The Squam Lake Loon Initiative

Progress Report to the Nuttall Ornithological Club
Charles Blake Fund

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Loon Preservation Committee

September 2010

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Background

In 2005, the Loon Preservation Committee (LPC) recorded a dramatic single-year decline of seven pairs of loons on Squam Lake (from 16 pairs in 2004 to nine pairs in 2005). This decline represented 44% of Squam's loon population, a drop unprecedented on Squam or any other large lake in LPC's 36-year history of monitoring loons in New Hampshire. It also brought Squam's loon population to its lowest level since LPC began to survey Squam Lake in 1975 (Figure 1).

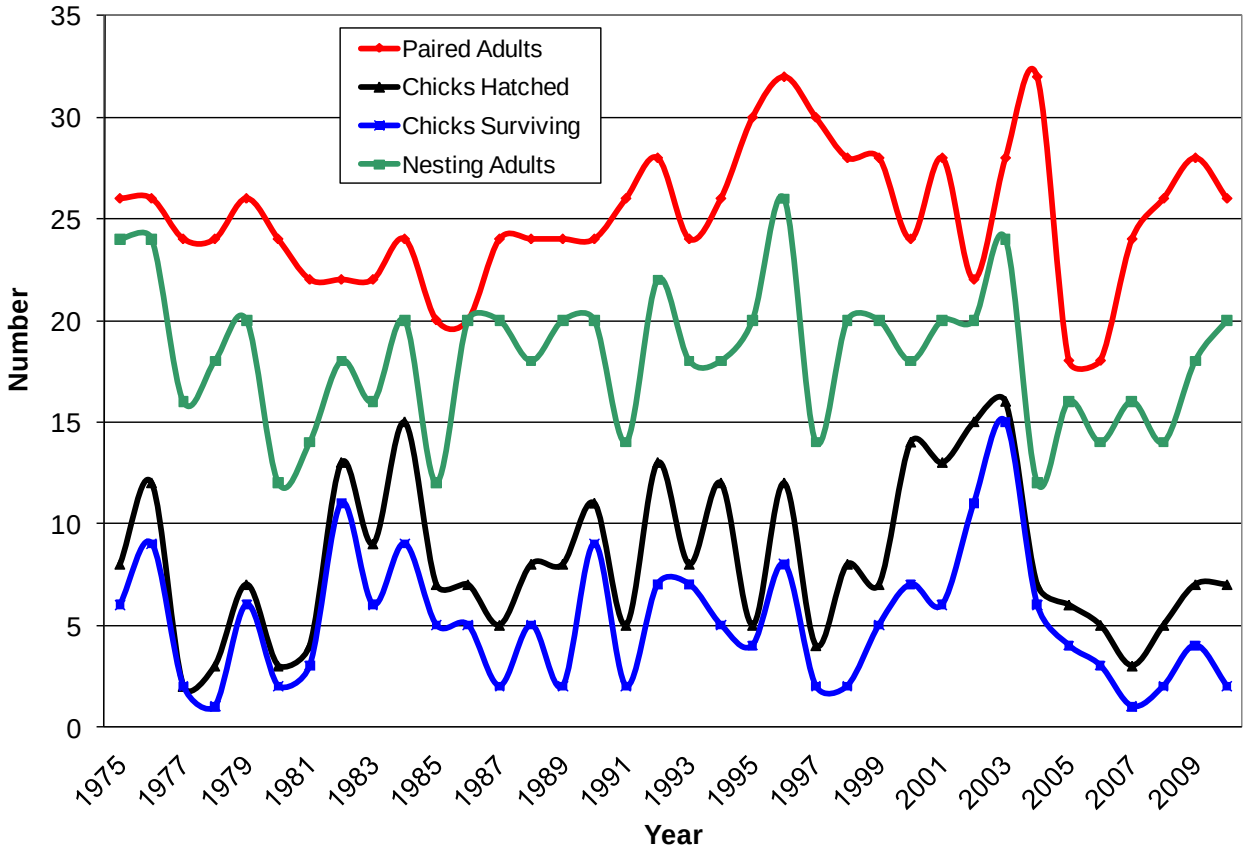

Figure 1: Loon Population of Squam Lake from 1975 to 2010.

The pattern of adult loon mortality between breeding seasons on Squam suggests two possible causes of this decline: (1) a water-based point source releasing contaminants (e.g., heavy metals or organochlorines) that are stored in fat or muscle tissue. These contaminants could be mobilized when tissues are metabolized during stress events like the fall feather molt and migration, and

therefore result in winter mortality; or (2) lake-specific pathogens (e.g. parasites, fungi, bacteria or viruses) that become acute during autumn stress events such as feather molt and migration, and result in winter mortality. Nearby lakes did not experience similar declines, and the localized nature of the decline makes it unlikely that the causes are ocean contaminants or pathogens.

In 2007, LPC recorded three new pairs of loons on the lake after two years of record low loon populations. However, this welcome news was tempered by the near-complete reproductive failure of the loon population. Only three chicks were hatched on Squam Lake, and only one survived to late August and was presumed to have fledged. Loons on Squam have not experienced a reproductive failure of this magnitude since 1978, the year LPC petitioned, successfully, to have loons added to the Threatened Species list in New Hampshire. Breeding success of loons on Squam has remained too low to maintain a stable population (Grear *et al*. 2009), with an average of only 2.7 surviving chicks between 2008 and 2010 (Figure 2).

