zero. However, the differences for juveniles had many structural zeros (i.e., lakes likely without breeding activity), which made the normal probability plot appear non-normal. The majority of the paired observations were either identical or had differences within one or two loons. Sixty-eight and 88% of the adult and juvenile loon count differences lay between -1 and 1, respectively. Adult and juvenile loons were not observed by either volunteer on 22 and 84 lakes, respectively.

The medians of the loon count differences did not vary significantly by lake size class for adults ($\chi^2=5.7370$, $p=0.1251$) or juveniles ($\chi^2=6.3016$, $p=0.0978$). In addition, adult and juvenile loon count differences were not significantly different than zero in any size class (Table 7). However, a contrast for an ordering in the median count differences by lake size class was significant ($F_{1,35}=3.96$, $p=0.0485$; Fig. 4). The variability of the differences also increased on larger lakes.

**A comparison of first time (new) vs. returning volunteers' adult and juvenile loon counts over a two year period.**

The frequency distributions of differences of adult and juvenile loon counts on the same lake for new and returning volunteers (1995 counts minus 1994 counts) are presented in Figs. 5 and 6, respectively. Returning volunteers counted slightly more loons in 1995 than in 1994, which can be explained by substantially larger loon counts being made on eight lakes in 1995. New volunteers had no count differences of this magnitude.

The frequency distribution of the differences for the two groups appeared to be approximately normal. The results of the Wilcoxon test indicated that the medians of the two frequency distributions were equal to zero for adult (t=0.000, p=1.000) and juvenile (t=0.489, p=0.625) loon count differences.

## DISCUSSION

### Effect of training

The results indicate that pre-training of volunteers did not have a significant effect on their counts of adult loons when compared to untrained volunteers' loon counts. Because the true values for the number of resident loons were not known, it is not possible to determine whether untrained or trained observers tended to undercount or overcount relative to the true value. However, on average, the differences between the pairs of observers were not significantly different from zero.

These results are consistent with those of Meyer and Daulton (1995) in Wisconsin. They did not detect any significant difference between 81 paired loon counts conducted by DNR trained biologists vs. volunteers, on lakes ranging from 15 to 3,111 acres in size. In two small (n=23) Wisconsin studies (Daulton 1993), volunteers detected about 90% of the adult territorial pairs observed by the DNR biologists on lakes < 400 acres. DiBello and Bissonette (1984) compared loon counts of two observers on large lakes (n=5) and found that counts were similar.

Although training did not have a significant effect overall, there were two cases where training may have improved the results. Untrained observers on one lake overcounted the number of loons by seven compared to simultaneous counts of the trained observer and aerial observers, each of whom obtained the same count. A television reporter who spoke with the untrained observers at the boat landing upon completion of the survey noted that the observers actually thought they had counted the same loons more than once. In the other case, an untrained observer likely misidentified two adults as juveniles. Juveniles were not detected by any other observers on that lake in 1994. In addition, untrained observers, on average, took longer than trained observers to survey medium and large lakes (150-700 acres), indicating that training may improve survey efficiency.

Observer error does not appear to be a significant source of "measurement error", given a large enough number of observers. Improvement in observer skills provided by the training were not detected, except for the possible increase in efficiency. Efficiency would be a more important concern if there were monetary costs associated with the observations.

Prior experience of volunteers may be a more important factor than training. Volunteers were recruited from previous loon survey volunteers (from the 1989 statewide random survey and the Minnesota Loon Survey), members of the Minnesota Ornithological Union, numerous Audubon chapters, the Sierra Club, and MN DNR, U.S. Fish and Wildlife, and U.S. Forest Service employees. Other volunteers were lake residents familiar with their lake and loon activity. In general, the typical volunteer had experience in loon observations.

A possible source of error was "observer-expectancy bias" wherein trained and untrained observers have different expectations of what their survey results should be. Balph and Balph (1983) noted that if the variables were well-defined and easily recorded, as in our-study, bias should be minimal. It might have been possible to blind the volunteer accuracy participants to details and results of the study, but I felt it was important to inform the volunteers about the study to maintain their interest.

Effect of experience

The frequency distributions of loon count differences between 1994 and 1995 for the new and returning volunteers were both normal with means of zero. Although returning volunteers counted slightly more adults in 1995 than in 1994 compared to new volunteers, this difference could easily be caused by other sources of error (e.g., loon movement).

A possible source of bias in the 1994-1995 study was the possibility that experienced volunteers might not have returned to lakes on which they had not observed loons in the previous year (1994). If this response by volunteers occurred, new volunteers in 1995 may have surveyed a higher proportion of lakes without loons. To assess whether this may have occurred, I calculated the percent of lakes without loons in 1994 for the two groups. The percentages of lakes with no loons observed by the new and returning volunteer groups in 1994 were 42 and 39%, respectively. Thus, bias does not appear to have occurred.

Based on this study, experience may have a small but non-significant effect. I did not assess the previous experience of volunteers, thus some new volunteers likely had prior experience in loon and bird observation. To assess the degree of prior experience more definitively, new volunteers should be questioned prior to the survey.

It was encouraging to observe that the distributions of the count differences between the two years for both groups were uniformly normal and that the distributions' medians were centered on zero. Over the 1994-1995 period, I would not expect the adult loon population to change within the index areas. The common loon is a long-lived species, and changes in the population likely occur very slowly over time.

Effect of lake size

Median loon count differences did not vary among lake sizes. Although Meyer and Daulton (1995) did not specifically assess loon count differences across lake size strata, they did not observe differences between volunteer and DNR biologist loon counts in their study on lakes up to 3,111 acres in size (i.e., differences in loon counts on lakes of any one size class did not influence the overall results).

The variance in adult and juvenile loon count differences increased with lake size in our studies. In contrast, C.V.'s of repeated adult loon counts were highest on small lakes. In the context of wanting to assess population changes over time, however, differences of plus or minus one loon on small lakes would not likely cause major changes in total loon counts for an entire index area. In fact, changes of this magnitude would be expected as adults will often leave their breeding territory to feed elsewhere. However, larger differences in loon counts, which tend to occur on large lakes, will have a greater influence on monitoring results.

Two important conclusions can be made from these observations. First, if sample sizes are large enough, differences between volunteer loon counts are normally distributed about a mean of zero, especially on lakes s 700 acres in size. Second, the variance of loon counts will increase with lake size. Because the training study was randomized and simultaneously examined the effects of training, lake size, and time, the conclusions about volunteer accuracy on lakes under 700 acres were more rigorous than the study that assessed two groups of arbitrarily selected volunteers.

Numerous factors likely contribute to the increased variance in adult loon counts on large lakes. Large lakes with multiple loon territories are more conducive to loon movement than lakes containing only one common loon territory, especially in regards to non-resident adult loons, i.e., non-breeding "floaters" and visiting breeding loons from smaller, surrounding lakes (Croskery 1988, McIntyre 1988a). Belant et al. (1993) noted that counts of non-resident loons on a 5292 ha reservoir ranged from 0 to 27 during the nesting and brood-rearing periods. Obviously, more loons can occupy large lakes, thus creating the potential for a wider range in the counts.

Many examples of this variability were observed. In the overall MLMP, 66 more adult loons were counted in 1995 (878 adults) than in 1994 (812 adults). The majority (65%) of this increase occurred on only five lakes, all over 1000 acres in size (see Hanson, Chapter 4). Most of these "extra" loons were observed in large congregations, and many of them were likely non-resident/non-territorial adults. To a lesser extent, variation caused by loon movement also was observed on small lakes. On a 64-acre lake, one observer counted six adult loons, and the second observer counted zero loons on a different day. At least four of the loons observed on this lake likely were non-residents, as lakes this small can support only one territorial pair of adults.

It is possible that observation skills may be more important on extremely large bodies of water. Therefore, I would recommend that future studies be conducted to assess the effects of training and experience of observers on lakes z 700 acres in surveys where such large lakes are important.

Loon movement was not directly assessed in any of these studies. In the study on training effect, all efforts were made to minimize the effect of movement by having surveys conducted at the same time, but some timing differences still occurred. In the studies of paired counts and volunteer experience, observer error cannot be distinguished from the effect of loon movement, because the pairs of counts were conducted at different times. DiBello and Bissonette (1984) noted that loon movement alone could cause much year-to-year variability in results on individual lakes. Large sample sizes should help reduce the effect of loon movement, but this has not been thoroughly tested. Johnson (1981) found that many studies employ a large sample approach in hoping that the effects of numerous variables "average out." Other investigators (Walter Piper, Smithsonian Institution, and James Paruk, University of Idaho) have been collecting data on the population dynamics of the common loon on small and large lakes, including the amount of time loons spend on a lake. Frequency of loon movement may be estimable from these data.

Effect of time

Surveying lakes on three consecutive days could cause a learning effect in the volunteers. However, no significant trend in the count differences was observed between the trained or untrained volunteers over time.

The only marginally significant difference detected between trained and untrained observer loon counts was on day three and in the pairwise difference between day two and three. On day three on lakes where two paired observations were not conducted at the same time, two more adult loons were counted by trained observers. Also on day three, an untrained observer likely misidentified two adults as juveniles as mentioned earlier. If these anomalies were removed from the data, the difference on day three and the pairwise difference between day two and three would not be significant.

On any given day, the number of adult loons present may vary, especially on large lakes (see previous discussion). In the studies on paired counts and effects of experience, the effect of day or loon movement could not be separated from observer effects. Given the large number of lakes included in these studies, the overall measurement bias was small because the counts by the two sets of observers in both studies were similar. I can cautiously conclude that in the MLMP, where the sample size is even larger, the overall effects of adult loons being absent from a lake or visiting loons being present on any given day will likely cancel out.

Noncompliance of observers with study design

The six surveys that were conducted more than one hour apart were retained in the training study. Five of the six non-compliant surveys occurred on small and medium-sized lakes where loon movement tends to be less than on large lakes. One of the lakes did not appear to have quality loon habitat. The net effect of keeping these observations in the study would likely increase the count differences between observers. This effect was observed on day three as discussed previously. Because no overall significant difference between trained and untrained observers was detected with the non-overlapping observations included, the conclusion that training had no effect is stronger.

For all the studies, I only specified the minimum amount of time to spend surveying, not a limit on how long to spend. As a result some observers spent 30 minutes, whereas others spent two to four hours. Specifying time limits based on lake size may have increased compliance. For future studies, I would specify time limits as well as minimum times to spend observing (e.g., 30 minutes for small lakes, one to two hours for medium-sized lakes, and two to three hours for large lakes).

### Juveniles

In the training study, two volunteers (one trained and one untrained) each missed a pair of juveniles. As noted earlier, one of the untrained observers misidentified two adults as juveniles. In the study assessing paired counts, there were six counts where the number of juveniles differed by three or four. Juveniles loons are unable to fly until 11 to 12 weeks of age, and thus will always be present on a lake unless mortality occurs. These results indicated that juveniles will occasionally be missed, double counted, or misidentified during surveys. Overall., however, differences between trained and untrained volunteer juvenile loon counts have a mean of zero.

### Boat vs. Shoreline Survey Methods

Volunteers conducted the loon surveys from the shoreline and by boat. I recommended that all surveys on large lakes be conducted by boat but did not require it. Testing the accuracy of shore and boat surveys was beyond the scope of this study. Koskimies and Poysa (1989) found that point counts of waterbirds from numerous locations along the lakeshore gave nearly identical results as counts from a boat.

## SUMMARY AND CONCLUSIONS

Of the different components of this study, only the aspect assessing training controlled for the effect of loon movement by requiring that observations be made at the same time. However, because a few surveys were conducted at different times and for different lengths of time, loon movement still may have influenced the results. For the purposes of the MLMP where annual censuses are being conducted, the source of variation is not important. The important point is that all the studies indicated that volunteers tend to obtain similar adult and juvenile loon counts and the overall measurement error is small.

The study on the effect of training on volunteer accuracy showed that short training sessions did not significantly influence the survey results. The training study and paired count study both demonstrated that variation in loon counts increased on larger lakes. However, training did appear to increase survey efficiency. Training programs, if feasible, will likely improve observer efficiency, ensure compliance to survey protocols, and increase commitment to and understanding of the monitoring program.

The sources and magnitude of variation identified in these studies will be used to help interpret annual changes in the MLMP census results. The effect of loon movement, especially on large lakes, should be considered when interpreting the results of the MLMP. Utilizing volunteers who are already familiar with the large lakes should decrease the variability. For the largest lakes, this step has already been taken. Training material, whether written instructions or in a workshop format, should be targeted toward reducing variability on large lake surveys.

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Table 1. Minnesota Loon Monitoring Program (MLMP) lake survey regions ("index areas") by selection criteria. Selection criteria include current loon density and potential anthropogenic threats and were rated low, moderate, or high in relation to other index areas. Those threats that are likely to be greatest are listed in bold. Rated threats are not applicable to all lakes and were used as guidance for selecting the index areas.

| | **Index Area** | | | | | |
|---|---|---|---|---|---|---|
| | Becker | Itasca | Cook / Lake | Otter Tail | Aitkin / Crow Wing | Kandiyohi |
| **Rank of index area by potential threat level** (1 - lowest, 6 - highest) | 1 | 2 | 3 | 4 | 5 | 6 |
| **Selection Criteria** | | | | | | |
| Current Loon Density [a]: | *High* | *High* | *High* | *High* | *High* | ***Low*** |
| Acid Rain Sensitivity [b]: | *Low* | ***High*** | ***High*** | *Low* | *Low* | *Low* |
| Human Population / Road Density [c]: | *Low* | *Low* | *Low* | *Moderate* | ***High*** | ***High*** |
| Projected Human Population Growth [d]: | *Low* | *Low* | *Low* | *Low* | ***High*** | ***High*** |
| Land Ownership [e]: | *Public* | *Public* | *Public* | ***Private*** | ***Private*** | ***Private*** |

[a] Strong and Baker 1991
[b] Minnesota Pollution Control Agency, date unknown
[c] Minnesota State Planning Agency 1995
[d] Minnesota State Planning Agency 1994
[e] Land Management Information Center 1993

Table 2. Volunteer accuracy study design. The three groups[a] of matched pairs were distributed among lake size class and day in a Latin square.

| *Lake Size Class* | *Day of Survey* | | |
|---|---|---|---|
| | One | Two | Three |
| Small (10-149 acres): | Group A | Group C | Group B |
| Medium (150-399 acres): | Group B | Group A | Group C |
| Large (400-700 acres): | Group C | Group B | Group A |

[a] Each group consisted of five paired trained and untrained volunteers. Volunteers were randomly assigned to lakes within each group.

Table 3. Means (standard errors) of differences in adult loon counts by paired observers (trained minus untrained volunteer count) by group for each lake size and day combination. Marginal lake size and day means represent overall effects. n=5 for each lake size and day combination, n=15 for marginal means, and n=45 for entire study mean.

| *Lake Size Class* | *Day of Survey* One | Two | Three | Overall by Lake Size |
|---|---|---|---|---|
| Small (10-149 acres): | -0.20 (0.20) | -0.60 (0.40) | 0.40 (0.40) | **-0.13 (0.22)** |
| Medium (150-399 acres): | 0.60 (0.51) | -0.20 (0.37) | 0.40 (0.24) | **0.27 (0.23)** |
| Large (400-700 acres): | -1.00 (1.64) | 0.80 (0.97) | 1.00 (0.55) | **0.27 (0.66)** |
| **Overall by Day:** | **-0.20 (0.56)** | **0.00 (0.38)** | **0.60 (0.24)** | 0.13 (0.24) |

Table 4. Model-based estimates of the means of the treatment effect (training / no training) within levels of the two confounding factors, day of survey and lake size.

| Level | Mean (s.e.) | df | t | p-values |
|---|---|---|---|---|
| Day 1 | 0.096 (0.327) | 28 | 0.29 | 0.772 |
| Day 2 | -0.374 (0.327) | | 1.14 | 0.262 |
| Day 3 | 0.616 (0.327) | | 1.89 | 0.070 |
| Small | 0.142 (0.293) | 12 | 0.49 | 0.635 |
| Medium | 0.126 (0.293) | | 0.43 | 0.674 |
| Large | 0.355 (0.293) | | 1.21 | 0.250 |

Table 5. Mean number and coefficient of variation (C.V.) of adult loons observed on each lake based on six repeated surveys. The mean C.V. is given for each lake size class.

| Lake Size | Lake Name | Mean number of adult loons | Coefficient of variation (C.V.) | Mean C.V. by lake size class |
|---|---|---|---|---|
| small (10-149 acres) | Turtle | 0.33 | 154.9 | 83.7 |
| | Edquist | 1.00 | 89.4 | |
| | Lingroth | 1.17 | 100.2 | |
| | Blue | 3.50 | 74.0 | |
| | Sanders[a] | 0.00 | 0.0 | |
| medium (150-399 acres) | Section 12 | 2.67 | 38.7 | 52.3 |
| | Sisabagamah | 1.50 | 55.8 | |
| | Hanging Kettle | 1.83 | 41.1 | |
| | Thornton | 1.33 | 61.2 | |
| | Townline | 1.17 | 64.5 | |
| large (400-700 acres) | Section 10 | 3.33 | 41.0 | 46.8 |
| | Elm Island | 2.67 | 56.4 | |
| | Lone | 4.67 | 78.6 | |
| | Ripple | 7.83 | 27.3 | |
| | Spirit | 2.67 | 30.6 | |

[a] Zero loons were observed on Sanders lake for all six surveys.

Table 6. Total adult and juvenile loon counts and means (standard errors) of loon count differences of paired observers (n=139). Observers were arbitrarily assigned to one of two groups. Differences equal observer 1 counts minus observer 2 counts.

| | Number of Loons | | |
|---|---|---|---|
| Age | Observer 1 | Observer 2 | Mean differences (s.e.) |
| Adults: | 375 | 346 | 0.201 (0.156) |
| Juveniles: | 70 | 75 | -0.036 (0.080) |

Table 7. One-sample t-tests of the differences between paired adult and juvenile loon counts for each lake size class analyzed separately ($H_o$: $\mu=0$). Observers were arbitrarily assigned to one of two groups. Count differences equal observer 1 counts minus observer 2 counts. Surveys were conducted during the same five-day period (14-18 July 1995). Eighty-nine, 29, 8, and 13 lakes were surveyed in the small, medium, large, and very large lake size classes, respectively.

| | | Adults Loons | | Juvenile Loons | |
|---|---|---|---|---|---|
| Lake size class | df | t | p-values | t | p-values |
| Small (10-149 acres) | 88 | 0.07 | 0.944 | 0.00 | 1.000 |
| Medium (150-399 acres) | 28 | 1.07 | 0.291 | 1.32 | 0.199 |
| Large (400-700 acres) | 7 | 0.51 | 0.626 | 1.87 | 0.104 |
| Very Large (>700 acres) | 12 | 1.33 | 0.205 | 0.30 | 0.766 |

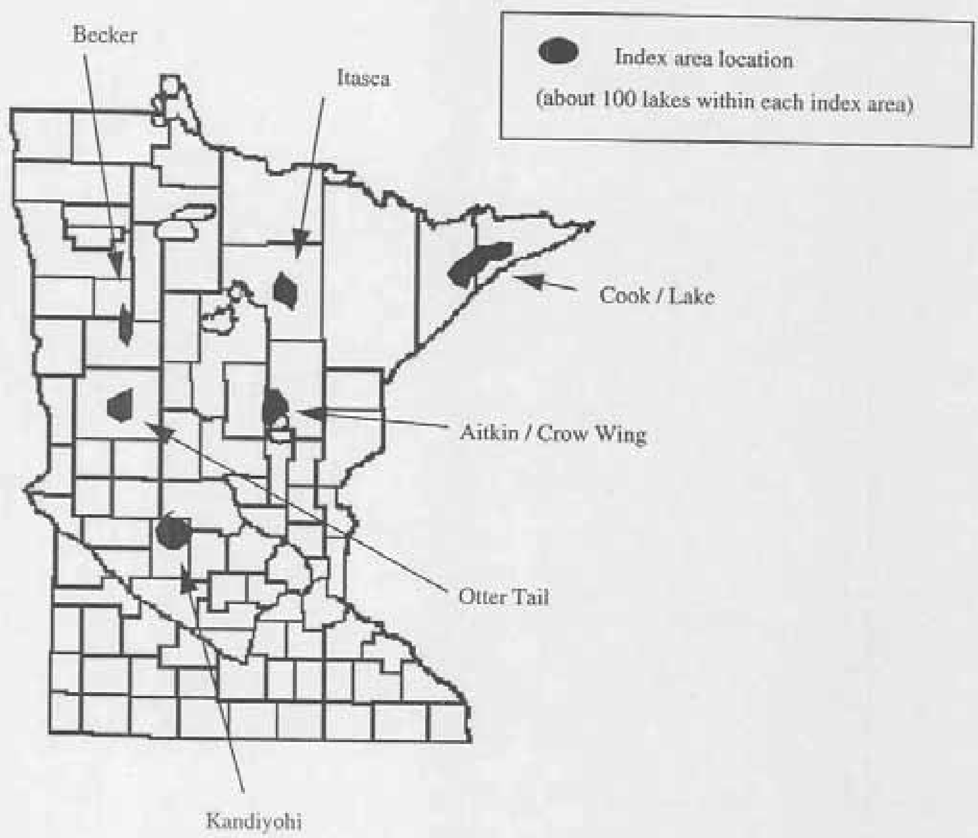


**Figure 1. Location of six survey regions ("index areas")**

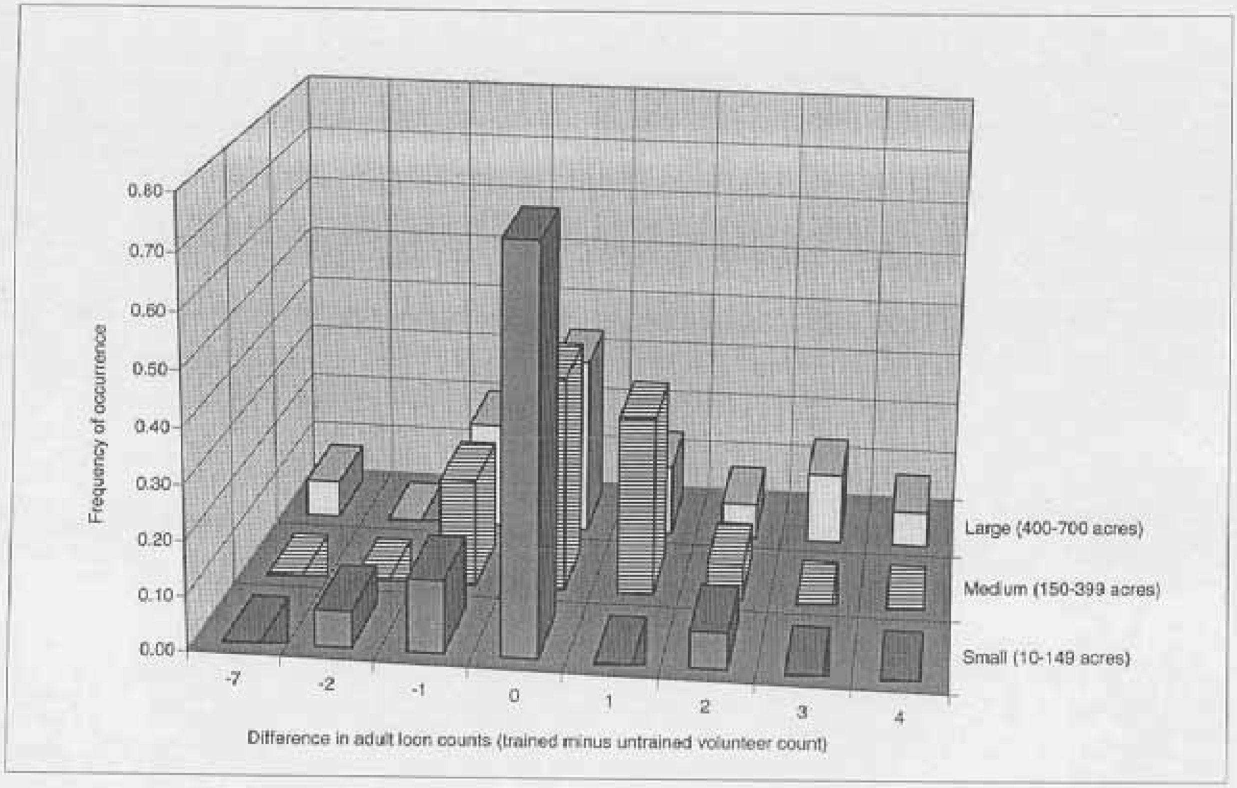


Figure 2. Frequency distribution of the adult loon count differences between trained and untrained volunteers by lake size class (n=15 for each size class). Paired counts were conducted on the same day during the same time period.

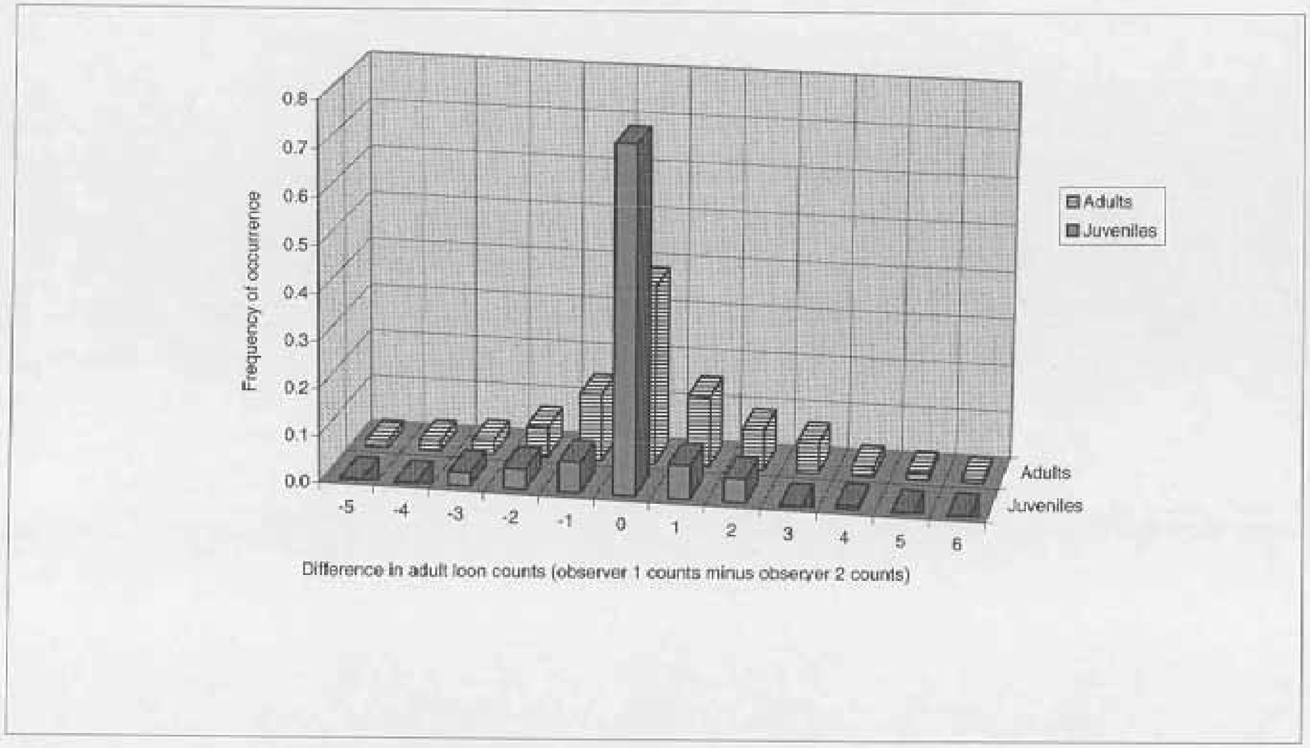


Figure 3. Frequency distribution of adult loon count differences between two groups of arbitrarily assigned volunteers. Paired counts were conducted during the same five-day period (14-18 July 1995) on 139 lakes.

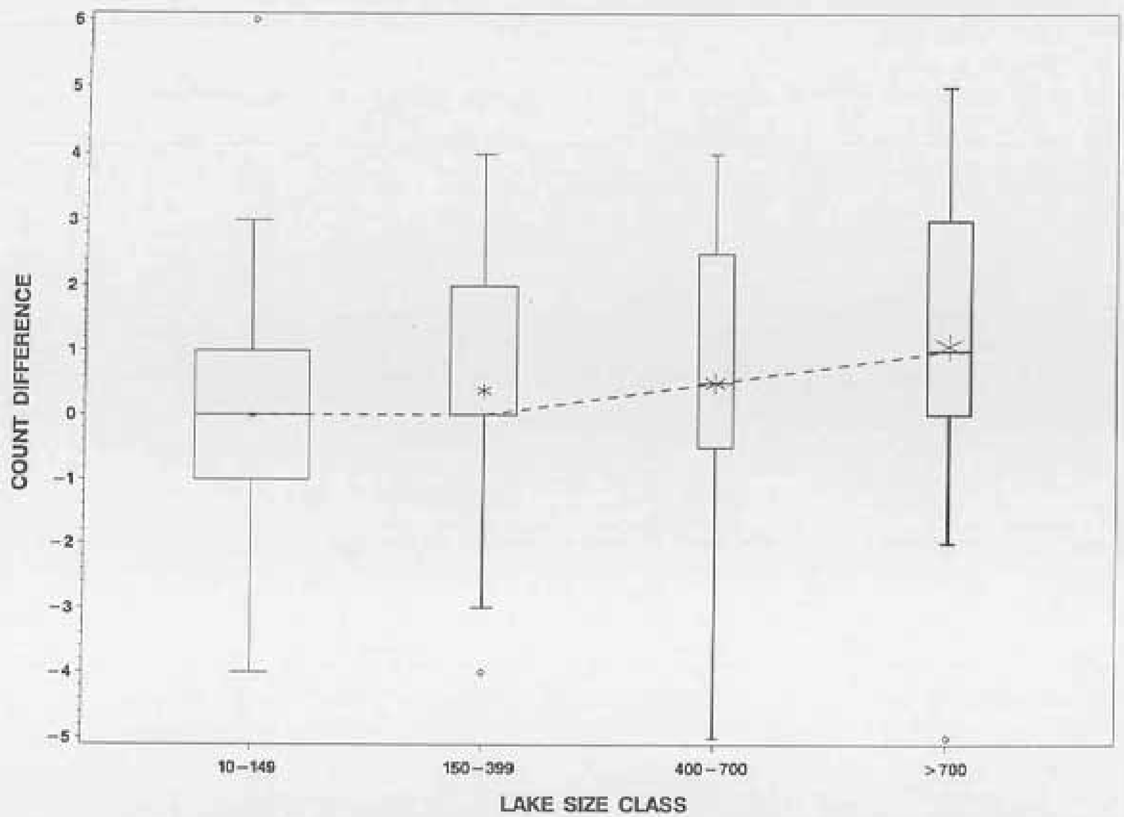


Figure 4. Box and whisker plot of the differences between paired adult loon counts for four lake size classes. Observers were arbitrarily assigned to one of two groups. Count differences equal observer 1 counts minus observer 2 counts. Surveys were conducted during the same five-day period (14-18 July 1995). 89, 29, 8, and 13 lakes were surveyed in the small, medium, large, and very large lake size classes, respectively.

