

MERCURY ACCUMULATION IN RAPTORS

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## **Dedication**

This thesis is dedicated to my father, Dr. Richard Keyel, without whom none of this would have happened. He is the person who really got me interested in science and then even more interested in birds. While not alive to see any of my graduate experience, I believe he would be proud of me.

## Abstract

Mercury (Hg) is a toxic heavy metal that when methylated to form methylmercury (MeHg), bioaccumulates in exposed organisms and biomagnifies through food webs. Most studies examining Hg concentrations in birds of prey have focused on species associated with aquatic systems such as Bald Eagle (*Haliaeetus leucocephalus*). My goal was to assess Hg concentrations in multiple species of migrating raptors in the upper Midwestern US. From 2009-2012, 966 raptors of 11 species were captured at Hawk Ridge, Duluth, MN, USA. Breast feathers were sampled and analyzed for total Hg concentrations, which is a good analog for methylmercury.

Mean Hg concentrations ranged from 0.11 – 3.46 ppm. Carbon and nitrogen stable isotope values were analyzed for Sharp-shinned Hawk (*Accipiter striatus*) and Merlin (*Falco columbarius*) because they had the highest mean Hg concentrations with 3.46 and 2.15 ppm respectively. Stable isotope analysis suggested that both species consumed terrestrial prey and that total Hg concentration increased with trophic level. Further analysis of Sharp-shinned Hawk and Merlin feather samples show Hg increases with age. The Hg concentrations observed in Sharp-shinned Hawks, Merlins, and Northern Goshawks (*Accipiter gentilis*) represent a concern when compared with concentrations found in the American Kestrel (*Falco sparverius*); one of the few raptors with enough experimental data for comparison.

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## Introduction

Analyses such as the Raptor Population Index use raptor migration data to estimate population trends of North American raptors (Farmer and Hussell 2008). These trends are important for assessing which populations are in decline. Birds of prey have large home ranges and are top predators, so they act as environmental indicators (Rodriguez-Estrella et al. 1998). Environmental contaminants can have significant impacts on raptor populations such as DDT's effect on Peregrine Falcon (*Falco peregrinus*) and Bald Eagle (*Haliaeetus leucocephalus*) populations (Grier 1982, Falk et al. 2006). These species and other raptors may act as a warning for the ecosystem as a whole. Mercury (Hg) is a naturally occurring heavy metal and when methylated into methylmercury (MeHg) is toxic to organisms (e.g., Evers et al. 2005, Albers et al. 2007, Heinz et al. 2011). Mercury data have not been presented for many species of raptors and previous studies tend to be restricted to single species such as Bald Eagles (e.g., Burger and Gochfeld 2009, Rutkiewicz et al. 2011), American Kestrels (*Falco sparverius*; eg. Albers et al. 2007, Fallacara et al. 2011a), and Peregrine Falcons (eg. Mora et al. 2002, Barnes and Gerstenberger 2015).

Human activities have increased the amount of Hg available in the environment, with coal-fired power plants being the largest source of anthropogenically-released Hg (Evers et al. 2007). Additional sources include wastewater plant discharge, chlor-alkali plants, artisanal gold mining, textile mills, and weapons manufacturing facilities (Driscoll 2007, Evers et al. 2007). Mercury from these sources is released into the atmosphere and deposited across the landscape. Total deposition rates have increased by 3.4 times since

the 1850s (Swain et al. 1992) and Hg bioavailability has increased in wetlands (Zillioux et al. 1993). Wetlands are important sites for methylation of Hg to form MeHg (Krabbenhof et al. 1997, King et al. 2001). The principal organisms responsible for methylation of Hg in wetland sediment are sulfate-reducing bacteria (SRB), primarily found in anoxic conditions (Compeau and Bartha 1985).