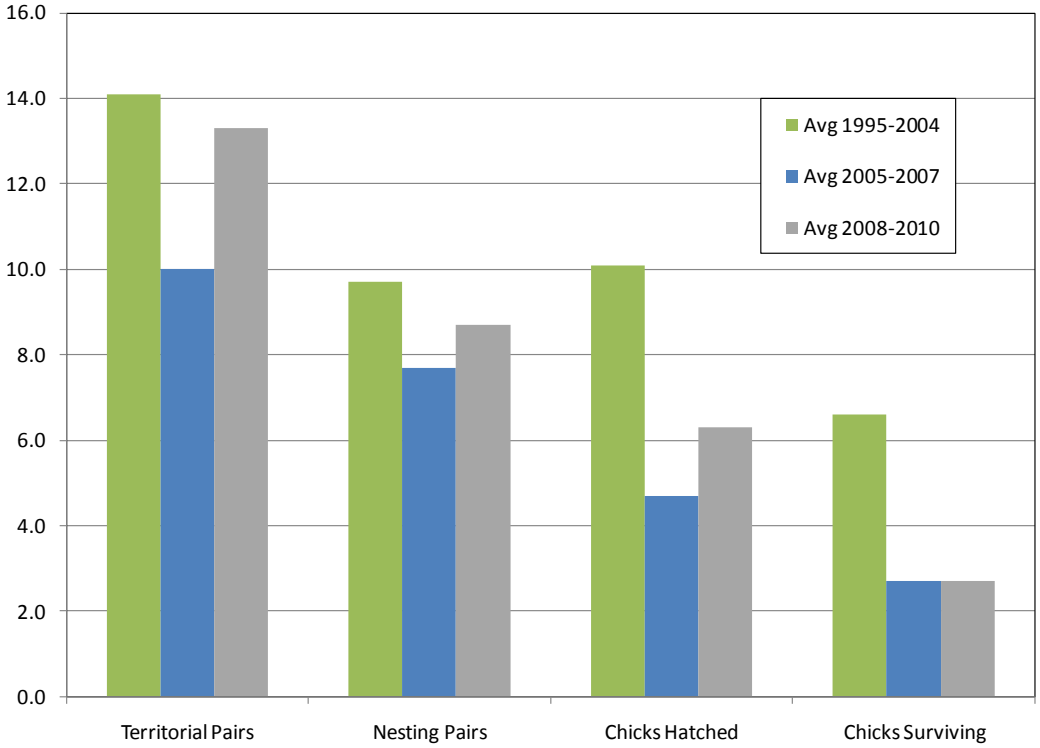

Figure 2: Loon populations and breeding success on Squam Lake before, during and after the 2005-2007 period.

Increased human use of Squam Lake, and the establishment of eagles on the lake, might contribute to lowered breeding success of Squam's loons. However, there is no known mechanism to link either of these factors with the large-scale die-off of adult loons between breeding seasons. Since loons are recognized as indicators of the health of aquatic ecosystems, the decline of Squam's loons could mark a serious environmental problem on the lake. Squam residents and visitors use the lake for recreation and for fishing; therefore, the decline indicates a potential human health concern on Squam as well. Residents have reported changes in fish populations on Squam, including a decline in yellow perch and an increase in smallmouth bass. Food web changes such as these can

significantly alter the biomagnification of contaminants in aquatic food webs, and introduce new pathogens into lake ecosystems.

The Squam Lake Loon Initiative

The *Squam Lake Loon Initiative* begun in 2007 is an increased monitoring, research, management and outreach effort to: **1.** Determine the overall survival and reproductive success of Squam's remaining loon population; **2.** Assess causes of nest failure and collect inviable eggs from failed nests for analysis of a wide range of contaminants and pathogens; **3.** Rescue sick or injured loons to increase loon survival whenever possible; **4.** Find and collect loon carcasses, determine causes of death, and test liver samples from dead loons for contaminants and pathogens; **5.** Band loons to allow us to identify and track individual birds and collect blood and feather samples for analysis; **6.** Determine survival and breeding success of previously banded and sampled loons, and relate survival and breeding success of individuals to their levels of contaminants and pathogens; **7.** Incorporate results into a systems dynamics model to determine the relative contributions of a wide range of possible stressors on the mortality and reproductive failure of loons on Squam Lake; and **8.** Restore and maintain a healthy and stable population of loons on Squam Lake as a component of a healthy state-wide population of loons.

Population Monitoring

LPC biologists monitored loons on Squam Lake and Little Squam Lake throughout the 2007-2010 breeding seasons. The regular season for these field surveys was extended from 12 to 14 weeks and supplemented with periodic fall surveys to look for early- and late-season loon mortality and chick survival. An annual volunteer loon census event in late July provided an additional estimate for adult and loon chick presence and abundance, and LPC staff and volunteers conducted five intensive sweeps of Squam Lake to supplement regular monitoring and estimate the total number of adult loons (breeding and non-breeding) present on the lake.