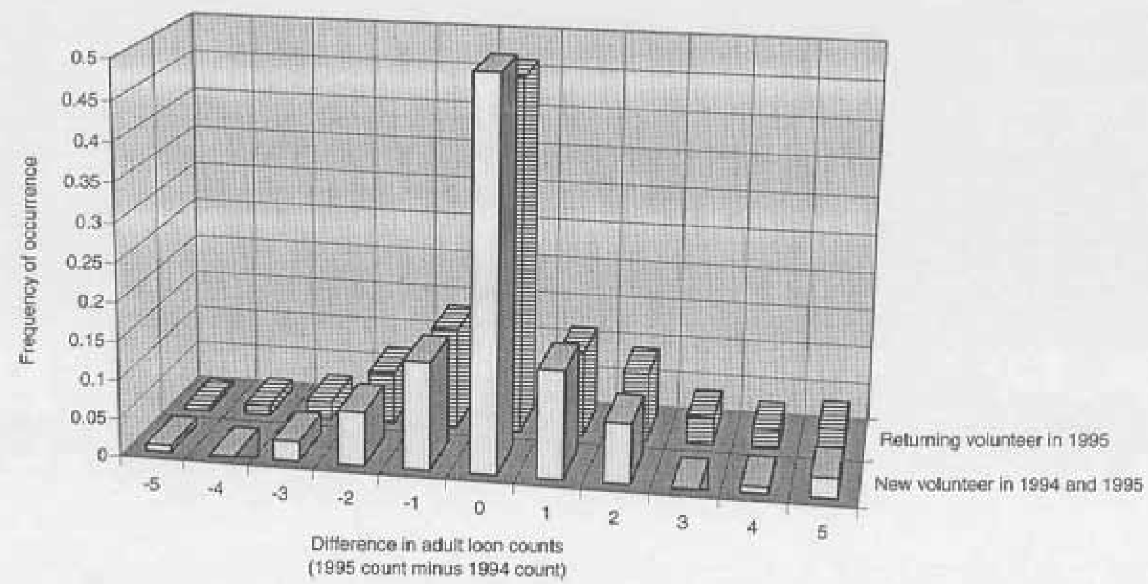


Figure 5. Frequency distribution of adult loon count differences on the same lake over two successive years (1994 and 1995) for two groups of observers: new volunteers **in both** years (n=114) and new volunteers in 1994 who returned in 1995 (n=471).

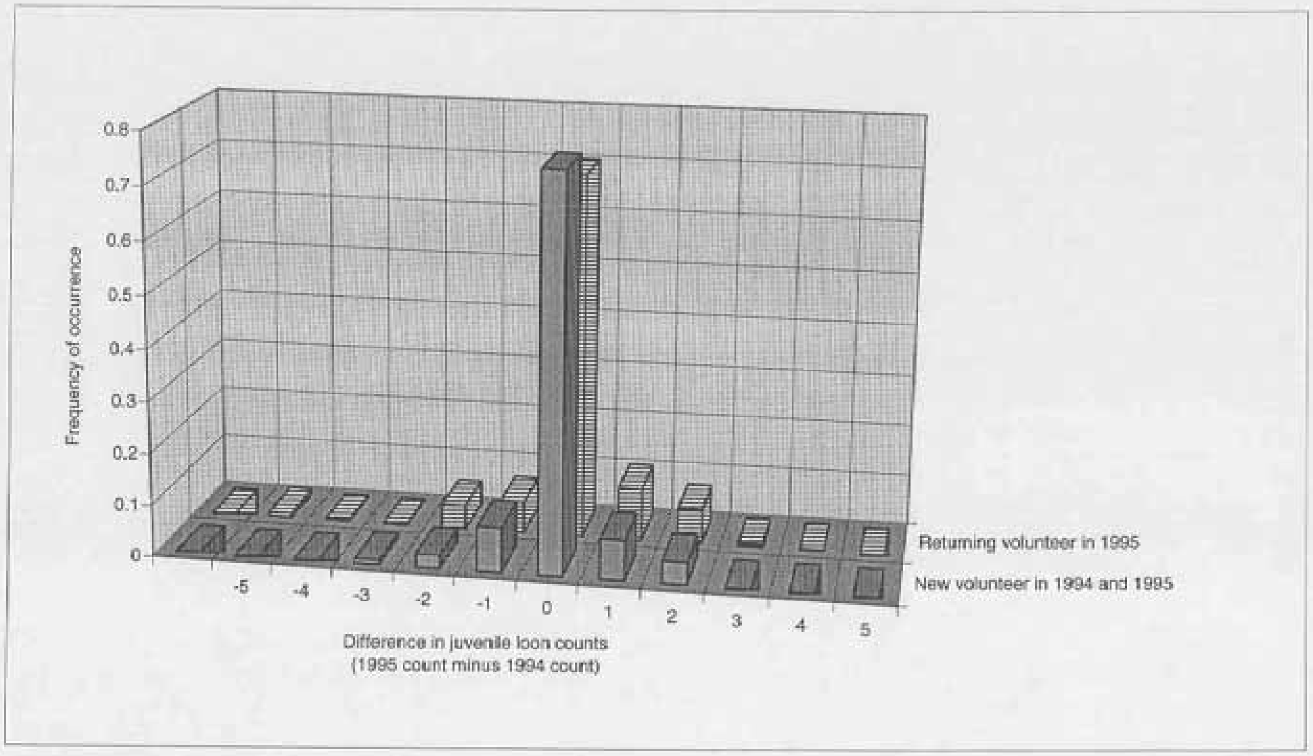


Figure 6. Frequency distribution of juvenile loon count differences on the same lake over two successive years (1994 and 1995) for two groups of observers: new volunteers in both years (n=114) and new volunteers in 1994 who returned in 1995 (n=471).

## Chapter 2: A modeling exercise to determine the power of detecting decreasing trends in adult common loon numbers in Minnesota

### INTRODUCTION

In 1994, the Minnesota Department of Natural Resources (MN DNR) initiated the Minnesota Loon Monitoring Program (MLMP) to annually assess the status of the adult loon population and reproductive success throughout the state. The MN DNR's primary concern is to detect a decline in the loon population before the problem becomes so serious as to require regulatory action (e.g., threatened or endangered species status). It would be helpful for the MN DNR to know what rate of change is required and how long monitoring is necessary before a negative trend could be statistically detected.

The probability of mistakenly failing to reject a false null hypothesis is called statistical power (Toft and Shea 1983). Low power indicates a greater chance of not rejecting the null hypothesis when a real change has occurred (false negative). The reason for non-detection of a change could include small sample size, large variability in the data, brief sampling period, or small a used in statistical tests. High power is desired, especially in regards to conservation problems. For example, concluding that a population is stable when an actual decline has occurred may be detrimental to a rare species (Taylor and Gerrodette 193). Power is usually calculated using a measure of effect size or rate of change in abundance, sample size, precision (e.g., variance, coefficient of variation), and statistical a levels (Gerrodette 1987, Peterman 1990). If no direct measure of variance is available, Peterman (1990) described a simulation procedure to assess power that uses a random variable to assess variability. !For a more detailed discussion of power and its applications see Gerrodette (1987), Green (1988) Peterman (1990), Rotenberry and Wiens (1985), Taylor and Gerrodette (1993), and Toft and Shea (1983).

The error associated with sampling is low because the MLMP is based on a complete census of six regions ("index areas") consisting of about 100 lakes each. However, measurement error exists from observer error, loon movement, weather condition, etc. (See Hanson, Chapter 1 for a discussion of measurement error.) Thus, the annual MLMP survey results are based on variable counts that peed to be considered when interpreting trends. I developed a computer model to simulate adult loon population declines and variable volunteer loon counts. I used linear regression to assess modeled loon abundance against time and quantified the proportion of cases in which the null hypothesis (Ho) was correctly rejected (i.e., a statistically significant negative slope was detected).

The objective of the study was to assess the power of detecting significant declines of the modeled loon population while varying count variability, the length of monitoring period, the number of lakes surveyed, and a levels. The outcome of the study should provide the MN DNR guidance on how many years of monitoring are necessary to detect various rates of decline in the adult loon population within the MLMP survey region.

## METHODS

A stochastic spreadsheet model was used to determine the power of detecting predetermined declines in tie adult loon population. Parameters included measurement error estimates, predetermined annual population declines, time (in years), number of lakes surveyed, and a levels. The response variable was the power in detecting significant changes in the population. For year zero, I used loon count data from the entire MLMP 1995 results, n=630, and two of the six index areas, n= ~100, where n is the number of lakes surveyed.

Three levels of measurement error were used, which were derived from three distributions of differences of paired adult loon counts on individual lakes from actual volunteer count data (Fig. 1). For a measure of low variability, differences of paired volunteers' loon counts conducted on the same lake at the same time were assessed ("same time"). These differences primarily measured observer error. Moderate variability was determined from paired counts conducted on the same lakes during the same five-day period ("5-day period"). This assessment incorporates other sources of measurement error in addition to observer error, especially loon movement and surveying under potentially different environmental conditions. The largest measure of variability in loon counts was done by comparing the 1994 and 1995 results on the same set of lakes with the assumption that the real population on these lakes did not change between years ("between years").

The study site and survey methods are described in Hanson, Chapter 4. Because the magnitude of the adult loon count differences increased with lake size, the differences were divided into four size classes. An example of the distribution of count differences by lake size class is presented in Fig. 2 for the "between year" measurement error.

Variable counts were simulated by randomly selecting point from the distribution of count differences and adding the appropriate number of loon from the expected loon count on individual lakes. The model was run at chosen constant population decline rates of 0.0, 0.7, 1.0, 1.7, 2.4, 3.0, 4.3, and 5.6%. For each parameter combination, the model was run 500 times. Each run was 20 years. The untransformed loon counts from each run were plotted against time using linear regression, and the percent of statistically significant slopes using a t-test at a levels of 0.05 and 0.10 were tallied at 5, 7, 10, 15, and 20 years. The percent of significant negative slopes indicated the power of detecting an actual decline (i.e., correctly rejecting the null hypothesis when the null hypothesis was known to be false). A sample Of three runs of the model are presented in Fig. 3.

Power curves were constructed for the three levels of variability and the two alpha levels across the five time periods. Power levels of 0.8 (ß=0.2) were assumed to be adequate in determining the period of time necessary to confidently detect changes io the population. If greater power is desired for the time periods assessed in this study, detectable decline rates would be larger.

The variability of the differences in paired adult loon counts was assumed to adequately assess measurement error. For the "between year" count differences, I assumed that the overall population did not change from 1994 to 1995. 1 also assumed that annual decline rates and the number of loons expected to be observed on a lake remained constant. This last assumption is violated when loons leave their territorial lake. However, the distribution of loon count differences for the 5-day period and between years should account for loon movement and other sources of error.

## RESULTS

The monitoring time and rates of decline required to obtain a power level of 0.8 in detecting population declines using the three levels of measurement error are presented in Fig. 4. Measurement error in estimates of abundance had a greater effect for short monitoring periods: For example, a decline of 2.2% per year may be detectable after five years assuming low measurement error (counts at same time) compared to 31,.4% per year for high measurement error (between years). (If the original loon population within the survey region was 1000 adults, a 3.4% annual decline would result in loon population of 841 after five years of monitoring.) After 10 to 15 years of monitoring, most population declines of 0.5I to 1 % per year should be detectable whether low or high levels of variability are assumed.

For the remainder of the analyses, I will use the high measurement error (count differences "between years") for modeling variable counts to provide the most conservative estimate of power.

The power curves for monitoring the loon population over a 5 to 20 year time period are shown in Fig. 5. If after five years of monitoring no significant slope is detected, the loon population probably has not declined at a rate greater than 3.4% per year, but may have declined at smaller rates. As the time of monitoring progresses, smaller decline rates should become more detectable. For example, the probability of being able to detect a 1 % annual decline after five years is only 0.1 but is about 0.8 after 10 years. (After 10 years, an annual decline rate of 1.0% would result in a loon population of 904 within the six index areas based on an original population of 1000.)

Increasing α from 0.05 to 0.10 to determine the significance of the slope of the least squares line resulted in annual population declines to be detectable sooner (Fig. 6). For example, after five years of monitoring, an annual decline rate of about 2.8% may be detectable using an a of 0.10 compared to 4.3% using an a of 0.05. As time progresses, the calculated power became similar using either an a of 0.05 or 0.10.

The number of lakes surveyed is extremely important in the ability to detect declines as demonstrated by the comparison of power curves for all lakes in the MLMP and two index areas modeled separately (Fig. 7). Given an annual decline rate of 3.4% where power equaled 0.8 for all MLMP lakes, the power to detect a decline within a single index area was only about 0.3. Extrapolating from the power curve for the five year time period, a decline of approximately 7.5% would have to occur to obtain power of 0.8 for a single index area (Fig. 8). (If an index area had 150 adult loons in year zero, there would be 102 adults:, after five years given an annual decline rate of 7.5%.) As monitoring periods of 15 and 20 yeas are approached, the effect of sample size diminished. Although the adult loon populations varied between the two index areas (i.e., Aitkin had more loons than Otter Tail), power curves were similar for each.

**DISCUSSION**

Model simulations of the common loon population demonstrate that declines within the MLMP should be detectable within a reasonable timeframe from a natural resource management perspective. The power of differentiating the true slop& from a slope of zero (i.e., no change in abundance) for this study appears to be high in comparison to monitoring of other animal populations because the of small measurement error and the large number of lakes surveyed. Gerrodette (1987) calculated that it would take 11 years) to detect a population increase of about 4.5% annually in California sea otters *(Enhydra lutris) ( at* a power level of 0.95 using a single annual aerial, survey. For the MLMP, it would take about five years for the same decline rate and power level. Edwards and Perkins (1992) determined that annual changes of 10% in the northern offshore spotted dolphin population *(Stenella attenuata)* may be detectable in 10 years using a power level of 0.9. Using power of 0.9 in this study, a 1.3% annual decline may be detectable in 10 years. For a study on the vaquita *(Phocoena sinus)* population, a rare porpoise, Taylor and Gerrodette 0993) found that to monitor the population tong enough to obtain high power in detecting a decline may result in the near extinction of the species.

For individual index areas, if a significant negative slop(; is not observed, it will take a longer time or larger decline rates before changes in the population can be detected with adequate power compared to assessing all MLMP lakes. The results for lithe Aitkin/Crow Wing and Otter Tail index areas are probably applicable to the remaining four index areas. Measurement error will likely be more pronounced in annual loon counts from a single index area compared to the entire MLMP, increasing the chances of falsely rejecting the null hypothesis. Harris (1986) and

Gerrodette (!,1987) suggested that conducting multiple counts within years would reduce measurement error caused by variable counts, but unfortunately logistical and financial constraints do not make this option feasible unless the project was conducted at a much smaller scale. To reduce the effect of variable counts and to increase power, especially for monitoring changes within individual index areas compared to the entire study area, longer monitoring periods, pooling of two or three years of data (Kendall et al. 1992), or using a large a will have to suffice. See Hanson (Chapter 4) for further discussion on dealing with the effects of variable counts.

The results of the analysis should be interpreted conservatively as unknown biases in the model may exist arid modeled count variability may underestimiate real variance (Gerrodette 1987). These results indicate the minimum number of years necessary to monitor the loon population within the MLMP study area given a constant rate of increase. In the actual loon count data from 1994 and 19'95, 66 more adults were counted in 1995. The observed difference was primarily caused by large congregations of adults on a few large lakes (see Hanson, Chapter 4). These congregations may indicate an actual population increase, or they may occur so sporadically that even large sample size did not reduce their influence. I modeled a zero percent change in the adult loon population and found that changes of this magnitude or greater (change of 66 loons between years) occurred in 23.4% of the runs. Thus, the variation in loon counts used in the model appears to be adequate. Even if there is more variability in the loon counts than modeled here, after 10 to 15 years of monitoring, changes in the population may be detectable regardless of the variability as indicated by the detectable decline rates becoming nearly identical.

## CONCLUSION

The variability in adult loon counts appears to be low enough to allow population changes to be detected before the population becomes threatened. Longer monitoring periods will be required to distinguish small changes from measurement error for the adult loon population within the MLMP study area. For individual index areas, longer monitoring periods will be necessary to obtain the same power levels as when assessing the entire MLMP results. If significant declines are detected either for the entire MLMP or within index areas, steps pan be confidently taken to determine what is causing the observed decline. Count variability may still influence the results, however. To ensure that measurement error is not the cause of the observed decline, an extra year or two of surveying should provide confirmation.

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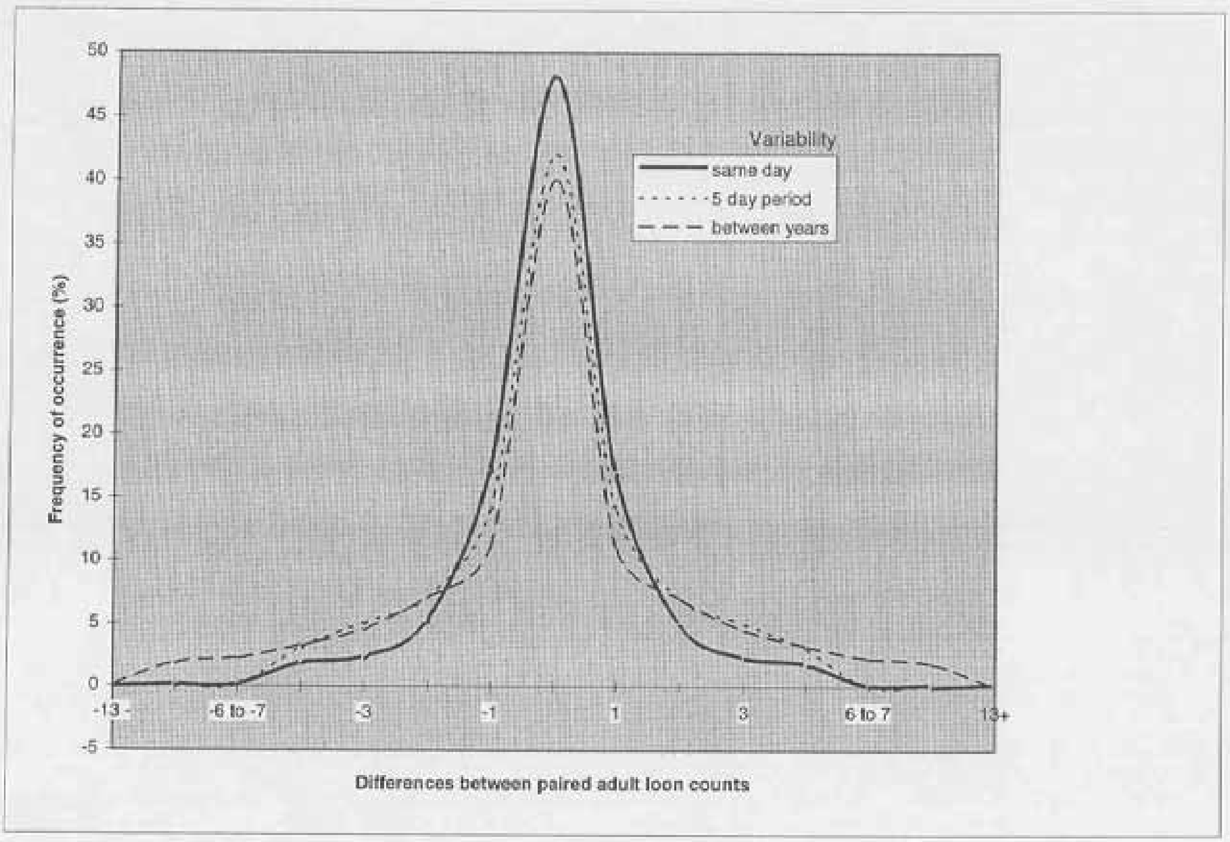


Figure 1. Distribution of differences of paired adult loon counts conducted on the same lake used to measure three levels of measurement error (i.e., counts conducted at the same time, during the same 5 day period, and between years).

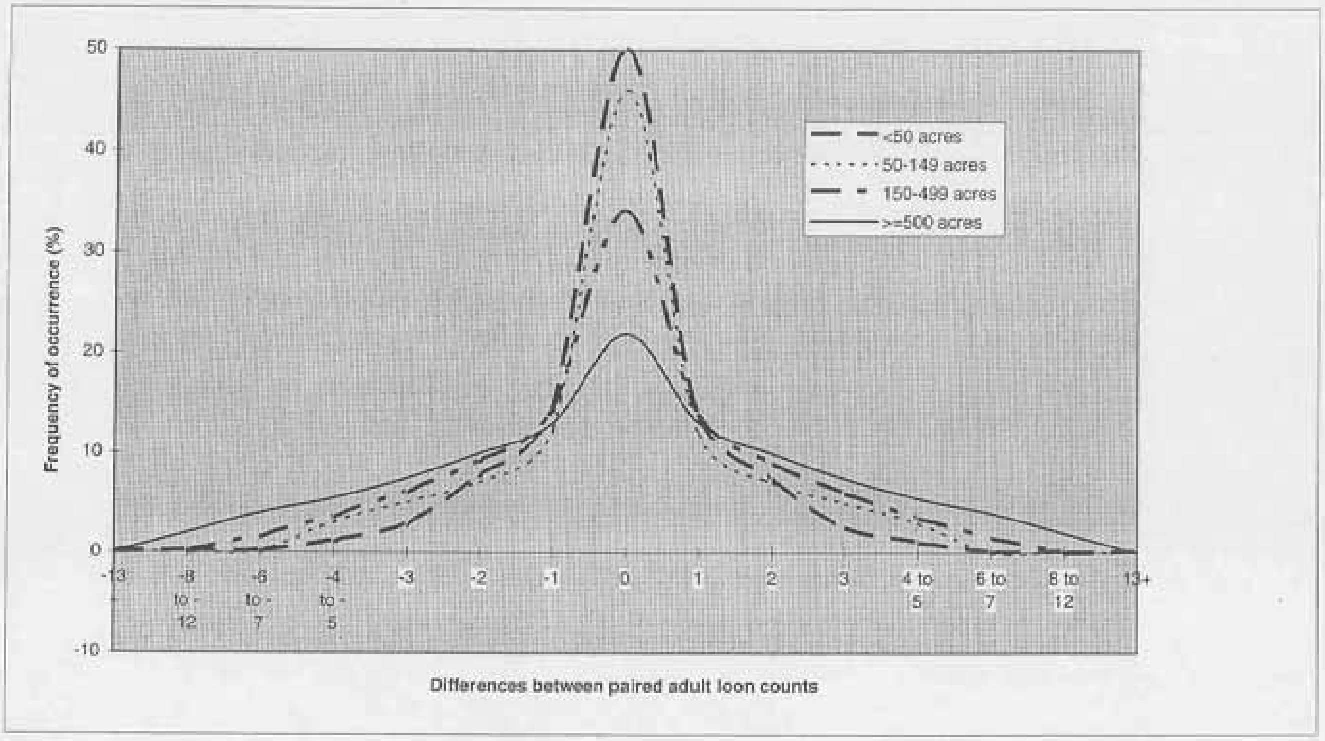


Figure 2. Distribution of differences of paired adult loon counts conducted on the same lake in two different years ("between year" variability) across four lake size classes.

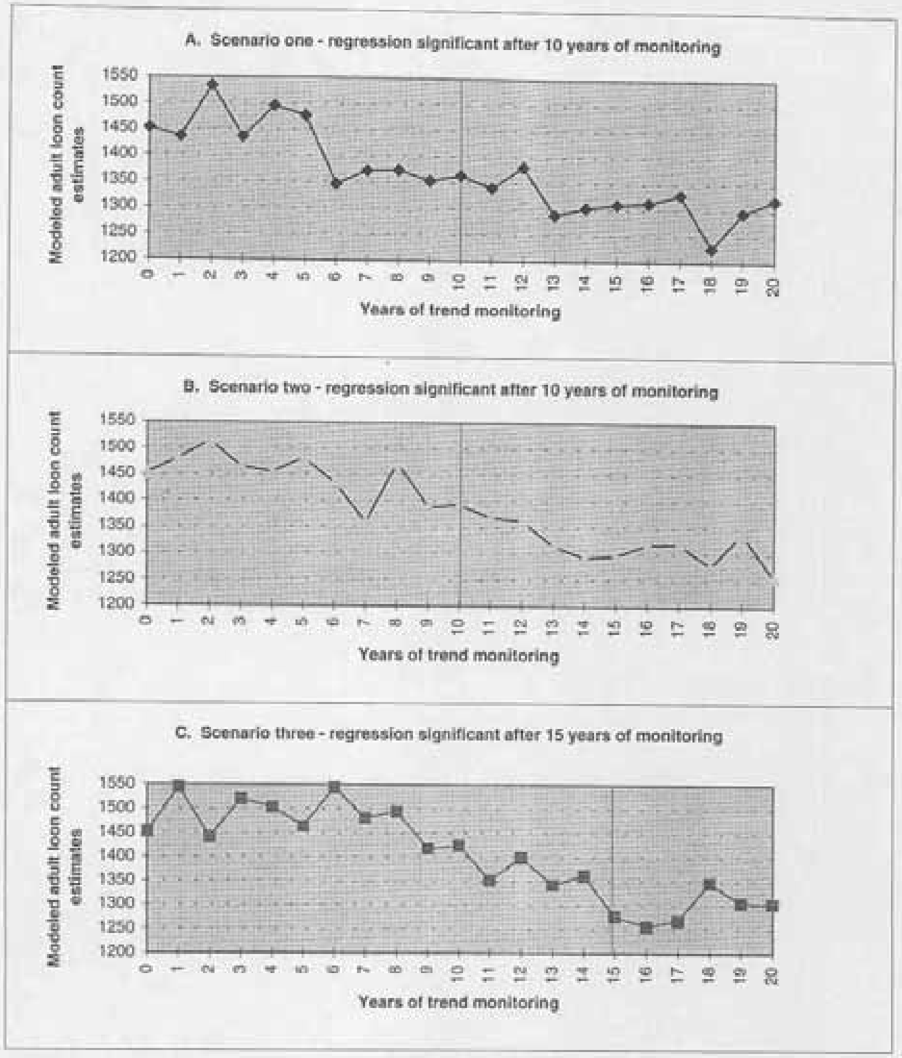


Figure 3. Samples of three runs of the stochastic model of estimated adult loon abundance based on a pre-determined decline rate of 1.0 % per year and variable counts. Variability was determined from the distribution of paired loon count differences on the same lakes "between year". Slopes were calculated at 0, 5, 7, 10, 15, and 20 year time intervals. Slopes were significant at 10 years for scenarios one and two and at 15 years for scenario three (alpha = 0.05). Power was determined by quantifying the proportion of runs in which the slope was statistically significant.

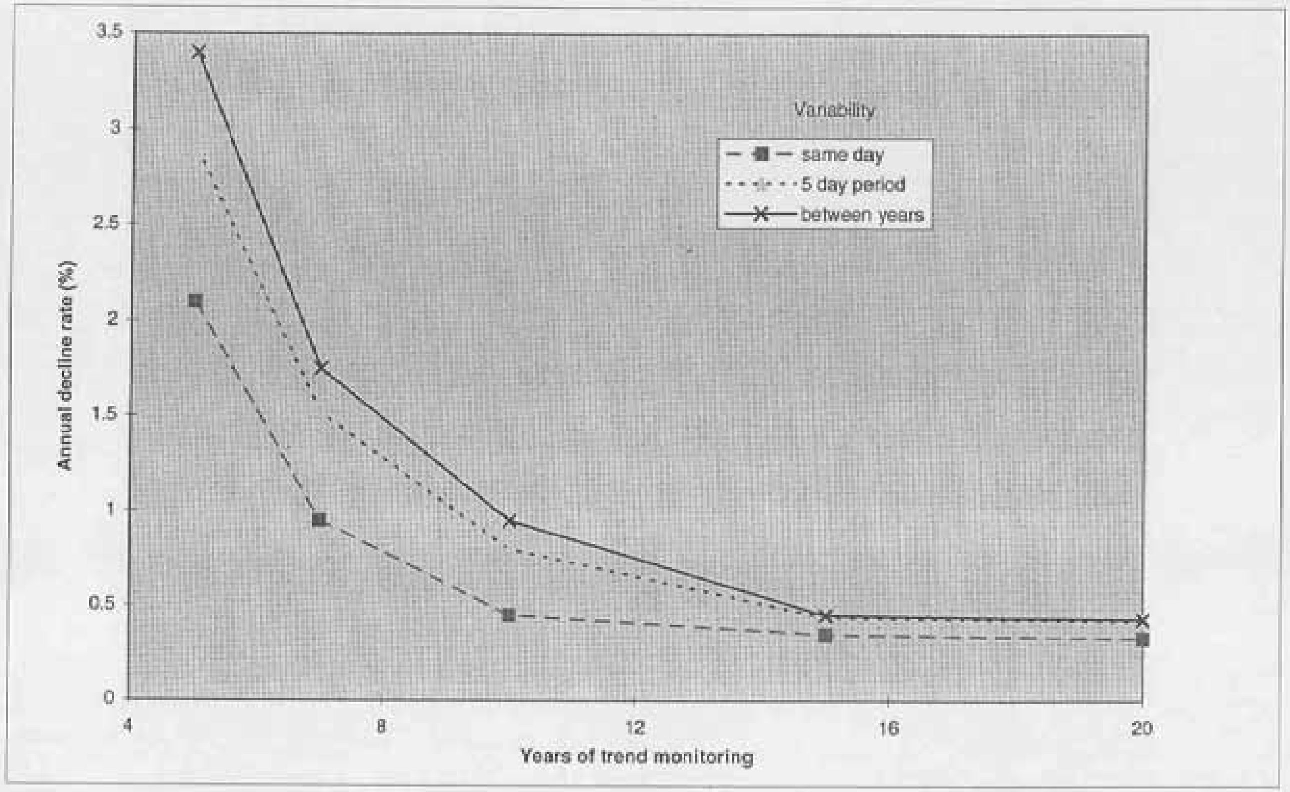


Figure 4. Detectable annual adult loon population decline rates at power of 0.80 as a function of trend monitoring time period for three levels of measurement error in volunteer adult loon counts (i.e., differences of paired counts conducted during the same day, 5 day period, and between years). Results are based on modeling pre-determined declines over 5 time periods and 8 rates of decline and estimating abundance using variable counts. The model was run 500 times and the percent of slopes significantly less than zero (alpha=0.05) are used to calculate the power at each decline rate.

