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Author(s): Kevin P. Kenow, David Adams, Nina Schoch, David C. Evers, William Hanson, Dave Yates, Lucas Savoy, Timothy J. Fox, Andrew Major, Robert Kratt and John Ozard

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Migration Patterns and Wintering Range of Common Loons Breeding in the Northeastern United States

KEVIN P. KENOW[1,*], DAVID ADAMS[2], NINA SCHOCH[3], DAVID C. EVERS[4], WILLIAM HANSON[5], DAVE YATES[4], LUCAS SAVOY[4], TIMOTHY J. FOX[1], ANDREW MAJOR[6], ROBERT KRATT[1] AND JOHN OZARD[2]

[1]U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, WI, 54603, USA

[2]New York State Department of Environmental Conservation, Albany, NY, 12233, USA

[3]Wildlife Conservation Society's Adirondack Loon Conservation Program, Saranac Lake, NY, 12983, USA

[4]BioDiversity Research Institute, Gorham, ME, 04038, USA

[5]FPL Energy Maine Hydro, Lewiston, ME, 04240, USA

[6]U.S. Fish and Wildlife Service, Concord, NH, 03301, USA

[*]Corresponding author; E-mail: kkenow@usgs.gov

Abstract.—A study, using satellite telemetry, was conducted to determine the precise migration patterns and wintering locations of Common Loons (*Gavia immer*) breeding in the northeastern United States. Transmitters were implanted in 17 loons (16 adults and one juvenile) that were captured on breeding lakes in New York, New Hampshire, and Maine during the summers of 2003, 2004, and 2005. Transmitters from ten of the birds provided adequate location data to document movement to wintering areas. Most adult loons appeared to travel non-stop from breeding lakes, or neighboring lakes (within 15 km), to the Atlantic coast. Adult loons marked in New Hampshire and Maine wintered 152 to 239 km from breeding lakes, along the Maine coast. Adult loons marked in the Adirondack Park of New York wintered along the coasts of Massachusetts (414 km from breeding lake), Rhode Island (362 km), and southern New Jersey (527 km). Most of the loons remained relatively stationary throughout the winter, but the size of individual wintering areas of adult loons ranged from 43 to 1,159 km^2, based on a 95% fixed kernel utilization distribution probability. A juvenile bird from New York made a number of stops at lakes and reservoirs en route to Long Island Sound (325 km from breeding lake). Maximum functional life of transmitters was about 12 months, providing an opportunity to document spring migration movements as well. This work provides essential information for development and implementation of regional Common Loon conservation strategies in the Northeastern U.S. *Received May 20 2008, accepted 15 January 2009.*

Key words.—Common Loon, *Gavia immer*, migration, movements, radio-mark, satellite telemetry, wintering.

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The Common Loon (*Gavia immer*) breeds throughout the Northeastern United States (McIntrye and Barr 1997) where it is considered a species of management concern (Evers 2007) and listed as a Species of Special Concern in New York, Massachusetts and Connecticut, and as Threatened in New Hampshire. Current management of the species in the Northeast has focused on determining the status of breeding populations and assessing the impacts of contaminants on productivity (Evers *et al.* 2008). While several surveys have been undertaken to assess the abundance and distribution of breeding Common Loons in the Adirondack Park of New York (Arbib 1963; Trivelpiece *et al.* 1979; Parker and Miller 1988), New Hampshire (McCoy 1988; Fair 1990; Taylor and Vogel 2000), and Maine (Lee and Arbuckle 1988; Hitchcox 2000; Evers *et al.* 2008), timing and patterns of migration and wintering range of these breeding populations have not been adequately documented. Depending on where they stage during migration and winter, these populations may be at risk from exposure to ocean contaminants or spills, entanglement in fishing gear, offshore habitat disturbances, and/or outbreaks of Type E botulism (*Clostridium botulinum*) on the Great Lakes (Evers 2007). Unexplained Common Loon population declines in the Lake Umbagog region of Maine and New Hampshire may be the result of mortality during migration and/or winter (Evers *et al.* 2006).

To effectively plan for the long-term conservation of Common Loon populations in the Northeastern U.S., there is a need to determine where these birds occur during migration, winter and other non-breeding (e.g., sub-adult) periods. A collaborative region-wide satellite telemetry study was initiated to determine the precise migration patterns and wintering locations of representative birds from selected Northeastern populations.

METHODS

Common Loons were captured using night-lighting techniques (Evers 1993) in the summers of 2003, 2004, and 2005. Study sites included the Adirondack Park, New York, Lake Umbagog, New Hampshire/Maine, and three lakes on the Upper Kennebec River, Maine (Flagstaff, Moosehead, and Wyman Lakes). Satellite platform transmitter terminals (PTTs; model PTT-100, Microwave Telemetry, Inc., Columbia, Maryland and 2-part implantable PTT, Northstar Science and Technology, LLC, King George, Virginia; Use of trade or product names does not imply endorsement by the U.S. Government) were implanted subcutaneously on the backs of 17 loons (16 adults and one juvenile) following the surgical implant procedures described in Kenow *et al.* (2002). To configure the PTTs for subcutaneous implantation, transmitter components and battery were potted separately and connected by a wire. The transmitter component portion averaged 20.9 × 11.3 × 63.3 mm in size and the battery pack dimensions averaged 18.9 × 56.4 mm. The combined package had a volume of about 24 ml and mass of about 45 g (range = 43.5 to 47.5 g).

Surgical techniques and the 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). The surgical procedure was conducted in a portable laboratory and the time required to complete the implantation surgery averaged 12.6 min (range = 8 to 22 min). With induction of anesthesia, the entire procedure averaged 28 min (range = 19 to 48 min). After surgery, the loon was held in a container until demonstrating control of head and neck and an ability to assume an alert posture. Loons were released at the site of capture an average of 40 min (range = 11 to 64 min) following surgery. Each loon was also marked with an aluminum numbered U.S. Fish and Wildlife Service band and a unique combination of colored leg-bands to aid with field identification of individuals. When feasible, attempts were made to recapture radiomarked adults in subsequent breeding seasons to remove expired transmitters.

Behavior of radiomarked loons was periodically monitored during the 15 to 45 days following capture and PTT implantation to assess if behavioral abnormalities resulted from the marking technique. Individuals were observed intensively for multiple 1- to 4-hour periods. For the first week after PTT implantation, specific attention was paid to level of activity and interactions with mates, chicks, and other loons to determine if there were any behavioral changes associated with the PTT. We also monitored source territories and surrounding areas in subsequent breeding seasons for the return of radiomarked loons and to document mate and site fidelity, mate switching, and the reproductive status for each individual.