In 2010, 13 territorial loon pairs were tallied on Big Squam Lake. Ten of those pairs nested, hatching seven chicks, with only two chicks surviving to fledge. These numbers continued the trend observed since 2007 on Squam: a gradual return to an adult population size approaching the long-term average but with low reproductive success. Nesting propensity was higher on Squam Lake in 2010 and nest success approached the long-term mean before 2005 (50% in 2010 versus 56% before 2005), but chick survivorship was very low (28% in 2010 versus a mean of 66% before 2005). Net productivity on Squam in 2010 was 0.15 chicks surviving per territorial pair (CS/TP), compared to a non-Squam statewide average in 2010 of approximately 0.47 CS/TP.

Management

Increased nest site and brooding area management in 2010 to improve Squam Lake loon reproductive success included providing eight floating nest platforms, nest signs and floatlines at nine of the ten nest sites, and chick warning signs in brooding areas. These were accompanied by outreach to the public through slideshows and talks at Squam Lake organizations (e.g. Rockywold Deephaven Camps) and weekly boat tours for the public in conjunction with the Squam Lakes Natural Science Center. Also in 2010, LPC field biologist Tiffany Grade began field work for her

University of Wisconsin-Madison graduate research on human recreation and loon brooding and foraging behavior on Squam Lake.

Contaminants Testing

In March and April of 2010, contaminants data for loon eggs collected from 2001-2008 were compiled and analyzed. This analysis included 12 eggs from Squam Lake and 18 eggs from reference lakes, drawing on companion datasets from Maine and New York (BioDiversity Research Institute, unpublished). Testing covered a wide range of contaminants, with over 350 different analytes and over 4,700 records in the compiled database. Eggs collected from Squam between 2005 and 2007 revealed high levels of a number of contaminants, including PBDE (flame retardants), PFOS (stain guards), PCB (industrial insulating/cooling agents), and chlordane (a pesticide). For these classes of compounds, we compared loon egg contaminant levels between Squam Lake and reference lakes, and between Squam eggs collected from 2005-2007, and before and after that period. Geometric mean concentrations were compared between each category with Wilcoxon rank-sum tests, after treating non-detect data using the Kaplan-Meir estimator provided by Helsel (2005).

Our analyses showed that levels of some contaminants in eggs collected during the initial decline and reproductive failure of loons (2005-2007) were significantly ($P<0.05$) higher than levels in Squam Lake loon eggs collected before or after this period, and significantly ($P<0.05$) higher than levels found in eggs collected from other lakes (Figures 3,4,5).

Other contaminants including DDT, PFOS and strontium were also present in generally higher levels in Squam loon eggs collected during the 2005-2007 period than in eggs collected before or after this period, or in eggs collected on reference lakes (Figures 6,7,8). However, differences were not statistically significant or only marginally significant. Larger sample sizes of eggs might have revealed statistically significant differences in levels of these contaminants as well.

The effects on loons of these contaminants, and especially combinations of contaminants, are not known. However, some of these contaminants were present in loon eggs collected from 2005 to 2007 at levels that have been shown to affect the physiology, health and/or reproductive success of other species (e.g., Woodford *et al.* 1998) (Figure 9), and some contaminants were present in Squam Lake eggs at levels that were many times greater than in eggs from other lakes.

From 2007-2010, LPC tested three liver samples from loons collected on Squam Lake and three samples from loons on other lakes for the same set of contaminants tested in eggs. Levels of some contaminants were high in livers from both Squam Lake loons and other loons; however, results were highly variable, due in part to differences in sex, age, body condition, and time of year collected. We found that eggs provided a more useful sample because of the relative uniformity and comparability of samples.

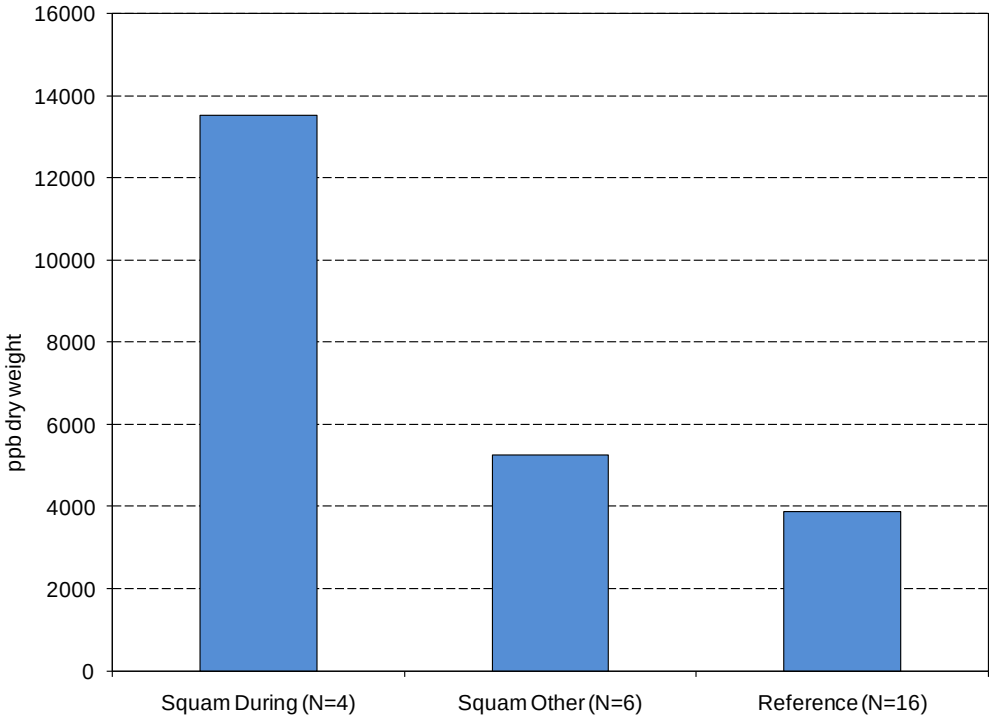

Figure 3: Levels of PCB in loon eggs collected on Squam Lake during the decline, outside of the decline, and from reference lakes.

