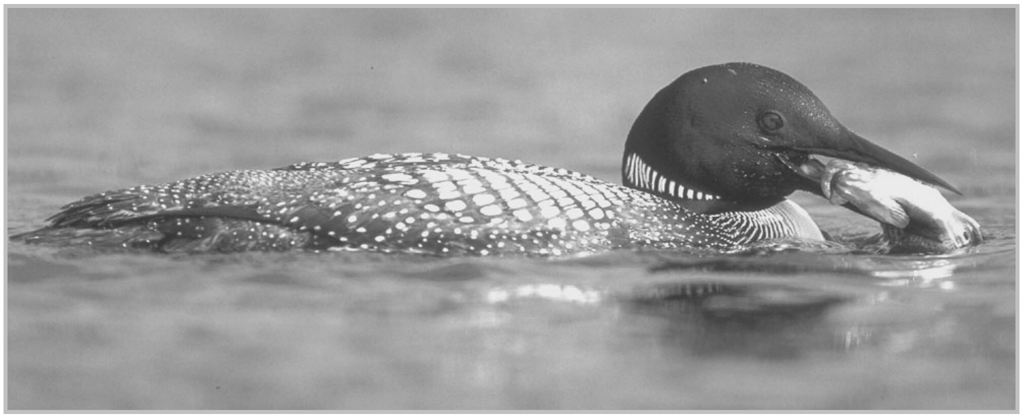
mercury exposure in common loons at seney nwr



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I introduction

In 1987 a long-term research project involving common loons (*Gavia immer*) was initiated at Seney National Wildlife Refuge (NWR) in Schoolcraft County, Michigan. The work addressed itself to elucidating aspects of the species' population dynamics, and did so through the development and refinement of a safe, replicable procedure for the nighttime capture and color-marking of individual adult and juvenile loons (Evers 2001; Figures 2 & 4a). Utilizing this technique, which has subsequently been employed for comparable monitoring activities at study sites within Michigan's Upper Peninsula and across Canada and the northern United States, 34 adults and 127 juveniles have been banded at Seney NWR over the past 19 years (Evers et al. 1998, McCormick et al. 2006). In conjunction with the color-marking process, since 1991 blood and feather samples have frequently been collected during capture for the purpose of quantifying mercury (Hg) exposure. This report summarizes the Hg levels documented in refuge loons from 1991-2005, places these findings within the context of regional exposure patterns, and suggests possible avenues for future Hg-related research involving Seney NWR.

Figure 2. The Seney G pool pair (April 1998)

II mercury in the environment

The threat posed by the toxic metal mercury has been a well-publicized source of public concern and scientific research for over thirty years (Lutter et al. 2002). As a persistent, native element, it is primarily cycled via emission from natural and anthropogenic sources (Pacnya and Pacnya 2002), atmospheric transport across local, regional and global geographies (Fitzgerald et al. 1998, Seigneur et al. 2003), and deposition onto terrestrial and aquatic environments (Sorensen et al. 1990). A substantial long-term increase in this atmospheric deposition – by some estimates representing a twenty-fold amplification since pre-industrial times (Swain et al. 1992, Schuster et al. 2002) – has paralleled the escalation in global Hg emissions resulting from industrial activities such as coal burning and municipal waste incineration (Fitzgerald et al. 1998, Pacnya and Pacnya 2002).

The methylation of mercury creates an especially pernicious organometal (CH_3Hg^+) from the standpoint of toxicity to humans and wildlife; in sublethal doses its effects can include sensory and motor deficiency, behavioral impairment, reproductive interference, immunological suppression, and genetic damage (Wolfe et al. 1998). While this process of methylation can occur across a wide range of habitats (Miller et al. 2005), aquatic ecosystems – which can harbor methylmercury (MeHg) derived from both in-lake sources and drainage of surrounding watersheds – are the primary receptors of MeHg loading in the natural world. Because the molecule assiduously bioaccumulates (accruing in the tissues of individual organisms over time) and efficiently biomagnifies (increasing in concentration during trophic transfer), the upper-level biota of such environments are at particular risk from MeHg exposure (Mason et al. 2000, Macdonald et al. 2002). As the conduit by which humans most frequently intersect aquatic communities on a consumptive level, fish have received the majority of investigation related to mercury contamination (US EPA 1997, Downs et al. 1998). Furthermore, as fish residing in freshwater lentic environments have generally demonstrated higher relative levels of exposure than comparable species dwelling in marine and freshwater lotic systems (Fimreite 1974, Evers et al. 2005), attention to lakes has been correspondingly prioritized. In 1989 the State of Michigan, having initiated sampling efforts six years prior, placed a special Hg fish advisory on the functional entirety of its 10,000+ inland lakes. This guidance, which recommended consumption limits and abstentions on many popular game species, is still in place today (MI DCH 2004, MI DEQ 2005).

III seney nwr

Included within this lake advisory are the impoundments of Seney NWR. Encompassing over 95,000 acres within the eastern-central aspect of Michigan's Upper Peninsula (Figure 3a), the refuge's extensive system of impoundments (i.e., pools) was created in the 1930's and 40's via the diversion of several creeks into lowland sedge marshes which had been effectively enclosed by the construction of earthen dikes connecting to natural sandy pine ridges. The present-day network, which includes 21 major pools totaling 7000+ acres of surface water, is divided into three management units defined by the main source ditches which feed the refuge (Losey 2003; Figures 3b-c). The pools are broadly shallow (<1m), and reach a maximum depth (2-2.5m) along the dikes that contain them; they are characterized by abundant small islands and extensive stretches of emergent wetland (Figure 3d). Adjustable spillways allow for water level manipulation on most of the refuge's basins.

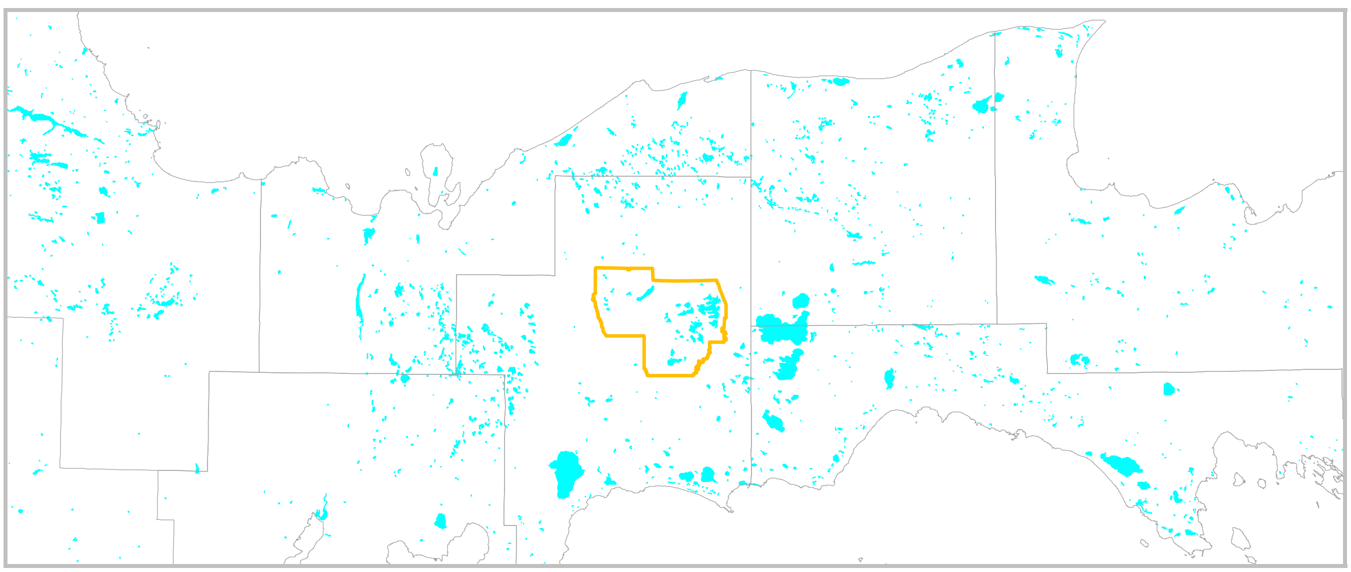

Figure 3a. Boundary of Seney NWR within the eastern-central Upper Peninsula

Although common loons have formed a conspicuous presence at Seney since the earliest years of the refuge's creation, their occupancy and productivity on specific pools was not systematically monitored until 1987 (Seney NWR 1936-1987). This effort coincided with both the initiation of banding activities on the refuge and the legislative declaration of loons' threatened status within Michigan (MI LRC 1992). Over the ensuing eighteen years – during which time many refuge adults and most of their offspring were color-marked during nighttime capture – the breeding population at Seney more than doubled to 15 pairs, and annual productivity rose from an average of 5.8 fledged chicks in 1987-1992 to 11.7 in 2000-2005. This rise in occupancy was facilitated by management practices which generally favored higher water levels on most of the refuge's pools, thereby resulting in more overall territories with viable habitat. Beyond this specific policy, however, Seney has always afforded its loon population an attractive breeding environment. In addition to the surplus of nesting islands and hummocks that typify most pools, the refuge's longstanding (and functionally unique) prohibition on all forms of watercraft has established an invaluable buffer zone between humans and loons; the latter, owing to their vulnerability on land, can be extremely sensitive to recreational disturbances during their month-long incubation period (Smith 1981, Titus and Van Druff 1981, Kaplan 2003, Vucetich et al 2004). One indirect measure of the significance of this protection could be the refuge's number of fledged chicks per territorial pair – as a quantification of population-level reproductive efficiency, Seney's long-term average of 0.70 (1987-2005) far exceeds the values recorded at other federally-managed areas in the Upper Peninsula (including Isle Royale National Park and the Ottawa National Forest), and is comparable to the highest values documented in populations across the species' North American breeding range (McIntyre and Barr 1997, Kaplan 2003, Common Coast Research & Conservation [CCRC] unpubl. data).