Sequestration of MeHg results in bioaccumulation in tissues. MeHg is thus transferred from the primary producers to the consumers which prey upon them (Haney and Lipsey 1973, Atwell et al. 1998). At each trophic level, consumers obtain bioaccumulated MeHg from the previous trophic level, which results in higher concentrations of MeHg (Jaeger et al. 2009). Larger birds often have higher Hg concentrations than smaller birds (Evers et al. 2005). This is important for raptors because birds of prey exhibit reverse sexual dimorphism, meaning females are larger than males (Newton 1979). Total Hg is a good analog for MeHg because other forms of Hg are not easily sequestered in tissues (Evers et al. 2005, Evers et al. 2011b, Rimmer et al. 2011), thus most Hg found in bird tissues is MeHg. However, birds can reduce their body MeHg burdens during molt and adult females can eliminate MeHg into eggs (Nichols et al. 2010). Feathers have a high affinity for MeHg sequestration and most of the MeHg in birds may be in their feathers (Nichols et al. 2010).

Biomagnified concentrations of MeHg cause adverse effects in organisms (Atwell et al. 1998). In birds, MeHg exposure can cause behavioral, reproductive, neurological, and hormonal changes (Scheuhammer et al. 2007). American Kestrels in captivity all died after about three weeks of being fed 12 ppm of MeHg (Bennett et al. 2009). Albers

et al. (2007) reported that the number of fledglings and percent of nestlings that fledged were markedly reduced at a concentration of 0.3 ppm Hg in the diet. Carolina Wrens (*Thryothorus ludovicianus*) exhibited a 10% decline in reproduction at feather MeHg concentrations of 2.4 ppm (Jackson et al. 2011). Evers et al. (2005) report detrimental effect threshold values for Common Loons (*Gavia immer*) to be 3.0 ppm in the blood and 40 ppm in feathers. Above those concentrations, Common Loons exhibited reproductive declines. In addition to reduced numbers of young and eggs hatched, MeHg can also have teratogenic effects, such as physical deformities (Heinz et al. 2011).

Stable isotopes of carbon and nitrogen can be used to trace diet sources and estimate trophic level. In addition, stable isotopes are used to trace MeHg sources and measure MeHg biomagnification between trophic levels (Atwell et al. 1998, Tavares et al. 2009, Lavoie et al. 2013). The ratio of  $^{15}\text{N}:^{14}\text{N}$  (generally reported in  $\delta$  notation as the  $\delta^{15}\text{N}$  value) can be used to determine the relative trophic position of organisms (Thompson, 1995, Bearhop 2002). Across trophic levels, stable isotope composition of a consumer closely resembles that of its prey, although stable isotope values are offset by the trophic fractionation of the tissue (Peterson and Fry 1987). For feathers, the fractionation rate for  $\delta^{15}\text{N}$  values is  $\sim 3\text{‰}$  and for  $\delta^{13}\text{C}$  values is  $\sim 2.2\text{‰}$  (Hobson and Clark 1992). Terrestrial and aquatic primary producers vary in the ratio of  $^{13}\text{C}:^{12}\text{C}$  (i.e.,  $\delta^{13}\text{C}$ ; Hobson 1999a). Primary producers in aquatic food webs generally have lower  $\delta^{13}\text{C}$  values compared to primary producers in terrestrial food webs with mean values of  $-35\text{‰}$  compared to  $-28\text{‰}$  respectively (Peterson and Fry 1987). With higher methylation rates in aquatic ecosystems compared with terrestrial ecosystems, the diet source may be an

important factor influencing Hg concentrations in birds. Raptor diets vary widely by species, and while most raptors consume terrestrial-based prey (e.g., Cooper's Hawk; Curtis et al. 2006), some raptors consume aquatic-based prey (e.g., Bald Eagle; Buehler 2000).