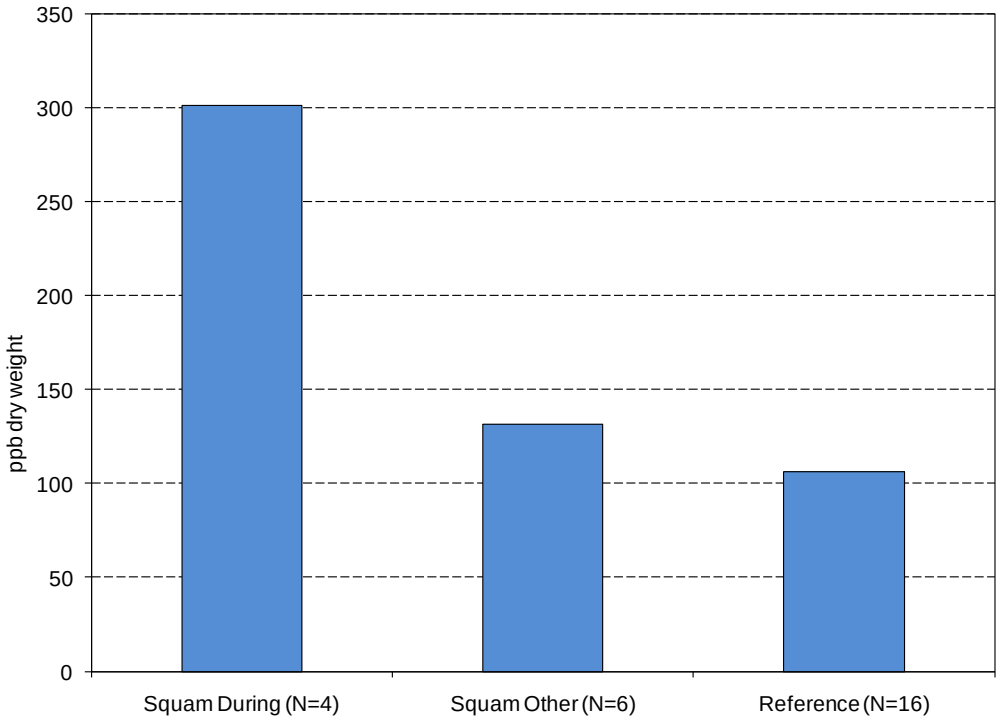

Figure 4: Levels of Chlordane in loon eggs collected on Squam Lake during the decline, outside of the decline, and from reference lakes.

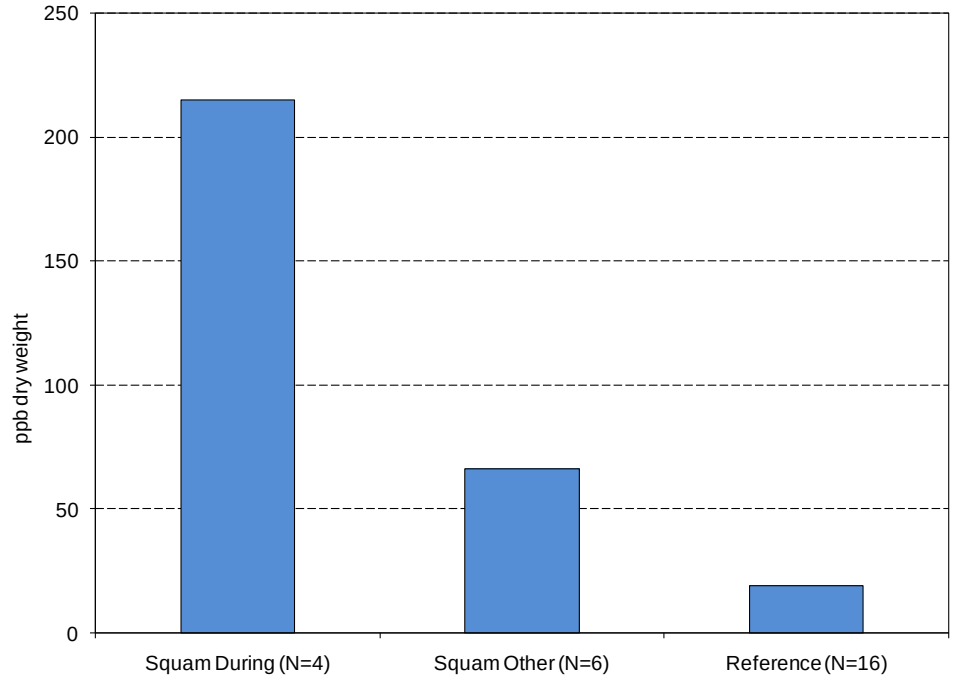

Figure 5: Levels of PBDE-99 in loon eggs collected on Squam Lake during the decline, outside of the decline, and from reference lakes.