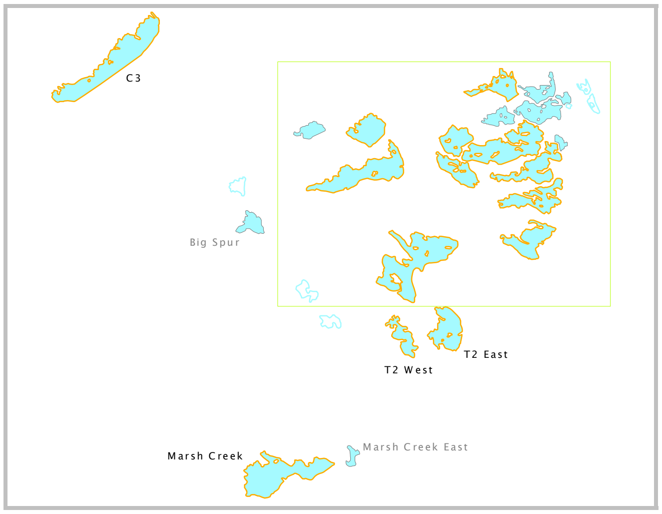

Figure 3b. Seney NWR pools – Units 2 & 3

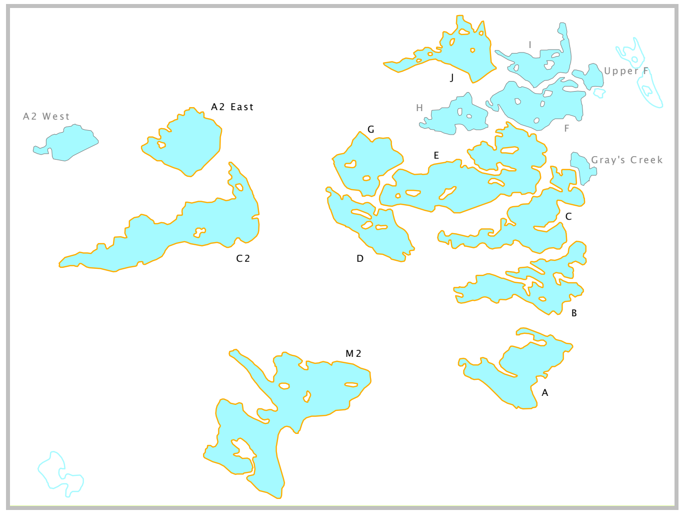

Figure 3c. Seney NWR pools – Units 1 & 2

Figure 3d. Seney NWR Unit 1 pools – E, C, B & A

During the 2005 season the refuge's 15 territorial pairs occupied 14 different pools (Figures 3b-c, outlined in orange), while another eight impoundments were sporadically utilized for feeding by these 30 loons and by additional unpaired individuals (Figures 3b-c, outlined in gray). The territorial residents included 21 color-marked adults (who have been monitored, on average, for 10.8 years), including five originally banded as juveniles (ABJs); the unpaired population included another 12 color-marked adults (most of whom were 3-5 year-old ABJs in search of a territory and/or mate). The average span of ongoing monitoring for banded adults highlights their 96% annual return rate, while the substantial number of active ABJs underscores the refuge's exceptional long-term productivity. In concert such figures underscore Seney's utility as a site for the study of common loons.

IV mercury exposure in seney nwr fish

In 1996 and 1997 the East Lansing Field Office of the U.S. Fish & Wildlife Service conducted mercury testing on four species of fish – northern pike (*Esox lucius*), yellow perch (*Perca flavescens*), white sucker (*Catostomus commersoni*), and pumpkinseed (*Lepomis gibbosus*) – collected from 12 Seney pools. This project followed earlier refuge sampling in 1987 and 1988 which had recorded levels of Hg in some northern pike that exceeded Michigan's criteria for limited human consumption (0.5 *u*g/g wet weight), but which had been compromised by poor laboratory quality assurance/quality control practices (Best 1999). The follow-up effort tested 125 total fish fillets and determined that the Hg levels in seven pike and six perch samples exceeded the 0.5 *u*g/g consumption advisory; the pools from which these elevated fish were collected – A, H, and I in Unit 1, M2 in Unit 2, and C3 and Marsh Creek in Unit 3 – represented half of all tested impoundments. Table 1 compares the findings for the specific species (excluding pumpkinseed, for which there were only ten samples from a single impoundment) with pooled data for the entire Upper Peninsula gathered by the Michigan Department of Environmental Quality and the United States Environmental Protection Agency (Gloss et al. 1990, MI DEQ 2005). As a surrogate for the measure *u*g/g, Hg concentrations are hereafter expressed in parts per million (ppm), with all values recorded in wet weight. All averaged (avg) terms refer to the arithmetic mean of measurements.

	Seney NWR pools (1996–97)				Upper Peninsula lakes (1983–2003)			
	n	avg Hg (ppm)	avg wt (g)	>0.5 ppm	n	avg Hg (ppm)	avg wt (g)	>0.5 ppm
northern pike ~ skin off	48	0.32	1065	10.4%	585	0.50	1436	36.4%
yellow perch ~ skin off	50	0.12	129	10.0%	506	0.30	62	15.4%
yellow perch ~ skin on	50	0.13	129	10.0%	173	0.21	199	2.9%
white sucker ~ skin off	17	0.05	773	0.0%	101	0.13	425	2.0%
white sucker ~ skin on	17	0.04	773	0.0%	164	0.21	~	8.5%

Table 1. Hg levels in fish from Seney NWR (Best 1999) vs. fish from Upper Peninsula lakes (Gloss et al. 1990, MI DEQ 2005)

A high percentage of Hg loading in fish – almost all of which occurs as methylmercury (Grieb et al. 1990) – is amassed via diet (Hall et al. 1997). Consequently, pisvicorous and omnivorous species such as pike, perch, walleye (*Stizostedion vitreum*) and bass (*Micropterus dolomieui* and *M. salmoides*) tend to carry higher Hg levels than lower-level herbivorous species (Sorensen et al. 1990). Because individual fish accumulate Hg in their tissues over time, size can correlate with exposure levels for specific species. This tendency is of particular interest from the standpoint of public health, where a significant positive relationship between Hg and size for single-species samples can enable length-specific recommendations regarding human consumption (MI MDCH 2004). However, numerous studies have demonstrated that the strength of such a correlation tends to vary widely between species (Rose et al. 1999, Greenfield et al. 2001). A recent examination of an extensive New England database, for example, determined that while 27.4% of northern pike Hg was statistically explained by length, only 2.0% of yellow perch Hg was similarly dependent (Kamman et al. 2005).

This discrepancy was also evidenced by the testing at Seney in 1996 and 1997. By pooling all samples collected from the refuge's impoundments, a significant positive relationship was documented between fillet Hg and fillet length for northern pike; utilizing the same approach, no such correlation was demonstrated for yellow perch fillets (Best 1999). Indeed, the lack of such a relationship was pronounced: The six perch samples which surpassed the 0.5 ppm threshold – with a mean Hg content over eighteen times higher than their counterparts – were, on average, 1.1 cm *shorter* than the 44 refuge samples which did not exceed the advisory criteria. In response, Best (1999) issued a length-specific warning regarding the limited consumption of northern pike, and – in the absence of any predictive measure for Hg exposure – a suggested abstention on all consumption of yellow perch.

V common loons as obligate piscivores

Loons are opportunistic foragers, and can supplement their diet with a wide range of aquatic vertebrates and invertebrates (particularly crayfish); fish, however, constitute the bulk of their prey ingestion (Barr 1996). In the northern Great Lakes region, breeding adults return to their territorial lake concurrent with spring thaw, typically in early to mid April. Nesting pairs will generally begin incubation at some point in May, and – if successful – will hatch one or two young roughly 28 days later. Semiprecocial, downy loon chicks are wholly dependent upon their parents for food, and will be provided with prey items of increasing size during their rapid growth in the first two months of life. This dependency wanes as juvenile development nears completion – by eight weeks most chicks will be fully-feathered (Figure 4a), competent in foraging, and capable of consuming adult-sized prey items (McIntyre and Barr 1997).