The transmitters were programmed to transmit on a variable schedule based on the anticipated stage of migration during the loon's annual cycle—8 hours on: 72 hours off during the breeding season, 8 hours on: 48 hours off while migrating, 6 to 8 hours on: 96 hours off on the wintering grounds, and 8 hours on: 48 hours off during spring migration and the subsequent breeding season. Transmitter signals were received by equipment on polar-orbiting National Oceanic and Atmospheric Administration Tiros-N weather satellites. Data were transferred to the Service Argos data processing center in Landover, Maryland, where locations were estimated from the Doppler shift in the transmitter's carrier frequency. Location estimates were acquired using Argos Standard Service Processing (Argos Location Classes [LC] 3, 2, 1, and 0) and Auxiliary Location Processing (service for wildlife researchers; LC A, B, and Z). One standard deviation of nominal accuracy for location estimates with LC 3, 2, 1, and 0 were <250, 250 to 500, 500 to 1,500, and >1,500 m, respectively (Service Argos 2008). No estimates of accuracy were provided for LC A, B, and Z locations and the feasibility of these locations must be user-determined. We selected one location per 8-hour transmission period for each individual to describe the location of that individual. This selection of the single "best" location per transmission period was premised on a superior Argos precision index, plausibility of location (e.g., land vs. water) or in the event of a tie, the location derived from the most received transmissions.

The bathymetric data used for analysis were obtained from U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Geophysical Data Center Coastal Relief Model (Divins and Metzger 2007). Volumes 1-3 of the Coastal Relief Model datasets were merged using ArcMap (Environmental Systems Research Institute, Inc., Redlands, California) to form a continuous relief dataset that stretched from Maine to Florida. Degree of slope was calculated from the relief data using ArcMap. Spot measurements of water depth and slope were determined for each loon location.

Distance to shore was calculated by creating a shoreline coverage and then measuring the Euclidean distance of each loon location to the shoreline. The shoreline coverage was created by reclassifying Coastal Relief Model bathymetry values of >0 to values of no data and values < = 0 to equal 1. The reclassified raster relief data were then converted to line coverage. The line coverage was edited to remove segments that were not shoreline but represented the eastern terminus of the relief data.

Winter ranges of individual loons were calculated using the minimum convex polygon, standard deviational ellipse of 2 deviations, and fixed kernel (Worton 1989) methods. Fixed kernel home ranges were calculated using the least square cross validation *ad hoc* calculation of a smoothing parameter (Silverman 1986). The 95% utilization distribution probability contour was used to define the kernel home range and 50% contour used to define core use areas. Summary statistics were calculated for the intersections of each home range with areas of water depth >0 (home range calculations do not include terrestrial areas).

The wintering distribution of loons radiomarked in the present telemetry study was compared to the distribution of band recoveries and re-observations of loons color-marked in a larger banding effort across the Northeastern U.S. During summers 1993 to 2007, adult and juvenile Common Loons were captured and banded in New York, New Hampshire, and Maine. All loons were marked with a combination of USFWS aluminum and one to three plastic color leg bands which allowed for remote identification of individuals.

RESULTS

Three adult and one juvenile Common Loon were captured and radiomarked during August 2003, eight transmitters were deployed during July 2004, and five birds were radiomarked during July 2005 (Table 1). We documented the movement of ten of the loons to wintering areas along the Atlantic Coast (Table 1, Figs. 1-3). Four of these loons provided us movement information on the subsequent spring migration. Four other radiomarked birds were found dead prior to or during migration, and transmitters on three additional birds failed before the loons left their breeding areas.

The behaviors of radiomarked birds were monitored following PTT implantation. Within the first few days of surgery, birds were observed preening the antenna, but thereafter adapted to the presence of the antenna. Three loons were subdued and lethargic for several days post-surgery however, most exhibited normal behavior within four to five days post surgery and three loons behaved normally (feeding/diving/stretching/back with mate and/or chicks) within 24 hrs after PTT implantation. Of four female loons radiomarked in New Hampshire and Maine, two decreased their brooding activities, and males for these respective pairs performed the majority of the chick rearing activities for the remainder of the summer (both chicks survived to fledging).

PTT Performance

We obtained 3,156 high quality locations (defined as Argos Location Class 1-3, accurate to <1,000 m) from a total of 6,995 location determinations (45%) from the 17 birds radiomarked (Table 2). The PTTs functioned for a total period of 25 to 363 days and the actual number of days for which location data were received ranged from 3 to 115. The average number of locations received per day for each unit varied from 3.4 to 10.3. About 91% of the accepted locations (used in movement analysis) were of location class LC1 or better.

Movements

Post-nesting Dispersal and Autumn Staging—Departure dates, from lakes on which they held breeding territories, were variable among the ten radiomarked Common Loons that provided migration data (Table 3; Figs. 1-3). Three loons (*2520, 42496* and *52463*) moved from breeding lakes in September to larger water bodies enroute to their wintering areas. Loon *21031* moved directly to its wintering area in early October 2004. The other six birds (*11030, 11031, 42470, 42463, 52468*, and juvenile *42464*) remained on or near breeding lakes into November before migrating to their wintering areas.

Migration to Wintering Grounds—The ten radiomarked adult Common Loons that provided migration data arrived at their wintering areas between 20 September and 25 November. Those loons marked in New Hampshire and Maine wintered off the Maine Coast, 152 to 239 km from breeding lakes. Adult loons marked in the Adirondack Park wintered along the coasts of Massachusetts (414 km from breeding lake), Rhode Island (362 km), and southern New Jersey (527 km). Evidence suggests that the birds traveled directly between breeding lakes/staging areas and coastal wintering sites, as they had completed migration within the 48 hours between consecutive transmission cycles (Figs. 1-3). We documented a brief (1-5 days) stopover of Loon *42463* off the south shore of Long Island, about 120 km north of its ultimate wintering area off the New Jersey coast near Atlantic City, New Jersey.

The single radiomarked juvenile loon (*42464*) made relatively short distance movements as it migrated from Nicks Lake, New York, stopping at several water bodies in New

Table 1. Transmitter identification, age, sex, mass, legband, and capture data for 17 Common Loons (*Gavia immer*), equipped with transmitters for satellite telemetry, in New Hampshire, Maine, and the Adirondack Park, New York, 2003-2005.