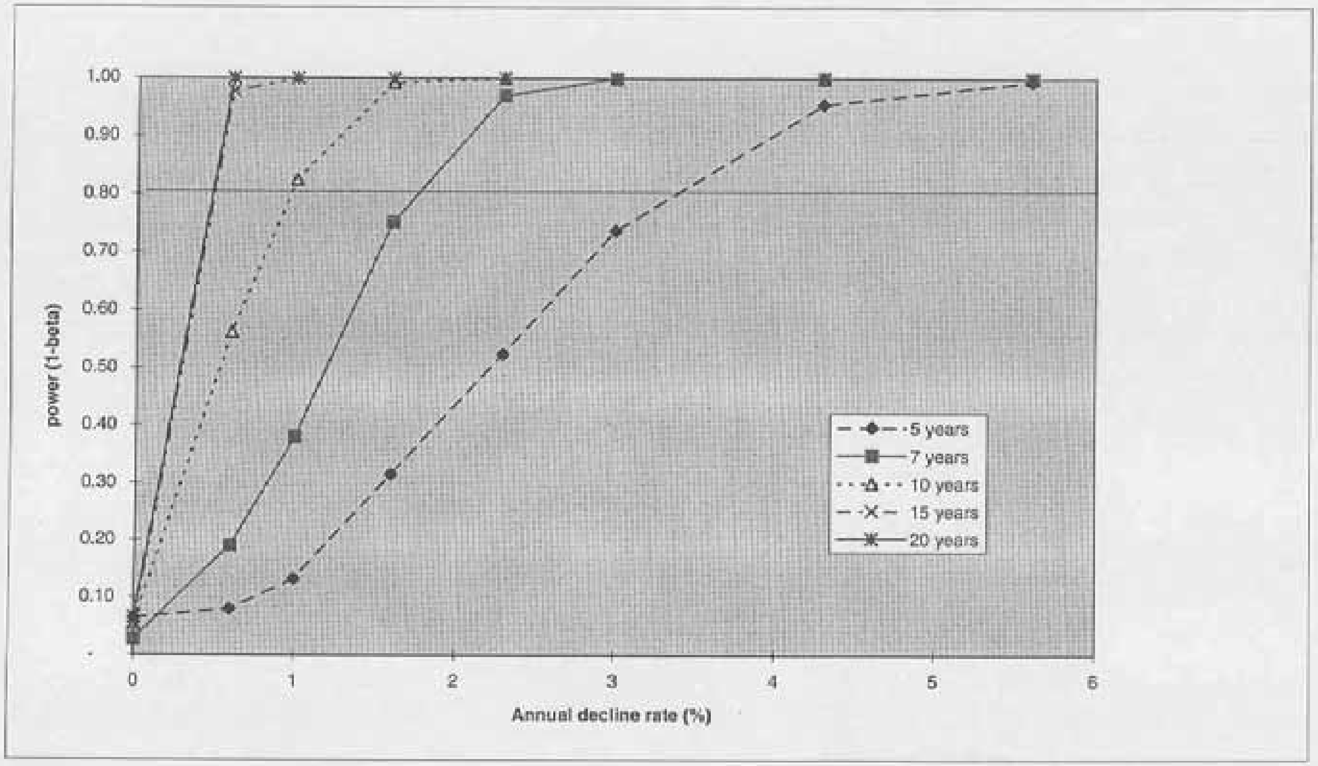


Figure 5. Power curve for detecting adult loon population declines at 5 time intervals and 8 rates of decline. Results are based on modeling predetermined declines and estimating abundance based on the variability of adult loon count differences on the same lakes between two years. The model was run 500 times and the percent of slopes significantly less than zero (alpha = 0.05) are used to calculate the power at each decline rate. Power of 0.80 is highlighted with horizontal line.

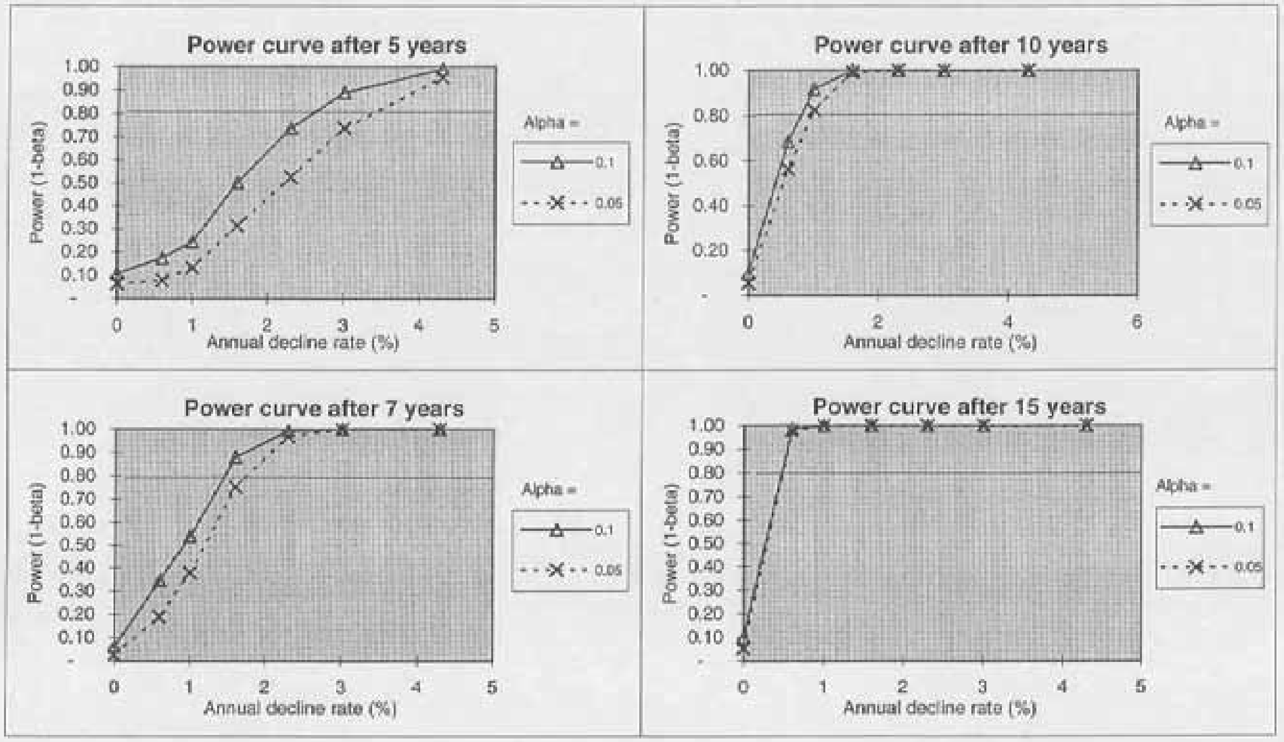


Figure 6. Power curves for detecting a decline in the adult loon population at alpha levels of 0.05 and 0.10 (significant negative slopes in model) over 4 time intervals and 7 rates of decline. · Results are based on modeling predetermined declines and estimating abundance based on the variability of adult loon count differences on the same lakes between two years. The model was run 500 times and the percent of slopes significantly less than zero were used to calculate the power at each decline rate. Power of 0.80 is highlighted with horizontal line.

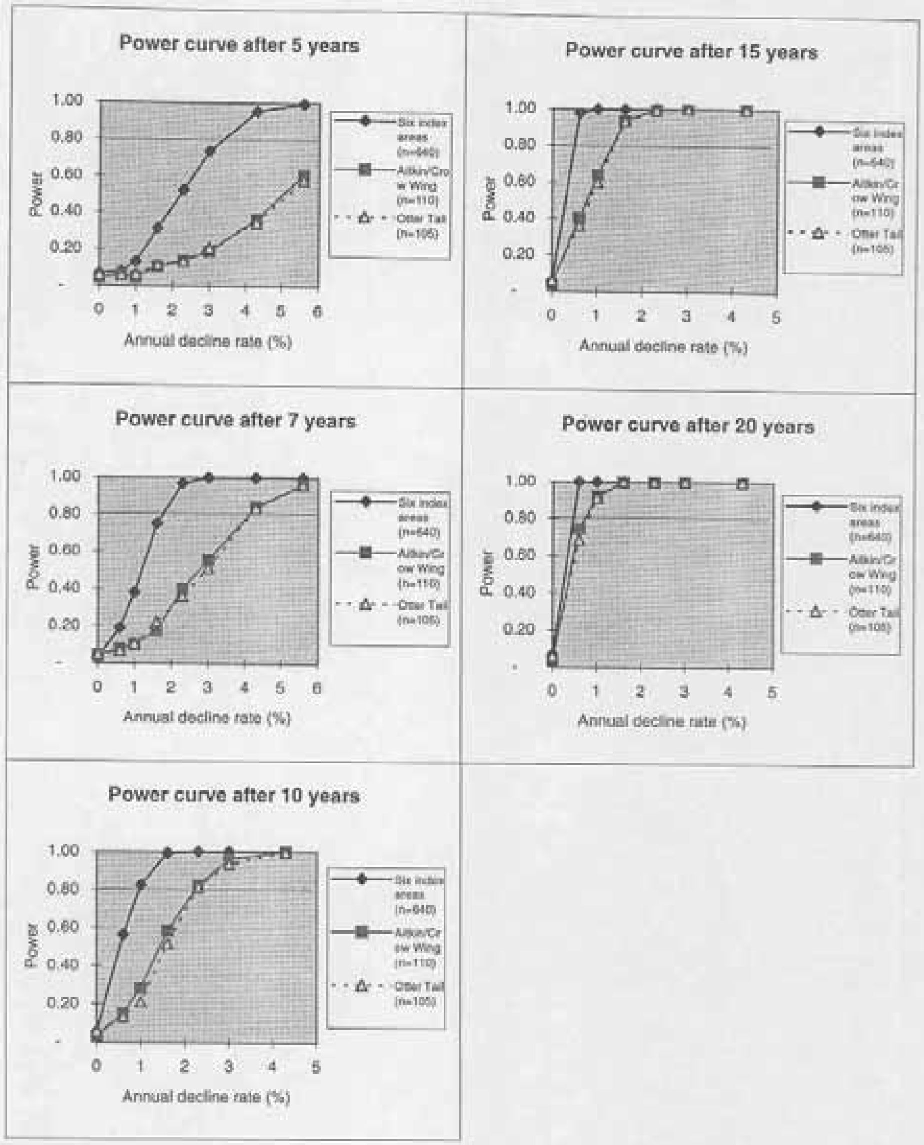


Figure 7. Power curves for detecting a decline in adult loon population within all six index areas (n=640) and for two individual index areas (Aitkin/Crow Wing and Otter Tail, n=about 100) over 5 time intervals and 8 predetermined decline rates. Count estimates were modeled based on the variability of actual loon counts on the same lakes over two years. The model was run 500 times and the percent of slopes significantly less than zero (alpha=0.05) are used to calculate the power at each decline rate. Power of 0.80 is highlighted with horizontal line.

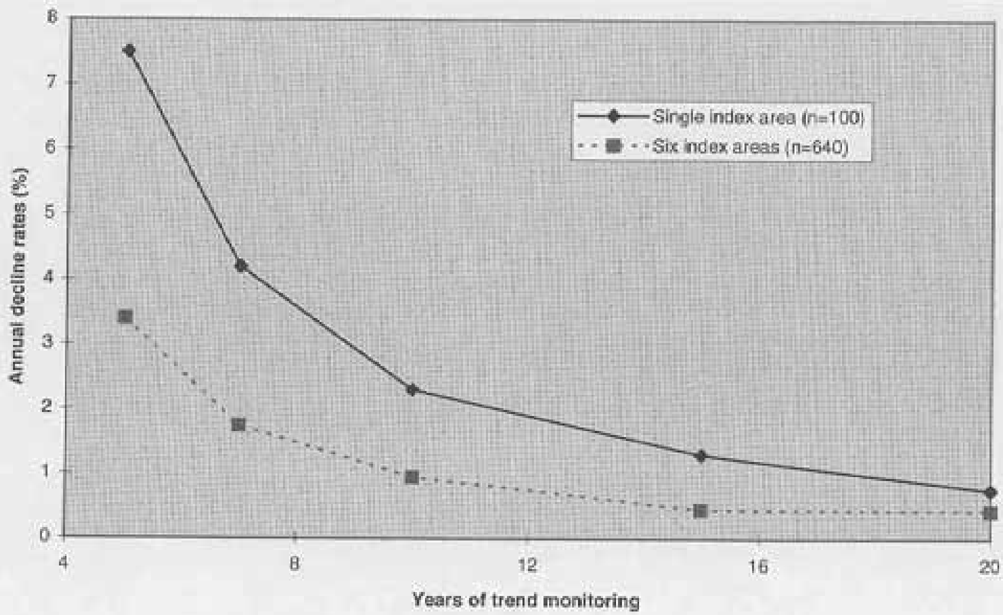


Figure 8. Detectable annual adult loon population decline rates at power of 0.80 as a function of trend monitoring time period for large and small number of lakes surveyed. Results are based on modeling pre-determined declines over 5 time periods and 8 rates of decline and estimating abundance based on the variability of adult loon count differences on the same lakes between two years. The model was run 500 times and the percent of slopes significantly less than zero (alpha=0.05) are

**Chapter 3:** 'A **comparison of ground and aerial counts of the common loon as a component of along-term monitoring program in Minnesota.**

## INTRODUCTION

Aerial surveys have been used extensively to provide estimates of animal population size and density especially for large terrestrial mammals (Caughley ey 1974, Caughley et al. 1976, Siniff and Skoog 1964, Steinhorst and Samuel 1989), sea mamm s (Geibel and Miller 1984, Myers and Bowen 1989, Packard et al. 1986), waterbirds (Broome 1985, Henny et al. 1972, Rodgers et al. 1995), and the common loon (Gavia immer) (Lanctot and Quang 1992, Strong and Baker 1991, DiBello and Bissonette 1984, Mooty 1987, McIntyre 191, S. Stockwell pers. comm., Zimmer 1979). Aerial survey results usually provide underestimates of the actual number of individuals present due to visibility bias (i.e., not all animals are sighted) (Caughley 1974). Previous studies indicated that aerial counts underestimated loon numbers when compared to ground counts, but the results have varied considerably (DiBello and Bissonette 1984, Mooty 1987, McIntyre 1991, Zimmer 1979). Despite evidence of visibility biases, aerial surveys have been necessary for surveying remote regions or where the costs of equivalent ground surveys are prohibitive (Caughley 1974).

Visibility bias for aerial surveys is influenced by two general components: aerial survey biases and characteristics of the species to be surveyed. Aerial survey biases include surface water and lighting conditions, altitude and speed of the airplane, pilot/observer experience, and observer fatigue (Caughley 1974, Pollock and Kendall 1987). Bases dependent on the species being surveyed include habitat type (e.g., vegetation, topography) and behavioral characteristics. Components of visibility bias are discussed in-depth in other papers (Broome 1985, Caughley et. al. 1976, Caughley 1974, Myers and Bowen 1989, Seber 1982).

Seber (1982) recommended three ways to deal with visibility bias in aerial surveys: 1) attempt to make the bias constant and use the results as indices, 2) calculate a correction factor utilizing ground counts to derive ratio or least squares estimates, and 3) correct for the bias using sampling and transect theory. Pollock and Kendall (1987) reviewed several estimation procedures including ratio estimates from aerial and ground counts, two sample capture-recapture (Peterson) estimator, two sample removal method, line transect modeling, and bounded counts. They concluded that the best estimation technique was the total ground count assuming that relatively accurate ground counts could be obtained. Jolly (1969 as cited in Pollock and Kendall 1987) noted that only a few ground courts were necessary in developing a precise ratio estimate.

When comparing ground to aerial counts, the ground count is assumed to be unbiased and precise (Seber 1982). This assumption often fails for animals Pound in dense vegetation and rough terrain. Broome (1985) found that aerial sightability of waterfowl declined with patchy backgrounds (e.g., reed beds, meadows, shallow water) but improved in open water areas. Henny et al. (1972) had to abandon the use of ground counts of waterfowl because of dense aquatic vegetation. Aerial survey accuracy also decreases when counting large groups and flocks of mixed species (Broome 1989, Caughley 1974, Myers and Bowen 1989, Rodgers et al. 1985, Samuel et al. 1987).

Some of the sources of visibility bias mentioned above for waterbirds are not applicable to the common loon. The common loon is conspicuous water ird ranging from 30 to 36 inches in length with contrasting black and white markings and spends t e majority of time in open water habitat. Loons rarely form large flocks during the breeding season or flock with multiple species (McIntyre 1988a).

Species-specific visibility biases that apply to the common loon include adult diving behavior and the size, color, and behavior of chicks. When feeding and moving from one area to another, adult loons may spend a considerable amount of time below the water surface. Loon chicks may be difficult to detect because of their smaller size and uniform color. Chicks less than two weeks of age spend much time in the immediate proximity to adults, including on adults' backs or under their wings, making detection difficult. Loons also exhibit bit a dive response to low-flying aircraft (Lanctot and Quang 1992, DiBello and Bissonette 1984',, personal observation). Aerial loon surveys will likely suffer from the same aerial survey biases as other species mentioned previously. Evidence of both aerial and species-specific biases is demonstrated by the variability of air/ground count ratios from other studies, which ranged from 0.28 to 1.0 (DiBello and Bissonette 1984, Lee and Arbuckle 1988, Mooty 1987, McIntyre 1991, Zimmer 1979).

In 1994 and 1995, aerial surveys were utilized in the Minnesota Loon Monitoring Program (MLMP), a project initiated by the Minnesota Department of Natural Resources (MN DNR) to annually assess the adult common loon population and its reproductive success in six distinct regions ("index areas") of the state. Complete censuses, were conducted on over 600 lakes z 10 acres in surface area. About 10% of the lakes were aerially surveyed; the remainder were surveyed by volunteers and MN DNR and U.S. Fish and Wildlife Service personnel. The MLMP was established because Minnesota provides habitat for over 50% of the breeding common loon population in the lower 48 contiguous states (Strong and Baker 1991), the existence of significant anthropogenic threats, and concern over the decline of the breeding range over the past century. The objective of the MLMP is to census 600 lakes annually within the six index areas in order to ensure rapid detection of declines in the number of adults and for reproductive success. Loons historically had summer ranges in southern Minnesota, northern Iowa, southern Wisconsin, Illinois, Indiana, and Connecticut (Bohlen 1989, Dins more et al. 1984, Palmer 1962, Roberts 1932). Recently loons reestablished summer residence in Massachusetts (Blodget and Lyons 1988). Anthropogenic threats, including habitat loss and degradation (Titus and VanDruff 1981, McIntyre 1988a,b), direct human activity (e.g., recreational disturbance, drowning in commercial fish nets) (McIntyre 1988a,b, Robinson 1993, Stocek 193, Titus and VanDruff 1981), and environmental contaminants, including mercury deposition, acid precipitation, and lead (Alvo et al. 1988, Barr 1986, Daulton and Meyer 1995, Ensor et al. 1992, Pokras et al. 1993, Swain and Helwig 1989) have been documented throughout the loon's breeding range. Because of historical declines and present threats, the common loon is considered threatened in Michigan, New Hampshire, and Vermont (see Hanson, Chapter 4).

Because aerial surveys were conducted on inaccessible lakes and lakes ≥ 500 acres in size, two studies were conducted in 1994 and 1995 to assess the accuracy of aerial counts in relation to ground counts. In 1994, lakes were surveyed from both the air and the ground at or near the same time. In 1995, a larger group of lakes was surveyed from both the air and ground over the same week-long survey period, but not necessarily at the same time.

These studies will help determine to what extent aerial surveys should be used in the future of the MLMP and will provide guidance on the use of aerial surveys for other loon monitoring programs. Because the MLMP utilizes volunteers for the ground surveys, it costs more to conduct aerial surveys than to conduct the ground surveys. If ground surveys are found to provide more accurate and precise estimates of loon numbers than aerial surveys, the DNR would only conduct aerial surveys on inaccessible lakes. Based on qualitative observations that the 1994 aerial surveys were highly variable on large lakes, ground surveys were also conducted on all lakes z 500 acres in. 1995 in addition to aerial counts.

The objectives of the study were divided into three co components: 1) determine whether ground surveys should be used in lieu of aerial surveys where both are feasible, 2) assess the variability of aerial/ground count differences, especially in relation to lake size, and 3) calculate adult and juvenile loon correction factors using aerial/ground count ratios.

## METHODS

Study site

Loon surveys were conducted within six index areas located in southwest Aitkin/east-central Crow Wing Counties, north-central Becker County, west Cook/east Lake Counties, central Itasca County, north Kandiyohi County, and central Otter Tail County (Fig. 1). Each index area included about 100 lakes $\geq$10 acres in surface area. The six index areas were chosen to be indicators of the major anthropogenic threats (i.e., habitat loss, recreational disturbance, lake acidification and associated mercury contamination) that may occur in different regions of Minnesota. The following criteria were used as measures of the potential threats to loons from pollutants, human activity, and habitat loss: 1) lake sensitivity to acidification, 2) human population density, 3) road density, 4) projected human population growth, and 5) land ownership. Regions with relatively low, moderate, and high levels of potential threats were identified using these criteria. Current human population density and road density were used simultaneously as indicators of current human activity levels. I assumed that recreational disturbance and development would tend to be less of a threat on public lands than on private lands, because human activity and development would be less restricted on private lands. At least two index area were located in regions with higher levels of threats and two in regions with lower levels. Suitable index area locations were identified using map overlays and geographic information system (GIS) data. The results are summarized' in Table 1. (See Hanson, Chapter 4 for complete description of site selection.)

The Aitkin/Crow Wing index area is located within the northern coniferous forest biome (Coffin and Pfannmuller 1988). Local vegetation varies from sands of conifers including red *(Pinus resinosa)* and white pine *(Pinus strobus)* to areas of mixed aspen *(Populus* sp.), white birch *(Betula papyrifera),* maples *(Acer* sp.), and basswoods *(Tilia americana).* Most lakes were formed by ice blocks left in glacial till associated with the St. Croix moraine (MN DNR 1968). Shoreline of most lakes is primarily privately owned. Both seasonal and permanent homes are common in the area, but only 10 lakes have public access.

The Becker index area overlays sections of both the no hem coniferous and eastern deciduous forest biomes (Coffin and Pfannmuller 1988). Most 1akes in the index area are located in till in the Alexandria moraine, but some are found in glacial out lash plains (MN DNR 1968) resulting in a mix of shallow to deep lakes. Many lakes surveyed in t e Becker index area are located within or near the Tamarack National Wildlife Refuge where the a is little or no shoreline development. A few of the larger lakes surrounding the refuge have moderate to high levels of development where shoreline ownership is either private, county, state, or part of the White Earth Indian Reservation (MN DNR 1991).

The Cook/Lake index area is located within the northern coniferous forest biome (Coffin and Pfannmuller 1988). Lakes were formed primarily from three processes: ice left in glacial till in the Highland moraine, glacial erosion, and glacial drift damming valleys (MN DNR 1968). Most lakes are located within the Superior National Forest an Pat Bayle Minnesota State Forest. A few lakes are located along the southern edge of the Bound Waters Canoe Area Wilderness. Shoreline on some of the larger lakes is privately owned,, but most small and medium-sized lakes have little or no development (MN DNR 1991).

The Itasca index area lies in the northern coniferous forest biome (Coffin and Pfannmuller 1988). Local vegetation consists of a mixture of conifers and hardwoods. Lakes in the Itasca index area were formed primarily by ice left in glacial till (MN DNR 1968). The majority of lakes are found within the Chippewa National Forest, but shoreline sections of many lakes are privately owned. Development varies from moderate to none. A few lakes s are bordered by county and state lands (MN DNR 1991).

The Kandiyohi area is located on the border of the tallgrass ass prairie and eastern deciduous forest biomes (Coffin and Pfannmuller 1988). Lakes tend to a shallow with shorelines supporting dense growths of aquatic vegetation. A few large areas of maple, basswood, and oak forests still exist around some lakes. Most of the index area lakes a in a terminal moraine. Two water bodies, Mongalahia and Crow River, were greatly enlarged by the damming of the Crow River (MN DNR 1968). Almost all lakes are located on private to lands. Five lakes are located in Sibley State Park (MN DNR 1991).

Lakes the in Otter Tail index area are located within they eastern deciduous forest biome. Most treeless areas are dominated by agriculture (Coffin and Pfannmuller 1988). Local vegetation includes maple *(Acer* sp.) and basswood *(Tilia america)* forests, aspens (*Populus* sp.), and oaks *(Quercus* sp.). Lakes were formed by both ice block basins ins in glacial till and in till-filled pre-glacial valleys (MN DNR 1968). All lakes are located on private lands (MN DNR 1991). Many of the shallow lakes in Becker, Kandiyohi and Otter Tail index areas have extensive tracts of emergent aquatic vegetation. Lakes in open areas in Kandiyohi and Otter Tail index area are highly influenced by agriculture activities along their borders.

**A comparison of ground and aerial surveys conducted at the same time (1994 study).**

Forty three paired aerial/ground count comparisons were made on lakes located in the Aitkin/Crow Wing (n=36), Becker (n=6), and Itasca (n=1) index are s of the MLMP. Lakes were surveyed on July 15 and 16, 1994. Thirty nine lakes were < 700 acres s in size, and four lakes were between 700 and 1300 acres.

<u>Aerial counts</u>

Aerial surveys were conducted from fixed winged aircraft with two observers, the pilot and a trained biologist. Surveys took place between 0900 and a 1000 h and involved circling lakes at an altitude of 70-170 m above ground level (agl) at 70-90 knots. Two passes were made over each lake. If loons were observed, an additional pass was made to confirm species and age identification and to check for the presence of other loons that may have been missed or dived. Three separate aerial surveys were conducted in the three index areas.

Ground counts

Concurrent with the aerial surveys, I compared trained and untrained volunteers' adult and juvenile loon counts in the Aitkin/Crow Wing index area. Most ground observers were participating in this study on the effect of training. To compare the aerial and ground counts, I used the volunteer count that was closest to the time of the aerial count for that lake. In the Becker and Itasca index areas, ground counts were conducted by U.S. Fish and Wildlife Service and MN DNR personnel.

Ground surveys were conducted from shorelines and b3 boat for a minimum of 30 minutes. Volunteers were encouraged but not required to use a bat or canoe on larger lakes. Observations from the shoreline were made from multiple vantage pints to ensure that all surface water areas were observed. Instructions for boat surveys varied on a size and shape of the lake. For small and medium-sized lakes, volunteers were to stay about 00 m from shore while systematically circling the lake. All islands were to be completely circled led. For large, round lakes, in addition to the procedures described above, observers systematical y surveyed open water regions by boating out and back to the shore every 400 to 800 m. For large , convoluted lakes, observers surveyed narrow sections and bays completely before moving on o other parts of the lake. Boat surveyors were asked to stop the boat and scan the entire water surface ace every 400 m for loons.

Statistical analysis

A one-sample t-test was used to assess whether the differences between aerial and ground loon counts differed from zero. The null hypothesis was that the difference would be equal to zero. Based on initial least square models assessing the relationship between aerial and ground counts, it appeared that the ratio of aerial counts to ground counts may change with lake size. Therefore, to assess whether lake size influenced loon counts, I used ordinary least squares to fit the model

$$\log(y_i) = \beta_0 + \beta_1 \log(x_i) + e_{i,}$$

where $y_i$ was the ratio of aerial to ground count on lake (aerial count+l/ground count+l), and $x_i$ was lake size on same lake i.

If aerial counts differed significantly from ground count based on the t-test, then a correction factor was calculated that could be used to adjust loon counts for lakes only surveyed aerially. If the slope of the least squares line was not significantly different from zero, then a simple correction factor was calculated using a ratio estimate a described by Seber (1982). The correction factor, p, equals $\Sigma Y_i / \Sigma X_{i,}$ where $Y_i$ was the aerial count on lake i, and $X_i$ was the ground count on lake i. However, if a significant slope was detected, then aerial/ground count ratios varied with lake size. The equation for the least squares line was used to calculate correction factors for each lake by size.

I made the assumption that the probability of a loon being seen from the airplane was constant. Ground counts should provide an adequate baseline from which to compare aerial counts based on two observer accuracy studies, where differences between n paired observers' adult loon counts were distributed normally with a mean of zero (see Hanson, Chapter 1).

**A comparison of ground and aerial surveys conduct d at different times (1995 study)**

In 1995, ground and aerial surveys were compared on 7 lakes selected from the 645 lakes within the six index areas. Most lakes $\geq$ 500 acres in the MLMP were surveyed from the air and ground, and inaccessible lakes < 500 acres were surveyed from a air. Paired surveys were conducted during the same one-week period. I assumed that any patterns in adult loon count differences between the two methods would be detectable. During is one-week period in mid-July, it is unlikely any major changes in adult loon movement patterns would have occurred. As the breeding season progresses, adult loons begin to congregate in larger groups consisting of nonbreeders, failed breeders, and visiting adults from active territories, and rates of movement increase (Croskery 1988, McIntyre 1988a). Juvenile loons are unable to fly until 10-12 weeks of age, and thus their numbers should remain constant over the survey period. Any differences in juvenile loon counts should be a result of counting biases and not because juvenile loons moved to a different lake. Ten, 13, 17, 6, 16, and 9 lakes were surveyed from the air and ground in the Aitkin/Crow Wing, Becker, Crow Wing, Itasca, Kandiyohi hi, and Otter Tail index areas, respectively.

Aerial surveys

Because calm wind conditions were important for aerial surveys, the aerial survey period was extended to 8 days (14-21 July 1995). Five different pilots and observers conducted the aerial surveys, but all groups followed the same instructions. The methods described in the 1994 study were used. I conducted a Kruskal-Wallis test to determine if aerial and ground count differences varied by pilot. Pilot was a five level factor, and the adult loon count difference (ground minus aerial count) was the observational unit.

Ground surveys

Ground surveys were conducted over a five-day period (14-18 July 1995) and used similar survey methods as described in the 1994 study. Surveys were to be conducted between 0600 and 1200 h. Volunteers were told to not survey under windy or heavy rain conditions. Large lakes (>500 acres) were surveyed by volunteers familiar with the lake or by MN DNR personnel.

Statistical analysis

The analysis described for the 1994 study was repeated or the 1995 results. (See "statistical analysis" in previous section).

**The effect of repeating aerial counts at different time intervals**

The effect of time between paired surveys and the influence of loon movement was qualitatively evaluated by resurveying lakes at three different time intervals. 1) 17 of the same lakes were surveyed on two successive days ("long" interval). 2) Seven lakes were resurveyed from the air between one and two hours after the initial survey ("moderate" interval). 3) Ten lakes were resurveyed immediately after the first survey ("short" interval). The four largest lakes were included in all three time intervals, and all of the lakes from the moderate and short interval were included in the long interval. A Kruskal-Wallis test was used to test if count differences varied between the three time intervals.