As top-level piscivores, the sheer volume of fish biomass consumed by common loons during the course of a single breeding season is substantial. Table 2 compares breeding-ground fish consumption estimates for adults and juveniles (at points in mid-summer and early autumn) to the average extent of past fish sampling efforts in the Upper Peninsula. While parents – like all adult loons – may forage upon a series of local waterbodies during spring and summer months, they do not feed their young with prey items collected beyond their nesting lake; thus the entire pre-fledged dietary input to a juvenile loon derives from its natal environment (Meyer et al. 1998). In the table below, figures for adults record the estimated consumption of fish upon migratory return from southern wintering grounds, and can include input from more than one lake source; estimates for juveniles are wholly tethered to a single aquatic ecosystem.

fish sampling	avg fish samples	avg fish wt (g)	total fish wt (kg)
Seney NWR (1996–1997) ~ per pool	10	570	5.7
Upper Peninsula ~ ELS II (1987) ~ per lake	24	189	4.5
Upper Peninsula ~ DEQ (1983–2003) ~ per lake	30	600	17.7
fish consumption ~ late July			
juvenile loon (5 weeks)	715	14	10.0
adult loon	1344	50	67.2
fish consumption ~ early September			
juvenile loon (10 weeks)	1302	25	32.6
adult loon	1680	50	84.0
loon family (2 adults + 2 juveniles)	5964	39	233.1

Table 2. Fish sampling efforts in the Upper Peninsula (Gloss et al. 1990, Best 1999, MI DEQ 2005) vs. estimated fish consumption by common loons (Barr 1986, Kenow et al. 2003)

Top predators in aquatic ecosystems can exert a strong influence upon their respective communities (Carpenter et al. 1987, Steinmetz et al. 2003), and can in turn be strongly influenced by them. Large piscivores express the highest levels of Hg exposure among North American wildlife (Evers et al. 2005), and have been shown to suffer a variety of antagonistic repercussions – including embryo mortality and altered adult and chick behavior – related to elevated Hg levels (Heinz 1979, Thompson 1996, Bouton et al. 1999). Such findings have been extended to common loons, whose Hg concentrations can reflect a million-fold increase from the lake water in which the metal begins its trophic magnification (Evers et al. 2004). Behavioral abnormalities (Nocera 1998, Counard 2001) and lowered reproduction (Barr 1986, Meyer et al. 1998, Evers et al. 2004) have been connected to high Hg in loons at study areas in New England, the Canadian Maritimes, Ontario and northern Wisconsin.

Beyond such effects-based investigations, loons can, as comprehensive piscivorous integrators, theoretically express in their Hg exposure a synthesis of the overall Hg levels in the fish communities upon which they primarily feed. Limited linkages of this type have been demonstrated between the Hg content in specific species – particularly yellow perch, a preferred prey item – and breeding adults and/or their young who have nested upon or hatched from the sampled water body (Scheuhammer et al. 1998, Counard et al. 2000, Evers et al. 2004, Burgess and Hobson 2006). Table 2 underscores the potential efficacy in utilizing loons as barometers of Hg bioavailability within the fish populations of particular aquatic ecosystems: Owing to logistical and economic limitations, traditional testing for Hg exposure in fish typically involves fewer total samples and less collective biomass than that consumed by both adult and juvenile loons during the course of the breeding season. Furthermore, these fish samples are generally divided between a number of species whose Hg values can not be pooled on an intra-lake basis, and whose utility in inter-lake Hg evaluations may be limited by the vagaries of species distribution.

VI sampling metrics and methods

In contrast to fish sampling, assessment of Hg exposure in loons involves non-lethal collection methods, and the implementation of different evaluative metrics. Whereas fish are generally tested for Hg on the basis of whole-body or (more frequently) fillet content, loons are appraised via blood and feather samples. The former, measured in its homogenous whole-blood form, offers a snapshot of recent dietary exposure to Hg, while the second secondary (S2) flight feather (Figure 4b) – the standard remex employed for testing – can provide a longer-term portrait of persistent Hg accumulation. This distinction between matrices derives from the toxicokinetic pathways of Hg exposure: Upon ingestion, dietary Hg – over 95% of which occurs as MeHg – is highly bioavailable to loons, and is rapidly incorporated into the bloodstream (Fournier et al. 2002). As the primary route by which loons (like most birds) attempt to sequester this toxic Hg, feathers serve as a diagnostic endpoint for depuration over the span of their growth (Furness et al. 1986, Thompson and Furness 1989).

This interrelationship between diet, blood and feather is a relatively straightforward matter in juvenile loons. Chicks initiate feather growth within three weeks of hatching, after which dietary inputs of Hg are largely transferred to this emerging plumage (McIntyre and Barr 1997, Kenow et al. 2003). Upon completion of feather growth – at approximately eight weeks of age – juveniles lose the ability to effectively sequester Hg via this pathway, and are consequently vulnerable to rapid escalation in blood Hg levels and concomitant deposition within muscle tissue and internal organs (Fournier et al. 2002, Kenow et al. 2003). Meanwhile, the Hg bound tightly within their feathers reflects exposure from one lake source over most of the juvenile's initial two months of life.

For adults, the diagnostic aspect of this relationship between metrics is somewhat more complicated. The annual replacement of adult flight feathers occurs as a two-week remigial molt on oceanic wintering grounds, which for Great Lakes loons generally involve the Gulf of Mexico or the southern Atlantic Coast (McIntyre and Barr 1997, Evers et al. 1998, CCRC unpubl. data). Because Hg, which can bind tightly to muscle tissue, is often remobilized during the high-energy expenditure of molt, the sequestration of Hg which occurs during this feather growth can incorporate not only recent dietary inputs but also a portion of the chronic body burden carried by the bird (Furness et al. 1986). As Hg loading in marine environments is comparatively low, most of this burden is likely amassed on northern lentic breeding grounds, when – unlike developing juveniles – adults cannot excrete their ingested Hg into growing feathers (Evers et al. 2005).

All four matrices – blood and feather samples from both adult and juvenile loons – are collected and analyzed via methods described fully in Appendix A. Briefly, the capture process involves locating a loon at night via canoe or motorboat, and –

through the use of a powerful spotlight and a suite of mimicked and recorded vocalizations – luring the targeted bird toward the watercraft. When in close proximity, the bird is caught with a large landing net, safely restrained, and transported to shore. In addition to color-banding efforts (Figure 4a) and the collection of various physiological measurements, the relevant biotic samples are obtained by drawing 1-5 cc of blood from the medial metatarsal vein and by clipping both S2 flight feathers below the base of the feather tract. All blood and feathers collected at Seney NWR since 1991 (as well as all samples from the broader Upper Peninsula) have been tested at Michigan State University's Diagnostic Center for Population and Animal Health, whose Hg-testing facility has consistently scored above the 95^{th} percentile in international inter-laboratory comparison programs (Gill 2002). Samples have been analyzed for total Hg concentration via cold-vapor atomic absorption spectroscopy and, in the case of feathers, preliminary screening via inductively coupled argon plasma emission spectroscopy.

Figure 4a. A fully feathered juvenile loon from Moccasin Lake, Alger Co. (August 2005)

Figure 4b. The secondary (S2) flight feather utilized for Hg assessment in loons

VII mercury exposure in seney nwr loons

Tested matrices from Seney NWR loons include 117 juvenile blood, 23 juvenile feather, 53 adult blood and 56 adult feather Hg values. While successful breeding adults have been captured and sampled at a roughly consistent rate from 1991-2005, juvenile Hg measurements derive more heavily from recent seasons: 66.7% of both blood and feather values originate from the highly-productive span of 2000-2005. Because most refuge chicks have been sampled prior to full feather completion, the disparity between their aggregate blood and feather samples is substantial.

Among 94 pre-fledged juveniles – those whose feather development was incomplete at the time of sampling – blood Hg averaged 0.106 ± 0.054 ppm (one standard deviation [SD] unless otherwise noted). These chicks spanned the ages of 4-8 weeks, and weighed an average of 2433 ± 612 g. Among 25 fledged juveniles – those with completed feather development – mean blood Hg was 0.263 ± 0.078 ppm, and mean feather Hg was 2.16 ± 0.47 ppm. These fledglings were 8-11 weeks old, and weighed 3107 ± 513 g. Nine such juveniles were first sampled as developing chicks before being recaptured – at an average of 34 days later – when fully feathered: While mean body mass increased by 52% during that interval, average blood Hg – having eclipsed the physiological cessation of active sequestration in emerging feathers – rose by 209%.

Figure 5 compares the normalized, log-transformed blood and feather Hg values of fully developed Seney juveniles with those of sampled loon fledglings from across the Upper Peninsula. These off-refuge juveniles represent a non-random sample of lakes primarily located within three long-term study areas (Isle Royale National Park, Ottawa National Forest and the Munising Moraine region of western Alger, northern Schoolcraft and eastern Luce counties); collectively they incorporate a substantial extent of regional geography, hydrology and chemistry (see Section VIII below). Two central observations are expressed within the figure:

1. On a broad scale – representing a 27-fold range of exposure across both measured matrices – the relationship between the blood and feather Hg values of fledged juvenile loons was highly and significantly correlated ($r^2 = 0.84$, $df=75$, $f=374.5$, $p<0.001$). Among Seney juveniles only, this relationship was less tightly correlated but still highly significant ($r^2=0.57$, $df=24$, $f=30.19$, $p<0.001$).
2. Seney fledglings fell within the middle to low-middle range of Hg exposure across the Upper Peninsula, with blood values between the 21st and 70th percentiles and feather values between the 15th and 62nd percentiles ($n=76$).

