LOONS:

Old History and New Findings

Proceedings of a Symposium

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Loons: Old History and New Findings

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Conveners and editors:

Judith W. McIntyre
Utica College of Syracuse University
1600 Burrstone Road
Utica, New York 13502
jmcintyre@utica.ucsu.edu

David C. Evers
BioDiversity Research Institute
411 Route 1, Suite 1
Falmouth, Maine 04105
david.evers@BRILoon.org

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PREFACE AND ACKNOWLEDGMENTS

This document showcases the burgeoning research on the Common Loon. Topics of the manuscripts range widely from parasites and disease, to behavior and population dynamics. There are many new technologies that ornithologists and wildlife biologists now use, including implementation of satellite transmitters to track inter-seasonal movements and use of computers to quantitatively differentiate vocalizations. Changes in loon research have also been dictated by the ability of biologists to capture and uniquely color-mark individuals for future identification. Information based on past speculation on certain life history traits and behaviors is now changing through observations of known loon individuals over time. Several of the following manuscripts document these changes.

In addition to the peer-reviewed manuscripts, reports by Canada and each of the 15 states with breeding loons are provided by the organization or agency charged with monitoring the status of its loon population. Preceding these reports is a geographic summary and overview of the present status of North America's breeding loons.

These new findings are bringing our knowledge about loons to new levels. This scientific base will understandably provide resource managers and policy makers with the tools to appropriately apply conservation measures to ensure that loons remain a viable part of our northern landscape.

Each of the 12 papers were peer-reviewed by two or more scientists with expertise in the relevant discipline. We thank the following for their thoughful comments which went far to improve these papers: Robert Askins, Luis Baptista, Jack Barr, Gerald Bartelt, Robert Beason, Donald Bruning, Neil Burgess, Mary Clench, Francesca Cuthbert, Jeff Fair, Donald Forrester, Mark Fuller, Donald Kroodsma, Scott Lanyon, Stuart Paulus, Walter Piper, William Seeger, Ken Stromberg, Jeffrey Walters, and Doris Watt.

We thank Anne Olson Bialke for her cover illustration. She spent her childhood with Minnesota loons, and she now watches and listens to loons in New York's Adirondack Park. Please check the back cover, because like loons in their aquatic settings, they may swim and call on one side of our canoe, and then dive and pop up on the other!

Mercer Companies, Inc. of Albany, New York, sponsored the publication of these Proceedings through a generous contribution. We thank them, and in particular Michael Tucker, who have had a long-standing interest in loons, and have supported loon research for many years with generous grants.

Judith W. McIntyre, Utica, New York
David C. Evers, Falmouth, Maine
October 2000

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INTRODUCTION TO THE SYMPOSIUM

JUDITH W. MCINTYRE

UTICA COLLEGE OF SYRACUSE UNIVERSITY, BURRSTONE ROAD, UTICA, NEW YORK 13502

Welcome to the symposium on Loons, Old History and New Findings. It is exciting to be back at the University of Minnesota where I received my doctorate in 1975, and to be co-convening this session with David Evers, who is currently a doctoral student with a dissertation topic similar to *mine-loons!*

The last issue of Audubon Field Notes noted that "loons are all the rage these days" and then went on to summarize numerous sightings of loons of all species at unusual places, sometimes in large numbers. Because Minnesota's State Bird is the Common Loon (*Gavia immer*), and has always been "all the rage" here, we felt it was fitting that this should be The Year of the Loon at the AOU. We thank our hosts and the Scientific Committee for accepting our proposal. We also think it was neat of them to have a loon join an auk as the logo for this meeting!

An enthusiastic public conservation effort directed to loons began 27 years ago with the initiation of Minnesota's Project Loon Watch, the first loon monitoring effort in the world to involve public observers. Five years later, New Hampshire's Loon Preservation Committee began as a project of the New Hampshire Audubon Society to protect breeding loons on New Hampshire lakes and provide public education on the value and needs of loons. Since then, a dedicated corps of volunteer "loon rangers" has provided protection for breeding loons with the result that New Hampshire's loon population has doubled since 1975. There are now more than 20 similar citizen volunteer groups across the United States and Canada.

Others in Europe, primarily in Sweden and the British Isles, survey and pursue conservation for Arctic (*G. arctica*) and Red-throated Loons (*G. stellata*). In 1980, the North American Loon Fund (NALF), a private, non-profit organization, was founded as an umbrella group for all local loon organizations, and has become an informational clearinghouse for research, management and educational efforts, has provided research funding, designed color-marking protocol and produced educational programs.

NALF is holding its annual members' meeting and its summer meeting of the Board of Trustees in conjunction with the AOU. Many of NALF's members are new to the AOU, and we not only welcome them today, but hope they will become members of the AOU, just as we hope others of you will become members of NALF. Everyone is welcome to attend the NALF members' meeting and workshop this evening in Coffman Union, beginning at 7 pm, where annual state and provincial status reports will be given and updates on some of the European populations will be available. Papers from this Symposium and summaries of this evening's status reports will be published as a refereed Proceedings volume. Its publication is being sponsored by the Mercer Companies of Albany, N.Y., and will be available for purchase from NALF.

This audience knows what loons are; they are not obscure, rare, or recently discovered birds that are unknown and/or unrecognized by all but a few ornithologists. Large segments of the public recognize loons by their pictures or calls. But beyond being able to correctly say, "That's a loon!" there are many misconceptions about exactly what loons are, what they do and with whom they do it, and how their populations can maintain stability. Before 12 research papers are presented today, I would like to review some earlier views on loons, the Old History part of this symposium, and introduce some of the New Findings to be discussed this afternoon.

Loons have long been called primitive birds. It is common to hear that loons are very ancient, and perhaps related to a wide diversity of other groups, including *Hesperornis* spp., large, toothed, flightless, diving birds that died out at the end of the Cretaceous. Over and over again we have read, especially in the popular press, that loons are really old. Yet, the fossil record shows an age of only about 40 million years, first identified at the end of the Eocene, when there were also numerous other avian groups, including penguins, auks, parrots, cranes, hawks, and owls (Storer 1988). Anatomical similarites have led some authors to place loons with both grebes and hesperornithines (e.g. Heilman 1927, Cracraft 1982), although most researchers, including Storer (1956), Olson (1985) and Sibley and Monroe (1990) attribute those morphological similarities to convergence.

Nearly 40 years ago, after Sibley (1960) compared electrophoretic patterns of egg-white proteins, he suggested a relationship between the Gaviiformes and the Charadriiformes (Sibley and Ahlquist 1972). Storer (1956, 1978) also suggested a larine ancestry, based on morphological characteristics. DNA tests provide more recent evidence (Sibley and Ahlquist 1983, Sibley and Monroe 1990) that loons share ancestry with the procellariids, and that their next closest relatives are penguins (Spheniscidae) and frigatebirds (Fregatidae). A big hole in today's symposium is a lack of new findings concerning the relationship of the five loon species to each other.

Beginning in the early 1970's, much research was devoted to assessing the influence of human disturbance on maintenance of stable loon populations (Vermeer 1973, McIntyre 1975, Sutcliffe 1980, Titus and Van Druff 1981, Heimberger et al. 1983). One factor, long thought to play a negative role in successful reproduction, was invasion of breeding habitat by the speed, wake and noise of motorboats. Canoes and rowboats were considered less offensive. They probably are, after chicks have hatched, but during nesting, slow craft often poke along the shoreline, causing loons to flee their nests and leave their eggs exposed. Today, personal watercraft which combine speed with the ability to go anywhere, at any water depth, are causing major problems in some places, as they can disturb both nesting birds and those with young. To date no publications have appeared following research designed to collect and analyze quantitative data on the effects of personal watercraft, a much-needed study waiting to be done.

There have been many misconceptions about loon behavior, initially described by Huxley (1923) in one of his papers on sexual relationships among monomorphic birds. Although it was a 39-page paper, it was based on only 11 days spent observing Red-throated Loons on an island off the west coast of Spitsbergen in early July, while Huxley was on an Oxford University expedition. In it, Huxley described what he called the Pleisiosaur-race ceremony in which running chases between two birds are a major component. He called it courtship, and probably because his description of loons chasing each other was the first to be published, in paper after paper for decades after that, especially in the popular press, conspecific chases among loons of all species have been labeled courtship. However, chasing is aggressive, not sexual, behavior, and may end in physical combat, sometimes to the death. True courtship is quiet, and involves side-by-side swimming, mutual turning-away, synchronous short dives, soft mewing calls, and eventually ends when one bird leads the other to the shore for copulation.

I started banding and color-marking loons here in Minnesota during the 1970's. Even though our methods were crude and labor-intensive, and fewer than 50 individuals were marked, those studies yielded interesting information. Do young stay with their parents through migration and maintain family groups on the wintering grounds? With marked birds, I could say "no" (McIntyre 1975). Young loons from small lakes that support only one breeding pair move to larger lakes shortly after they can fly, where each retains a small feeding locations for one or two months; they then leave on migration together with other young of the year from neighboring territories (McIntyre 1975, 1988). It had also been thought that adults returned to the same territories year after year, and re-sightings confirmed that they do (McIntyre 1974). Minnesota birds stage on Lake Michigan early in fall migration, stop on major reservoirs along the way south, and winter along the Gulf coast of Florida (McIntyre 1973, 1988), all information confirmed from marked birds.

Today, with improved capture methods and a paid team of loon banders, hundreds have been marked and the resulting new studies are disputing many long-held beliefs. Several questions will be answered this afternoon from these recent studies. Do loons really mate for life? Are loons good parents? How do pairs divide their parental care duties? We think we can identify individual males by their yodels; each male sounds different from other males, at least to our ears. A study analyzing yodels from marked birds will be reported.

Because much behavioral work has focused on breeding biology, we sometimes forget that birds live 12 months a year. The breeding season lasts only half a year and the rest of the time birds are doing something else (e.g. McIntyre 1978, McIntyre and Barr 1983, Powers and Cherry 1983, Daub 1989, Haney 1990, Ford and Gieg 1995). Although there have been only a dozen or so field studies on loons outside the breeding season, more are now underway, and today there will be two new papers on non-breeding biology. One describes foraging strategies of wintering Common Loons along the Florida coast and the other, using implanted satellite transmitters, concerns migration routes and ranges.

In the 1800's loons were considered pests, trouble to game fishermen and shot in large numbers. By the turn of century, loons were still being shot for sport. Eaton (1910) stated loons were injurious to fish and frog populations in New York. Forbush (1912), writing of Massachusetts, described tiers of boats with gunners lined up across the channel between Buzzards Bay and Manomet Bay, a favorite route for spring migrants when there was a southwest wind; the men were shooting at migrating loons. Some 50-60 were killed each day, and more than twice that number were wounded and eventually lost. However, only a few years later, Forbush (1925) pressed for a stop to loon shooting, suggesting that the birds may be beneficial to fish by helping to maintain healthy populations.

Brewster (1924) described the shooting of loons from the decks of passenger boats on Lake Umbagog in Maine, a sufficiently common event that the arrival of boats at the docks was said to be announced by the sound of gunfire. Even under today's restrictions, there still is some loon hunting by native peoples in northern Canada and shootings still occur from time to time in other parts of the range. Sometimes this results from the inability of hunters to tell the difference between waterfowl and loons, and occasionally there are still intentional shootings. I recently retrieved a live loon from a New York lake, blinded after being shot through both eyes.

Organochlorines were identified as the cause of mortality and/or lowered reproduction for a wide range of avian species during the 1960's, but loon populations in general were not negatively affected, despite occasional moribund individuals with high contaminant loads (Ream 1976). Significant eggshell thinning did not occur in loons. I compared Common Loon shell thickness from Minnesota eggs I collected in the early 1970's with those collected prior to 1946 (Anderson et al. 1970); although thinning was statistically significant, it averaged less than 10% and was insufficient to hinder normal hatching. In some parts of the range, e.g. northern Saskatchewan, eggshells displayed no thinning (Fox et al. 1980).

Twenty to 25 years ago, the increase of human recreational use of lakes preferred by nesting loons was considered threatening. Boats with motors were of special concern, but canoes and rowboats were thought to be relatively benign. However, field studies showed that canoes and slow fishing boats have the potential to pose even greater threats to nesting loons because they tend to poke slowly along the shoreline. They may force loons off their nests and leave the eggs vulnerable to predators; motorboats generally travel in deeper water away from the shore. Educating the public to the needs of loons and ways in which people and loons can share the same lakes has eased much of that concern, and loons usually adapt to people as long as they are not approached too closely. The greatest threat from recreational use at present is personal watercraft which can maneuver in shallow water and disturb nesters, can separate adults and young on open water, and are fast enough to run over and kill chicks and the occasional adult.

Mercury poisoning has been a health concern in several parts of the world. Attention was initially focused on Minimata, Japan in the 1950's. Later, mercury was recognized as posing problems in other locations, including lakes in the English-Wabigoon River system of northwestern Ontario. It was necessary to close the commercial fisheries at Grassy Narrows, which subsequently changed the character of an entire native community. Evaluation of the effects of dietary mercury on reproduction and reproductive behavior was conducted using Common Loons as the test subjects in the early 1970's (Frank et al. 1983, Barr 1986), and data from those studies have been used as the standard for comparison with mercury loading and the consequential potential impact on loons in other systems. Lead, another heavy metal, has recently been identified as a toxic threat, primarily via its use in fishing gear, which loons ingest in lieu of grit.

Three studies of loon mortality, from Minnesota, Wisconsin, and New England, will be discussed today. We will hear about a complex of causes, including toxins, trauma, abnormalities, and aberrant behavior in birds with known toxic burdens. A major study of mortality on the wintering grounds implicates other factors, including salinity, turbidity, and a fluctuating food base.

We begin with a paper given by a man who has spent a lifetime studying loons and grebes, among other birds, and whose first ornithological paper was published exactly 60 years ago in a 1937 issue of the Auk. Robert Storer of the Museum of Zoology, University of Michigan, will begin our symposium with "Why do loons have fewer parasites than grebes?"

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WHY DO LOONS HAVE FEWER PARASITES THAN GREBES?

ROBERT W. STORER

MUSEUM OF ZOOLOGY, UNIVERSITY OF MICHIGAN, ANN ARBOR, MICHIGAN, 48104

EXPANDED ABSTRACT: For a recent work on the multicellular parasites of grebes (Storer 1999, Misc. Publ. Univ. Mich Mus. Zool. no. 188), I found reports of 249 species of helminths (113 trematodes, 86 cestodes, 13 acanthocephalans, and 37 nematodes) and 25 species of external parasites (12 mites and 13 lice). In a parallel study of the parasites of loons under preparation, I have found reports of but 112 species of helminths (59 trematodes, 22 cestodes, 13 acanthocephalans, and 18 nematodes) and 3 species of external parasites (1 mite and 2 lice). Further search in the literature and reports from current work will raise the number from loons somewhat, but I doubt if the total number of loon parasites will be 25 percent higher; and because of the paucity of knowledge of the parasites from grebes in the Southern Hemisphere, especially South America, where the greatest number of endemic grebe species is found, the total number of grebe parasites can also be expected to increase considerably.

In spite of the incompleteness of the data, several things are evident. First, the degree of host specificity among grebe parasites is much greater than that among those of loons. With the exception of one species in each, the families Amabiliidae and Dioecocestidae, containing 30 and 7 species respectively, consist entirely of grebe specialists (species of parasites only known to occur commonly in members of one taxonomic group of hosts), and none has been found in a loon. An additional 65 species or a total 100 (40 percent) of the species of grebe helminths are considered grebe specialists. In contrast, 16 species (17 percent) of the loon helminths are considered loon specialists. This suggests that the grebes may be an older group than the loons.

So far, 46 species of helminths have been found in both loons and grebes, but none is common in both groups. Of these shared species, 40 are rare parasites of both. Of these, 31 species are generalists (species of parasites that are known to occur commonly in more than one taxonomic group of hosts), 9 are specialists in other groups and rare in loons and grebes, 5 are loon specialists rare in grebes, and 1 is a grebe specialists rare in loons. In these results, there is nothing to indicate that any of these parasites have shared evolutionary histories in the two host groups.

The known external parasites of loons consist of one feather mite of a genus (*Brephosceles*) not found in grebes and two species of the louse genus *Craspedonirmus*, which is unique to loons and not closely related to any other genus in its family. In contrast, some of the 12 species of mites and 13 species of lice found on grebes are the same or are related to species occurring on coots (details in Storer 1999), a situation best explained by crossing over resulting from the frequent physical contact between grebes and coots (including fighting, using the same platforms, and having mixed clutches) resulting from nesting in similar situations and a long history of sympatry. (Both have the greatest variety of species in South America, which is probably the center of evolution of the two groups.)

In summary, loons have approximately one half the number of multicellular parasites known from grebes, 46 species are shared, and those that are, do not indicate a common evolutionary history with that of the grebes. The greater degree of host specificity in grebes suggests that these birds may have branched off the avian stock earlier than the loons.

CAUSES OF MORBIDITY AND MORTALITY IN THE COMMON LOON IN MINNESOTA, 1991-1996

JIMMY PICHNER[1] & PEREGRINE L. WOLFF[1,2]

[1]MINNESOTA ZOOLOGICAL GARDENS, 13000 ZOO BLVD., APPLE VALLEY, MN 55124
[2] PRESENT ADDRESS, WALT DISNEY WORLD ANIMAL PROGRAMS, WALT DISNEY WORLD CO., PO BOX 10000, LAKE BUENA VISTA, FL 32830-10000

ABSTRACT

Between 1991 and 1996, 72 Common Loons (*Gavia immer*) from Minnesota were examined by the personnel of the Minnesota Zoological Garden. Of these 72, 16 injured loons were obtained alive and 56 loons were obtained as carcasses. The results of the gross necropsy included 46 loon deaths due to trauma and 26 loon deaths due to disease. Of the 46 loon deaths due to trauma, 30% (n=14) were directly caused by intraspecific aggression, or spearing by another loon. Adult common loons (n=47) examined in this study had significantly higher levels of mercury in liver, kidney and feather tissue than juveniles and chicks (n=17) $P<0.001$. Mercury levels greater than 3 ppm were found in 65.6% of the loons examined (n=64) and may be a contributing factor to loon mortality in adults where 87.7% of the adults had levels over 3 ppm (n=47). Lead toxicity was found in 4.6% (n=3) of the loons examined (n=64) and does not appear to be a significant cause of death in Minnesota.

INTRODUCTION

Minnesota is the summer home to 10,000 -12,000 common loons (*Gavia immer*) (Strong and Baker, 1991). In this study we examine the mortality and morbidity factors in the Minnesota common loon population, which is similar in scope to a study conducted by Ensor et al. (1992). The primary difference between the Minnesota Zoological Garden (MZG) study and the study conducted by Ensor et al. (1992) is the ability of the MZG to hold and evaluate live, injured loons. Previous studies had been limited to the evaluation of carcasses only.

Specimens were acquired by the MZG with the help of the Minnesota Department of Natural Resources (MNDNR), volunteers, and rehabilitators. The loons were examined on necropsy and a gross cause of death was determined. Correlations between cause of death and heavy metal tissue concentrations were examined. These data when used in conjunction with other similar studies should be instrumental in identifying lakes or regions where high loon morbidity or mortality is occurring.

METHODS

METHODS

Loon Acquisition

Loons were acquired from 1991 to 1996, with the MZG acting as the Regional clearinghouse for dead and injured loons in Minnesota. The MNDNR, LoonWatch volunteers and rehabilitators were instrumental in providing the MZG with 72 common loons from Minnesota. Sixteen loons were alive when acquired and 56 were dead. The breakdown of loons collected in Minnesota, by county, is shown in Figure 1.

Physical Examinations and Necropsies

All live, injured loons acquired by the Minnesota Zoo underwent a complete physical evaluation upon arrival. Birds assessed as unfit were euthanized humanely and immediately examined at necropsy. Live loons were housed in the MZG loon holding facility in the Animal Health Building or housed in the Minnesota Trail beaver pond exhibit until their death. The physical examination of the live loons included body weight, gross body and feather condition, age, evaluation of all body systems, a radiograph, complete blood count, serum chemistry panels, and when possible blood mercury and lead assay. Live, injured loons were maintained at the MZG for exhibition and educational purposes until their death at which time they were submitted for necropsy.

All dead loons acquired by the MZG were stored in freezers and necropsied as soon as possible to minimize tissue changes due to autolysis.

Tissue Analysis

A complete set of tissue samples were taken for histopathology on all loons. These tissues were preserved in buffered 10% formalin and submitted for analysis to Dr. Mark Pokras at Tuft's University. Brain and nerve tissue were collected for heavy metal analysis and submitted to Dr. Alexander delaHunta at Cornell University.

Heavy Metal Analysis

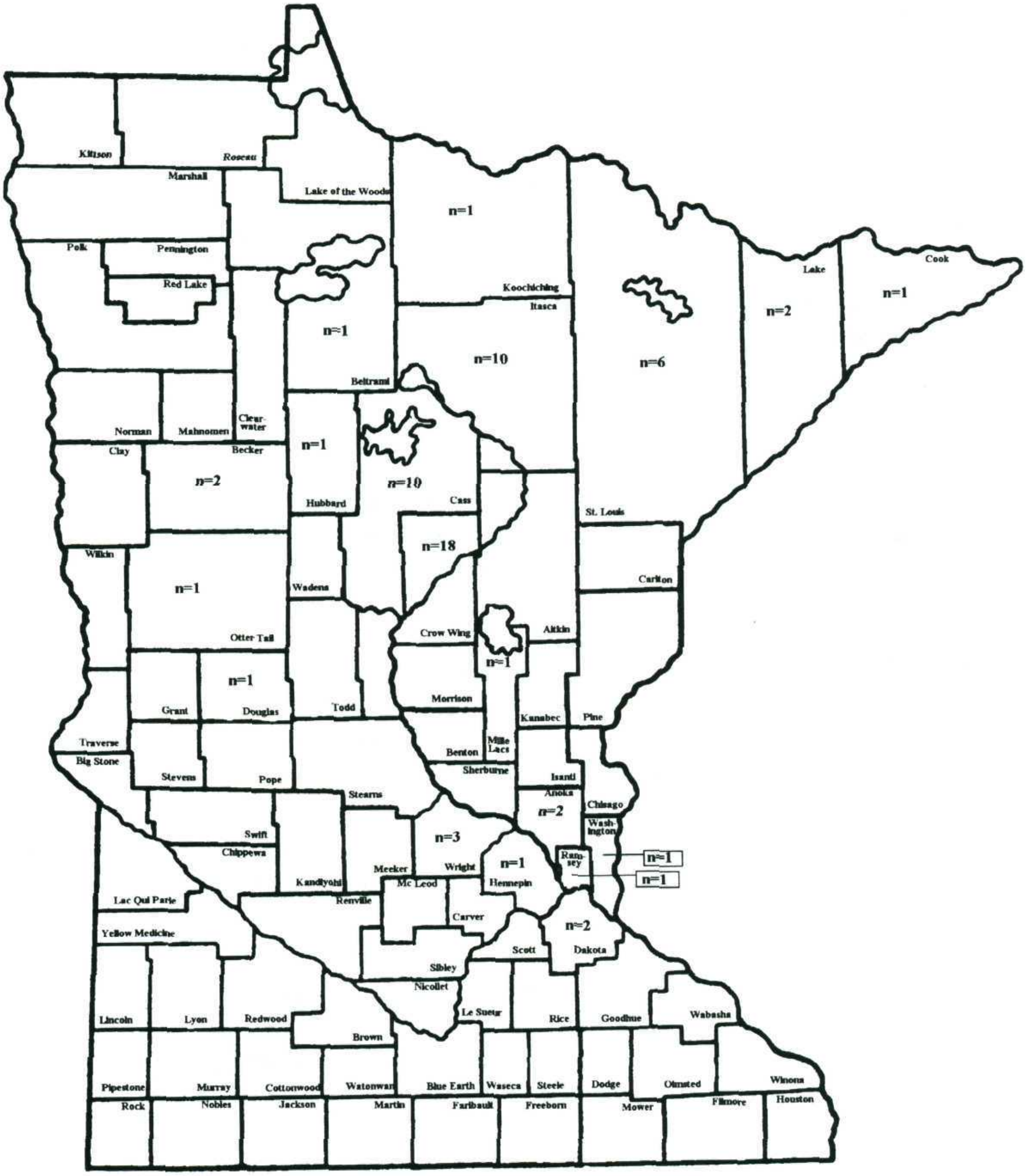
Blood mercury assays were performed on five of the live loons acquired by the zoo. Whole blood samples were collected and samples were analyzed by Michigan State University College of Veterinary Medicine, using anodic stripping voltammitry. Control samples are run through Wisconsin proficiency testing, calibrating against known standards before each test.

Blood lead assays were performed on seven of the live loons acquired by the zoo. The procedure involved drawing 50 ul of whole blood using Na, Heparin or EDTA as an anticoagulant. Samples were analyzed by the University of Minnesota Veterinary Diagnostic Laboratory, using the graphite furnace atomic absorption method.

Samples of liver and kidney tissues and feathers were collected and frozen at -70° C for heavy metal analysis. Primary, secondary, breast and scapular feathers were collected. Frozen tissues were submitted to the Animal Health Diagnostic Laboratories at Michigan State University. Liver and kidney tissues and feathers were analyzed for concentrations of mercury and lead using inductively coupled argon plasma (ICP) emission spectroscopy (Thermo Jarrell Ash Polyscan 61E). Mercury concentrations below 2 ppm were analyzed by cold vapor atomic absorption spectroscopy (CV-AAS) and concentrations above 2 ppm were random verified using the same technique (regression analysis: $y=0.927x+0.577$; $r=0.997$; Bland/Altman analysis: mean difference=0.15 ppm; mean+2S=1.47, mean-2S=-1.17 ppm).

Standardization tests by NBS are run on each batch of tissues against known standards. Heavy metal concentrations in this paper are recorded in ppm wet weight for liver and kidney tissues and in ppm dry weight for feathers (Appendix 1).

FIGURE 1. Distribution by county of 65 Common Loons collected in Minnesota, 1991-95.



Aspergillosis Analysis

Elisa tests were run to test for the presence of the Aspergillosis antibody in 5 of the loons in this study. The test was developed for raptors by The Raptor Center at the University of Minnesota. The test required 0.5 - 1.0 ml of plasma or a minimum of 300 ul of plasma. Species specific conjugates, labeled with horseradish peroxidase, were made up either in rabbits or goats against plasma from domestic turkeys, pooled psittacine plasma or pooled falcon (primarily gyrfalcon and peregrine falcon) plasma. The test is conducted in a 96-well polystyrene microtiterplate plate which is coated with *Aspergillus* antigen, a filtered, dialyzed, lyophilized, and reconstituted product from week-old cultures of *Aspergillus fumigatus* grown in broth.

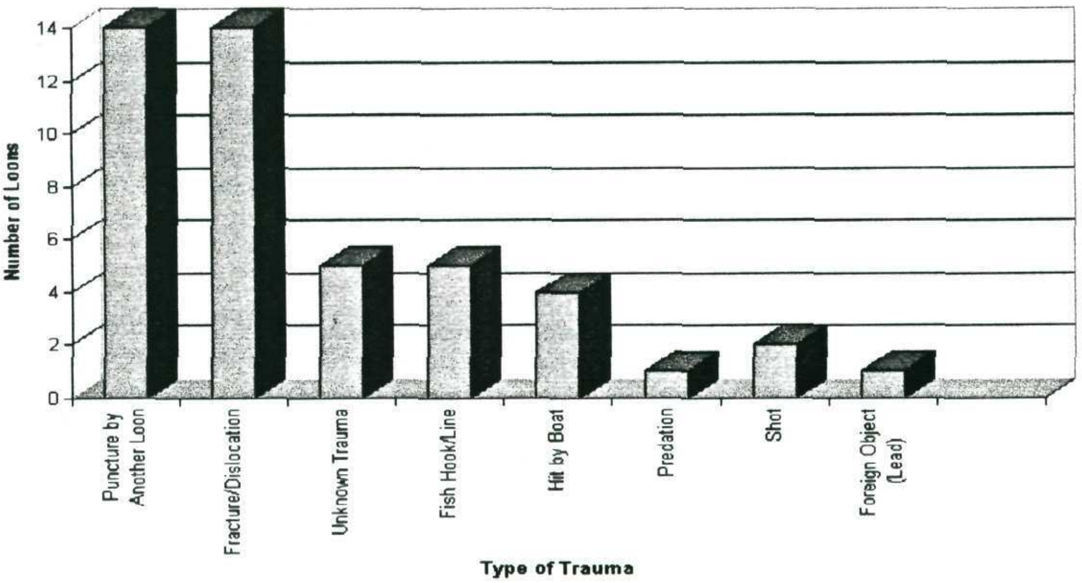
Statistical Analysis

Tests for statistical significance in mercury and lead concentration between tissues, age classes, genders, and cause-of-death were performed using an unpaired student's t-test using 99% confidence intervals and ANOVA techniques. Systat, version 5.03, Systat Inc. was used for all statistical analysis.

RESULTS

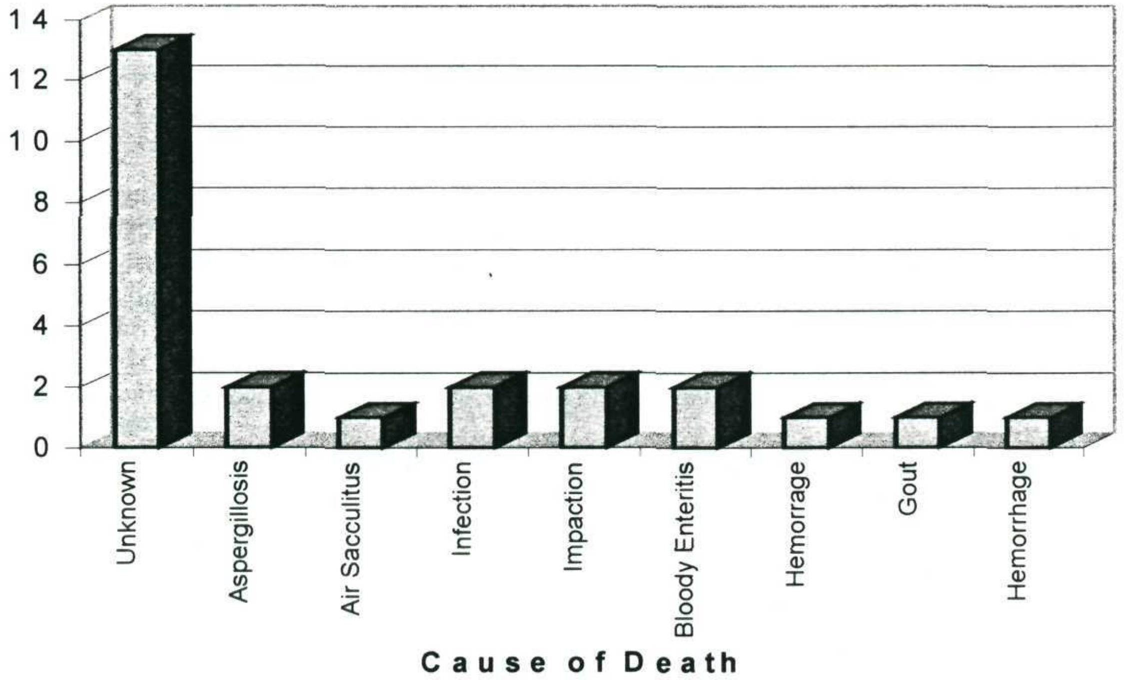
The loons were placed in three age categories based on plumage assessment during necropsy. Chicks were classified as <80 days of age based on a comparison to photographs of a known age loon (Pichner, Unpublished). All birds >80 days of age and showing the typical juvenile plumage were classified as juveniles. Birds in typical breeding plumage or in basic plumage were classified as adults. The adults in basic plumage typically have several lesser coverts remaining from the breeding plumage. The age breakdown of the 72 loons in the study included 9 chicks, 11 juveniles, and 52 adults. The sex breakdown of the study population included 34 females, 31 males, and 7 loons of unknown sex.

FIGURE 2. Breakdown of trauma related deaths in Common Loons (n=46).



During necropsy, the cause of mortality was determined and listed as either trauma related or disease related. Any mortality in which direct physical trauma was not noted on necropsy was listed as disease. There were 46 trauma related causes of death and 26 disease related causes. Deaths due to trauma (n=46) were categorized as follows: intraspecific aggression, fractures or dislocations of unknown cause, unknown trauma, entanglement in fishing line or fish hooks, boating accidents, predation, gun shot, and lead poisoning (Figure 2). Deaths due to disease (n=26) were categorized as follows: Aspergillosis, air sacculitus, infection, bloody enteritis, impaction, hemorrhage, lead poisoning, parasitic load, gout and unknown (Figure 3).

FIGURE 3. Breakdown of disease related deaths in Common Loons (n=26)



Mercury Concentrations

Liver tissue, kidney tissue, and feathers were analyzed for the presence of mercury residues. Chick mean mercury concentrations were 4.69 ppm (n=3) for feathers, 1.37 ppm (n=6) for kidney tissue, and 1.53 ppm (n=8) for liver tissue. Juvenile mean mercury concentrations were 5.58 ppm (n=9) for feathers, 3.36 ppm (n=9) for kidney tissue, and 3.45 ppm (n=10) for liver tissue. Adult mean mercury concentrations were 10.45 ppm (n=46) for feathers, 9.08 ppm (n=41) for kidney tissue, and 10.86 ppm (n=45) for liver tissue.

Age was found to be a significant factor in the observed concentration of mercury. Adults had significantly higher concentrations of mercury than either juveniles or chicks in feather, kidney and liver tissue (P<0.001). Only one juvenile (n=10) and no chicks (n=7) had mercury concentrations in liver or kidney >3 ppm, while 41 adults (n=47) had mercury liver and kidney concentrations >3 ppm.

No significant difference was found between the mercury concentrations of juveniles and chicks in feather, kidney or liver tissue. Three chicks had increased feather mercury concentration, but fairly low liver and kidney mercury concentrations. Two of these chicks were approximately 21 days old and were picked up in Wright County after being speared by another loon pair. The third chick was approximately 45 days old and was picked up with a fractured wing in Crow Wing County.

No statistical difference was detected in the mercury concentration between male and female feather, kidney or liver tissue. This was true regardless of the age class considered. There is no statistically significant difference in the liver, kidney or feather mercury concentrations between trauma related deaths and disease related deaths.

Lead Concentrations

Blood lead assays were performed on seven of the live loons acquired by the Minnesota Zoo. All seven of the assay results were 0.1 ppm or less.

Feather, kidney and liver tissue from 65 carcasses were analyzed for lead residues. Three birds (5%) had concentrations of lead in their liver that ranged from 19.1 to 35.2 ppm and kidney from 68.1 to 120 ppm. Feather lead concentrations ranged from 1.34 to 24.5 ppm. All three loons had visible radiodense material. Lead fishing sinkers were removed from the urodeum of one loon and the ventriculus of the other two.

No difference in mean lead liver, kidney and feather concentrations was apparent between males and females or between age classes. Lead levels behave as a binary variable, either you have it or you don't. The small number of affected birds did not allow a statistical analysis of age or sex related differences. Appendix 1 lists the lead concentrations for liver and kidney tissues and feathers for all loons in this study.

Aspergillus sp.

The results of the *Aspergillus* sp. titers ranged from 0.019 to 0.136 and were considered negative. Three of the five loons tested had titers below 0.050 and died from causes other than aspergillosis. The remaining two loons that were negative for aspergillosis died of the disease within 10 days of blood collection for the test. In addition to the two loons listed here that tested negative and died of aspergillosis, eight other loons in the study population were diagnosed during necropsy as having aspergillosis.

DISCUSSION

Mercury Toxicity

All of the loons in this study had detectable mercury concentrations in tissues and feathers. Liver and kidney mercury concentrations of greater than 3.00 ppm made up 65.6% (n=64) of this study population. These results agreed with Ensor et al. (1992) who found that 62% of the liver mercury concentrations in the Minnesota loons examined were greater than 3.00 ppm. Hen pheasants with liver mercury levels of 3-13.7 ppm in the liver were observed to have a significant decrease in hatchability

(Fimreite, 1971). The levels observed in loons in this study are well within this range and may be a contributing factor in the deaths of the birds examined.