## RESULTS

### A comparison of ground and aerial surveys conducted at the same time (1994 study)

The total number of adult and juvenile common loons observed from the ground and air are listed in Table 2. Because of the low number of juvenile loons present, statistical tests on the effect of method and lake size were only conducted for adult loons.

Adult loons

Using a one-sample t-test, the differences between the round and aerial loon counts were significantly different from zero ($t = 2.38$, $df = 42$, $p = 0 .0218$). Only four aerial adult loon counts exceeded ground counts, all occurring on lakes larger an 400 acres, whereas 18 ground counts were greater than aerial counts. No loons were observe from the ground or the air for 4 of the 21 identical counts. Ground counts exceeded aerial counts by 13 on two lakes, 800 and 1266 acres in size. No other differences of this magnitude were observed in this part of the study. Ground minus aerial count differences ranged from -4 to 13. The mean number of adult loons counted from the ground and the air was 3.32 and 2.00, respectively

The relationship between the log of aerial/ground count ratios and log of lake size (Fig. 2) indicated a potential negative slope ($t = 1.96$, $p = 0.056$ ), but the relationship was weak as indicated by the large variance of the ratios around the regression line, $\log(y_i)) = 0.207 - 0.143 \log(x_i)$. The variance appeared to increase for larger lakes. Three data points from the largest lakes highly influenced the linear regression model. The scales of both axes are log transformed.

Juvenile loons

Based on six repeated ground surveys to each lake assessed in the Aitkin/Crow Wing index area, two juveniles were present on each of 6 of the 36 lakes surveyed. Ground and aerial observers counted 11 and 4 of the 12 juvenile loons present, respectively. One juvenile loon detected from the air was not detected by the designated ground observer or five other observers who surveyed the lake. On the 1266 acre lake mentioned previously, the aerial observers detected only 1 of 8 juveniles detected from the ground.

**A comparison of ground and aerial surveys conducted at different times (1995 study)**

Adult loons

Ground and aerial adult and juvenile loon counts are presented in Table 3. Using a one sample t-test, ground and aerial adult loon count differences were significantly different from zero ($t = 5.53$, $df = 70$, $p = 0.000$). Only five aerial counts were greater than ground counts, whereas 46 ground counts exceeded aerial counts. For 16 of the 20 identical counts, no loons were observed from the ground or the air. The count differences ranged from -10 to 21. The mean number of adult loons counted from the ground and the air was 5.39 and 2.35, respectively.

The relationship between the log of aerial/ground count ratios and log of lake size (Fig. 2) indicated a potential negative slope ($t = -1.94$, $p = 0.05$ 3), but the ratios were highly variable around the regression line, $\log(y_i) = 0.122 - 0.145 \log(x_i)$. The scales of both axes are log transformed.

Juveniles

Ground and aerial loon counts were significantly different for juvenile loons using a one-sample t-test ($t = 3.89$, $df = 70$, $p = 0.002$). For juvenile loons, tree aerial counts were greater than ground counts, and 26 ground counts were greater than aerial counts. For 39 of the 40 identical counts, no juveniles were observed using either method. Juvenile aerial and ground count differences ranged from -2 to 8. The mean number of juveniles counted from the ground and air was 0.96 and 0.32, respectively.

The least squares regression line of the log of aerial/ground ratios plotted against the log of lake size showed neither a significant slope nor intercept different from one ($\beta_0$: $t = 0.67$, $p = 0.509$, $\beta_1$: $t = -1.40$, $p = 0.166$) (Fig. 3). The correction factor, p, or juvenile loons was 0.34.

Observer effect

Adult loon count differences between aerial and ground surveys were significantly different for the Itasca index area compared to Aitkin/Crow Wing, Coo Lake, and Kandiyohi index areas using a Kruskal-Wallis test ($\chi^2=18.057$, $p=0.0012$). The same pilot conducted surveys in Becker and Otter Tail index areas, and these differences were indistinguishable from the other four index areas.

**Calculating correction factors utilizing both the 199 and 1995 results**

Because ground adult and juvenile loon counts significantly exceeded aerial counts, the loon counts from the 30 lakes that were surveyed only from the air in 1994 were adjusted to make them comparable to the 1995 ground counts. Using the least squares regression line of aerial/ground ratios plotted against lake size from the 1994 and 1995 studies, aerial counts of adult loons were corrected according to the lake size. The equations for calculating the correction factors for by lake size were

1994 study: $\log(y_i) = 0.207 - 0.143 \log(x_i)$ and
1995 study: $\log(y_i) = 0.122 - 0.145 \log(x_i)$,

where $y_i$ was the ratio of aerial to ground count on lake (aerial count+l/ground count+l), and $x_i$ was the lake size on lake i. For juvenile loons, a ratio estimate of 0.34 (aerial count/ground count) was used to make corrections. For these 30 lakes, the actual and corrected aerial loon counts from 1994 and 1995 and actual ground counts from 1995 are presented in Table 4.

**Effect of repeating aerial counts at different time intervals**

The effect of repeating aerial counts over three different time intervals indicated that the magnitude of count differences increased positively wit the amount of time between surveys ($\chi^2 = 8.50$, $p = 0.014$). The differences for the hour and day intervals were not distinct from each other. The mean ranks are presented in Table 5, and the frequency distribution of the differences between adult and juvenile loon counts for the three time intervals are presented in Fig. 5.

## DISCUSSION

### Effects of survey method and lake size

The results of the 1994 and 1995 studies clearly demonstrate that aerial surveys underestimate adult and juvenile loon numbers compared to ground surveys. These underestimates tend to increase with lake size as indicated by the negative slops of the aerial/ground count ratios plotted against lake size in the 1994 and 1995 studies (Figs. 2 d 3). Lee and Arbuckle (1988) reported a similar relationship between small and large lakes, where the mean aerial/ground count ratios were 0.48 (n=17) and 0.33 (n=36) for lakes below and above 500 acres, respectively. The slopes of the least squares line for the 1994 and 1995 studies were nearly identical, but the aerial/ground count ratios were smaller for the 1995 study (smaller intercept). This difference between the two studies may be explained by at least two factors. First, the size of lakes included in the two studies differed. In the 1994 study, 74% of the lakes were < 500 acres, whereas in the 1995 study, only 14% were this small. For large lakes in both studies, aerial/ground count ratios were smaller than ratios for small lakes, thus the 1995 study may have bee biased toward large lakes. Loon counts conducted during the same time (1994 study) probably provide a better comparison of the two methods, because factors, such as loon movement, should have less of an effect on the results. Second, the aerial and ground counts in the 1994 study ere conducted during the same morning of the same day compared to the 1995 study, where counts is were conducted during the same five day period. Thus, in the 1995 study, the effect of loons moving from lake to lake was greater, which may have contributed to smaller ratios being observed in the 1995 study.

In addition to observing that lake size may influence the accuracy of aerial loon counts, the other major finding of this study is that the aerial/ground court ratios vary widely. The least square lines for the 1994 and 1995 studies are based on weak relationships ships between aerial/ground count ratios and lake size, and the variability of these ratios appears o increase with lake size. This increased variability is likely attributable to more loons inhabiting large lakes in association with observer errors in under- and overcounting loons and loon movement. DiBello and Bissonette (1984) also reported large variance for individual lake results, but t e variance was greater on a small lake (30 acres) than a large lake (2000 acres). However, DiBello and Bissonette's sample sizes were small (n=10). DiBello and Bissonette (1984) observed that on small lakes, where fewer loons are likely to be observed, differences of 1 or 2 loons dramatically affected the ratio between the two survey methods. On large lakes, where more loons may be pre present, changes of one or two does not affect the ratio as much. This may be true, but numerous adult count differences greater than 10 were observed on the largest lakes in the 1994 and 1995 studies, contributing to the high variance in the ratios in the studies reported here.

Lake size and high variance in aerial/ground count ratios s may partially explain the wide range of aerial/ground count ratios reported in other studies (0.2 to 1.0) (DiBello and Bissonette 1984, Lee and Arbuckle 1988, McIntyre 1991, Mooty 1987, and Zimmer 1979) (Table 5). McIntyre (1991), Mooty (1987), and Zimmer (1991) did not report lake s sizes or assess the variance for calculated aerial/ground ratios. The range of estimated aerial/ground count ratios based on the least squares line of the 1994 study falls within the range of reported values. For example, calculated aerial/ground count ratios using the 1994 least squares 1 line for 100, 500, and 2000 acre lakes equaled 0.83, 0.66, and 0.54, respectively. It would be helpful to reassess these other studies to determine whether aerial/ground ratios decrease with increasing lake size. It would also be prudent to assess the variability of aerial/ground count ratios of these studies. Use of ratios without knowledge of the variability could result in placing too much credence in population estimates based on adjusted aerial counts.

The correction factors used to adjust the 1994 aerial loon counts are based on highly variable results. This variability should be considered when con paring these results to loon counts in future years.

**Other sources of variability**

In addition to lake size, the differences in aerial and ground counts may have also been influenced by methodology differences such as survey heights, pilot observer experience, and time intervals between paired surveys.

Survey intensity: altitude and speed

In 1995, five different pilot/observers conducted aerial surveys, each with varying experience in surveying loons. Despite the standard aerial survey protocol, the intensity and heights of each survey likely varied by pilot. Instructions suggested that aerial surveys be conducted between 70 and 170 m agl depending on weather conditions and pilot preferences. For all the observations made in the Aitkin/Crow Wing index area, the aerial/ground and count ratios were highest. These aerial surveys were conducted between 70 and 90 m agl with a minimum of two passes. For one of the Itasca lakes, where the aerial count grossly under underestimated loon numbers, the ground observer who was a wildlife biologist for the MN DNR noted that the plane appeared to be "very high". The low aerial/ground count ratios observed in Itasca were likely influenced by at least some aerial surveys being conducted in the upper height range.

Survey heights were lower for the two studies with air/ round count ratios above 0.78 [i.e., McIntyre (1991) 35-75 m, Zimmer (1979) 100 m]. DiBello and Bissonette (1984) allowed for the same range of survey heights that were used in these studies dies (70-170 m). From a qualitative perspective, it appears that detection levels likely decrease as survey heights increase over 100 m agl, thus altitude may be a potential cause for some of the variability in the observed aerial/ground count ratios between studies and among index areas.

Survey time and speed could also contribute to variable counts. Zimmer (1979) circled an area for three minutes when a loon was observed to check for of other loons that may have dived. This increased survey time may have contributed to Zimmer’s higher detection rates. Most pilots in the MLMP made a minimum of two passes over each lake surveyed. The speed at which the different pilots conducted surveys was not recorded.

The effects of aerial speed and altitude were not thoroughly investigated in this study, but have been studied by others (Broome 1985, Caughley 1974, Caughley et al 1976, Lanctot and Quang 1992). Lanctot and Quang (1992) recommended that flights be conducted at faster speeds to reduce the diving response of loons, but did point out t at lower speeds may be necessary to distinguish adults from juveniles. DiBello and Bissonette to (1984) and Caughley (1974) thought increased speed would reduce the time available to make observations. In consideration of altitude, Caughley (1974) found that sightability decreased at higher altitudes, but noted that at lower altitudes, observation time is decreased per unit area. Broome (1985) recommended that aerial surveys for waterbirds be conducted at altitudes o 45-50 m agl. Although surveying at higher elevations allows for a greater area to be observed, detection efficiency appears to be reduced. For large lakes, surveying at lower heights will require a more intensive search to cover the lake surface adequately.

Pilot experience

When I separated the count differences from the 1995 study by index area, four of the five differences where aerial counts exceeded ground count occurred in the Aitkin/Crow Wing index area. The pilot for this index area also conducted the surveys for 36 of the 43 lakes surveyed in 1994, where aerial/ground count ratios were highest.

Disturbance of loons

Another potential factor contributing to the higher air/g air/ground count ratios in the 1994 study was the airplane causing loons to dive, potentially leave the lake, or become wary of loud motors or large objects (e.g., airplanes, boats). It has been well documented that aerial surveys cause loons to dive (personal observation, DiBello and Bissonette 1984, Lanctot and Quang 1992). What is not known is whether the disturbance of aerial surveys would cause loons to remain wary for a short time after the survey or even cause them to leave the lake. In the 1994 study, most aerial surveys were conducted during the hour before or during the ground surveys. If loons remained wary or left the lake, ground counts could have been reduced, thus increasing the aerial/ground count ratio. One ground observer noted that an adult ton flew from the lake immediately after the plane flew overhead.

Loon movement

Loon movement, especially on large lakes, can be frequent (Croskery 1988, McIntyre 1988a). DiBello and Bissonette (1984) noted that loon movement alone could cause much year-to-year variability of loon counts on individual lakes. The effect of loon movement may have been exacerbated for surveys conducted at different times as observed in the time interval study (Fig. 5). In the 1995 study, the largest differences may have occurred because surveys were conducted on different days. For the aerial count that exceeded its paired ground count by 10, the MN DNR staff person, who was part of both surveys over two day, felt loon movement was the likely cause of the difference. Large sample sizes should help reduced the effect of loon movement and the effect of timing, but this has not been thoroughly tested. Johnson (1981) found that many studies employ a large sample approach in hoping that the effects of numerous variables "average out". Until further studies are conducted on the effects loon movement, other techniques will have to be used to reduce the sources of variability discussed in this paper.

Lighting conditions

One last factor that may highly influence aerial counts is the glare of sunlight off the water. While circling and keeping an eye on identified loons, I found that looking toward the sun or having the sun directly behind the line of sight made detection of the loons difficult or impossible. Broome (1985) and a MN DNR biologist (Jack Mooty, pers. comm.) found that cloud cover increased sightability on open water bodies.

**Biases of ground surveys**

Ground surveys may be subject to some of the same biases as aerial surveys (e.g., water and lighting conditions, diving loons, and loons leaving the lake), but to a lesser extent (Seber 1982). Ground observers can scan the lake surface for longer periods of time than aerial observers, allowing them to better detect diving or moving loons and compensate for poor viewing conditions.

## CONCLUSIONS AND RECOMMENDATIONS

The 1994 and 1995 studies indicated that aerial surveys underestimate adult and juvenile loon counts compared to ground surveys, and these underestimates  increase with lake size. Using a simple correction factor based on the mean aerial and ground counts was not appropriate for adult loons, but was for juvenile loons. For adults, a least squares  line provided a better estimate of the aerial/ground count ratio taking into account the effect of lake size. The magnitude of count differences was high, especially for large lakes, and ranged from -10 to 21. The variance of the aerial/ground ratios was also high for all lake sizes and ended to be larger for large lakes.

If aerial surveys must be used on a broad scale in the future for the MLMP, the heterogeneity of sighting probability should be further investigated and sightability model potentially could be developed. Seber (1982) and Steinhorst and Samuel ( 989) agreed that ratio estimates can be used if the sighting probability remains relatively constant. ether aerial surveys are used to provide indices of abundance or population/density estimates, the variance on these indices and estimates is likely to be high. Confirmation of any population trends based solely on aerial surveys could not likely be made until many years, if not decades, of data are collected.

Sources of visibility bias that were not explicitly examined in this study became apparent including the effects of pilot/observer experience, aerial survey height, and lighting. Optimum heights, based on this and other studies appear to be under 100 agl. For the MLMP, lower altitudes should have been specified rather than allowing a broad range of acceptable survey heights. I also recommend that aerial surveys for the MLMP be conducted when there is cloud cover, and in cases of "poor" lighting, second passes be made from a different angle.

Caughley (1974) concluded that it may not be possible o reduce bias in aerial surveys. For places where ground counts are not feasible, as many factors a possible should be standardized and search effort should be high to increase the accuracy of aerial surveys (e.g., a minimum of two passes, repeat passes over identified loons, surveys conducted between 50 and 100 m agl).

Because of logistical and budget constraints, it will be difficult to ensure that a strict aerial protocol will be followed in future MLMP surveys. Methodology will vary slightly and experience could vary greatly depending on the pilot an observer. Because ground surveys can be done for 97% of the lakes in the MLMP, aerial surveys should be restricted to inaccessible lakes. The lakes surveyed aerially can be used as an in ex of abundance for that particular set of lakes. Only surveys conducted under the same conditions should be compared directly (Caughley et al., 1976), thus it is imperative that pilots and observers use the same protocol annually. The use of replicate counts should be further investigated.

For the lakes surveyed only from the air in 1994 but no being surveyed from the ground, the correction factors calculated in this study can be used for that data with the understanding that the variability was higher than the ground count data from 1995.

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Table 1. Minnesota Loon Monitoring Program (MLMP) lake survey regions ("index areas") by selection criteria. Selection criteria include current loon density and potential anthropogenic threats and were rated low, moderate, or high in relation to other index areas. Those threats that are likely to be greatest are listed in bold. Rated threats are not applicable to all lakes and were used as guidance for selecting the index areas.

| | Index Area | | | | | |
|---|---|---|---|---|---|---|
| | Becker | Itasca | Cook / Lake | Otter Tail | Aitkin / Crow Wing | Kandiyohi |
| **Rank of Index area by potential threat level** (1 - lowest, 6 - highest) | 1 | 2 | 3 | 4 | 5 | 6 |
| **Selection Criteria** | | | | | | |
| Current Loon Density [a]: | *High* | *High* | *High* | *High* | *High* | ***Low*** |
| Acid Rain Sensitivity [b]: | *Low* | ***High*** | ***High*** | *Low* | *Low* | *Low* |
| Human Population / Road Density [c]: | *Low* | *Low* | *Low* | *Moderate* | ***High*** | ***High*** |
| Projected Human Population Growth [d]: | *Low* | *Low* | *Low* | *Low* | ***High*** | ***High*** |
| Land Ownership [e]: | *Public* | *Public* | *Public* | ***Private*** | ***Private*** | ***Private*** |

[a] Strong and Baker 1991
[b] Minnesota Pollution Control Agency, date unknown
[c] Minnesota State Planning Agency 1995
[d] Minnesota State Planning Agency 1994
[e] Land Management Information Center 1983

Table 2. Total number of adult and juvenile loons counted from paired aerial and ground surveys (n=43). Mean differences (ground minus aerial count by lake) and standard errors (s.e.) are given. Ground and aerial surveys were conducted on the same day on either 15 or 16 July 1994.

| | Ground count | Aerial count | Mean difference of ground minus aerial counts (s.e.) |
|---|---|---|---|
| Adult loons | 143 | 86 | 1.33 (0.49) |
| Juvenile loons | 25 | 12 | 0.30 (0.22) |

Table 3. Total number of adult and juvenile loons counted from paired aerial and ground surveys (n=71). Mean differences (ground minus aerial count by lake) and standard errors (s.e.) are given. Ground and aerial surveys were conducted during the same one-week period in mid-July, 1995.

| | Ground count | Aerial count | Mean difference of ground minus aerial counts (s.e.) |
|---|---|---|---|
| Adult loons | 383 | 68 | 3.04 (0.55) |
| Juvenile loons | 167 | 21 | 0.66 (0.17) |

Table 4. Corrections of aerial loon counts using aerial and ground count comparisons for 30 lakes that were only surveyed aerially in 1994. Correction factors were used on the 1995 aerial counts for compartive purposes only, because ground counts were conducted in 1995. Adult loon correction factors were based on the linear regression of aerial/ ground count ratios plotted against lake size using two different studies conducted in 1994 (n=43) and 1995 (n=71). The juvenile loon correction factor was based on a simple ratio of aerial/ground counts from the 1995 study (n=71) because no significant relationship was observed with lake size.

| | Adult loons | | Juvenile loons | |
|---|---|---|---|---|
| | 1994 | 1995 | 1994 | 1995 |
| Aerial counts | | | | |
| Uncorrected aerial counts | 80 | 72 | 22 | 6 |
| Corrected aerial counts using 1994 study results | 160 | 148 | - | - |
| Corrected aerial counts using 1995 study results | 202 | 188 | 64 | 17 |
| Ground counts | - | 185 | - | 20 |

Table 5. Kruskal-Wallis test comparing adult loon count differences of paired aerial surveys conducted over three time intervals. The time intervals between paired counts were 1) 5-10 minutes ("short")(n=10), one hour ("moderate")(n=7), and one day ("long")(n=17).

| Time interval between counts | Mean rank |
|---|---|
| 5-10 minutes | 10.3 |
| 1 hour | 22.6 |
| 1 day | 19.3 |

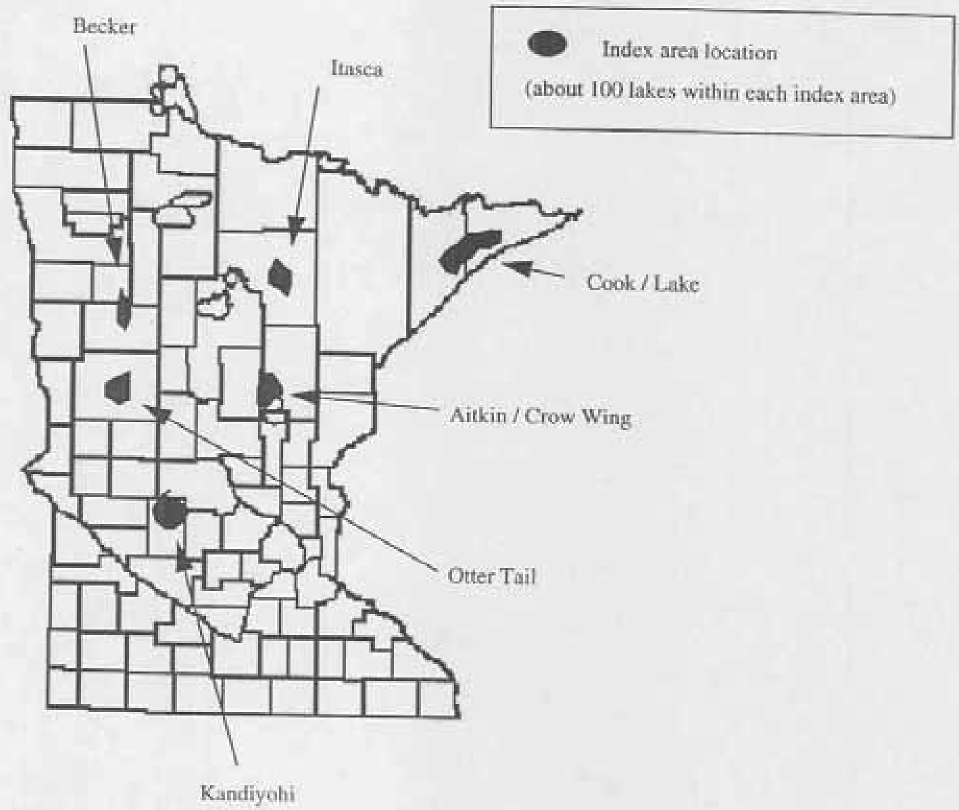


**Figure 1. Location of six survey regions ("index areas")**

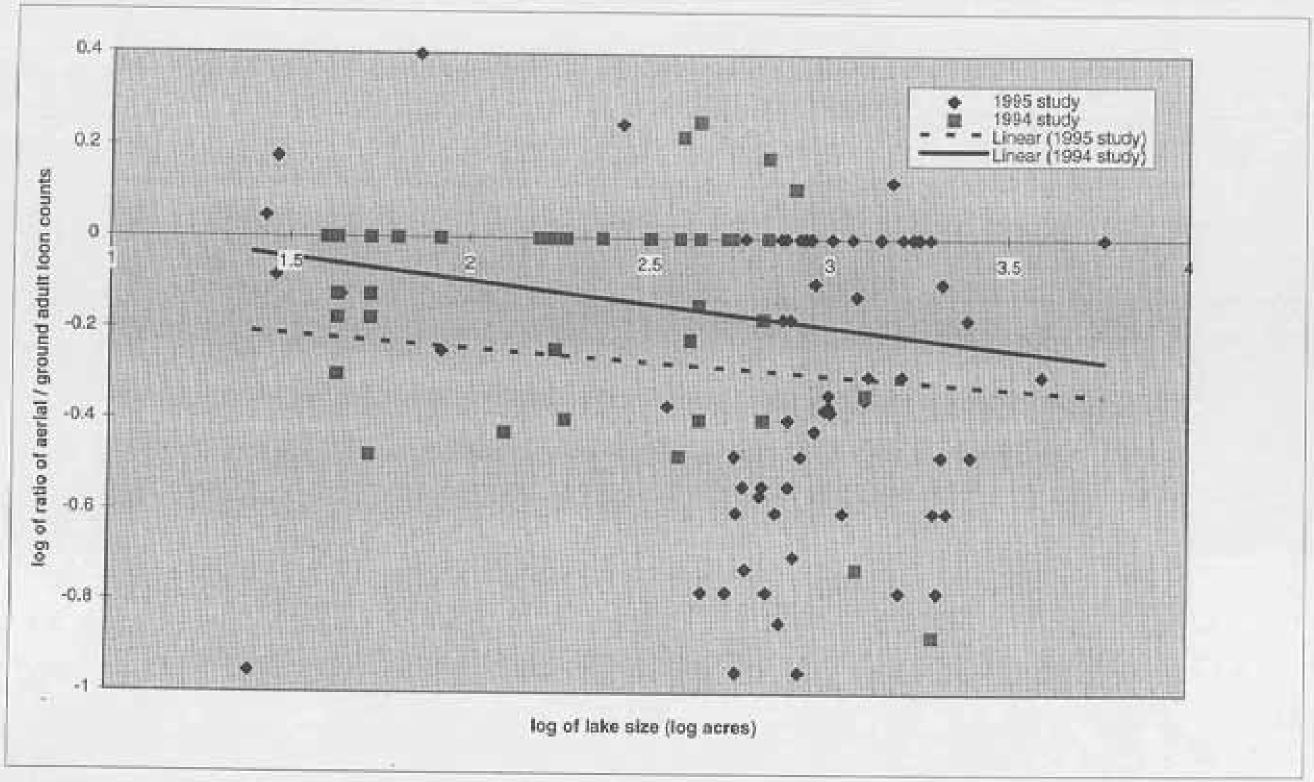


Figure 2. Aerial/ground adult loon count ratios for individual lakes as a function of log of lake size for two separate studies conducted in 1994 and 1995. For the 1994 study, loon counts were conducted on the same day (n=43). For the 1995 study, loon counts were conducted during the same week-long period (n=71). Aerial/ground count ratios were calculated from the log ((aerial count +1) / (ground count +1)).

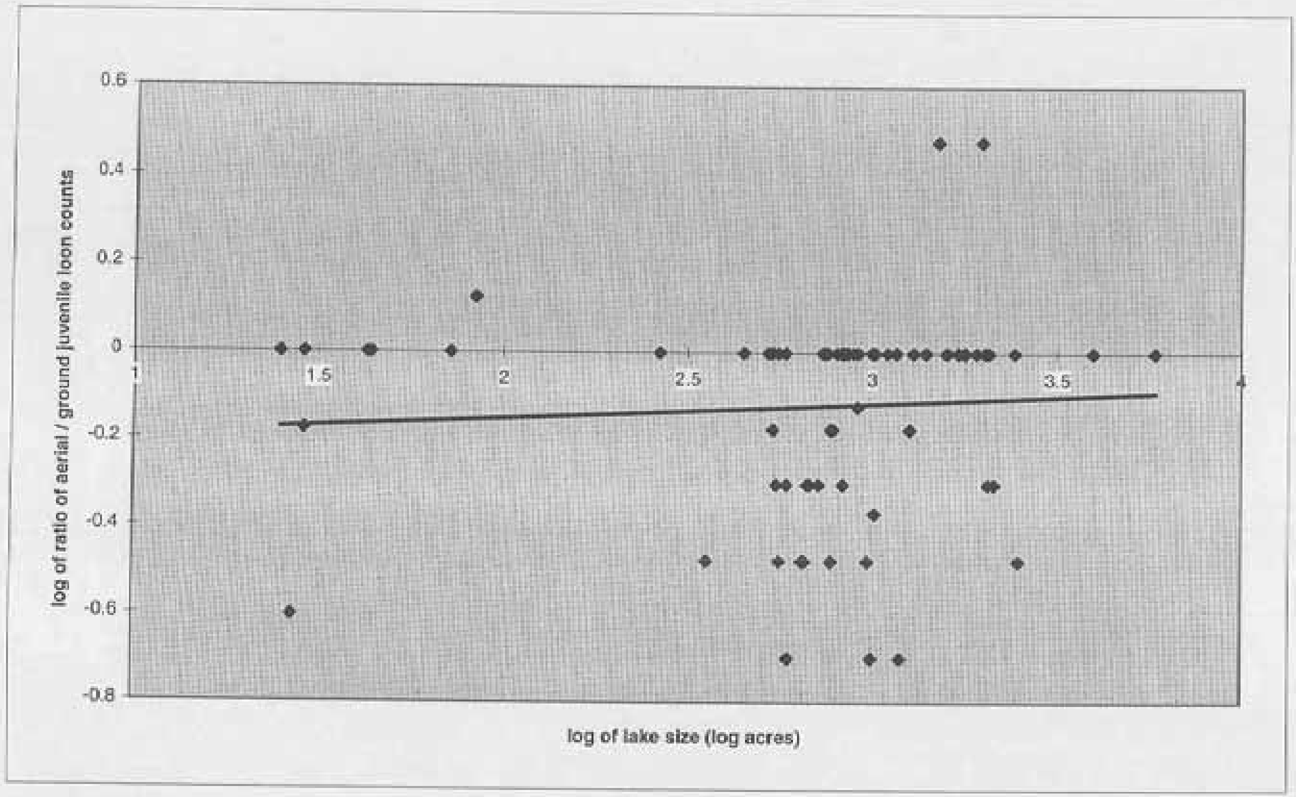


Figure 3. Aerial/ground juvenile loon count ratios for individual lakes as a function of log of lake size for the 1995 study (n=71) Loon counts were conducted during the same week-long period. Aerial/ground count ratios were calculated from the log ((aerial count +1) / (ground count +1)).