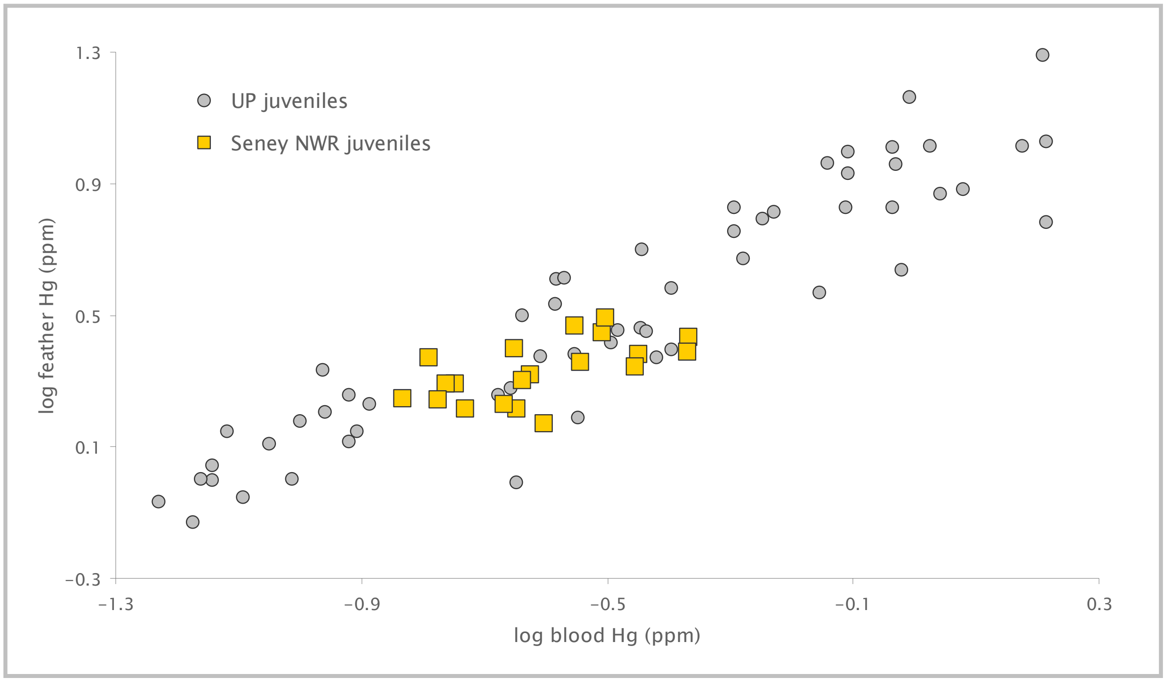

Figure 5. Correlation between blood and feather Hg levels in fully developed juvenile loons from Seney NWR and other Upper Peninsula lakes (1992–2005)

Seney Hg measurements for adult loons were balanced between genders and matrices. Mean female blood Hg was 0.652 ± 0.166 ppm ($n=25$), while female feather Hg averaged 7.96 ± 2.14 ppm ($n=28$). Among males, blood Hg was 1.076 ± 0.328 ppm ($n=28$) and feather Hg was 11.37 ± 3.50 ppm ($n=28$). Blood and feather Hg disparities between sexes were significant (blood: $p<0.001$, $t=5.88$, $df=36$; feather: $p<0.001$, $t=4.04$, $df=41$), as was the dimorphism among a subset of weighed adults: Males averaged 4737 ± 288 g and females averaged 3670 ± 181 g ($p<0.001$, $t=12.56$, $df=25$). All three differences – blood Hg, feather Hg, and weight – have been consistently observed among studied populations across North America (McIntyre and Barr 1998, Evers et al. 1998). While the latter represents an innate morphological characteristic, Hg variation has most frequently been hypothesized to reflect a consequence of this disparity in mass: Bigger males tend to consume larger prey items, which – owing to correlations with size and/or trophic level – tend to carry higher Hg concentrations (Evers et al 2004, Burgess and Hobson 2006).

Figure 6 plots the normalized, log-transformed blood and feather values of Seney males and females against established risk thresholds for adult loons. These levels, quantified by Evers et al. (2004), represent a synthesis of studies involving Hg exposure in loons and other avian species: The *moderate risk* threshold corresponds to comparatively elevated levels of Hg with unknown impacts upon the individual, while the *high risk* threshold equates to toxic levels of Hg with documented adverse effects on a molecular-, organism- or population-level scale. Two central observations are again expressed within the figure:

1. The correlation between blood and feather Hg for Seney adults, although not as strong as the relationship between juvenile matrices, was still significant (r^2=0.32, *df*=50, *f*=23.2, p<0.001). This linkage supports the contention (discussed above in Section VI) that Hg depuration into feathers grown on oceanic wintering grounds can be influenced by breeding-ground inputs of dietary Hg.

2. While no refuge adults registered *high risk* Hg levels in blood or feather, a sizeable percentage – especially among males – crossed *moderate risk* boundaries: 52% of male blood and 84% of male feather values exceeded such levels, while only 4% of female blood and 32% of female feather values surpassed those thresholds.

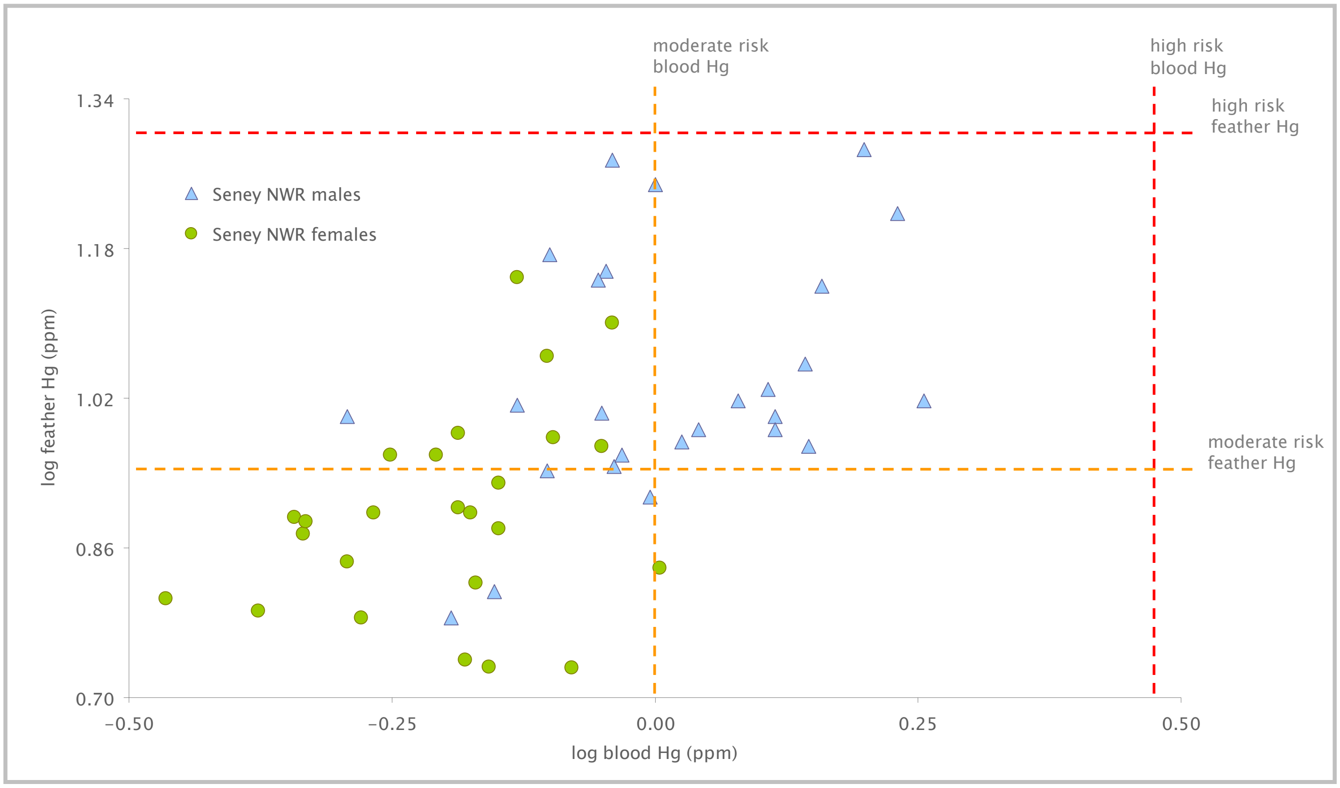

Figure 6. Correlation between blood and feather Hg levels in adult loons from Seney NWR (1992–2005) relative to established Hg risk thresholds (Evers et al. 2004)

Figure 7 compares average Seney adult Hg values – as well as two juvenile matrices – with off-refuge samples collected in northern Michigan (predominantly the Upper Peninsula) from 1991-2005. All off-refuge means reflect sample sizes greater than 50; standard deviations for all averages are expressed by one-sided error bars on the columns. The following inferences can be drawn from the figure:

1. In as much as the broad-based, non-random collection of off-refuge samples sketches a reasonable approximation of regional Hg levels in common loons, Seney NWR does not represent an environment of comparatively high exposure: Refuge means for six matrices averaged 33.1% less (range = 10.5%-55.0%) than their off-refuge equivalents.

2. Coefficients of variation for these six matrices (which express the standard deviation as a percentage of the mean) averaged 26.0% lower (range = 8.6%-62.4%) among Seney measures when compared to off-refuge values. Variation among Seney juvenile feather values represented both the largest difference within this comparison (62.4%) and the

smallest coefficient among Seney matrices (21.8%). Because juvenile exposure is more precisely linked to the dietary contributions of one Hg source (the natal lake) than adult exposure, and because the juvenile feather embodies a standardized span of Hg input – eight weeks – not matched by pre-fledged blood measurements, the relative narrowness of this metric among Seney loons tentatively underscores the comparative homogeneity of the refuge's interconnected pool system.