Barr (1986) concluded that mercury concentrations of 2 to 3 ppm in adult loon brain tissue and eggs may negatively affect reproductive success and territorial and nesting behavior. Research on common loons and other wildlife suggest that increased concentrations of inorganic mercury and its more toxic form of organic methyl mercury may affect loon populations through physical contamination as well as through reduced reproductive success (Alexander 1985, Belant and Anderson 1990, Heinz 1979, Schuehammer 1991, Wiener 1987). Scheuhammer (1991) concluded that mercury concentrations necessary to cause reduced reproductive success are 1/5 of the contamination concentrations that produce external signs of toxicity. External signs of mercury toxicity include vision impairment and muscle coordination impairment (McIntyre, 1988). For loons, who obtain food by sight, and depend on their speed and agility for survival, these conditions can prove to be fatal. Mercury toxicity was implicated in 1983 when a large die-off of common loons occurred off the coast of Florida (Graham, 1984). The impact of high mercury concentrations in loon tissue and its relationship to loon mortality and morbidity is poorly understood. It is impossible to determine whether high mercury concentrations in loon tissues directly result in death. Forrester, et.al. (1997) postulated that the impact of mercury concentrations may not be as a predisposing factor to disease and trauma, but may instead be one of a combination of factors causing debilitation and death in the loon.

This study found no significant difference in mercury concentrations of loons dying from trauma or disease. These results do not concur with Ensor et al. (1992) who concluded that the mercury concentrations were higher in loon deaths due to disease than injury.

Mercury and Age Class

Adult loons had significantly higher concentrations of mercury in their livers, kidneys, and feathers than the concentrations of juveniles. These results agree with many of the published studies that adult loons have significantly higher mercury concentrations than immature loons (Frank et al. 1983, Barr 1986, Pokras 1992, Burger 1994).

It appears, however, that at least some of the chicks examined were exposed to high concentrations of mercury. Barr (1986) showed that chicks had a higher percent methyl mercury concentration by weight than adults in all tissues collected. Mercury toxicity is a chronic problem in adults, but it may be a more acute problem in chicks (Barr, 1986). The feather mercury concentration in chicks (4.58ppm) was not statistically different than other age classes in this study. It is possible that due to the frequent molts in chicks, most of the mercury was being shunted into the feathers, allowing the liver and kidney mercury concentrations to remain low.

Mercury and Gender

Male and female loons did not have significantly different mercury concentrations in kidneys, liver or feather tissue. These results agree with Ensor et al. (1992), Barr (1986) and Burger (1994) whose studies showed no significant gender difference for mercury accumulation. Evers et al. (1996) did indicate a marked gender difference in mercury accumulation; males showed a 20-37% higher feather mercury than females, and the authors suggest that this is due to mercury deposition in shells and embryos by the females and by prey selection.

Mercury Blood Levels

The blood mercury data from this study are similar to those found by Evers et al (1996) and Pokras et al (1992). Evers recorded blood mercury concentrations with a range of 0.9-1.6 ppm with one loon from Wisconsin with a level of 2.4 ppm. Our data ranged from 0.92-1.16 ppm. Pokras et al. (1992) recorded serum mercury levels ranging from 0.14-5.52 (n=14).

Lead Toxicity

The lead toxicity results of this study (4.6%, n=4) were less significant than other documented studies. Ingested metal was found to be a problem in 67.5% of adult loons in the study by Pokras et al (1992). Ensor et al (1992) found lead poisoning to be a cause of 17% of the deaths in that study population. Lead poisoning does not appear to be a major cause of loon mortality in Minnesota.

Intraspecific Aggression

The most interesting finding in this study was the large number of trauma deaths due to spearing by other loons (n=14, 30%). Ten of the 14 loons (71.3%) that died of spearing had liver mercury concentrations above 3.00 ppm wet weight. Loons impaired by high mercury concentrations may be more susceptible to attack by other loons. Unpaired loons are constantly testing territorial birds and an individual that is hampered by elevated mercury concentrations may not be able to defend itself or its territory successfully. Intraspecific aggression between loons is not well documented, however and more research is necessary.

This study population does not represent a random sampling of the loon population of Minnesota, as all loons acquired were dead or dying. The mercury concentrations found in the common loons in this study underscore the need to better understand the impact mercury has on the common loons health. This study does indicate that mercury contamination may be having an adverse effect on the health of common loons. This study, however, does not take into account the selenium concentrations found in the loons. High selenium levels may provide a protective effect from mercury. Lead poisoning does not appear to be a significant mortality factor in Minnesota loons at this time.

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APPENDIX 1. Summary of Common Loon heavy metal levels (ppm, wet weight) and gross cause of death.

Loon	Age	Sex	County	Lake	Hg-Feathers	Hg-Kidney	Hg-Liver	Pb-Feather	Pb-Kidney	Pb-Liver	Gross Death
1	A	F	Crow Wing	Big Trout	8.63		5.8	<1.78		0.49	Trauma
2	A	F	Cass	Agate	6.32		5.9	<2.38		0.49	Disease
3	A	M	Crow Wing	Gladstone	11			<3.45		.	Disease
4	A	M	Crow Wing	Cross	15.4		6.54	<1.27		0.49	Trauma
5	J	F	Itasca	Pokegama			2.02			0.5	Disease
6	A	M	Itasca	Bass	.		12.6			7.8	Disease
7	A	F	Douglas	Miltona	6.68	6.8	20.03	<.992	0.49	0.49	Disease
8	A	?	Becker	Tulaby			.				Disease
9	C	M	Wright	Lake John	4.9	2.01	1.97	<1.01	0.5	0.49	Trauma
10	C	F	Wright	Lake John	5.02	1.98	1.95	<5.56	0.49	0.48	Trauma
11	J	M	Crow Wing	Serpent	1.29	1.94	2	<1.00	0.5	0.49	Disease
12	J	F	Crow Wing	Mille Lacs	1.44	1.99	1.96	<1.01	0.49	0.48	Trauma
13	A	F	Crow Wing	Mille Lacs	9.96	20.2	9	24.5	120	35.2	Trauma
14	C	F	Crow Wing	Rush	4.15	1.98	2	<.996	0.49	0.49	Trauma
15	A	M	Crow Wing	Bay	9.17	14.8	22.1	<.963	0.49	0.5	Trauma
16	A	F	Cook	Mink	9.96	7.36	30.02	<.994	0.5	0.5	Trauma
17	J	F	Crow Wing	Rush	1.88	1.99	2	1.6	0.49	0.5	Disease
18	A	M	Crow Wing	Hubert							Trauma
19	A	M	Cass	Leech	18.1	2.94	4.65	<.988	0.48	0.51	Disease
20	A	F	Cass	Woman	7.18	5.95	8.2	<1.01	0.45	0.5	Trauma
21	A	M	Cass	Island	8.01	19.1	2	<1.95	0.49	0.5	Trauma
22	A	F	Crow Wing	Mille Lacs	6.66	2	2.1	<2.00	0.5	0.49	Disease
23	A	F	Ottertail	Eagle	5.7	2		<2.43	0.5		Disease
24	A	M	Itasca	Pokegama	1.55	2.7	2	<1.66	68.1	19.1	Trauma
25	A	M	St. Louis	Big Sturgeon	12.3	18.4	3.8	<1.80	0.5	0.5	Trauma
26	C	F	Lake	Basswood		2	2		0.5	0.58	Trauma
27	A	M	Cass	Mull	13.9	5.8	4.3	<2.21	0.5	0.49	Trauma
28	A	F	Cass	Boy	8.99	2.1	5.7	<2.42	0.5	0.49	Trauma
29	A	M	St. Louis	McCormick	14.8	10	10.9	<1.75	0.49	0.5	Trauma
30	A	M	Washington	Long	16.1	10.6	20.7	<2.23	0.5	0.5	Trauma
31	C	F	Cass	Cass			2			0.49	Disease
32	A	M	St. Louis	Clear	20.9	16.3	17.2	<1.95	0.5	0.49	Trauma
33	A	M	Cass	Cass	12.6	7.8	21.6	<1.94	0.5	0.49	Trauma
34	A	?	Dakota	Kingsley							Trauma

Loon	Age	Sex	County	Lake	Hg-Feathers	Hg-Kidney	Hg-Liver	Pb-Feather	Pb-Kidney	Pb-Liver	Gross Death
35	A	M	Koochiching	NA/International Falls	3.76	2	5.2	<1.26	0.5	0.5	Disease
38	A	F	Itasca	Pokegama	11.9	5.2	5.5	<1.59	0.5	0.5	Trauma
39	A	M	St. Louis	Murphy	10.2	8.4	9.8	<.804	0.5	0.49	Trauma
40	A	F	Hubbard	Fishhook	8.8	12.8	39.6	<1.30	0.5	0.5	Disease
41	A	?	Cass	Cass	12.6	7.8	21.6				Disease
43	A	?	Anoka	Coon	9.89	7.5	4.3	<1.25	0.59	0.48	Disease
44	A	F	.	.	9.1	5.6	8.3	<1.53	0.61	0.56	Disease
6605	C	F	Wright	Twin			2			0.5	Disease
7678	A	F	Crow Wing	Horseshoe	8.54	5.8	6.6	<.982	0.51	0.5	Trauma
7679	A	F	Crow Wing	Upper Mission	5.55	3.9	3.6	<1.01	0.5	0.49	Trauma
7970	J	F	Mille Lacs	NA/Princeton	2.33	2	2	<1.36	0.5	0.49	Trauma
7262	A	M	Dakota	Black Dog						.	Disease
6760	A	M	Crow wing	Partridge						0.49	Disease
6640	J	F	Crow Wing	Perch							Trauma
45	A	M	Itasca	Spider	9.23	19.5	16.3	<1.34	94.6	33.7	Disease
46	A	M	Itasca	.	4.37		1.6	<1.76		0.47	Trauma
47	A	?	Itasca	Bass Lake	6.52	9.7	5.1	<1.21	0.68	0.49	Trauma
48	A	M	Lake	White Iron	17.9	11.2	15.1	<1.03	0.52	0.47	Trauma
49	A	M	Crow Wing	Beach Bear	13	3.4	7.2	<1.61	0.55	0.47	Trauma
50	A	F	Crow Wing	Meyer	8.04	5	7.5	<1.91	0.59	0.51	Disease
51	A	F	Crow Wing	?	13.8	4.8	4.5	<1.44	0.55	0.46	Trauma
52	J	F	Migrant	Iowa	2.24	0.61	0.65	<1.42	0.47	0.4	Trauma
53	J	F	Hennepin	Minnetonka	6.1	0.86	1.8	<1.64	0.51	0.49	Trauma
54	A	F	.	.	18.3	26.8	38.3	<1.61	0.54	0.45	Trauma
55	A	F	.		9.76	6.3	7.3	<1.45	0.52	0.45	Trauma
8247	A	F	Cook	Vermillion	16.3	9.5	8.5	<1.92	0.6	0.58	Disease
RR1	A	F	Becker	Floyd	12.7	12.6	7.7	<1.50	0.58	0.56	Trauma
8298	A	M	Ramsey	.	8.13	1.8	1.7	<1.21	0.52	0.42	Trauma
8326	A	M	Itasca	Rice	7.86	4.1	1.5	<1.44	0.55	0.42	Disease
8613	A	F	Table 1.	Dark	7.59	3	8.1	<1.41	0.63	0.51	Trauma
8630	A	F	Anoka	Pickerel	8.65	6.5	5.6	<1.53	0.6	0.47	Trauma
8835	J	?	Kandiohyi	Green	23.6	18.2	18.8	<1.31	0.62	0.55	Trauma
8892	J	F	Wright	Silvia	3.18	0.89	1.6	<1.38	0.61	0.52	Trauma
8906	A	M	.	.	14.3	34.3	34.6	<1.51	0.72	0.54	Trauma
A	C	M	Itasca	Pokegama	.	0.11	0.16		0.55	0.51	Trauma
B	C	M	Itasca	Pokegama	.	0.13	0.2		0.55	0.47	Trauma
C	J	F	Wright	Twin	8.13	1.8	1.7	<1.30	0.6	0.55	Trauma

MORTALITY IN BREEDING COMMON LOONS: HOW SIGNIFICANT IS TRAUMA?

ROSE MICONI[1], MARK POKRAS[1], & KATE TAYLOR[2]

[1] TUFTS WILDLIFE CLINIC, 200 WESTBORO ROAD, N. GRAFTON, MA 01536-1895
[2] LOON PRESERVATION COMMITTEE, P.O. BOX 604, MOULTONBORO, NH 03254

ABSTRACT

From 1989-1996, 227 Common Loons (*Gavia immer*) found dead or moribund on fresh water lakes in New England were examined as part of a mortality study. We discuss the large percentage of loon mortality due directly or indirectly to human activities. A summary of the necropsy analysis indicated that 89 loons had died from trauma due to gunshot, impacts from boats and personal watercraft, fishing gear, and plastic entanglement. We also discuss mortality from "natural" causes including infectious disease, intraspecific aggression, and parasites. Organic contaminants and metals were elevated in New England loons. Possible links between contaminants, disease and trauma are discussed.

INTRODUCTION

New England Common Loons are among the largest birds in the genus *Gavia* with adults weighing up to 6.5 kg in our study. Their long-term fidelity to breeding sites facilitates field studies. Common Loons have been designated endangered, threatened or species of special concern in most New England states.

New England lakes have long been an attraction for recreational activities such as boating and fishing. As these activities increase with growing populations so do chance encounters between loons and lake users. For example, since 1976 New Hampshire has experienced a 38.5% increase in human population (New Hampshire Office of State Planning, pers. comm.). This has been associated with a concomitant increase in lakeshore development and recreational use. Boating licenses have increased by 99.7% from 1976 thru 1999 (New Hampshire Marine Patrol 1997). Increases in boating activities, horsepower and boat speeds have created greater risks for loons. The newest threat to loons has been personal watercraft. Their lack of a propeller and shallow draft have allowed access to water previously inaccessible to motorized craft. Loon family groups utilize shallow water for brooding areas (McIntyre 1988, Strong 1986), and are at risk of being struck or separated by personal watercraft.

Another problem for loons on these populated lakes is an increase in predators. As human populations rise, so does the availability of food waste and garbage. This has attracted opportunistic species, such as gulls (*Larus* spp.), Common Ravens (*Corvus corax*), American Crows (*Corvus brachyrhynchos*), and raccoons (*Procyon lotor*), which prey on loon eggs and chicks (McIntyre 1977, Sutcliffe

1980). As pressures on loons become greater, reproduction may decrease and birds may abandon breeding sites. In this study we investigated the proportions of loon mortality due to both anthropogenic and natural causes.

METHODS

From 1989 to 1996, 227 Common Loons found dead from all New England states were sent to Tufts Wildlife Clinic for necropsy. All carcasses were accompanied by biological collection sheets containing the location of the lake from which the loon was collected, date, nearest town, and collector's name(s). Collectors also regularly provided observations on causes of mortality. Upon arrival, birds were assigned unique identification numbers, radiographed, and weighed.

For the purpose of the present analysis we included only adult and chick age classes. Birds were aged as adults if we found white-spotted feathers of breeding plumage anywhere on the body. Birds were aged as chicks if they were preflighted and found on their natal water bodies. Body condition was evaluated based on physical characteristics including weight, amount of body fat, feather wear and abundance of parasites.

If carcasses were received within 48 hours of death, necropsies were performed immediately. If carcasses could not be received within 48 hours, specimens were frozen. Loons were examined externally at the time of necropsy. Measurements of the tarsus, culmen and bill depth were recorded on necropsy forms. Tissues from each organ were saved in formalin and submitted for histopathology. When gross lesions were present, they were also processed and examined. Liver, blood clot and brain samples were removed and placed into toxicologically clean jars (I-Chem Co. New Castle, DE) for contaminants testing. Stomach contents were also preserved. Sex was determined by examination of the gonads. Loon cadavers were then labeled, placed in body bags, frozen, and sent to Northeastern University to be prepared as museum specimens.

Based on the history provided and necropsy findings, birds dying traumatically were placed into one of three categories: boat trauma, loon trauma or other trauma.

1) Boat trauma: birds had evidence of massive blunt trauma with fractures of wings, spine and/or skull. There was often extensive bruising and internal bleeding (Table 1).

2) Loon trauma: bruising and lacerations on the neck and back of the head and/or sharp punctures to the sides and ventrum of the torso were considered diagnostic of attacks by other loons (Table 1).

3) Other trauma: multiple causative agents are included such as monofilament entanglement, ingestion of fishing gear injuring birds internally, gunshot, and "natural" causes (Table 2).

TABLE 1. Trauma from boats (including personal watercraft) and other loons

Trauma Type	Adult-Female	Adult-Male	Adult-Unknown	Chick-Female	Chick-Male	Chick-Unknown	Total
Boats	6	5	0	7	9	5	32
Loons	2	2	0	4	7	7	22
Total	8	7	0	11	16	12	54

RESULTS

Major Pathological Findings

Of the 227 loons examined, 89 died from traumatic causes. In many cases, one specific cause of mortality was determined at necropsy. In other cases, traumatized loons had additional problems such as heavy parasite burdens, aspergillosis (a fungal respiratory disease), or fractures that may have predisposed them to trauma.

Thirty-two birds died from being struck by boats or personal watercraft (Table 1). Of these, eleven were adults from freshwater lakes (5 males, 6 females). Of these eleven, four had aspergillosis, and three had lead fishing gear in their gizzards as well. Twenty-one chicks were struck and killed by boats (7 female, 9 males, 5 unknown) and did not have prior debilitating conditions before being struck.

TABLE 2. Predisposing factors for traumatic deaths.

Trauma Type	Adult-Female	Adult-Male	Adult-Unknown	Chick-Female	Chick-Male	Chick-Unknown	Total
Shot	3	0	0	0	0	0	3
Fishing Gear	1	3	0	0	0	0	4
Plastic	0	0	1	1	1	0	3
Lead	3	2	0	0	0	0	5
Infections	5	3	0	1	4	2	15
Parasites	0	2	0	0	1	0	3
Predation	0	0	0	0	1	1	2
Total	12	10	1	2	7	3	35

Twenty-two birds were killed by other loons (Table 1). Some of these birds were observed being attacked or killed by adult loons in the field. Additional birds were classified in this category due to

Twenty-two birds were killed by other loons (Table 1). Some of these birds were observed being attacked or killed by adult loons in the field. Additional birds were classified in this category due to bruising and lacerations on the neck and back of the head and/or sharp punctures to the sides and ventrum of the torso diagnostic of attacks by other loons. Only four of the 22 were adults (2 male, 2 female) and one of these, a male, also had aspergillosis. The remaining 18 birds were chicks (7 male, 4 female, 7 undetermined sex).

The final trauma category contained birds which died from other causes: (Table 2) monofilament entanglement, ingestion of sharp fishing gear, gunshot, or disease. Twenty-four of these birds were adults (11 males, 12 females, 1 undetermined) and 12 were chicks (7 males, 2 female, 3 undetermined sex).

DISCUSSION

It is significant that 39% (89 of 227) of loon mortality on New England lakes was due to trauma. Anthropogenic trauma accounted for 45% of these (40 of 89). Another 25% (22 of 89) were killed by conspecifics. We will examine each major category of trauma and discuss the preexisting conditions that may contribute to traumatic deaths.

Boat Trauma (11 adults, 21 chicks)

Although several loons were observed being struck by boats or personal watercraft, most of our diagnoses were based on a predictable pattern of massive blunt trauma. Only one adult in our sample showed evidence of having been struck by a propeller. It is difficult to quantify the extent to which boat trauma may be accidental (due to increased speed, or boating at night), or malicious attack. However, in at least two cases, personal watercraft were observed to have chased loons extensively before striking them.

Loon Trauma (4 adults, 18 chicks)

Loons are large, strong birds with impressive bills. A certain amount of intraspecific aggression is expected, this known as agonistic behavior. Encounters between loons, such as in the case of aggressive conflicts on territory boundaries or intrusions with the purpose of usurping the territory, are normal. It is when these conflicts result in death to either the territory holder or intruder that individual fitness can be investigated.

Assuming such intraspecific killing is pathological, two hypotheses can be made based on the data from our study. First, those birds doing the killing are hyperaggressive, and second, that the loons being killed are behaving abnormally, predisposing them to attacks. Such behavior might both attract aggressive responses from territory holders, and make it more difficult for the impaired birds to escape from attackers. Neurotoxins (e.g. mercury), or preexisting pathologies (infections, injuries, etc.) may affect behavior in this manner. Current studies may help illuminate these questions.

Other Trauma (23 adults, 12 chicks)

Although 20 of the 227 adult birds in our study had ingested fishing hooks, we observed clinically significant trauma in only 1 bird. Such trauma can lead to secondary infections or otherwise weaken birds, predisposing them to other causes of mortality (Table 2).

Another hazard related to fishing is entanglement in monofilament fishing line. Monofilament can tangle around wings, legs or bills impairing feeding and mobility and leading to death. In this study four loons died directly from monofilament entangled around wings and bill (Table 2).

Loons are regularly shot. In our study three birds died from gunshot. More loons live with lead or steel pellets in their tissues. Gunshot can also result in fractures or soft-tissue injuries significant enough to impede normal flight or diving. These birds often perish prematurely from other causes including predators, boat collisions and infectious disease (Table 2).

Relatively little is known about predation on loons, since chicks or adults taken by predators are rarely found. Thus, in our study, this number is probably significantly under-represented. We have encountered injuries to two chicks, which appear to have been inflicted by bites from mammalian predators. One chick had infected bite wounds bilaterally beneath the wings. A second chick had two 1 cm wounds penetrating into the body cavity.

Predisposing Factors

This category enumerates factors that could cause loons to be more susceptible to various forms of trauma. We have noted that sick or injured loons often beach themselves, exposing them to predation or human interference.

Some loons were debilitated in some manner before being traumatized. Twenty-three adults and 12 chicks exhibited disease, lead toxicosis or other problems that appeared to have predisposed them to trauma (Table 2).

We know that loons ingest lead fishing gear (Pokras & Chafel, 1992). They may be doing this when they ingest stones to aid in their digestion or when swallowing a sinker or jig head attached to an escaped fish. Lead toxicosis is the result of lead entering the gizzard where a combination of stomach acids and abrasion breaks down the metal, which is absorbed into the blood stream (Cook and Trainer 1966, Clemens et al 1975). Lead is a potent neurotoxin, which may cause birds to react more slowly to a variety of dangerous stimuli (Hunter and Wobeser 1980). Effected loons have been observed to be less mobile, less reactive to stimuli and less likely to dive as frequently or for as long a time. This may predispose them to collisions with boats, personal watercraft or predation.

Finally, a few loons in this study had heavy parasite burdens in addition to traumatic injuries (Table 2). The parasites weakening them and predisposed birds to trauma. Unfortunately in most cases specimens arriving for necropsy were too autolysed to make this determination (Table 2).

CONCLUSIONS

It can be concluded from our data that 45% of the mortality from trauma in New England loons was directly due to anthropogenic factors. Additionally, it is possible that such factors as contaminants or stress alter birds' behavior or immunocompetence and further predispose them to trauma and infectious disease. Thus, loons may be victims twice; first when they are compromised by some predisposing factor, and second when trauma is the ultimate cause of death.

The Common Loon is an excellent indicator species for anthropogenic perturbations in aquatic ecosystems. As the human population grows, we must take steps to alter the public's behavior and to reduce stressful interactions on loon breeding lakes. Even small changes in the way we use lakes that support Common Loons will help insure the continuation of breeding loons on New England lakes.

ACKNOWLEDGMENTS:

We would like to thank all the biologists at The Loon Preservation Committee of New Hampshire who have been instrumental in collecting data on loon breeding behavior and reproductive success. We would also like to thank the biologists of Biodiversity Research Institute, for their efforts on banding and blood collection. Judy Walker, staff naturalist for the Maine Audubon Society, has done a wonderful job of collecting carcasses for necropsy and educating the public about Common Loons. We would especially like to thank veterinary students including Inga Sidor, Christopher Jordon, Holly Haefele and Amina Johnson for all their participation in this study. Without the support of the U.S. Fish & Wildlife Service, Maine Division of Inland Fisheries & Wildlife, New Hampshire Fish and Game Department, Massachusetts Division of Fish and Wildlife, Vermont Department of Fish and Wildlife, Vermont Institute of Natural Science, and other cooperating agencies this work would never have been possible.

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LOCAL VARIATION IN FORAGING STRATEGIES EMPLOYED BY WINTERING COMMON LOONS

LUCY S. VLIETSTRA

STATE UNIVERSITY OF NEW YORK, COLLEGE OF ENVIRONMENTAL SCIENCE AND FORESTRY, SYRACUSE, NY 13210 PRESENT ADDRESS: 321 STEINHAUS HALL, DEPARTMENT OF ECOLOGY AND EVOLUTIONARY BIOLOGY, UNIVERSITY OF CALIFORNIA, IRVINE, CALIFORNIA, 92697.

INTRODUCTION

Differences in foraging behavior among species are often due to differences in morphology and life history (Maurer 1996), whereas geographic differences in foraging behavior within species are often attributed to variation in resource availability (Schoener 1971, Cairns 1987). Intraspecific foraging behavior may also vary locally, but causal factors may be more difficult to identify because they may be related to fine-scale differences in resource availability, intrinsic differences among individuals, or both (e.g., Van Buskirk and Smith 1989, Bosakowski and Smith 1996). Local differences in intraspecific foraging behavior may lead to differences in energy intake, reproductive success, or survivorship among individuals; therefore, knowledge of factors affecting differences in foraging behavior may clarify the role of individual variation in population dynamics (Polis 1984).

Common Loons (*Gavia immer*) exhibit variation in foraging behavior across their winter range. In Rhode Island, foraging loons are primarily solitary, nonaggressive, and occasionally form small groups (Daub 1989, Ford and Geig 1994), while in Virginia, loons defend individual feeding territories (McIntyre 1978). In North Carolina and Florida, foraging strategies vary locally: loons forage solitarily and in single- and multispecies groups that may include up to 200 loons (Jodice 1993; P. Spitzer, unpublished report; personal observations).

In this study, I examine potential factors influencing local variation in foraging strategies used by Common Loons wintering off Florida's Gulf Coast. Variation in group size suggests that costs and benefits of grouping differ among individuals. To examine these differences, I compared time budgets and movements among loons in three group types: solitary loons, small groups, and large groups (exact sizes are defined in Results). I also compared behavior of loons in each group type in relation to tide movements and water salinity, two factors that may influence prey availability and foraging success.

STUDY AREA

I conducted this study from 13 January to 6 April 1997 at St. George Sound (29(45'N, 85(20'W), a 30,770 ha bay located on Florida's central Panhandle. St. George Sound is part of Apalachicola Bay, an estuary that receives the Apalachicola River, Florida's largest river in terms of flow (annual flow = 665m3/sec), and is separated from the Gulf of Mexico by a 48-km-long barrier island. Freshwater input from the Apalachicola River and bounding from the Gulf by a barrier island result in an east-west gradient in water salinity ranging from 0.05 to 30 ppt (Livingston 1984). Water temperatures are relatively warm during winter (approx 12-15° C, reflecting high air temperatures and shallow water depths (<15 m, = 3-4 m). Tides are diurnal to semidiurnal and range in height from 0.13 to 0.23 m (Livingston 1984). St. George Sound receives relatively little human use during winter except by commercial oyster harvesters using small boats at the western end of the Sound. Common Loons are the only species in their family (Gaviidae) that regularly overwinter on the Gulf Coast, but Red-throated Loons (*G. stellata*) are occasional visitors.

METHODS

Shoreline surveys: I conducted systematic, diurnal observations of loons within 2 km of shore at 14 fixed points around St. George Sound. I used a 40X spotting scope to locate loons from each point and, after noting time of day, I recorded the group size and location (compass-scope technique; McIntyre 1978) of every loon or group of loons that I observed. I later recorded each sighting on a National Oceanic Atmospheric Administration (NOAA) nautical chart from which I derived measures of spatial distribution and distance from shore for each loon. At each point, I recorded the number of loons engaged in each behavior per group at the moment the group was observed (1 observation/group; scan-sampling) for each loon. I classified behavior according to the following criteria: (1) feeding: multiple dives, peering underwater, prey handling; (2) drifting: floating, no travel; (3) preening: arranging feathers with bill; (4) surface travel: swimming on the water's surface; and (5) sleeping: bill rested on back. I also recorded any other behaviors such as aggression or flight.

To correlate behavior with tide movements, I used Tidemaster tide charts (Pittsburgh, PA) and time *of day to derive "tide stages" ranging from low to high tide (stages -2, -1, 0, 1, +2) for each observation.* I conducted shoreline surveys 5-7 times every two weeks, alternating starting points to minimize time-of-day bias. I also stratified surveys across daylight hours (07:00-18:15) and tide stages. After 18:15, I conducted nonsystematic observations of loons from various points around the Sound and noted general behavior patterns until dark. I removed surveys from analysis when high chop conditions (wind >40 kph) occasionally precluded reliable observations. Throughout the study, water-salinity levels were measured every 15 minutes by an automatic datalogger (Apalachicola National Estuarine Research Reserve, Apalachicola, FL) located at the northeastern end of St. George Sound.

Travel surveys: To compare travel patterns among loons in each group type (including solitary loons), I measured the distance that groups traveled during 30-minute observation periods. To derive travel distances, I recorded the location of each group every five minutes onto a NOAA nautical chart and measured the distance of the path between starting and ending locations for each group. Travel surveys accounted for distance traveled by loons engaged in any type of behavior including foraging, drifting, preening, etc. during 30-min observations. In this way, "travel distances" differed from the "surface travel" behavior category collected during shoreline surveys (see above).

Statistical Analysis: To analyze variation in the spatial distribution of each group type over time, I used chi-square tests and standardized residuals to compare the number of each group type present during the first and second half of the study period among the northeastern end of the Sound (survey points 1-6), the western end (points 7-10), and the southeastern end (points 11-14).

Because I conducted instantaneous behavioral observations, data for solitary loons over the study period were recorded as number of loons' observed/behavior (e.g., 1000 loons/foraging, 550 loons/drifting, etc.), whereas behavioral data for groups were recorded as percent loons engaged in each activity for each group (e.g., group 1 = 30% foraging, 70% drifting; group 2 = 50% foraging, 50% preening). Therefore, to compare behavior among group types, I converted the number of events observed per behavior for solitary loons to percent loons observed in each behavior per group (e.g., a solitary loon always exhibited a single behavior at 100% frequency and other behaviors at 0% frequency). For the initial analyses presented here, I compared the mean percent time spent in each behavior by loons among the three group types with a univariate randomized complete block design analysis of variance (ANOVA) with two week periods as the blocking factor (SAS Institute 1989). I used Fisher's LSD to detect significant differences in all pairwise comparisons ($P < 0.05$; SAS Institute 1989). To assess trends in water salinity over time, I derived daily averages of water salinity from 15-minute samples and applied linear regression analysis.

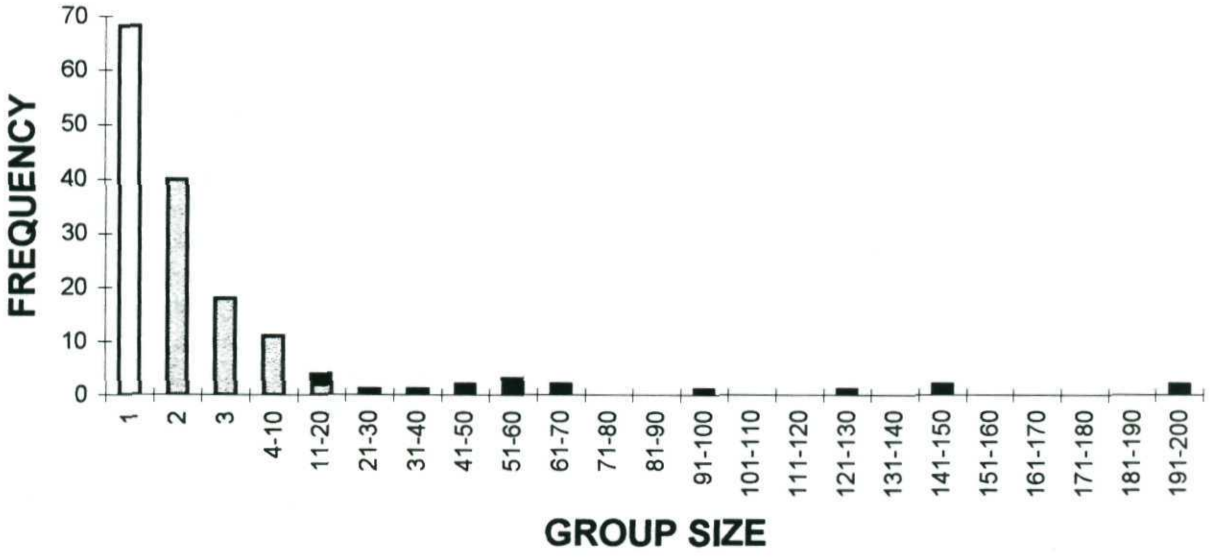
I also used univariate ANOVA to compare the mean percent frequency of different group types in each behavior with time of day (early morning: 07:00-09:15; late morning: 09:15-11:30; midafternoon: 11:30-13:45; late afternoon: 13:45-16:00, early evening: 16:00-18:15) and tides stages. I also used univariate ANOVA to analyze changes in the distance from shore of each group type with tide stage. In an earlier analysis, I conducted all ANOVAs by using an arcsine transformation. However, because of the binary nature of the solitary loon data, this transformation did not improve the normality of the data nor enhance variance homogeneity. Therefore, I present results from the untransformed data. Nearly all of the significant contrasts described here are highly significant, thus reducing the probability of Type II errors.

RESULTS

I observed loons in groups containing 2-200 loons, but solitary loons were the most common group type (95%, N = 1933; Figure 1). All groups containing 2-14 loons never included other species (4%, N = 89; "small group" type; hereafter, loon-only groups [LOGs]), but all groups containing 15-200 loons (1%, N=17) always included other species such as Northern Gannets (*Sula bassanus*), Double-crested Cormorants (*Phalacrocorax auritus*), Brown Pelicans (*Pelecanus occidentalis*), herring, ring-billed, and Laughing Gulls (*Larus argentatus, L. delewarensis, L. atricilla*), and Royal and Forster's Terns (*Sterna maxima, S. forsteri*) ("large group" type; hereafter, multispecies groups). Solitary loons and LOGs occurred throughout the study period, but multispecies groups were present only during the first 5 weeks (13 Jan-16 Feb). During 13 Jan-16 Feb, more loons were observed in St. George Sound than during the remainder of the study period (2399 vs. 1175 loons; t-test; t215 = 2.93, $P = 0.010$).

During the first 5 weeks, solitary loons were more common on the western end of St. George Sound, and multispecies groups were more common on the eastern end (chi-square 24 = 53.06, $P < 0.001$). When multispecies groups were absent, solitary loons still were more likely to occur on the western end of the Sound (chi-square 24 = 735.23, $P < 0.001$).

FIGURE 1. Frequency of groups observed in St. George Sound, Florida, 13 January to 7 April, 1997. Shaded bars show single-species groups, and solid bars show multispecies groups.

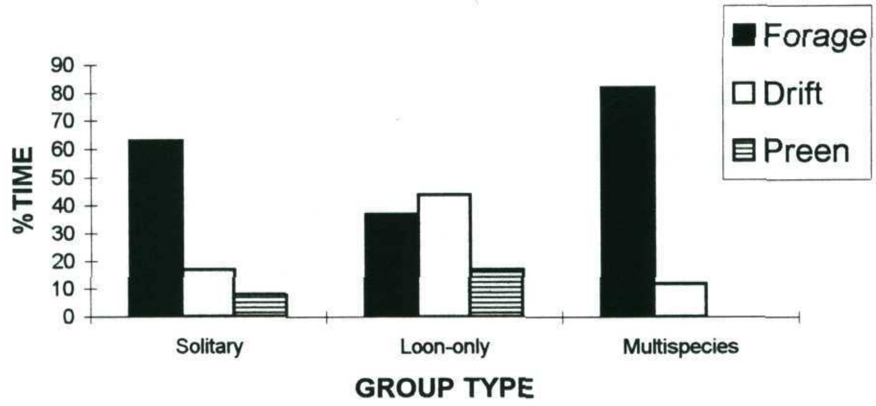


Intra- and interspecific aggression among loons was rare. On one occasion, I observed a loon "surface rush" away from another loon. A few days later, a loon performed a "penguin dance" display toward a Double-crested Cormorant that was foraging within 2 m of the loon (terminology follows McIntyre 1988).