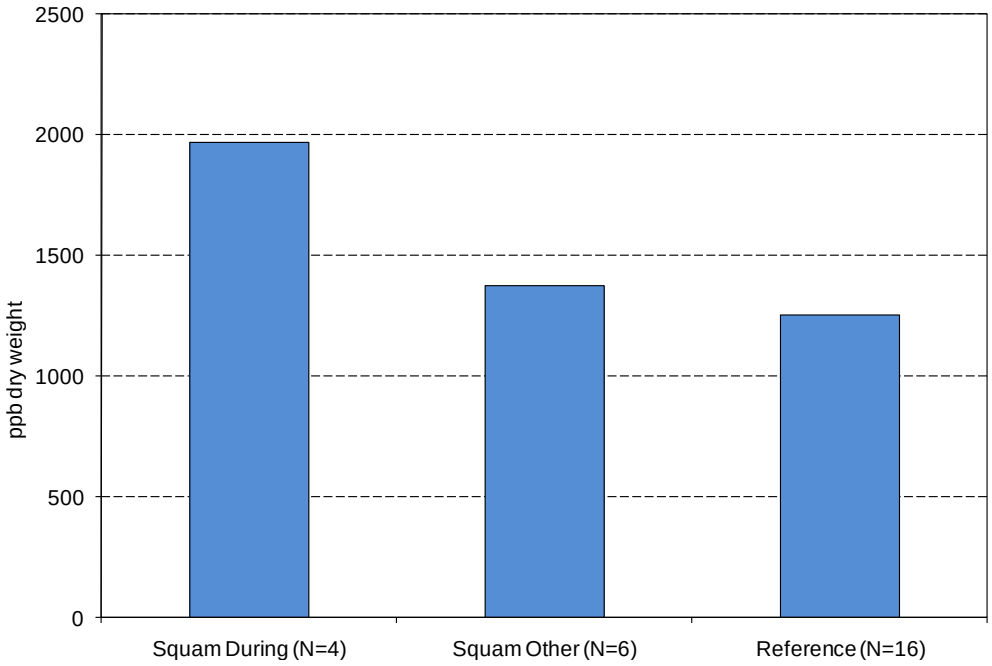

Figure 6: Levels of DDT in loon eggs collected on Squam Lake during the decline, outside of the decline, and from reference lakes.

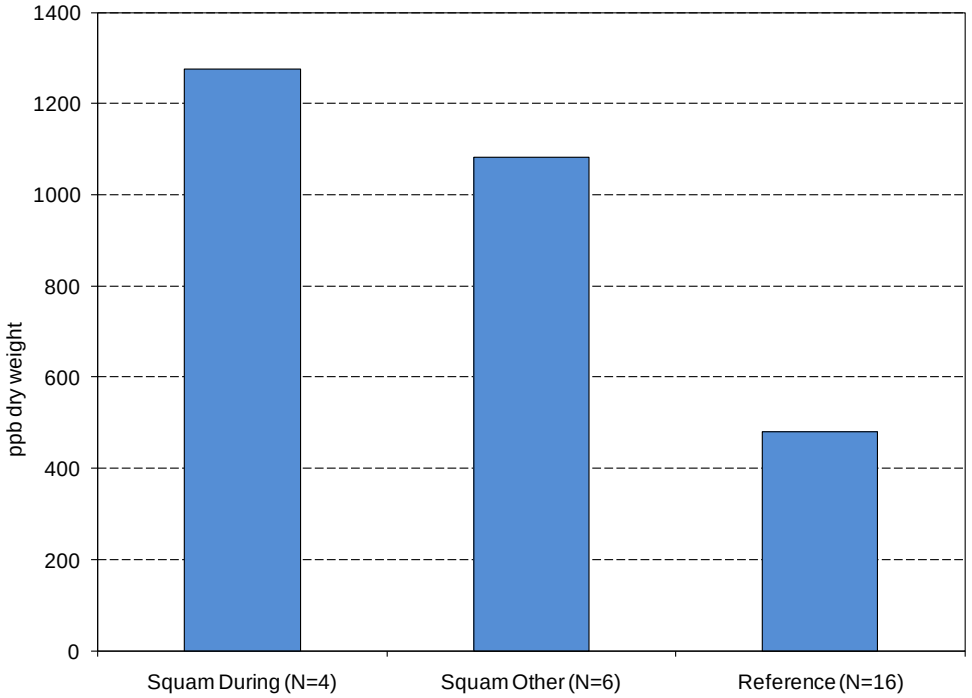

Figure 7: Levels of PFOS in loon eggs collected on Squam Lake during the decline, outside of the decline, and from reference lakes.