PTT No.	Age/sex	Mass (g) when radiomarked	Date radiomarked	Capture/release location	Capture/release coordinates
11030	Adult female	4,950	16 August 2003	Dead Cambridge territory, Lake Umbagog, Oxford County, ME	Lat 44.712N, Lon 71.049W
11031	Adult female	4,300	17 August 2003	Leonard Marsh territory, Lake Umbagog, Coos County, NH	Lat 44.813N Lon 71.045W
21031	Adult female	4,500	13 July 2004	North Branch territory, Flagstaff Lake, Franklin County, ME	Lat 45.198N, Lon 70.456W
2520	Adult female	4,675	15 July 2004	Three Island Cove territory, Lake Umbagog, Coos County, NH	Lat 44.770N, Lon 71.053W
42706	Adult male	6,500	25 July 2005	Houston Cove territory, Wyman Lake, Somerset County, ME	Lat 45.088N, Lon 69.933W
42707	Adult male	6,300	26 July 2005	East Outlet territory, Moosehead Lake, Piscataquis County, ME	Lat 45.588N, Lon 69.707W
57610	Adult female	5,400	26 July 2005	Yellow Camp territory, Wyman Lake, Somerset County, ME	Lat 45.092N, Lon 69.924W
42463	Adult male	5,554	20 August 2003	Beaver Lake, Lewis County, NY	Lat 43.874N, Lon 75.163W
42464	Juvenile unknown	3,525	21 August 2003	Nicks Lake, Herkimer County, NY	Lat 43.681N, Lon 74.992W
42465	Adult male	5,800	17 July 2004	Newton Falls Reservoir, St. Lawrence County, NY	Lat 44.223N, Lon 74.982W
42466	Adult female	4,200	17 July 2004	Upper St. Regis Lake, Franklin County, NY	Lat 44.412N, Lon 74.294W
42467	Adult male	5,650	18 July 2004	Spitfire Lake, Franklin County, NY	Lat 44.417N, Lon 74.273W
42468	Adult male	6,500	18 July 2004	Clear Pond, Franklin County, NY	Lat 44.592N, Lon 74.286W
42469	Adult female	4,700	18 July 2004	Lake Kushaqua, Franklin County, NY	Lat 44.521N, Lon 74.112W
42470	Adult female	4,300	19 July 2004	Little Clear Pond, Franklin County, NY	Lat 44.360N, Lon 74.284W
52463	Adult female	4,200	28 July 2005	Wolf Lake, Essex County, NY	Lat 44.019N, Lon 74.220W
52468	Adult female	5,100	29 July 2005	Little Clear Pond, Franklin County, NY	Lat 44.360N, Lon 74.284W

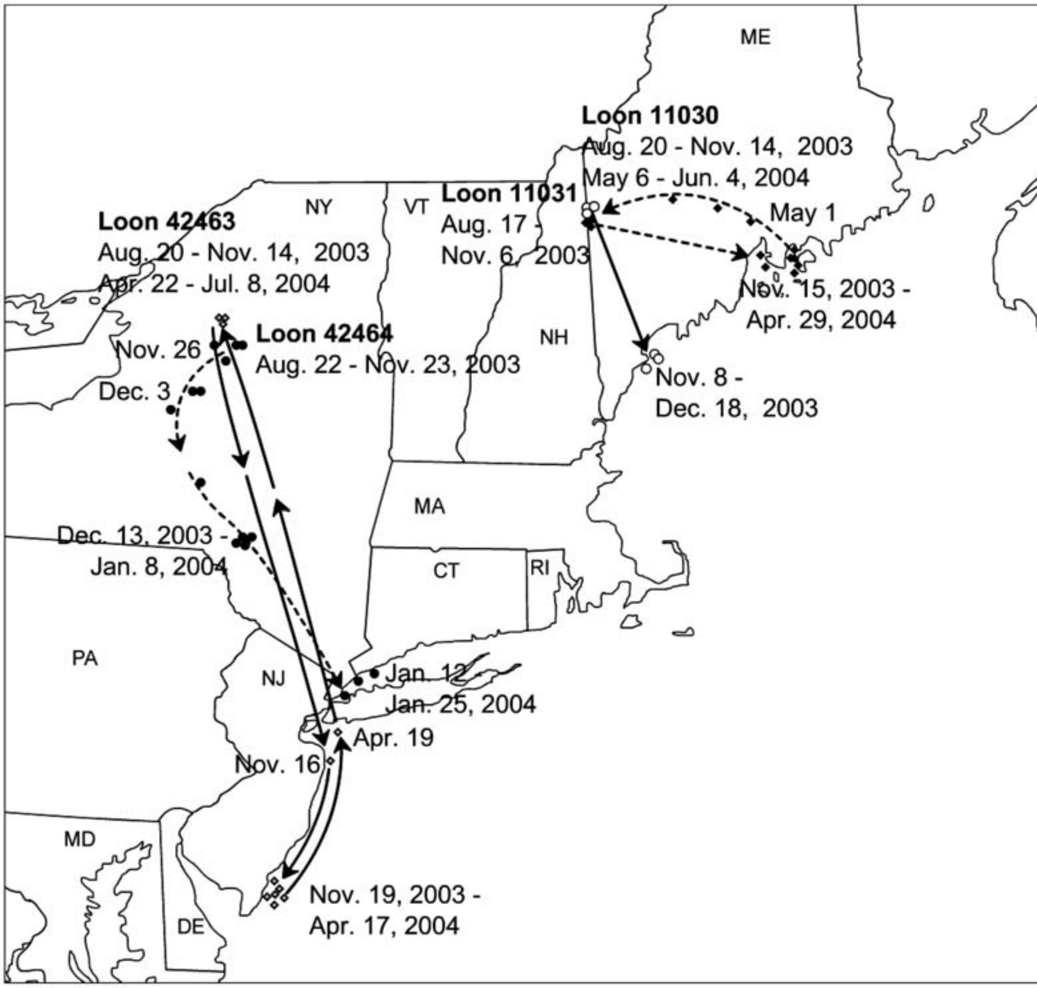

Figure 1. Movements of Common Loons (*Gavia immer*) radiomarked in summer 2003 on breeding territories in the northeastern United States.

York state before moving to Long Island Sound (Table 3; Fig. 1). Overall, this loon took about 51 days to reach its Atlantic Ocean wintering location in Long Island Sound after leaving its natal lake. Transmitter sensor data indicated that this bird died between 21 and 25 January 2004 in Long Island Sound. No carcass was recovered, and consequently, the death of the bird remains unconfirmed.