Overall, loons spent most of their time foraging (67%), drifting (20%), and preening (10%). The remaining 3% of time was spent in surface travel or sleeping. Because surface travel and sleeping comprised such a small proportion of time, the remainder of the discussion will focus on patterns in foraging, drifting, and preening.

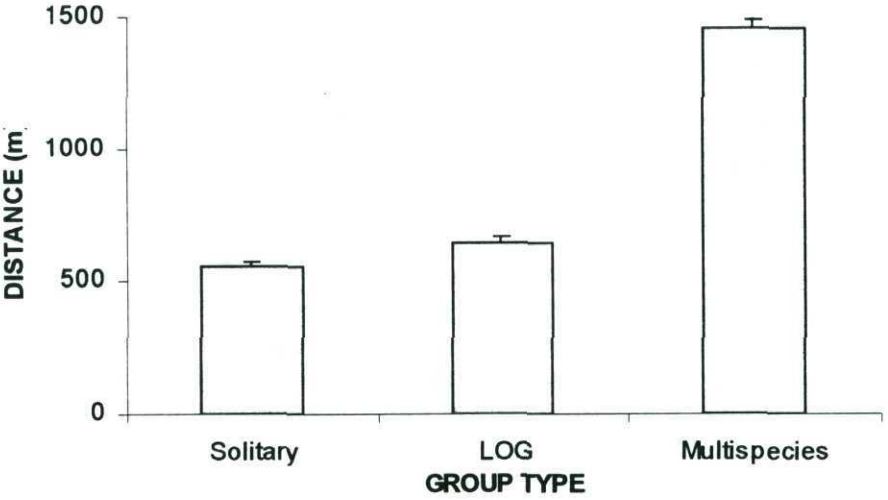
Solitary loons, loons in LOGs, and loons in multispecies groups differed in mean time spent foraging (F2, 1950 = 11.01, $P < 0.001$), drifting (F2, 1950 = 17.6, $P < 0.001$), and preening (F2, 1950 = 3.23, $P = 0.004$; Figure 2). Solitary loons preened more than grouped loons. Loons in LOGs drifted more and foraged less than other loons ($P < 0.05$). Loons in multispecies groups foraged slightly more than solitary loons ($P = 0.11$), but other observations suggest multispecies groups were associated with foraging behavior. Multispecies groups comprised both foraging and nonforaging loons with foraging loons forming a tightly packed cluster at the leading edge of the group. These loons also dove synchronously and were always associated with other foraging species. Nonforaging loons in multispecies groups had once been in the cluster but drifted behind and eventually away from the group.

FIGURE 2. Proportion of solitary loons, and loons in LOGs and multispecies groups observed in each behavior. The behaviors, locomotion and sleeping, are not shown.



Solitary loons foraged more in the early morning than at other times of day (F4, 1865 = 27.06, P < 0.001). No loons were observed in LOGs in early morning; loons in LOGs foraged less in the early evening than other times of the day (F4, 64 = 6.99, P = 0.004). Multispecies groups were also absent shortly after sunrise, but otherwise, loons in multispecies groups did not change behavior with time of day (Fs3, 13 < 2.15, Ps > 0.05). At dusk (>18:15), most loons formed small, single-species groups of 2-200 individuals in which they primarily drifted and preened.

FIGURE 3. Distance traveled by solitary loons, and loons in loon-only groups (LOG) and multispecies groups during 30-minute focal observations.



Solitary loons and loons in LOGs foraged more (solitary loons: $F4, 1865 = 10.25, P < 0.0001$; LOGs: $F4, 64= 3.68, P < 0.05$) and moved closer to shore (solitary loons: $F4, 1872 = 4.01, P = 0.003$; LOG: $F4, 66 = 4.22, P = 0.004$) during low than high tide stages. Individuals closer to shore foraged more than those farther away (solitary loons: $F1, 1613= 11.06, P < 0.001$; LOG: $F1, 69= 7.80, P = 0.007$). Time spent in each activity was similar among tide stages for loons in multispecies groups ($F3, 13= 0.87, P = 0.51$).

Loons in multispecies groups traveled farther during 30-minute travel observations than other loons ($F2, 76= 19.84, P < 0.001$; Figure 3). Water salinity decreased throughout the study period ($r^2 = 0.113, P = 0.002$), with lowest salinities occurring after 4 March (t-test; $t84 = 6.83, P < 0.001$; Figure 4).

DISCUSSION

Solitary Loons. Solitary loons were the most common group size in St. George Sound, and they spent an intermediate amount of time foraging compared to loons in LOGs and multispecies groups (Table 1). In other studies, most wintering loons also foraged alone (Virginia: McIntyre 1978; Rhode Island: Daub 1989, Ford and Geig 1994) and foraged more in the morning (McIntyre 1978, Daub 1989, Ford and Geig 1994). This pattern is presumably typical of species that do not forage at night but must satisfy energetic requirements during the day.

TABLE 1. Mean percent time foraging by solitary loons at three wintering sites.

Site	% Time foraging	Source
Chincoteague, Virginia	55	McIntyre (1978)
Weekapaug, Rhode Island	23	Daub (1989)
Weekapaug, Rhode Island	32-38	Ford and Gieg (1994)
St. George Sound, Florida	67	This study

Solitary loons and loons in LOGs foraged more and moved closer to shore during low than high tide stages, and loons closer to shore foraged more than those farther away. McIntyre (1978) also observed increased foraging by loons during low tide and suggested that loons take advantage of prey concentrated behind receding water. In the marine environment, prey is often patchy, but tide movements may produce a more even prey distribution (Mann and Lazier 1996:232-235), thus increasing energetic returns for solitary foragers or those in small groups (Stephens and Krebs 1986).

In contrast, Daub (1989) and Ford and Gieg (1994) found that solitary loons in Rhode Island showed no change in behavior with tide stage. Daub (1989) suggested that the lack of a relation between tide stage and foraging activity in Rhode Island loons compared to Virginia loons may have been due to the lower tidal range at her more northerly study site. However, tidal ranges in Florida are even lower than in Rhode Island, but Florida loons still showed greater foraging during low than high tide stages. It is possible that the tidal effect on foraging depends less on the tidal range and more on the structure of the habitat. My study and the study of loons in Virginia were conducted in sheltered bays whereas the Rhode Island study was conducted along an open ocean shoreline. Bays have more shoreline per unit water along which fish may concentrate and may provide greater concentrating affects than open beaches with less shoreline.

Loon-Only Groups. Grouping behavior is often attributed to benefits involving increased predator protection (via an enhanced vigilance, dilution, or confusion effect), increased foraging efficiency when prey is patchy, or both (Pulliam and Caraco 1984). According to this classification, it is unlikely that loons gained foraging benefits by forming small, monospecific groups; loons in LOGs foraged less and drifted more during the day than other loons. Loons also formed LOGs at dusk (unpublished data) when light levels were too low for these visual predators to forage (Barr 1996); to our knowledge, loons, unlike some other nonbreeding diving birds (e.g., Western Grebes, *Aechmophorus occidentalis*) do not take phosphorescent prey. Although loons have generally been considered free of nonhuman predators in winter, new evidence from a long-term carcass study (Forrester et al. 1997) and other sources (Simons 1985; R. Miconi, Tufts School of Veterinary Medicine, personal communication) suggest that, in addition to emaciation, wintering loons suffer considerable mortality from sharks or other large fish. Because loons are most vulnerable to underwater attack while they are above the water's surface and when light levels are low, loons may reduce their risk of predation by forming LOGs while drifting and at night.

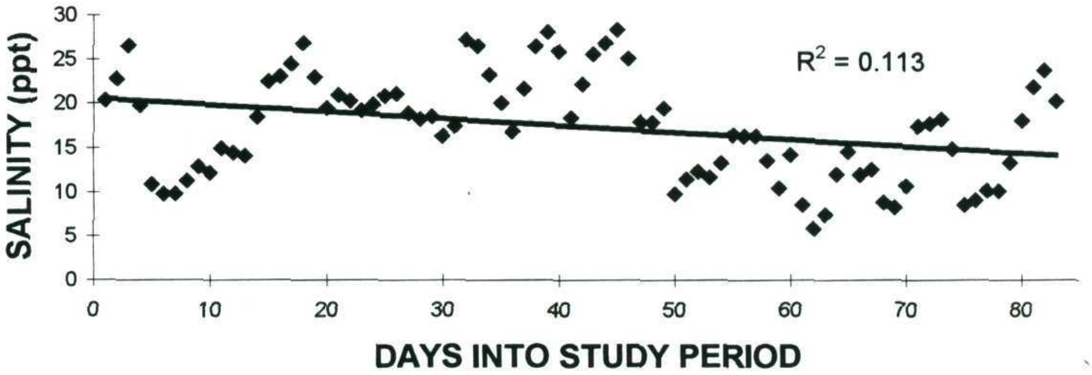
Multispecies Groups. In contrast to loons in LOGs, loons in multispecies groups foraged more than other loons and likely gained greater foraging benefits in groups than when foraging alone. Four observations suggest that loons in multispecies groups used a large, common, mobile prey source, such as large schools of fish: (1) multispecies groups were always relatively large, indicating a large prey patch; (2) loons that were clustered at the leading edge of the group dove synchronously, indicating a common prey source; (3) multispecies groups had high travel rates during 30-minute observations, suggesting high prey mobility; and (4) total number of loons in St. George Sound increased on days that I observed multispecies groups, suggesting these groups traveled into the Sound from the surrounding area. While loons in multispecies groups foraged more than other loons, it is unknown whether other species had a positive, neutral, or negative affect on their foraging success.

Multispecies groups were absent in the early morning; otherwise, these loons showed no change in foraging behavior with time of day or tide stage. The morning absence of multispecies groups may reflect a time lag between sunrise and prey detection. However, their absence may also be related to differences in relative foraging success in solitary and grouped individuals. Solitary foragers should optimize energy gains when prey is relatively evenly spaced; grouped foragers should do so when prey is relatively patchy (Stephens and Krebs 1986). I observed loons beginning each day alone, during which time they spent a high proportion of time foraging. In the morning, individuals may assess their relative foraging success for the day: if foraging success is low in the morning or if prey appears patchy, solitary loons may switch to group foraging where information is available concerning prey location or where the actions of group members may increase prey availability. On the other hand, if foraging success is relatively high in the morning, loons may remain solitary, and avoid interference. In this case, the morning absence of multispecies groups may reflect a period of foraging "assessment".

Variation and Resource Distribution. In addition to differing in behavior, groups differed in their temporal and spatial distribution. During January and February, when multispecies groups were present, the most common schooling fish in St. George Sound was Gulf silversides *(Mendidia peninsulae; L. Edmiston*, Apalachicola National Estuarine Research Reserve, personal communication), a species that prefers relatively high-salinity water (ca. 20-27 ppt; Lucas 1982) such as that at the eastern end of the Sound. Multispecies groups were also more common at the eastern end, possibly forming over schools of silversides. Solitary loons and LOGs were more common at the western end of the Sound where water salinity was lower and Atlantic croaker (*Micropogonoas undulatus*) and spot (*Liostomus xanthurus*), larger fish, were more abundant (Kobylinski and Sheridan 1979, Livingston 1984).

Throughout the study, flow from the Apalachicola River increased (ANERR, unpublished data), and by early March, water-salinity levels had decreased throughout the Sound (Figure 4). As water salinity dropped, fish associated with high-salinity water (e.g., silversides) also likely moved eastward out of the Sound. Coincident with decreased water salinity and likely departure of silversides, was the absence of multispecies groups. Northern Gannets, obligate marine birds that forage on prey found in high-salinity water (Nelson 1978), also disappeared from the sound by late February (unpublished data), providing further evidence for a salinity-related prey shift. The influx of lower-salinity water may have also caused an increased abundance of Atlantic croaker and spot in the eastern Sound (Livingston 1984), where solitary loons were more numerous.

FIGURE 4. Water salinity (ppt) measured at Cat Point, St. George Sound, throughout the study period.



Jodice (1993) conducted aerial surveys of the northeastern Gulf of Mexico and observed multispecies groups with up to 200 loons and other piscivorous birds and dolphins. He noted multispecies groups at different locations across the Panhandle, indicating a dynamic pattern in their formation and movements (P. Jodice unpublished data). Spitzer (unpublished report) also observed large multispecies groups along the North Carolina coast, and speculated their presence was related to the presence of Gulf menhaden (*Brevoortia tyrannus*). Future research involving surveys of broad-scale loon movements coupled with data on regional shifts in water salinity and species-specific fish movements would improve our understanding of factors influencing intraseasonal resource use by loons and their foraging ecology.

Future Research. While resource distribution may affect local variation in the behavior of wintering Common Loons, age, sex, and prior experience may also influence foraging decisions. Age, in particular, may affect foraging in loons because only adults undergo complete remigial molt (Pre-Basic III) during winter, and molt can be an energetically costly process (Murphy 1996). Although I did not determine the proportion of adults and immature loons in each group type, judging by plumage, both age classes occurred in group type (unpublished data). Future work may involve color-marking individuals of this monomorphic species, determining molt status and monitoring behavior over time with respect to group participation.

SUMMARY

In conclusion, tide movements, predation pressure, and water salinity appear to contribute to variation in foraging strategies in wintering common loons. Tide movements may concentrate prey along shorelines providing optimal energy returns for solitary foragers, while predation risk from sharks or other large fish may influence the formation of small single-species groups. Large multispecies groups appear to be foraging aggregations concentrated over schools of fish that move with seasonally shifting water-salinity levels. Factors intrinsic to foragers may also affect foraging success including age, sex, and prior experience, but the relative contribution of these factors to foraging decisions is unknown. Future studies on marked individuals may clarify the role of intrinsic factors on foraging decisions.

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LOON VOCAL TAGGING: AN EVALUATION OF ITS FEASIBILITY USING A BANDED POPULATION OF LOONS

CHARLES WALCOTT[1] AND DAVID EVERS[2]

[1]SECTION OF NEUROBIOLOGY AND BEHAVIOR, CORNELL UNIVERSITY, ITHACA, NY 14853
[2]BIODIVERSITY RESEARCH INSTITUTE, 411 ROUTE 1, SUITE 1, FALMOUTH, ME 04105

"Vocal-tagging" of Common Loons, *Gavia immer*, that is, recognizing an individual male loon by the characteristics of its yodel, has been suggested repeatedly. McIntyre, 1988, states: " Sonogram analysis confirms that during the summer, each individual male loon gives the same yodel, distinctive from those of other male loons in the population." She then goes on to report Barklow's conclusion (McIntyre, 1988, p 15) that over the 10 years of his study, his recordings of yodels from each territory was the same each year. She concludes that: "...the evidence seems overwhelming that each male has a distinctive yodel, which remains constant from year to year, and which can be used to vocally tag individuals." But this individual recognition of yodels from individual loons has been accomplished mainly by visual comparison of their sonograms. Further, without marked birds it cannot be certain the same bird was on the same territory each year. Finally, visual comparison of sonograms like simply listening to the yodels is an inherently subjective approach. While there is clearly nothing wrong with subjectivity, for vocal tagging to be widely used it would be helpful to be able to describe the differences between the yodels of individual loons in easily measured, quantitative terms. An effort to vocal tag loons is worth pursuing as a tool to identify individuals in studies of population structure, turnover and construction of life tables (review in Baptista and Gaunt, 1997).

In order for vocal tagging to be a useful, objective, technique it is necessary to show that: (1) the yodel of any one male is stable over time; (2) there are differences between the yodels of different loons; and (3) loons are consistently different from each other. In other words, each loon must occupy an individually distinctive and stable acoustic space.

Miller (1988) has pioneered the effort to develop quantitative statistical methods to recognize individual loons by their yodels. He found that yodels from loons on the same territories were stable over the five years of his study (Miller, pers. com.). Furthermore, the differences between the yodels of males on different territories were greater than the variation in the yodel of any one individual on the same territory. This finding satisfies all three of the criteria above and would seem to validate the use of recorded loon yodels for recognizing individual male loons. Unfortunately these studies were not conducted on marked loons so Miller could not be certain of identity. Miller relied on the male loon's return to the same lake year after year and a consistency of the loon's behavior to indicate that he was recording the same individual. Evers et al. (1996) have shown that Miller's assumption that the same loon occupies the same territory year after year is largely correct, but there is an annual replacement rate of approximately 20% per year (See also Piper et al 1997). This means that over the five years of Miller's study of six territories there could have been 6 territorial exchanges by male loons.

In light of the frequent turnover of loons on breeding territories, we have repeated Miller's analysis using two banded populations of Michigan loons. We have confirmed Miller's findings that the yodels of male loons are stable over a period of years and that different loons in a population have different yodels, although there seem to be one or two interesting exceptions. This paper summarizes our results; a more detailed description is in Walcott et al. 1999.

MATERIALS AND METHODS

This research was conducted at the Seney National Wildlife Refuge (NWR), in Schoolcraft County on Michigan's Upper Peninsula, 1990-1997. Evers has been banding, recording and studying the loons at Seney NWR since 1989. We also used a smaller sample of loons from Isle Royale National Park (NP), Keweenaw County, Michigan (Figure 1A). The results reported here are based on 172 yodels from six males at Seney NWR (Figure 1B) and 28 yodels from six males on Isle Royale NP.

Figure 1A. A map of Michigan's Upper Peninsula showing the relative location of the Isle Royale National Park and the Seney National Wildlife Refuge.

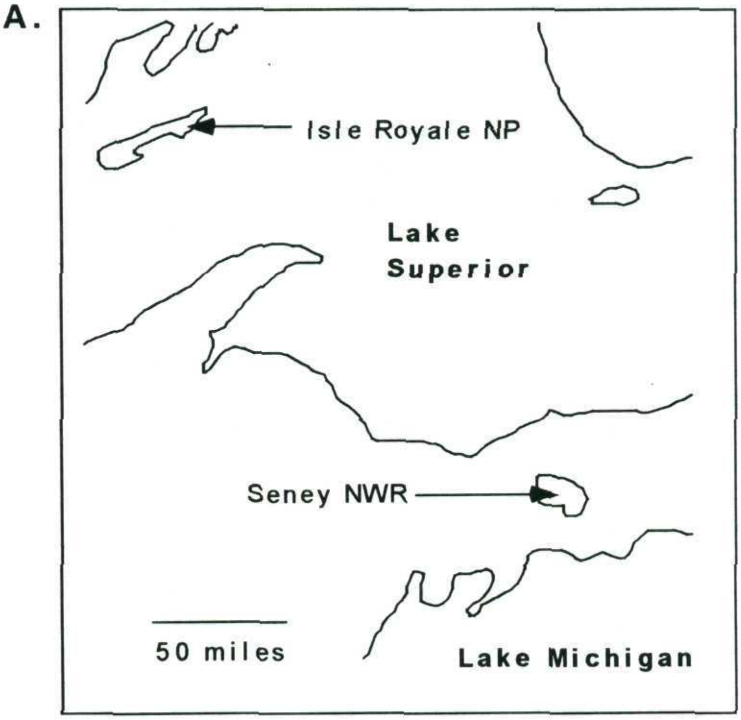
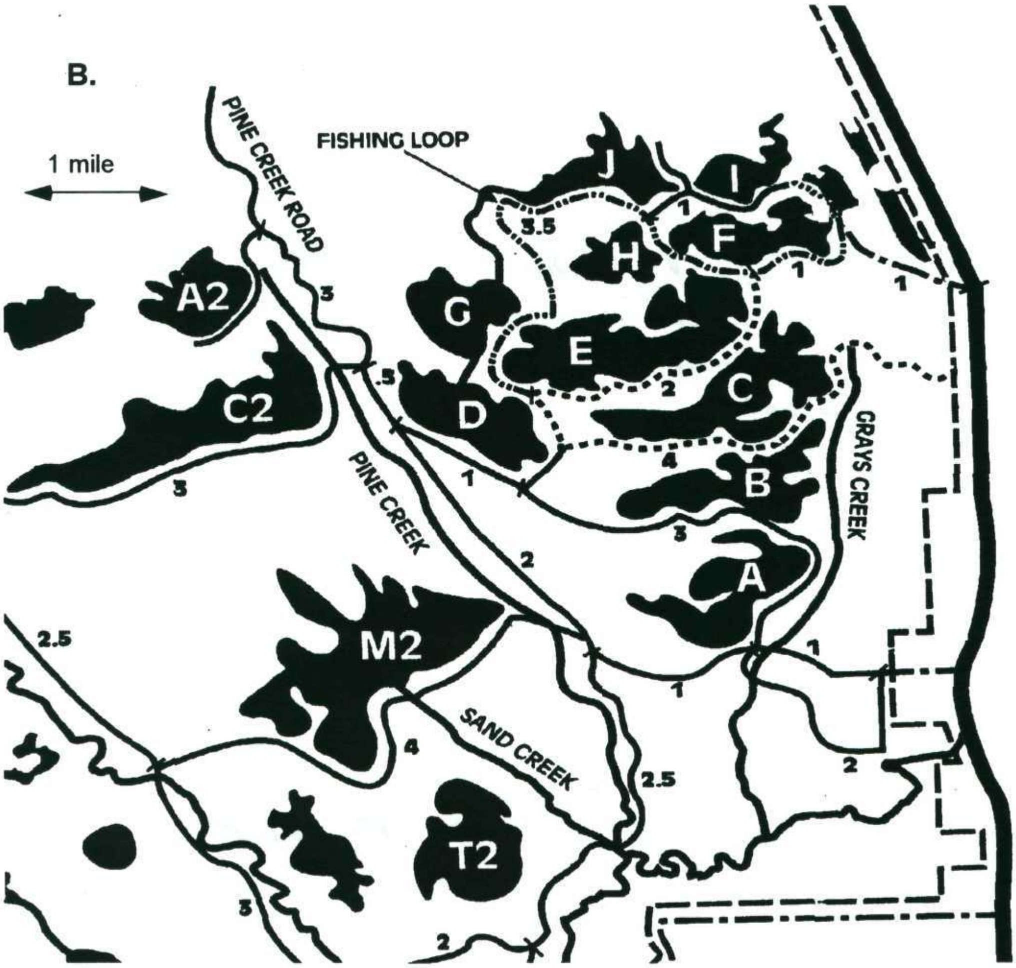


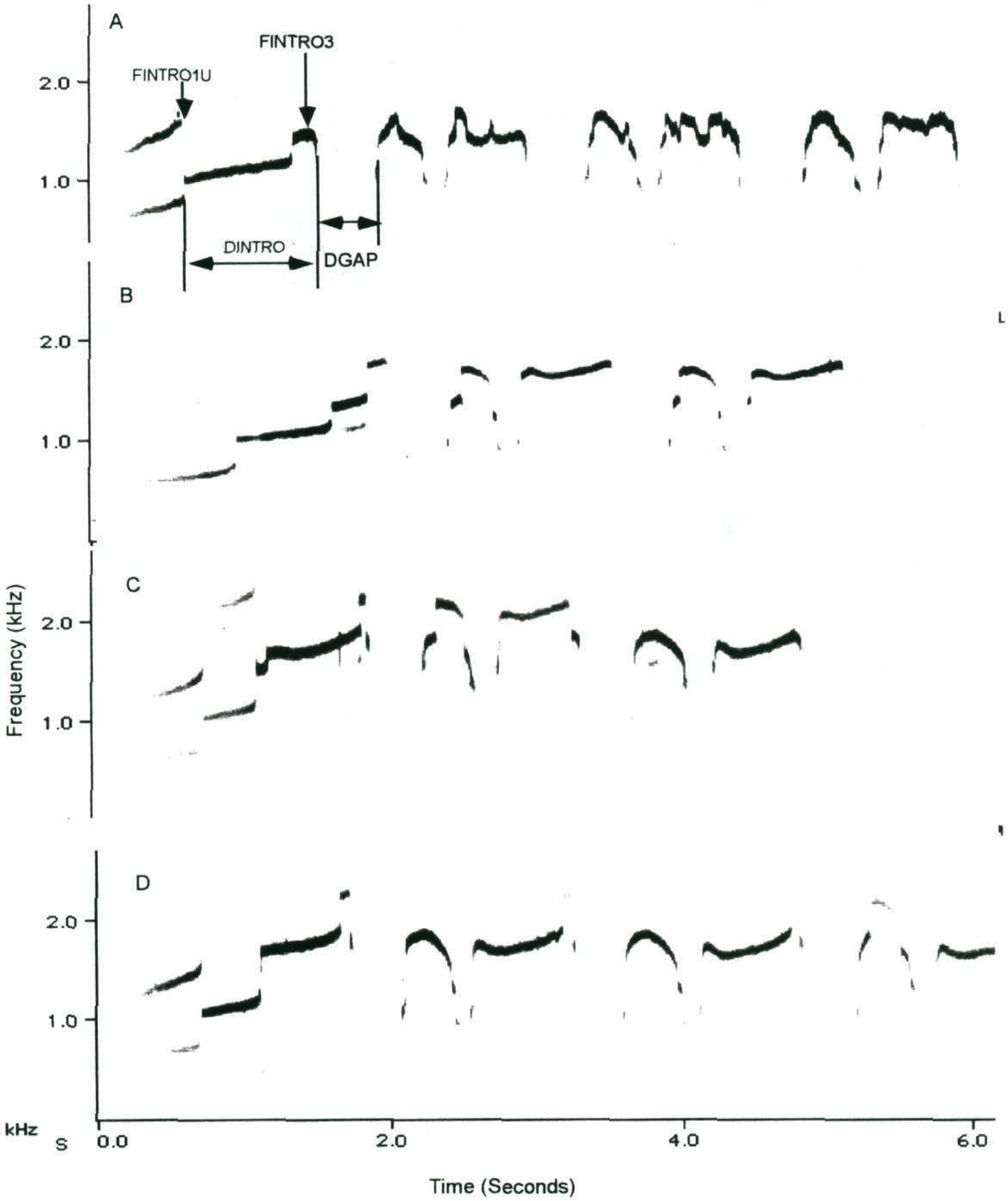
FIGURE 1B. The location of the various Common Loon territories in the Seney National Wildlife Refuge. The various "pools" are in black; the scale is at the upper left.



In early May, banded male loons were identified and then stimulated to yodel by playbacks of recorded wails, flying tremolos and yodels. These methods are described by Miller (1988) and by McIntyre (1988). In addition, spontaneous yodels were recorded opportunistically throughout the breeding season. Yodels were recorded on tape using several different microphones, recorders and formats. The yodels were then digitized and analyzed using "Canary, version 1.2" running on a Macintosh Quadra 950 computer. We found that four measurements were most useful in separating the yodels of different loons: FINTRO1U, the frequency of the end of the Measurements were made from both amplitude and spectral displays, and factor analysis was performed using Systat, 5.2.1.

Starting with the measurements used by Miller (pers. com.) and proceeding by trial and error we found first note of the introduction, FINTRO3, the frequency of the end of the last note of the introduction, DINTRO, the duration of the gap between the introduction and the first repeat syllable (Figure 2).

FIGURE 2. Sonograms for two loons in the Seney population. The four measurements used in the analysis are shown in A. These include two measures of frequency and two of duration. The spectrogram in A is a yodel recorded from the B-Pool male in 1993. B is a spectrogram of a yodel from the same loon (B-Pool) after it was displaced from B-Pool in 1996. C. is from a yodel of the male in T2-West Pool made in 1993 while it was on T2-West Pool. D is from the T2-West Pool male recorded in 1997 the year after it had displaced the old B-Pool male.

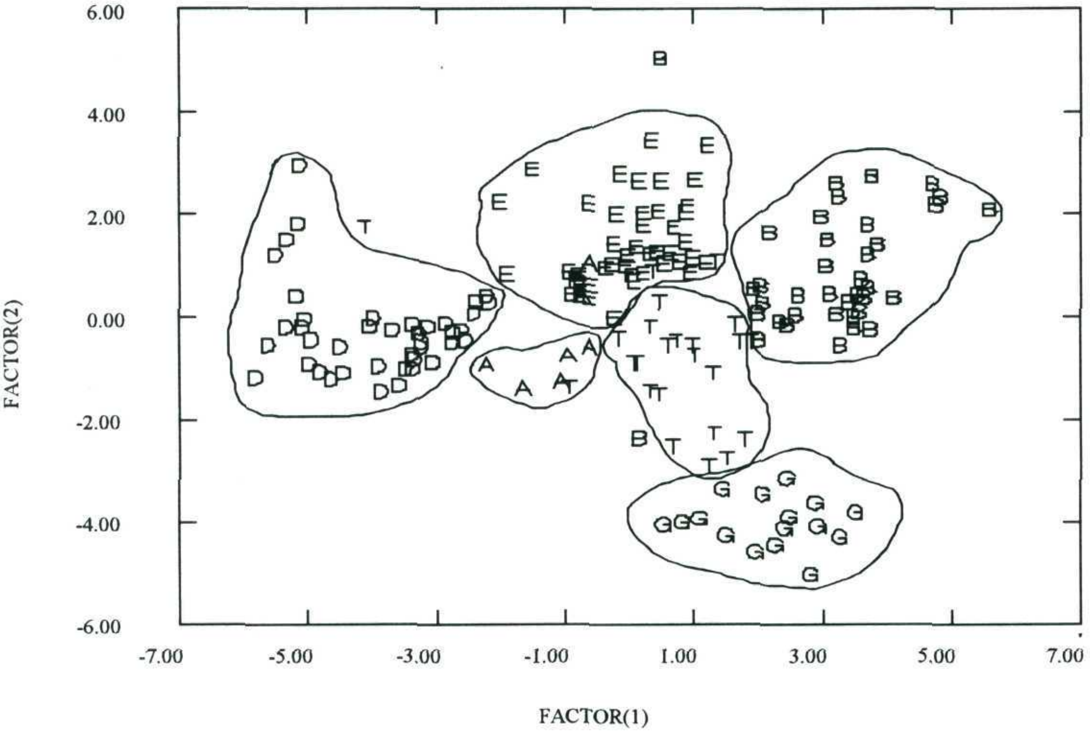


RESULTS

Factor analysis was successful in correctly classifying 93% of the yodels from known Seney NWR loons recorded between 1990 and 1995. To avoid the error of building the model and testing it on the same data set, we built the model on the yodels recorded in 1990-93 and used it to classify the 41 yodels recorded in 1994-95. It correctly classified 100% of the yodels.

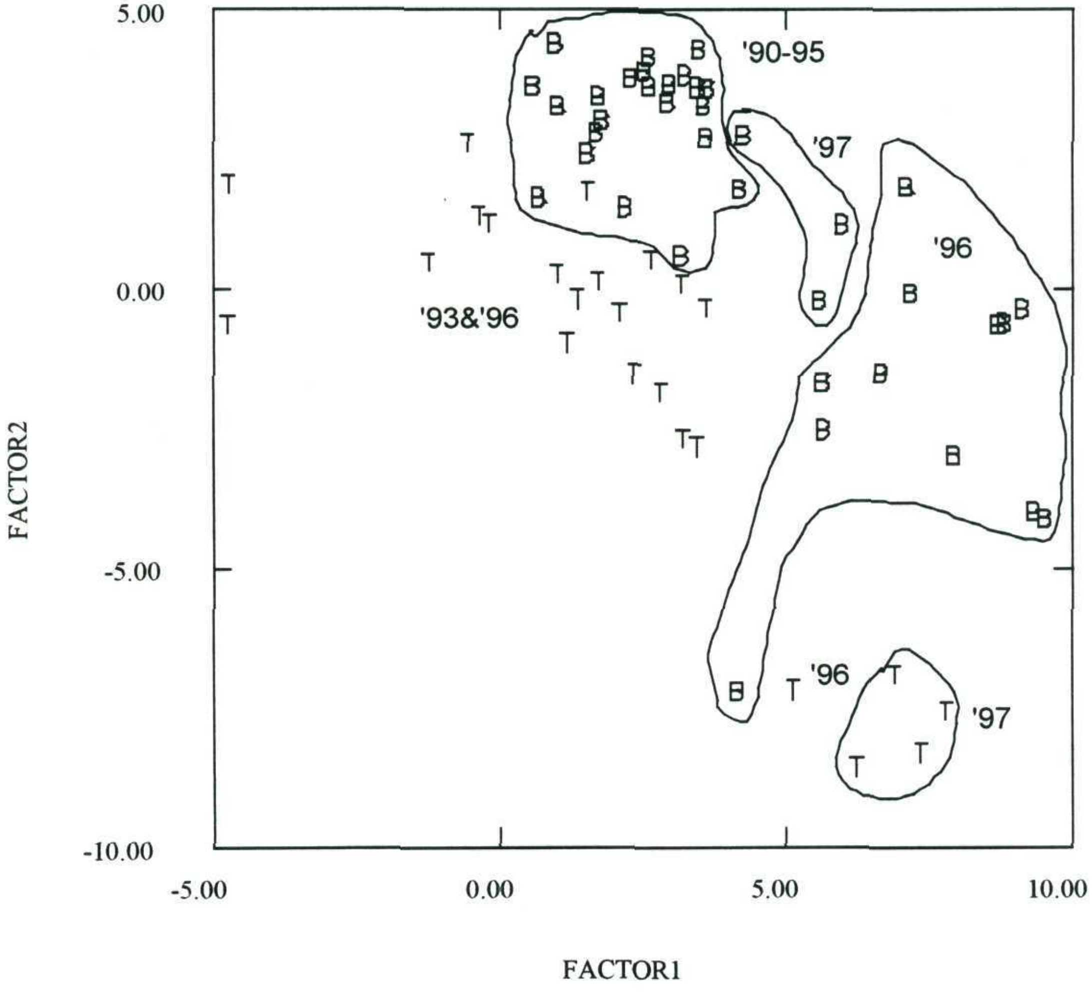
Plotting the yodels of each loon shows that they are well clustered (Figure 3). Applying these same regression equations to yodels from loons at Isle Royale NP also was successful in separating the individuals. Clearly, a loon's yodel is stable from year to year. Further, the yodel of each individual varies less than the difference between individuals. These results confirm what Miller (pers. com.) has found: a small number of measurements of the frequency and timing of the yodel allows us to reliably identify yodels from individual male loons

FIGURE 3. Factor analysis of all the 172 Seney loon yodels recorded from 1990-97 showing the groupings generated by plotting Factor 2 against Factor 1. Each letter (A, B, D, E, G, T) stands for a yodel from an individual loon. "A" represents the A-Pool loon, "B" the B-Pool and so on. Notice that yodels from each loon generally form a discrete group.



Two observations made while recording yodels at the Seney NWR have led us to question how reliable this technique may be if a loon switches territory. In 1990 and 1991 two male loons were on the D-Pool territory. Recordings of these two loons could not be differentiated by the four measures we used. In 1996 the male from T2-West invaded B-Pool and displaced the resident male. The displaced B-Pool male established residence nearby on the same body of water but its yodel changed after the day of its fight with T2-West. The T2-West male, now occupying B-Pool also changed its yodel, but less dramatically (Walcott et. al. 1999). In 1997 the T2-West male remained on B-Pool and the old B-Pool male was recorded nearby in C-Pool. The yodel of the old B-Pool male in 1997 plots in between that of 1996 and its traditional yodel.

FIGURE 4. A plot of Factor 2 vs. Factor 1 for the yodels recorded from B-Pool loon and the loon from T2-West before and after the territorial takeover. This plot shows the changes in the yodels of the B-Pool loon after its territory was taken over by the loon from T2-West in 1996. "T's" indicate the loon from T2-West, "B's" the B-Pool loon. Yodels from the T2-West loon in 1993 and 1996 are near the top center of the graph. Yodels from the B-Pool loon from 1990-95, before the takeover, are circled near the top center. Yodels recorded from the B-Pool loon in 1996 after the takeover are circled on the right; notice the greater variation in the measures represented here by the spreading of the points. In 1997 only 3 yodels were recorded from the B-Pool loon, now temporarily resident on C-Pool. They lie almost exactly between the pre and post takeover yodels. Finally, 4 yodels recorded from the T2-West loon now resident on B-Pool are plotted at the lower right.



Conversely the T2-West male gave one yodel that was indistinguishable from what it had given in previous years but then, within minutes of the first, gave five more that were quite different (see Figure 4). These latter five yodels had the same timing as before, but the frequency of FINTRO1U was 30 Hz higher ($p<0.001$, paired T-test) and FINTRO3 was 349 Hz higher ($p=0.013$). Even a single example should make us cautious about concluding how stable loon yodels are over time.