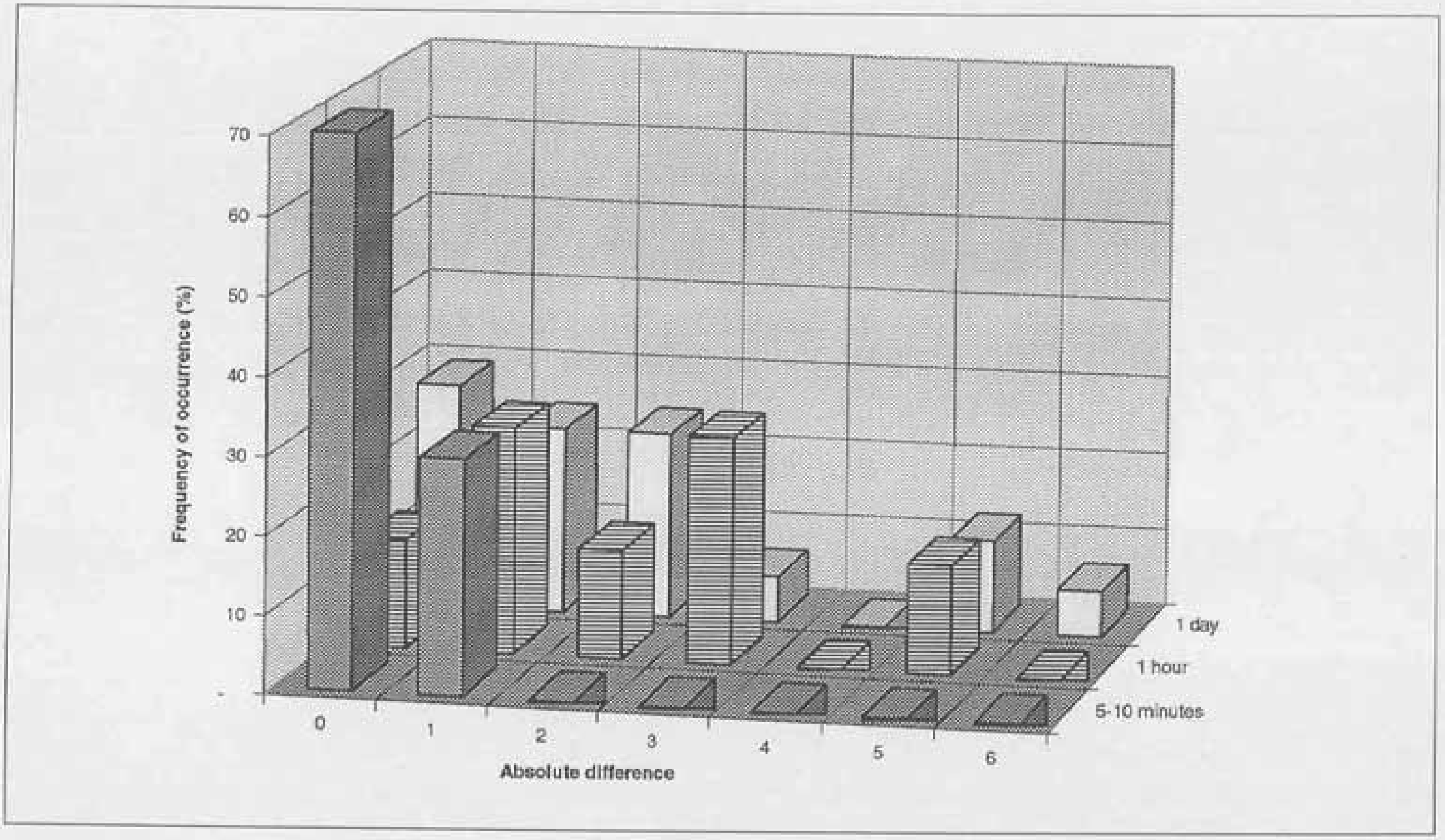


Figure 4. Frequency distribution of the absolute difference of adult loon counts between paired aerial surveys over three time intervals. The time intervals between paired counts were 1) 5-10 minutes (n=10), 2) one hour (n=7), and 3) one day (n=17).

**Chapter 4: Assessment of the first two years of mo monitoring the common loon in six distinct regions of Minnesota**

**INTRODUCTION**

The common loon (*Gavia immer*) faces many anthropogenic threats, including habitat loss and degradation (Titus and VanDruff 1981, McIntyre 1988 ,b), direct human activity (e.g., recreational disturbance, drowning in commercial fish nets) (McIntyre 1988a, b, Robinson 1993, Stocek 1993, Titus and VanDruff 1981), and environmental contaminants (e.g., mercury deposition, acid precipitation, and lead) (Alvo et al. 1988, Barr 1986, Meyer and Daulton 1995, Ensor et al. 1992, Pokras et al. 1993, Swain and Helwi 1989). Loons historically had summer ranges in southern Minnesota, northern Iowa, southern Wisconsin, Illinois, and Indiana (Bohlen 1989, Dinsmore et al. 1984, Palmer 1962, Roberts 193 ). Recently loons reestablished summer residence in Massachusetts (Blodget and Lyons 1988). Because of historical declines and current threats, the common loon currently is considered threat threatened in Michigan, New Hampshire, and Vermont. Numerous monitoring programs and research efforts (e.g., toxicity studies) throughout North America have been established to address these concerns. The Minnesota Department of Natural Resources (MN DNR) conducted a scientifically valid survey of Minnesota's adult common loon population in 1989 utilizing over 700 volunteers The statewide survey documented that Minnesota contains breeding habitat for more than 0% of the adult loons in the contiguous U.S. (Strong and Baker 1991). In 1994, the MN DNR initiated the development of a program that could detect changes in the adult loon population and reproductive success more rapidly than would a statewide population estimate.

In developing this monitoring program, I assessed the information that could be obtained from two different monitoring approaches: single surveys and repeated surveys throughout the breeding season. Single surveys can provide population estimate of the survey region. In states with several thousand lakes (i.e., Maine, Michigan, Minnesota , Wisconsin), a single survey is only feasible on a small sample of lakes. These samples usually result in large variances and require many years of effort before declines can be confidently detected (Eberhardt 1978, Gerrodette 1987, Peterman 1990). Single surveys of individual lakes or small regions may provide more accurate population estimates, but the results are only applicable to the specified survey region. For small states, this approach works well. For example, in New Hampshire, state population estimates are based on a single survey of all lakes in the state (J. Fair, pers. comm.). Repeated surveys throughout the breeding season provide territory, nesting, and fledging data that are difficult to obtain from single surveys, and are usually conducted on lakes where volunteers live. For all of these survey designs, variance can be minimized using standardized methods, conducting field tests to determine the accuracy of survey methods, using phenologically comparable dates, dispersing census locations over entire areas of concern, checking for consistency among observers, sampling all relevant habitats, and utilizing multiple observers within each survey region (Jarvinen and Vaisanen 19781.

To survey enough lakes to adequately monitor loon activity on Minnesota's approximate 12,000 lakes ($\geq$ 10 acres), a single annual survey is the only economical approach. The MN DNR still desired a monitoring program that would provide insight into the causes of population and productivity declines, should either be detected. The initial idea for monitoring loons in Minnesota was to conduct a statewide random survey of lakes every five years (R. Baker, pers. comm.). In 1989, the resulting population estimate of 11,626 ± 1,271 adult loons had a relatively low variance compared to most animal surveys of this magnitude (Strong and Baker 1991). The nature of the survey, however, would not provide much information about potential causes of population changes. Also, based on the confidence interval of this population estimate, a minimum decline of about 25% would have to occur in the subsequent survey before any significant change would be detectable. Furthermore, the time, effort, and funds necessary to recruit hundreds of volunteers every five years was a major concern. With this in mind, the MN DNR and I developed the MLMP in 1994 utilizing volunteers to census over 600 lakes within six regions of the state ("index areas") annually. The prim objectives of the MLMP included:

1) Providing the ability to detect changes in population size for target population within a five year time period.
2) Providing the ability to detect long-term change in productivity for target population.
3) Providing insight into the causes of population d productivity declines, should either be detected.
4) Generating credible long-term data on Minnesota's loon population.
5) Creating a well-documented and easily-implemented monitoring protocol.
6) Instilling commitment and sense of stewardship among volunteers.

Annual censuses of loon populations in the Minnesota index areas will provide data on differences in loon numbers and densities among index areas and among lakes with different physical and biological characteristics and changes in numbers of successful and potential territories. Detection of any population or productivity changes would be followed owed by steps to determine the mechanisms behind the changes. If changes occur differentially among index areas or lakes, the potential threats associated with the affected index areas) should provide guidance for future research.

## METHODS

### Study Site

Loon surveys were conducted within six index areas located in southwest Aitkin/east-central Crow Wing Counties, north-central Becker County, west Cook/east Lake Counties, central Itasca County, north Kandiyohi County, and central Otter Tail County (Fig. 1). Each index area included about 100 lakes z 10 acres in surface area. Only regions of the state with relatively high lake densities were considered. Except for two lakes, only 1akes less than 3000 acres in surface area were included. Extremely large lakes were avoided because use of the logistical difficulty of surveying large open areas and the negative influence of even the slightest winds on sighting ability. Lakes < 50 acres in size were most numerous ( 1.3%), and lakes ≥ 500 acres were least numerous (10.7%). Seventy percent of Minnesota's lakes are between 10 and 100 acres, which corresponds well with the distribution of lake sizes in the MLMP (MN Pollution Control Agency 1992). The geographic characteristics of each index area are summarized in Table 1. All but the Kandiyohi index area were located in counties where adult loons occupied > 50% of the lakes (Strong and Baker 1989).

The six index areas were chosen to be indicators of the major anthropogenic threats (i.e., habitat loss, recreational activity, lake acidification and associated mercury contamination) that may occur in different regions of Minnesota. When spatial pattern are of concern, such as these regional threats, systematic sampling may be preferable to random sampling (Eberhardt 1978). The following criteria were used as measures of the potential threats to loons from pollutants, human activity, and habitat loss: 1) lake sensitivity to acidification, 2) human population density, 3) road density, 4) projected human population growth, and 5) and ownership. Regions with relatively low, moderate, and high levels of potential threats were identified using these criteria. Current human population density and road density were used s simultaneously as indicators of current human activity levels. I assumed that recreational activity and shoreline development would tend to be less of a threat on public lands than on private lands, because human activity and development would be less restricted on private lands. At least two index area were located in regions with higher levels of threats and two in regions with lower levels. Suitable index area locations were identified using map overlays and geographic information system (GIS) data. The results are summarized in Table 2.

Most lakes in the MLMP are located in the northern cot coniferous and eastern deciduous biomes with a few lakes in the prairie region (Coffin and Pfannmuller 1988). Ninety-six percent of Minnesota's 11,842 lakes are found in coniferous and deciduous regions (MN Pollution Control Agency 1992), thus the index areas are representative of most lakes in Minnesota, although geological and other unidentified factors may vary locally. Lakes in the coniferous biome are estimated to be about 24% oligotrophic, 48% mesotrophic, 25% eutrophic, and 3% hyper-eutrophic. Six percent of the lakes are impaired (i.e., exhibit excessive eutrophicatio) based on Carlson's Trophic State Index (TSI), summer Secchi transparency, and epilimnetic co concentrations of chlorophyll-a and total phosphorous. The lakes within the eastern deciduous region are estimated to be 5% oligotrophic, 22% mesotrophic, 43% eutrophic, and 28% hyper-eutrophic, of which 44% are impaired (MN Pollution Control Agency 1992).

The Aitkin/Crow Wing index area is located within the northern coniferous forest biome (Coffin and Pfannmuller 1988). Local vegetation varies from stands of conifers including red (*Pinus resinosa)* and white pine *(Pinus strobus)* to areas of mi mixed aspen (*Populus* sp.), white birch *(Betula papyrifera),* maples *(Acer* sp.), and basswoods ( *Tilia americana).* Most lakes were formed by ice blocks left in glacial till associated with the St. Croix moraine (MN DNR 1968). Shoreline of most lakes is primarily privately owned. Both seasonal and permanent homes are common in the area, but only 10 lakes have public access.

The Becker index area overlays sections of both the northern coniferous and eastern deciduous forest biomes (Coffin and Pfannmuller 1988). Most 1akes in the index area are located in till in the Alexandria moraine, but some are found in glacial outwash plains (MN DNR 1968) resulting in a mix of shallow to deep lakes. Many lakes surveyed in a Becker index area are located within or near the Tamarack National Wildlife Refuge where there is little or no shoreline development. A few of the larger lakes surrounding the refuge have moderate to high levels of development where shoreline ownership is either private, county, state, or p of the White Earth Indian Reservation (MN DNR 1991).

The Cook/Lake index area is located within the northern coniferous forest biome (Coffin and Pfannmuller 1988). Lakes were formed primarily from three processes: ice left in glacial till in the Highland moraine, glacial erosion, and glacial drift damming valleys (MN DNR 1968). Most lakes are located within the Superior National Forest an Pat Bayle Minnesota State Forest. A few lakes are located along the southern edge of the Bound Waters Canoe Area Wilderness. Shoreline on some of the larger lakes is privately owned, but most small and medium-sized lakes have little or no development (MN DNR 1991).

The Itasca index area lies in the northern coniferous for forest biome (Coffin and Pfannmuller 1988). Local vegetation consists of a mixture of conifers and hardwoods. Lakes in the Itasca index area were formed primarily by ice left in glacial till (MN DNR 1968). The majority of lakes are found within the Chippewa National Forest, but shoreline sections of many lakes are privately owned. Development varies from moderate to none. A few lakes are bordered by county and state lands (MN DNR 1991).

The Kandiyohi area is located on the border of the tallgrass prairie and eastern deciduous forest biomes (Coffin and Pfannmuller 1988). Lakes tend to be shallow with shorelines supporting dense growths of aquatic vegetation. A few large areas f maple, basswood, and oak forests still exist around some lakes. Most of the index area lakes a in a terminal moraine. Two water bodies, Monongalia and Crow River, were greatly enlarged by the damming of the Crow River (MN DNR 1968). Almost all lakes are located on private a lands. Five lakes are located in Sibley State Park (MN DNR 1991).

Lakes the in Otter Tail index area are located within the eastern deciduous forest biome. Most treeless areas are dominated by agriculture (Coffin an Pfannmuller 1988). Local vegetation includes maple *(Acer* sp.) and basswood *(Tilia americana)* forests, aspens (*Populus* sp.), and oaks *(Quercus* sp.). Lakes were formed by both ice block b sins in glacial till and in till-filled preglacial valleys (MN DNR 1968). All lakes are located on private lands (MN DNR 1991).

Many of the shallow lakes in Becker, Kandiyohi, and Otter Tail index areas have extensive tracts of emergent aquatic vegetation. Lakes in open areas in Kandiyohi and Otter Tail index area are highly influenced by agriculture activities along their borders.

In addition to surveys within the six index areas, the Sportsmen's Club of Lake Vermillion has been conducting loon surveys for the past decade. Lake Vermillion supports hundreds of loons, and thus serves as a seventh index area for northeastern Minnesota. The annual surveys are well-organized, and the methodology is comparable to the MLMP (B. Shook and M. Jackson pers. comm.).

<u>Study design</u>

Surveys were conducted from 15-19 July 1994 and 14- 8 July 1995. The survey dates were selected to best assess the adult common loon population , territorial occupancy, and reproductive success from a single annual survey. Although Strong (1990) suggested that several long visits to each lake throughout the breeding season would be ideal to adequately monitor adult loon populations, this level of effort is not possible for financial and logistical reasons in the Minnesota survey. Volunteers for 600 selected lakes can only be relied upon for a single visit. Factors considered in selecting the survey dates included juvenile mortality and seasonal movement. Most juvenile mortality occurs during the first two weeks post -hatching (McIntyre 1988a). In mid-July in Minnesota, most juvenile loons should be between two and four weeks of age, and therefore very likely to fledge (McIntyre 1988a). Alvo et al. (198 ) and Dulin (1988) reported that a second period of increased juvenile mortality may occur in highly acidic lakes at four to five weeks of age, possibly caused by food shortages. Thus, Belant et al. ( 993) and Strong (1990) recommended that surveys be conducted when juveniles are greater than six to seven weeks of age (early August in Minnesota). However, I decided to conduct the surveys in July rather than early August to avoid the increasing movement of adult loons away from their territorial lakes, which occurs as the breeding season progresses (Croskery 1988, McIntyre 988a,

D. Evers pers. comm.). Additionally, adults spend more time away from the juveniles as the young grow older (McIntyre 1988a), making detection more difficult. Family groups are more conspicuous soon after hatching than later in the breeding season (Daulton 1993).

Although many single annual surveys are conducted one designated day to reduce the effect of loon movement, poor weather conditions and missed surveys may confound results among years. For example, in the early 1990's in Maine where a single day was used for conducting surveys, foggy conditions likely reduced the number of loons observed, making that year's data difficult to compare to other years (S. Stockwell, pers. comm.). For the MLMP, volunteers were allowed to choose from among multiple days to complete their surveys to ensure that all lakes were surveyed under ideal weather conditions. Conducting surveys over multiple days instead of on a single day should prevent poor sighting conditions from biasing the results, thus making surveys more comparable among years.

*Ground surveys:*

Measurement error was minimized by having volunteer follow a standard survey protocol. All surveys were conducted between 0500 and 1200 h. Ground surveys were conducted from shorelines and by boat for a minimum of 30 minutes. Volunteers were encouraged but not required to use a boat or canoe on larger lakes. Koskimies and Poysa (1989) reported that point counts of waterbirds from numerous locations along the lakeshore gave nearly identical results as counts from a boat. Observations from the shoreline were made from multiple vantage points to ensure that all surface water areas were observed. Instructions for boat surveys varied according to the size and shape of the lake. For small and medium-sized lakes, volunteers were to stay about 100 meters from shore while systematically circling the lake. All islands were to be completely circled. Strong (1985) found that common loons, especially those with young, tend to stay within 200-300 meters of the shoreline. For large, round lakes in addition to the procedures described above, observers systematically surveyed open water re ions by boating out and back to the shore every 400 to 800 meters. For large, convoluted lakes, observers surveyed narrow sections and bays completely before moving on to other parts of the lake. Boat surveyors were asked to stop the boat and scan the entire water surface every 400 meters or loons. Volunteers recorded the location and number of adult and juvenile common loons observed, the beginning and end time of observation, observation method (e.g., by boat/canoe r from shore), equipment used (e.g., binoculars, spotting scope), weather and surface water conditions, level of confidence in completing an accurate survey, and a qualitative assessment of the percent of disturbed/developed shoreline (See App. 1). Volunteers estimated the percent of disturbed/developed shoreline using six categories: 1) 0% and no road access to lake, 2) 0% and single road leading to lake, 3) 0-25%, 4) >25-50%, 5) >50-75%, and 6) >75-100%. Categories 1 and 2 were used to differentiate lakes with and without potential public access. Volunteers were instructed to evaluate disturbed/developed shoreline based on the extent of disturbed natural vegetation (e.g., pastures, lawns, rip rap) and the presence of docks, cabins/houses, resorts, campgrounds, roads, and boat landings.

*Aerial surveys:*

Lakes < 500 acres and ≥ 500 acres were surveyed from the ground and air, respectively, in 1994. In 1995, most lakes ≥ 500 acres were surveyed from the air and ground. In both years, inaccessible lakes < 500 acres were surveyed from the air. Aerial surveys were conducted from fixed winged aircraft with two observers, the pilot and MN DNR biologist or myself. These surveys involved circling the lake at 70 to 170 meters above ground level (agl) at 70 to 90 knots. Two passes were made over each lake. If loons were observed, an additional pass was made to confirm species and age identification and to check whether for the presence of other loons that were missed or had dove. Aerial surveys were conducted only under calm wind conditions. (See Hanson, Chapter 3 for a comparison of ground and aeria1 loon counts.)

*Recruitment and training:*

In 1994, volunteers were recruited from previous loon survey volunteers (from the 1989 statewide random survey and the Minnesota Loon Survey), members of the Minnesota Ornithological Union, numerous Audubon chapters, the Sierra Club, and MN NR, U.S. Fish and Wildlife, and U.S. Forest Service employees. In addition to targeting specific audiences, general press releases were used and numerous radio interviews were conducted regionally and statewide. In 1995, returning volunteers were encouraged to recruit friends and relatives. Many lake residents were recruited after learning about the MLMP from 1994 volunteers. Press releases were again sent out and flyers were distributed to public agencies near the survey locations. Returning 1994 volunteers were asked to survey additional lakes.

Volunteers received written instructions that covered a following topics: finding a back-up observer, checking lakes before the survey, obtaining access to the lake, when to survey, weather conditions under which to survey, minimum length of survey, what to count, loon movement and other potential problem areas, and pictures and descriptions of potentially confusing avifauna (See App. I). In June, 1994 eight 90-minute training sessions were held throughout the state in conjunction with the MLMP. All volunteers in the MLMP were strongly encouraged to attend. The training program covered many of the same topics as in the written instructions but in more depth and with visual and verbal explanations (See App. II). The more critical training material covered bird and age class identification, photos of loons at various distances, how to pick out a loon while scanning from a distance, how to keep track of loons already observed, methods for surveying different sized and shaped lakes, and appropriate observation rates. The training also explained the design and purpose of MLMP, giving volunteers a better understanding of the program. Training programs were not offered in 1995 because no difference in loon counts was detected between trained and untrained volunteers in 1994 (see Hanson, Chapter 1). For an assessment of the use of volunteers and the effectiveness of the instructions, see Appendix III.

**Analyses**

The analyses were divided into three sections:

1) adult and juvenile loon numbers and densities, breeding activity, and consistent and intermittent lake use,
2) effects of disturbed/developed shoreline and human population density on adult and juvenile loon presence, and
3) changes in adult and juvenile loon abundance dance from 1994 to 1995.

<u>Adult and juvenile loon densities, breeding activity. consistent and intermittent lake use, and fledging success</u>

*Loon numbers, density, and breeding activity:*

I analyzed the 1994 and 1995 adult and juvenile loons counts for all lakes and by index area for the number of individuals present, three density measures, and number of known and potential territories. Adult loon density measures were the percent of lakes with loons present (i.e., lake occupancy rate), the number of loons per lake, and the number of loons per 100 acres of surface water area. All density calculations were conducted for each of four lake size classes (10-49, 50149, 150-499, a 500 acres), which were the same lake size classes used in previous loon surveys in Minnesota and Wisconsin (Strong and Baker 1991, D Daulton 1993). The number of territories was determined by counting each location where juveniles were present. Because some juvenile mortality likely occurs between two and six weeks of a e (mid-July to mid-August in Minnesota), I assessed the extent of juvenile mortality and fledging rates by conducting second surveys in mid to late August. These results are presented in Appendix IV.

*Consistent and intermittent lake use:*

I determined which lakes in each index area and lake size class were occupied by adults and juveniles in both years (consistent lake use) and in either year (intermittent lake use). A relative measure of loon habitat quality among index areas and lake size classes was determined by comparing the percentage of lakes used consistently by adults and juveniles to the percentage of lakes used intermittently.

*Identifying potential territories:*

The consistent presence of adult loons on a lake without Juveniles may indicate the presence of an established territory. To determine whether the consistent presence of adult loons could be used as an indicator of potential territories, lakes were identified that had breeding activity in one year only but had two or more adults in the other year. If the percent of lakes with two or more adults was high in the other year when no breeding was detected, then the observation of two adults in both years may indicate an occupied territory. Thus, lakes that had two or more adults and no juveniles observed on them in both 1994 and 1995 may have potential loon territories. The presence of two adults was used instead of only one to obtain a conservative estimate.

<u>Effects of disturbed/developed shoreline and human population density on adult and juvenile loon presence</u>

I assessed the percent of disturbed and/or developed shoreline and human population density estimates by township in relation to both adult and juvenile loon presence and absence. I employed these two characteristics as indicators of potential habitat loss and direct disturbance from recreational activity. The presence of juveniles indicated that the lake was suitable for breeding. The estimated human population was obtained for each township (MN State Planning Agency 1995) and the population density of the township was calculated. Each lake within a township was assigned the same human population density estimate. Presence and absence of adult loons or breeding activity in either year was indicated with a one and zero, respectively. I used logistic regression to analyze the predictive power of disturbed/developed shoreline and human population density on the presence of adult loons and breeding activity. I also analyzed the results separately for four lake size classes: small 10-49 acres (n=259), medium 50149 acres (n=203), large 150-499 acres (n=137), and very large z 500 acres (n=77).

<u>Changes in adult and juvenile loon abundance from 194 to 1995</u>

Adult and juvenile loon counts from 1994 and 1995 vi ere compared on lakes surveyed in both years using the same methods (e.g., aerial counts compared to aerial counts and ground counts compared to ground counts).

## RESULTS

### Adult and juvenile loon numbers and densities, breeding activity, and consistent and intermittent lake use

<u>Adult loons</u>

In both 1994 and 1995, 486 lakes were surveyed. Loon counts for individual lakes are given in Appendix V. A summary of the results for all lakes surveyed in 1994 (n=511) and 1995 (n=630) are presented in Appendix VI.

*Differences among index areas:*

Itasca, Becker, and Aitkin/Crow Wing had the highest number of adult loons and densities, and Kandiyohi had the lowest values (Table 3). Although) adult lake occupancy rates were similar for

Itasca, Becker, and Aitkin/Crow Wing, the number of adults per 100 acres in Itasca and Aitkin/Crow Wing was two to four times higher than in Becker.

Assessing consistent vs. intermittent lake use, adults were present on 71.3% of all lakes in either 1994 or 1995 (Table 4). The percent of lake occupied in either year by adults ranged from 42.0% for Kandiyohi to 89.7% for Becker. Of the 345 lakes tat had adults present in either 1994 or 1995, 65.4% had loons present in both years (Table 4)f The values ranged from 47.1 % in Kandiyohi (the most intermittent lake use) to 90.8% in Itasca (the most consistent lake use).

*Effect of lake size:*

Adult loon numbers and density by lake size class for 1994 and 1995 are summarized in Table 5. For a summary of adult loon numbers and density by index area for each size class, see Appendix VII. Adult lake occupancy was lowest in the 10-49 aces lake size class. However, these small lakes provided a substantial source of habitat (20% of the adults observed), and 46% of the lakes < 25 acres had adults present. Lake $\geq$ 500 acres had the lowest adults per 100 acres. Adult lake occupancy in either year ranged from 59.7% for lakes < 50 acres to 87.1 % for lakes between 150 and 499 acres (Table 6).

**Juveniles**

*Differences among index areas:*

Itasca and Becker had the highest juvenile loon numbers and lake occupancy rates and Cook/Lake and Kandiyohi the lowest (Table 3). For Aitkin/Crow Wing, juvenile numbers and lake occupancy were considerably lower than Itasca and Becker, although adult results were similar for these three index areas. In Kandiyohi, the majority of juvenile loons were observed on two large lakes that are part of the Crow River flowage.

Thirty-five percent of all lakes had juveniles present in either 1994 or 1995, and 11.7% of the lakes had juveniles in both years (Table 7). Thus, only 33.3% of lakes with known breeding activity had successful loon territories in both years. Otter Tail and Cook/Lake had the fewest lakes with breeding activity in both years and Becker lad the most.

*Effect of lake size:*

For lakes < 50 acres, 42 out of 201 lakes (20.9%) supported breeding activity in either 1994 or 1995 (Table 8). Over 50% of the lakes $\geq$150 acres supported breeding activity in either 1994 or 1995. The smallest lakes with juveniles were 14 acres in Itasca and Otter Tail, and the smallest lake with two territories was 114 acres in Cook/Lake. A 323- acre lake in Itasca had four successful territories in 1994, and the lake with the most territories in one year was in Kandiyohi with seven.

Identifying potential territories

For lakes that had juveniles present in only one of the two years, 68% of these lakes had two or more adult loons present in the year when no breeding activity was observed. Fifty-two lakes had $\geq$ 2 adults observed on them in 1994 and 1995 but lacked breeding activity (Table 9).

**Effects of disturbed/developed shoreline and human population density on adult and juvenile loon presence**

Adult and juvenile loons were present on 466 and 216 lakes out of 676 lakes, respectively, in either 1994 and/or 1995. Lake names, lake size, adult lake occupancy rate, presence of breeding, shoreline development factor, and township human population density estimates are listed in Appendix V.

The average disturbed/developed shoreline factors by index area increased positively with human population density (Table 10). The mean values among index areas had a range of 1.6. Disturbed/developed shoreline factors were similar among index areas for lakes < 50 acres and exhibited much more variation for lakes $\geq$ 150 acres (able 11).

Adult loon presence

Lake surface area and shoreline disturbance/development increased positively and significantly with adult loon presence (Table 12A). Human population density by township was inversely related to adult presence and was also significant.

Although a association of adult presence and shoreline disturbance/development was significant for all lakes, by lake size class, it was only significant for the smallest lake size class (< 50 acres) (Table 13 ). Human density was negatively associated and significant only for lakes $\geq$ 150 acres.

Breeding activity (juvenile loon presence)

For all lakes, lake surface area and shoreline disturbance/development increased significantly with breeding activity (Table 12B). The relationship between township human population density and juvenile to n presence was not significant for all lakes, but was negatively associated and significant or lakes $\geq$ 500 acres (Table 13B). By lake size class, shoreline development was significant only for small lakes. No significant trends were observed for any of the variables for adults or breeding loons on lakes in the 50-149 acre size class.

**Changes in adult and juvenile loon abundance from 1994 to 1995**

Adult loon

Volunteers counted 809 adult loons in 1994 and 875 in 1995, but the percent of lakes with adult loons present was about the same for both years, 58.8 % in 1994 and 58.6 % in 1995 (Figs. 2A and 2B). The increase of 66 adults was largely attributable to 52 additional loons being observed on only five lakes (i.e., increases of 13, 11, 10, 9 and 9) in Itasca and Aitkin/Crow Wing index areas. The largest decrease on any individual lake from 1994 to 1995 was 7. The number of adults per lake an per 100 acres reflected the increase in loon numbers (Figs. 2C and 2D). Lake occupancy rate changes, however, tended to be more independent of loon numbers.

By index -ea, comparisons between 1994 and 1995 results indicated that the number of loons increased in Itasca, Aitkin/Crow Wing, and Otter Tail index areas and decreased in Kandiyohi (Figs. 2A-D). These trends were also observed in the number of adults per lake and per 100 acres surface water. As noted earlier, the increase in the number of adults in Itasca and Aitkin/Crow Wing was attributable to large congregations of adults on a few lakes. Aitkin/Crow Wing and Cook/Lake experienced the greatest changes in lake occupancy with a decline of 7% and increase of 9%, respectively. Results by lake size class are presented in Figure 3.

Juvenile loons

Almost exactly the same number of juvenile loons were counted in 1994 (190) and 1995 (193), however, t e percent of lakes with juveniles present increased from 21.2% (103 lakes) in 1994 to 24.1% (11 lakes) in 1995 (Figs. 4A and 4B). Productivity on large lakes with multiple territories declined in 1995 (i.e., fewer juveniles present), although there was an increase in the juvenile lake occupancy rate.

Despite the overall number of juveniles being similar in 1994 and 1995, the results were more variable for each index area (Fig. 4A). The number of juveniles counted in Cook/Lake index area doubled from 11 to 23. Itasca and Kandiyohi had decreases of 12 and 6 juveniles, respectively. The other tree index areas exhibited changes in loon number of less than four. Small increases in juvenile lake occupancy were observed in Becker and Otter Tail. In Itasca, although the number of juveniles detected decreased substantially, the percentage of lakes with juveniles present stayed the same. By like size class, the biggest increase in juvenile numbers, territories, and occupancy rates occurred on lakes between 50 and 499 acres (Figs. 5A and 5B).