Wintering—Wintering areas of radiomarked loons in this study stretched along the Atlantic Coast from Maine to New Jersey. We collected substantial (individual bird tracked for >90-day period, >25 days with location data) wintering movement data on eight adult loons. Six of the eight loons remained in one contiguous area throughout the winter: Loon *11030* spent the winter off the Maine coast in Penobscot and Blue Hill Bay; *2520* wintered off the Maine coast in Muscongus Bay; *42463* spent the winter off the New Jersey coast near Atlantic City; *42470* wintered in Buzzards Bay, Massachusetts with the exception of a brief visit to Rhode Island Sound, *52463* wintered in Block Island Sound, Rhode Island; and *52468* wintered in Cape Cod and Plymouth Bays, Massachusetts. In contrast, Loon *21031* used multiple areas along a 95 km stretch of the Maine coastline during October through early January before the transmission signal

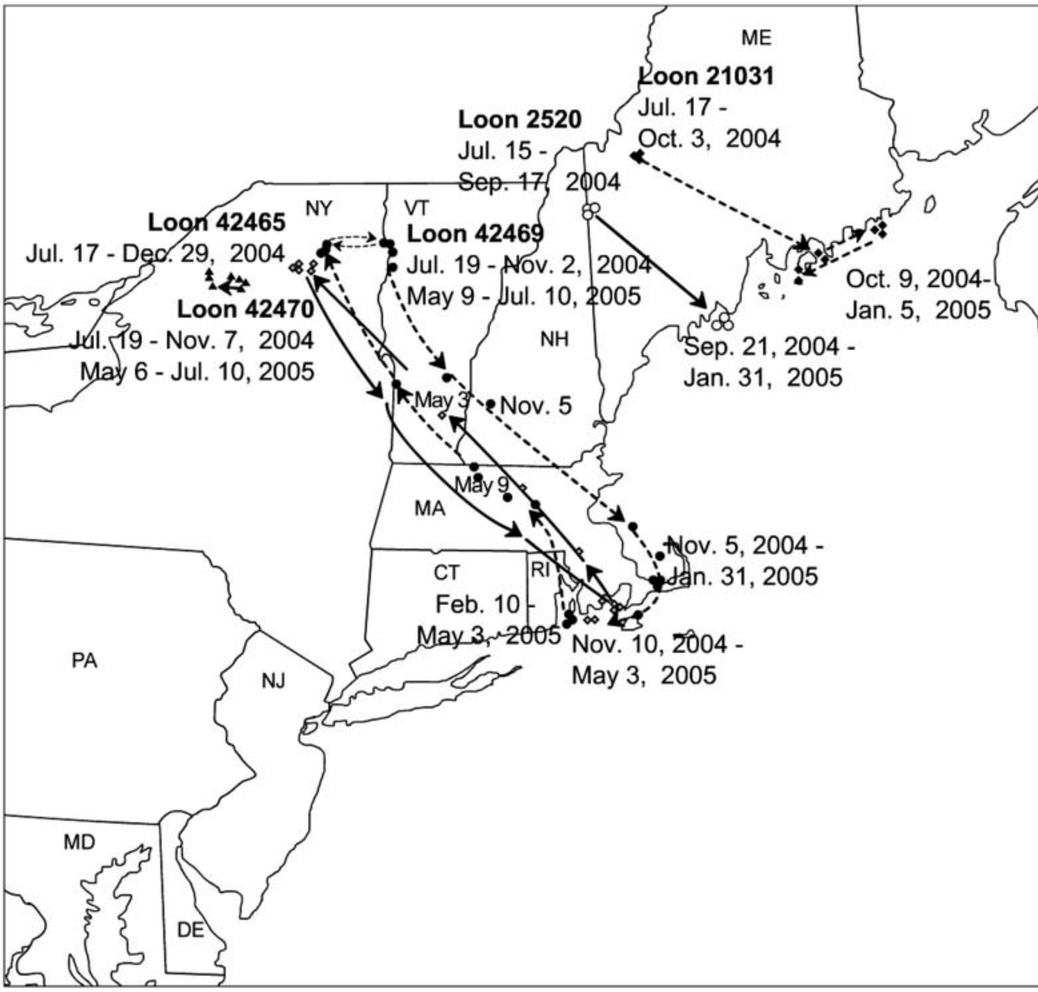

Figure 2. Movements of Common Loons (*Gavia immer*) radiomarked in summer 2004 on breeding territories in the northeastern United States.

was lost. After spending nearly 3 months in Cape Cod Bay, Loon *42469* moved 87 km to Narragansett Bay, Rhode Island in early February.

Most wintering locations (95%) were within 10.5 km of a coastal land mass (50% of locations were within 1.3 km), and the average distance to the nearest shore of these radiomaked loons varied from 0.4 to 8.1 km (Table 4). Ocean water depth at wintering locations averaged from 3.1 to 19.6 m and underlying ocean floor was generally fairly level, with a slope of less than 1% at 92% of the locations (Table 4). Winter range size of individual loons (excluding partial ranges of *21031* and *2520*), as determined using the minimum convex polygon method, averaged 344 km^2 (range = 2 to 1,122 km^2; Table 5). Winter range size determined using the fixed kernel 95% utilization distribution probability contour averaged 547 km^2 (range = 43 to 1,159 km^2) and core use-areas (50% fixed kernel contour) averaged 192 km^2 (range = 8 to 468 km^2; Table 5).

Spring Migration and Subsequent Breeding Seasons—We documented the return migration of four loons (*11030*, *42463, 42469*, and *42470*) to their breeding lakes during the subsequent spring (Figs. 1 and 2). Locations of female (*11030*) were recorded at three lakes across central Maine while returning to Lake Umbagog; evidence suggested the bird