Little information is available on Hg concentrations for many wild raptors. My study goal was to determine Hg concentrations in birds of prey migrating through the center of the North American continent. I also explored life history characteristics associated with Hg concentrations and differences in Hg based on sex, age, and date of capture. Stable isotopes were used to determine relative trophic position and food base to examine relationships with Hg values. Due to their larger size, females may have higher concentrations of Hg than males. Older birds have lived longer and Hg burden may increase with age. I also expect raptors feeding at higher trophic levels and those associated with aquatic-based food webs to have higher concentrations of Hg than those at lower trophic levels and terrestrial-based food webs.

## Methods

### *Study Area*

All samples were collected during fall migration (September through November) from the banding station at Hawk Ridge, Duluth, MN, USA (46.847306°, -92.031934°) located near the westernmost point of Lake Superior (Evans et al. 2012). Situated at ~300 m above sea level, Hawk Ridge is positioned on basalt rock that extends along the north shore of the lake. Raptors migrating past Duluth are thought to originate from breeding grounds in Canada and northern Minnesota.

### *Samples*

Raptors were sampled from 2009-2012 (n = 966; Evans and Nicoletti, pers. comm.). Birds were captured using mist nets, bow nets and dho gazas (Evans et al. 2012). Captured birds were identified, aged as either hatch year (HY; birds in their first year of life) or after hatch year (AHY), sexed as either male or female, and banded using methods described by Pyle (2008). Two to four breast feathers were then plucked from the birds and placed in a small envelope.

### *Hg Analysis*

Feathers were analyzed for total mercury concentration by atomic absorption spectrometry using a DMA-80 Direct Mercury Analyzer (Milestone Inc.) at Biodiversity Research Institute in Portland, ME following methods described by Evers et al. (2005) and using Dolt-4 and Dorm-4 as standard reference materials. Mean Hg concentrations (+/- SE) were calculated for all 11 species (n > 10) and for age and sex classes for those species. Analysis of variance was used to compare the natural log of Hg concentrations

among species, age within species, sex within species and cohort within species. The Hg concentrations were log-transformed to achieve a normal distribution and homogenous variance.

I conducted further analysis for the two species with the highest mean Hg concentrations: Sharp-shinned Hawk (*Accipiter striatus*), and Merlin (*Falco columbarius*). Multimodel inference was used to generate variable importance values following Burnham and Anderson (2002). Multiple variables (year in which the bird was banded, ordinal day on which the bird was banded, age of the bird, sex of the bird, and all bivariate interaction terms) were compared against the natural log of the feather mercury concentration using general linear models. I then calculated variable importance based on Akaike's Information Criterion, corrected for small sample size ( $AIC_c$ , Burnham and Anderson 2002). Variable importance was calculated as the summation of  $AIC_c$  weight for each model in which the variable occurs (Burnham and Anderson 2002).

#### *Stable Isotope Analysis*

Breast feathers from Merlins and Sharp-shinned Hawks were analyzed for carbon and nitrogen stable isotope ratios. Feathers from a maximum of ten individual Sharp-shinned Hawk and Merlin from each age and sex class were selected for isotope analysis; however, there were only 20 total AHY Merlins. Each sample was cleaned with a 2:1 Chloroform:Methanol solution (Hobson 1999b) and then placed in pre-combusted scintillation vials and dried at 50°C for 12 hours. After drying, the samples were minced and 0.7 µg were placed into Costech 4x6 mm tin cups. Samples were then analyzed with a Costec 4010 EA and Thermo Delta Plus XP isotope ratio mass spectrometer. Stable

isotope ratios are reported in standard  $\delta$  notation, wherein Vienna Pee Dee Belemnite and air are standards for  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$ , respectively. The analytical error, the mean standard deviation of replicate reference material, was  $<0.1\%$  for  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$ . I estimated Pearson's correlation coefficients between Hg and  $\delta^{13}\text{C}$  and between Hg and  $\delta^{15}\text{N}$  by sex, age, and cohort within each species. All analyses were conducted in R (version 2.14.0; R Development Core Team 2013).