TABLE 1. The classification of all the yodels recorded from six different male Common Loons at the Seney National Wildlife Refuge between 1990 and 1997. The discriminant analysis model classified 155 of the 172 yodels correctly for an accuracy of 90%.

Loon	Unknown	A-Pool	B-Pool	D-Pool	E-Pool	G-Pool	T2West	Total
A-Pool	0	6	0	0	1	0	0	7
B-Pool	1	0	34	0	1	0	3	39
D-Pool	0	4	0	37	0	0	0	41
E-Pool	0	0	0	0	44	0	1	45
G-Pool	0	0	0	0	0	16	0	16
T2West	0	1	0	1	1	3	18	24
Total	1	11	34	38	47	19	22	172

To see what affect this territory switch had on the accuracy of the yodel classification, we built a model using all 172 yodels from the Seney loons (Table 1). This included the changed yodels from both the T-2 West and the old B-Pool males. This model correctly classified 155 yodels for an overall accuracy of 90%. Thus, despite the inclusion of the changed yodels of the T-2 West and B-Pool males, the vast majority of the yodels were correctly classified.

DISCUSSION

Our results support Miller's (pers. com.) conclusions that a relatively small number of measurements enable one to characterize the yodel of an individual male loon. For our populations, four measurements, two of timing and two of frequency, were sufficient. Interestingly, all these measurements were of the introduction, not of the repeat syllables.

In considering the three criteria posed at the outset, the measurements we have used clearly demonstrate the individuality of each loon's yodel. Furthermore, over the seven years of this study, most of the yodels were remarkably stable from one year to another. If one looks at the graphs of factor distributions of all the males (Figure 3), each loon's yodels mostly fall in quite distinct, discrete clusters. The year-to-year distributions show changes in each loon's yodels, but these changes are mostly small relative to the differences between different loons. All in all, the results support the hypothesis that each male loon has a recognizable yodel that is different and distinct from that of other neighboring loons. While this conclusion is based primarily on the loons recorded at the Seney NWR, the recordings of loons from Isle Royale NP are consistent with this idea.

Still, it is important to remember that our studies extend over only a few years, a fraction of the life span of a male loon. Furthermore, there are many unanswered questions about the stability of a loon's yodel when it switches territories. We have only one example of a territory switch and it clearly resulted in a change in the male's yodel, not only in the male that was displaced but also in the one that replaced it. Using the model built on data from 1990 to 1995, the change in yodels in 1996 and 1997 is particularly clear. It is notable that the changes in the yodels of these two loons were such that they did not compete with the yodels of other loons in the population. Further, these changes were quite abrupt; for the B-pool loon they took place following the fight. For the T2-West male there was a small change following the fight but a much larger one the following year. We need more examples of territorial switches to really understand how it affects the loon's yodels. (NOTE: By the fall of 1999 we had recorded a total of 4 such changes at Seney. In each of these 4 when the male switched territories its yodel changed significantly).

When we built a new model using all the Seney yodels, both elicited and spontaneous from 1990 to 1997, the change in the yodels of the B-Pool male and the T-2 West male become much smaller although they are still clearly present. Whether these changes are significant to the loons is an open question; we don't know what acoustic cues are used by loons to determine individuality.

In conclusion, it would appear that four simple measurements of frequency and timing allow one to characterize the yodel of a particular male loon in a given population. Thus, at least on a limited basis, vocal-tagging as Miller (1988) proposes would appear to be a feasible procedure. But for it to become conclusively useful on a wider basis we need to know more about the population dynamics of Common Loons and how changing social status and territory may alter yodel structure over time. We also need to know more about the yodel's geographic variability and, finally, it would be interesting to know what characteristics of the yodel signal individuality to other loons. Still, whatever the loons may be relying on to tell one another's yodel apart, we can do it with only four simple measurements.

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DO COMMON LOONS MATE FOR LIFE? SCIENTIFIC INVESTIGATION OF A WIDESPREAD MYTH

WALTER H. PIPER[1], DAVID EVERS[2], MICHAEL W. MEYER[3], KEREN TISCHLER[2], & MARGARET KLICH[4]

[1]DEPT. OF BIOLOGY, GEORGE MASON UNIV., FAIRFAX, VA; PRESENT ADDRESS: CHAPMAN UNIVERSITY, ORANGE, CALIFORNIA 92866
[2] BIODIVERSITY RESEARCH INSTITUTE, 411 ROUTE 1, SUITE 1, FALMOUTH, ME 04105
[3]DEPARTMENT OF NATURAL RESOURCES, 107 SUTLIFF AVE., RHINELANDER, WI, 54501
[4]135C WAVERLEY DR., GUELPH, ON, N1G 2W1

ABSTRACT

The study of loon behavior and population ecology has been revolutionized by recent refinement and intensive use of techniques for capture and marking of adults. Repeated censuses and behavioral study in a Wisconsin population marked in the wake of this advance have shed light on the degree of mate-fidelity in loons. The popular myth that loons mate for life is not upheld by scientific data, regardless of the way in which "mate for life" is defined. Indeed, numerical projections derived from census data indicate that typical males and females probably attempt reproduction with three or more different mates during their lifetimes. The causes and consequences of the "mate for life" myth are explored.

INTRODUCTION

By virtue of its haunting vocalizations, striking plumage and curious behavior, the common loon has become one of the best known and most beloved creatures in North America. Its abundance, conspicuousness and association with northern aquatic habitats used by humans have made this species a symbol of vanishing wilderness (McIntyre 1988, McEneaney 1991, Dennis 1993). As a by-product of the intense emotion and interest focussed on the common loon, numerous myths have flourished about its biology. One of the most persistent is that loons mate for life (Sjölander and Ågren 1972, Terres 1980, Johnsgard 1987, del Hoyo et al. 1992, Dennis 1993). Despite the absence of scientific evidence to support or refute this notion, it has become firmly entrenched in popular and even scientific circles.

DEFINITIONS

The way that "mate for life" is defined depends upon whose life is referred to. The phrase has been taken to mean to form and maintain a pair bond with only one individual during one's own lifetime and cease breeding altogether in the event of that mate's death. Such everlasting fidelity has been claimed for the Greylag Goose (*Anser anser*, e.g. Heinroth 1911, Lorenz 1963). Humans, which form emotional attachments to mates, often refrain from re-pairing after loss of a mate. In general, however, failure of a reproductively-capable animal to re-pair and continue reproducing results in a loss in reproductive success and should occur rarely in humans, loons or any species (Wickler and Seibt 1983).

A second, more widespread definition of "mate for life" is to remain paired with a single mate during the mate's lifetime but to re-pair after the mate's death (also termed "permanent monogamy"; see Marzluff and Balda, 1992:133). By re-pairing, animals exhibiting permanent monogamy maintain access to reproductive opportunities; thus, it seems far more adaptive than everlasting fidelity. Indeed, permanent monogamy is found in many socially monogamous species (Tickell 1968, Wood 1971, Rowley 1973, Marzluff and Balda 1992, see reviews in Rowley 1983, Ens et al. 1996) and in a variety of cooperative breeders (see papers in Stacey and Koenig, 1990). Hereafter I will use the phrase "mate for life" to mean, "exhibit permanent monogamy."

WHY IS IT THOUGHT THAT LOONS MATE FOR LIFE?

It is far easier to define mating for life than it is to determine why, in the absence of scientific data, many authors have ascribed this mating pattern to loons. Some possible explanations can be offered, however.

One important factor has been the publication of countless books and articles on loons by loon enthusiasts—people who feel a strong emotional attachment to loons but do not view their behavior with scientific objectivity. Perhaps such enthusiasts have consciously attempted to justify the protection of loons by imbuing them with ideals that humans aspire to, such as lifelong fidelity to a single mate. More likely, they have simply drawn inferences loosely. For example, it is not difficult to see how non-biologists predisposed to project human traits onto animals could deduce that loons exhibit permanent monogamy. Imagine such a person who observes the nesting behavior of loons on a certain lake over many years. This person would observe a high degree of constancy in loons nesting on his lake in terms of appearance, arrival date, behavior towards intruders, vocalizations, chick-rearing and fidelity to nesting sites. Lacking information on the behavior and morphology of loons generally, he might quite logically deduce that the pair consisted of the same male and female each year.

A second factor that has undoubtedly fostered the spread of the mate for life myth is a well-known but insidious form of exaggeration, whereby a speculation by one scientist or popular author evolves—through repeated citation—to the point where it is accepted as fact. Although it is difficult to illustrate this process with a specific example, we can find numerous statements, which, quoted loosely and out of context, might contribute to the myth. For example, Strong et al. (1987:126) stated that: "There are few data documenting territory reuse by individually marked common loons.... but most pairs probably return to the same territories each year". It is easy to imagine that even such a circumspect statement could lead to less prudent citations by other authors suggesting that loons mate for life (e.g., Johnsgard 1987, del Hoyo et al. 1992, Dennis, 1993).

More than any other scientific source of the myth, we can point to the article by Sjölander and Ågren (1972). These authors contributed some important information with respect to nesting and social behavior, but also stated that: "Even if a definite proof is lacking there are many reasons to believe that loons pair for life" (Sjölander and Ågren 1972:305). In fact, the evidence they offer is weak and circumstantial: constancy in territories and nest sites between years, lack of elaborate courtship and the short time interval between arrival on territories and egg-laying. Sadly, the appearance of such a confident statement in a prominent ornithological journal has been accorded undue weight (e.g., Johnsgard 1987, del Hoyo et al 1992). Indeed, Terres (1980:595) cites the Sjölander and Ågren article specifically to support the belief that loons mate for life.

A final contributing factor to the mate for life myth has been simply the lack of solid data to refute it. Although loon research has been ongoing for many decades, scientific publications on loons consist of a motley assortment, including many Master's and Ph.D. dissertations, obscure government reports, articles in regional ornithological journals and other documents with limited distribution (see list of references in McIntyre 1988). Despite the vast number of publications on loons, we currently have a very superficial understanding of pairing patterns and most other aspects of social behavior.

The refinement of techniques used to capture and mark common loons and subsequent efforts of numerous collaborators to study a growing marked population have made it possible to examine rigorously the notion that loons mate for life. Armed with these powerful data, we will revisit this issue. In so doing we will also discuss the ramifications of this myth for those of us carrying out research on and seeking to conserve loons.

METHODS

Research contributing to this report was carried out from 1993 - 1997 in Oneida Co., northern Wisconsin, an area containing about 200 natural lakes 4 ha or larger. Techniques are published elsewhere (Piper et al. 1997a, b). Briefly, between 1991 and 1997 we captured 109 adult loons with chicks and 8 loons without chicks at night on 56 study lakes using small motorboats, spotlights, and salmon landing nets. We marked legs of captured birds with unique combinations of a metal band and 1-3 plastic colored bands and drew 6-10 ml of blood for analysis of mercury exposure and extraction of DNA. Routine censuses were performed shortly after ice-out from 1992 to 1997 to determine whether marked birds had returned to their past territories. We visited study lakes 6-30 times each year to detect disappearances of pair members, monitor social behavior and measure reproductive success. Since most study lakes were clustered in a 25-30 km diameter area within which additional lakes lacking pairs were also visited, there were numerous opportunities to reobserve birds that had disappeared from their territories, providing they had dispersed short distances.

RESULTS AND DISCUSSION

DO LOONS MATE FOR LIFE?

In asking if loons mate for life, we are really asking what proportion of all loon pairs that breed together in one year are still together the next year, the year after, and so forth. Thus, we are asking about the duration of "pair bonds". There are two problems to confront here. First, even a 5-year study, such as ours, will be insufficient to answer the question thoroughly, because this is a fraction of the life spans of many loons. Fifteen years or more might be required to follow the complete breeding lives of many individuals. Second, we face the age-old problem of deciding whether animals that have disappeared from their breeding territories have moved away (in which case we view the pair bond as having been broken) or died. If we decide to view all disappearances as indicating deaths, then we will underestimate the rate at which breeders leave their mates to breed elsewhere (termed the "divorce rate", hereafter; see Choudhury, 1995) and thus exaggerate the duration of pair bonds. If, on the other hand, we regard all disappearances as emigration, then we will certainly overestimate the divorce rate and underestimate the duration of pair bonds.

Fortunately, neither difficulty deals a mortal blow to our investigation. Despite the relatively short duration of our study, we can make simple and reliable projections of divorce rates across loons' lifetimes. The death vs. emigration issue is troubling only if we are unable to locate marked loons after they leave their territories. As we shall see, our data actually produce a rather clear picture of the divorce rate in loons.

DIVORCE RATE IN THE STUDY POPULATION

The first step in computing a divorce rate is to arrive at a representative sample of independent study pairs. We used data from 35 independent pair-years in the computation, which represented cases wherein both pair members were banded and then re-sighted frequently enough during exactly the 365 days after banding to verify the presence or absence of both pair members. Most individuals that left their territories were re-located at least once elsewhere, an indication that they were alive and healthy but no longer paired with their original mate (see Piper et al. 1997a). Cases wherein birds disappeared between fall and spring migration were excluded, because many of these probably represented deaths.

In 8 of 35 pairs, divorce certainly occurred within the 365-day period of observation; that is, one bird departed from the territory, while its mate re-paired with another bird. Of these eight certain divorces, five resulted from territorial takeover (see also Piper et al. 1997a); two were likely takeovers and the eighth case resulted from desertion. In an additional 2 cases, birds suddenly disappeared without explanation in mid-breeding season and were not re-sighted elsewhere. Since they involved remote lakes for which re-sightings were unlikely, the 2 sudden disappearances were likely cases of divorce. However, we conservatively viewed these disappearances as deaths and thus use 8/35 = 22.8% as an estimate of the annual divorce rate in our population.

Although the divorce rate seems quite high in loons, it is not unusually so when compared to other migratory birds without continuous pair bonds (see Appendix 19.1 in Ens et al. 1996). When we use the annual rate of divorce to project the number of divorces that individuals might experience over a 10-year breeding career, we see that loons divorce and re-pair with surprising frequency (Table 1). A typical loon on a breeding territory, for example, has less than one chance in 13 of avoiding divorce over a 10-year breeding career. Most loons divorce and re-pair one to four times in a decade.

Table 1. The probability of different numbers of divorces in 10 years of a loon's lifetime.

Number of divorces in a 10-year period	Probability[a]
0	0.075
1	0.22
2	0.30
3	0.23
4	0.12
5	0.043
6 or more	0.015

[a]Probabilities computed using formula:

$\binom{N}{r} p^r q^{N-r}$ = prob. of a given outcome,

where N = number of trials; r = number of successes; p = prob. of a success; q = prob. of a failure e.g.

$\binom{10}{2} (1-0.228)^8 (0.228)^2 = 0.295$

We need to keep in mind that this projection is based on the mean divorce rate in our population. Some individuals, by chance or because of their own behavioral tendencies, might experience lower or higher rates of divorce than these projections indicate. To get a feel for the variability in divorce rates, we can look at pair bonds among our marked pairs. We found the following distribution among 13 pairs followed closely for 4-year periods (projected values in parentheses): 6 pairs (4.62 projected) had no known divorce (2 disappearances attributed to death), 5 (5.45) had 1 divorce, 1 (2.42) had 2 divorces, 0 (0.48) had 3 divorces, and 1 (0.04) had 4 divorces. Thus, the projections agree rather well with actual data.

ARE LOONS BONDED WITH MATES OR TERRITORIES?

A recurring problem in studies of pair bonds and divorce among territorial species is to determine whether animals are bonded to their mates, as we presume, or to their territories (see discussion in Ens et al., 1996). Although a large body of literature suggests that animals might benefit from remaining mated with the same individual (e.g., Rowley 1983, Emlen 1990, Marzluff and Balda 1992, Fairweather and Coulson 1995), an equally large body suggests that site fidelity is more important than mate fidelity (Morse and Kress 1984, Desrochers and Magrath 1996, Newton and Wyllie 1996).

It is too early to tell whether mate- or site-fidelity or both are important determinants of dispersal behavior in loons. However, events that occur during territorial takeover suggest that site-fidelity might be more important. After its mate is driven off territory by a usurper, a given loon faces a choice between remaining with its mate or remaining on its territory and re-pairing with the usurper. In about a dozen cases observed thus far, loons have always chosen to pair with usurpers on their territory rather than follow their defeated ex-partner to a new site.

The mate- vs. site-fidelity argument has important implications for students of loon behavior. In the quest to refute the notion that loons mate for life, one can easily become obsessed with the idea that a loon's mate is paramount to its behavior and reproductive success. If so, one might take the high divorce rate in loons to mean that loons spend considerable effort in locating a compatible mate, perhaps through trial and error. While such a hypothesis is tenable and not without precedent in the mating literature (e.g. Coulson and Thomas 1983), it is less plausible than a second hypothesis that loons merely seek a territory *of the highest quality and divorce only when forced to do so by usurpers that drive them off territories.* (Note that divorce includes cases wherein a pair splits up involuntarily.) In any event, future studies should address explicitly the possibility that mate-fidelity, site-fidelity or both might play a role in loon reproductive behavior. Since divorces/territory losses decrease reproductive success in the short term, we might expect that loons have evolved behavioral means of reducing the frequency and impact of territory- or mate-loss. Clearly, our findings open up a rich area for scientific investigation.

WHY IS IT IMPORTANT TO BE RIGOROUS IN STUDYING LOON BEHAVIOR?

We believe that those of us studying loon behavior and ecology have a special mandate to collect and interpret our data carefully. Loons are not one of the legions of virtually anonymous study animals that most biologists work with but instead are important symbols of northern ecosystems. Study of the health of loon populations and their reproductive capacity might help us learn about the health of their habitat (e.g. Titus and Van Druff 1981; but see Strong 1990). Perhaps more importantly, scientists studying loons can, by means of lectures and popular articles, pass on information about loon biology that will be devoured by a public hungry for information. Whether we came to be fascinated with loons via a scientific path or otherwise, all of us who love loons would like to see their populations thrive. We can best help our cause by recognizing and promulgating the truth about their mating behavior: loons do not mate for life, by any definition of the phrase. By dispelling this deeply-rooted myth about Common Loons, we will be helping to lay the groundwork for rigorous scientific investigation in the future.

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INCUBATING ROLES AND PATTERNS IN COMMON LOONS (*GAVIA IMMER*)

JAMES D. PARUK

IDAHO STATE UNIVERSITY, DEPARTMENT OF BIOLOGICAL SCIENCES, POCATELLO, ID 83209:
PRESENT ADDRESS: FEATHER RIVER COLLEGE, QUINCY, CALIFORNIA 95971

INTRODUCTION

Several studies have investigated sex roles of the Common Loon during the nesting period. Some were done on unmarked birds which makes the determination of the incubating sex uncertain (Sjolander and Ågren 1972, Taylor 1974, McIntyre 1975), since sexes are essentially monomorphic. Studies done on marked birds were done in one hr (Evers 1994), 3 hr (Gostomski and Evers 1998) or 3-4 hr (Mager 1995) time blocks. My study was done on marked birds, and behavioral observations were continuous from predawn to post sunset. This allowed me to detect patterns of nest exchanges, and record both total time incubating and time of incubation for each sex, giving a more reliable measure of parental effort.

STUDY SITES AND METHODS

I studied 11 pairs of Common Loons during four breeding seasons, 1993-1996. The 28-29 day incubation period was divided into trimesters, of 9 days each, and each pair was observed for three full days during each trimester. Observations began when individual pairs initiated nesting (as early as 16 May). Pairs were monitored continuously from 0.5 hr before sunrise to 0.5 hr after sunset, for a total of 16-18 hours each day, depending on daylength. Nesting loons were observed for a total of 99 days, or 1660 observation hours. This intensive sampling scheme was possible due to the assistance of numerous volunteers from Earthwatch Institute. Volunteers were trained in the use of spotting scopes (if necessary) and identification of colored leg bands. Initially they were paired with one of my assistants or with me before they were approved to work with other volunteers or independently.

We observed either from stationery blind, or from shore near public access sites. Distance to each nest varied from 70m - 240m. Observations were made with a Kowa TSN-2, 20X or a Bushnell Spacemaster 25X-spotting scopes.

Time of daily nest exchanges and length of each incubation period for each sex were recorded. In order to decide whether the last nest exchanges of the day, and their subsequent incubation lengths, were included in the analyses, the following criteria were established to minimize loss of data. If a loon had been incubating for less than the average incubation length for that trimester before observations ceased for the day, it was excluded from the analyses (n= 61, 61,6%); if it had been incubating for longer than the average incubation length for that trimester, it was included in the analyses (n=38, 38.4%). Thus, all incubation lengths presented in Table 1 are underestimates.

To determine if there was a nest exchange during the night, nests were observed the following morning (n= 68, 68.7%) until the identity of the bird on the nest could be ascertained.

Adult loons and juveniles were captured at night during 1989-1996 from small motorboats (Evers et al. 1996). All adults and juveniles were banded with a single U.S. Fish and Wildlife Service metal band and individually banded with 1-3 plastic, colored leg bands (Hermes, Inc.) in unique combinations. The colored bands were easily observable during a nest exchange. Males were distinguished from females during the nesting cycle by vocalization (only males yodel).

Four pairs of loons (one in 1993, three in 1994) were monitored at Seney National Wildlife Refuge (SNWR, 45° N, 86°W) in Michigan's eastern Upper Peninsula. The Refuge contains 21 artificially controlled, shallow pools, generally 1 m deep, but up to 3 m deep along the dikes. Three of the pools were nearly equal in area (D=79.8 ha, G=81.8 ha, B= 98.4 ha), but E pool was approximately twice as large as the other pools (E=198.4 ha). Pools B and G were isolated from the other pools, and D and E pools were perpendicular, separated by a dike 10 m wide. The E pool loons' territory was located on the eastern edge of the pool, furthest away from the D pool loons. Each pair defended the entire pool from conspecifics, although the E pair was not observed on the extreme westernmost edge of the pool (closest to D pool). These territories are called whole lake territories.

Seven pairs of loons were monitored in northern Wisconsin (46 °N, 90° W) (5 in 1995 and 2 in 1996). Five pairs were located on the Turtle Flambeau Flowage (TFF) and two pairs on nearby lakes (One Man, Deer). TFF is a large impoundment (5,978 ha) with 22-24 nesting pairs of Common Loons. It has numerous islands (>150) and irregular shorelines which permit separate loon territories, or partial lake territories. Less than 5% of the shoreline of TFF is developed. Dominant recreation use of TFF includes fishing and camping. The average depth of TFF is 3 m, with a maximum depth of 16 m. One Man and Deer Lakes are small (10.9 and 14.6 ha, respectively), relatively shallow (mean = 6.5 m and 5.5 m deep, respectively) and categorized as whole lake territories.

Water clarity was obtained during the incubation period by taking a Secchi disc reading within each loon territory. Seine nets were used to record potential prey availability and relative fish densities (#/area seined).

All statistical tests were performed using SYSTAT and significant differences ($p< 0.05$) revealed by the MANOVA or ANOVA tests were then analyzed with Tukey's test to show where the differences were (Zar 1984).

RESULTS AND DISCUSSION

Although McIntyre and Barr (1997) report that incubation length and nest exchange patterns in Common Loons are idiosyncratic, I propose some testable hypotheses. For example, they may be the result of loons balancing their daily energy needs, which are potentially influenced by prey type and density (Barr 1996), water clarity (Gostomski and Evers 1998), territory type, and territory size.

Gostomski and Evers (1998) report Lake Superior nesting loons spend less time foraging than inland nesting loons at SNWR. They suggest that differences in water quality (clarity) and prey base may account for these differences. For example, average Secchi disc readings for Lake Superior (n=10) and SNWR (n=5) are 6.0 m (J. Oelfke, pers. comm.) and 3.6 m, respectively (the latter being tannin-stained). Prey composition varied as well, with Yellow Perch (*Perca flavescens*), Suckers (*Catastomus* sp.) and Lake Herring (*Coregonus artedii*) dominant in Lake Superior waters; whereas Brown Bullhead (*Ictalurus nebulosus*) was the dominant (>95%) fish species at SNWR pools (R. Urbanek, pers. comm.). Underwater visual accommodation in loons is excellent (Barr 1973), but at what level and to what extent their vision is compromised remains unknown. Loons on lakes with Secchi disc readings of 1.5 m or less could not breed successfully (Barr 1986).

If incubation lengths and nest exchange patterns are coupled with foraging times and if daily behavioral patterns are flexible and optimized (Orians 1961), then one might expect that loons would have more frequent nest exchanges and shorter incubation periods where water clarity and prey densities are highest since foraging times would be shorter. My data do not support this view. SNWR had both shallower and clearer water (3.6 m Secchi disc) than TFF (2.6 m Secchi disc). Average incubation length for loons at SNWR (n=4) was 5.0 hr (297 m) compared to 4.1 hr (254 m) at TFF (n=5).

It is possible, however, that loons at TFF may have been able to meet their daily caloric needs more quickly than loons at SNWR, resulting in shorter incubation times and more frequent nest exchanges. Prey composition varied between the sites. At TFF, the dominant fish species in descending order were Walleye (*Stizostedion vitreum*), Yellow Perch (a preferred prey item, Barr 1973) and sunfish (*Lepomis sp.*) (J. Roth, pers. comm.) whereas Brown Bullhead were dominant at SNWR. Moreover, the projecting spines behind the pectoral fins of large bullheads appeared to give loons difficulty in swallowing (pers. obs.). These differences in prey composition between the sites, more than water clarity alone, may account for the observed differences in incubation lengths at these sites.

One Man Lake (2.0 m Secchi disc) had significantly lower fish densities ($F= 21.45$, $p< 0.01$) than the other loon territories (n=10). Resident One Man Lake loons incubated for slightly longer times than loons on other whole lake territories (n=5), averaging 5.0 hr across all trimesters as compared to 4.7 hr. One member of the pair would leave the lake each day to forage on other lake (s) and on a three occasions did not exchange nest duties between 10 and 14 hours. To what extent loons can fast without seriously compromising performance is unknown, but the data from loons at One Man lake suggest they can go up to 14 hr without seriously affecting performance. Loons at One Man Lake successfully raised one young in both 1995 and 1996. These observations suggest that nesting behavioral patterns may be related to prey availability and that average loon incubation lengths of 4-5 hr may be optimal, but wide variation is possible.

Other factors such as territory type and size may also influence loon nesting behavior. Loons on whole lake territories incubated for significantly longer times ($F=14.61$, $p < 0.05$) than loons nesting on partial lake territories (4.9 hr$\pm$ 1.6 hr and 4.1 hr $\pm$ 1.6 hr, respectively, Table 1). One explanation for this difference is the presence and high number of conspecifics observed in or near partial lake territories (Belant 1991, Paruk, unpubl. data.). Breeding loons are highly territorial and agonistic encounters with conspecifics are known (McIntyre 1988, Piper et al. 1997). Loons on whole lake territories (SNWR, One Man and Deer Lakes) had fewer encounters with conspecifics than loons on partial lake territories (e.g. TFF) (J. Paruk, in prep.). Precisely how incubation patterns are affected is unclear. Perhaps resident loons need to patrol their territorial boundaries more frequently than loons on whole lake territories (i.e., maintain a high profile).

Nest exchange patterns may be optimized so males can be off the nest at night. I made no nocturnal observations, but was able to determine if there had been at least one overnight nest exchange by noting which sex was on the nest at dusk and which was on at dawn. Of 68 observations, 16 (23%) had exchanged nest duties during the night at least once. Loons on whole lake territories exchanged incubation duties at night more often than loons on partial lake territories ($t=2.635$, $p < 0.05$). This suggests that at night, males more continuously patrol the partial lake territories, where potential interactions with conspecifics are higher. Wentz (1988) observed increased nocturnal chorusing on partial lake territories compared to loons on whole lake territories and Gostomski and Evers (1998) reported male loons were more likely the last bird incubating at the end of the day and females more likely on the nest at the start of the day, support this idea.

TABLE 1. *Average incubation lengths (min. ± standard deviation) of Common Loons by sex, territory* type* and trimester, 1993-96.

		Trimester		
Sex	1	2	3	Average (min)
Female	241 ± 112	279 ± 103	307 ± 100	276 ± 104
Whole*	252 ± 111	290 ± 92	336 ± 96	
Partial*	228 ± 116	266 ± 122	273 ± 104	
Male	225 ± 111	278 ± 93	304 ± 97	269 ± 100
Whole*	234 ± 113	307 ± 101	327 ± 98	
Partial*	215 ± 110	242 ± 91	277 ± 100	
Female/Male				
Whole*	243 ± 112	298 ± 96	331 ± 99	291 ± 100
Partial*	223 ± 113	254 ± 106	275 ± 101	251 ± 106

* Loons that defended an entire lake from conspecifics are called whole lake territories. Loons that share a portion of a larger lake with other conspecifics are called partial lake territories

Territory size did not appear to have an affect on incubation lengths, but because of the low sample size (n=2, One Man and Deer Lakes were 10.9 ha and 14.6 ha in size, respectively) and complications of low food availability in one (One Man Lake) it is difficult to reach any conclusions. If nesting behavior is related to food availability and loons optimize their behaviors then it is conceivable nest exchange patterns and incubation periods may change accordingly on smaller loon territories.

There was no significant difference in incubation length between the sexes during any trimester ($F=0.159$, $p> 0.05$). Average female and male incubation length (min) and standard deviation (min) was 276m ± 104 and 269 ± 100, respectively or, approximately 4.5 hr ± 1.5 hr (Table 1). Both sexes incubated significantly less during the first trimester than either the second or third trimesters ($F=18.99$, $p < 0.01$). The average incubation length for either sex during the first trimester was just under 4.0 hr ± 1.9 hr, as compared to 4.6 hr ± 1.8 for the second trimester and just over 5.0 hr ± 1.8 hr for the third trimester. The trend towards increasing incubation length during the incubation period has been previously reported (Sjolander and Agren 1972, Barr 1996), and it seems likely that fluctuating hormonal levels may be partly involved (McIntyre 1988).

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INFLUENCE OF BROOD SIZE AND CHICK AGE ON PARENTAL EFFORT IN COMMON LOONS

JOHN N. MAGER, III

DEPARTMENT OF ZOOLOGY, MIAMI UNIVERSITY, OXFORD, OH 45056 USA; PRESENT ADDRESS: SECTION OF NEUROBIOLOGY AND BEHAVIOR, CORNELL UNIVERSITY, ITHACA, NY 14853

ABSTRACT

Post-hatching parental activities calculated from time-activity budgets were evaluated in 12 pairs of Common Loons with respect to brood size and chick age between 1993 and 1995. A significant decrease in the total time parents spent in parental activities was correlated with time spent carrying chicks, suggesting that cumulative parental demands are high and decrease substantially with chick age. To meet increasing demands to feed chicks, parents fed chicks larger prey rather than by increasing the time spent foraging or the frequency they fed chicks. There were no significant differences found in any parental activity with respect to brood size, except that parents raising two chicks spent 0.15% more time defending chicks than parents raising one chick. Because this activity may be energetically costly, yet only represents a fraction of diurnal activities, results perhaps question the notion that larger broods incur greater parental demands if sufficient resources are available and whether post-hatching parental effort is influential in the evolutionary shaping of clutch size in Common Loons.

INTRODUCTION

Parental costs are believed to be substantial in Common Loons (*Gavia immer*). In addition to extensive time invested in incubation, parents must also carry, feed, and protect offspring 10 to 12 weeks after hatching (McIntyre 1988). Few studies have quantified post-hatching parental effort, in other words, the quantitative aspect of an individual's reproductive effort that considers cumulative post-zygotic care of the offspring (Trivers 1972, Low 1978, Alexander and Borgia 1979) in Common Loons, or have even evaluated variation in parental effort with respect to various environmental threats and habitat quality. Additionally, studies of variation in parental effort with life history parameters such as chick age, brood size, and gender-specific reproductive strategies are limited, but are nevertheless important when evaluating the parental demands required to raise offspring to fledging age. In this study, I evaluated variation in parental effort of breeding Common Loons with respect to the parameters of brood size and chick age.

Brood Size Effects. The small clutch size of the Common Loon (1-2 eggs per nesting attempt) may reflect an evolutionary consequence of substantial post-hatching parental demands. Modal clutch size in precocial birds that feed their offspring is believed to restricted, in part, by the maximum number of offspring that can be successfully raised by the parents; smaller broods reflect lower parental requirements to raise offspring whereas larger broods reflect greater parental requirements (Lack 1947, Klomp 1970, Winkler and Walters 1983). With regard to individual parental behaviors, the amount of parental effort is predicted to vary with brood size according to whether the behavior is depreciable or nondepreciable, i.e. whether the benefit to each offspring depreciates with larger broods (Clutton-Brock 1991). Lazarus and Inglis (1986) predicted that depreciable parental activities should increase with increasing brood size, while nondepreciable parental activities should not vary with brood size in species where predation risks involve the loss of individuals rather than the entire brood, such as in most precocial birds. Because activities associated with feeding the young are depreciable, I predicted that there would consequently be an increase in these activities in larger broods. Because activities associated with protecting the young are nondepreciable, I predicted that these activities would not be influenced by brood size.

Chick Age Effects. It is difficult to predict how parental effort in Common Loons should change with chick age because models must simultaneously consider the benefits and costs to both parents and offspring (Clutton-Brock 1991). Parental effort should increase with chick age because the reproductive value of the offspring to the parent in terms of raising another brood to the same developmental stage increases with chick age (Dawkins and Carlisle 1976, Rushforth Gunn and Batt 1985, Clutton-Brock 1991). Conversely, parental effort should also decrease with chick age as the value of parental care—in terms of augmented offspring fitness as young become more independent and in terms of feeding and protection, decreases (Trivers 1974, Rushforth Gunn and Batt 1985, Clutton-Brock 1991).

Most general predictions of age-related patterns of parental effort have been associated with the developmental pattern of the offspring. Rushforth Gunn and Batt (1985) noted that parental effort in most precocial birds decreases during the post-hatching phase because young become more independent as they grow older, whereas parental effort in altricial species increases with chick age until fledging because chicks are entirely dependent upon the parents for protection and nutrition. It may be difficult to predict whether loons would exhibit parental care patterns typical of altricial or precocial species with respect to brood age because loon chicks exhibit characteristics of both altricial and precocial development. This difficulty in classifying the developmental pattern of Common Loons is evident in the literature. Loon development has been classified as "precocial 4" (Nice 1962), "precocial 2" (Winkler and Walters 1983, based upon Ricklefs 1979), "semiprecocial" (McIntyre 1988, McIntyre and Barr 1997), and "subprecocial" (Gill 1995). Loon chicks can be considered precocial because they have natal down and open eyes after hatching, and leave the nest within 24 hr after hatching. However, because loon chicks are not able to feed themselves and require parental feedings for up to 8-10 weeks after hatching (McIntyre 1988), loon chicks can also be characterized as altricial. I predicted that parental activities associated with protecting chicks would decrease as chicks age increases because evidence suggests that loon chicks exhibit more precocial attributes with respect to these activities. Conversely, I predicted that chick-feeding activities would increase with chick age in order to meet the increasing nutritional demands of the chicks.

STUDY AREA AND METHODS

Research was conducted at the Ottawa National Forest, Michigan, an area with a high density of breeding loons (Evers 1993a). Migrating loons arrive soon after winter ice has melted from lakes between mid and late April, and remain at their summer territories until late October. After arriving, adults establish territories and form pair bonds. After a clutch of 1-2 eggs is laid, both adults incubate the clutch for 25 to 29 days. The second egg is usually smaller and laid usually within 24 hours after the first (McIntyre 1988). Banding records strongly suggest that there is strong nest site and mate fidelity in this region, as 90% of all returning adults pair with the mate from the previous year at the same territory (Evers 1993a). Extra-pair copulations have not been documented for this species, nor were they witnessed among pairs during the study. Additionally, results of DNA fingerprinting were consistent with genetic monogamy and no evidence of extra-pair fertilizations (Piper, et al. 1997).

If a clutch is lost during the incubation period, females often lay a second clutch of either one or two eggs unless it is late in the breeding season (McIntyre 1988). Reports of supernumerary clutches (i.e. three eggs) for Common Loons have been noted, but it is not known whether such clutches were laid during one nesting attempt represent multiple clutches laid by one female or possibly more than one female (McNicholl 1993). For the first 14 to 16 days after hatching, chicks are able to ride upon the parents' backs for protection and to reduce heat loss into the water (Black 1976, McIntyre 1988). Loon chicks also depend upon the parents for food and protection until chicks are 8 to 10 weeks old (Barr 1973, McIntyre 1988). Males and females equally provide food to chicks (Mager 1995), and it has been estimated that they must supply about 62 kg of food to each chick (Parker 1985).