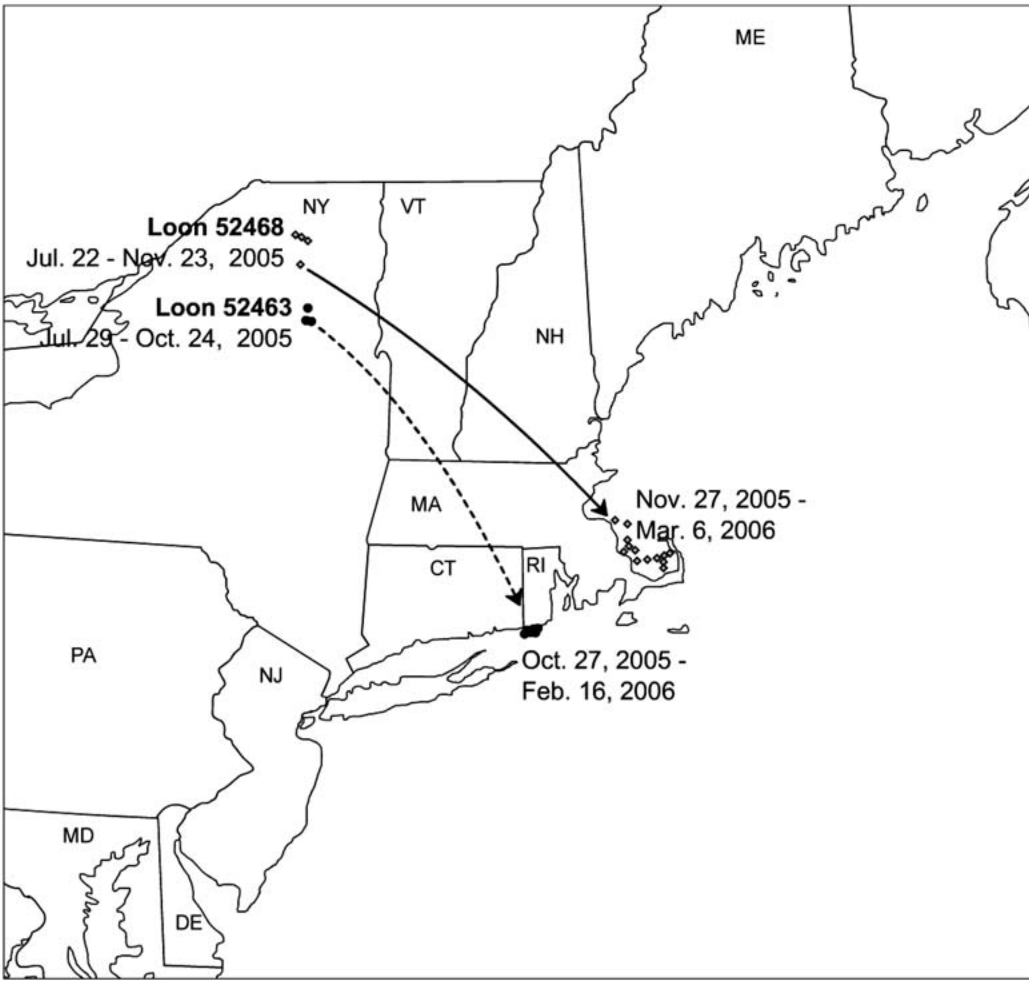

Figure 3. Movements of Common Loons (*Gavia immer*) radiomarked in summer 2005 on breeding territories in the northeastern United States.

made the journey in 3-5 days in 2004. Loon *11030* was observed in the same area she occupied the previous summer and remained on Lake Umbagog throughout the summer but was not part of a territorial loon pair. In 2005, Loon *11030* paired with an unbanded male in her original territory but a nest attempt was not documented. Loon *11030* was not observed on Lake Umbagog or surrounding lakes in 2006 or 2007.

Loon *42463* staged 8 km south off the coast of Rockaway Beach, New York on 19 April 2004, approximately 163 km north of its wintering area along the New Jersey coast, before returning inland. The staging took place near where this individual staged during fall migration. After departing the coast, this loon was at its breeding lake in the Adirondack Park with the next transmission cycle on 21 April. Loon *42463* nested successfully, was recaptured in July 2004, and the transmitter was removed. Following transmitter removal, this loon continued to raise a chick with its mate through summer and fall 2004 and has returned in subsequent years to the same territory on Beaver Lake.

Movements of two adult females that migrated in spring 2005 from coastal areas of Rhode Island (*42469*) and Massachusetts (*42470*) were documented during flight. Loon 42469 was located at a Massachusetts lake on 6 May and returned to its breeding

Table 2. Duration of tracking and distance to wintering areas for Common Loons (*Gavia immer*) radiomarked on breeding areas in New Hampshire, Maine, and the Adirondack Park, New York, 2003-2005.

PTT No.	Functioning period	Number days with locations	Distance from breeding area to wintering area (km)	
			Following course	Straight line
11030	16 Aug 03 to 30 June 04	105	172	172
11031	17 Aug 03 to 02 Dec 03	41	152	152
21031	13 Jul 04 to 08 Jan 05	55	256	239
2520	15 Jul 04 to 05 Feb 05	63	156	156
42706[a]	25 Jul 05 to 21 Aug 05	3	na	Na
42707[a]	26 Jul 05 to 01 Sep 05	7	na	Na
57610[a]	26 Jul 05 to 19 Aug 05	3	na	Na
42463	20 Aug 03 to 11 July 04	111	555	527
42464	22 Aug 03 to 25 Jan 04	57	446	325
42465[a]	17 Jul 04 to 29 Dec 04	41	na	Na
42466[a]	17 Jul 04 to 02 Nov 04	29	na	Na
42467[a]	18 Jul 04 to 21 Aug 04	13	na	Na
42468[a]	18 Jul 04 to 23 Aug 04	13	na	Na
42469	18 Jul 04 to 14 Jul 05	115	455	425
42470	19 Jul 04 to 17 Jul 05	114	434	424
52463	28 Jul 05 to 16 Feb 06	62	363	362
52468	29 Jul 05 to 06 Mar 06	66	414	414

[a]Migration to wintering area not documented due to transmitter performance problems or death of loon.

area near Lake Kushaqua, New York on 9 May. Loon *42469* was re-observed on Lake Kushaqua in summer 2006 and on a neighboring lake in 2007. Loon *42470* was documented leaving Buzzards Bay, Massachusetts on 3 May 2005 and was at her breeding lake (Green Pond, New York) during the subsequent transmission cycle on 5 May. The bird remained near Green Pond in May and June but then relocated about 3 km to Little Green Pond, New York in July. Loon *42470* was observed on Little Green Pond, New York, in summer 2005 and returned to Little Green Pond in 2006 and in 2007. Both birds were observed with other loons, presumably as members of territorial pairs. However, neither pair successfully raised chicks.

While we were not able to document the spring migration of Loons *2520*, *52463* and *52468*, because the batteries had expired prematurely on the PTTs in these birds, Loon *2520* was re-observed three consecutive years following radiomarking (observation period through 2007) on Lake Umbagog, New Hampshire, and was successful in pairing and defending her traditional territory each season. No nest attempts were documented in 2005 or 2006. Loon *2520* nested in 2007, however the eggs were predated and the pair did not attempt to re-nest. Loon *52463* was re-observed throughout summer 2006 on Goodnow Flowage, New York, the lake she had staged on during the previous fall. She was observed with other loons during the course of the summer, but did not successfully nest. Loon *52468* was not re-observed in summer 2006, but she was sighted during summer 2007 on other lakes within the Adirondack Park.

Band Recoveries and Re-observation of Common Loons Banded in the Northeastern U.S.

New York—From 1998-2007, 166 adult Common Loons were captured and color marked from breeding lakes in the Adirondack Park, New York. Five of these adult loons have been re-observed or recovered on wintering areas (BioDiversity Research Institute, Unpublished data). The majority of the winter loon recoveries were located along the Atlantic Coast in southern New England and southern New York. The exceptions were a loon recovered in North Carolina and a live color banded loon observed in Florida.