Lake Vermillion results

The numbed of adult and juvenile loons counted on Lake Vermillion from 1983 to 1995 is presented in Appendix IX (Sportsman's Club of Lake Vermillion 1994, M. Jackson pers. comm.). Counts were similar from 1983 to 1992, but in 1993 the number of adults observed almost doubled. In 1994 and 1995 numbers fell, but were substantially higher than the decade before. The Lake Vermillion results were not included in the analysis of loon counts from the six index areas.

## DISCUSSION

### Adult and juvenile loon numbers and densities, breeding ding activity, and intermittent and consistent lake use

Differences among the six index areas

Based on adult loon numbers and densities within the six index areas, Itasca, Becker, and

Aitkin/Crow Wing provided the best habitat for adults and Kandiyohi the poorest (Table 3). Juvenile loon numbers and lake occupancy densities reflected the adult loon results except in Aitkin/Crow Wing, which had low breeding success relative to the high number of adults observed (Table 3). Itasca and Aitkin/Crow Wing tend to have deep, clear lakes which are associated with optimum loon habitat (McIntyre 1988a, Strong 1985, Blair 1989, Zimmer 1979). Although many lakes in Becker are shallower, the lakes are productive. The low adult loon numbers and densities in Cook/Lake are the only results from 1994 and 1995 that differed substantially from the loon densities observed for each respective county in the 1989 statewide survey (Strong and Baker 1991).

Aitkin/Crow Wing has higher levels of human activity and shoreline development than the other index areas, except for Kandiyohi. This activity potentially affected reproductive success. Breeding success was highest in regions which are predominantly located on public lands and have lower levels of human activity (i.e., Itasca and Becker). Based on conversations with volunteers in Aitkin/Crow Wing, several cases of nesting failure were likely caused by disturbance from recreational activities. Lakes in Cook and Lake Counties are commonly thought to provide ideal loon habitat, but observations do not support this perception. There are at least two possible explanations for this finding. First, the low productivity in Cook/Lake may be associated with the nutrient poor waters of the region (Gorham et al. 1982) and their sensitivity to lake acidification (MN Pollution Control Agency, date unknown). Second, the density of lakes is low compared to other index areas and the Boundary Waters Canoe Area Wilderness (BWCA) region to the north of the Cook/Lake index area. Loon occupancy of isolated lakes, especially small lakes, may be lower than that of more densely grouped lakes, but this relationship needs to be further assessed. Surveying more interior lakes in Cook and Lake would have been preferred, but conducting surveys within the BWCA was not logistically feasible. Lake Vermillion, located 50 miles northwest of the Cook/Lake survey area, is densely populated with loons and also has high productivity.

The low productivity in both Cook/Lake and Kandiyohi may cause these index areas to be potential "sinks" in the population, i.e., emigration maintains population in the area, not productivity (Pulliam 1988). Kandiyohi is at the southern periphery of the breeding range, where loon densities would be expected to be lower. Additionally, numerous lakes in Kandiyohi are highly influenced by agricultural activities and shoreline development.

Effect of lake size

*Large lakes:*

As expected, lake occupancy rates were higher for larger lakes (Table 5), because they provide more resources. However, many lakes ≥ 150-500 acres in Otter Tail, Cook/Lake, and Kandiyohi did not have consistent adult loon occupancy in both 1994 and 1995 compared to the other three index areas (Table 6). Shape, depth, clarity, recreational use, and most likely, breeding habitat and food abundance, influenced these differences, but the exact causes are unknown.

The shape of large lakes influenced adult loon densities within the three index areas with higher adult densities. The 1994 and 1995 surveys confirmed that loons are more abundant and may establish more territories on large lakes with visual barriers (e.g., islands, peninsulas) (McIntyre 1988a). Itasca and Aitkin/Crow Wing, whose lakes ≥ 500 acres tend to be convoluted, had many more adult loons per 100 acres than Becker, which has round, open large lakes (App. VII).

*Small lakes:*

Although the larger lakes can support more loons than small lakes, small lakes provide an important source of habitat because they are numerous. Small lakes in Itasca and Becker likely provide better habitat than those in Cook/Lake and Kandiyohi based on higher occupancy rates (App. VII). Possible factors that may reduce the habitat quality provided by small lakes include winter freeze-outs, influence of runoff, inadequate shorelines for nesting, and isolation from quality habitat.

Many loon surveys do not include lakes < 25 acres, assuming loon use is minimal (Daulton 1993, Robinson 1987). McIntyre (1975) and Sjolander and Agren (1972 as cited in Daulton 1993) designated 25 acres as the minimum size lake that loons will use. Zimmer (1979) detected a 3.5% adult lake occupancy rate for lakes < 30 acres throughout Wisconsin. However, Perry (1987) observed an adult lake occupancy rate of 36% on 10-24 acre lakes in Crow Wing County, Minnesota in the mid-1980's. For the 1989 Minnesota statewide survey, 25% of the 10-25 acre lakes were occupied (Strong and Baker 1991). The results from the MLMP study (46% adult occupancy of 10-25 acre lakes) indicate that the perception that loons do not utilize lakes < 25 acres may be wrong as even in Kandiyohi, where adult densities were the lowest in the MLMP, about 23% of the lakes < 25 acres were utilized.

*Density measures and lake size:*

The number of adults per 100 acres appears to be inversely related to lake size. Density measures are probably most useful for making comparisons within the same study area over time and to indicate habitat differences among areas. Caution should be used when comparing loon densities among regions or states based on region-specific studies (Table 14). Observed differences among regions may reflect the effect of lake size more than food quality, nesting sites, or environmental degradation. For example, lakes in Itasca State Park are relatively small compared to other regions in Minnesota. The high number of adults per 100 acres corresponds to the densities observed on the smaller lakes in this study.

<u>Identification of potential territories</u>

Loon territories can be positively identified by the presence of juveniles, nesting adults, and possibly by adults showing territory defense behavior (e.g., yodel call by males). Lakes were surveyed post-nesting, thus unsuccessful territories (i.e., no nesting, failed nesting, early chick mortality) were not identified. D. Evers (pers. comm.) has casually observed that loon pairs are successful in rearing young about once every three years, on average. Breeding pairs that are not successful often remain on the territory for various periods of time depending on the level of resources on the lake (McIntyre 1988a). For those territories that were only successful in one year (either 1994 or 1995), the percent of lakes with two adults present in the non-breeding year was relatively high (68%), thus the assumption that the presence of two adults may be used as an indicator of potential territories may be appropriate. It is possible that about two-thirds of the 52 lakes with two adult loons and no juveniles present in both years had established loon territories.

<u>Consistent and intermittent lake use</u>

*Index areas - adults loons:*

Lakes where adults are consistently observed likely provide higher quality habitat (e.g., abundant resources) compared to lakes in regions with greater levels of intermittent lake use (e.g., Kandiyohi) (Table 4). It should be made clear, however, that one cannot conclude from the observed a absence of adult loons in a single annual survey that loons did not utilize the lake in that particular ear. Loons may have been off the lake at the time of observation or observers may have failed to detect adults. Two possible explanations for higher rates of intermittent use include the need for loons to utilize several lakes to obtain adequate resources and the presence of fewer established territories allowing loons to more easily visit "undefended" lakes. In contrast, Itasca had the greatest test number of lakes occupied by adult loons in both years, indicating that most lakes, including s all ones, likely provide sufficient resources (Table 6 and App. VII). In addition, when a lake is actively "defended", the number of visiting loons (e.g., non-breeders, failed breeders) may be reduced, especially on small lakes.

*Index areas - breeding success:*

Variability in breeding success between years was observed in this study, because 33.3 % of those lakes with documented breeding activity had juveniles present in both years (Table 7). Because juveniles rarely leave their natal lake, changes in juvenile lake occupancy between years should reflect the a actual success and failure in breeding, but observers may have failed to detect breeding activity. Nesting success and juvenile survival can be highly variable from year to year because of weather, predation, water level changes, and other numerous factors (McIntyre 1988a, Strong 1990). Becker had the most lakes with juveniles in both years, thus this index area may provide the best nesting and chick-rearing habitat. Otter Tail and Cook/Lake had the fewest lakes with successful breeding in both years, thus nesting failure and chick mortality may be high.

**Effects of d disturbed/developed shoreline and human population density on adult and juvenile loon presence**

*Developed/ disturbed shoreline:*

The finding that lakes with higher levels of disturbed/developed shoreline within the MLMP study area had greater adult and juvenile loon occupancy rates has been observed in several studies (Caron and Robinson 1994, McIntyre 1988a, Timm and McCall 1993). However, by lake size class, this relationship was only significant for lakes less than 50 acres. This trend within the small lake size class may have been driving the observed effects for all lakes, because small lakes accounted for a large percentage of the lakes in the study (37%). For small lakes, people and loons probably avoid the shallow, marshy, and bog-like lakes preferring the deeper, clear lakes

(McIntyre 1988a).

The extent of f disturbed/developed shoreline was a subjective measure, especially with regard to what percent of the shoreline is disturbed or natural vegetation. For over 130 lakes, two different volunteers made independent estimates of disturbed/developed shoreline and less than two percent of the estimates differed by more than one level (e.g., one volunteer estimated a level 6, another volunteer estimated a level of 4).

*Human population density*

Large lakes located in more densely populated townships had fewer adult loons observed on them and less breeding activity compared to regions with fewer people. Thus, human population density may be an indicator of the quality of loon habitat on lakes $\geq$ 150 to 500 acres. Stockwell and Jacobs 1993) also observed this relationship. It is the large lakes that receive most recreational and development pressures, especially in densely populated areas. However, Strong (1985) observed that loons on small, highly disturbed lakes may not be able to avoid the potential negative effects of human activity, whereas on large lakes, loons can move to less disturbed areas of the lake.

I limited the factors assessed in this study to levels of disturbed/developed shoreline, human population density, and lake size. Data on aquatic life, shoreline length, lake depth, water transparency, and water chemistry data were only available for a portion of the lakes included in the MLMP. Previous studies have clearly shown that adult occupancy and breeding are positively associated with lake size, depth, and shoreline length (Blair 1989, McIntyre 1988, Strong 1985, Zimmer 1979, Valley 1985), thus I did not want to focus on all of these habitat characteristics. I included lake size in the analysis with the expectation that adult loon presence and breeding activity would increase on larger lakes.

**Evaluation If changes in loon abundance from 1994 to 1995**

*All lakes in the MLMP:*

From 1994 to 1995, adult lake occupancy rates and juvenile loon numbers remained nearly constant (Figs. 2B and 4A). Adult loon numbers and juvenile lake occupancy rates increased slightly (Figs. s. 2A and 4B). Adult loon population changes over a two year period would likely be very small, because adults are long-lived (20-30 years) and have low rates of mortality once they reach adulthood (McIntyre 1988a). Breeding success will fluctuate more than adult numbers, because of a variability in nesting success and juvenile survivorship. This variation could easily explain the mall increase in juvenile lake occupancy.

The increase in adult loon numbers occurred primarily in Itasca and Aitkin/Crow Wing, where large congregations were observed on a few large lakes (Fig. 2A). The large congregations of adults in 1995 may have been caused by several factors, including the possibility that an actual increase in the adult population occurred within Itasca and Aitkin/Crow Wing, and/or by chance, more large congregations were observed in 1995 than in 1994. First, if the population increased and territory occupancy rates were high, then there may be a surplus of adults (i.e., non-breeders). Non-breeders often congregate on large lakes where territorial boundaries are less distinct (Croskery 188, McIntyre 1988a). Second, because of the infrequent occurrence of large congregations of adults (Croskery 1988, McIntyre 1988a), more congregations may have been observed in 1995 by chance. Only 12 lakes are ≥ 500 acres within the Itasca and Aitkin/Crow Wing index areas. Results from several more years of monitoring should reveal the frequency in which congregations of adults on large lakes are observed.

The higher adult loon numbers in 1995 were reflected in the number of adults per lake and per 100 acres, but not in lake occupancy rates. Lake occupancy rates may be more robust to the effects of large congregations of adult loons moving around as only presence/absence is being assessed. However, lake occupancy may not measure changes in loon abundance on large lakes that usually have loons resent. Only the absence of adults would indicate lower abundance and possible degraded ha habitat. Another potentially useful measure of loon abundance would be to adjust loon counts of large congregations and monitoring territory occupancy rates. (See section on "coping with variable counts" for more details.) Use of multiple density measures may be especially useful for comparing count data among years when some lakes are not surveyed in a given year. The robustness of the different density measures should be further assessed.

*Lakes within index areas:*

For individual index areas, more variability in loon abundance was observed between years than when all lakes in the MLMP were assessed. The smaller number of lakes surveyed (70-100 per index area) likely contributed to the increased variability.

**Evaluation of the use of a single annual survey**

<u>Variable counts from using single annual survey</u>

Using only a one-time annual census essentially provides a single "snap-shot" of loon activity. Loon occupancy on individual lakes varied considerably between years (Table 4), but the overall percent of occupied lakes changed very little (58.8 to 58.6%) (Table 3). Loon counts on individual lakes between years may vary because of measurement error, which, for the purposes of this study, includes observer error, loon movement between lakes (i.e., large congregations of loons), and other unidentified sources of error. Actual changes in loon numbers may also occur between years, especially productivity. Observer error is likely small based on volunteer accuracy studies comparing paired volunteers' loon counts (see Hanson, Chapter 1 discussion). The results indicated that the differences between paired volunteers' loon counts were normally distributed around a mean of zero. Loon movement and the effects of large congregations likely contribute more to changes in loon numbers between years than observer error.

When assessing all the lakes in the MLMP, overall changes caused by measurement error appear to be small because of the large number of lakes surveyed (Johnson 1981, Faanes and Bystrak 1981), but the compensating effects of large sample size has not been thoroughly tested. Understanding the types of variation that may occur should make it easier to interpret whether actual population changes are occurring, if a trend is detected.

<u>Coping with the variable counts</u>

The precision of detecting trends based on variable counts can be improved through a number of steps, including repeating surveys within breeding seasons, adjusting loon counts of large groups, assessing territory occupancy rates, pooling multiple years of data, and utilizing multiple measures of loon abundance.

*Repeated surveys within years:*

Ideally, multiple counts would be conducted throughout the breeding season (Harris 1986, Strong 1990). Logistical and financial constraints precluded the feasibility of multiple surveys on 600 lakes. Three to four surveys per year may be possible using a smaller sample size, but the data would be much less sensitive to statewide trends in the loon population. The Wisconsin DNR and LoonWatch successfully conducted multiple surveys over the breeding season on 80 lakes over an eight year period (Meyer and Daulton 1995). They obtained data on territorial occupancy and nesting, hatching, and fledging rates. If more detailed data such as these are required for the MLMP, especially for potential problem areas, a program modeled after the Wisconsin surveys would be appropriate.

*Adjusting loon counts of large congregations:*

The potential fluctuation in loon numbers caused by large congregations of adults could be minimized by only counting the groups as two adults. In this way, the presence of adults is still accounted for, but the variation in numbers is reduced.

*Territory occupancy rates:*

Another feasible approach to dealing with variable counts from a single survey is to assess known territories each year, especially for lakes with multiple territories. Adult loons reoccupy the same territories year after year making territory occupancy and subsequent breeding activity a reliable measure of adult loon numbers and productivity (Strong 1990). Monitoring known territories and corresponding presence of adults, even in years of unsuccessful breeding, will help reduce the effect of the movement of non-breeders and large gatherings of loons.

Before territories can be tracked, juveniles or nesting activity must first be identified. Differentiating between failed breeders and non-breeders may be difficult with a onetime survey, especially on lakes with multiple territories. Belant et al. (1993) and Strong (1990) both noted that nonresident adult loons utilize large lakes and make population estimates of territorial pairs difficult. An assumption could be made that the presence of adults in the location of the territory indicates an occupied territory. The validity of this assumption was moderately supported with the results from this study, but further investigations could be made. The observer would have to know the location of the territory for large lakes, but for small lakes this would not be necessary. .

In the MLMP, only 15 lakes were positively identified as having multiple territories in 1994 and 1995, although this number will probably increase as more data are collected.

*Pooling multiple years of data:*

Kendall et al. (1992) suggested that to improve the power of detecting trends, data can be pooled from multiple years. For each individual lake, the average number of loons observed over a specified time period could be calculated. Any trends detected across the pooled groups will be less influenced by annual variations. Pooling of data, however, assumes that population changes were negligible during the period of pooling.

*Multiple measures of loon abundance:*

Another way to reduce variability is by using multiple measures of loon abundance. I have summarized some possible measures and positive and negative attributes of each in Table 15. Adult lake occupancy rates may serve as a robust measure of the suitability of lakes for loon use (Robinson 1993, this study), reducing the problem caused by large congregations of loons. As discussed in the introduction, because adult loons can utilize a wide variety of habitats and tolerate environmental change, the number of juveniles present may be a better indicator of population stability and habitat quality than adult measures of abundance (Strong 1988).

J. Fair (pers. comm.) noted that the adult loon population within New Hampshire appeared stable throughout the 1960's and 1970's, although at historically low levels. The primary problem was low productivity. As protective and educational measures were taken in the late 1970's and 1980's, productivity increased, which was followed by increases in adult numbers. This type of observation indicates that as many measures as possible should be used to assess the status of the common loon population (e.g., adult and juvenile numbers, lake occupancy rates, territory occupancy, breeding success rates per territory, and other density measures). Recent color-banding data and subsequent studies on population dynamics may reveal which life history stages most influence changes in population levels (D. Evers, M. Meyer, pers. comm.) such as reduced adult or juvenile survivorship or loss of habitat or decreased range (Spellerberg 1991).

*Power analysis of detecting trends:*

Single annual surveys likely have lower statistical power in detecting trends compared to replicated surveys, thus it will take a longer period of time to positively detect positive or negative trends (Eberhardt 1978, Harris 1986). To determine the power of detecting trends in the MLMP, I modeled the variability observed in paired volunteer adult loon counts against predetermined population declines using actual loon count data (see Hanson, Chapter 2). Annual declines of 34% may be detectable within five years of monitoring and declines of 1 0% within 10 years for all lakes within the MLMP. These results are based on modeling a high level of count variability. The power analysis demonstrates that declines within the MLMP should be detectable within a reasonable timeframe from a natural resource management perspective. If a significant decline is detected, one or two more years of monitoring will likely confirm whether the trend is real or may have been caused by variable counts. For individual index areas, if no change in loon numbers is observed, it will take a longer period of monitoring before changes in the population can be detected with adequate power. A power level of 0.8 was used as a basis for adequate power with alpha set at 0.05 in determining the significance of modeled population declines over time.

Potential problems with the MLMP

Because common loons only spend a portion of their lives in the breeding range, changes observed in the loon population could be caused by events during migration or on the wintering grounds. Strong (1990) noted that this migratory behavior and the loons adaptability to a wide range of. habitats and stressors do not make the loon an ideal indicator of the health of lake ecosystems. There is also a chance that changes occurring in Minnesota's loon population may not be detected by the index area lakes (e.g., other lake regions may have a different set of problems facing them). And lastly, one time surveys may underestimate true numbers (Jarvinen and Vaisanen 1978).

There are problems with any monitoring program of wildlife populations. Given Minnesota's 12,000 lakes and about as many adult loons, annual surveys provide a detailed assessment of the status of the loon population within the six index areas. The major concern for the MN DNR will be differentiating between real population and reproductive changes and those suggested by observed trends based on July loon counts. The large sample size and the analysis of data over many years dampen out the effects of loon movement and other measurement errors.

## CONCLUSIONS

Two years of monitoring the adult common loon population and productivity have been completed within six regions of Minnesota. The objectives of the study have been met. First, within a five year time period, relatively small changes in the adult loon population (>3.4% annual decline) within the six index areas should be detectable. If the population changes less than 3.4% annually, power may be inadequate to differentiate a decline from no change after five years. As monitoring continues, smaller annual decline rates will be detectable. For individual index areas, the power of detecting trends is less, thus it will take a longer time period to differentiate the true slope from a slope of zero. Although a power analysis for detecting trends was not conducted for juvenile loons, many sources of measurement error will influence juvenile loon counts less than adult loon counts (e.g., loon movement from lake to lake, congregations of adults, diving). Annual observed changes in productivity should closely reflect actual reproductive success. For adult loon counts, observer error appears to be small compared to these other sources of measurement error based on the volunteer accuracy studies, where paired volunteers on the same lake consistently counted about the same number of loons.

Several steps can be taken to potentially reduce the effects of variable counts using a single-annual survey. If greater statistical power is desired, two to three years of data could be pooled at time by calculating the average number of loons observed on individual lakes. In addition, assessing multiple measures of loon abundance will provide a better picture of the status of the loon population within the six index areas (e.g., lake occupancy rates, breeding success, territory occupancy, other density measures, and loon numbers). Assessing whether adults are present on known territories, especially on lakes with multiple territories, should reduce the effects of large congregations of adults and allow changes in productivity to be detected sooner than only counting the number of juveniles. As the monitoring program continues, the amount of annual variation in each of these measures can be compared, and potentially, some of the factors to which each measure of abundance is sensitive can be identified. It may be possible to develop a computer model that can determine which measures of abundance are most robust to annual variation in loon counts.

Second, insights into the potential causes of any observed declines can be obtained from the potential threats associated with the index areas and individual lakes. For example, there may be a potential association of low adult and juvenile densities and mercury and acid deposition on lakes in the Cook/Lake index area. It may be that the nutrient poor waters and lower lake density in this region caused loon numbers to remain lower than interior lakes, but anthropogenic threats also need to be considered. The lower juvenile numbers in Aitkin/Crow Wing compared to Becker and Itasca and lower adult and juvenile numbers in Kandiyohi may be related to high levels of shoreline development and human activity. If declines in loon abundance are observed in these index areas, these associations provide starting points for further investigations into the specific causes. In addition, other regions of the state with similar physical and biological characteristics and human activity levels may be experiencing similar problems. Because adult and juvenile loon activity can be closely monitored within small regions, potential problems in either component of the loon population should be identified. If problems are observed with productivity, further studies may be required to determine the problems is associated with nesting and/or chick-rearing. For example, lakes of concern could be monitored more closely throughout the breeding season.

And last, a foundation for a long-term database, survey protocol, and logistical support are well-established (e.g., over 400 volunteers participating, maps collected, instructions and data forms developed). The results from the first two years clearly describe the loon activity within the survey regions, for different lake size classes, and for individual lakes. Indicators of human activity have also been identified using estimates of shoreline development and disturbance and human population densities. Assessing the effects of current human activity is difficult as many factors contribute to adult loon lake occupancy and reproductive success, including habitat quality, experience of loons, nesting history, climatic events, predation, water level fluctuations, time of disturbance during the breeding season, and others (McIntyre 1988a, Stockwell and Jacobs 1993). Determining which of these factors influence adult occupancy and productivity may only be identifiable after many years of monitoring. There may be a "human activity" threshold level where loon activity is negatively effected by human activity, but this level likely varies greatly by lake. Presently, the exact cause of lower productivity and adult presence in some of the index areas cannot be determined. If any declines are detected on the high human activity lakes either individually or on a broad scale, but no declines are observed on low human activity lakes, the evidence would strongly suggest that human activity may be having negative effects on the loon population. However, if declines are detected and no patterns are observed that correlate with high levels of human activity, other factors are likely involved, which may or may not include direct human activity (e.g., airborne contaminants, density dependent factors). This type of information would still help the MN DNR determine what steps to take next in addressing the population declines.

Trends in occupancy, adult population size, and productivity within the index areas will be used to infer potential changes in the larger statewide population. Detection of a negative trend in the loon population within a majority of index areas, in specific regions, or on certain types of lakes (e.g., small or large, developed) will serve as a warning to initiate further in-depth analysis of the potential causes of the trend. The MN DNR can more closely analyze the MLMP data by lake size, human activity levels, territory occupancy on individual lakes, and other potential factors. Further research into problem areas could be conducted such as monitoring a subset of lakes throughout the breeding season to obtain territory, nesting, and hatching data. In addition, other monitoring activities can be periodically reviewed (e.g., the Minnesota Loon Survey data, Lake Vermillion, Knife Lake, and Whitefish Chain counts, the Chippewa National Forest aerial survey data, and studies from nearby states). Extensive studies in Minnesota and Wisconsin are currently being conducted on mercury contamination and possible effects on loon behavior, breeding success, and other biological processes (D. Evers and M. Meyer, pers. comm.). In Minnesota, mercury levels in loons in Itasca County and Voyageur's National Park have been monitored since 1992 (D. Evers, pers. comm.). The Minnesota Pollution Control Agency (MPCA) and Minnesota Zoo are conducting necropsies on recovered loons to determine the causes of death (J. Pichner, pers. comm.). All of these studies should provide an even more complete picture of the common loon population in Minnesota.

Birth and death rates, immigration, and emigration of loons may vary among the different geographic regions (Pulliam 1988) of Minnesota. However, Minnesota as a whole is located at the southern periphery of the common loon breeding range. For this reason, if a decline in Minnesota's loon population were to occur, there may be little effect on the overall population of North America's common loons. Any reduction in range size, especially if caused by anthropogenic effects, is nonetheless a concern for lake ecosystems. The monitoring activities, in Minnesota should allow early detection of a population decline if one were to occur, and would prompt preventive action before the problem would become too serious. Such action could include education programs such as those in New Hampshire, whose success has contributed to an increase in loon numbers and productivity since the 1970's. Other preventive measures could include shoreline protection around nesting and chick rearing areas. Lastly, perhaps the very design of the MLMP will instill a stewardship ethic toward the loons and lakes in a willing corps of volunteers--this may be one of the largest factors in ensuring the common loon's viability in the state of Minnesota.

## RECOMMENDATIONS

Based on the analysis of the first two years of the MLMP, I can make a number of recommendations about survey methodology, types of survey data that may be useful in assessing the status of the loon population within the six index areas, and potential areas of concern.

### Methodology

If the MLMP needs to be streamlined in the future, I would recommend omitting small lakes (1025 acres) where no loons have been observed after at least four years of monitoring. Some small lakes will probably never be utilized by loons, and keeping definite non-loon lakes in the program may result in higher volunteer attrition rates. These lakes could be resurveyed periodically (e.g., every 10 years) for two to three years in a row to check if lakes are reoccupied. Because many, if not most lakes above 50 acres may support some loon use, these lakes should not be omitted.

### Useful information for assessing the loon population and reducing the effects of variable counts

In future years, the effects of large congregations of loons on overall adult loon counts should be assessed to determine whether adult numbers remain at or above the 1995 level or whether congregation events are sporadic enough to cause the observed increase from 1994 to 1995.

To reduce the effects of large congregations of loons on large lakes and other causes of variable counts, several measures of loon abundance should be monitored (Table 15). First, adult lake occupancy should be monitored. Second, an adjustment of congregation numbers could be made by counting all groups of three or more adults as only two adults. Third, an attempt could be made to identify the locations of established loon territories, and then the success and occupancy of these territories could be tracked over time. Territories likely cover the entire lake for lakes under 200 acres. For larger lakes, multiple territories may exist and monitoring territorial occupancy could be more difficult. Volunteers who live on these lakes and follow loon activity over the entire breeding season should conduct the loon surveys, if possible. If territorial loons cannot be positively identified in the July census on larger lakes, a pilot program could be initiated to identify territorial pairs in late May/early June.

To help with the positive identification of territories, a more intensive assessment should be make on lakes where adults are continuously present in future years but no breeding activity is documented. Landowners could be questioned about the history of loon activity and extra surveys could be conducted in late May or June to document whether territorial behavior or actual nesting occurs. If the lake has a territorial pair of loons, further investigation may reveal the reason for unsuccessful breeding. Interpretation of trends in productivity can likely be improved by continually monitoring breeding success rates on individual lakes and documenting on which types of lakes productivity is consistently lowest and highest.

Identification of trends

A minimum of four to five years of data should be collected before any potential trends are assessed. If no significant slope is detected, the power analysis should provide guidance on how long monitoring must continue to detect various decline rates. If a negative trend is detected, a year or two more of surveys should be conducted before taking action. However, if some potential concerns arise, further analysis of the data and other monitoring activities could be initiated.

Potential areas of concern

Adult loon lake occupancy and breeding success were lower on lakes above 150 acres in surface area that were located in regions with higher human population densities (i.e., Kandiyohi, Otter Tail) compared to regions with fewer people. These lakes should be monitored closely, in addition to lakes in Cook/Lake where there may be a potential association of low adult and juvenile densities and mercury and acid deposition. Although adult numbers and occupancy rates were relatively high in Aitkin/Crow Wing, Becker, and Itasca, breeding success in Aitkin/Crow Wing was less than that observed in Becker and Itasca. Breeding activity should be monitored closely in the future in Aitkin/Crow Wing to determine how many established territories exist and whether high levels of breeding failure are occurring. If breeding failure is high, a closer assessment of nesting and chick-rearing success may be appropriate to determine whether any association exists with the higher levels of human activity in the region.

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Table 1. Summary of number of lakes included in the Minnesota Loon Monitoring Program (MLMP), lake size ranges, and total water surface and land area by survey region ("index area") in 1995.

| Index Area | Number of lakes [a] | Lake size range (acres) | Total water surface area (acres) | Total land area ($km^2$) [b] |
|---|---|---|---|---|
| Aitkin / Crow Wing | 111 | 10 - 2,435 | 21,800 | 550 |
| Becker | 105 | 10 - 3,943 | 35,500 | 800 |
| Cook / Lake | 121 | 10 - 1,294 | 21,300 | 1,100 |
| Itasca | 110 | 10 - 2,066 | 19,000 | 400 |
| Kandiyohi | 109 | 10 - 5,821 | 32,500 | 900 |
| Otter Tail | 108 | 10 - 2,360 | 25,000 | 600 |
| **Total** | **664** | | **155,100** | **4,350** |

[a] This total is the number of lakes assigned in 1995. Only 486 lakes were surveyed in both 1994 and 1995.

[b] Total land area within survey regions.