## Results

I measured breast feather total Hg concentrations in 11 raptor species and concentrations were detectable for all individuals (Figure 1, Appendix A). These concentrations varied by species and were highest in Sharp-shinned Hawks (Figure 1). American Kestrels and Long-eared Owls (*Asio otus*) were the only two species to average less than 2 ppm. Mean Hg concentrations and sample sizes varied among families and within Accipitridae and Falconidae (Table 1). Broad-winged Hawk (*Buteo platypterus*) and Long-eared Owl had mean Hg concentrations  $<1.0$  ppm and Northern Harrier (*Circus cyaneus*) mean Hg concentrations were between 1 and 2 ppm. Accipitridae tended to have higher concentrations of Hg with Cooper's Hawk (*Accipiter cooperii*), Northern Goshawk (*Accipiter gentilis*) averaging between 1 and 2 ppm, and Sharp-shinned Hawks  $>2$  ppm. In Falconidae, mean Hg concentrations ranged from 0.61 ppm in American Kestrel (min-max: 0.03-3.32 ppm) to 2.15 ppm in Merlin (min-max: 0.14-15.95 ppm).

After hatch year birds had significantly higher feather Hg than HY, but sex differences in Hg were only significant for Merlin (Table 2). Combined sex and age categories were significant for all species that also showed a significant difference in age,

likely affected by those Hg concentration differences. After hatch year Merlins and Sharp-shinned Hawks had the highest concentrations with means of 5.61 ( $\pm$  0.80) and 4.97 ( $\pm$  0.23) ppm respectively (Figure 2).

In Merlins, ordinal day and age had the highest AIC<sub>c</sub> weight with values of 0.98 and 0.95 respectively and Hg increased with both. The best model (lowest AIC<sub>c</sub>) included ordinal day with sex and age interactions (Table 3). Merlins migrating later in the season had higher concentrations of Hg than those earlier in the season, while HY and males had lower feather Hg concentrations than AHY and females (Figure 3). The best model for Sharp-shinned Hawk was year and age (Table 4). Sharp-shinned hawks captured in 2009 had higher feather Hg concentrations than in the following years and AHY birds were found to have higher Hg concentrations than HY birds (Table 5).

There was considerable overlap for  $\delta^{15}\text{N}$  and  $\delta^{13}\text{C}$  values for Sharp-shinned Hawk and Merlin (Figure 4, Appendix B). The  $\delta^{13}\text{C}$  values suggest both species are feeding in terrestrial-based food webs (means -21.84‰ and -22.04‰ respectively). In Sharp-shinned Hawks,  $\delta^{15}\text{N}$  values were correlated with  $\ln(\text{Hg})$  for most age and sex cohorts (Pearson's Correlation Test mean: 0.30  $p < 0.01$ ), but  $\delta^{13}\text{C}$  values were not ( $r = -0.22$ ,  $p > 0.05$ ). Merlin feathers also showed a significant correlation between  $\delta^{15}\text{N}$  values and  $\ln(\text{Hg})$  ( $r = 0.29$ ,  $p = 0.03$ ), and only HY males showed a significant relationship with  $\delta^{13}\text{C}$  values ( $r = -0.57$ ,  $p < 0.01$ ). These  $\delta^{13}\text{C}$  values were also consistent across age and sex cohorts (Figure 5). There was little difference in  $\delta^{15}\text{N}$  values between ages of Sharp-shinned Hawks, though there was  $\sim 1.5$ ‰ difference between HY and AHY Merlins which could indicate that these birds are feeding at different trophic levels (Figure 6).



## Discussion

I found that Hg concentration in migrating raptors vary widely. Mercury contamination in birds has been an ongoing concern and little data were available for wild raptors. American Kestrel is the only raptor species with experimental Hg exposure data, but those studies focused on dietary dosage rather than the birds' natural diet. I discuss here the variations and patterns in Hg concentrations within and across species of raptors trapped along the Central Flyway. I also provide an estimated adverse reproductive effects threshold in feathers of captive female American Kestrels to put the results from wild birds in context.