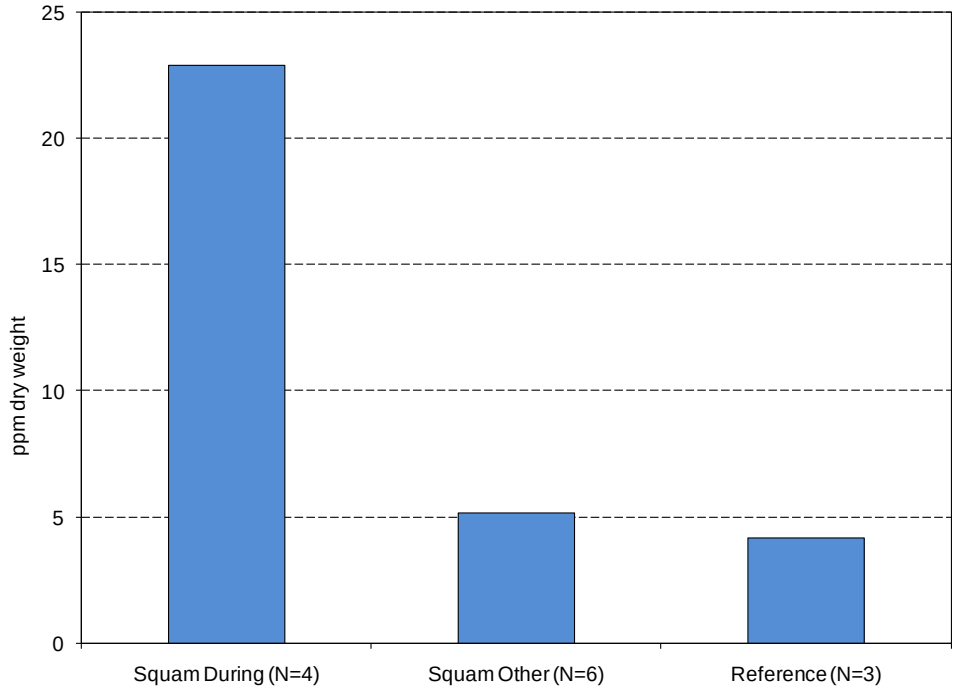

Figure 8: Levels of strontium in loon eggs collected on Squam Lake during the decline, outside of the decline, and from reference lakes.

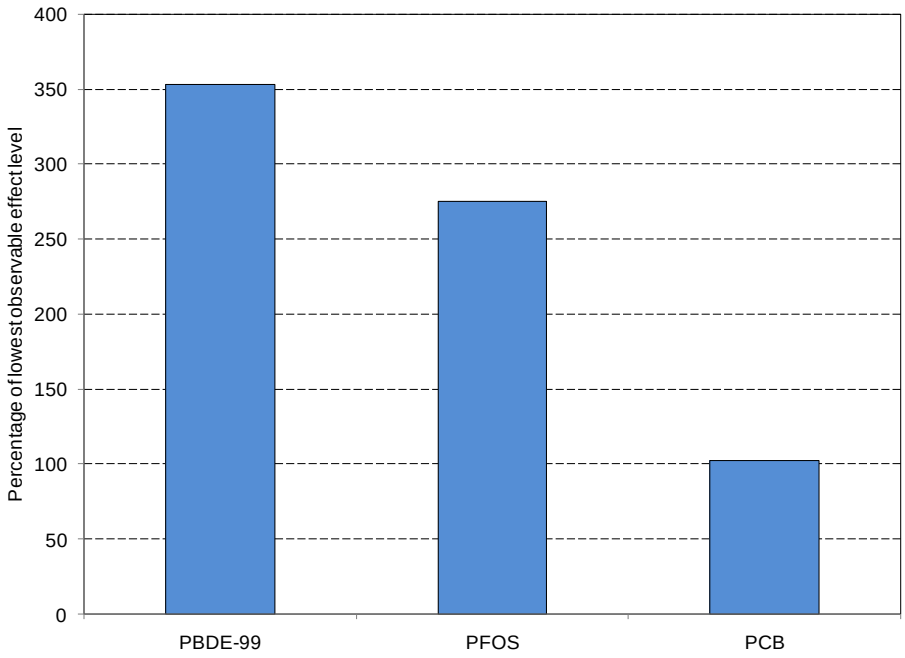

Figure 9: Levels of contaminants in Squam Lake loon eggs collected from 2005 to 2007 as a percentage of the lowest observable effects level (LOEL) recorded for other species.

Causes of Mortality

Two adult loon mortalities were recorded to date on Squam Lake in 2010, one caused by a boat collision and the other from ingested lead fishing tackle. These causes were consistent with findings from necropsies and pathology testing for seven other adult loons found between 2004 and 2007 and examined at Tufts University School of Veterinary Medicine and the University of New Hampshire (Figure 10). Necropsies did not reveal excessive parasite burdens or identify other pathogens that might have contributed to the declines on Squam, but the state of decomposition of many carcasses limited our ability to detect these pathogens.

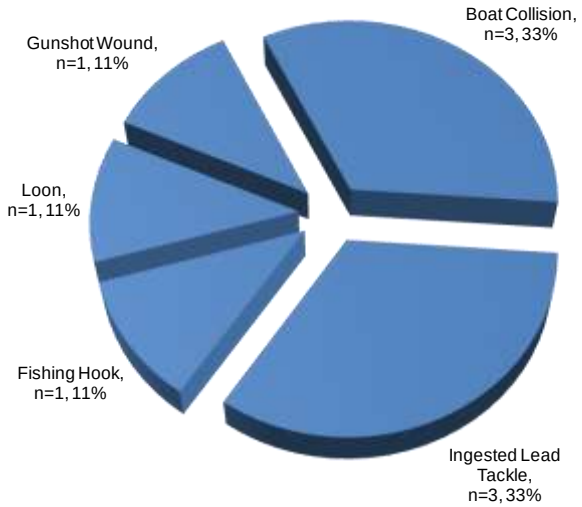

Figure 10: Causes of death of nine adult loons collected from Squam Lake, 2004-2010.