Table 2. Minnesota Loon Monitoring Program (MLMP) lake survey regions ("index areas") by selection criteria. Selection criteria include current loon density and potential anthropogenic threats and were rated low, moderate, or high in relation to other index areas. Those threats that are likely to be greatest are listed in bold. Rated threats are not applicable to all lakes and were used as guidance for selecting the index areas.

| | **Index Area** | | | | | |
|---|---|---|---|---|---|---|
| | Becker | Itasca | Cook / Lake | Otter Tail | Aitkin / Crow Wing | Kandiyohi |
| **Rank of index area by potential threat level** (1 - lowest, 6 - highest) | 1 | 2 | 3 | 4 | 5 | 6 |
| **Selection Criteria** | | | | | | |
| Current Loon Density [a]: | *High* | *High* | *High* | *High* | *High* | ***Low*** |
| Acid Rain Sensitivity [b]: | *Low* | ***High*** | ***High*** | *Low* | *Low* | *Low* |
| Human Population / Road Density [c]: | *Low* | *Low* | *Low* | *Moderate* | ***High*** | ***High*** |
| Projected Human Population Growth [d]: | *Low* | *Low* | *Low* | *Low* | ***High*** | ***High*** |
| Land Ownership [e]: | *Public* | *Public* | *Public* | ***Private*** | ***Private*** | ***Private*** |

[a] Strong and Baker 1991
[b] Minnesota Pollution Control Agency, date unknown
[c] Minnesota State Planning Agency 1995
[d] Minnesota State Planning Agency 1994
[e] Land Management Information Center 1983

Table 3. Summary of adult and juvenile loon counts by index area on lakes surveyed in both 1994 and 1995 as part of the MLMP (n=486). Only lakes surveyed by the same method were compared (e.g., aerial and ground counts).

| | Year | Itasca | Becker | Aitkin / Crow Wing | Otter Tail | Cook / Lake | Kandiyohi | Total |
|---|---|---|---|---|---|---|---|---|
| Number of lakes surveyed | | 75 | 68 | 95 | 84 | 83 | 81 | 486 |
| **Adult loons** | | | | | | | | |
| Number of adult loons counted | 1994 | 245 | 118 | 180 | 92 | 109 | 65 | 809 |
| | 1995 | 277 | 117 | 217 | 106 | 107 | 51 | 875 |
| **Adult loon density** | | | | | | | | |
| Adult occupancy [a] | 1994 | 82.7% | 70.6% | 71.6% | 50.0% | 48.2% | 32.1% | 58.8% |
| | 1995 | 82.7% | 72.1% | 66.3% | 51.2% | 53.0% | 29.6% | 58.6% |
| Number of adults per lake [b] | 1994 | 3.27 | 1.74 | 1.89 | 1.10 | 1.31 | 0.80 | 1.67 |
| | 1995 | 3.69 | 1.72 | 2.28 | 1.26 | 1.29 | 0.63 | 1.80 |
| Number of adults per 100 acres surface water | 1994 | 1.88 | 0.53 | 1.01 | 0.70 | 0.74 | 0.33 | 0.80 |
| | 1995 | 2.12 | 0.53 | 1.21 | 0.81 | 0.72 | 0.26 | 0.87 |
| **Juvenile loons** | | | | | | | | |
| Number of juveniles counted | 1994 | 54 | 38 | 39 | 19 | 11 | 29 | 190 |
| | 1995 | 42 | 42 | 39 | 24 | 23 | 23 | 193 |
| **Juvenile loon density** | | | | | | | | |
| Juvenile occupancy [a] | 1994 | 33.3% | 35.3% | 22.1% | 16.7% | 8.4% | 14.8% | 21.2% |
| | 1995 | 33.3% | 41.2% | 24.2% | 22.6% | 15.7% | 11.1% | 24.1% |
| Number of territories [c] | 1994 | 36 | 28 | 25 | 14 | 7 | 21 | 131 |
| | 1995 | 29 | 29 | 25 | 19 | 13 | 16 | 131 |

[a] Occupancy rate is the percent of lakes with loons present.

[b] Total number of loons / total number of lakes

[c] Territories were identified by the presence of juvenile loons. Many large lakes had multiple territories.

Table 4. Percent of lakes in the MLMP with adults present (adult lake occupancy) by index area for lakes surveyed in both 1994 and 1995. Adult lake occupancy is given for either year, for each year separately, and for lakes with adults present in both years. To assess the rates of intermittant use, the number of lakes occupied in each year and in both years is given as a percent of lakes with loon activity in either year. These results are presented in the last three column.

| | | *Adult loon occupancy as a percent of all lakes* [a] | | | | | *Adult loon occupancy as a percent of those lakes with any loon activity in either 1994 or 1995.* [a] | | |
|---|---|---|---|---|---|---|---|---|---|
| **Index area** | **Number of lakes** | **Either 1994 or 1995** | **1994** | **1995** | **Both 1994 and 1995** | **Number of lakes with adults in either 1994 or 1995** | **1994** | **1995** | **Both 1994 and 1995** |
| Itasca | 75 | 86.7 | 82.7 | 82.7 | 78.7 | 65 | 95.4 | 95.4 | 90.8 |
| Becker | 68 | 89.7 | 70.6 | 72.1 | 54.4 | 61 | 78.7 | 80.3 | 60.7 |
| Aitkin / Crow Wing | 95 | 83.2 | 71.6 | 66.3 | 54.7 | 79 | 86.1 | 79.7 | 65.8 |
| Otter Tail | 84 | 63.1 | 50.0 | 51.2 | 38.1 | 54 | 79.2 | 81.1 | 60.4 |
| Cook / Lake | 83 | 65.1 | 48.2 | 53.0 | 36.1 | 54 | 74.1 | 81.5 | 55.6 |
| Kandiyohi | 81 | 42.0 | 32.1 | 29.6 | 19.8 | 34 | 76.5 | 70.6 | 47.1 |
| **Total** | **486** | **71.3** | **58.8** | **58.6** | **46.6** | **347** | 82.5 | 82.2 | 65.4 |

[a] percent

Table 5. Summary of adult and juvenile loon counts by size class on lakes surveyed in both 1994 and 1995 as part of the MLMP (n=486). Only lakes surveyed by the same method were compared (e.g., aerial and ground surveys).

| | | Size Class (acres) | | | | |
|---|---|---|---|---|---|---|
| | Year | 10-49 | 50-149 | 150-499 | 500+ | Total |
| Number of lakes surveyed | | 201 | 141 | 93 | 51 | 486 |
| Percent of total lakes | | 41.4% | 29.0% | 19.1% | 10.5% | |
| Total surface area of lakes | | 5729 | 12262 | 26066 | 56855 | 100912 |
| **Adult loons** | | | | | | |
| Number of adult loons counted | 1994 | 177 | 180 | 250 | 202 | 809 |
| | 1995 | 152 | 205 | 300 | 218 | 875 |
| **Adult loon density** | | | | | | |
| Adult occupancy [a] | 1994 | 49.3% | 56.7% | 74.2% | 74.5% | 58.8% |
| | 1995 | 41.3% | 64.5% | 84.9% | 62.7% | 58.0% |
| Number of adults per lake [b] | 1994 | 0.88 | 1.28 | 2.69 | 3.96 | 1.66 |
| | 1995 | 0.76 | 1.45 | 3.23 | 4.27 | 1.80 |
| Number of adults per 100 acres surface water | 1994 | 3.09 | 1.47 | 0.96 | 0.36 | 0.80 |
| | 1995 | 2.65 | 1.67 | 1.15 | 0.38 | 0.87 |
| **Juvenile loons** | | | | | | |
| Number of juveniles counted | 1994 | 40 | 42 | 47 | 61 | 190 |
| | 1995 | 35 | 61 | 55 | 42 | 193 |
| **Juvenile loon density** | | | | | | |
| Juvenile occupancy [a] | 1994 | 14.4% | 20.6% | 28.0% | 37.3% | 21.2% |
| | 1995 | 12.4% | 27.7% | 39.8% | 30.8% | 24.1% |
| Number of territories [c] | 1994 | 29 | 30 | 30 | 42 | 131 |
| | 1995 | 25 | 40 | 38 | 28 | 131 |

[a] Occupancy rate is the percent of lakes with loons present

[b] Total number of loons / total number of lakes

[c] Territories were identified by the presence of juvenile loons. Many large lakes had multiple territories.

Table 6. Percent of lakes in the MLMP with adults present (adult lake occupancy) by lake size class for lakes surveyed in both 1994 and 1995. Adult lake occupancy is given for either year, for each year separately, and for lakes with adults present in both years. To assess the rates of intermittant use, the number of lakes occupied in each year and in both years is given as a percent of lakes with loon activity in either year. These results are presented in the last three column.

| | | *Adult loon occupancy as a percent of all lakes* [a] | | | | | *Adult loon occupancy as a percent of those lakes with any loon activity in either 1994 or 1995.* [a] | | |
|---|---|---|---|---|---|---|---|---|---|
| **Lake size class (acres)** | **Number of lakes** | **Either 1994 or 1995** | **1994** | **1995** | **Both 1994 and 1995** | **Number of lakes with adults in either 1994 or 1995** | **1994** | **1995** | **Both 1994 and 1995** |
| 10-49 | 201 | 59.7 | 49.3 | 41.3 | 30.8 | 120 | 82.5 | 69.2 | 51.7 |
| 50-149 | 141 | 73.8 | 56.7 | 64.5 | 48.2 | 104 | 76.9 | 87.5 | 65.4 |
| 150-499 | 93 | 87.1 | 74.2 | 84.9 | 72.0 | 81 | 85.2 | 97.5 | 82.7 |
| 500+ | 51 | 80.8 | 74.5 | 62.7 | 57.7 | 42 | 92.2 | 77.6 | 71.4 |
| **Total** | **486** | **71.3** | **58.8** | **58.6** | **46.6** | **347** | **82.5** | **82.2** | **65.4** |

[a] percent

Table 7. Percent of lakes in the MLMP with loon breeding activity by index area for lakes surveyed in both 1994 and 1995. Breeding activity is given for any lake with juveniles present in either year, for each year separately, and for lakes with juveniles present in both years. It is apparent that loons do not nest each year or are unsuccessful (e.g., 35.1% of all lakes had juveniles present in either 1994 or 1995, but only 11.7% had juveniles present in both years). To better assess this effect by lake size class, lakes with breeding activity in each year and in both years is given as a percent of those lakes with known breeding activity in the last three columns (e.g., 33.3% of the lakes with known breeding activity had juveniles present in both years).

| | | *Breeding activity as percent of all lakes* [a] | | | | | *Breeding activity as a percent of those lakes with known breeding activity in either 1994 or 1995* [a] | | |
|---|---|---|---|---|---|---|---|---|---|
| **Index area** | **Number of lakes** | **Either 1994 or 1995** | **1994** | **1995** | **Both 1994 and 1995** | **Number of lakes with breeding activity in either 1994 or 1995** | **1994** | **1995** | **Both 1994 and 1995** |
| Itasca | 75 | 50.7 | 33.3 | 33.3 | 17.3 | 38 | 65.8 | 68.4 | 34.2 |
| Becker | 68 | 54.4 | 35.3 | 41.2 | 25.0 | 37 | 64.9 | 81.1 | 45.9 |
| Aitkin/Crow Wing | 95 | 34.7 | 22.1 | 24.2 | 11.6 | 33 | 63.6 | 69.7 | 33.3 |
| Otter Tail | 84 | 34.1 | 16.7 | 22.6 | 8.2 | 29 | 51.7 | 72.4 | 24.1 |
| Cook/Lake | 83 | 21.7 | 8.4 | 15.7 | 4.8 | 18 | 38.9 | 72.2 | 22.2 |
| Kandiyohi | 81 | 19.8 | 14.8 | 11.1 | 6.2 | 16 | 75.0 | 56.3 | 31.3 |
| **Total** | **486** | **35.1** | **21.2** | **24.1** | **11.7** | **171** | **60.8** | **71.3** | **33.3** |

[a] percent

Table 8. Percent of lakes in the MLMP with loon breeding activity by lake size class for lakes surveyed in both 1994 and 1995. Breeding activity is given for any lake with juveniles present in either year, for each year separately, and for lakes with juveniles present in both years. It is apparent that loons do not nest each year or are unsuccessful (e.g., 35.1% of all lakes had juveniles present in either 1994 or 1995, but only 11.7% had juveniles present in both years). To better assess this effect by lake size class, lakes with breeding activity in each year and in both years is given as a percent of those lakes with known breeding activity in the last three columns (e.g., 33.3% of the lakes with known breeding activity had juveniles present in both years).

| | | *Breeding activity as percent of all lakes* [a] | | | | | *Breeding activity as a percent of those lakes with known breeding activity in either 1994 or 1995* [a] | | |
|---|---|---|---|---|---|---|---|---|---|
| **Lake size class (acres)** | **Number of lakes** | **Either 1994 or 1995** | **1994** | **1995** | **Both 1994 and 1995** | **Number of lakes with breeding activity in either 1994 or 1995** | **1994** | **1995** | **Both 1994 and 1995** |
| 10-49 | 201 | 20.9 | 14.4 | 12.4 | 6.0 | 42 | 69.0 | 59.5 | 28.6 |
| 50-149 | 141 | 36.2 | 20.6 | 27.7 | 12.1 | 51 | 56.9 | 76.5 | 33.3 |
| 150-499 | 93 | 52.7 | 28.0 | 39.8 | 15.1 | 49 | 53.1 | 75.5 | 28.6 |
| >500 | 51 | 55.8 | 37.3 | 31.4 | 26.9 | 29 | 69.0 | 72.4 | 48.3 |
| **Total** | **486** | **35.1** | **21.2** | **24.1** | **11.7** | **171** | **60.8** | **71.3** | **33.3** |

[a] percent

Table 9. Lakes in the MLMP where two or more adult loons and no breeding activity were observed in both 1994 or 1995 by index area. The number of potential active territories is based on the finding that 68.2% of all lakes with breeding adults in one year had two or more adults and no juveniles in the year without breeding activity. This group of lakes should potentially be checked for signs of nesting or loons exhibiting territorial behavior.

| Index area | Number of lakes with 2 or more adults present in both years and no breeding activity in either year | Names and lake numbers of lakes fitting criteria listed at left | | | | | |
|---|---|---|---|---|---|---|---|
| Aitkin / Crow Wing | 16 | 01-0116 | Four | 01-0153 | Laurel | 01-0174 | Thornton |
| | | 01-0118 | Raspberry | 01-0160 | Three | 01-0178 | Spirit |
| | | 01-0120 | Section Twelve | 01-0161 | Hammal | 18-0057 | Goose |
| | | 01-0123 | Elm Island | 01-0162 | Four | 18-0069 | Portage |
| | | 01-0129 | Sissabagamah | 01-0171 | Diamond | 18-0072 | Shirt |
| | | 01-0132 | Hansen | | | | |
| Becker | 7 | 03-0178 | Ballard | 03-0297 | South Twin | | |
| | | 03-0196b | South Chippewa | 03-0314 | Fish | | |
| | | 03-0197 | Blackbird | 03-0322 | Raspberry | | |
| Cook / Lake | 8 | 16-0251 | Turtle | 16-0385 | Fleck | 38-0057 | Hogback |
| | | 16-0346 | Cascade | 38-0024 | Crooked | 38-0060 | Whitefish |
| | | 16-0382 | Lichen | 38-0055 | Charity | | |
| Itasca | 15 | 31-0417 | Nose | 31-0618 | Duck | 31-0670 | Big Ole |
| | | 31-0424 | Snowshoe | 31-0622 | Dead Horse | 31-0671 | Big Island |
| | | 31-0438 | Sand | 31-0637 | Day | 31-0677 | Hole-in-Wall |
| | | 31-0461 | Three Island | 31-0653 | North Star | 31-0678 | Bill's |
| | | 31-0540 | Clubhouse | 31-0665 | Little North Star | 31-0680 | West Smith |
| Kandiyohi | 1 | 34-0146 | Eight | | | | |
| Otter Tail | 6 | 56-0484 | Mud | 56-0690 | Tonseth | | |
| | | 56-0570 | Bass | 56-0714 | Leeper | | |
| | | 56-0663 | Loon | 56-0737 | Eddy | | |
| **Total** | **52** | | | | | | |

Table 10. A comparison of the mean levels of developed/disturbed shoreline [a] and township human population density for each lake by index area. Developed/disturbed shoreline ratings were estimated by volunteers who surveyed each lake. Lakes within the same township were assigned the same human population density value.

| Index area | Developed / disturbed shoreline [a] | Township human density (people/mile$^2$) |
|---|---|---|
| Cook / Lake | 1.9 | 1.9 |
| Becker | 2.5 | 13.0 |
| Itasca | 2.7 | 4.6 |
| Otter Tail | 3.0 | 22.3 |
| Kandiyohi | 3.3 | 38.2 |
| Aitkin / Crow Wing | 3.5 | 37.6 |

[a] Levels of developed/disturbed shoreline (e.g., docks, lawns, rip-rap, pasture, housing, campgrounds, etc)

| Rating | Percent developed/disturbed shoreline |
|---|---|
| 1 | 0 % - no road leading to lake |
| 2 | 0 % - single road leading to lake |
| 3 | 0-25 % |
| 4 | >25-50 % |
| 5 | >50-75 % |
| 6 | >75-100 % |

Table 11. A comparison of the mean levels of developed/disturbed shoreline for individual lakes by lake size class and index area. Developed/disturbed shoreline ratings were estimated by volunteers who surveyed each lake.

| | Lake size class (acres) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Index area** | **10-49** | (n) | **50-149** | (n) | **150-499** | (n) | **500+** | (n) |
| Cook / Lake | 1.5 | (43) | 1.7 | (39) | 2.4 | (28) | 3.2 | (11) |
| Becker | 2.0 | (36) | 2.4 | (36) | 2.8 | (23) | 3.1 | (19) |
| Itasca | 2.1 | (52) | 3.0 | (26) | 3.7 | (24) | 3.7 | (6) |
| Otter Tail | 2.4 | (44) | 3.0 | (39) | 3.4 | (21) | 4.2 | (14) |
| Kandiyohi | 2.4 | (35) | 3.4 | (40) | 3.8 | (18) | 4.3 | (17) |
| Aitkin / Crow Wing | 2.7 | (49) | 3.3 | (29) | 4.7 | (23) | 5.4 | (10) |
| **Total** | **2.2** | (259) | **2.8** | (209) | **3.5** | (137) | **4.0** | (77) |

[a] Levels of developed/disturbed shoreline (e.g., docks, lawns, rip-rap, pasture, housing, campgrounds, etc.)

| Rating | Percent developed/disturbed shoreline |
|---|---|
| 1 | 0 % - no road leading to lake |
| 2 | 0 % - single road leading to lake |
| 3 | 0-25 % |
| 4 | >25-50 % |
| 5 | >50-75 % |
| 6 | >75-100 % |

Table 12. Assessment of the relationship between adult and juvenile loon presence and human activity factors and lake size using logistic regression. Presence and absence was denoted with a 1 and 0, respectively. Shoreline development/disturbance levels ranged from 1 to 6 increasing with greater levels of disturbance. The mean shoreline development factor was 2.8 (s.d.=1.4). Township human population density ranged from 1.2 to 107.1 people per square mile with a mean of 19.4 (s.d.=24.2).

**A. Adult loon presence**

| Predictor variables | Coefficient | std. error (s.e.) | p-value |
|---|---|---|---|
| Lake surface area | 0.0019 | 0.0004 | 0.0065 |
| Shoreline development/disturbance | 0.2055 | 0.0725 | 0.0046 |
| Township human population density | -0.0088 | 0.0035 | 0.0111 |

**B. Juvenile loon presence**

| Predictor variables | Coefficient | std. error (s.e.) | p-value |
|---|---|---|---|
| Lake surface area | 0.0006 | 0.0002 | 0.0043 |
| Shoreline development/disturbance | 0.2404 | 0.0675 | 0.0004 |
| Township human population density | -0.0045 | 0.0038 | 0.2380 |

Table 13. Assessment of the relationship between adult and juvenile loon presence and human activity factors and lake size using logistic regression by lake size class. "Positive" refers to a positive relationship between loon presence and lake size or human activity factors (e.g., increase together). "Negative" refers to an inverse relationship. For example, as township human population increased on lakes > 150 acres, the number of lakes with adult loons present decreased. Presence and absence was denoted with a 1 and 0, respectively. Shoreline development/disturbance levels ranged from 1 to 6 increasing with greater levels of disturbance. The mean shoreline development factor was 2.8 (s.d.=1.4). Township human population density ranged from 1.2 to 107.1 people per square mile with a mean of 19.4 (s.d.=24.2).

**A. Adult loon presence**

| Lake size class | Lake surface area | Shoreline development/disturbance | Township human population density |
|---|---|---|---|
| 10-49 acres | positive (p=0.0096) | positive (p=0.0123) | NS |
| 50-149 acres | NS | NS | NS |
| 150-499 acres | positive (p=0.0165) | NS | negative (p=0.0538) |
| 500+ acres | NS | NS | negative (p=0.0334) |

**B. Juvenile loon presence**

| Lake size class | Lake surface area | Shoreline development/disturbance | Township human population density |
|---|---|---|---|
| 10-49 acres | NS | positive (p=0.0141) | NS |
| 50-149 acres | NS | NS | NS |
| 150-499 acres | positive (p=0.0018) | NS | NS |
| 500+ acres | NS | NS | negative (p=0.0146) |

Table 14. A comparison of the number of adult loons per 100 acres from different lake regions throughout North America. The number and size of lakes included in each study was not reported for all studies.

| Study site | Sample type | Number of Adults per 100 acres | n | Source |
|---|---|---|---|---|
| Minnesota (this study - 1995) | Specific regions - total | 0.80 | 630 | MLMP 1995 results |
| | By lake size class | | | |
| | 10-49 acres | 2.67 | 235 | |
| | 50-149 acres | 1.61 | 193 | |
| | 150-499 acres | 1.05 | 128 | |
| | 500+ acres | 0.39 | 74 | |
| | Range by region | 0.19 - 1.90 | 100 [a] | |
| Itasca State Park | Specific region | 2.07 | NA | McIntyre 1978 as cited in Parker and Miller |
| Saskatchewan | Specific region | 1.99 | NA | Yonge 1981 as cited in Parker and Miller 1988 |
| Boundary Waters Canoe Area Wilderness | Specific region by lake size class | | | Titus and VanDruff 1981 |
| | < 200 acres | 2.05 | 30 | |
| | 200+ acres | 0.83 | 6 | |
| Maine | Southern half of state | 0.48 [b] | 296 | Lee and Arbuckle 1988 |
| | Range by County | 0.08 - 1.12 | NA | |
| New York - Adirondack Ecological Zone | Specific region | 0.35 | 557 | Parker and Miller 1988 |
| New Hampshire | Statewide | 0.19 | NA | Hammond and Wook 1976 as cited in Parker and Miller 1988 |

NA - not available

[a] Actual number of lakes within each index area ranged from 96 to 118.

[b] Total loon density based on average density of 16 counties. Not corrected for differences in the number of lakes between counties.

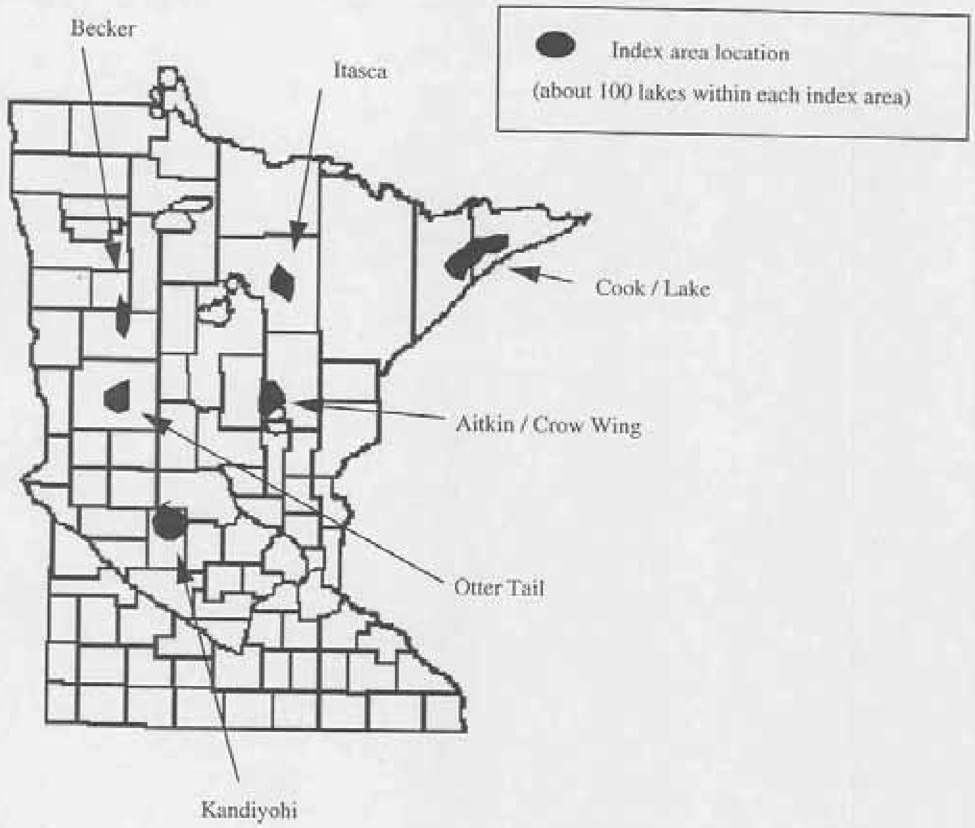



**Figure 1. Location of six survey regions ("index areas")**

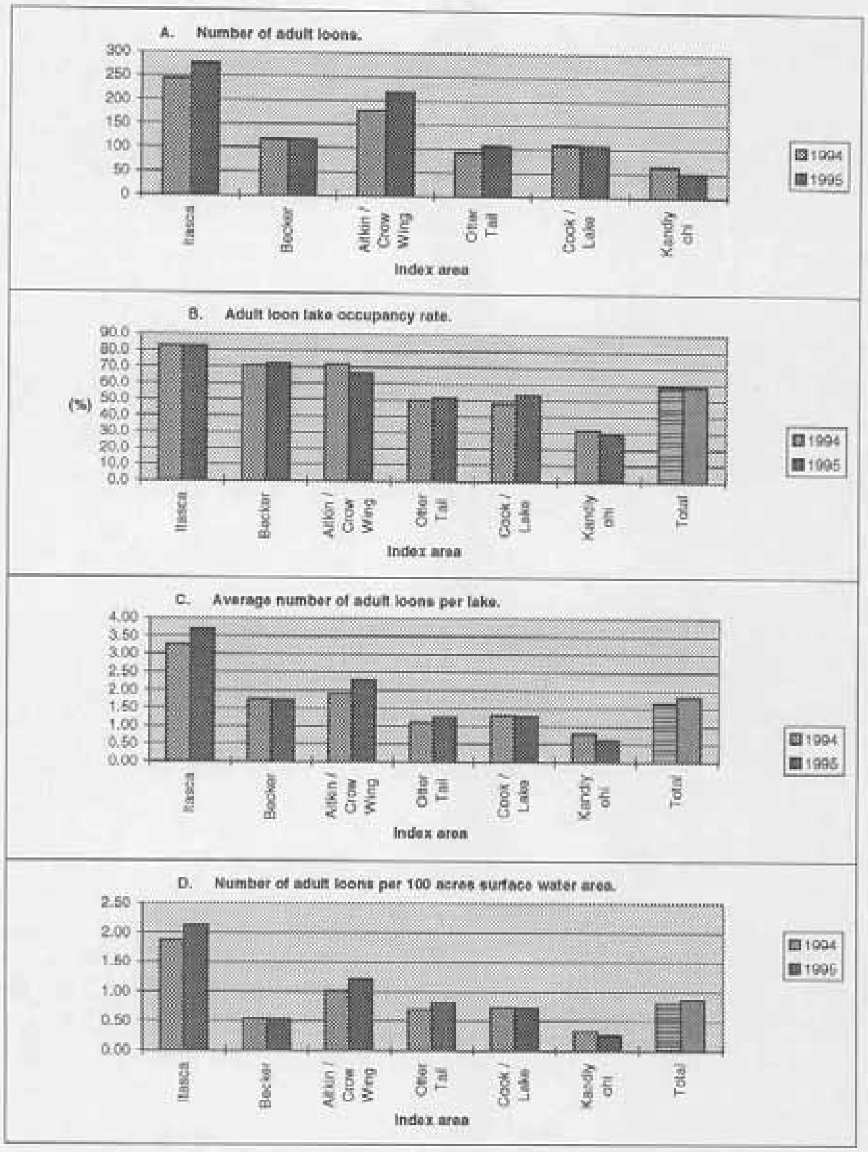



Figure 2. A comparison of 1994 and 1995 adult loon numbers and densities by index area of the MLMP. Only lakes surveyed in both years using the same survey method were included. Density measures included B) adult loon occupancy lake occupancy [a], C) average number of adults per lake [b], and D) number of adult loons per 100 acres surface area. Total number of lakes surveyed: Itasca (75), Becker (68), Aitkin/Crow Wing (95), Otter Tail (85), Cook/Lake (83), Kandiyohi (81), and overall (486).

[a] Adult loon lake occupancy is the percent of lakes with loons present.

[b] Number of adults per lake is the sum of adult loons / number of lakes.

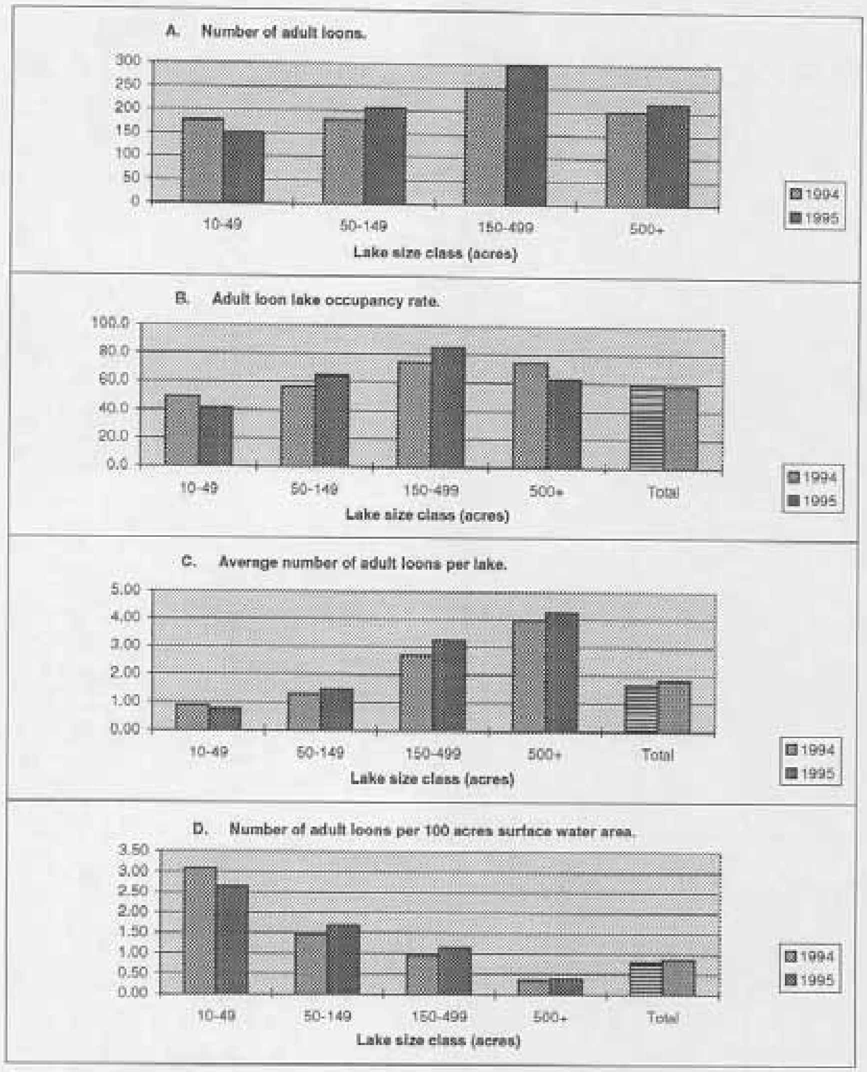



Figure 3. A comparison of 1994 and 1995 adult loon numbers and densities by lake size class within the six index areas of the MLMP. Only lakes surveyed in both years using the same survey method were included. Density measures included B) adult loon occupancy lake occupancy [a], C) average number of adults per lake [b], and D) number of adult loons per 100 acres surface area. Total number of lakes surveyed: 10-49 acres (201), 50-149 acres (141), 150-499 acres (93), 500+ acres (51), and overall (486).