### *General Hg Comparisons*

I found feather Hg concentrations in Peregrine Falcons (mean of 1.43 ppm) were similar to the mean 2.06 ppm Hg in Peregrine Falcons sampled in Texas (Mora et al. 2002). Zolfaghari et al.'s (2007) mean feather concentrations of 1.00 ppm Hg in Northern Goshawk was also similar to my mean of 1.23 ppm Hg in Northern Goshawks. However, their mean feather concentration of 1.03 ppm Hg in Sparrowhawk (*Accipiter nisus*) is lower than my mean feather concentration of 3.26 ppm Hg in Sharp-shinned Hawk.

### *Food Selection*

Species with mean feather Hg concentrations less than 1 ppm were generally small mammal specialists, while those with mean concentrations over 2 ppm were primarily avian specialists. Species with mean Hg concentrations between 1 and 2 ppm tended to feed upon more diverse prey (e.g., combinations of mammals and birds). American Kestrels and Long-eared Owls are both under 1 ppm and are both mammal

specialists, though Kestrels also prey upon arthropods (Marks et al. 1994, Smallwood and Bird 2002). Merlins and Sharp-shinned Hawks are predominantly small bird specialists, though migrating Merlins will also depredate insects (Bildstein and Meyer 2000, Warkentin et al. 2005). Cooper's Hawks, Northern Goshawks and Northern Harriers tend to prey on both mammals and birds and had Hg values between mammal and bird specialists (Squires and Reynolds 1997, Curtis et al. 2006, Smith et al. 2011). For comparison, Bowerman et al. (1994) found Hg concentrations in body feathers of adult Bald Eagle to range from 0.20-48 ppm with an average of 21 ppm. While Bald Eagles have a general diet, they are primarily piscivorous (Buehler 2000).

I hypothesized that feather Hg differences among raptor species would reflect differences in food webs and trophic position, such that the diet of mammal specialists would be based in a terrestrial food web, whereas bird specialists diet would be based in an aquatic food web. While I did not measure stable isotope ratios for any of the mammal specialists, stable isotope ratios for two species of bird specialists (Merlins, Sharp-shinned Hawks) indicated their diet was based in terrestrial food webs. Therefore, the generalization that diets of these bird specialists were based in an aquatic food web is not supported. My stable isotope data were consistent with Hobson's (1999b) Sharp-shinned Hawk  $\delta^{15}\text{N}$  values of 7.1‰, though their  $\delta^{13}\text{C}$  value of -25.6‰ was lower than our mean of -22.0‰. If bird specialists' food chains are longer than mammal specialists' food chains, then this is a possible explanation for why bird specialists have higher concentrations of Hg. Mercury was significantly correlated with  $\delta^{15}\text{N}$  for Sharp-shinned Hawks and Merlins. Sharp-shinned Hawks feeding at higher trophic levels had higher Hg

concentrations than those feeding at lower trophic levels. Spiders have high concentrations of Hg, and could be one possible explanation why raptors feeding on insectivorous songbirds would have higher Hg loads than those feeding on mammals (Cristol et al. 2008, Gann et al. 2015).

### *Sex Patterns*

I hypothesized that females would have higher Hg concentrations than males because they are larger. Of the 11 species tested, only the Merlin had significantly higher Hg concentrations in females. Reverse sexual dimorphism is more extreme in Accipiters like Sharp-shinned Hawks (Snyder and Wiley 1976). If size were an important factor, then I would expect Accipiters to have significant differences in feather Hg among sexes. However, because only Merlin had a significant difference between males and females, it seems unlikely that reverse sexual dimorphism is responsible for the observed Hg bioaccumulation pattern. Similarly, my data suggest it is unlikely that diet differences between males and females have an impact on Hg burden. Adult females can eliminate Hg in their eggs, lowering their overall body burden (Lewis et al. 1993, Ackerman 2007, Nichols 2010). However, this mechanism also resulted in no difference in feather Hg between males and females.