Data were collected during the breeding seasons from 1993 to 1995 from a total of 12 breeding pairs. Behavioral samples taken via continuous sampling methods (Martin and Bateson 1993) were conducted between 0500 and 2100 hr to best represent all diurnal activities. Breeding loons were identified and distinguished by the specific combinations of their colored leg bands (Evers 1993a, 1993b). Samples for each focal pair ranged in duration from three to four hours. Because both parents could be confidently observed from one site, behaviors of both adults were observed and recorded simultaneously (Altmann 1974). If it was impossible to view both parents at once, only the activities of the parent nearest the chicks were recorded. Loons living on lakes where they were the only territorial pair were seldom absent for greater than 5% of the sampling time (mean time an adult was out of sight = 2.33 min (1.29% of sampling time, n = 419 samples)).

A total of 1148 h of post-hatching behavioral data were gathered: 357 h during 1993, 334 h during 1994, and 356 h during 1995 from a total of 419 samples. All but one territorial pair (which lived on a lake that supported three territories in 1995) lived on lakes that supported only that pair. All but one of the clutches (which hatched two chicks) that successfully hatched chicks were believed to be the first clutch laid by the territorial female that year. As a result of predation, not all of the chicks from the study survived to a fledging age. For example, both chicks from a two-chick brood were killed within 5 d after hatching by another territorial loon intruding far into the territory.

I measured parental effort from the time-activity budgets as the proportion of the 3-4 hr sample period parents were involved in twelve dependent (i.e. time invested into one behavior restricts time invested into another) activities (Table 1) and one independent (i.e. time invested into one activity regardless of other activities) activity. This independent activity was the proportion of time parents spent within a 30m distance of the chicks, and was measured to estimate parental protection by being in close proximity to the chicks (i.e. in attendance). In addition to measuring the time-activity budgets, I measured the frequency with which each parent fed chicks (number of feedings per hour) as well as the size (length in mm, as approximated by Dulin (1988)) of prey parents fed chicks.

TABLE 1. Common Loon behavioral definitions among somatic or reproductive effort, including mating and parental efforts.

Category	**Behavior and Context**
SOMATIC EFFORT	
Foraging	Bouts of diving underwater < 1 min that did not result in feeding chicks or function as aggressive or mating display.
Locomotion	Surface swimming, flying, and "walking" on land. Did not include courtship and aggressive displays.
Resting	Drifting on water surface, either sleeping or awake.
Maintenance	Preening and bathing.
Social Gathering	Circle-swimming, jerk-diving (Sjölander and Årgen 1972, McIntyre 1988), and non-aggressive interactions between resident loons and conspecifics.
REPRODUCTIVE EFFORT	
Mating	
Courtship	Ritualized circle-swimming, jerk-diving, and head-turning within the resident pair.
Copulation	Sequence of highly stereotyped behaviors (Sjölander and Årgen 1972, McIntyre 1988).
Territory Defense	Physical and/or vocal defense against conspecifics and interspecifics prior to egg-laying.
Parental	
Nest Building	Nest-building and maintenance.
Incubation	Incubating and turning of eggs.
Chick Feeding	Dive, catch, and present prey to chicks. Measurement ceased when no food offered 1 min after last feeding.
Aggressive Defense	Defense after egg-laying. Includes penguin dancing, crouch and yodel displays (McIntyre 1988), vocalizations, and chases.
Chick Carrying	Parents carry chicks on their backs.

To standardize the number of samples conducted per individual and for chick age when samples were taken, weekly means of each individual's activity budgets were calculated and considered as the dependent variable in brood age analyses. I tested data for normality and homoscedasity, then analyzed data using linear regression to test for relationships with chick age. I used repeated measures analysis of variance (ANOVA) to test for differences among weekly means that may not have been evident from regression analyses. Brood size effects were also analyzed by repeated measures ANOVA. Analysis of variance was performed using the GLM procedure of the SAS statistical package (SAS Institute 1990), and I accepted standard experiment-wide statistical significance for all comparisons at a maximum alpha value of 0.05.

RESULTS

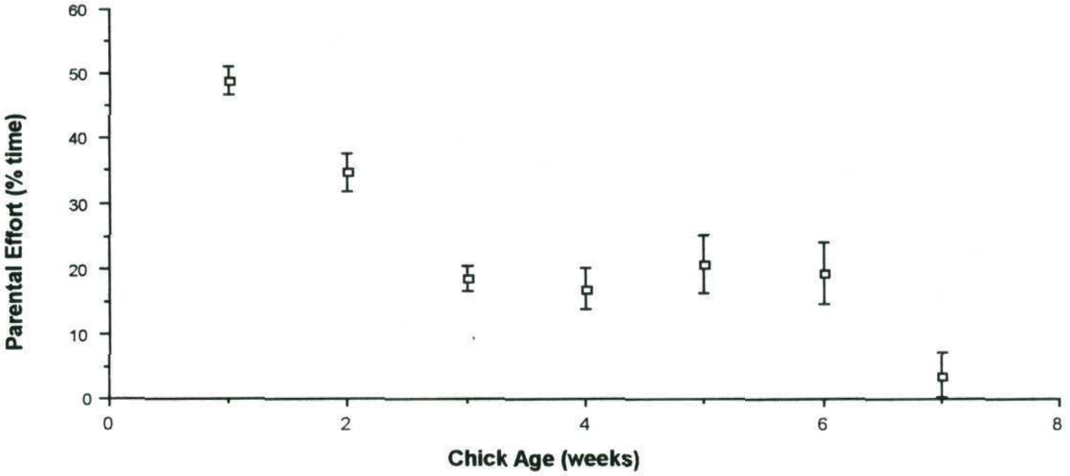
Brood Size Effects. There was not a significant difference between parental effort (i.e. the cumulative amount of time spent in dependent parental activities) given by parents raising one chick (28.8%) and parents raising two chicks (27.0%, F1, 22 = 0.228, P = 0.64). There was also no significant difference in each dependent and independent parental activity, nor in the frequency and size of prey fed to chicks between individuals raising one chick and individuals raising two chicks, except that parents raising two chicks aggressively defended the chicks more than parents raising one chick (Table 2), suggesting that the added costs of raising additional offspring are associated with protection. However, the difference in this behavior may be related to the frequency parents were disturbed rather than the brood size, as parents raising two chicks were disturbed (0.377 + 0.057 events / sample) more frequently than parents raising one chick (0.222 + 0.042 events / sample). Though the parental effort in terms of feeding chicks did not vary between parents of one and parents of two chick broods, each chick from two-chick broods received significantly fewer food items (4.093 + 0.273 / h) than each chick from a one-chick brood (9.368 + 0.673 / h; F1, 22 = 8.692, P = 0.01), suggesting a benefit to offspring of one-chick broods. The proximate survival of chicks did not appear to increase though, as all chicks (except for those lost to predation early in the post-hatching period) successfully fledged.

TABLE 2. Parental activities (mean + 1 SE) of breeding Common Loons parenting one or two chick broods during the post-hatching period. * = sig. at P < 0.05.

Behavior	one chick parents (n = 12)	two chick parents (n = 12)	F$_{1.22}$	P=
Feeding Offspring				
% time foraging to feed chicks	9.94 + 1.88	8.32 + 1.65	0.42	0.52
Frequency chicks fed (#/ hr)	5.18 + 1.21	3.90 + 0.80	0.79	0.38
Length of prey fed to chicks (mm)	16.20 + 2.32	21.97 + 4.87	1.14	0.30
Protecting Chicks				
% time carrying chicks	5.55 + 1.00	5.69 + 0.88	0.01	0.91
% time within 30m of chicks	35.25 +4.85	38.11 + 6.86	0.12	0.74
% time aggressively protecting chicks	0.10 + 0.03	0.37 + 0.09	8.65	< 0.01*

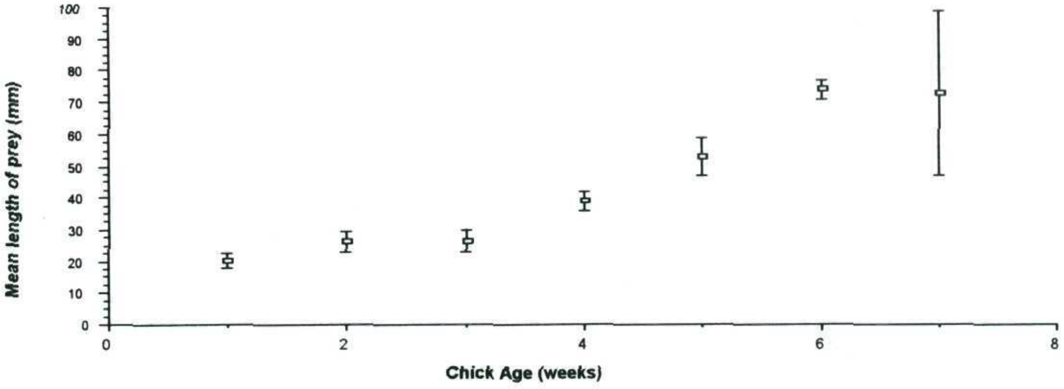
Chick Age Effects. The proportion of time parents spent caring for the chicks significantly decreased with chick age during the first seven weeks of the post-hatching period (slope = -6.965, r^2 = 0.408, P < 0.001; Figure 1). Parents spent nearly half of their diurnal activity budgets caring for the young during the first week after hatching, but only one fifth of their activities during the sixth week, suggesting a significant drop in parental costs. This decrease though is correlated with, and hence reflects the highly significant decrease in the proportion of time parents spent carrying the young (parental effort = 0.879 (time carrying) + 19.282, $r^2 = 0.544$, $P < 0.001$). Carrying chicks accounted for 65.4% of all parental activities during the first week and for 42.7% during the second week after hatching. There was not a significant change in the proportion of time (ranging between 0.25% and 0.58%) parents spent aggressively protecting the chicks (slope = -0.04, $r^2 < 0.01$, $P = 0.94$), indicating that the costs associated with this activity do not change with chick age. The proportion of time parents spent attending to the chicks also did not vary with chick age (slope = -1.631, $r^2 = 0.025$, $P = 0.13$) and ranged between 56% and 71%.

FIGURE 1. The mean proportion of time parents were involved in any dependent parental activity during the first seven weeks of the post-hatching period. Error bars indicate + 1 SE.



In those activities associated with feeding chicks, there was no change in the proportion of time (ranging between 12.5% and 20.1%) parents foraged to feed young (slope = 0.732, $r^2 = 0.011$, $P = 0.33$), nor in the frequency (ranging between 4.1 feedings / h and 10.4 feedings / h) parents fed young (slope = 0.2108, $r^2 = 0.017$, $P = 0.21$). There was however a significant increase in the mean length of prey items fed to offspring (slope = 8.863, $r^2 = 0.433$, $P < 0.001$), Figure 2).

FIGURE 2. The mean length of prey fed to young during the first seven weeks of the post-hatching period. Error bars indicate ± 1 SE.



DISCUSSION

Brood size effects. Aside from the time spent aggressively protecting the young, the way at which parents raising one chick versus parents raising two chicks did not differ. The finding that parents raising two chicks invested greater time in aggressively defending the offspring than parents raising one indicates that brood size may influence parental activities in Common Loons. Similar findings have been cited in studies of other precocial birds, such as White-fronted Geese (*Anser albifrons*) (Masden 1991), Bar-headed Geese (*Anser indicus*) (Schindler and Lamprecht 1987), and Cackling Canada Geese (*Branta canadensis minima*) (Sedinger and Raveling 1990), suggesting that aggressive behavior is possibly a form of depreciable rather than nondepreciable care, that there may be differences in parental quality among individuals (Paine 1992), or a reexamination of variation in parental care among precocial birds is needed.

The biological significance of the difference in defending chicks may be substantial, because this activity may be energetically costly to the parent. However, the biological significance of difference between the times parents of one and two-chick broods spent aggressively protecting the young may be questionable because the difference between group means is fractional (i.e. < 0.005% of daily activities). This difference may represent a negligible contribution in terms of energetic cost to a parent in that it may not decrease adult body condition (e.g., readiness for migration or future reproductive success). Additionally, the significant difference between the two groups in the frequency of disturbance events suggests that time spent aggressively protecting the young may be related to disturbance frequency rather than brood size, which in turn may be reflective of habitat quality. It can be additionally argued that spending more time aggressively protecting the chicks places the parent at greater risk of predation because they are more conspicuous to potential predators. However, few if any predators of adult Common Loons have been identified in the Ottawa National Forest, which would suggest that the differences in risk are not significant. These issues therefore further question whether statistically significant differences in agonistic activities are related to brood size.

If there were no real differences in the activities of parents raising two chicks versus parents raising one, it can be inferred that the costs of raising either one or two chicks were similar. One possible explanation may be that loons maximize parental effort regardless of brood size because the demands to raise even one chick are high. Parental demands would be high in terms of reproductive value of the parent in that the amount of parental effort needed to raise another chick to the same age in terms of cost and risk are great (i.e. successfully copulating and incubating another clutch). However, demands on these parents are small when compared to the demands on parents raising chicks on lakes where prey availability is low due to low alkalinity (Alvo 1985, Parker 1985). This suggests that parents in this study may not have been spending a maximum amount of available time for parental activities. Future studies that correlate variation in aspects of habitat quality with variation in parental effort would be beneficial in elucidating parental costs of successfully raising offspring.

Alternatively, post-hatching parental activities may not be costly and may not be influential in the evolutionary shaping of clutch size in Common Loons. If not hindered by neither other parental duties nor a lack of adequate resources, adult loons will allot ample time and energy to raise either a brood of one or two chicks to fledging. The amount of parental effort may reflect only the amount of parental effort necessary to raise offspring to a fledging age. Given sufficient resources and limited disturbance, it may be relatively easy to successfully raise two chicks. I assumed that all chicks in two-chick broods were receiving ample resources because of the visual similarity in chick body size. Due to a dominance hierarchy, which is established between chicks, if chicks were not receiving adequate resources to fledge, there would have been definite discrepancies in the size, development, and behavior between the chicks (Dulin 1988, McIntyre 1988). If the subordinate chick among a two-chick brood was not receiving enough food, it would not have developed as quickly as the dominant chick, would have lagged behind the family unit as the discrepancy between each chick's development increased, and would have eventually starved to death (Dulin 1988, McIntyre 1988). However, if the dominant chick was satiated it would have allowed the subordinate to accept food (Dulin 1988). Because both chicks in each of the two-chick broods were similar in size in this study, it is likely that both were receiving adequate food. Moreover, these chicks were receiving enough nourishment from parents investing the same amount of parental effort that was provided to one-chick broods. Therefore, it is possible to conclude that parents were successfully able to raise two chicks without investing additional energy into parental activities.

Caring for the young therefore may not be as costly as previously hypothesized, at least if adequate resources are available and accessible. However, an important consideration is that evaluations of brood size effects were conducted by observing natural variation in brood size. Experimental manipulation of brood size in addition to natural experiments would be important to completely understand the evolutionary relationships between brood size and parental effort in this species (Clutton-Brock 1991). If the costs of raising two or even three chicks are not found to be more than those raising one, then other factors are likely to be responsible for the evolution of the small clutch size in Common Loons, such as the condition of the female (Raveling 1979) and the physiological costs associated with egg production (i.e. the "egg-formation hypothesis"), or the physiological ability of parents to successfully incubate clutches of greater than two eggs (Klomp 1970, Winkler and Walters 1983). Future studies that evaluate variation in parental activities with variation in clutch size and brood size and reduced productivity would enhance our knowledge of the factors, which influence the small clutch size in this species.

Chick age effects. The cumulative time parents were involved in any parental activity decreased significantly with chick age. This decrease is correlated with the time spent carrying the chicks, which suggests that in terms of time investment, carrying the chicks accounts for a substantial portion of parental demands. The change in carrying activity can be attributed to the physical limitation and increasing activities of growing chicks (Black 1976, McIntyre 1988), but may also indicate that chicks require less protection as they become larger and more mobile. Contrary to my predictions, the time invested protecting the chicks did not decrease significantly with chick age. Parents continually spent roughly 55% to 70% of their time attending to the offspring each week, and continually spent about one half of a percent of their time aggressively defending the young. This however may not reflect substantial energetic costs to the parents. The costs associated with attending to the young were probably not substantial, in that being an independent activity, the time spent within 30m of the chicks can be optimized in a variety of ways (e.g. sleeping, preening, or feeding themselves or chicks) and can be energetically costly or inexpensive. The biological significance of no variation in time spent in these activities is probably limited because the amount of time aggressively protecting the young was limited. Although actively defending the young may be energetically expensive, the amount of time a parent spends in this activity was very small and might reflect relatively little parental cost during the post-hatching period.

Results do support the prediction that demands to feed aging chicks increase with chick age. To meet these demands parents do not spend a greater proportion of time foraging to feed chicks, nor do they feed chicks more frequently. Rather, parents feed chicks larger prey. Common Loons are visual underwater predators and may invest greater energy pursuing larger fish than smaller ones. Though larger fish provide increased nutritional benefit, the amount of energy loons spend catching larger fish is likely greater than the energy spent catching smaller fish (Barr 1996). As long as the time parents spend foraging to feed offspring and the frequency parents feed the young remain constant, the increase in prey size infers an increase in parental effort in terms of energetic cost.

Results demonstrate that time-activity budgets are not the only aspects, which need to be considered when appraising parental effort in this species. For example, increased nutritional demands were not met by an increase in the time spent foraging, but in the size of prey fed to chicks. Additionally, time-activity budgets do not accurately represent the differences in risk and energetic cost between different parental activities. For example, the activities associated with carrying the young (e.g. the parent may sleep when carrying the young) are likely not as energetically demanding as feeding the young (e.g. the parent dives, catches, and ultimately presents the food to the young), and therefore it would be inappropriate to consider these behaviors equivalent ("problem of currency", Knapton 1984). Though time investment is critical, future investigations of parental demands should consider not only the time invested into particular parental activities, but the relative energetic costs associated with them (i.e. time-energy budgets). Though time-activity budgets suggest significant decreases in parental effort with chick age, future studies that appraise the changing energetic costs and risks would enhance knowledge of Common Loon parental effort.

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COMPARISON OF COMMON LOON POPULATIONS, BASED ON LONG TERM MONITORING, IN KEJIMKUJIK NATIONAL PARK, NOVA SCOTIA AND LA MAURICIE NATIONAL PARK, QUÉBEC

JOSEPH KEREKES[1] & DENIS MASSE[2]

[1]JOSEPH KEREKES, CANADIAN WILDLIFE SERVICE, ENVIRONMENT CANADA, 16TH FLOOR, 45 ALDERNEY DRIVE, DARTMOUTH, N.S., B2Y 2N6, CANADA

[2]DENIS MASSE, PARC NATIONAL DE LA MAURICIE, 2141 CHEMÍN ST-PAUL, ST. MATHIEU DU PARC, QUÉ. G0X 1N0, CANADA

The breeding populations of Common Loon (*Gavia immer*) in 25 oligotrophic lakes in Kejimkujik National Park (KNP), (381 km^2, 1988 - 1995) and 76 lakes in La Mauricie National Park (LMNP), (544 km^2, 1987 - 1996) were compared. The aquatic resources of KNP are described in Kerekes (1990) and that of LMNP are given in Anonymous (1981). The lakes in both areas are oligothrophic and in KNP are more acidic (Table 1). The results of the monitoring of loon populations for KNP are given by Kerekes *et al*, (1994, 1996, 1997) and for LMNP by Masse (1995). The number of residential pairs remained stable (~39) in KNP, while it increased from 20:2 to 27 (mean = 24.6) in LMNP. The reproductive success (number of young survived to six weeks of age) declined in both areas during the study, with a mean number of fledged young 11.1 (range 5-18 in 1988 - 1995) in KNP and 13.8 (range 6-20) in LMNP. Larger lakes (>40 ha) were the preferred breeding habitat in both study areas but occasionally small lakes (7-10 ha) are used for breeding in LMNP. Changing water levels (flooding, or drop in water level in different years) during the nesting period caused some of the low breeding success in certain years in both areas. In LMNP the breeding success was lower in five lakes that were more heavily utilized by the public (>15 persons/ha/year). Four of these are heavily utilized (>45 pers./ha/year) and were abandoned by breeding loons. Public use (back country canoe trips) is the suspected cause of lower breeding success in at least five lakes in KNP. A possible negative effect of increased traffic since 1987 by researchers on loon reproduction is unknown. Another unknown negative effect on the breeding success of loons, predation on chicks by Great Black-backed Gulls (*Larus marinus*) is suspected in KNP. Great Black-backed Gulls do nest on some lakes occupied by loons. The lowering of the water level by the removal of the dam in Grafton Lake contributed to the reduced breeding success in KNP in 1994 and 1995 (Benjamin and Kerekes 1997).

TABLE 1. Comparison of selected features lake water quality in lakes used by Common Loons in Kejimkujik and La Mauricie National Parks, Canada.

Parameter	Kejimkujik NP	La Mauricie NP
Surface area	385 km2	544 km2
pH	4.5 - 6.0	5.5 - 6.5
Total phosphorus (µg/L)	5 – 15	3 - 17
Colour (mg Pt/L)	5 – 80	5 - 45
Distance from the sea (km)	40 – 60	>400

The number of adult loons is more than twice as high in KNP, yet the average number of chicks is about the same, 11.1 vs. 10.3 when the two parks are normalized to that of the same surface area (Table 2). The relative closeness to the seacoast (40 - 60 km in two directions) in KNP seems to ensure that all, and even marginal territories (e. g. 20 - 30 ha lakes) are filled, presumably with young, non-breeding adults when became vacant. It has been shown elsewhere that marked young loons may return to lakes when three years old, but do not breed until five years of age or later (Evers *et al.* 2000). The apparent low rate of loon reproduction in KNP may be partially explained by the relatively large number of non-breeding, residential pairs present.

TABLE 2. Comparison of lake characteristics and the numbers of loons in Kejimkujik and La Mauricie National Parks normalized to that of the same surface area*.

Parameter	Kejimkujik NP	La Mauricie NP
Surface area	385 km^2	544 km^2 (385 km^2)
Unit surface area	1	0.707 (1)
Number of lakes >1 ha	41	162 (114)
Number of lakes >20 ha	26	32 (22)
Number of lakes >40 ha	19	21 (15)
Number of lakes >80 ha	10	14 (9.8)
Number of lakes used for breeding	18	29 (21)
Number of lakes used for feeding	-	42 (30)
Mean # residential loon pairs	39.3	24 (17)
Mean # breeding loon pairs	14?	13.8 (9.8)
Mean # chicks	11.1	14.7 (10.3)
Mean # chicks/residential pairs	0.28	0.61

* Assuming that both parks were of the same area of 385 km2, the area KNP. Converted figures are in brackets.

In more continental areas, including that of LMNP (distance from the sea is >400 km), not all lakes of suitable size for breeding are occupied by loons. For example in LMNP, two large undisturbed lakes (123 & 354 hectares) are not used for breeding. Thus in terms of the available loon breeding habitat, these areas where many lakes are not occupied by loons, are not as productive as they appear, when loon productivity is considered only in terms of residential pairs vs. fledging young.

Besides loons, Common Mergansers (*Mergus merganser*) also breed in lakes (>40 ha) both in KNP (Kerekes *et al.* 1997) and LMNP (Hebert and Masse 1998). The possible effects of competition on loon reproduction between the two species are not known. It was observed in KNP that lakes between 40 - 80 ha may support a breeding pair of either Common Loon or Common Merganser, while lakes >80 ha may support two or more breeding pair of Common Loons or Common Mergansers together (Kerekes *et al.* 1997).

The very low reproductive success in KNP, and the possible source(s) and effects of the high levels of mercury found in loons are the subject of intensive investigations (Beauchamp *et al.* 1998, Burgess *et al.* 1998). Management measures in LMNP include the use of artificial nesting islands, control of public access on certain lakes and a public education program. Considering that young loons do not nest until 5-11 years of age (Evers et al. 2000) and they may live longer than 25 years (McIntyre and Barr 1997), it will be several more years until firm conclusions could be made on loon population trends both in KNP and LMNP.

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EFFECTIVENESS OF ABDOMINALLY IMPLANTED SATELLITE TRANSMITTERS TO IDENTIFY COMMON LOON MIGRATION ROUTES, STAGING AREAS, AND WINTERING RANGE

KEVIN P. KENOW[1], MICHAEL W. MEYER[2], PETER S. REAMAN[3], DAVID C. EVERS[3], DAVID C. DOUGLAS[4], & JEFF HINES[5]

[1]U. S. GEOLOGICAL SURVEY, UPPER MIDWEST ENVIRONMENTAL SCIENCES CENTER, 2630 FANTA REED ROAD, LA CROSSE, WI 54603
[2]WISCONSIN DEPT. OF NATURAL RESOURCES, 107 SUTLIFF AVE., RHINELANDER, WI 54501
[3]BIODIVERSITY RESEARCH INSTITUTE, 411 ROUTE 1, SUITE 1, FALMOUTH, ME 04105
[4]U. S. GEOLOGICAL SURVEY, ALASKA SCIENCE CENTER, 1011 E. TUDOR ROAD, ANCHORAGE, AK 99503
[5]MINNESOTA DEPT. OF NATURAL RESOURCES, 1201 E. HWY. 2, GRAND RAPIDS, MN 55744

ABSTRACT

Most of the United States Common Loon *(Gavia immer)* population nests on lakes in Wisconsin, Minnesota, and Michigan where state resource management agencies have developed research and habitat protection programs. Research in these states has focused on monitoring loon population trends and investigating limiting factors during breeding. Additional life history information concerning seasonal patterns of movement and habitat selection are needed to develop regional and national Common Loon conservation strategies. This includes identification of important migration routes, staging areas, and location and assessment of habitat requirements on the wintering grounds. Recent advances in transmitter attachment techniques have allowed biologists to successfully monitor waterfowl movements using new technology that employs miniaturized satellite transmitters configured for intra-abdominal implants. We implanted satellite transmitters in the abdominal cavities of three breeding Common Loons in 1996 and assessed the effects of the technique on behavior of the birds and evaluated transmitter performance. Behavioral observations indicated that time activity budgets of radiomarked birds were negatively impacted. Transmitter performance was poor and few transmissions were received by ARGOS receivers. These results indicate that the intra-abdominal transmitter configuration evaluated in this study was not appropriate for Common Loons.

Many studies have investigated the breeding biology and behavior of common loons (e.g., McIntyre 1975, Titus and Van Druff 1981, Strong 1985, Barr 1986, Evers 1994, Evers et al. 1996) and several studies described the winter ecology of loons (Dewar 1924, McIntyre 1978, Daub 1989, Ford and Grieg 1995). However, critical aspects of their natural history remain unknown, such as seasonal patterns of survival, movement, and habitat selection away from the breeding grounds. The use of satellite telemetry offers biologists the potential to identify the distribution of regional breeding populations during the winter, help quantify winter habitat requirements of marked breeding populations, and assist in locating important staging areas. This information is needed to develop regional and national Common Loon conservation strategies.

The research effort described here was developed as a demonstration project to assess the feasibility of applying satellite telemetry technology to Common Loons. Specific tasks were to 1) implant satellite transmitters (platform transmitter terminals [PTTs]) in adult Common Loons and compare pre- and post-marking behavior and 2) identify migration routes, staging areas, and wintering areas of radiomarked Common Loons. Here we report on the utility of PTTs implanted in the abdominal cavity adult loons as determined during the first year of a 2-year project.

The technology needed to construct accurate and reliable PTTs for tracking by satellite that were small enough to attach to birds was not available until the early 1980s. At that time a 170-g PTT was developed and tested using Trumpeter *(Cygnus buccinator)* and Tundra Swans (*C. columbianus*), Bald Eagles (*Haliaeetus leucocephalus*), and Antarctic Giant Petrels (*Macronectes giganteus*) (Strikwerda et al. 1986). PTT size has since been reduced and several species of birds have been radiomarked (Ely et al. 1993, Weimerskirch et al. 1993, Petersen et al. 1995, Petrie et al. 1996, Ely et al. 1997). Most PTTs are designed to work with the Argos Data Collection and Location System, a Doppler positioning system carried aboard the NOAA TIROS-N satellites. Each transmitter's unique identification number and 32-256 bits of sensor data are encoded in the transmitted signal. The transmitter frequency is doppler-shifted by the satellite motion and the measured frequency shifts are used to determine the transmitter position. Fancy et al. (1988) and Harris et al. (1990) provided an overview of the Argos system and its application to wildlife tracking. A PTT must emit a signal many times stronger than that of a conventional radio transmitter. In addition, the frequency needs to be very stable in order for the Doppler shift method to work.

The challenge facing us was to attach a 34-g transmitter to loons without causing undo behavioral changes nor did we want the transmitter to effect flight performance during migration or diving efficiency during feeding. Several attachment techniques have been used on waterfowl and other waterbirds. Transmitters have been attached externally by means of harness, neck collars, bib collars, tail clips, leg bands, nasal saddles, tape, adhesives, sutures, and subcutaneous anchors. Biologists have observed problems associated with many of these techniques. These problems range from feather wear, skin abrasions, poor retention, preoccupation with package removal, weight loss, interference with diving, and additional energetic costs associated with package weight and drag (K. P. Kenow et al. unpubl. data).

Biologists attempted to attach conventional radio transmitters to Common Loons in the late-1980s using both a wing-loop backpack harness and a bib collar (Ray Anderson, Univ. WI-Steven's Point pers. comm.). These were attached to breeding adults during summer months. Both attachment techniques were unsuitable as the birds caught their lower mandibles in the loops or under the collar around the neck and bridled themselves. This phenomenon has also been observed in a few instances when bib collar transmitters have been attached to Redhead (*Aythya americana*) and Canvasback (*Aythya valisineria*) ducks (Montgomery 1985, Sorenson 1989).

Transmitter implants, now used on several waterfowl species (Woakes and Butler 1975, Korschgen et al. 1984, Olsen 1992, Rotella et al. 1993, Korschgen et al. 1996a, Korschgen et al. 1996b, Harms et al. 1997), provide a method of attachment that circumvents the problems associated with external attachments. Korschgen et al. (1996a) developed and evaluated a surgical procedure for implanting intra-abdominal transmitters with external whip antennas in diving ducks. An external antenna was necessary because of transmission loss associated with internal antennas. The spring migration of Canvasbacks radiomarked with pulse-encoded VHF transmitters in Louisiana was documented using this technique (Korschgen et al. 1995). The technique has also been successfully used to implant satellite transmitters to monitor the movement of Spectacled Eiders (*Somateria fischeri*) at sea (Petersen et al. 1995).

METHODS

The PTTs used in this project (model PTT100, Telemetry 2000, Columbia, MD 21046; use of manufacturer's name does not imply government endorsement) weighed about 34 g and were programmed to transmit at a duty cycle that varied from 8 h on: 24 h off to 8 h on: 72 h off. With this configuration, the expected transmitter life was about 6 months. The transmitters were implanted in the abdominal cavity of the birds with a whip antenna exiting the caudal abdominal wall and overlying skin, while the loon was under a general anesthetic (Korschgen et al. 1996a). Surgical techniques and handling and care of loons were done under approval of the Animal Care and Use Committee of the Upper Midwest Environmental Sciences Center and complied with the Animal Welfare Act (Public Law 99-198 and 9 CFR Parts 1, 2, and 3).

Winter Work with Rehabilitated Common Loon. The application of the transmitter implant technique with Common Loons was first investigated using a bird submitted to the Suncoast Seabird Sanctuary, Indian Shores, Florida during winter 1996. This bird had been repeatedly "beaching" itself. Following rehabilitation, we implanted a dummy PTT that contained a functioning conventional VHF transmitter. The dummy PTT was similar in configuration, size, and weight to that used in Spectacled Eiders (Petersen et al. 1995). Following surgery, the loon was observed for 7 days in a holding pond and then released in Tampa Bay, Florida. The bird was located using radiotelemetry and observations were conducted to compile time activity budgets for the radiomarked and unmarked reference loons using the same area.

Breeding Ground Work. In late-July and early August 1996 we implanted functional PTTs in 1 male and 2 female adult Common Loons captured at Spider Lake, Itasca County, Minnesota and Frank and Trilby Lakes, Vilas County, Wisconsin. Each individual had a mate and one chick. These birds were captured using nightlighting techniques (Evers 1993) in association with ongoing state research projects. Each loon was marked with a unique combination of colored leg bands to aid with field identification of individuals. Time-activity budgets of loons targeted for radiomarking and the unmarked mate were quantified for 5 days before and up to 17 days following capture and PTT implantation to assess if behavioral abnormalities resulted from the marking technique. Non-random daily observations of 60-min duration were recorded using a continuous sampling scheme (Tacha et al. 1985). Adult behaviors were classified according to Evers (1994): 1) chick feeding, 2) foraging, 3) locomotion, 4) resting, 5) preening, 6) agonistic, 7) one pair-member out of sight, and 8) miscellaneous behavior.

RESULTS AND DISCUSSION

Winter Work with Rehabilitated Common Loon. Our observations of the radiomarked rehabilitated bird before release suggested no abnormal behavior. We did not observe any preening directed at the antenna or antenna exit site. Upon release to Tampa Bay, we observed that the marked bird spent 29% of its time engaged in preening (Table 1). Mean dive times differed (t=6.34, $P < 0.01$) between the radiomarked (32.7 secs) and reference (42.6 secs) loons. The radiomarked loon began beaching itself again on the third day post-release (10 days post-surgery) and was found dead on the fourth day post release. Depredated remains were submitted to the Research Animal Resources Center at the University of Wisconsin-Madison for necropsy and the bird was diagnosed with (1) focal pulmonary abscess and (2) parasitic hepatitis. These preexisting conditions confound the interpretation of our observations.

Table 1. Mean dive times and percent of time unmarked and radiomarked Common Loons in Tampa Bay, Florida were observed in selected activities during 20 Feb-15 March, 1996.

Subject (no. of 30 min observations)	Observation period	Mean Dive Time (+/- sd) (minutes)	Percent of Time					
			Forage	Drift	Preen	Locomotion	On	Other
Not marked (n= 74)	20 Feb - 8 March	42.6±13.3 n=260	60.1	12.4	16.2	6.0	0.0	5.3
Radiomarked (n=43)	13 March - 15 March	32.7±9.1 n=83	40.8	0.8	29.2	13.8	9.2	6.2

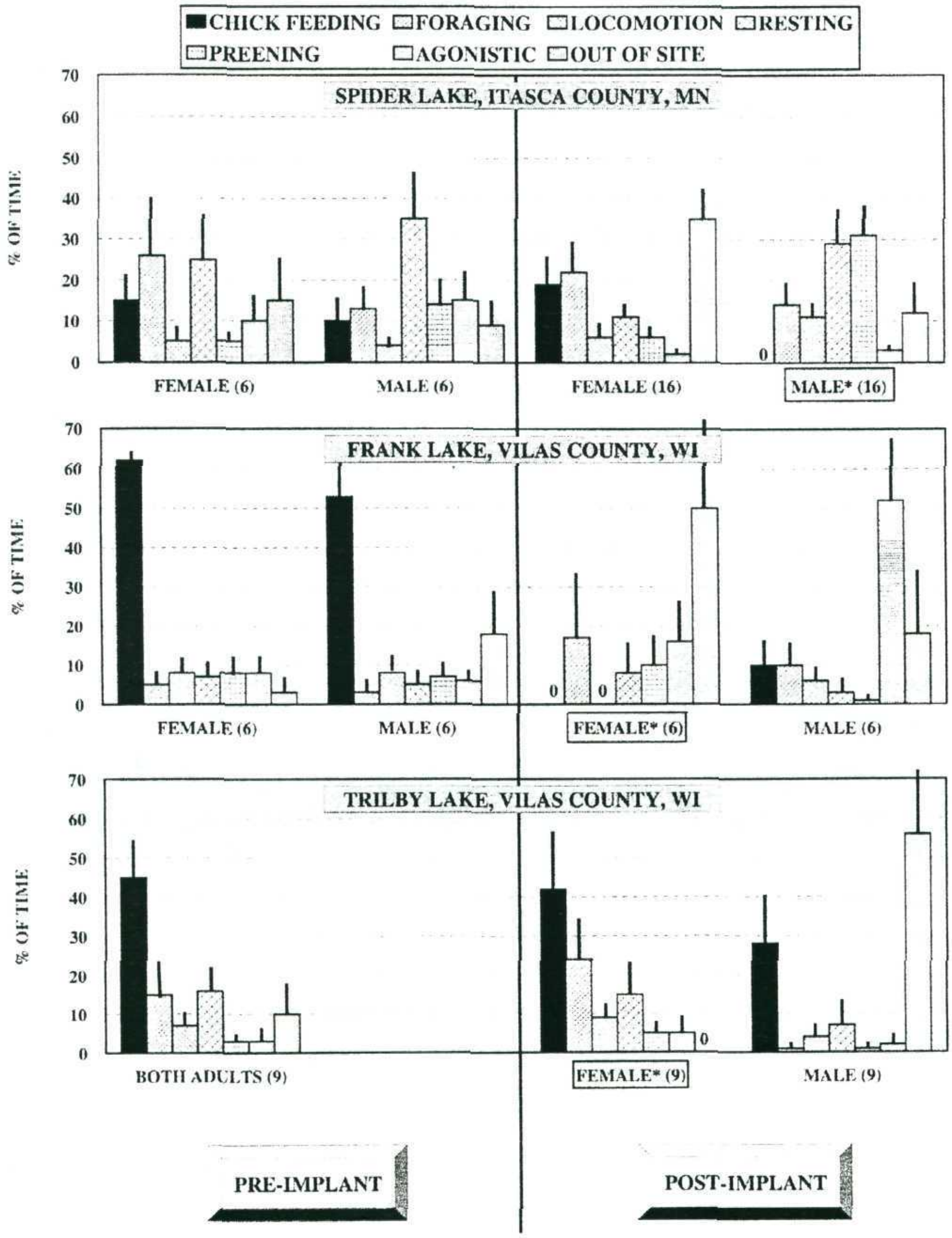
Breeding ground work. A total of 38.9 observation hours before and 66.0 observation hours after the PTT implant were accumulated for adult loons during July and August 1996. Behavioral response to PTT implants was variable among the 3 adult Common Loons that were radiomarked (Figure 1). Limited replication precluded statistical analysis of the data using an appropriate multivariate approach. However, inferences can be made based on a qualitative examination of the data. The time-activity budget of the radiomarked male loon at Spider Lake differed most with respect to chick feeding (8% pre-implantation, 0% post-implantation).