Capture and Banding

In 2010 during four nights of capture work, we captured and banded four unbanded loons on Squam Lake and recaptured five loons banded in previous years. This total was an increase over the 5-6 loons captured in each of the previous three years, and brought the number of confirmed (resighted or newly banded) marked loons on Squam to over 20, or more than two-thirds of the breeding population.

Health Testing

Working in collaboration with Tufts Veterinary School, North Sandwich Animal Hospital and Plymouth Animal Hospital, complete blood counts (CBC), serum chemistry tests and blood parasite scans were performed on blood samples collected during 2010 capture and banding work. Results were compared with an earlier round of blood chemistry profiles from Squam Lake in 2008. Notably, heterophil/lymphocyte (H/L) ratios were dramatically higher in 2010, indicating a higher level of chronic stress in loons sampled this year. Hotter weather during the 2010 breeding season is one possible explanation for this shift, since H/L ratios have been shown to indicate heat stress (among other stressors) in domestic poultry (Post *et al.* 2003). As in 2008, when there were positive results for fungal infection and avian influenza in two Squam loons, 2010 blood chemistry profiles also identified potential problems. Two loons presented elevated bile acids, an indicator of liver dysfunction and another loon showed signs of blood loss anemia, possibly from a conspecific injury. A fourth loon had high blood lead levels and was later recovered in a moribund state, radiographed to confirm the presence of lead fishing tackle, and euthanized. The 2010 round of blood work continued the development of baseline parameters for loon blood chemistry in the wild (cf. Haefele *et al.* 2005), and refined our capacity to use these tests as immediate health assessments and to pinpoint specific chronic problems and stressors.

Fish Testing

In conjunction with the New England Field Office of the United States Fish and Wildlife Service, and the New Hampshire Department of Fish and Game, LPC staff captured a number of yellow perch and small-mouthed bass from Squam Lake and from Lake Winnisquam in 2009 to determine concentrations of a subset of contaminants in fish species preyed on by loons. These samples are being analyzed to help determine possible sources of contaminants being observed in loons on Squam Lake. Future sampling to identify possible sources of contaminants may include invertebrates, water, and/or sediment samples.

The Squam Lake Systems Dynamics Model

LPC is working with Lori Siegel of Siegel Environmental Dynamics to integrate results of all of the above analyses into a systems dynamics model to better understand recent changes in Squam's loon population (see Figure 11). This model seeks to gain insight into whether any given stressor is enough to drive the population decline or, as might be expected in such a complex system, is enough to compromise the integrity of loons such that, in concert with other stressors, it threatens the population. In elucidating these stressors the model will help LPC and others make more informed decisions to protect Squam's loons and the ecological integrity of Squam Lake.

Data gaps, including a lack of quantifiable data on populations of prey fish and populations of many egg and chick predators, have resulted in much uncertainty in the estimates of many relationships within the model. However, simulations suggest several possible causes of the recent declines in adult loons and reproductive success of loons on Squam. These include contaminant levels in eggs; increasing temperature trends that could potentially result in changes in human use of lakes, incubation, and increased egg predation and cyanobacteria concentrations; low- and high-powered boating; and fish integrity.

The structure of the systems dynamics model is established and will be updated with new data collected in 2010. The functional relationships driving the model are still preliminary, and definitive statements regarding causes of the loon decline and how to better manage loons and Squam Lake to prevent future declines are not yet possible. However, the flexibility of the model permits incorporation of new data and relationships as they become available, and the current state of the model reveals interrelationships of factors and identifies probable contributors to the decline.