New Hampshire—A total of 59 Common Loons were captured and color-marked on

Table 3. Sequential locations and dates for 10 Common Loons (*Gavia immer*) radiomarked for satellite telemetry in New Hampshire, Maine, and the Adirondack Park, New York, 2003-2005.

Loon ID	Breeding lake	Fall staging areas	Wintering area	Spring staging	Breeding
11030	16 Aug-13 Nov 03 (Lake Umbagog)		15 Nov 03-28 April 04 (Penobscot Bay, Blue Hill Bay, ME coast)	01- 04 May 04 (Swan Lake, Unity Pond, Wesserunsett Lake, ME)	06 May-30 June 04 (Lake Umbagog) Observed on Lake Umbagog in subsequent years.
11031	17 Aug-06 Nov 03 (Lake Umbagog)		08 Nov-18 Dec 03 (Cape Elizabeth, ME coast) *Lost signal on wintering area.*		
21031	13 Jul-03 Oct 04 (Flagstaff Lake)		06 Oct 04-08 Jan 05 (Frenchman Bay, Englishman Bay, Blue Hill Bay, Swans Isl., ME coast) *Lost signal on wintering area.*		
2520	15 Jul-17 Sep 04 (Lake Umbagog)	15 Sep 04 (Lower Richardson Lake, ME)	20 Sep 04-05 Feb 05 (Muscongus Bay, ME coast) *Lost signal on wintering area.*		*Observed on Lake Umbagog in subsequent years.*
42706	25 Jul-21 Aug 05 (Wyman Lake)		*Bird died prior to migration, transmitter malfunctioned*		
42707	26 Jul-01 Sep 05 (Moosehead Lake and adjacent Indian Pond)		*Bird died prior to migration, transmitter malfunctioned*		
57610	26 Jul-19 Aug 05 (Wyman Lake)		*Transmitter signal lost prior to migration*		
42463	20 Aug - 14 Nov 2003 (Beaver Lake)	16 Nov 2003 (Central New Jersey coast)	18 Nov 2003-17 April 2004 (Southern New Jersey coast)	19 April 2004 (Rockaway Beach, NY coast)	21 April-8 Jul 2004 (Beaver Lake)
42464	22 Aug-24 Nov 2003 (Nicks Lake)	26 Nov 2003-7 Jan 2004 (Long Lake, Oneida County, NY; Brantingham Lake, Lewis County, NY; Delta Lake, Rome, NY)	13 Dec 2003-7 Jan 2004 (Pepacton Reservoir, NY) 12 Jan-25 Jan 2004 (Long Island Sound) *Bird died in wintering area*		
42465	17 Jul-18 Sep 2004 (Newton Falls Reservoir)	20 Sep-29 Dec 2004 (Big Creek, St. Lawrence County, NY; Oswegatchie Reservoir at Emeryville Power Plant, NY)	*Bird died prior to migration*		

Table 3. (Continued) Sequential locations and dates for 10 Common Loons (*Gavia immer*) radiomarked for satellite telemetry in New Hampshire, Maine, and the Adirondack Park, New York, 2003-2005.

Loon ID	Breeding lake	Fall staging areas	Wintering area	Spring staging	Breeding
42466	17 Jul - 2 Nov 2004 (Upper St. Regis Lake)	*Transmitter malfunctioned prior to migration*			
42467	18 Jul - 21 Aug 2004 (Spitfire Lake)	*Transmitter malfunctioned prior to migration*			
42468	18 Jul - 22 Aug 2004 (Clear Pond)	*Bird died prior to migration*			
42469	18 Jul-10 Sep 2004 (Lake Kushaqua, Clear Pond)	12 Sep - 2 Nov 2004 (Lake Champlain/ Lake Kushaqua, NY)	5 Nov 2004-31 Jan 2005 (Cape Cod Bay, MA) 10 Feb-3 May 2005 (Narragansett Bay, RI)	6-9 May 2005 (Quad Pond, Sterling Junction, MA)	9 May-13 Jul 2005 (Clear Pond, Rainbow Lake, Lake Kushaqua, Lake Clear)
42470	19 Jul - 4 Nov 2004 (Little Clear Pond, Little Green Pond, Green Pond)	7 Nov 2004 (Lake Colby, NY)	10 Nov 2004-3 May 2005 (Buzzards Bay, MA)	3 May 2005 (In flight)	5 May-17 Jul 2005 (Green Pond, Little Green Pond)
52463	28 Jul-24 Sep 2005 (Wolf Lake)	27 Sep-24 Oct 2005 (Goodnow Flowage, NY)	27 Oct 2005-16 Feb 2006 (Block Island Sound, RI)		Observed on Goodnow Flowage in 2006 breeding season.
52468	29 Jul-23 Nov 2005 (Little Clear Pond)		25 Nov 2005-6 Mar 2006 (Cape Cod Bay/ Plymouth Bay, MA)		Was not observed on breeding lake in summer 2006; observed in neighboring lakes in summer 2007.

Table 4. Characteristics of winter locations of Common Loons (*Gavia immer*) radiomarked on their breeding territories in New Hampshire, Maine, and the Adirondack Park, New York, 2003-2005.

Loon ID	No. of winter locations used in analysis	No. of days on wintering range	Average distance to nearest shore (km ± SD)	Maximum distance from nearest shore (km)	Average water depth (m ± SD)	Average ocean floor slope (% ± SD)
11030	41	171	1.35 ± 0.83	3.11	19.6 ± 16.7	0.83 ± 1.18
21031	30	94 (partial)	0.72 ± 0.42	1.85	3.1 ± 6.8	0.37 ± 0.72
2520	42	138 (partial)	0.39 ± 0.31	1.29	10.4 ± 5.4	0.81 ± 0.80
42463	45	151	8.06 ± 5.65	26.60	13.8 ± 5.1	0.07 ± 0.25
42469	35	179	0.89 ± 0.73	2.84	10.8 ± 7.2	0.71 ± 0.67
42470	46	174	2.93 ± 1.48	7.31	14.8 ± 1.4	0.04 ± 0.29
52463	34	112	1.43 ± 0.94	4.43	14.6 ± 6.0	0.38 ± 0.49
52468	27	101	6.08 ± 5.44	17.86	17.9 ± 12.9	0.26 ± 0.45

Lake Umbagog from 1993-2007. Six of these loons, banded as adults, have been recovered from wintering areas (BioDiversity Research Institute, Unpublished data). Three loons were recovered along the Atlantic Coast in Maine and three loons were recovered in coastal Massachusetts. In addition, three juvenile loons banded on Lake Umbagog have been recovered during winter months, all of which were found in coastal Maine.