### *Age Patterns*

AHY birds had higher Hg concentrations in all species except Long-eared Owl and Cooper's Hawk, but this may be due to low Hg concentrations and small sample size respectively. Older birds have had more time to bioaccumulate Hg (Evers et al. 1998). Mercury increased in older Merlins, but it also increased throughout the migration

season. HY birds migrate past Hawk Ridge earlier in the year than AHY, which is consistent with previous studies (e.g. Mueller et al. 2004). While not statistically significant, some AHY Merlins had greater  $\delta^{13}\text{C}$  values than HY which could indicate a dietary shift with age. The mean concentration of 1.44 ppm in HY Peregrine Falcons observed in this study is lower than the mean concentrations of 3.76 ppm in HY Peregrine Falcons in Nevada (Barnes and Gerstenberger 2015). There are higher environmental concentrations of total Hg in Nevada than northern Minnesota (NADP-3 2007), likely due to higher deposition rates.

#### *Temporal Differences*

For Merlins, ordinal day was the most important covariate to Hg feather concentration. For many species of raptors, including Merlin and Sharp-shinned Hawk, younger birds migrate earlier than older birds (Mueller et al. 2000). Therefore, it is possible that ordinal day was another index to age. However, ordinal day was not an important variable in the Sharp-shinned Hawk models. Instead, year was more important than ordinal day. Birds captured in 2009 had the highest mean Hg concentration, whereas those captured in 2010 had the lowest mean Hg concentration. Both 2012 and 2013 had intermediate mean Hg concentrations. These patterns are consistent for both age classes. Based on these data, there is no apparent explanation why Hg concentrations would be higher in 2009 and then drop in 2010, except the possibility that populations of Sharp-shinned Hawk sampled in these years were from different regions of the United States and Canada with different Hg exposures.

### *American Kestrel Reproductive Adverse Effects Threshold*

No studies have reported adverse effects thresholds for raptors. Laboratory dosing studies with American Kestrels have established effects thresholds for reproductive declines in response to dietary Hg in captive females. Although Nichols et al. (2010) did not report modeled concentrations in feathers, they did report that the expected ratio of total Hg in feathers compared to whole blood is ~15. As indicated earlier, Albers et al. (2007) reported adverse reproductive effects in American Kestrels dosed with 0.3 ppm/day. If proportionality was maintained, this would correspond to a blood Hg concentration of 2.5 ppm. Multiplying this by 15.0 gives a feather Hg concentration of 37.5 ppm which is close to the 40 ppm threshold found in Common Loons by Evers et al. (2007). These values suggest that raptors with Hg concentrations of 37.5 ppm or higher likely would have reduced reproductive success or potentially other Hg-related effects.

### *Conclusion*

Feather Hg concentrations varied within and among species. There were higher concentrations in AHY birds than HY. Mercury concentrations in raptors appear to vary by diet strategy, with bird specialists having higher concentrations than mammal specialists. Stable isotope values for Sharp-shinned Hawks and Merlins suggest both species are feeding in terrestrial-based food webs and that Hg varies by trophic level. For all samples measured, concentrations were below the 37.5 ppm threshold calculated using reproductive effects data for American Kestrels. However, feather Hg concentrations in some individuals were over 10 ppm, which were within a factor of three of the 37.5 ppm threshold. This threshold was calculated based on birds in captivity and may not have the

same relevance to birds in the wild. It is likely that the hazards and stress of migration, demands for obtaining food, avoiding predators, and several other factors to which birds are exposed would lower that threshold.