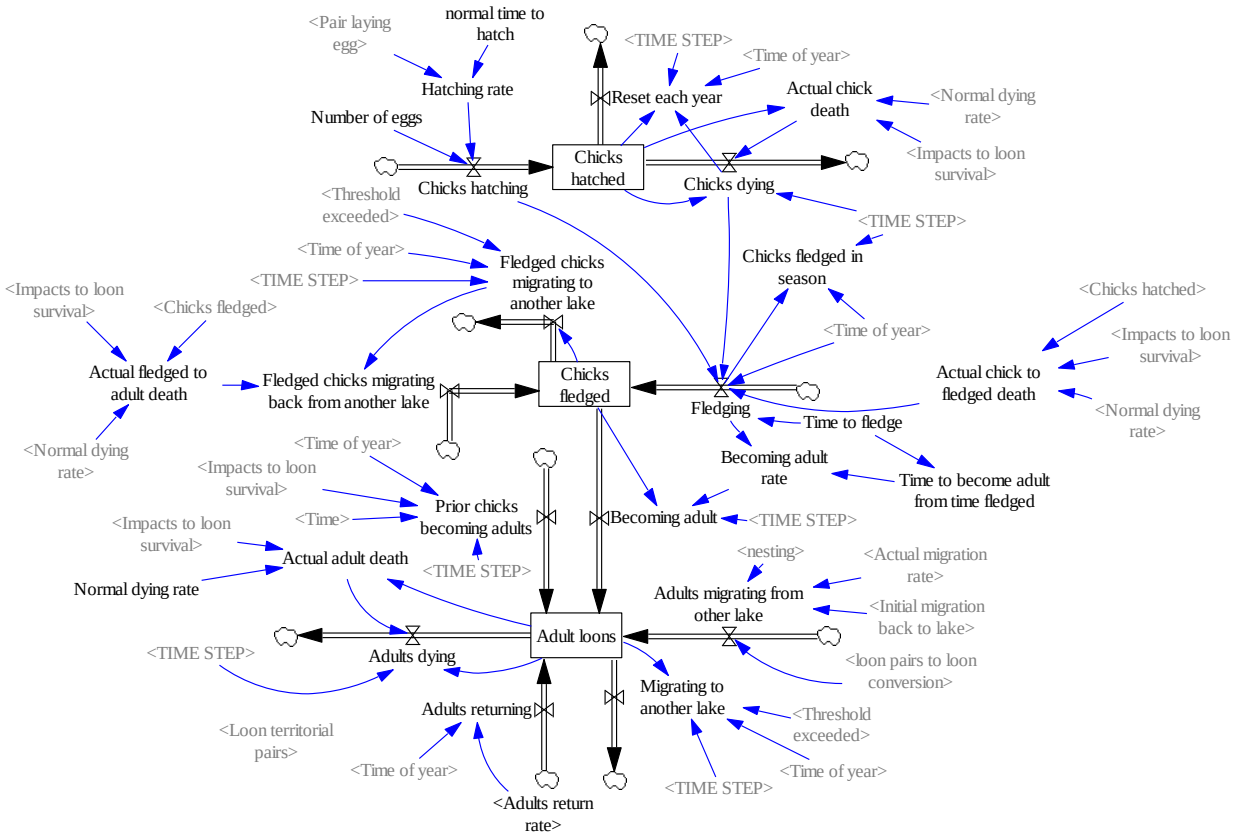

Figure 11: Graphical representation of a small part of the Squam Lake Loon Systems Dynamics Computer Model.

Next Steps

The Squam Lake Loon Study has already provided critical baseline data on contaminants and other environmental stressors on loons which will be invaluable to assess changes in, and effects of, contaminants and pathogens in the future. The collaboration of researchers formed as a result of the decline of loons on Squam Lake is unprecedented, and the testing being done on loon samples is the most comprehensive undertaken anywhere to date. The achievement of the *Squam Lake Loon Initiative* objectives (see page 3) will result in an accurate record of loon populations and productivity on Squam Lake in 2010 and future years, including causes of nest failures; the quick response to sick or injured loons to increase chances of survival of these loons; an increased number of banded and sampled loons on Squam to increase our knowledge of the survival and breeding success of known individuals, and the relationship of survival and breeding success with contaminant burdens; a refined systems dynamics model to elucidate the effects of multiple co-occurring stressors on the survival and breeding success of loons; and management and outreach sufficient to recover and maintain the Squam Lake loon population. We anticipate that this initiative will help avoid future declines of loons on Squam and on other lakes; bring to light what could be a systemic problem on Squam indicated by the decline of loons; inform other LPC initiatives such as the New Hampshire Loon Recovery Plan; and help LPC and others make more informed decisions to protect Squam's loons, other wildlife, and the ecological integrity of Squam Lake.

Squam Lake will continue to play a leading role in advancing our understanding of loons and their challenges in New Hampshire. Determining the causes of the declines of loons on Squam Lake is the first step in reversing these declines and protecting Squam's loons. Funds raised to support LPC's continuing work on Squam will help LPC to continue to extend its field seasons on Squam; test additional samples to increase our understanding of the role of contaminants in loon mortality and reproductive failure, and track changes in contaminants levels over time; educate lake users to encourage a culture of respect and appreciation for loons; and manage Squam's loons to recover a healthy population of loons on the lake.

Acknowledgements

The *Squam Lakes Loon Initiative* has been funded through foundation grants including the Charles Blake Fund of the Nuttall Ornithological Club, the Squam Environmental Preservation Fund, and the Robert Earl McConnell Foundation; through donations of concerned Squam Lake residents and visitors; through pledges to the Squam Lake Swim; and from Loon Preservation Committee operating funds.

The United States Fish and Wildlife Service funded laboratory costs associated with the analysis of four loon eggs and the capture and testing of fish samples from Squam Lake and a control lake, Winnisquam Lake. The BioDiversity Research Institute provided in-kind services to assist with loon banding, and the Tufts University Cummings School of Veterinary Medicine School provided in-kind services and materials to necropsy loon carcasses and test loon blood and tissue samples.

Financial Report

The Nuttall Ornithological Club Charles Blake Fund awarded LPC $2,000 for the Squam Lake Loon Initiative in 2009. The majority of these funds ($1,641.50) were used to help fund LPC's Squam Lakes Biologist, Senior Biologist and Staff Biologist for an extended 14-week field season in 2010 to accomplish the monitoring, management, banding, collection of inviable loon eggs, and collection of loon carcasses summarized in this report ("Staff costs" in the proposal budget). Remaining funds ($358.50) were used to effect repairs on LPC's Boston Whaler boat motor to support LPC's work on Squam Lake ("Use of motorboat and field equipment" in the proposal budget).

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