Maine—From 1994-2007, 229 Common Loons were color-marked in western Maine, including Flagstaff, Wyman, and Moosehead Lakes, and surrounding lakes and ponds. A total of 15 loons have been recovered on wintering areas, including three adult loons from Flagstaff Lake and one adult from Wyman Lake (BioDiversity Research Institute, Unpublished data). Of the three loons from Flagstaff Lake, two were recovered from the Atlantic coast in Maine and one recovered in coastal Massachusetts. The single Wyman Lake winter recovery was from Massachusetts. Eleven additional loons banded at surrounding lakes have been recovered on wintering areas. The majority of these recoveries were from the Atlantic Coast in Maine and Massachusetts, with a few individuals recovered from areas of the Atlantic Coast extending from Connecticut to New Jersey.

DISCUSSION

Satellite telemetry was successfully used to document spatial and temporal migration patterns and wintering range of Common Loons breeding in the Northeastern United States. Of the 17 PTTs deployed in this study, 10 (59%) provided the information needed to address our study objective. Five (29%) of the PTTs failed prior to migration, a higher rate of transmitter failure than that experi-

Table 5. Winter range sizes[a] (km^2) of Common Loons (*Gavia immer*) radiomarked on their breeding territories in New Hampshire, Maine, and the Adirondack Park, New York, 2003-2005.

Loon ID	No. of winter locations used in analysis	No. of days on wintering range	Minimum convex polygon (km^2)	50% fixed kernel (km^2)	95% fixed kernel (km^2)	95% ellipse (km^2)
11030	41	171	66.4	82.2	423.2	262.7
21031	30	94 (partial)	403.9	233.8	746.1	498.7
2520	42	138 (partial)	5.7	1.1	7.8	5.4
42463	45	151	1,122.4	373.7	1,159.3	1,334.1
42469	35	179	650.1	467.9	881.4	2,394.4
42470	46	174	32.6	14.5	48.3	19.3
52463	34	112	2.2	8.4	43.2	14.0
52468	27	101	188.0	207.8	724.0	380.2

[a]Winter range calculations include water only and do not include terrestrial areas within each measured area.

enced using the same technique with Common Loons by Kenow *et al.* (2002), where all six PTTs functioned through fall migration.

Wintering Common Loons are found along the Atlantic and Gulf Coasts from Newfoundland and Labrador to Mexico (McIntyre and Barr 1997), with notable concentrations off the coasts of the Carolinas and Virginia (Haney 1990; Spitzer 1995) and along the Florida Gulf Coast (Jodice 1993). Our satellite telemetry results further document that loons breeding in eastern New Hampshire and Maine winter along the Maine coast, and loons breeding in the Adirondack Park of New York winter along coastal regions from Massachusetts to New Jersey. Wintering locations are close to the breeding areas of these populations (i.e., 152 to 527 km) relative to mid-continent loons that migrate 1,884 to 2,121 km from breeding lakes in Minnesota and Wisconsin (Kenow *et al.* 2002). The short migration distances apparently diminish the use of staging areas in autumn, whereas Midwestern loons make extensive use of inland waters (Lake Michigan and lakes and impoundments in the southeastern United States) while en route to wintering sites along the Gulf and south Atlantic coasts. Timing of autumn migration was variable among loons from the Northeast and arrival at wintering areas (20 September to 25 November) was earlier than Common Loons tracked via satellite telemetry from the Midwest (26 November to 18 December; Kenow *et al.* 2002).

The wintering areas used by Common Loons radiomarked in this study are generally consistent with banding recovery data from the larger loon banding effort in the Northeast U.S. While most of the 29 band recoveries and observations of color-marked individuals during the winter were along the same Atlantic coastal areas as the radiomarked birds, the banding return data indicated the winter distributions of these populations extend farther south. Our radiomarked loons from the Adirondack Park, New York, ranged as far south as New Jersey. Banding data also indicated individuals from this population venture as far south as Florida. Radiomarked loons from Lake Umbagog utilized coastal Maine as a wintering area. Recoveries of banded individuals from Lake Umbagog agree with these findings and have shown some loons from Lake Umbagog also winter as far south as the Cape Cod, Massachusetts area. The majority of recoveries of Common Loons banded in northwestern Maine, indicates a winter distribution in coastal areas along the northern Atlantic Coast, concentrated in Maine and Massachusetts and ranging as far south as New Jersey.

The timing of spring migration of radiomarked loons was consistent with observations of birds returning to Adirondack Park breeding lakes in late April to early May (Schoch 2002). Staging areas do not appear to be essential during spring migration as two of the four loons appeared to make direct flights from the coastal areas to breeding lakes. A stopover at Quad Pond, Massachusetts was documented for Loon *42469* followed by a direct flight to its breeding lake 2 days later. Only Loon *11030* was documented at multiple lakes during spring migration. In-flight location data received from PTTs indicated that Common Loons traveled essentially in straight lines to their destinations, directly over mountain ranges (e.g., Green Mountains of Vermont, Catskill Mountains of New York) rather than following major river valleys.

We documented the death of four of the radiomarked loons prior to migration. Causes of death of these individuals are uncertain, but the PTT implant or the implant procedure may have been a contributing factor. In the cases of Loons *42706* and *42707*, possible aspiration of digestive tract contents during induction of the anesthetic may have resulted in a respiratory infection that contributed to their demise. These individuals died 27 days (*42706*) and 37 (*42707*) days following surgery, and while carcasses were recovered, we were unable to establish specific cause of death in either bird. The contributing causes of the unusual movements, failure to migrate, and mortality of Loon *42465* are unknown. The carcass of Loon *42468* was recovered about six days after death and moderate tissue autolysis had occurred. Pathological examination and tissue toxicology tests of Loon *42468* indicted very high iron and a potentially lethal level of zinc, most likely the result of ingested fishing tackle (W. Stone, Unpublished pathology report, NYDEC).

Breeding success of radiomarked adults subsequent to PTT implantation is a concern. The observed rate of return of adults to the breeding grounds subsequent to radiomarking of 0.50 (8 of 16) was lower than the expected return rate for adult Common Loons in the Northeast U.S. of 0.87 (Mitro *et al.* 2008). We observed 6 of 16 (38%) radiomarked adult loons on their respective territories the following breeding season. Nesting has only been confirmed for Loons *2520* (female) and *42463* (male) in subsequent years. The reduced rate of subsequent breeding may be a consequence of either higher mortality or inability to effectively compete for territories as a result of reduced condition, and may point to a limitation of the radiomarking technique.