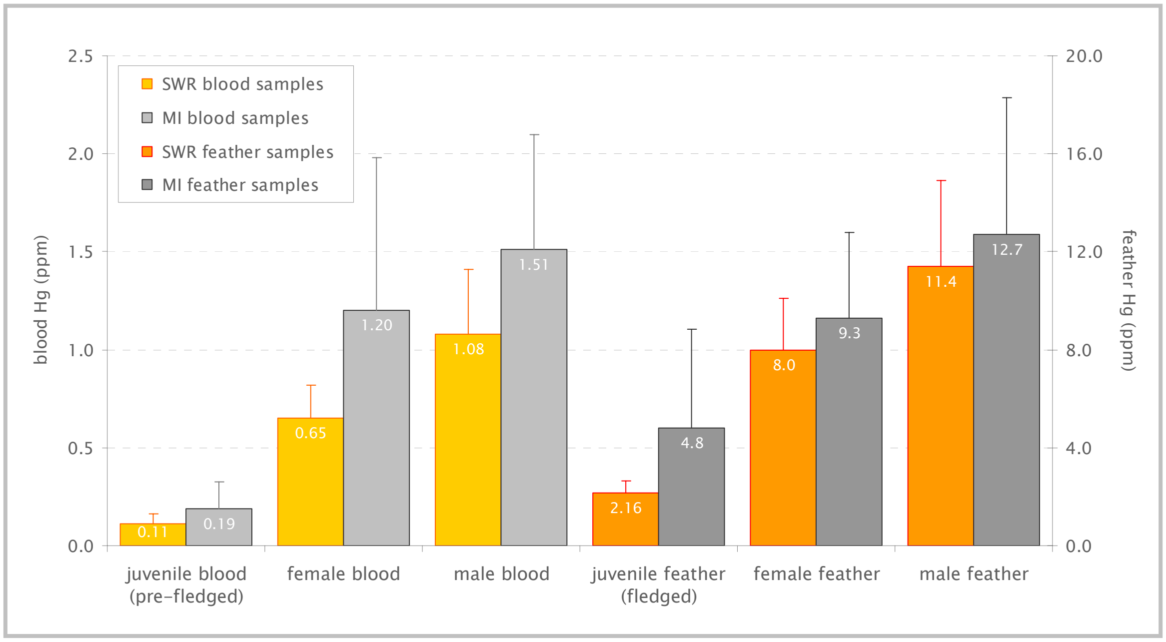

Figure 7. Blood and feather levels in loons from Seney NWR and other northern Michigan lakes (1991–2005; error bars = SD)

VIII exposure variables

A comprehensive review by Ullrich et al. (2001) recently concluded that "despite a considerable amount of literature on the subject, the behavior of mercury and many of the transformation and distribution mechanisms operating in the natural aquatic environment are still poorly understood." Between such uncertainties and ambiguities, however, there exist a series of predictive relationships of considerable utility, especially in regard to the endpoint issue of public health. Foremost among them is the inverse correlation between lake pH and Hg concentration in fish, which has been repeatedly documented across a wide range of species and geographies (Cope et al. 1990, Suns and Hitchin 1990, Scheuhammer et al. 1994, Scheuhammer and Graham 1999, Greenfield et al. 2001, Kamman et al. 2005). Not surprisingly, a comparable association has been established between lake pH and Hg exposure in common loons (Meyer et al. 1998, Counard 2001, Burgess et al. 2005). Progressing backward from such patterns of exposure in fish and top-level piscivores, research has suggested that [a] the overwhelming majority of Hg in upper-level aquatic organisms occurs as MeHg (Furness et al. 1986, Grieb et al. 1990, Fournier et al. 2002); [b] this MeHg is accumulated and magnified from proportionally lower levels of MeHg in aquatic invertebrates, zooplankton and phytoplankton (Sorensen et al. 1990, Mason et al. 2000); [c] the amount of unbound MeHg available for uptake (via passive diffusion) by phytoplankton is largely governed by rates of methylation in the water column and lake sediment (Watras et al. 1995); [d] such methylation – which converts Hg into MeHg, and which primarily occurs as a consequence of the activities of sulfate-reducing bacteria – is significantly influenced by the relative acidity of the lake environment (Xun et al. 1987, Wiener et al. 1990, Winfrey and Rudd 1990). Thus, the chemistry of a specific aquatic system tends to prove a more important determinant of MeHg uptake by its fish and piscivores than variables such as regional spatial traits, fish community attributes or total Hg concentrations in the water itself (Kelly et al. 1995, Rose et al 1999, Greenfield et al. 2001).

The brief summation above, it should be stressed, is a highly generalized overview of research findings; as a mechanistic explanation of MeHg uptake in lake environments, it is also more strictly relevant to aquatic systems lacking permanent inflows or outflows – so-called seepage lakes. Because the hydrology and Hg loading of such waterbodies are dominated by atmospheric inputs, acidic precipitation can create low pH lake conditions which facilitate increased methylation and Hg bioavailability (Eilers et al. 1986, Schnoor et al. 1986, Rapp et al. 1987, Grieb et al. 1990). MeHg loading in drainage systems, by contrast, is less directly influenced by the acidifying effects of precipitation, and is consequently governed – in the prevailing absence of low pH conditions – more heavily by watershed inputs derived from methylation of Hg in surrounding wetland areas. To this end, Hg concentrations in fish from drainage systems have been positively correlated to catchment area (Sonesten 2003), percentage of near-shore wetlands (Driscoll et al. 1995, Grigal 2002), dissolved organic carbon (DOC) content (Sorensen et al. 1990, Driscoll et al. 1995), and water color (Porvari and Verta 1995); collectively these relationships suggest a process of terrestrial methylation in wetland environments and consequential MeHg transport into drainage lakes via binding with DOC and other organic substances (Miskimmin et al. 1992, Driscoll et al. 1995, Porvari and Verta 1995).

An additional hydrologic pattern of note – especially in relation to conditions at Seney NWR – is the oft-demonstrated phenomenon of elevated Hg in fish from reservoirs (Jackson 1991, Bodaly and Fudge 1999, MI DEQ 2005). Research in this arena has generally focused upon the effects of initial flooding, whereby large amounts of inundated terrestrial plant matter can stimulate the activities of Hg methylating microorganisms such as sulfate-reducing bacteria, and lead to increased MeHg uptake in the years following reservoir creation (Porvari and Verta 1995). An ongoing fluctuation in the water levels of such reservoirs can, depending upon duration and season, replicate on a milder scale this process of terrestrial inundation. Evidence also suggests that for impoundments with shallow wetland perimeters, episodes of drying can aerobically release MeHg in sediment that had been previously methylated in anoxic conditions and thereafter bound to sulfides and other particles; upon reflooding this MeHg can be leached from the sediment and rendered bioavailable within the reservoir (Snodgrass et al. 2000).

The refuge's relationship to such general exposure variables is mixed. In as much as pH represents the single most prominent predictor variable in regards to Hg exposure in fish and top-level piscivores, Seney's pools do not represent a particularly high-risk environment: Subsurface readings taken from April-September in 2004 and 2005 with a handheld Hach SensIon1 portable pH meter averaged 7.58 ± 0.38 for 110 samples from 19 different impoundments. While standardized by neither season nor frequency, the values are broadly indicative of a circumneutral aquatic system, and concur with earlier measurements obtained from refuge pools in the mid to late 1990s (E. Collier pers. comm.). Other refuge characteristics, however, could potentially lend themselves to increased MeHg bioavailability: Seney impoundments collectively drain a large watershed (~110,000 acres) of abundant wetland in northern Schoolcraft and eastern Alger counties, are generally characterized by high color, and experience frequent episodes of significantly fluctuating water levels.

The extent to which such variables ultimately influence MeHg bioavailability is, of course, also regulated by the sheer amount of Hg atmospherically deposited upon the terrestrial and aquatic landscape. In November of 2003 a wet deposition monitor was installed at Seney NWR by the Mercury Deposition Network – a branch of the National Atmospheric Deposition Program – for the purposes of recording weekly levels of Hg in the refuge's rain and snow. Figure 8 – which compares the two-month moving averages for total Hg in Seney precipitation with longer-term data sets collected at two sites in northern Wisconsin – highlights the dramatic seasonal variation in wet deposition which has been a well-documented (if incompletely understood) feature of atmospheric Hg removal (Glass et al. 1991, Hoyer et al. 1995, Vanarsdale et al. 2005). For 2004 – the first year of complete recording at the refuge – Seney's total Hg deposition of 8.0 g/m^2 was the highest among seven stations in the northern Great Lakes area (mean = 6.9 g/m^2; NADP 2005). As the only such instrumentation currently operating in northern Michigan, Seney's MDN monitor serves as the best available estimation of regional Hg deposition across a broad extent of the eastern and central Upper Peninsula.

This regional singularity is of particular interest in the context of topical developments involving Hg emissions. Figure 9 lists total point-source air releases of Hg in 2003 for municipalities in northern Michigan, northern Wisconsin, and southern Ontario (EC 2005, US EPA 2005). The largest emitter within the region – Marquette, MI – is primarily defined by We

Energies' Presque Isle Power Plant, a coal-burning facility that accounted for 85% of the city's 2003 emissions. Through a civil settlement with the U.S. Environmental Protection Agency, We Energies recently agreed to install a new filtration technology (TOXECON) on its Presque Isle smokestacks which will potentially remove 90% of Hg from airborne emissions (US EPA 2003, We Energies 2005). If the installation of such technology – which was slated for completion in the fall of 2005 – proves effective at drastically curbing Hg emissions, the regional landscape of atmospheric Hg loading could undergo substantial alteration.