The day following radiomarking of the Frank Lake female, six invading loons were observed on Frank Lake and agonistic interaction dominated the activity of the resident male. Intruding loons were observed on Frank Lake for about one week. The radiomarked female was absent for five days before being sighted on the lake again. It was not with the resident male and chick. Prolonged absence from a pre-fledged chick is atypical behavior for adult loons during the post-nesting period (Evers 1994). The time apportioned to chick feeding was less during post-implantation observations relative to pre-implantation for both the male and female. The occurrence of the intruding loons was likely related to the implant episode and resulting behavioral changes in the radiomarked female.

The time activity budget of the female on Trilby Lake did not indicate any adverse effects of radiomarking. Chick feeding comprised 42% of this bird's time-activity budget post-implantation compared with 44% (mean value for both adults since we were unable to identify individuals during the pre-implantation period) pre-implantation and preening occupied only about 5 % of its time during the post-implantation period.

Each pair was caring for one chick at the time of implantation. Both the Frank and Trilby Lake chicks survived to fledging. The Spider Lake chick survived the 2-week post-implantation observation period but it is unknown if this bird fledged. All three radiomarked adults returned to their territories in the spring of 1997 with their same mate. The Frank Lake pair did not nest, and the Trilby Lake pair

FIGURE 1. Time-activity budgets (% of time) of radiomarked Common Loons and their mates both prior to (Pre-implant) and following (Post-implant) abdominal implantation of a satellite transmitter (Platform Transmitter Terminal) during summer, 1996. Numbers in parentheses following sex indicate sample size (number of sample periods). Whiskers indicate SE. Treatment individuals are indicated with shaded boxes.



nested and laid two eggs that were depredated during mid-incubation. Limited observations (2) were made of the Spider Lake pair during the 1997 nesting season. This pair was not observed nesting on either visit and it is unknown if they initiated a nest. High levels of nest abandonment in Minnesota and Wisconsin in 1997 confounded the interpretation of these observations.

PTT Performance. Signal qualities from the transmitters carried by the three loons were poor and transmissions were not regularly received by the ARGOS receivers aboard the NOAA Tiros-N weather satellites. Transmitter function had been confirmed using a satellite uplink receiver following implantation although output signal strength was not measured. Follow-up observations in the spring of 1997 indicated that each bird still possessed a transmitter. We suspect that the transmitters migrated anteriorly in the abdominal cavity after surgery and drew the antenna in with it. As a result, the antenna may have passed through a substantial amount of body tissue before exiting the bird and the transmitted signal would be attenuated. The attenuated signal was apparently insufficient to reach the orbiting satellite (~850 km overhead) with any regularity. This suspicion is supported, in part, by post-mortem examination of the radiomarked rehabilitated bird from Florida. We found that the transmitter had migrated 22-32 mm following implantation. As a result, the antenna traveled 47 mm from the transmitter before exiting the skin and could contribute to significant signal attenuation (Paul Howey, Telemetry 2000 pers. comm).

Each PTT was programmed to transmit at 3-day intervals through early September, at daily intervals from early September through mid December, and at 4 day intervals from mid December through mid May 1997. We received little information from the PTTs. A total of 75 transmission sets were received on 43 days from the three transmitters. Location estimates were calculated for only 37 transmission sets (all from the Frank Lake bird) of the 75 received (Table 2). Usually only one or two transmissions were received in a single satellite overpass and the data were insufficient for calculation of the bird location. All 37 locations estimates for the Frank Lake bird occurred before migration and indicate use of larger lakes (e.g., Lost, Canoe and Plum lakes) within an 8-km radius of Frank Lake.

TABLE 2. A summary of transmissions from PTTs implanted in Common Loons received by Argos receiving equipment during July 1996 through March 1997.

Loon ID	Location of release	Date of release	# days trans-mission sets received	# of trans-mission sets received	# of trans-mission sets that produced location estimates	Date of last transmission
PTT 2520	Spider Lake, Itasca Co., MN	7-19-96	9	10	0	3-24-97
PTT 2522	Frank Lake, Vilas Co., WI	8-5-96	33 (25[a])	64	37[b]	10-19-96
PTT 2523	Trilby Lake, Vilas Co., WI	8-6-96	1	1	0	12-3-96

[a] Indicates the number of days on which transmission sets produced location estimates.

b Of the transmission sets that produced locations, 30% were of ARGOS Location Class(LC) B, 24% LC A, 20% LC 0, 16% LC 1, 8% LC 2, and 3% LC 3 (see Harris et al. 1990 for description of location quality indicies and their precision).

While conducting controlled experiments using loon carcasses provided by the Wisconsin DNR, we found that a transmitter implanted subcutaneously, in the center of the back provided improved peak signal levels and that a higher proportion of transmitted signals were received and processed by ARGOS equipment than for transmitters implanted in the abdominal cavity (K. P. Kenow, unpubl. data). The manufacturer of the transmitters confirmed that the subcutaneous site should promote higher signal quality on a theoretical basis over the abdominal implant configuration (Paul Howey, Telemetry 2000 pers. com.). Dorsal subcutaneous implants have been successfully used on juvenile and adult Canvasbacks and Mallards (*Anas platyrhynchos*) (Korschgen et al. 1996c, R. L. Riviere and K. P. Kenow, unpubl. data) but have not been tested on Common Loons.

CONCLUSIONS

The behavioral abnormalities observed in breeding adult Common Loons radiomarked with PTTs implanted in the abdominal cavity are cause for concern. The timing of radiomarking should be scheduled to minimize the impacts on the maintenance of pair bonds, preservation of breeding territories, and rearing of chicks. In this regard, when using radiotelemetry to document migration and winter range of adult breeding loons, researchers should consider delaying capture and radiomarking until the chicks are 6-8 weeks old and accept the possibility of reduced capture efficiency. Also, long-term (several successive breeding seasons) behavioral impacts should be considered in addition to relatively short-term (two weeks post-surgery) observations.

Poor performance of PTTs implanted in the abdominal cavities of loons has prompted us to assess an alternative implant technique. We are currently evaluating the subcutaneous technique with satellite transmitters in domestic geese to determine a suitable package configuration. Following this work, we plan to evaluate the technique in captive loons to ensure physiological and behavioral acceptance of this configuration before using it on free-ranging birds.

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DEMOGRAPHIC CHARACTERISTICS OF THE COMMON LOON IN THE UPPER GREAT LAKES

DAVID C. EVERS [1,2], JOSEPH D. KAPLAN [1], PETER S. REAMAN [1], JAMES D. PARUK [1,3], & PAUL PHIFER [1]

[1] UNIVERSITY OF MINNESOTA, FISH AND WILDLIFE DEPT., 200 HODSON HALL, ST. PAUL, MINNESOTA 55108
[2] BIODIVERSITY RESEARCH INSTITUTE, 411 ROUTE 1, SUITE 1, FALMOUTH, ME 04105
[3] IDAHO STATE UNIVERSITY, POCATELLO, IDAHO; PRESENT ADDRESS: FEATHER RIVER COLLEGE, QUNICY, CALIFORNIA. 95971.

ABSTRACT

We provide several aspects of Common Loon life history that were previously undescribed. From 1989-98, information was collected from 1,165 uniquely marked loons followed for 1-10 years at eight geographically distinct sites. Reproductive success (fledged young per territorial pair) at four sites ranged from 0.51 to 0.84, indicating breeding populations within the study were relatively stable. Territorial fidelity of adults ranged from 66-86% among sites with a mean of 81%. Territory fidelity was highest in whole lake territories (84%) and lowest in partial lake territories (72%). Male loons defending multiple-lake territories had significantly less territory fidelity (71%) than females (81%). Of the marked adults not returning to their previous years' territory, 12% changed territories within 12 km of their previous territory, 3-4% did not establish a territory for 1-4 years, and 3-4% were not relocated and represent the maximum annual mortality rate of the established breeding adults. The mean rate of mate switching was 19% per year and was similar among males and females. Most mate switching occurred at two periods during the breeding cycle (between ice-off and first nesting and again within one week following a nest failure. The estimated survival rate of adults banded as juveniles (ABJs) at three years ranged from 17-25% for three study sites. Of these returning ABJs, breeding territories were established 1-64 km from their natal lake. First year breeding ages ranged from 5-11 years with a mean of 7 years. A total of 35 loons banded in the Upper Great Lakes were recovered outside their breeding area. Of these, 24 were relocated during the winter along Florida's Gulf Coast and along the Atlantic Coast of Florida to North Carolina. Seven one-year olds were relocated summering from the Gulf Coast north along the mid-Atlantic Coast to New Jersey. Continued monitoring of the color-marked individuals will provide information on lifetime reproductive success. New innovative techniques that also require loons in-hand, such as satellite telemetry, isotope tracing, and genetic diversity, will further define the life history of the loon's Great Lakes breeding population so current and future conservation measures can be implemented based on site-specific knowledge.

DEMOGRAPHIC CHARACTERISTICS IN THE UPPER GREAT LAKES LOONS: OLD HISTORY AND NEW FINDINGS

INTRODUCTION

Capture, marking and release of birds began at the end of the 19th century and has increased in application to better understand the natural history of birds. The method of leg banding (or "ringing" in Europe) is now widely accepted as the primary means for determining movements, longevity, and individual performance of birds. By recapturing birds or using remote identification methods through auxiliary marking techniques, investigators can follow individuals over time and even determine lifetime reproductive success (LRS). Although LRS studies are difficult (Newton 1992 identified only 23 major studies worldwide) shorter-term marking studies have provided extensive information for many bird species in North America.

Before 1989, capture and marking of Common Loons (*Gavia immer*) was relatively rare, especially compared to capture rates of other relatively common North American birds. In 1989, the U.S. Bird Banding Lab reported that only 922 Common Loons had been banded since initiation of the federal banding program. Because of minimal banding efforts, studies involving uniquely marked loons were rare before the 1990s (Sutcliffe 1979, McIntyre 1988, Strong 1988, Morse et al. 1993). Two exceptions were opportunistically captured loons banded during waterfowl capture efforts by the Minnesota Department of Natural Resources (Eberdhart 1984) and a small but relatively successful capture effort on the Turtle-Flambeau Flowage, Wisconsin (Belant et al.1991).

In 1989, a reliable and efficient method to capture adult and juvenile Common Loons provided access for wildlife biologists to monitor known individuals over time. The capture technique developed by Evers (1993), and later refined was extensively used by the coauthors and was responsible for the capture of 2,111 Common Loons from 1989-98. Of these uniquely marked loons, 621 adults and 544 juveniles are the basis for describing the population dynamics of the Upper Great Lakes breeding population of Common Loons. Sampling areas were scattered across this region from northeastern Minnesota into north-central Wisconsin, across Michigan's Upper Peninsula and into south-central Ontario.

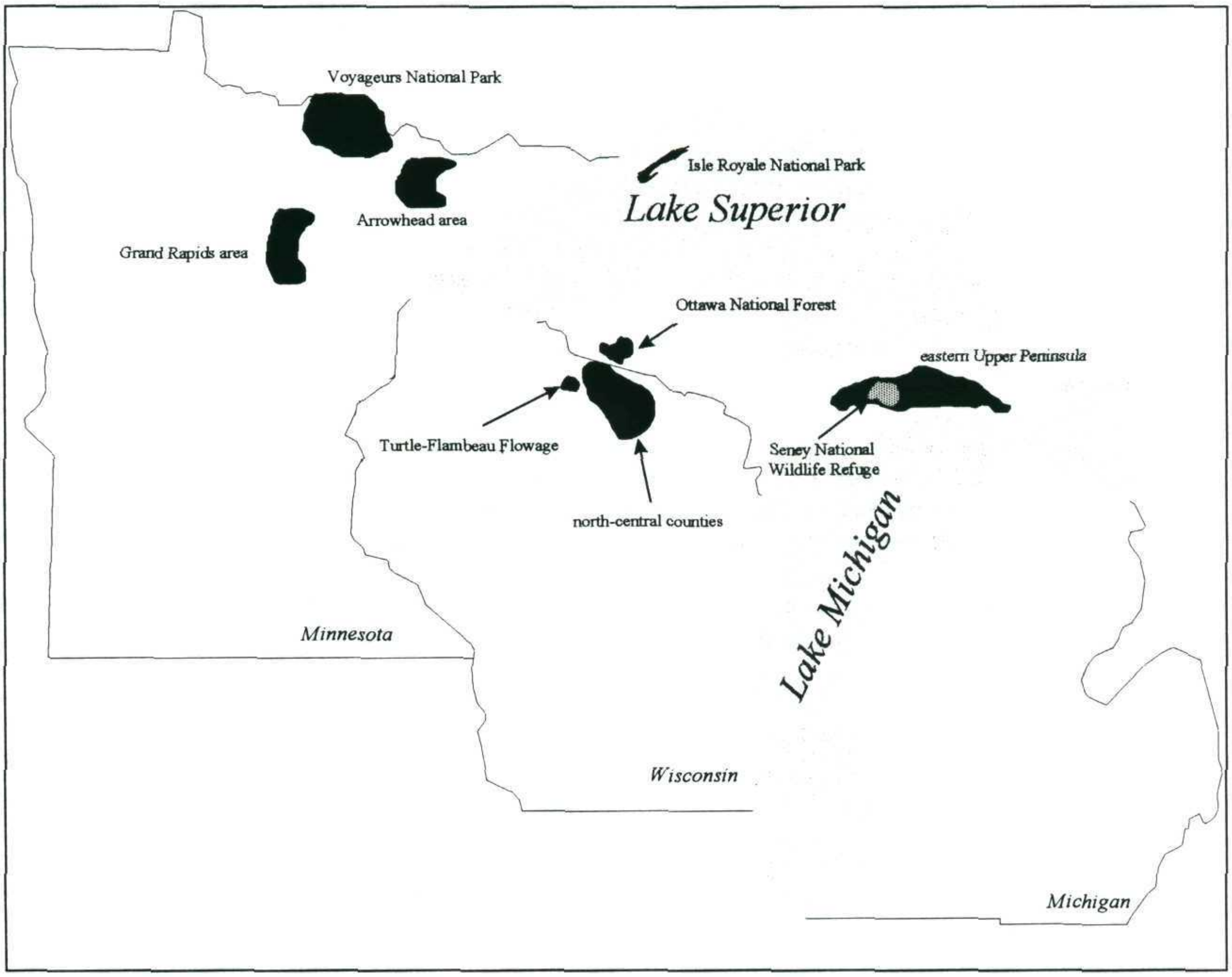
STUDY AREA

Much of the upper Great Lakes Region study area is part of the Canadian Shield, while along the eastern and southern fringes sedimentary bedrock forms the landscape (Albert *in* Evers 1997). The acidic soils derived from silica-rich bedrock are most representative of the Upper Great Lakes. These soils are less suitable for agriculture and therefore most areas have remained forested and are now publicly owned by federal and state agencies.

The study areas were primarily chosen within these protected areas. However, they are representative of the region's waterscape and likely provide an accurate sampling of the breeding loon population (Figure 1). Evers (2000) estimated the current U.S. Upper Great Lakes population at 6,100 nesting pairs. The eight upper Great Lakes Region study sites were distributed from north-central Minnesota to the eastern Upper Peninsula. Loons were banded in two other areas (Arrowhead area in Minnesota and southeastern Ontario) but subsequent monitoring efforts were minimal. A total of 286 loon territories found on 180 lakes were monitored between 1989 and 1998.

The eastern Upper Peninsula is a large, five-county area with extensive tracts of public lands, including the Hiawatha National Forest, Seney National Wildlife Refuge, and Lake Superior National Forest. These protected areas provide an important refuge for breeding loons. The Hiawatha National Forest is a 348,000 ha area divided into western and eastern units and bordered by Lake Superior to the north and Lakes Michigan and Huron to the south.

Figure 1. Map of the Upper Great Lakes study areas.



The Seney National Wildlife Refuge (NWR) lies in the east-central portion of the Upper Penisula and contains 21 artificially-controlled pools, totaling around 9,000 ha (7,000 acres). Most pools are concentrated in the eastern one-third of the refuge. These pools range in size from 11-364 ha and are relatively shallow, averaging less than 1 m in depth and reaching a maximum depth of 2-2.5 m along the dikes. They have sandy bottoms, with mean pH levels from May through October between 7.2-8.3. Mean turbidity for pools with nesting pairs is 9 +/- 5 FTU (range 0-24 FTU) while pools unoccupied by nesting pairs have a turbidity greater than 28 FTUs. The surrounding topography is flat with large emergent wetland areas interspersed with forested sandy, red pine (*Pinus resinosa*) ridges. Between 14-16 pools have established loon territories.

Two designated study areas are in the western Upper Peninsula, Isle Royale National Park (NP) and Ottawa National Forest (NF). Ottawa NF is a 386,000 ha area located at the western end of the Upper Peninsula. Two districts in the Forest have one of the highest densities of nesting loons in Michigan (Watersmeet and Bessemer). Situated in the south-central part of the Watersmeet District is the Sylvania Wilderness Area, an 8,500 ha roadless area containing 20+/- lakes suitable for nesting loons.

Isle Royale NP is in Lake Superior, 118 km northwest of Michigan's Keweenaw Peninsula. It is a roadless archipelago comprised of more than 200 islands and encompassing 544 sq. km. Bordered by 740 km of Lake Superior shoreline and containing more than 50 interior lakes, Isle Royale provides ample breeding habitat for the Common Loon. This is a unique area as it contains the only breeding population of loons using the Great Lakes shoreline for nesting. The long protected coves characteristic of the eastern end afford suitable nesting habitat. Although wave action is reduced in these areas, major seiches ranging from 10-60cm can inundate nests (Fettig 1991, Fettig and Kreumanker 1991).

In Wisconsin, we captured loons in a four-county area in the north-central part of the state (Vilas, Oneida, Forest, and Iron counties) in cooperation with the Wisconsin Department of Natural Resources and George Mason University. Over 800 lakes provide habitat for a dense breeding loon population. Few lakes are large enough for occupancy by more than one pair. This area has many low pH lakes that are associated with high mercury levels, prompting several studies (e.g., Meyer et al. 1995, Meyer et al. 1998).

The Turtle-Flambeau Flowage is a 7,700 ha reservoir created in 1926 and is a study site in Iron County treated separately from other lakes in the area. It is a circumneutral, turbid lake with an average depth of 3 m and maximum depth of 16 m. Only 5% of the shoreline is developed. The breeding loon population has been well studied since 1985 (Belant and Anderson 1991, Belant et al. 1991, Paruk 1999).

The bulk of the U.S. Great Lakes breeding loon population occurs in northern Minnesota (Evers 2000). Two study areas were sampled to represent this area: Voyageur's National Park (VNP) and the Grand Rapids area in Itasca County. VNP was established in 1975 and contains nearly 89,000 ha of protected area with 30 lakes, including four large reservoirs (Rainy, Kabetogama, Namakan, and Sand Point). The reservoirs comprise 39% of the total park area and 96% of the total water area. Annual summer water level fluctuations cause widespread nest failures for the loon population (Reiser 1988) and apparently create a large population sink. The Grand Rapids region has another dense concentration of nesting pairs. Primary study lakes include Pokegama (5,140 ha), Wabana (850 ha), Bass (1,012 ha) and Deer (1,578 ha). Each lake has multiple loon territories. Pokegama and Deer shorelines are over 50% developed while Wabana and Bass are less than half developed.

Loons were also captured on small lakes in south-central Ontario in 1992 and in Minnesota's Arrowhead region from 1997-98, but because we did not closely monitor these marked individuals they are only included with the banding results.

METHODS

Evers (1993) described the basic capture technique for adult loons accompanied by their chicks. Night-lighting techniques and playback recordings were essential. Since then, this technique has been refined to capture adult loons in a wide variety of weather conditions, ambient lighting, and lake types. Capture efficiency is highest (>90%) for adults accompanied by young chicks (<5 weeks), in flat water conditions, and with little ambient lighting. Loons are held for an average of 30 minutes. During that time a custom-sized; colored leg band is fitted around the loon's tarsus. One to three color bands and an U.S. Fish and Wildlife Service numbered band provides a dual system of identification. Six different colors along with engraved stripes, spots, and alpha-numeric codes provide several thousand combinations for remotely distinguishing individuals.

The unique color band combination allows accurate identification of individuals. Band colors are most easily read when raised above the water surface during loon foot waggling, stretching, and preening behaviors. Color bands can also be made determined underwater with optimal lighting and water conditions or by the observer gaining a higher vantage point. Most individual identification was made within 0.5-2.0 hours of observation with a 30-60x spotting scope.

Data on adult return rates were recorded primarily from ice-out to late May. During our study, far less than 1% of color-marked adults lost any color bands and no loons lost all color bands. Recaptured adults (n=281) exhibited either no or very minimal band wear on the tarsi. Monitoring of marked individuals typically continued throughout the summer for each study site to determine reproductive success, rate of mate and territory switching, and the return of adults banded as juveniles (ABJs). The summer monitoring intensity varied from high (nearly daily coverage), to moderate (weekly coverage), and low (monthly coverage). The information subsequently gathered from each site relates to coverage intensity (Table 1). Adults found on nearby territories are not included in return rate calculations until they have returned to their new territory for a second year. This protocol avoided bias in survey effort.

TABLE 1. Annual summary for types and coverage of data collected by study site

State	Study Site	Banded	Returns	Productivity*	Coverage**
Michigan (MI)	Seney NWR	1987-98	1990-98	1987-98	High
	Eastern Upper Peninsula	1990-96	1991-98	1990-96	Low
	Ottawa NF	1991-98	1992-98	1985-98*	Low
	Isle Royale NP	1991-98	1992-98	1990-98	Mod-High
Wisconsin (WI)	Turtle-Flambeau Flowage	1991-96	1992-97	1985-96*	Low-High
	North-central counties	1991-98	1992-97	1992-97*	Mod-High
Minnesota (MN)	Grand Rapids area	1992-98	1993-98	1992-98	Mod
	Voyageurs NP	1992-97	1993-98	1979-98*	Mod
	Arrowhead area	1997-98	1997-98	none	Low
Ontario (ON)	South-central	1992	1993,96	none	Low

* Coverage intensity is based on a daily (high), weekly (moderate), and monthly (low) basis.

** Productivity data were collected by biologists with BioDiversity Research Institute (BRI) and collaborators as part of various monitoring programs.

Territory type was classified for each pair monitored. Territorial pairs defend a defined area of a waterbody against conspecifics during the breeding season for more than four consecutive weeks (Olson and Marshall 1952). Established territorial holders do not allow intruding loons to remain within their territory. Pairs that laid at least one egg were designated as nesting. Successful pairs hatched at least one chick. Small chicks were designated as five weeks or less and were characterized by retaining some brown, downy plumage on the head, neck and back. Because true fledging rates are difficult to determine and juvenile mortality is minimal after two weeks we define large chicks as those that are older than five weeks to indicate juvenile survival. The N/T ratio (e.g., nesting pairs/territorial pairs) was used as a standard for describing the number of territorial pairs that lay an egg while F/T and F/N ratios (i.e., number of fledged young by territorial and nesting pair, respectively) indicate two ways to measure chick survival.

RESULTS

Banding and resighting

Recovery and resighting data from 1,165 loons banded in the upper Great Lakes Region from 1989-1998 provided insight into the loon's life history. A similar ratio of the number of marked males (327 or 53%) vs. females (294 or 47%) and adults (621 or 53%) vs. juveniles (544 or 47%) minimized age-sex biases during interpretation. Among study site effort varied considerably (Table 2).

The 621 adult loons captured and marked occupied 286 designated territories on 180 lakes (Table 3). Loons have three distinct types of territories (Table 3). Multiple-lake territories include at least one other lake, in addition to the natal lake, that is used by the territorial pair for foraging. Lake size of multiple-lake territorial pairs (11%, n=32) that were confirmed through field observations of marked individuals was 32-148 ha. Whole lake territories are areas where pairs restrict their breeding season activities to the natal lake and other established breeding pairs are not present. Of the 286 territories monitored, 43% (n=122) were whole lake territories. Finally, partial lake territories occur on larger lakes containing two or more pairs. This type of territory accounted for 46% (n=132) of the pairs studied.

TABLE 2. Capture and color-marking effort by study site, 1989-1998

State	Study Site	Adult Male	Adult Female	Adult Total	Juvenile Total	Total
MI	eastern Upper Peninsula	19	15	34	26	60
MI	Seney NWR	10	14	24	39	63
MI	Ottawa NF	28	26	54	27	81
MI	Isle Royale NP	15	16	31	43	74
MN	Voyageurs NP	36	27	63	42	105
MN	Grand Rapids area	42	36	78	36	114
MN	Arrowhead area	11	10	21	19	40
ON	south-central	15	9	24	36	60
WI	north-central counties	131	120	251	253	504
WI	Turtle-Flambeau Flowage	20	21	41	23	64
	TOTAL	327	294	621	544	1165

Reproductive measurements

Reproductive success was monitored for eight of the study sites, although monitoring efforts were not equal across all sites (Table 1). Color-marked individuals as well as neighboring territory holders were typically monitored for adult and ABJ site fidelity and reproductive success. For example, in the Ottawa National Forest, 24 territories had color-marked loons although an average of 37 territories were monitored for nine years. However, because we did not distinguish whether these target territorial pairs laid eggs, two types of categories, nesting and successful pairs, were not complete (Table 4).

TABLE 3. Upper Great Lakes study sites and characterization of Common Loon territory, 1989-98.

State	Study Site	Whole	Partial	Multiple	Lakes	Territories
MI	eastern Upper Peninsula	5	6	5	14	16
MI	Isle Royale NP*	1	16	0	2	17
MI	Ottawa NF	7	8	9	21	24
MI	Seney NWR	7	4	2	11	13
MN	Grand Rapids area	7	31	1	15	39
MN	Voyageurs NP	1	39	1	6	41
WI	North-central counties	94	4	12	108	110
WI	Turtle-Flambeau Flowage	0	24	2	3	26
	Total	122	132	32	180	286
	(Total %)	43%	46%	11%		

* Most of the loon territories monitored at Isle Royale NP are within coves and bays of Lake Superior

Although individual reproductive success of color-marked loons was not determined, mean density and reproductive success of loons nesting at four study sites allows comparison of Upper Great Lakes breeding productivity (Table 4) to that of other breeding populations in North America. On average, the total breeding population at the Michigan study sites was 81 territorial pairs/year. These birds fledged an average of 55 juveniles/year. Territorial pairs nested 59-92% of the time. Reproductive success (measured as number of chicks greater than five weeks of age) ranged from 0.51-0.79 juveniles per territorial pair or 0.77-0.87 juveniles per nesting pair.

TABLE 4. Size of monitored breeding population (mean +/- sd) and reproductive success (mean +/- sd) for four Michigan study sites, 1987-98.

Study Site	Territorial Pairs	Nesting Pairs	Successful Pairs	# small chicks	# large chicks	N/T ratio	F/T ratio	F/N ratio
e. Upper Pen.	19.0+/-3.6	11.2+/-1.2	-	-	9.7+/-1.8	0.59	0.51	0.87
Isle Royale NP	15.7+/-1.4	14.5+/-1.2	9.0+/-3.2	-	12.3+/-4.8	0.92	0.79	0.85
Ottawa NF	37.4+/-2.3	-	-	-	27.2+/-7.0	-	0.76	-
Seney NWR	9.2+/-2.2	7.0+/-1.7	5.0+/-1.4	6.7+/-2.3	5.4+/-2.4	0.76	0.59	0.77
					MEAN	0.76	0.66	0.83

1 N/T ratio is the number of nesting pairs divided by the number of territorial pairs

2 F/T ratio is the number of large chicks divided by the number of territorial pairs

3 F/N ratio is the number of large chicks divided by the number of nesting pairs

Territory Fidelity

Between 1990-98, the return rate of marked adults to a territory was determined at eight study sites (Table 5). Territory fidelity ranged from 66-86% and differences between sexes were not significant within study sites ($p<0.05$) and overall ($p<0.001$). Based on 1,183 color-marked adults potentially returning to their previous year's territory, 958 or 81% were re-observed at the territory they occupied the previous year. The remaining 19% of adults not re-observed at their previous year's territory were frequently found elsewhere one to four years later.

TABLE 5. Territory fidelity of adult loons, 1990-98, in the Upper Great Lakes Region

		Total # of marked			Total # returning			Percent Return		
State	**Study Site**	**M**	**F**	**Both**	**M**	**F**	**Both**	**M**	**F**	**Both**
MI	Seney NWR	66	62	128	57	53	110	86	86	86
WI	north-central cos.*	175	141	316	153	120	273	87	85	86
MI	Isle Royale NP	43	55	98	37	46	83	86	84	85
MI	Ottawa NF	88	102	190	71	84	155	81	82	82
MI	eastern UP	47	37	84	35	30	65	75	81	77
MN	Voyageurs NP	83	62	145	65	45	110	78	73	76
MN	Grand Rapids area	44	38	82	32	29	61	73	76	74
WI	Turtle-Flambeau	57	50	107	37	34	71	65	68	66
	TOTAL	671	566	1183	498	460	958	81	81	81

* Includes up to 1996.

Territory fidelity did vary by territory type (Table 6). Adults were more likely to return to their previous territory if each individual was part of the sole pair on the lake. Fidelity for whole-lake territories was nearly equal between males and females ($p>0.05$). Unlike whole-lake territories, territorial *pairs that used multiple lakes did significantly differ between sexes ($p>0.05$). Lower territory fidelity was* found on large waterbodies where territorial pairs were frequently adjacent to each other without physical boundaries.

Mate Fidelity and Switching

The frequency of mate switching determined for one study site, the Seney NWR, was 19% (n=134 pairings by marked individuals). Further analysis of other sites will provide more confidence in the rate of mate switching, differences between sexes, and triggers related to frequency.

Natal Site Fidelity

Adults-banded-as-juveniles (ABJs) generally return to their natal lake area after three to five years (n=27, mean was 4.4 +/-1.4 years, range was 3-8 years of age at first reobservation). The fidelity of ABJs to their natal sites ranged from one to 64 km with a mean of 13 km (n=27). Although returning ABJs were found interacting with their parents, no pairing was observed. Study sites with the number of associated ABJs are Seney NWR (7), north-central counties of Wisconsin (7), Isle Royale NP (6), Ottawa NF (3), Turtle-Flambeau Flowage (2), Voyageurs NP (1), and Grand Rapids area (1). Based on recent evidence of these 27 returning ABJs the average first year breeding was seven years (n=7 individuals that initiated breeding, range is 5-11 years).

TABLE 6. Rate of return for adult loons by territory type, 1990-98 in the Upper Great Lakes Region

Territory Type	M	F	Both	M	F	Both	M	F	Both
Whole Lake	433	416	849	364	352	716	84	85	84
Multiple Lake	49	52	101	35	42	77	71	81	76
Partial Lake	184	150	334	134	108	242	73	72	72

A total of 35 loons (17 adults and 18 banded as juveniles) were reobserved outside the Upper Great Lakes breeding range. Of these, 72% were from coastal areas during the winter (December-April), 11% from coastal summer areas for one-year-olds, 6% of mid-migrant adults, and 9% of mid-migrant juveniles.

DISCUSSION

The Common Loon inhabits lakes in forested regions of Canada, Alaska and the northern tier of the contiguous United States. The upper Great Lakes breeding population is at the southern periphery of this range and is in an area of high human development and recreational use. Although <1% of North America's breeding loon population is in the upper Great Lakes (Evers 1999), the loon's high public profile and recognition as an indicator of aquatic integrity (e.g., Evers et al. 1998), makes this region an important study area for improving public awareness for the species and the lake ecosystems it inhabits.

The 621 adult and 544 juvenile loons uniquely color-marked from 1989-98 constitute a small percentage of the upper Great Lakes breeding population. However, the eight study sites include a wide range of lake habitats and therefore most likely provide a relatively accurate picture of loon population dynamics for the region. These waterbodies varied in size from a 32 ha beaver pond (Ottawa NF) to 910 square km Rainy Lake (Voyageurs NP) and in depth from an average of one meter (in Seney NWR) to over one hundred meters (in Lake Superior at Isle Royale NP). Shoreline development and recreational use also varied tremendously from wilderness lakes with virtually no human disturbance to lakes with fully developed shoreline and heavy recreational use.

Although reproductive success was monitored for many of the color-marked adults, individual efforts are not quantified here. The nesting-territorial pair ratio was determined for three sites in Michigan and varied from 59% (eastern Upper Peninsula) to 92% (Isle Royale NP). These were the only sites where we could definitively confirm presence and absence of eggs for the entire population of monitored pairs. Hatching success was difficult to verify unless daily observations were made.

We primarily measured reproductive success for these sites by determining the presence of large chicks (i.e., >5 weeks). The number of juveniles surviving per nesting pair ranged from 0.77 to 0.87 and for each territorial pair ranged from 0.51 to 0.79. McIntyre (1988) summarized 24 productivity databases from North American loon populations and found a mean of 0.60 chicks surviving per territorial pair. The 22-year statewide database of New Hampshire's increasing breeding population showed a mean of 0.77 chicks/nesting pair and 0.53 chicks surviving per territorial pair (Taylor and Vogel 2000). Based on these comparative databases it appears that breeding loons in the Great Lakes' study sites had typical reproductive success and were therefore a fair representation of this species' population dynamics.

Adult territory fidelity was determined within eight Great Lakes' study sites. However, because the capture of adult loons is biased toward adults successfully producing at least one young, our territory fidelity rates primarily represent established and productive adults. Unsuccessful territorial or non-territorial adults may comprise up to 46% of an entire summer loon population (Taylor and Vogel 1999) while Croskery (1990) found a similar trend in the size of the nonbreeding population in northwestern Ontario. He found 49% of the 254 loon territories monitored over a four-year period failed to produce young.