[a] Adult loon lake occupancy is the percent of lakes with loons present.

[b] Number of adults per lake is the sum of adult loons / number of lakes.

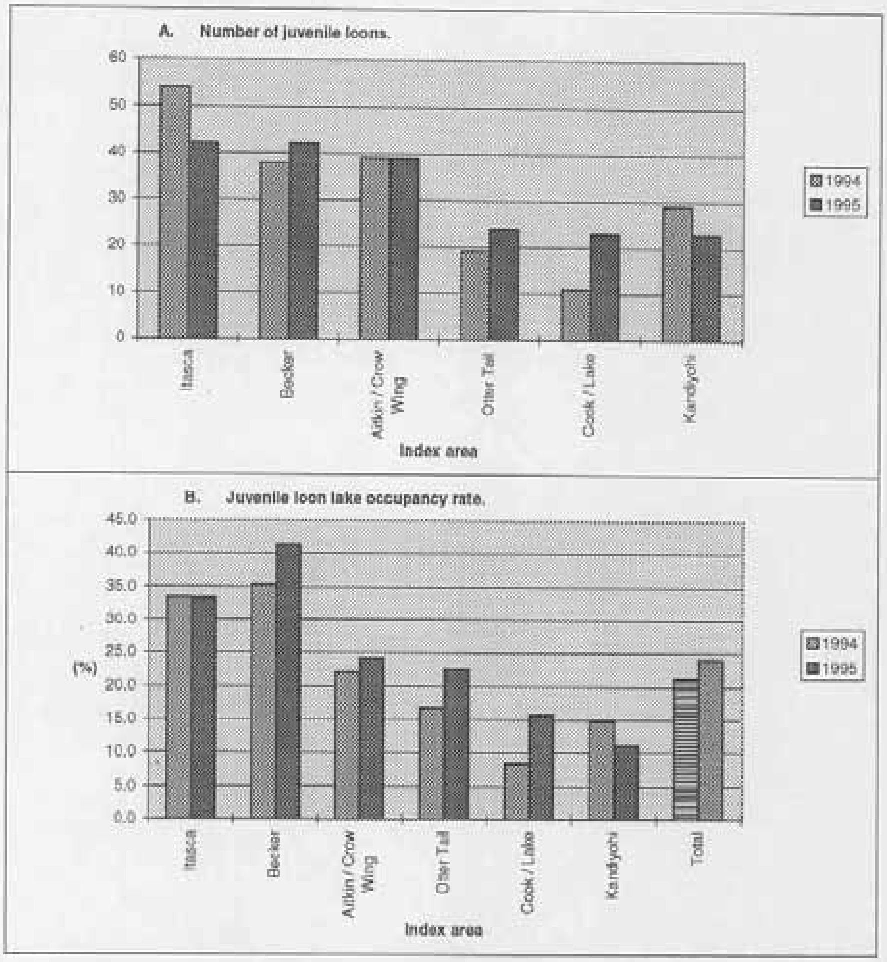



Figure 4. A comparison of 1994 and 1995 juvenile loon numbers and lake occupancy rate[a] by index area. Only lakes surveyed in both years using the same survey method were included. Total number of lakes surveyed: Itasca (75), Becker (68), Aitkin/Crow Wing (95), Otter Tail (85), Cook/Lake (83), Kandiyohi (81), and overall (486).

[a] Juvenile loon lake occupancy is the percent of lakes with juveniles present.

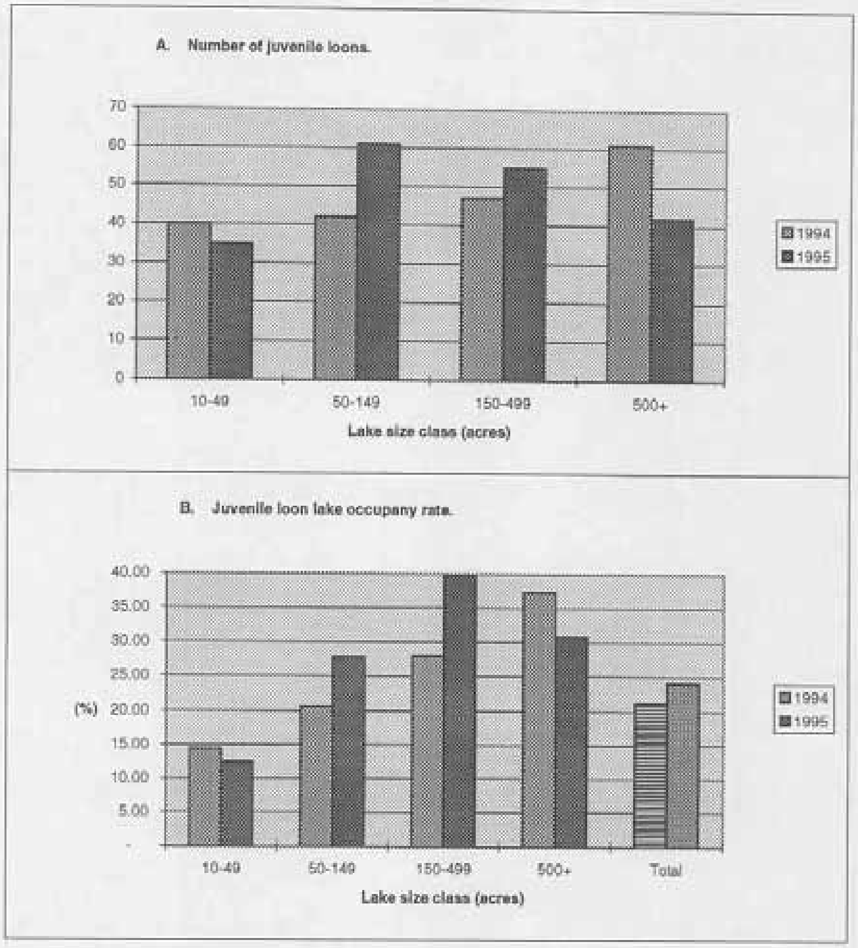



Figure 5. A comparison of 1994 and 1995 juvenile loon numbers and lake occupancy rate* by lake size class. Only lakes surveyed in both years using the same survey method were included. Total number of lakes surveyed: 10-49 acres (201), 50-149 acres (141), 150-499 acres (93), 500+ acres (51), and overall (486).

* Juvenile loon lake occupancy is the percent of lakes with juveniles present.

## Appendix I. 1995 volunteer survey instructions and data form for the Minnesota Loon Monitoring Program

### The Minnesota Loon Monitoring Program - LOON SURVEY INSTRUCTIONS
**JULY 14-18, 1995 (5:00 a.m. - 12:00 noon)**

If you have any questions or difficulties prior to or during the survey, contact Eric Hanson at (612) 646-5616. Eric will be by the phone during the survey dates (July 14-18) from 6 am to 2 pm if you have any questions or problems.

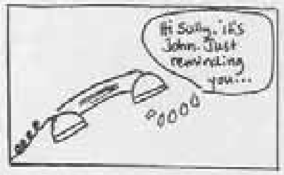
---

**WELCOME!!** Thank you for participating in this year's Minnesota Loon Monitoring Program. We are counting on you to survey your lake(s) once during the five day survey period of July 14-18. We hope that your day is successful as well as enjoyable. We have put together a simple set of instructions to aid you in monitoring your lake. Please read the instructions carefully. If you have any questions, do not hesitate to call Eric Hanson at the above number.

Thank you to all the volunteers who have helped take unassigned lakes. In some index areas we had a surplus of volunteers, thus some of you may not have been assigned additional lakes. We will keep your names on record for 1996 if some volunteers do not return next year.

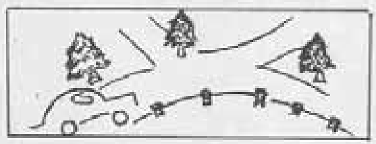
**THINGS TO DO BEFORE THE SURVEY:**

***Contact your back-up observer.**




-It is important that all 600 lakes are surveyed by someone.
-Take time to contact the back-up person just in case you cannot survey your assigned lake(s) for whatever reason.

***Check your lake early:**

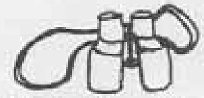


-Some lakes will be difficult to find and access or require permission from a landowner to access (see below).
-Take your map and check the lake **1-4 weeks in advance**, if you can.
-Not all roads are "vehicle friendly". Be cautious; if road conditions look marginal, try walking first.
-Make sure that the lake you have found is the correct lake. Some lakes are unnamed or are known locally under a different name--always refer to your map for confirmation. Again, call Eric Hanson if you have questions.
**-Mark on the map the best route to reach the lake (road #'s, distances, landmarks) and landowner contacts.**

***Private land issues:**

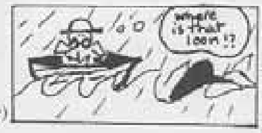
-If the only access to the lake is through private land, try to ask for permission from the landowner before crossing their land.
-Bring your data forms and instruction sheet to help explain the program. If you or the landowner have any questions, do not hesitate to call Eric Hanson.

**PRACTICE SCANNING LAKES WITH BINOCULARS**



-Looking for loons seems relatively simple. It IS if the loons are right in front of you. BUT loons that are a 1/2 mile away are more difficult to "pick out", especially if there are any waves. Practice scanning lake surfaces with BINOCULARS, look for the white breast of a loon, look for black dots that move and disappear each time you scan. PRACTICE, PRACTICE, PRACTICE - Scan, Look with just your eyes, Scan, and Scan some more.

**THE DAY OF THE SURVEY:**





***When do I survey the lake?**

-Any day from July 14 (Friday) through July 18 (Tuesday)

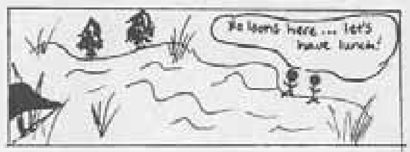
-Survey your lake(s) between 5:00 a.m. and 12:00 noon.

**-Do not survey in heavy rain or whitecap conditions.** If there are moderate to high winds, wait till the next morning to survey, unless no alternative day is available. Loons become very difficult to see in choppy waves and are next to impossible to see in whitecaps (i.e., BIG waves).

-Ideal survey conditions: NO WAVES, NO WIND...SMOOTH AS GLASS (winds are calmer earlier in the morning)

-Try to plan for a day with a favorable forecast (calm) during the five days from which you have to choose.

***How long do I survey the lake?**




Stay at least:

- 1 to 4 hours for medium to large lakes (over 100 acres).
- 30 minutes for small lakes (under 50 acres).

- Loons move around or may be feeding underwater. Give loons time to come into view. But be careful, survey the lake only once; do not stay so long that you count the same loons multiple times.

**LOON FACTS:**

* Most breeding pair of loons will have 1 or 2 young.
* Lakes smaller than 150 acres are unlikely to have more than 1 breeding pair of loons, which means small lakes will rarely have more than 1 or 2 juvenile loons.
* Adult loons frequently fly to other lakes for feeding and social interactions, thus while you survey your lake, the loon(s) may be off the lake or "extra" loons could be visiting.
* Chicks up to 1-2 weeks of age have black feathers. Juvenile loons are brown and gray from 2-4 weeks and then turn gray and white after about 4 weeks of age.
* Female and male adult loons are indistinguishable by feather pattern amd color. They share nest and chick raising duties equally on average. (It's a myth that only "mom" tends to the nest and young.)

**MONITORING TIPS:**

The Minnesota Loon Monitoring Program

<u>What to count?</u>

-Count all loons on the lake including those leaving or landing. (Do not count loons that fly overhead and do not land.)

-Count only loons you see, but use calls that you hear to help you find loons.

-Be careful not to count cormorants as loons - from a distance they can look alike. <u>Use binoculars and look for the white on the breast of the loon.</u> Cormorants are entirely dark.

<u>Surveying from shore:</u>

-Make sure that you can see the entire lake.

-View the lake from multiple vantage points, if necessary.

-If you cannot see the entire lake, view for a longer time period in case there are loons "around the corner".

<u>Surveying by boat:</u>

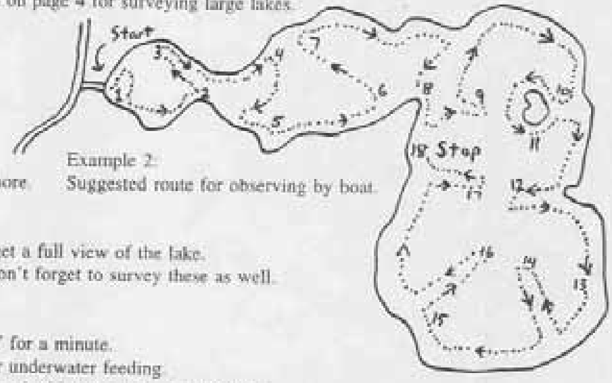
-For round lakes, stay about 200 feet from shore moving around the lake (points 8-18 in diagram).

-For narrow, long lakes, move back and forth (zig zag) down the length of the lake (points 1-8 in diagram).

-<u>Stop the boat</u> every 400 yards to <u>fully scan the lake</u> w/ binoculars and eyes (steady and quiet).

**-Large lakes:** See separate instructions on page 4 for surveying large lakes.

Example 1:
Suggested vantage points for observing from shore.




Example 2:
Suggested route for observing by boat.

<u>Irregular shaped lakes:</u>

-Move around the lake to each bay to get a full view of the lake.

-Many lakes may have hidden coves; don't forget to survey these as well.

<u>General Tips:</u>

-If you see a loon, STOP and SURVEY for a minute.

* Other loons may be nearby or underwater feeding.
* Note the location of the loon and which direction it is moving.

-<u>Be careful not to double count loons as you move around the lake</u> by keeping track of loons already counted.

* Keep looking back to see where they are.
* Keep track of which way the loons are moving.

-It is helpful to do a trial run ahead of time.

-Visiting the lake ahead of time will tell you how to best survey the lake.

* Is there sufficient access to launch a boat or canoe or is there a landowner to ask permission.
* How good are the views from shore? Is a boat or canoe necessary?

**EXTRA SURVEYS OF LAKES and TINY LAKES**

- For those of you that surveyed lakes filled with tall vegetation, if you have time, survey your lake in late June/early July for a PRE-count. If you can only visit your lake once, please wait until July 14-18. Compare how viewing conditions differ between the two dates. (The reason we chose the mid-July survey date is that most juvenile loons are 2-4 weeks of age by mid-July and are past the period of highest mortality.)

- Too many volunteers - We'll never have enough volunteers. This year there are some lakes that have more than one person surveying them. Next year (1996), some volunteers will be unable to return, and we will ask some of the second surveyors to switch to these unassigned lakes. Thanks for your cooperation with these potential lake assignment changes in future years.

- TINY LAKES: if a lake has less than 10 acres of open water (400 ft. by 1000 ft.), we will likely eliminate that lake from the monitoring program and will assign you a different lake. Let us know if you think your lake is this small.

## The Minnesota Loon Monitoring Program - LARGE Lake Survey Guidelines

**(Lakes larger than 400 acres)**

1) HIGHEST PRIORITY - survey under calm, no wind conditions.

Survey lakes early in the morning. (Try to begin at 5:00 or 6:00 am to make sure you have calm water conditions). There is also less boat activity early in the morning.

2) Have three observers in the boat (with a minimum of two people).

- Driver
- Two observers
- Everyone should have binoculars

3) Scan the lake in FRONT, to the SIDES, and BEHIND boat.

- If you see a loon, STOP and SURVEY for a minute.
  * Other loons may be nearby or underwater feeding.
  * Note the location of the loon and which direction it is moving.
- Be careful not to double count loons as you move around the lake.
- If you see a loon far ahead, keep an eye on where it is moving.
- Keep track of loons you have already counted and where they are moving.

4) Stop the boat every 400 yards to fully scan the lake w/ binoculars and eyes.

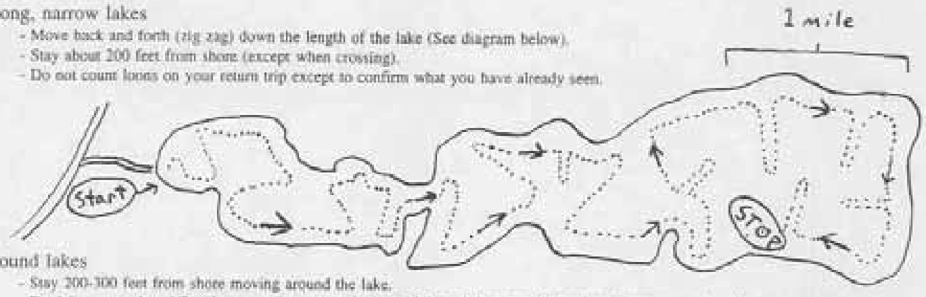
- Stopping allows you to use binoculars from a "steady", non-moving, non-vibrating boat.
- With the motor off, you can hear loons call from all parts of the lake.

5) **Routes for surveying lakes**

- Use your maps to write down the location of the loons as you survey.
- Use peninsulas and islands as landmarks for marking what you have already surveyed and to note where the loons are.

A) Long, narrow lakes

- Move back and forth (zig zag) down the length of the lake (See diagram below).
- Stay about 200 feet from shore (except when crossing).
- Do not count loons on your return trip except to confirm what you have already seen.

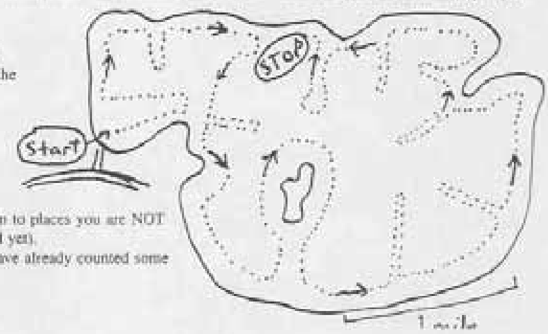



B) Round lakes

- Stay 200-300 feet from shore moving around the lake.
- For lakes more than 1/2 mile across, boat towards the middle and then straight back on the same route. Continue surveying along the shore for 1/2 mile. Repeat survey out towards the middle and then back to shore again (See diagram below).
- If you see a loon in the middle of the lake, keep a close eye on where it is moving (e.g., toward areas you have not surveyed yet).

C) Islands and Bays

- Completely circle around islands before continuing.
- Survey bays in there entirety before continuing on the main part of lake.




General Tips:

- Write down a tentative boat route ahead of time.
- It is helpful to do a trial run.
- Avoid double counting.
  * Loons do move fast and far and may swim to places you are NOT (e.g., part of the lake you have not surveyed yet).
  * Be conservative - if you think you may have already counted some loons, do not count them again.

**FILLING OUT THE DATA SHEET:** The Minnesota Loon Monitoring Program

Please read through the data sheet before you conduct your survey. Bring these instructions along with you when you survey the lake. If you have any questions call Eric Hanson (612) 646-5616 before you conduct your survey.

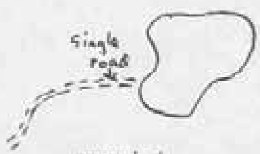
***General information and questions 1-2**

-Review the general information and access information. Make any necessary corrections. Please give detailed directions on how to best reach the lake including landowners names and phone numbers. Fill out questions 1 and 2 when you reach the lake.

*** Question 3: Percent of disturbed/developed shoreline**

-Shoreline disturbance/development includes structures, docks, lawns, pasture, and roads that disrupt natural vegetation along the lakeshore.

-Circle the category that most appropriately matches the amount of disturbed/developed shoreline on the lake. (a. 0% no human activity b. 0% single road only c. 0-25% b. 25-50% c. 50-75% d. 75-100%)




example 1
0% single road


example 2
25-50%

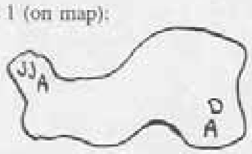

example 3
75-100%

***Question 4: Loon Activity**

-Mark the location of the adults and juveniles on the map using A for each adult and J for each juvenile.

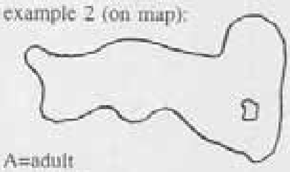
-On the data form, describe the location and area of the lake where the adult and juvenile loons were seen.

example 1 (on map):




A=adult
J=juvenile
#4 on data form: 1 adult, 2 juvenile in NW bay near marsh
1 adult in SE bay near island

example 2 (on map):



A=adult
J=juvenile
#4 on data form: no loons on lake

***Question 5: Summary**

-Write in the total number of adult and juvenile loons observed in the spaces provided.

example 1 (above): adults 2
juvenile 2
no loons ☐

example 2 (above): adults ___
juveniles ___
no loons ☑

****IMPORTANT****

**-Even if there are no loons on the lake, please complete the data form in full and return it. It is equally important to know about the lakes that loons do not use as well as those that are used.**

***Question 6: Canada Goose Information - NEW for 1995**

Please indicate on the data form the number of adult and juvenile Canada geese that you observe. Since loons are not the only species to use lakes, the MN DNR would like to gather information on another easily identifiable waterbird - the Canada goose.

***Questions 7-10**

-Please fill out as requested on the data form.

**RETURNING THE DATA FORM:**

-Check to see that all information has been completed on the data form.
-The data forms need to be received as soon as possible. Please return the following to the MN DNR the next mailing day or postmarked by July 20:

*the data form
*the map with:
-location of loons
-route taken to reach lake
-landowner contact/phone number

-Use the enclosed envelope or mail to:

Minnesota Loon Monitoring Program
MN DNR - Nongame Wildlife Program
Box 7, 500 Lafayette Dr.
St. Paul, MN 55155-4007

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REMEMBER:

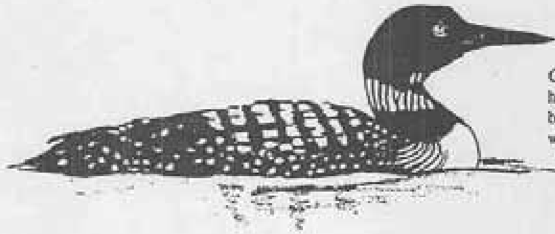
1) **Survey the lake under calm water conditions.**
2) **Ask for permission before crossing private lands.**
3) **Be careful- wear life vests in boats and canoes.**
4) **Try to avoid disturbing the loons.**
5) **USE binoculars.**
6) **Bring a spotting scope, data form, maps, instructions, and a bird book.**
7) **Have fun.**

---

Thanks for your assistance and concern in helping Minnesota's common loons.

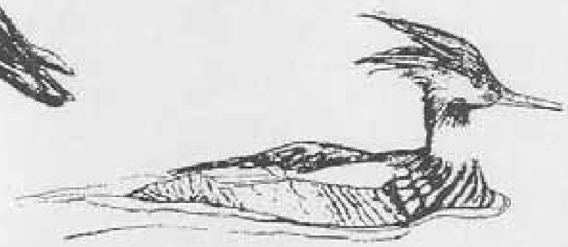
HANDY BIRD REFERENCE

Although adult common loons are quite distinctive; distance, poor observation conditions, and lack of familiarity with similarly shaped birds could cause misidentification. Some birds that you may have specific problems with include the Canada goose, red-breasted merganser, common merganser, double-crested cormorant, red-necked grebe, western grebe, and immature common loon. Please study the drawings on this form and read the following text to ensure that you can distinguish these birds from a common loon. Consult a bird field guide if you have any questions.

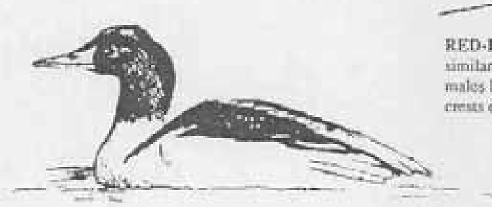


COMMON LOON - sits low in the water, jet black head and bill, black neck with white stripes, white belly, black back with white dots on the back and wings, body length 2-3 feet.

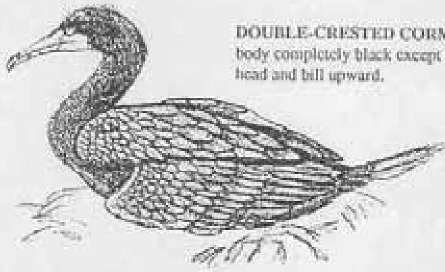
CANADA GOOSE - larger than a loon, sits higher in the water, black neck with no necklace stripes, solid white cheek patch.



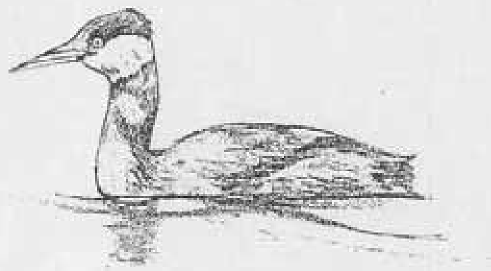
RED-BREASTED MERGANSER - half as large as common loon, similar silhouette, sexes different, females are dull gray with rusty heavy males have green head, white neck, and rusty breast, both sexes have crests on the back of the head and bright orange bills.



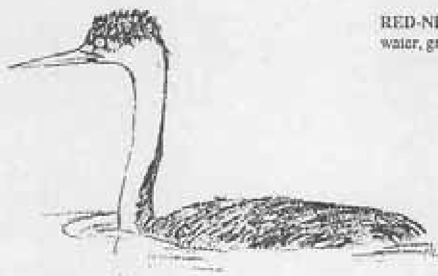
COMMON MERGANSER - similar to red-breasted merganser, but lacks rusty breast.



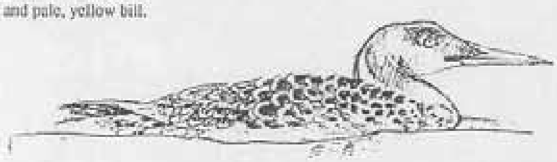
**DOUBLE-CRESTED CORMORANT** - similar in size and shape to loon, sits low in water, body completely black except for orange throat pouch, when swimming points its head and bill upward.



**RED-NECKED GREBE** - smaller than loon, similar silhouette, sits low in water, gray body, red neck, and white throat and cheek.



**WESTERN GREBE** - nearly as large as loon, similar silhouette, sits low in water, solid black body, long, white neck, and pale, yellow bill.



**IMMATURE COMMON LOON** - rarely seen in Minnesota during the summer, same shape and size as adult loons, plumage is gray or brown, white belly, but not black head with white stripes.

**1995 Minnesota Loon Monitoring Program Data Form**
5:00 a.m. - 12:00 noon, July 14-18 1995

- If you have any question prior to and during the survey, call Eric Hanson (612) 646-5616.
- Eric will be available 6am-2pm July 14-18 to answer any last minute questions.
- If both you and your back-up person cannot survey your lake, contact Eric immediately.

Index Area:
Lake Code:
Lake Name:

Legal Description:
Size (acres):

Survey Method:
Access Information:

Other Notes (if any):

(make any necesssary corrections)

Name:
Permanent Address:

Summer Address:

Telephone (home):
(work):

Summer telephone:

Names of additional observers in survey:________________________________________
Total number of observers:_____

**LAKE DATA:**

Observation Date: July _____. Observation Time: beginning________ end________

**Please circle all that apply**

1. **Mode of observation:** motorized boat non-motorized boat shoreline
**Equipment used:** binoculars spotting scope other_____

2. Weather Conditions: (do not survey in heavy rain/whitecap/windy conditions)
**Wind/water conditions:** calm ripples choppy
**Visibility:** poor good excellent
**Cloud cover:** fog light rain cloudy partly cloudy clear/mostly clear

3. Percent of disturbed or developed shoreline: (docks, lawns, cabins/homes, pastures, roads)
a. 0% Bushwack to lake - No disturbed or developed shoreline.
b. 0% Single road leading to lake - No disturbed or developed shoreline.
c. 0-25% d. 25-50% e. 50-75% f. 75-100%

**LOON ACTIVITY:**

Indicate adult with "A"
Indicate juvenile with "J"

***Mark where loons were found on the map provided AND RETURN THE MAP w/ data form to the MN DNR***

example:


4. Please describe the location where loons were observed.

example: 1 adult, 2 juveniles on west end near marsh; 1 adult on north shore in middle part of lake.

______________________________

______________________________

____________________________________________________________

5. Loon Totals:

Total number of adult loons observed.______

Total number of juvenile loons observed.______

Please check box if no loons were observed. ☐

6. Canada Goose Totals (NEW for 1995):

Total number of adult Canada geese observed.______

Total number of juvenile Canada geese observed.______

Please check box if no Canada geese were observed. ☐

7. A. Which of the following conditions affected your survey results? Circle all that apply.

*great visibility   *loons in clear view   *all parts of lake in view
*poor visibility   *loons far away   *parts of lake out of view

B. How confident are you of your survey results?   *observed most everything
*may have missed something

8. Will you be willing to survey this lake next year? ( )Yes ( ) No

9. Would you be interested in a leadership role (local volunteer coordinator) helping keep track of which volunteers are returning each year and which lakes need volunteers? In addition, volunteer coordinators will help find new volunteers and promote the program (distributing information, fliers, etc.). We need additional help in all but the Kandiyohi index area. ( ) Yes ( ) No

10. Suggestions for improving next year's survey:______________________________

11. Check the following before mailing to the MN DNR:

( ) Data form completely filled out.
( ) Map marked with 1) loon locations and 2) route taken to reach lake/landowner contact.

Please RETURN THIS FORM AND MAP THE NEXT MAILING DAY using the enclosed envelope or mail to:

* Minnesota Loon Monitoring Program, MN DNR - Nongame Wildlife Program,
Box 7, 500 Lafayette Dr., St. Paul, MN 55155-4007

***Appendices II – IX not included.***