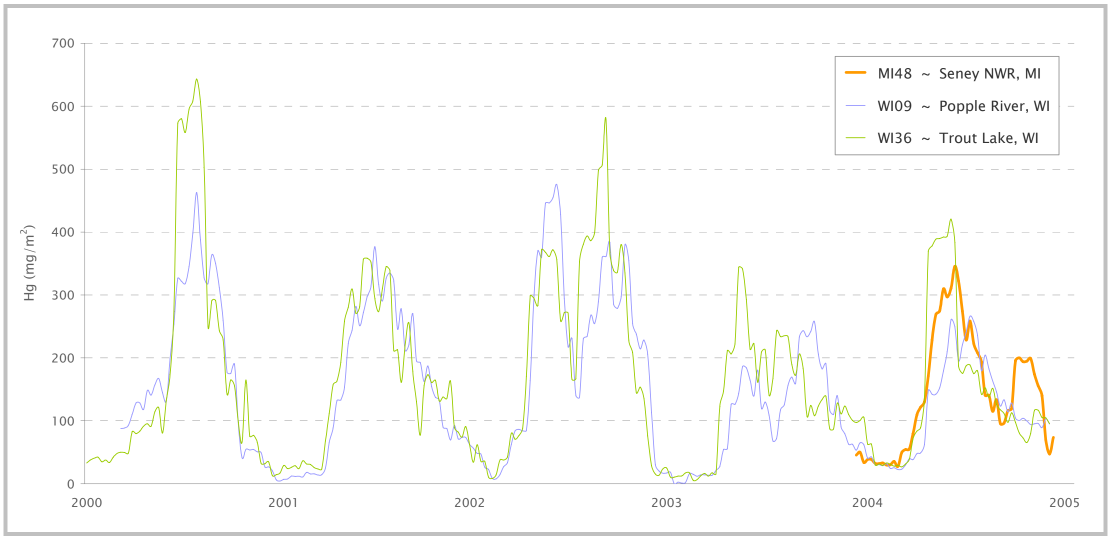

Figure 8. Weekly wet deposition of atmospheric Hg at Seney NWR and two northern Wisconsin monitoring sites – two-month moving averages (2000-2005; NADP 2005)

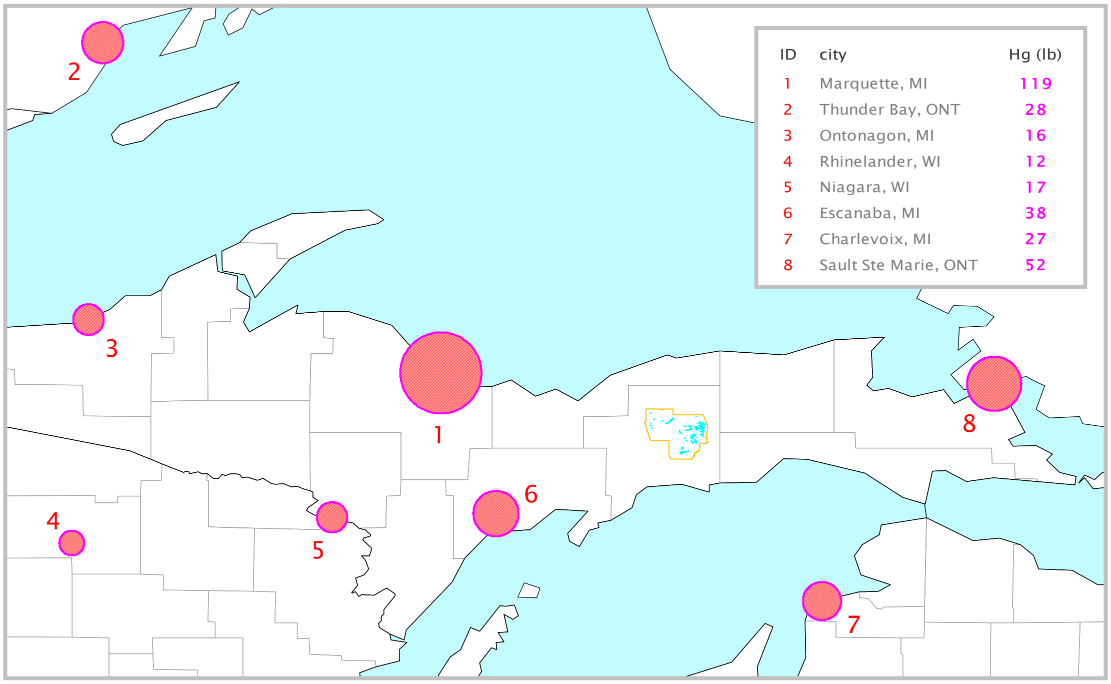

Figure 9. Municipal Hg air emissions in the Upper Peninsula and surrounding region (2003; EC 2005, US EPA 2005)

IX future research possibilities

The results of recent atlasing by Common Coast Research & Conservation have strongly suggested that the Upper Peninsula's breeding loon population is dramatically larger than the estimates of the mid-1980s which – in conjunction with comparably low estimates for the northern Lower Peninsula – originally prompted Michigan to list the species as state threatened (MI Loon Recovery Committee 1992, Kaplan et al. 2002, CCRC unpubl. data). The implication of this finding, however, is somewhat equivocal: Because [a] most of this documented increase likely reflects shortcomings in the methodology of the original surveying and not an actual rise in loon numbers, [b] long-term productivity at significant areas of loon occupancy (including Isle Royale NP and Ottawa NF) is less than half of that recorded at Seney NWR, and [c] the longevity of the species can lead to an exceedingly slow population-level reaction time in response to unsustainable levels of productivity (Vucetich et al. 2004), any overall *trend* in the Upper Peninsula's loon numbers remains unclear. At the same time, the substantial increase in the sheer number of known pairs (at least 400 as of 2005) renders common loons better-positioned to lend themselves to broad-based toxicological studies such as those involving Hg contamination in the Upper Peninsula's inland lakes. In as much as Seney NWR and its loon population might contribute to such work, two primary avenues of potential research suggest themselves, and are broadly outlined below:

Single-source assessment of Hg bioavailability in relation to fish consumption advisories

Juvenile loons, flightless until autumn fledging, are better equipped than their parents to provide accurate information regarding the Hg bioavailability in their natal aquatic environment. Most studies which have utilized them as a metric have focused upon their blood Hg, and have done so without regard for the variable of age (Evers et al. 1998, Meyer et al. 1998, Burgess et al. 2005); as blood Hg has been demonstrated to increase steadily during the period of time (3-7 weeks) in which these loon chicks are sampled (Fevold et al. 2003, Kenow et al. 2003) the relevance of geographic and temporal comparisons is potentially compromised. Flight feathers are consequently attractive because their period of growth is bounded within narrow developmental timeframes; additionally, the Hg in these remiges embodies dietary input over a longer duration and a more extensive range of prey sizes than that reflected in blood, where Hg has a half-life of only 3-4 days in pre-fledged juveniles (Fournier et al. 2002). The precision of such feathers is tentatively suggested by the respective coefficients of variation for Seney juveniles' pre-fledged blood Hg (44.5%), fledged blood Hg (29.7%), and fledged feather Hg (21.8%).

One possible application of this metric would be in conjunction with further sampling efforts involving Hg testing in refuge fish. Included in Best's (1999) report was the recommendation, as yet unrealized, that Seney NWR "will develop a monitoring protocol to quantify levels of Hg in edible fish fillets derived from refuge pools in future years." While prior studies have established certain significant relationships between Hg levels in common loons and single fish species (Scheuhammer et al. 1998, Counard et al. 2000, Evers et al. 2004, Burgess and Hobson 2006), no project has yet demonstrated that the Hg exposure in the former is broadly and predicatively reflective of the overall Hg loading within the fish biomass of a specific aquatic ecosystem. Such an undertaking at Seney – which could involve comprehensive autumnal sampling on pools with successfully hatched loon chicks – would, at the very least, serve to better illuminate the refuge's poorly-characterized fish communities. Ideally, this type of effort would synthesize with comparable off-refuge testing administered by the Michigan Department of Environmental Quality (MI DEQ) through their Fish Contaminant Monitoring Program (FCMP) so as to provide a viably broad representation of regional aquatic characteristics. Given their importance in Hg uptake, water chemistry parameters might also feature prominently in sampling efforts. The overarching goal of such a project would be to establish predictive relationships between fish and loon Hg – especially as reflected in juvenile feathers – such that the latter could be utilized as an efficient, precise and cost-effective indicator of single-source Hg bioavailability, and thereafter constructively applied in the service of lake-specific fish consumption advisories.

Temporal patterns in regional Hg loading

Using the metric of juvenile blood, Fevold et al. (2003) recently documented a 4.9% annual decline in loon Hg from 1992-2000 on northern Wisconsin lakes, and tentatively connected this trend to decreases in both atmospheric Hg deposition (10%)

and yellow perch fillet Hg (5%) that had been recorded during a similar period at an experimental study lake within the area (Hrabik and Watras 2002). In support of recent evidence that newly deposited Hg may be comparatively more bioavailable within aquatic environments (Renner 2002), the latter effort suggested that modest changes in deposition may discernibly affect Hg bioaccumulation over short time intervals. The possibility of replicating such a project at Seney and the surrounding eastern-central Upper Peninsula region is particularly compelling in light of the planned reductions in Hg emissions at Presque Isle Power Plant (see Section VIII above) and the present ambiguities regarding the regional consequences of such changes. The bulk of this uncertainty stems from the poorly-understood behavior of Hg shortly after it leaves coal-burning smokestacks and mixes with ambient air: If, as some research suggests, much of it remains in a form (reactive gaseous mercury [RGM]) that is more readily deposited within modest distances of its point source, then the possible regional effects of mitigated Hg releases at Presque Isle are considerable; if, as other studies have found, the bulk of this released RGM is rapidly converted into a far less volatile elemental form (Hg^0), then most of these anthropogenic emissions are likely carried into the upper atmosphere and ultimately deposited across broader geographies (Lindberg and Stratton 1997, Seigneur et al. 2003, Renner 2004).