Adult site fidelity for the Great Lakes region is 81% and does not differ between sexes ($p>0.05$). However, we documented significant inter-site differences ($p<0.01$). This variation appears to be related primarily to territory type rather than geographic-specific influences. Adults residing on whole lake territories are significantly ($p<0.05$) more faithful to their territories (84%) than their counterparts on multiple-lake (76%) and partial lake (72%) territories (Table 6). Seney NWR, Isle Royale NP, and north-central Wisconsin are primarily comprised of whole lake territories (85-86% territory fidelity) while the eastern Upper Peninsula and Ottawa NF have more multiple-lake loon territories (77-82% territory fidelity). Unlike the similarities of male and female territory fidelity for study sites and whole or partial lake territory types, we found a significant difference ($p<0.05$) in territory fidelity between the sexes for pairs maintaining multiple-lake territories (71% for males and 81% for females). This difference is likely because males guarding multiple-lake territories are more susceptible to intruding males usurping them (Piper et al. 1997). Adult territory fidelity was lowest on larger lakes where pairs occupy only part of the lake and physical boundaries are minimal (72% territory fidelity). Rates of successful intrusion appear to be highest on these territory types and are potentially related to the presence of neighboring common feeding areas harboring unsuccessful and non-breeding adults.

The remaining marked breeding adults not faithful to their previous year's territory fall into three categories: (1) those that shifted territories, (2) displaced breeders that wander and do not establish territories, and (3) adult mortality. Determining the movements of marked adults in each study site was not possible because of logistical limitations. Our best information was from Isle Royale NP, north-central Wisconsin, and Seney NWR. Monitoring at these sites indicates that approximately 8% of the adults shift territories to adjacent territories or up to 12 km distant. Another three to four percent wander and do not establish territories for one to four years, while the remaining three to four percent of the color-marked adults were not reobserved in subsequent years and represent the maximum annual adult mortality.

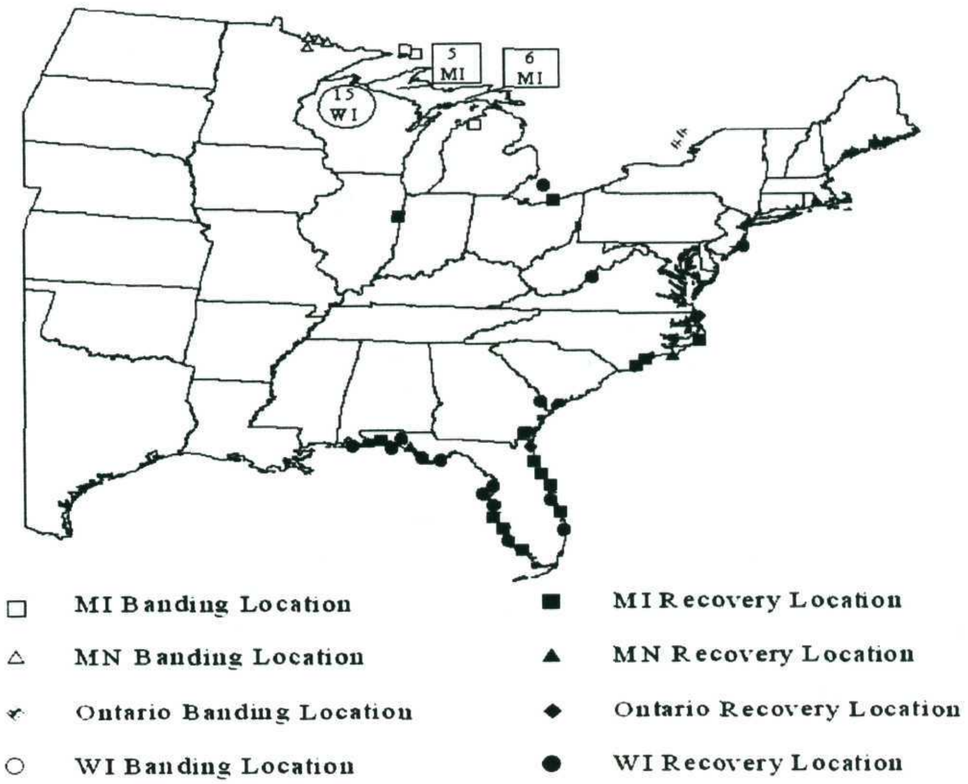
Limited recovery data suggest that most juvenile loons that leave their natal lake migrate to ocean wintering areas and typically remain on the ocean for the next two and one half years. Seven banded juveniles (Michigan-2, Minnesota-1, Ontario-1, and Wisconsin-3) were found one year later summering (June through August) in Alabama (1) and Florida (3) north along the mid-Atlantic Seaboard (North Carolina-2 and New Jersey-1). One- and two-year old loons are known to remain on the ocean and move along North America's mid-Atlantic coast (McIntyre 1988).

Upon the return of an ABJ, the average dispersal distance from the natal lake was 13 km and ranged up to 60 km. Some individuals did not breed (defined as a member of a pair that lays eggs) until 10 and 11 years of age. Mean first-year breeding appeared to be considerably later than previous predictions (e.g., Parker 1987). Continued monitoring of ABJs will increase the sample size of this cohort to better define the relationship of dispersal distances, breeding age, and reproductive success with individual fitness and age/sex variations.

Of the six migrant loons reobserved, three were juveniles. These young-of-the-year, banded in north-central Wisconsin and western Michigan area, were found later that fall (October-November) in northern Lake Michigan. Of the hundreds of marked adult loons migrating across the eastern United States, only three were reobserved, indicating little time spent in transition between breeding and staging or wintering areas. One transitional male was banded in the eastern Upper Peninsula and found dead on 9 December on Lake Erie near Cleveland, Ohio, while a female banded in north-central Wisconsin was found over two years later in Warm Springs, Virginia on 28 November. The only spring loon migrant was an adult female banded in Ottawa NF and found six years later (4 May) at Surf City, North Carolina.

Winter recoveries (December through April) were primarily from the Gulf Coast shoreline, between Gulf Shores, Alabama southeast to Macro Island, Florida (n=14), while seven loons were reobserved on the east coast from Miami Beach north to St. Augustine, Florida. Two winter recoveries outside these areas are (1) an adult female banded at Voyageurs NP and found on 11 January 1998 at Cape Lookout, North Carolina and (2) an adult male banded in northcentral Wisconsin and found on 1 December at Fripp Island, South Carolina.

FIGURE 4. Distribution of migrant and winter recoveries of Common Loons banded on their breeding lakes in the Upper Great Lakes Region, 1990-98.



Because pressures on lakes are ever increasing, loon nesting and nursery options are reduced, loon mortality related to anthropogenic forces grows, and water quality diminishes. Loon pairs and populations in the United States and southern Canada are stressed by the changes in their aquatic environments. Naturally, their fitness and resiliency is likely declining, exposing breeding populations to chronic or catastrophic environmental stressors such as contaminant poisoning (e.g., mercury (Alexander 1991, Evers et al. 1998), weather events, winter oil spills (Clapp et al. 1982.), and disease. For these and other reasons, the importance of monitoring breeding populations in the Great Lakes region is increasingly evident. Although major changes in the loon's breeding numbers, distribution, and reproductive success can be detected through traditional survey programs, the color-marking of individuals and subsequent monitoring will provide the data needed to make informed decisions before crisis situations are reached.

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AN UPDATE OF NORTH AMERICA'S COMMON LOON BREEDING POPULATION

DAVID EVERS, BIODIVERSITY RESEARCH INSTITUTE

The Common Loon breeds across the northern parts of North America including the near-shore areas of Greenland. The only extant breeding population outside North America is in Iceland. Rose and Scott (1996) provide estimates of 500,000-700,000 as the total population of Common Loons, with approximately one percent over-wintering in Europe. Approximately 300 pairs reside in Iceland (Petersen 1998) and Boertmann (pers. com.) estimates 200 and 2,000 pairs in Greenland.

Common Loons breed in Canada across an area that generally escapes direct human disturbance. They are found from Canada's treeline in the north to the southern border, except in the southern parts of the plains provinces. Breeding loons have abandoned some areas with heavy human disturbance such as southernmost Ontario (Cadman et al. 1987), but in general still maintain much of their historical breeding range. Although the number of territorial pairs is unknown in much of western and central Canada, waterfowl surveys by the Canadian Wildlife Service (CWS) and the U.S. Fish and Wildlife Service have estimated numbers in the Yukon, Northwest Territories, Ontario, Quebec, and the Canadian Maritimes (Table 1).

TABLE 1. Summary of the Common Loon breeding population in Canada[1]

Province	# of territorial pairs	# of adults	Source
Alberta	1,000	2,400	Fed. of Alberta Naturalists, pers. com., 1996[2]
British Columbia	unreported	n/a	n/a
Manitoba	unreported	n/a	n/a
New Brunswick	1,000	2,400	Erskine, 1992
Newfoundland	unreported	n/a	n/a
Northwest Territories	50,000	120,000	U.S. Fish & Wildlife Service, pers. com., 1996[2]
Nova Scotia	1,200	2,880	Erskine, 1992
Ontario	85,000	204,000	Canadian Wildlife Service, pers. com., 1999[2]
Quebec	75,000	180,000	Canadian Wildlife Service, pers. com., 1999[2]
Prince Edward Is.	1	2	Kerekes pers. com., 1999[2]
Saskatchewan	unreported	n/a	n/a
Yukon	200	480	U.S. Fish & Wildlife Service, pers. com., 1996[2]
KNOWN TOTAL	213,400	512,160	

[1] The definition of a territorial pair is two adults found paired during June and July surveys. Information from a 25-year database by the Loon Preservation Committee in New Hampshire show that, on average, 80% of the adult loon population defends a territory. Therefore, the 20% "buffer population" is added to the total number of adults.

[2] Each of these province estimates is from personal written communication with the indicated source.

Canada's breeding loon population far surpasses that found in the United States. For example, one province alone, Quebec, has approximately six times more loon pairs than the entire United States breeding population. Along with CWS, the Canadian Lakes Loon Survey assists with conservation issues and works to maintain a national monitoring effort.

The loon's large, contiguous breeding range in Canada has not deterred the importance and interest in much smaller populations found in the United States. An estimated 11,600 to 14,000 territorial pairs occur in the United States and 31-42% are found in Alaska (Table 2). This species has a prominent role in the conservation efforts of state and federal agencies and non-governmental organizations. Because loons are recognized as wilderness symbols and serve as sensitive indicators for some environmental stressors such as contaminants (i.e., mercury, Evers et al. 1998), their breeding populations are well known and surveyed.

TABLE 2. Summary of the Common Loon breeding population in the United States[1]

State	# of territorial pairs	# of adults	Population Trend	Source
Alaska	3,600-6000	8,890-13,200	Stable	Groves et al. 1996, Tankersley & Ruggles 1993
Idaho	4	20	Increasing	Panhandle Loon & Wetlands Project, 1999[3]
Maine	1,400	3,800	Stable	Maine Audubon Society, 1999[3]
Massachusetts	19	42	Increasing	Massachusetts Div. of Fish & Wildlife, 1999[3]
Michigan	416	1,500[2]	Decreasing	Schuette 1998
Minnesota	4,650	11,630	Stable	Minnesota Dept. of Nat. Res., 1997[3]
Montana	60	195	Decreasing	Montana Loon Society, 1999[3]
New Hampshire	200	457	Increasing	Loon Preservation Committee, 1999[3]
New York	132	331	Increasing	Audubon Society of New York, 1999[3]
North Dakota	50	120	Stable	North Dakota Game & Fish Dept., 1999[3]
Vermont	41	112	Increasing	Vermont Institute of Natural Sciences, 1999[3]
Washington	12	38	Increasing	Richardson and Spencer 2000
Wisconsin	1,056	3,017	Stable	Daulton et al. 1997
Wyoming	24	58	Stable	Wyoming Game & Fish Dept., 1998[3]
TOTAL	11,592 to 13,992	30,210 to 34,520		

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[1] The number of adults and territorial pairs are sometimes calculated if only one number is provided by the source. Since not all adults are part of territorial pairs a conversion factor of 20% is used. This is based on a 25-year database by the Loon Preservation Committee in New Hampshire. Since New Hampshire's breeding loon population is increasing, this is a conservative conversion factor for saturated breeding populations such as found in Maine and Minnesota.

[2] Because Michigan is surrounded by the Great Lakes, where non-breeders congregate from the entire region, a larger number of adult loons over-summering in Michigan is unpaired.

[3] State estimates are from personal written communication with the indicated source.

Some states have organizations that conduct comprehensive, annual standardized surveys, such as New Hampshire's Loon Preservation Committee, Vermont's Institute of Natural Science, and Montana's Loon Society. Other non-governmental organizations conduct partial surveys based primarily on volunteer networks such as the Maine Audubon Society, Audubon Society of New York, Michigan Loon Preservation Association, Sigurd Olson Environmental Institute, Panhandle Loon and Wetlands Project, and the Loon Lake Loon Association. State agencies have also picked up monitoring efforts such as in Massachusetts, Minnesota, North Dakota, and Wyoming. Alaska's monitoring efforts include state and federal agency aerial surveys (Groves et al. 1996) and contributions from the volunteer Alaska Loon Watch Program and Anchorage Audubon Society (Tankersley and Ruggles 1993).

The largest breeding populations are found in Minnesota (over 4,600 pairs), Alaska (3,600-6,000 pairs), Maine (approximately 1,400 pairs), and Wisconsin (over 1,000 pairs) (Table 2). Maine and Alaska are the only states where breeding loons are found statewide and have maintained their historical range. Other significant U.S. breeding populations (100 territorial pairs or more) occur in New York, Michigan, and New Hampshire. Smaller and typically much more isolated breeding populations occur in seven other states. Populations in the West are generally disjunct such as in Washington (especially those west of the Cascade Mountains), North Dakota, and Wyoming. Dispersal of subadult loons from British Columbia and Montana appear to have assisted the natural restoration of breeding pairs in Idaho (formerly extirpated since 1962).

Because of major conservation initiatives by federal, state, and local groups loon populations are generally stable across their United States range and are even increasing in areas where they were recently, locally extirpated. Loons are re-colonizing areas in New England (such as southern New Hampshire and across Vermont) and in the Northwest (including parts of northeastern Washington and the Idaho panhandle). Loons were extirpated in Massachusetts for 50 years but returned in 1975 and have now increased to 19 pairs. There are some areas where loon populations are struggling to replace themselves due to human disturbance. Michigan's population appears to continue to decline, and except for less than a handful of pairs, the southern part of the state is now devoid of a species where it was once quite common. Even lakes with historical breeding in the Upper Peninsula of Michigan have had pairs disappear (e.g., over a 40% decline in the eastern Upper Peninsula during the 1980s)(Evers 1994). Annual mortality of several hundred loons related to commercial fishing practices are likely responsible for this decline (Carey 1993). Certain watersheds in Montana also appear to have struggling local breeding populations, and although protected mountainous wilderness areas are extensive, most loon habitat is in valleys that are much more likely to be disturbed by humans.

Although some southern peripheral populations no longer exist in states such as Oregon, Illinois, and Ohio, the Common Loon is still found across much of its historical breeding range (McIntyre and Barr 1997). Thanks to the concerted efforts of the North American Loon Fund and its many state affiliates the loon's future looks promising. Even though major concerns related to widespread mercury contamination of the loon's prey base and catastrophic events such as winter oil spills, the species' survival and widespread distribution remains secure. The following Canadian and state by state reports provide a review of current activities conducted for loon conservation.

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STATUS REPORTS

ALASKA REPORT

BRIAN MCCAFFERY, U.S. FISH & WILDLIFE SERVICE

(Prepared under the auspices of the Alaska Loon Working Group, March 1998)

Red-throated (*Gavia stellata*), Arctic (*Gavia arctica*), Pacific (*Gavia pacifica*), Common (*Gavia immer*), and Yellow-billed (*Gavia adamsii*) loons nest in Alaska, and all but the Arctic Loon are regular and common breeders in at least some regions of the state. In fact, the number and diversity of loons in Alaska may be unmatched anywhere in the world. Because of their evocative calls and association with wilderness, loons generate a romantic mystique that extends interest in their welfare beyond that of conservation biologists. Despite this widespread appeal and their potential importance as indicators of environmental health, the status of loons in Alaska is not well understood. Information is fragmentary, relatively limited, and has not been widely disseminated.

To improve this situation, and in response to documented declines in some Alaskan loon populations, the Alaska Loon Working Group held its first meeting on 5 December 1997. Convened by Brad Andres (U. S. Fish and Wildlife Service, Migratory Bird Management, Alaska) and David Evers (BioDiversity Research Institute, Falmouth, Maine), the meeting attracted more than 25 loon biologists and enthusiasts that represented a wide range of interests, including federal and state governments, non-government organizations, consulting firms, industry, and private citizens. For the first time, information and insights about Alaska's loons were shared in a common forum. Investigators presented data on Alaska loon populations, and the conservation implications of their findings were discussed by the group. The Working Group decided to first produce a Preliminary Needs Assessment to review population status and information needs, and to later produce a Final Needs Assessment that would critically scrutinize available data, identify threats, and suggest research priorities.

This report represents the first phase of the Working Group's needs assessment. We briefly summarize current knowledge about the status of Alaska's loon populations, highlight major data gaps, and identify loon conservation and management issues. The conclusions about population trends presented here rely heavily on the work of pilot-biologists and observers who have flown aerial surveys for Migratory Bird Management, U. S. Fish and Wildlife Service. In the following species accounts, significant trends are based on simple linear regressions with a significance level of 5%, unless otherwise specified.

Red-throated Loon (*Gavia stellata*)

Red-throated Loons breed throughout the state (Armstrong 1995), and are most common in the tundra regions of western and northern Alaska (Gabrielson and Lincoln 1959). Populations appear to be stable on the North Slope (King and Brackney 1997) and in Alaska's boreal forest regions (Groves et al. 1996). The population inhabiting the western tundra, however, has declined significantly over the last 20 years. The decline, which is broadly distributed from Bristol Bay to Kotzebue Sound, is significant when all western tundra strata are pooled, and in each of the four individual strata in that region (Groves et al. 1996).

In the absence of additional data, it is difficult to generate hypotheses that explain the negative population trend. The decline of Red-throated Loons in Alaska has paralleled that of Oldsquaw (*Clangula hyemalis*)— stable on the North Slope (King and Brackney 1997) and declining dramatically in western Alaska (Conant and Groves 1997). Whether declines in these two populations share a common cause is unclear.

Arctic Loon (*Gavia arctica*)

Formerly considered conspecific, Arctic and Pacific loons were recognized as separate species in 1985 (American Ornithologists' Union 1985); they are distinguished by a suite of subtle structural and plumage characteristics (Birch and Lee 1997). Arctic Loons in Alaska are extremely rare, locally distributed, and comprise only a tiny fraction of the species' global population. The species breeds regularly from northern Europe to northeast Siberia (American Ornithologists' Union 1983) but is only a locally rare breeder on Alaska's western Seward Peninsula (Kessel 1989). Arctic Loons are casual spring migrants and summer visitants at other coastal locations on the peninsula (Kessel 1989), and they may be a very rare, but regular, spring migrant past Gambell on St. Lawrence Island (Dunn and Rose 1992).

Pacific Loon (*Gavia pacifica*)

Pacific Loons breed in all regions of Alaska except the southeast (Armstrong 1995). Aerial survey data reveal no significant negative trends anywhere in the state (Groves et al. 1996, King and Brackney 1997). This overall picture of stability is contradicted, however, by several site-specific breeding studies. On Tetlin National Wildlife Refuge, in the eastern interior, there was an apparent decline in both overall Pacific Loon numbers and productivity from 1989 to 1995 (T. J. Doyle., pers. com.). Similarly, the number of nests and the number of juveniles fledged seem to be declining in the Matanuska-Susitna Valley (Fair 1998). The most dramatic apparent decline has occurred along the coastal fringe of the Yukon-Kuskokwim Delta, where, from 1989 to 1997, the number of loon nests discovered by ground crews has declined at an annual rate of 21%, based on log-linear regression (Bowman et al. 1997). These data from the Yukon-Kuskokwim Delta, however, are not supported by aerial surveys conducted in the same area over the same interval, which indicate modest increases in Pacific Loon numbers (R. Platte, pers. com.).

The discrepancy between the aerial survey data and the local declines based on ground work is not easily explained. With long-lived birds such as loons, the proportion of birds breeding and/or their breeding success could decrease for many years without a corresponding decrease in overall population size. Whether or not breeding success is declining in Pacific Loons in Alaska remains to be determined. Our inability to draw even tentative conclusions about the status of Pacific Loons highlights the limits of our understanding of loon population dynamics.

Common Loon (*Gavia immer*)

Common Loons breed throughout the state but are relatively less common in tundra habitats than their smaller congeners (Gabrielson and Lincoln 1959, Armstrong 1995). Overall, Common Loon populations appear to be stable across Alaska. There is no significant trend either statewide or in the boreal forest strata (Groves et al. 1996). In the tundra strata (which support 40% of the state's Common Loons), however, there is evidence for a slight decline ($P < 0.1$) over the last 20 years (Groves et al. 1996). There is concern about the susceptibility of Common Loons to human development and recreational disturbance in south-central Alaska, particularly since the area in and immediately adjacent to the survey stratum supporting the greatest number of boreal forest loons (Kenai-Susitna) also supports most of Alaska's human population.

Yellow-billed Loon (*Gavia adamsii*)

In Alaska, Yellow-billed Loons breed only from the Seward Peninsula north, with most pairs nesting north of the Arctic Circle (North 1994). The bulk of the state's population (and a significant fraction of the species' global population) occurs on the arctic coastal plain (North 1994). Aerial surveys on the arctic coastal plain documented a slight, but significant, population increase between 1986-1997 (King and Brackney 1997). However, numbers of Yellow-billed Loons detected on surveys flown specifically for eiders in the same area between 1992-1997 remained relatively stable (Larned and Balogh specifically for eiders in the same area between 1992-1997 remained relatively stable (Larned and Balogh 1997).

Trend data notwithstanding, the absolute size of the Yellow-billed Loon population is cause for concern. At most, only several thousand of these rare birds nest in Alaska (North 1994), and most are concentrated in a fairly limited zone within the National Petroleum Reserve - Alaska (NPR-A) between the Meade and Colville rivers (Brackney and King 1995). Dense concentrations of Yellow-billed Loons south of Teshekpuk Lake are within an area that is currently being considered for oil and gas leasing under at least three of five leasing alternatives (Bureau of Land Management 1997). The potential effects of oil development, habitat loss, and increased disturbance on this species are unknown. Yellow-billed Loons on the arctic coastal plain may also be vulnerable to subsistence hunters and incidental mortality from entanglement in gill nets.

General Conclusions

There is cause for concern about Alaska's breeding loons. Each of the three widely-distributed species has suffered either local or regional declines over the last two decades, and the fourth species (Yellow-billed Loon) is vulnerable due to its small population size and limited geographic range. With the exception of aerial survey data, our knowledge about Alaska's loons is relatively shallow and fragmentary. Few site-specific studies of breeding biology have been undertaken, and it is unclear to what extent results can be extrapolated across the species' ranges. Our understanding of loon distribution and ecology away from the breeding grounds is even poorer. Several major gaps common to all four species include information on:

1) Demographic parameters (e.g., productivity, survival, age of first breeding);
2) Wintering distribution, including concentration areas and timing of use;
3) Use of the marine environment during breeding and non-breeding seasons;
4) Anthropogenic effects on loon survival and productivity (e.g., recreation, research, energy development, subsistence, incidental take in gill nets, and exposure to contaminants);
5) Detailed survey data on species that are rare (e.g., Yellow-billed Loon) or that occur in areas presently or potentially exposed to high levels of human disturbance (e.g., Matanuska-Susitna Valley, NPR-A);
6) Data on habitat use, availability, and quality in relation to loon abundance and productivity,
7) Relationships between loon population trends and the status of fish stocks in both the breeding and wintering areas;
8) Patterns of recolonization after population declines or extirpation, and
9) Data on population trends in Canada, especially for Yellow-billed Loons, that would enable us to interpret Alaska data in a rangewide context.

The Alaska Loon Working Group recognizes the need to synthesize and distribute information about Alaska's loons, including public education and in particular, through Alaskan schools. The Working Group is helping to promote the collection of additional data necessary for devising constructive management strategies (e.g., Warheit et al. 1997) and has compiled a loon project directory (Earnst 2000), has instituted an e-mail list to improve communication among members, and will be producing a detailed needs assessment. We hope that these preliminary steps will help educators, managers, biologists, and other concerned citizens to more effectively promote loon conservation in Alaska.

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CANADA REPORT

RUSS WEEBER, CANADIAN LAKES LOON SURVEY

The Canadian Lakes Loon Survey (CLLS) was initiated in Ontario in 1981 by Bird Studies Canada (then Long Point Bird Observatory), Environment Canada (Canadian Wildlife Service), the Ontario Ministry of Natural Resources and other co-operators. The program expanded nationwide in 1989. The program's objectives are to coordinate volunteers in monitoring Common Loon breeding productivity on Canadian lakes, and to provide information on the effects of acid precipitation, human disturbance and other factors on breeding loons. The CLLS has served an important role in lake biomonitoring by providing information on regional patterns in loon breeding success and has contributed to an improved understanding of relationships between lake acidity and loon breeding success (see McNicol et al. 1995).

One of the most important recent achievements has been the assignment of a unique code for each surveyed lake and lake section (or bay) in the CLLS database. This development allows easy access and analysis of all CLLS data (over 12,000 records) and links survey data from each water body through the time. With 18 years of data and information on over 4,000 lakes across Canada, the CLLS data base has the potential to address, at extensive temporal and spatial scales, several questions related to loon and lake conservation. With support from the Canadian Wildlife Service and Ontario Ministry of Natural Resources, analyses of temporal patterns in Ontario loon breeding productivity (1981-1997) have just been completed and a manuscript is in progress. Results of these analyses suggest that breeding productivity of Ontario's loons has declined, particularly during the 1987-1997 period. In addition, declines in productivity were more dramatic on lakes below pH 6 than on more alkaline lakes. These patterns suggest the proportion of acid lakeson the landscape may have important and long-term effects on the recruitment of juvenile loons.

Since 1981, CLLS data forms have requested information concerning loon occupation of lakes (single adults, pairs), breeding success (chick numbers and age/size classes), lake shoreline development, and human activity on the lake. Survey forms were modified in 1997 to encourage surveyors to record which week and which day of each week observations were conducted. This information should allow improved investigations of the causes and timing of chick mortality.

Approximately 700-1,000 volunteers have participated in the CLLS each year since 1989. Recruitment is conducted nationwide through media releases, interviews, ads and articles in magazines, and the Bird Studies Canada web pages (www.bsc-eoc.org). CLLS participants have played an integral role in several special projects over the last several years. These projects have included: water sampling for the Canadian Wildlife Service's lake biomonitoring program, distribution of signs which alert boaters and others to conservation issues concerning breeding loons, building and maintaining loon nesting platforms for selected lakes, submitting eggs and carcasses for toxicological analyses, and monitoring water level changes.

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WESTERN UNITED STATES AREA

IDAHO REPORT

JENNY TAYLOR, PANHANDLE LOON & WETLANDS PROJECT

The Panhandle Loon and Wetlands Project, a volunteer organization, tracks loon reports in North Idaho, primarily Bonner and Boundary Counties. Idaho Department of Fish and Game is currently not involved in loon monitoring or research. The only reports of loons nesting in Idaho in the last 30 years are at Thompson Hole in 1984 and 1988, Indian Lake in 1989, Lake Pend Oreille in 1995, and Priest Lake in 1998. In 1997, approximately 20 loons were counted during the mid-July North Idaho Loon Count. Dr. Charles Trost documented a historical breeding population of 14 nesting pairs.

Most large Idaho lakes, including Pend Oreille and Priest Lakes, receive high levels of boating and jet ski use, which may be the largest management concern for loons in Idaho. Toxic metal contamination is also a concern on Lake Coeur d'Alene and the lakes along the Coeur d'Alene River. Loons do appear to be recolonizing some of the lakes in Idaho's panhandle and recent conservation efforts and interest are promising for its reestablishment as a regular nesting species.

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MONTANA REPORT

LYNN KELLY, THE MONTANA LOON SOCIETY

Montana has the largest population of Common Loons west of the Mississippi River. Approximately 200 birds reside in the northwest corner of the state. Of these, 60-65 pairs will attempt to nest and 24-26 pairs will successfully raise 1-2 chicks each year. As a result of data revealing how biologically vulnerable the birds are (Evers et al. 1998), the loon has been elevated to a Priority 1 species by Montana Partners in Flight. The bird was already classified as a sensitive species by the U.S. Forest Service and a species of special concern by Montana Fish, Wildlife and Parks.

Recently, the Common Loon Working Group (CLWG) was formed to undertake the technical aspects of loon research and management. While CLWG consists mainly of agency biologists, anyone can be involved. The CLWG works closely with the Montana Loon Society (MLS) which is the volunteer base working to increase public awareness about loons, protect and enhance critical loon habitat, facilitate cooperation between government agencies, lakeshore owners and the general public and monitor the loon population in Montana.

Loon management in Montana consists of finding nest sites and protecting them with floating signs set between 70-140 yards from the nest (Kelly 1992). Public education occurs at the boat ramps and campgrounds associated with lakes where signs are found. This extra effort increases compliance with the signs and reduces the incidence of vandalism. Recently, MLS published a brochure entitled "Responsible Watercraft Use and Montana's Loons" which will be given to the public as we meet them. Its' simple message and attractive format will make it a very effective out-reach tool.

There are two surveys taken by MLS and CLWG. The Spring Occupancy Loon survey occurs on the Saturday closest to May 15. Its purpose is to discern the numbers of territorial pairs and single birds present in the population. "Loon Day" occurs on the third Saturday of July in order to determine chick survival. In 1998, 106 Loon Day volunteers surveyed 170 lakes. Over the years the numbers of adults have increased somewhat. However, the number of chicks has remained fairly constant from year to year with the exception of 1998 when Glacier National Park had a remarkably high chick production. We are not sure why 14 chicks survived to Loon Day instead of the usual 3-5 survivors. The increasing numbers of loons, especially adults, seen over the years is probably more indicative of better coverage of lakes on Loon Day than an actual increase in the population.

Loon banding projects occurred in 1996 and 1997 in cooperation with BioDiversity Research Institute resulted in eleven adults (including two recaptures) and eight chicks having been banded and color-marked. One juvenile banded near Troy, in extreme northwest Montana, was recovered 193 miles directly to the south in the Bitterroot Valley near Missoula. Recently we learned that a female loon banded in the Clearwater drainage east of Missoula was observed on Morro Bay, California between March and April, 1999. Evers, pers. com.). We suspected that the Montana population would be wintering along the Pacific Coast. However, to verify this with just nine banded adults was unexpected and very exciting.

Blood analysis for methyl mercury indicates that Montana's birds are within the normal range for this toxin. However, of three eggs tested for mercury in 1998, one was found to contain 1.34 ppm mercury. The normal level is 0.5 ppm while 1.0-2.0 ppm places the egg in a high-risk level, which includes reduced hatchability. (Evers et al. 2000) Montana Fish, Wildlife and Parks plan to test the fish in the lake to determine the level of this toxin. A point source of mercury is suspected but unconfirmed.

Dramatic growth of the human population in northwest Montana has greatly increased the amount of developed lakeshore and the levels of human activity of area lakes. The Montana Loon Society remains hopeful that with continued diligent management, habitat protection and public education, loons will continue to remain a viable part of our aquatic ecosystems.

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NORTH DAKOTA REPORT

SCOTT GOMES, NORTH DAKOTA GAME & FISH DEPT.

The North Dakota Game and Fish Department contracted Tom Gibson, a naturalist and photographer, to determine the status of Common Loons during the summers of 1990 and 1991. His study was conducted in Bottineau and Rolette counties, which are in the middle of the northern tier of counties in North Dakota, in the Turtle Mountains. They contain the only nesting habitat suitable for loons in North Dakota. Of the 58 lakes surveys from May-July, 48 loons including 14 pairs were identified. Based on these results, the North Dakota Game and Fish Department estimated that the entire Turtle Mountain area supports approximately 100-150 loons or 50 territorial pairs.

People are impacting many areas of the Turtle Mountains. The clearing of forests for agricultural purposes contributes to increases in water turbidity and contaminants. As found elsewhere, lakeshore developments and the corresponding increases in human recreational interests and ubiquitous predators, are conservation issues for this breeding population. The state has incentive programs such as the woodland tax credit and Critical Areas Protection agreements to protect some of these lake shorelines.

Although this small breeding population is vulnerable and relatively unmonitored, its isolation from impeding changes in the landscape will probably afford some protection until conservation networks are formed for annual monitoring. The isolation of this breeding population from other neighboring populations makes it potentially genetically unique but quite vulnerable to local extirpation therefore it has been designated as a "Watch Species" by the Endangered Species Committee of the North Dakota Chapter of The Wildlife Society.

WASHINGTON REPORT-STATE

SCOTT RICHARDSON, DAVID HAYS, ROCKY SPENCER & JULIE STOFEL, WASHINGTON DEPT. OF FISH & WILDLIFE

(EXCERPT OF EXECUTIVE SUMMARY FROM "WASHINGTON STATE STATUS REPORT FOR THE COMMON LOON).

Historic population levels of the Common Loon are not well known in Washington, with most of the available information dating from the past 15 years. It is currently a rare breeder and a common migrant and wintering species within the state. A total of 20 confirmed nest sites are known to have been

Whatcom counties. The number of confirmed nests during 1990-99 ranged from 8-10 each year, with 9-14 sites surveyed. Nesting at 12 additional sites has been reported but not confirmed.

Common Loons once were described as a fairly common breeding species both east and west of the Cascade Crest, but likely declined between 1890 and 1925 in much of Washington. Declines across the U.S. during this period are thought to have been the result of shooting by humans. A number of lakes in Washington appear to have offered ideal conditions for loon nesting in the past. Characteristic sites would have been relatively undisturbed forest lakes at least 20 ha in size, with deep inlets and bays. They would have had islands or logs and other floating debris for nest sites. Finally, they would have been characterized by good water quality, an adequate food source, and seclusion from intense human activity. At many lakes, unfortunately, these conditions have been lost.

Shoreline development, including homes, roads, and powerlines has eliminated nesting habitat and increased the level of human activity in the vicinity of potential loon nests. Human disturbance is likely to reduce loon productivity and may preclude nesting at important sites. Persecution directed toward loons can cause abandonment of nesting sites. Drastic changes in water level (frequent events at reservoirs) either flood nests or render them unapproachable, causing abandonment. Considering this species' ecology and the degradation of nesting lakes, we suspect this species has a reduced opportunity to breed in Washington, compared with historic conditions.

Although human influences are problematic, allowances for loons sometimes are made. Floating nest platforms, access restrictions, and educational campaigns have helped loons to persist and successfully reproduce at certain sites. The development of reservoirs on rivers from dam construction has created some nesting habitat for Common Loons. Currently, about half the loon nests documented each year are located on water bodies that are relatively inaccessible to people, so they have limited human disturbance.

Increased development and recreational pressure at sensitive nesting lakes must be actively managed to prevent further loss of nesting loons. Protection and education programs must be expanded to appropriate lakes that currently do not support breeding loons to allow the species to recolonize and nest undisturbed, ensuring a stable and well-distributed population. The use of rotenone to kill unwanted fish may affect the food supply of Common Loons for several years.

Although the Common Loon is not well studied in Washington, biologists have long been concerned about the health of the state population. Protective designations have been suggested since the early 1980's, but no action has been taken. The Common Loon does not merit State Endangered status, because it is not seriously threatened with extinction within the state. It does not appear to merit a State Threatened classification, because a significant portion of the current breeding population nests in secure habitat and is cooperatively managed. In addition, other lakes are relatively secure due to remoteness. However, we do not know if the population is increasing or decreasing, current status of many sites is unknown, and the magnitude of threats to the Common Loon is not well understood. Processes of dispersal and site colonization are also not well understood. New information on these issues may change our understanding of the status of common loons in Washington.

WASHINGTON REPORT-ORGANIZATION

JANEY YOUNGBLOOD, LOON LAKE LOON ASSOCIATION

The most exciting loon news in the state of Washington is that the Common Loon is being considered for threatened species status. The Loon Lake Loon Association has been involved with this important decision. At the present time, the loon population is holding steady or possibly gaining a bit. The count for 1999, includes 12 known established pairs. Funding projects of the Loon Lake Loon Association include the Annual Loonsday Walk, which in 1997 drew 850 people. For an entry fee, the participants walk 5.5 miles and in turn receive a loon T-shirt and/or sweatshirt. The proceeds from this event benefit the entire community, in addition to the Loon Lake Loon Association. The other funding project is the Loon Gift Shop in the Old Schoolhouse at Loon Lake. The shop is open year-round and many people learn about loons from the various items sold there.