While we did not identify specific threats to Common Loons breeding in the Northeastern U.S. during migration and winter, these populations may be at risk from exposure to ocean contaminants or oil spills on the Atlantic Coast. Adirondack loons wintered near past oil spill sites including Buzzards Bay, Massachusetts (spill occurred 27 April 2003), the southern coast of Rhode Island (North Cape Oil Spill, 19 January 1996), and Long Island Sound near Norwalk, Connecticut. Many Common Loons were killed in the Buzzards Bay and North Cape oil spills (Sperduto *et al.* 2003). Information on the origins and population affiliations of loons in wintering areas provided by this study will be useful in assessing the specific impacts of winter die-offs and with directing recovery efforts.

Additional movement data on Common Loons in the Northeastern U.S. are needed to elucidate gender-related, age-related, and within-region differences in migration and wintering range. While the findings of this study are informative, the limited sample size of radiomarked birds restricts our interpretation of some results. We see an important need for additional information on movements of juvenile loons to clarify their dependence on inland waters during migration and determine the extent of movements during their first few years (before they return to breeding areas). Future work should focus on minimizing PTT malfunction and risk to individual birds associated with PTT attachment or assessing the use of new generations of transmitters or new technologies that pose less potential risk to individual loons.

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LITERATURE CITED

Arbib, R. S. 1963. The Common Loon in New York State. Kingbird 13: 132-140.

Evers, D. C. 1993. A replicable capture method for adult and juvenile Common Loons on their nesting lakes. Pages 214-220 *in* Proceedings from the 1992 conference on the loon and its ecosystem: Status, management, and environmental concerns (L. Morse, S. Stockwell and M. Pokras, Eds.). U.S. Fish and Wildlife Service. Washington, D.C.

Evers, D. C. 2007. Status assessment and conservation plan for the Common Loon (*Gavia immer*) in North America. BRI Report 2007-20. U.S. Fish and Wildlife Service, Hadley, Massachusetts.

Evers, D. C., D. Yates and L. Savoy. 2006. Assessing the health of Common Loons breeding on Lake Umbagog. Report BRI 2006-13 BioDiversity Research Institute, Gorham, Maine.

Evers, D. C., L. J. Savoy, C. R. DeSorbo, D. E. Yates, W. Hanson, K. M. Taylor, L. S. Siegel, J. H. Cooley Jr., M.

S. Bank, A. Major, K. Munney, B. F. Mower, H. S. Vogel, N. Schoch, M. Pokras, M. W. Goodale and J. Fair. 2008. Adverse effects from environmental mercury loads on breeding Common Loons. Ecotoxicology 17: 69-81.

Haney, J. C. 1990. Winter habitat of Common Loons on the continental shelf of the southeastern United States. Wilson Bulletin 102: 253-263.

Hitchcox, S. 2000. Maine Report. Pages 108-110 *in* Loons: Old Loons: History and New Findings. Proceedings of a Symposium from the 1997 meeting, American Ornithologists' Union (J. W. McIntyre and D. C. Evers, Eds.). North American Loon Fund, Holderness, New Hampshire.

Jodice, P. G. R. 1993. Distribution of wintering loons in the northeastern Gulf of Mexico. Pages 172-193 *in* Proceedings from the 1992 conference on the loon and its ecosystem: Status, management, and environmental concerns (L. Morse, S. Stockwell, and M. Pokras, Eds.). U.S. Fish and Wildlife Service. Washington, D.C.

Kenow, K. P., M. W. Meyer, D. C. Evers, D. C. Douglas and J. Hines. 2002. Use of satellite telemetry to identify common loon migration routes, staging areas and wintering range. Waterbirds 25: 449-458.

Lee, M. and J. Arbuckle. 1988. Maine Common Loons: A glance back and an eye toward the future. Pages 167-176 *in* Papers from 1987 Conference on Loon Research and Management (P. Strong, Ed.). North American Loon Fund, Meredith, New Hampshire.

McCoy, B. 1988. The New Hampshire common loon recovery program. Pages 160-166 *in* Papers from 1987 Conference on Loon Research and Management (P. Strong, Ed.). North American Loon Fund, Meredith, New Hampshire.

McIntyre, J. W. 1979. Status of Common Loons in New York from a historical perspective. Pages 117-122 *in* The Common Loon: Proceedings of the North American Conference on Common Loon Research and Management (S. Sutcliffe, Ed.). National Audubon Society, New York.

McIntyre, J. W. and J. F. Barr. 1997. Common Loon (*Gavia immer*). No. 313 *in* The Birds of North America (A. Poole and F. Gill, Eds.). The Academy of Natural Sciences, Philadelphia, Pennsylvania.

Mitro, M. G., D. C. Evers, M. W. Meyer and W. H. Piper. 2008. Common Loon survival rates and mercury in New England and Wisconsin. Journal of Wildlife Management 72:665-673.

Parker, K. E. and R. L. Miller. 1988. Status of New York's Common Loon population – comparison of two intensive surveys. Pages 145-156 *in* Papers from 1987 Conference on Loon Research and Management (P. Strong, Ed.). North American Loon Fund, Meredith, New Hampshire.

Schoch, N. 2002. The common loon in the Adirondack Park: An overview of loon natural history and current research. Wildlife Conservation Society Working Paper 20. Available online at: http://www.wcs.org/media/file/WCS_WorkingPaper20_Schoch_lowres.pdf

Service Argos. 2008. Argos User's manual. Service Argos, Inc., Largo, Maryland. Available online at: http://www.argos-system.org/html/userarea/manual_en.html

Sperduto, M. B., S. P. Powers and M. Donlan. 2003. Scaling restoration to achieve quantitative enhancement of loon, seaduck, and other seabird populations. Marine Ecology Progress Series 264: 221-232.

Spitzer, P. R. 1995. Common Loon mortality in marine habitats. Environmental Review 3: 223-229.

Silverman, B. W. 1986. Density estimation for statistics and data analysis. *In* Monographs on statistics and applied probability Vol. 26. Chapman and Hall, London.

Taylor, K. and H. Vogel. 2000. New Hampshire Report. Pages 110-113 *in* Loons: old history and new findings. Proceedings of a Symposium from the 1997 meeting, American Ornithologists' Union (J. W. McIntyre and D. C. Evers, Eds.). North American Loon Fund, Holderness, New Hampshire.

Trivelpiece, W., S. Brown, A. Hicks, R. Fekete and N. J. Volkman. 1979. An analysis of the distribution and reproductive success of the common loon in the Adirondack Park, New York. Pages 45-55 *in* The Common Loon: Proceedings of the North American Conference on Common Loon research and management (S. Sutcliffe, Ed.). National Audubon Society, New York.

Worton, B. J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecology 70: 164-168.