The potential benefit under the former scenario is especially imperative in light of the aquatic characteristics of the surrounding region. Although Seney NWR is marked by circumneutral water chemistries, much of the eastern-central Upper Peninsula – especially its northern portions – is characterized by large numbers of exceedingly low-pH lakes. Extensive surveying during the 1980s established that the area is among the most broadly acidic in the Midwest (Rapp et al. 1987, Eilers et al. 1988, Nater and Grigal 1992), with a significant percentage of its waterbodies constituting seepage lakes that have had their pH lowered by long-term inputs of acidic precipitation (Schnoor et al. 1986, Eilers et al. 1998). In recent seasons Common Coast Research & Conservation has begun to focus atlasing and sampling efforts upon such lakes, particularly as contained within two important loon areas near Seney which are largely protected by federal ownership or state-facilitated conservation easements (the Western District of the Hiawatha National Forest and the Munising Moraine, respectively; Figure 11).

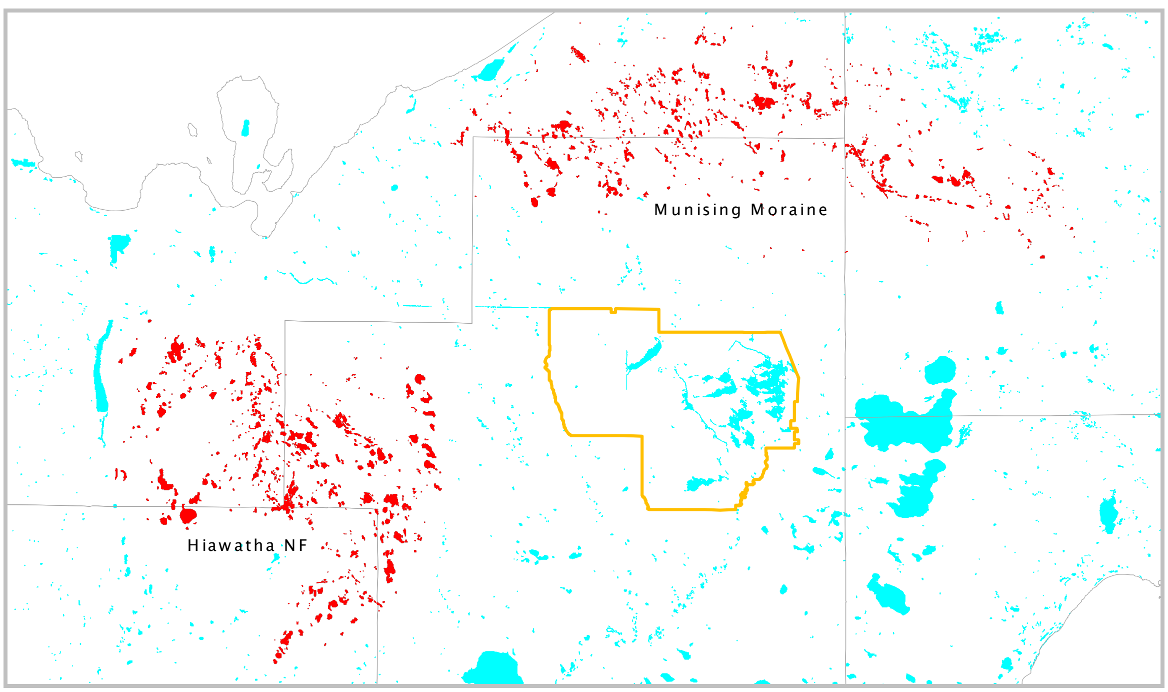

Figure 10. Study lakes within the Munising Moraine and Hiawatha National Forest

Figure 12 highlights the initial results of sampling fully-developed juveniles within these areas. The seven targeted loon chicks were hatched and fed upon seepage lakes with an average pH of 5.15; because the pH scale is logarithmic, this figure represents conditions which were over seventy times more acidic than those found in neutral (pH 7) environments. In support of previously demonstrated inverse correlations between pH and loon Hg exposure (Meyer et al. 1998, Counard 2001, Burgess et al. 2005), the average feather Hg in these juveniles (10.9 ppm) was over five times greater than the mean for Seney juveniles (as well as higher than the mean for all refuge *adults*). Collectively they suggest a pattern of problematically elevated Hg uptake, and – as they originate from within dense clusters of publicly accessible lakes – the potential of significant and widespread health concerns involving fish consumption.

Thus, demonstrated regional-level improvements in Hg loading to upper-level wildlife resulting from curbed releases from Presque Isle could illuminate much of the current regulatory debate concerning Hg emissions (Bradbury et al. 2004, Weiss 2005) while simultaneously easing a toxicological pressure upon the area's aquatic resources. The absence of such verifiable decreases would, of course, still lend important insight into the behavior of atmospheric Hg, and consequently into the arenas of federal and state Hg regulation. In either case, the baseline database of exposure levels that now exists for juveniles from Seney and the broader eastern-central Upper Peninsula could, in conjunction with corresponding samples gathered in coming seasons, form an integral part of a project that assessed temporal changes to the region's Hg loading.

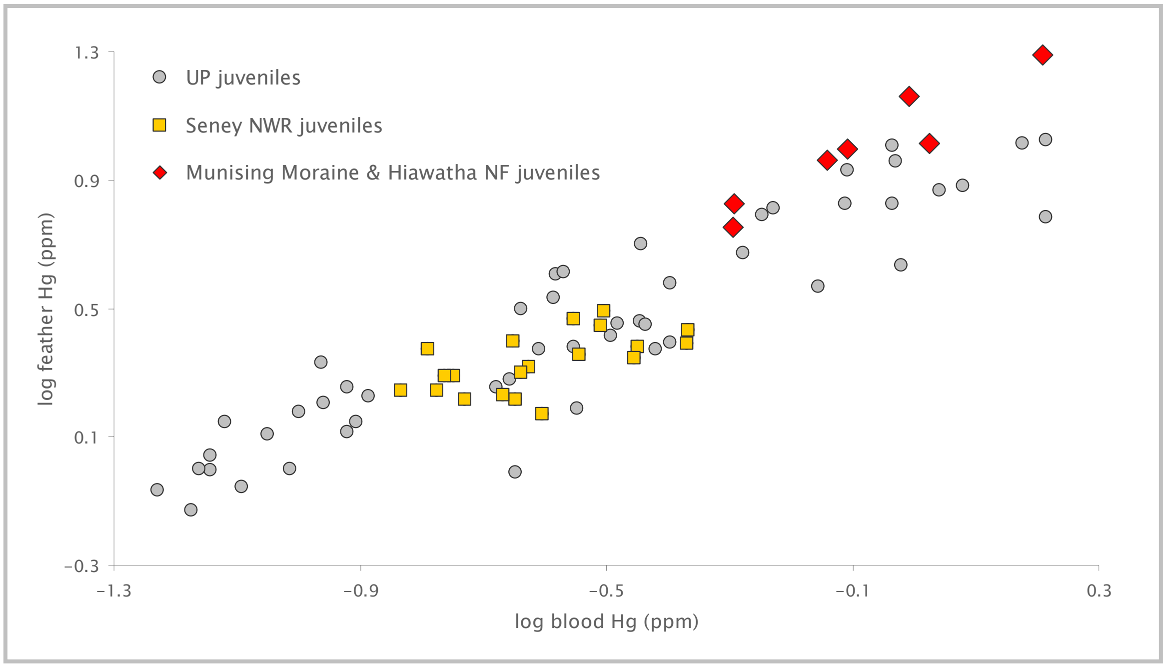

Figure 11. Correlation between blood and feather Hg levels in fully developed juvenile loons from the Munising Moraine & Hiawatha National Forest (2003–2005), Seney NWR and other Upper Peninsula lakes (1992–2005)

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This report's cover photograph was graciously donated by Gregory M. Nelson. Figure 3d originates from Seney NWR archives. All other pictures are credited to Common Coast Research & Conservation.

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XII appendix A: sample collection and analysis

From July through September, a 2-3 person team captured adult and juvenile loons at night using a canoe or 14-foot aluminum boat. Loons were located with a one million candlepower spotlight, slowly approached, and simultaneously drawn toward the watercraft with recorded or mimicked calls. When in close proximity, loons were carefully netted with a large salmon-landing net, safely restrained and transported to shore for sample collection. Both second secondary flight feathers (S2) of adults and fully-developed juveniles were removed from each wing by cutting the calamas below the base of the feather tract. Additional contour (breast and scapular) feathers were archived for future contaminant and stable-isotope analysis. Blood samples were taken from the medial metatarsal vein using a 1- to 6-cc syringe fitted with a 20- to 25-gauge needle, and transferred into a 1- to 7-cc Vacutainer. From 1991-1997, 10% buffered formalin was added as a preservative to blood samples following U.S. Fish and Wildlife Service protocol (Wiemeyer et al. 1984); from 1998-2005 samples were preserved by freezing. All loons of sufficient body size were marked with a U.S. Fish and Wildlife Service aluminum band and 1-3 additional colored leg bands to enable subsequent identification in the field. Finally, each individual was bill-measured and weighed prior to being released in its respective territory. Family groups were monitored to assure adults and juveniles regrouped after capture. No injuries or fatalities occurred as a result of the capture process. All handling and sampling procedures are in accordance with guidelines provided by the Animal Behavior Society.