In additional to saving money to retain the remaining wetlands, the LLLA has some ongoing research projects. One is partial funding of the Loon Banding Project in the Pacific Northwest with BioDiversity Research Institute of Maine. LLLA also supports the Okanogan Loon Habitat Expansion and Education Project in Okanogan County. At the present time, the loons are expanding in that area and the pairs at Lost and Bonaparte's Lakes have been very successful in producing fledged young over the past five years. In addition to habitat preservation and monitoring, a strong education program is conducted by Patti Baumgardner.

WYOMING REPORT

ANDREA CEROVSKI & DAN STEVENSON, WYOMING FISH & GAME DEPT. & TERRY MCENEANEY, YELLOWSTONE NATIONAL PARK

The Common Loon is of special concern because of its public appeal, vulnerability to human disturbance and environmental degradation, and its limited abundance and restricted distribution in Wyoming. Loons can be observed statewide during spring and fall migration and nonbreeding loons can be found throughout the state during the summer. However, suitable breeding habitat is restricted to the northwest corner of Wyoming and is easily lost or degraded due to human disturbance and habitat changes. In 1998, known nesting areas were surveyed to document loon nesting, production, and recruitment.

Seven lakes outside Yellowstone National Park with a past history of nesting were surveyed for production and recruitment in 1998 by Wyoming Game and Fish Department (Department) personnel. June nest occupancy surveys were not conducted in 1998 because the lakes could not be reached due to excessive snow on the access road. During the July production survey, single adult loons or loon pairs were observed on three of the seven lakes, and two chicks were observed on one of the seven lakes. During the September recruitment survey, one chick was observed on one of the lakes. In comparison, nesting was documented on four lakes in 1997 (six chicks produced), two lakes in 1996 (three chicks produced), five lakes in 1995 (three chicks produced), three lakes in 1994 (three chicks produced), two lakes in 1993 and 1992 (one known chick produced in 1993; production unknown for 1992), four lakes in 1990 (five to six chicks produced), and three lakes in 1989 (four chicks produced) (Cerovski et al. 1997, Cerovski et al. 1996, Cerovski et al. 1995, Cerovski 1994, Cerovski 1993, Ritter and Wulf 1991, Ritter 1990).

In Yellowstone National Park, 40 adults were observed in 1998. Twelve pairs attempted to nest, fledging a total of eight young on six different lakes. In comparison, five pairs produced six chicks on five lakes in 1997, five pairs produced four chicks on four lakes in 1996, 13 pairs produced eight chicks on 12 lakes in 1995 (two pairs nested on the same lake), 12 pairs produced 12 chicks on eight lakes in 1994, 12 pairs produced six chicks on four lakes in 1993, 11 pairs produced six chicks on four lakes in 1992, and 11 pairs produced nine chicks on nine lakes in 1990 (Cerovski et al. 1998, Cerovski et al. 1997, Cerovski et al. 1996, Cerovski et al. 1995, Cerovski 1994, Cerovski 1993, Ritter and Wulf 1991).

Beginning in 1996, Common Loon surveys were more intensive than in past years to better determine the success of nesting loons in producing young. The timeline for common loon surveys is as follows: nest initiation and status surveys are conducted in early to mid-June, production surveys are conducted in mid- to late July, and follow up recruitment surveys are conducted in late August to early

September. These surveys are scheduled to coincide with similar surveys conducted in Yellowstone National Park so data can be directly compared.

Nesting data on the seven lakes outside of Yellowstone National Park and the one lake within the Park that Department personnel inventory each year suggest that Common Loon breeding pair territories may encompass more than one lake. We believe that one breeding loon pair uses both Indian Lake and Bergman Reservoir; Indian Lake for nesting and foraging and Bergman Reservoir for foraging. In addition, because of the juxtaposition of the three lakes, it is likely that one pair uses Fish Lake, Junco Lake, and a nearby lake within Yellowstone as their breeding territory. Finally, the loon pair that nests on Arizona Lake may use a nearby lake, possibly Jackson Lake, for foraging later in the summer.

Large groups of common loons have occurred in Wyoming in past years. The largest recorded thus far was in April of 1989 when 1,000 to 2,000 loons were present on Flaming Gorge Reservoir (Ritter 1990). Other large groups of loons (19-46 birds per group) were also reported in April of 1989 at Lake Cameahwait, Lake DeSmet, and Soda Lake Wildlife Habitat Unit (Ritter 1990). In mid-April of 1994, a group of 112 were observed at Flaming Gorge Reservoir. The largest group observed in 1997 was 32 on Flaming Gorge Reservoir in late March.

Since 1989, the number of locations where Common Loons have been reported has decreased. In 1989, they were reported at 42 locations. The fewest number of locations where loons were reported occurred in 1996, with only 5 locations reported on the Department's Wildlife Observation System (WOS) database. This compares with 10 locations reported in 1993, 15 locations reported in 1994, 11 locations in 1997, and seven locations in 1998. Distribution information for 1995 could not be obtained from the WOS database due to complications. The decrease in the number of loons observed since 1989 is most likely due to a lack of reporting rather than a lack of loons. In addition to requesting that all Department biologists report all Common Loon sightings, a flyer will be distributed this spring asking wildlife watchers to report all loon sightings across Wyoming.

In October of 1996, the Department's Nongame Program distributed the updated Nongame Bird and Mammal Plan (Oakleaf et al. 1996), which presents and prioritizes management actions for the state's Species of Special Concern. Due to a population that is greatly restricted in the state during the breeding season, and on-going significant habitat loss from increased human use and disturbance of nesting lakes within its breeding range, the Common Loon is classified as a Species of Special Concern 1. As part of a cost-share agreement between the Department and U.S. Forest Service - Shoshone National Forest (SNF), 15 lakes with potential common loon nesting habitat within the SNF were surveyed in 1997 to determine loon presence and use (Cerovski 1998). Based on our observations and habitat evaluations, two lakes in the SNF had potential loon nesting habitat and were revisited in 1998; none were observed. Additional potential nesting lakes within the loon's breeding range outside of the SNF were identified and will be surveyed during 1999 and 2000 to determine loon presence and use.

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UPPER GREAT LAKES AREA

MICHIGAN REPORT

PAULINE SCHUETT & WILLIAM ROBINSON, NORTHERN MICHIGAN UNIVERSITY

(from the M.S. Thesis, "A survey of the Common Loon (*Gavia immer*) in Michigan, 1996).

A survey of Common Loons (*Gavia immer*) was conducted in Michigan in 1996 to (1) estimate the number of breeding pairs in Michigan and compare this number with that estimated in 1991, (2) determine the number of chicks produced per brood in each of six regions of Michigan, (3) estimate the total population in Michigan, (4) indicate patterns over time of Common Loons breeding in Michigan, and (5) describe geographical patterns of numbers of breeding pairs and locations of chick production.

The estimated number of breeding pairs in Michigan increased from 368 pairs in 1991 to 416 pairs in 1996, with the most substantial increases occurring on lakes in the state with no history of breeding loons. The number of chicks per brood decreased from 1.09 chicks in 1991 to 0.78 chicks in 1996. The northwestern Lower Peninsula region showed the greatest decrease in the number of chicks per brood, going from 1.32 in 1991 to 0.68 in 1998. The estimated total summering adult loon population in Michigan increased from 1,200 birds to almost 1,500 birds in 1996, with increases occurring in both the number of breeding pairs and the number of non-territorial loons. Previously occupied lakes were being used by breeding loons at a stable rate, while lakes with no known breeding history were occupied at a higher rate than in the early 1990s. Geographically, breeding loons occupied a higher percentage of lakes in the western Upper Peninsula than in the other regions of the state. In both the western Upper Peninsula and the northern Lower Peninsula, successfully breeding loons occurred in a concentrated distribution on lakes on which chicks were produced.

Population goals set in the Michigan Loon Recovery Plan were met only in the northern Lower Peninsula and the southern Lower Peninsula. Future research in Michigan should include a revision of survey techniques, such as surveying stratum III lakes (4-16 ha) again, revising the survey of large lakes by using an airplane or a motorboat to cover larger lake areas, and an increase in funding. Research, public education, and the designation and protection of Common Loon breeding habitat should continue so that Common Loons in Michigan may increase in numbers to meet the goal of 575 breeding pairs indicated in the Recovery Plan.

MINNESOTA REPORT

RICH BAKER, MINNESOTA DEPT. NATURAL RESOURCES

The Minnesota Loon Monitoring Program (MLMP) is a long-term project of the Minnesota Department of Natural Resources' Nongame Wildlife Program. Since 1994, nearly 1000 volunteer observers have annually gathered information about Common Loons (*Gavia immer*) in six 100-lake regions, or "index areas" of the state. The data these generous citizens collect provide the Nongame Wildlife Program with an early warning system for detecting changes in the numbers of these birds and the health of their lake habitats in Minnesota. In addition to reporting information about loons and habitat quality, observers also report on the presence of Canada Geese (*Branta canadensis*) on the lakes they survey.

An analysis of six years of MLMP data indicates that Minnesota's Common Loon population remains healthy in both number of adults and number of juveniles observed within the index areas. Indeed, data from the Becker index area indicates a slight, but significant increase in that area's loon population. The abundance of loons varies greatly across the state, and is lowest in the southwestern (Kandiyohi and Otter Tail) and northeastern (Cook/Lake) index areas, and highest in the north central (Itasca) index area. The number of juveniles per two adults seen, a measure of reproductive success, also varies among index areas, but appears to be highest in the southwestern (Kandiyohi) index area and lowest in the northeastern (Cook/Lake) index area. Finally, data on Canada Goose abundance illustrates a dramatic increase in the southwestern (Kandiyohi and Otter Tail) index areas, but stable populations elsewhere.

The value of MLMP data is widely recognized by Minnesota's biologists and planners, and its results have been incorporated into several summaries of statewide ecological health, including Minnesota Milestones, Minnesota Environmental Indicators Initiative, and Water Management 2000. The Nongame Wildlife Program hopes to continue this effort into the future.

WHY WE MONITOR THE HEALTH OF MINNESOTA'S LOON POPULATION

The Common Loon is Minnesota's state bird, and a source of pleasure to the thousands of lake dwellers and visitors who enjoy its enchanting sights and sounds. A statewide survey conducted by the Nongame Wildlife Program in 1989 found that Minnesota is the summer home to roughly 12,000 adult loons, more than in all other states combined, excluding Alaska. As with the bald eagle and grey wolf, Minnesotans are responsible for the stewardship of one of the nations' largest loon populations. The DNR uses the MLMP to track the health of the state's loons and lakes, and to help insure that this bird will grace Minnesota far into the future.

INDEX AREAS

Because it would be far too difficult to collect loon data from all 12,000 of Minnesota's lakes each year, the MLMP is designed to measure the health of loon populations within six 100-lake "index areas," selected because they are typical loon habitat. To help us detect problems from loss of shoreline habitat, the MLMP index areas are divided between those likely to experience rapid human population growth (e.g., Aitkin/Crow Wing and Kandiyohi index areas) and those in which impacts are likely to change more slowly (e.g., Becker, Cook/Lake, Itasca, and Otter Tail index areas). They are also divided between those with variable acid rain sensitivity, public or private land ownership, and road density. Index areas are named for the counties in which they are located.

VOLUNTEER OBSERVERS

Hundreds of generous volunteer visit assigned lakes on one morning within a ten-day period in early July. Depending on the size of the lake, the volunteers' methods vary. Surveys are conducted from shore, motorboat, and canoe. Nongame Wildlife Program staff provide survey guidelines to all volunteers, and ask for weather and shoreline conditions in addition to loon counts. Nongame Wildlife personnel compile and analyze questionnaire results.

LOON ABUNDANCE: **Adult Loons Seen/100 Acres of Lake Surface within an Index Area.**

During the six years studied, no statistically significant changes in adult loon abundance have been observed within any of the six index areas. Loon abundance ranged from 0.5 - 0.8 in the Kandiyohi index area to 3.2 - 3.8 in the Itasca index area. These differences among index areas confirm previous observations that in Minnesota, loons are most abundant in the central lakes region, and least abundant in the southwest agricultural region, where the species is at the very southern edge of its distribution in North America.

LOON OCCUPANCY: **Percent of Lakes in an Index Area with Any Adult Loons**

Occupancy can be thought of as the likelihood of seeing a loon on a lake. A small, but statistically significant increase in occupancy was detected in Becker County. Occupancy in all other index areas remained stable during the six years, but fluctuations up to 10% were observed in several areas. Occupancy was 65% - 73% in Aitkin/Crow Wing index area, 59% - 73% in Becker County, 44% - 54% in Cook/Lake counties, 69% - 76% in the Itasca County, 24% - 32% in Kandiyohi County, and 48% - 58% in Otter Tail County. This is consistent with previous observations regarding the distribution of loons within Minnesota.

LOON REPRODUCTIVE SUCCESS: **Juvenile Loons for Every Two Adult Loons on a Lake**

Measures of reproductive success are particularly important in monitoring the health of wildlife populations. Especially with long-lived species like the loon, focusing only on adult abundance or occupancy might cause biologists to miss less obvious problems. Productivity was calculated as the average number of juvenile loons for every two adults. When only one loon was seen on a lake, it was not included in the total number of adults later divided by two and used for the number of territorial pairs. No attempt was made to verify the actual number of territorial pairs. The sample size was small, and juveniles were frequently missed during the annual survey. However, it is assumed the error factor would be similar from year to year, hence these surveys are valuable in providing information on trends in population and productivity.

No statistically significant changes in reproductive success were observed within any of the six index areas during this study. The sample size was small, compared to a count of adult loons only, where sightings of single loons were also included, plus juveniles are likely to be missed during the annual count. However, it is assumed the error factor would remain stable from year to year, and these surveys would then provide data on reproductive success, repeatable from year to year. Over the six years, productivity was 0.29 – 0.44 in Aitkin/Crow Wing counties, 0.35 – 0.63 in Becker County, 0.07 – 0.41 in Cook/Lake counties, 0.28 to 0.54 in Itasca County, 0.46 to 0.82 in Kandiyohi County, and 0.32 – 0.61 in Otter Tail County. Results indicate that although Kandiyohi has the lowest abundance and occupancy figures, the adults living there are the most successful of any index area. The reason for this is unclear. The relatively poor reproductive success observed in Cook/Lake counties may be due to the generally low productivity of lakes in that region, or to heavy metal contamination in some of its waters. Further research would be needed to determine the causes of these patterns.

WISCONSIN REPORT

TED GOSTOMSKI, SIGURD OLSEN ENVRIONMENTAL INSTITUTE

Wisconsin LoonWatch assisted Isle Royale National Park (Michigan) and BioDiversity Research Institute (BRI) in an early season loon survey of the island's inland lakes in June of 1999. The significance of this was two-fold. First, it was the first early season loon survey conducted by the park's Resource Management staff, who have historically done a single visit survey in late July through August. The early season survey was designed to provide a clearer picture of the island's actual nesting population, and this information is being used by BRI to develop a loon nesting atlas for the park. Second, the contribution of volunteer time by Northland College students and citizen volunteers (coordinated by LoonWatch) marked the establishment of the LoonWatch Field Experiences Program, which is designed to provide students (and some citizens) with practical field experience in cooperation with state and federal agencies. LoonWatch program is continuing to work with Isle Royale Resource Management and BRI to develop the framework of a loon productivity monitoring program for the Visitor Experience and Resource Protection (VERP) portion of the park's Wilderness Management Plan. Under VERP, various natural and social indicators are used to monitor the impact of visitation on the park's resources. Natural indicators typically include things like the degree of soil compaction, the number of exposed tree roots, and the amount of bare ground in campsites or along the trails. Measuring impacts to wildlife such as loons has never been done.

LoonWatch is developing a second Field Experience opportunity in cooperation with biologists at Voyageurs National Park, Minnesota for the summer of 2000. The park is interested in assistance with loon surveys, which would require students to stay in the park for up to two months. LoonWatch staff, interns, and advisory council members delivered 47 loon or lake programs in 1999. Four of these programs were given in Minnesota. As of December, 1999 observation data from 117 lakes in Wisconsin had been entered. Data entry was delayed early in the fall when the LoonWatch database was lost for a few nervous weeks. Some forms remain to be entered, which should bring this total to just fewer than 200 lakes.

LoonWatch initiated a volunteer Speakers Bureau in the spring of 1999. Eight citizen volunteers attended a workshop in May to begin learning how to give public programs on the Common Loon. Participants are now reading and learning more about loons and preparing their own programs, which will be presented to a review panel in early 2000. The goal is to have five of the volunteers trained and ready to give programs by April of 2000.

NEW ENGLAND AREA

MAINE REPORT

SUSAN HITCHCOX, MAINE AUDUBON SOCIETY

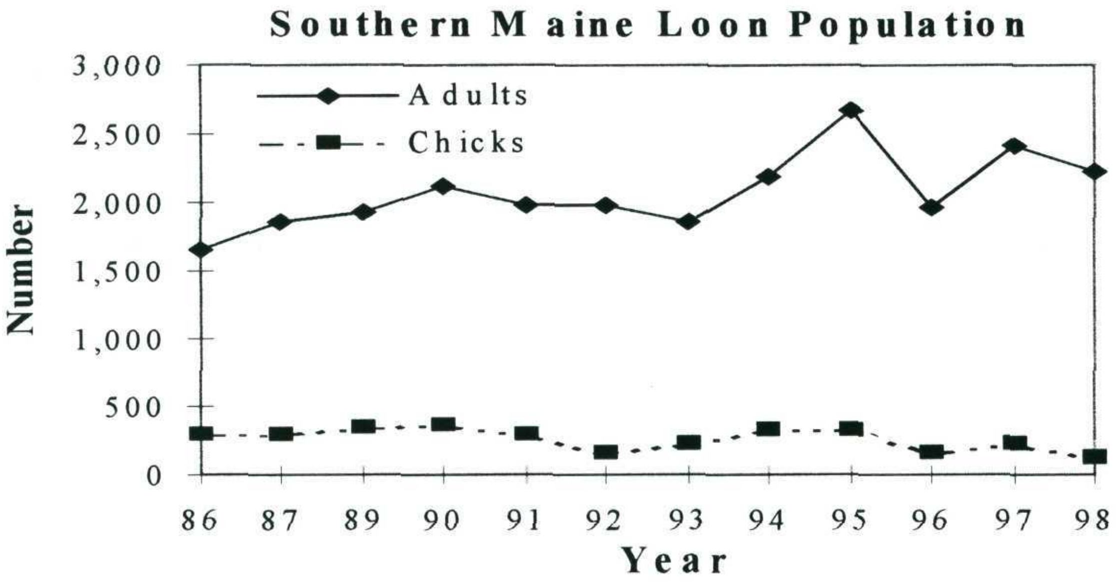
The Maine Loon Project is a part of the Maine Audubon Society, and was formed in the early 1980s because of concern over the state's loon populations. The Maine Loon Project has one half-time director and is run largely by volunteer efforts. Activities of the Maine Loon Project include school and adult outreach programs, research, lobbying, advocacy, production of a biannual newsletter (The Loon News), and population monitoring.

The Project has conducted an annual statewide loon survey since the early 1980's utilizing up to 500 volunteers each year. We use a stratified random sample of the loon count observations to extrapolate a population estimate for the southern half of the state (Figure 1). Coverage of volunteers in the northern half of the state is too sparse to allow annual statewide population estimates. However, the Maine Department of Inland Fisheries and Wildlife conducts aerial surveys every five years. Their last survey, done in 1996, estimated the northern Maine population to be approximately 1,400 adult birds. *Combining these two census methods puts the most recent estimate of a statewide population* somewhere around 3,800 adults. The program currently has no staff to monitor individual lakes, nests, or territories.

Staff and volunteers for the Maine Loon Project have been actively cooperating with Dr. Mark Pokras at Tufts University in his studies of loon mortality by collecting loon carcasses and sending them to Tufts for analysis. He has found lead poisoning and boat trauma to be the leading causes of death for loons in Maine. Volunteers for Maine Audubon have also been collecting non-viable loon eggs for the Northeast Loon Study Work Group for analysis of mercury concentrations.

For several years, staff of the Maine Loon Project has been involved with the Great Ponds Task Force, a group established by the Legislature to make recommendations for the protection of Maine's ponds and lakes. During the 1997 session, the Maine Legislature passed many of those recommendations into law. The new law bans personal watercraft on 242 gem ponds and lakes in northern Maine, and places horsepower limits on seven ponds in Acadia National Park. In the organized portion of the state, municipalities have the next two years to develop their own recommendations for limiting the use, operation, and types of watercraft. These recommendations will be brought to the Commissioner of Inland Fisheries and Wildlife who will then bring them to the Legislature for final approval. Staff from the Maine Loon Project helped develop and lead a workshop in July of 1998 on the new law, walking participants through the legal steps necessary for developing municipal restrictions and reviewing case law that applies to regulating personal watercraft.

FIGURE 1. Summary of southern Maine's Common Loon breeding population.



Staff from the Maine Loon Project actively cooperates with organizations like BioDiversity Research Institute to conduct research and field work on loons and mercury contamination. Based in part on this research, we have lobbied for numerous successful laws that reduce mercury emissions in Maine and in neighboring states.

The most recent activities of the Maine Loon Project include successfully introducing and lobbying for a lead sinker ban in the Maine legislature, and developing a lead sinker exchange program. We received a grant from the Maine Outdoor Heritage Fund and will work cooperatively with the Department of Inland Fisheries and Wildlife to conduct outreach activities at boat ramps and fishing derbies throughout the state. The grant provides funding for additional staff in the summers of 1999 and 2000, and will provide for a substantial inventory of lead-free tackle, as well as the production of additional educational materials.

MASSACHUSETTS REPORT

BRAD BLODGETT, MASSACHUSETTS DIVISION OF FISHERIES & WILDLIFE

Loons returned to Massachusetts in 1975 after almost a century's absence. They occur statewide as migrants and regularly put down on larger lakes and reservoirs inland. In summer they nest at the Quabbin Reservoir and six other lakes in Worcester County

In 1999, the number of identified territories increased slightly to 19 compared with 18 in 1998. However, the number of confirmed nesting pairs declined to 10 from 12 a year earlier. Five pairs produced a total of seven chicks, with seven presumptively fledging. Chicks fledged/nesting pair (7/10) declined for a third year in a row to 0.70 vs. 0.75 a year earlier and 1.28 in 1996. Productivity was adversely impacted in 1998 and 1999 by flooding, high water levels, and predation. Two of the 12 nesting pairs used rafts.

NEW HAMPSHIRE REPORT

KATE TAYLOR & HARRY VOGEL, LOON PRESERVATION COMMITTEE

The Loon Preservation Committee (LPC) was created in 1975 in response to declines in the populations and productivity of Common Loons in New Hampshire. LPC works to preserve loons and their habitats in New Hampshire through programs of research, management and public education, all fostered by an extensive network of members and volunteers. Many of our initiatives involve close coordination with federal, state and private organizations.

Monitoring Loon Populations

LPC has monitored loon populations and maintained records of productivity for virtually every nesting pair of loons in New Hampshire since 1976. Statewide coverage is accomplished by dividing the state into four multiple-lake and four single-lake monitoring regions. Eight field biologists survey these regions, collecting data on numbers of adult loons, numbers of territorial pairs, nesting success and survival of chicks each year. In the 1999 field season, LPC biologists spent 459 person-days surveying 359 lakes and ponds statewide. This number represents 100% of the waterbodies known to have held territorial pairs over the past three years. In addition to staff surveys, an annual statewide loon census on the third Saturday of July provides a mid-season check on the productivity of loons on the breeding grounds.

New Hampshire's loon population in 1999 consisted of 200 territorial pairs on 123 lakes. One hundred thirty-five pairs nested with 80 pairs producing a total of 123 chicks. Ninety-five of these chicks were surviving in mid-August and presumed to have fledged from their natal lakes. During 24 years of monitoring, LPC has recorded significant increases in numbers of territorial pairs ($P<0.001$, $r^2=0.97$), nesting pairs ($P<0.001$, $r^2=0.95$), successful nests ($P<0.001$, $r^2=0.83$), chicks hatched ($P<0.001$, $r^2=0.79$) and chicks surviving ($P<0.001$, $r^2=0.67$) (Table 1). However, our data have also revealed significant declines in the proportion of nesting pairs to territorial pairs ($P<0.001$, $r^2=0.45$) and survivorship of young (the proportion of surviving chicks to chicks hatched) ($P<0.01$, $r^2=0.39$) (Table 1). The increase in loon populations in New Hampshire has been driven by an increase in territorial pairs along with a steady to increasing trend in the number of chicks hatched per territorial pair ($P=0.14$, $r^2=0.09$) (Table 1) which until recently have been sufficient to offset declines in other parameters of reproductive success. Data collected over the past four years suggest that loon populations in New Hampshire may be leveling off or even beginning to decline after 20 years of relatively steady growth, but the existence and significance of recent population trends will only be apparent after several additional years of data are collected.

TABLE 1. Summary of reproductive parameters in New Hampshire, 1977-1999.

Year	Nesting pairs / territorial pair	Chicks hatched / territorial pair	Chicks surviving / territorial pair	Chicks hatched / nesting pair	Chicks surviving / nesting pair	Chicks surviving / chicks hatched
1977	0.70	0.51	0.45	0.73	0.65	0.89
1978	0.72	0.56	0.44	0.78	0.61	0.78
1979	0.71	0.71	0.59	1.00	0.82	0.82
1980	0.70	0.75	0.60	1.07	0.85	0.80
1981	0.78	0.65	0.54	0.84	0.69	0.82
1982	0.79	0.88	0.73	1.11	0.93	0.84
1983	0.77	0.89	0.72	1.15	0.93	0.81
1984	0.68	0.65	0.51	0.96	0.75	0.78
1985	0.71	0.80	0.66	1.13	0.93	0.82
1986	0.70	0.78	0.53	1.10	0.76	0.68
1987	0.69	0.76	0.52	1.10	0.76	0.69
1988	0.62	0.62	0.47	1.00	0.76	0.76
1989	0.66	0.69	0.49	1.03	0.74	0.71
1990	0.65	0.65	0.50	1.01	0.77	0.76
1991	0.62	0.65	0.52	1.05	0.83	0.79
1992	0.65	0.79	0.53	1.21	0.81	0.67
1993	0.72	0.66	0.49	0.91	0.68	0.74
1994	0.57	0.63	0.48	1.09	0.83	0.76
1995	0.61	0.57	0.42	0.94	0.69	0.73
1996	0.68	0.60	0.44	0.89	0.65	0.73
1997	0.59	0.62	0.47	1.05	0.80	0.77
1998	0.60	0.48	0.30	0.76	0.48	0.63
1999	0.68	0.62	0.48	0.91	0.70	0.77

Banding and Tissue Collection

LPC has participated with BioDiversity Research Institute (BRI) in the banding of all loons in New Hampshire since 1993. Initially banding occurred only on Lake Umbagog in the northern part of the state, but this effort expanded statewide in 1997. Currently LPC assists BRI in monitoring a population of 155 uniquely color-marked adult loons. The capture of loons for banding also permits the collection of blood and feather samples for analysis of mercury and other toxic contaminants. Loons captured in New Hampshire have among the highest concentrations of mercury found in loons anywhere in North America (Evers et al. 1998).

LPC routinely conducts opportunistic collections of abandoned loon eggs as part its monitoring program. These eggs are analyzed to determine fertility, level of development and mercury concentrations. Analysis of 36 eggs collected in the mid-1970s by LPC and 120 eggs collected from 1992-1998 detected 22 eggs (36%) with levels of mercury that could impact reproductive success (Haseltine et al. 1983, Barr 1986, Thompson 1996, Evers et al. 2000).

Causes of Mortality

LPC is uniquely positioned to act as an intermediary between a large number of concerned citizens, and researchers in veterinary colleges that have facilities, expertise and funding to determine causes of mortality. Each year LPC field biologists collect dead or moribund loons. Blood is collected from live birds, which are then examined and treated or euthanized by veterinarians. All carcasses, accompanied with observational data, are sent to Tufts University Wildlife Clinic for necropsy.

A total of 19 loons (15 adults and 4 chicks) were recovered by LPC in 1999. Lead poisoning as a result of ingestion of lead fishing tackle is known or suspected to be the cause of death of 10 of these loons. Collections made since 1976 implicate lead tackle ingestion as the primary contributor to loon mortality in New Hampshire.

Mapping Nesting and Nursery Sites

LPC digitally maps loon nesting and nursery sites using a Geographic Information System (GIS) to identify and protect areas of significant habitat across the state. The resulting maps are available to the Wetlands Bureau of the New Hampshire Department of Environmental Services, the New Hampshire Fish and Game Department and other agencies to ensure that public access points and other developments in wetlands or on shorelines incorporate buffer areas to protect nesting loons.

Management

Field biologists place protective signs and float-lines in areas of high visibility to restrict boats around established nests. These are placed at the first sign of nesting or with the establishment of a brood site. In 1999, 19 nest sites (14%) were roped off and/or signed by LPC staff. When present, field biologists restrict boat traffic in sensitive areas under the authority of the New Hampshire Marine Patrol.

Rafts are floated at specific sites in order to mitigate potential human and/or predatory impacts to nesting loon pairs in those areas. LPC considers raft usage only for established pairs experiencing successive nest failure due to artificial water level fluctuations or shoreline predation, and on lakes having a suitable location secluded from weather, shoreline disturbances and boat traffic. In 1999, 45 rafts were floated across the state. Loon pairs hatched 31 chicks from 28 rafts, representing 25% of the total number of chicks hatched in New Hampshire. Raft-hatched chicks comprised 42% of chicks in 1998 when record rainfall flooded over half of the established natural nests.

Outreach Program

LPC's educational initiatives are management efforts intended to educate the public on the status of New Hampshire's loons and human activities that can be detrimental to reproductive success. Field biologists present programs on loon natural history, post educational signs and posters at public areas, and distribute literature about loons and LPC's efforts in support of loons throughout the state. Informal education of lake users through personal contact with biologists, members and volunteers is encouraged.

Lead Sinkers and Monofilament

Ingestion of lead fishing sinkers and jigs and subsequent lead poisoning is by far the largest single cause of adult loon mortality in New Hampshire (refs). Educating anglers and the public about the effects of lead poisoning and monofilament entanglement on loons is a top priority of LPC. In addition to its Lead Education Initiative, LPC presented its cooperative research findings and facilitated informed discussion of this issue during its testimony in support of House Bill 1196, a bill to restrict the use of lead fishing sinkers and lead-headed jigs in New Hampshire in 1997-98. Effective January 1st of 2000, New Hampshire banned the use of lead fishing weights weighing less than an ounce and lead-headed jigs under one inch in length on lakes and ponds throughout the state.

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NEW YORK REPORT

NINA SCHOCH, NY DEPT. ENVIRONMENTAL CONSERVATION

The Northeast Loon Study Workgroup (NELSWG) is a consortium of organizations interested in contaminant research in loons and other piscivorous (fish-eating) animals. Members include Tufts University School of Veterinary Medicine, US Fish and Wildlife Service, the Loon Preservation

Committee of New Hampshire, the BioDiversity Research Institute, and the New York State Department of Environmental Conservation amongst others. Research on contaminants in piscivores has been on-going for almost a decade throughout the northern United States and Canada. Piscivores are good indicators of toxins in the aquatic environment since they are at the top of the aquatic food chain and bioaccumulate toxic chemicals, such as mercury, heavy metals, and organochlorines.

Research by NELSWG members is expanding to look at mercury levels in loons on their wintering water bodies, and to determine mercury and other contaminant levels in other piscivorous species, including mergansers, kingfishers, cormorants, mink, and otters. The results of these research efforts will provide for more defined management of waterbodies and populations of piscivorous animals, as well as to further promote more stringent regulation of airborne contaminants.

In New York, blood and feather samples were collected from 62 Common Loons on 31 Adirondack lakes during the summers of 1998 and 1999. Forty of the loons were adults and 22 were immature birds of the year. Eight immature birds were too young to be banded, but both color and aluminum federal bands were placed on the other 54 loons for future recognition. Preliminary results indicate that the blood mercury levels in these birds are lower than in loons in other northeastern states. Further data analysis will provide a better understanding of the level of mercury contamination in loons in the Adirondacks.

VERMONT REPORT

ERIC HANSON, VERMONT INSTITUTE OF NATURAL SCIENCE

The Vermont Institute of Natural Science (VINS) and the Nongame and Natural Heritage Program (NNHP) of the Vermont Fish and Wildlife Department (VFWD) continued their statewide monitoring and management program for the Common Loon (*Gavia immer*) for the 23rd year. Vermont's breeding loon population reached a record high of 33 nesting pairs in 1999. The Common Loon was designated a state endangered species in 1987 after documenting low breeding success in the early 1980s. Vermont's breeding loon population gradually increased from 1984-1989, stabilized during the early 1990s at 13-16 nesting pairs annually, and increased substantially over the past 5 years. Of the 33 pairs that attempted nesting in 1999, 25 successfully hatched 41 eggs, with 35 chicks surviving through August. These represented the highest number of nests, eggs hatched, and fledglings since record-keeping began in 1978. A total of 10 nest failures were documented in 1999, including 2 re-nesting attempts. Two abandoned nests may be attributable to human disturbance. Visiting adult loons, flooding, and predation of the eggs may have caused the other nest abandonments. The causes of mortality of 4fourchicks are unknown, but these deaths occurred within 2-3 weeks of hatching when chick mortality rates are highest. A fifth chick died as a result of injuries from harassment (see below). In October, a 14 week old chick was found dead on Zack Woods Pond. On July 17, over 240 volunteers surveyed 148 lakes as part of the Loonwatch program, an annual statewide loon count. Assessing the same group of 100 lakes surveyed over the past several years, volunteers counted 112 adults, 6 subadults, and 35 chicks, an increase from 79 adults in 1996, 99 adults in 1997, and 104 adults in 1998.

Education and Management Efforts:

For the first time, the VLRP conducted training sessions for Loonwatch volunteers and distributed educational materials at three county fairs. Management efforts included enhancement of loon nesting habitat through the placement of artificial nesting platforms and sign buoys to reduce human disturbance. In 1999, 13 of the 33 breeding pairs nested on nesting platforms. Four of these pairs nested for the first time in at least the past 15 years. Hydroelectric companies and other regulatory agencies continued their efforts to stabilize water levels during the nesting period. A sinker exchange program and an educational campaign about the dangers of lead sinkers and jigs was conducted through a cooperative effort with the National Wildlife Federation, Silvio Conte National Wildlife Refuge, VFWD, VINS, Vermont Audubon, and U.S. Fish and Wildlife Service. Volunteers and lake residents were more involved in monitoring breeding and territorial lakes and educating people about appropriate boating behavior when near nest sites and loon families. VFWD game wardens and biologists and Vermont State Park personnel also provided much assistance to the VLRP.

Threats to Loons

Fishing gear and the actions of people continue to be sources of mortality of Vermont's loons. Lakeshore owners and volunteers reported several cases of harassment of loons this year, two of which caused the deaths of a breeding adult and a chick. A breeding adult was shot on Long Pond in Westmore, and a chick was purposely snagged with a fish hook on Coles Pond in Walden. Concerned citizens and VFWD game wardens contributed greatly in stopping and reducing harassment on several other ponds. The VLRP captured and released an adult loon entangled in monofilament fishing line on Seymour Lake. Lake residents' prompt reporting of the entangled loon allowed for a quick response while the bird was still healthy. Three adult loons died of various caused including injuries to a wing, pneumonia, and unknown causes. A loon chick on Green River Reservoir had fishing line and a lure wrapped loosely around the base of the bill. After several failed capture attempts, the chick freed itself from the fishing gear.

Mercury Research

For the second year in Vermont, loons on several lakes were captured, color-banded, and had blood and feather samples taken for mercury contaminant analysis. Abandoned eggs were also sampled for mercury. *This research was part of a study assessing contaminants in the Common Loon population* throughout North America. From sampling efforts in 1998, mercury levels were low in loons captured on three ponds. However, mercury levels in eggs collected in 1997 and 1998 were high enough to potentially reduce survival of the eggs on four of 15 ponds. Breeding loons on these ponds will be carefully monitored in the future. This research is being conducted by researchers from BioDiversity Research Institute, the U.S. Fish and Wildlife Service, the U.S. Geological Survey, VINS, and VFWD.