Secondary feathers and blood samples were analyzed for total Hg concentrations at the Diagnostic Center for Population and Animal Health at Michigan State University. Feathers were initially washed to remove external contamination. Hg within feathers is strongly bound to disulfide linkages of keratin (Crewther et al. 1965) and is not disturbed by washing episodes (Applequist et al. 1984). Each feather was washed two times in reagent grade acetone, once in chromatography grade acetone (Burdick and Jackson, Muskegon, MI), three times in ultra pure water (4 bowl MilliQ System, Millipore Corp, Bedford, MA), one additional time in chromatography grade acetone, and then placed in a fume hood to dry overnight. Each washed feather, weighing 14-30 mg, was digested overnight at 90° C with 2 ml conc. HNO_3 (Instra-analyzed grade, J.T. Baker Inc., Phillipsburg, NJ) in a closed 30 ml Teflon container (Savillex Corp., Minnetonka, MN). The digests were quantitatively transferred to a 10 ml volumetric flask, mixed with 100 µg yttrium (JMC Specpure ICP/DCP Analytical Standards, Johnson-Matthey/Aesar, Ward Hill, MA), an internal standard, and diluted to volume. Samples were initially analyzed by inductively coupled argon plasma (ICP) emission spectroscopy (Polyscan 61E, Thermo Jarrell-Ash Corp, Franklin, MA) (Stowe et al. 1985). An aliquot of the sample was then taken from the initial 10 ml volumetric flask and diluted an additional 100 fold for analysis of Hg by cold-vapor atomic absorption spectroscopy (LCD mercury Monitor 3200, Thermo Separation Products, Riviera Beach, FL). Accuracy was monitored by concurrent analysis of two procedural blanks (in triplicate): NIST Oyster Tissue SRM 1566a with Hg certified at 0.0642 +/- 0.0067 µg/g (National Institute of Standards and Technology, Gaithersburg, MD) and NRC Tort 2 Lobster Hepatopancreas with Hg certified at 0.27 +/- 0.06 µg/g (National Research Council of Canada, Ottawa, Canada).

For blood analysis, a 100mg (1991–1997) or 500 mg (1998-2005) aliquot of each homogenized whole blood sample was digested with 2 ml conc. HNO_3 in a sealed 15 ml Teflon container overnight at 90°C. Digests were then quantitatively transferred to volumetric flasks and brought to volume with ultra pure water (100-250 ml for chicks and 500 ml for adults), maintaining a 2% HNO_3 solution, and analyzed as above by cold-vapor atomic absorption spectroscopy.

appendix B: Hg values in Seney loons ~ 2000-2005

USFWS band #	Territory	Age	Date	Weight (g)	Blood Hg (ppm)	Feather Hg (ppm)
888-160-41	A	Juvenile	17-Jul-00	2130	0.086	
918-133-67	A	Juvenile	14-Aug-04	2300	0.092	
918-133-77	A2 East	Juvenile	26-Jul-05	2775	0.083	
918-133-76	A2 East	Juvenile	26-Jul-05	2200	0.067	
888-160-55	B south	Juvenile	19-Jul-00	2190	0.141	
888-160-54	B south	Juvenile	19-Jul-00	2380	0.115	
888-161-44	B south	Juvenile	7-Aug-02	1975	0.132	
888-161-45	B south	Juvenile	7-Aug-02	1825	0.089	
888-161-49	B south	Juvenile	7-Aug-03	2500	0.187	
888-161-48	B south	Juvenile	7-Aug-03	2025	0.108	
918-133-57	B south	Juvenile	14-Aug-04	2650	0.154	
918-133-78	B south	Juvenile	26-Jul-05	1425	0.114	
888-161-47	C	Juvenile	6-Aug-02	1750	0.030	
918-133-61	C	Juvenile	15-Aug-04	3100	0.068	
918-133-64	C2	Adult	17-Aug-04	3575	0.466	7.72
918-133-60	C2	Juvenile	15-Aug-04	2775	0.143	
918-133-59	C2	Juvenile	15-Aug-04	2650	0.094	
918-133-60	C2	Juvenile	13-Sep-04	3250	0.428	2.45
918-133-59	C2	Juvenile	13-Sep-04	3100	0.351	2.21
918-133-90	C2	Juvenile	26-Jul-05	1350	0.055	
918-133-91	C2	Juvenile	26-Jul-05	1200	0.043	
918-133-90	C2	Juvenile	30-Aug-05	2300	0.173	1.95
918-133-91	C2	Juvenile	30-Aug-05	2350	0.147	1.76
888-160-80	C3	Juvenile	1-Aug-01	2900	0.163	
888-160-81	C3	Juvenile	1-Aug-01	3650	0.152	
888-161-39	C3	Juvenile	5-Aug-02	3925	0.275	
888-161-38	C3	Juvenile	5-Aug-02	3650	0.103	
918-133-55	C3	Juvenile	10-Aug-03	3650	0.151	
918-133-56	C3	Juvenile	7-Aug-04	1800	0.060	
918-133-56	C3	Juvenile	14-Sep-04	3250	0.237	2.08
918-133-75	C3	Juvenile	26-Jul-05	2850	0.080	
918-133-74	C3	Juvenile	26-Jul-05	3050	0.071	
918-133-74	C3	Juvenile	30-Aug-05	3600	0.225	1.64
918-133-75	C3	Juvenile	30-Aug-05	3750	0.249	1.48
888-160-70	D	Juvenile	27-Jul-00	2700	0.122	
888-160-57	D	Juvenile	28-Jul-00	1950	0.102	
888-160-57	D	Juvenile	22-Aug-00	2175	0.268	
888-160-57	D	Juvenile	6-Sep-00		0.321	2.60
888-160-90	D	Juvenile	25-Jul-01	2475	0.085	
888-160-83	D	Juvenile	8-Aug-03	3250	0.135	
888-160-89	D	Juvenile	8-Aug-03	2400	0.092	

USFWS band #	Territory	Age	Date	Weight (g)	Blood Hg (ppm)	Feather Hg (ppm)
888-161-37	E central	Adult	3-Aug-01	3400		5.24
858-086-52	E central	Adult	25-Jul-05	4750	0.790	8.75
918-133-72	E central	Juvenile	25-Jul-05	1550	0.048	
918-133-73	E central	Juvenile	25-Jul-05	1900	0.048	
888-160-65	E east	Juvenile	7-Aug-03	2550	0.126	
918-133-71	E east	Juvenile	25-Jul-05	3160	0.200	
888-160-67	F	Juvenile	28-Jul-00	3575	0.137	
888-160-69	F	Juvenile	29-Jul-00	3200	0.192	
888-160-67	F	Juvenile	22-Aug-00		0.284	1.55
888-160-94	F	Juvenile	3-Aug-01	2700	0.105	
888-160-99	F	Juvenile	3-Aug-01	2525	0.094	
918-133-52	F	Juvenile	8-Aug-02	3100	0.179	1.95
888-161-46	F	Juvenile	8-Aug-02	3200	0.168	1.75
888-160-53	G	Adult	18-Jul-00		0.915	8.86
888-160-52	G	Juvenile	18-Jul-00	1940	0.042	
888-160-37	G	Juvenile	18-Jul-00	2040	0.040	
888-160-88	G	Juvenile	2-Aug-01	2725	0.065	
888-161-34	G	Juvenile	3-Aug-01	2950	0.103	
888-161-43	G	Juvenile	7-Aug-02	2625	0.099	
888-161-42	G	Juvenile	7-Aug-02	3150	0.078	
628-227-10	H	Juvenile	16-Jul-00		0.078	
918-133-84	J	Adult	29-Jul-05	3925	0.454	7.81
888-160-97	J	Juvenile	25-Jul-01	3400	0.092	
888-161-40	J	Juvenile	5-Aug-02	2275	0.035	
918-133-86	J	Juvenile	29-Jul-05	1600	0.075	
918-133-85	J	Juvenile	29-Jul-05	1550	0.067	
918-133-82	M2	Adult	27-Jul-05	3900	0.833	5.39
888-160-60	M2	Juvenile	3-Aug-00	1800	0.068	
*	M2	Juvenile	12-Sep-00	2575	0.286	2.27
888-160-96	M2	Juvenile	2-Aug-01	2875	0.167	
888-161-33	M2	Juvenile	2-Aug-01	2600	0.121	
918-133-93	M2	Juvenile	30-Aug-05	3000	0.223	2.50
918-133-92	M2	Juvenile	30-Aug-05	2550	0.186	1.64
918-133-83	Marsh Creek	Adult	28-Jul-05	4650	1.280	10.7
918-133-69	Marsh Creek	Juvenile	24-Jul-05	2400	0.112	
918-133-80	T2 East	Adult	27-Jul-05	3725	0.668	7.89
918-133-81	T2 East	Juvenile	27-Jul-05	1750	0.094	
628-227-97	T2 West	Juvenile	17-Jul-00	2860	0.112	
888-160-66	T2 West	Juvenile	17-Jul-00	2440	0.109	
888-160-66	T2 West	Juvenile	22-Aug-00		0.246	2.36
888-161-41	T2 West	Juvenile	6-Aug-02	2150	0.175	
918-133-54	T2 West	Juvenile	6-Aug-02	3450	0.151	
918-133-68	T2 West	Juvenile	14-Aug-04	3425	0.314	3.09
918-133-79	T2 West	Juvenile	27-Jul-05	3375	0.370	