Figures and Tables

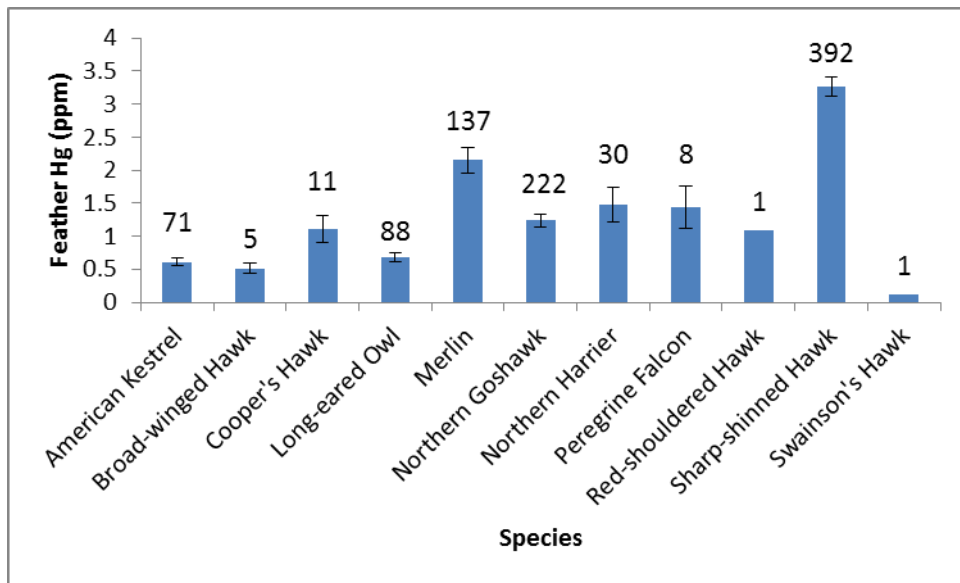


Figure 1. Mean mercury accumulation in 966 birds of prey banded at Hawk Ridge, Duluth, MN USA from 2009-2012. Sample size is listed above each bar and error bars represent one standard error.

Table 1 Summary data for all 11 species sampled. All samples are from Hawk Ridge, Duluth, MN, USA from 2009-2012. Sample size by age and sex classes, mean with minimum and maximum feather mercury concentrations, general diet preferences and mean with minimum and maximum  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  are provided. Age is either hatch year (HY), after hatch year (AHY) or unknown (U); Sex is either male (M), female (F), or unknown (U).

Species	Age (N)			Sex (N)			Total	Hg (ppm)	Diet Preference	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$
	HY	AHY	U	M	F	U		$\bar{X}$ (Min-Max)		$\bar{X}$ (Min-Max)	$\bar{X}$ (Min-Max)
AMKE	53	5	13	37	34	-	71	0.61 (0.03-3.32)	vertebrates and terrestrial arthropods	-	-
BWHA	5	-	-	-	-	5	5	0.51 (0.36-0.80)	vertebrates and arthropods	-	-
COHA	4	7	-	7	4	-	11	1.1 (0.17-2.65)	birds and mammals	-	-
LEOW	15	68	5	7	7	74	88	0.67 (0.09-4.71)	small mammals	-	-
MERL	117	20	-	77	60	-	137	2.15 (0.14-15.95)	birds and arthropods	-21.94 (-24.11- -16.15)	6.98 (3.61-13.8)
NOGO	196	26	-	152	70	-	222	1.23 (0.15-16.41)	birds and mammals	-22.04 (-23.64 - -20.73)	6.16 (4.03-8.99)
NOHA	25	5	-	17	13	-	30	1.48 (0.32-6.18)	birds and mammals	-	-
PEFA	8	-	-	5	3	-	8	1.43 (0.40-2.76)	birds	-	-
RSHA	1	-	-	0	-	1	1	1.09	vertebrates	-	-
SSHA	197	195	-	179	213	-	392	3.26 (0.40-27.18)	birds	-	-
SWHA	1	-	-	-	-	1	1	0.11	birds and mammals	-	-



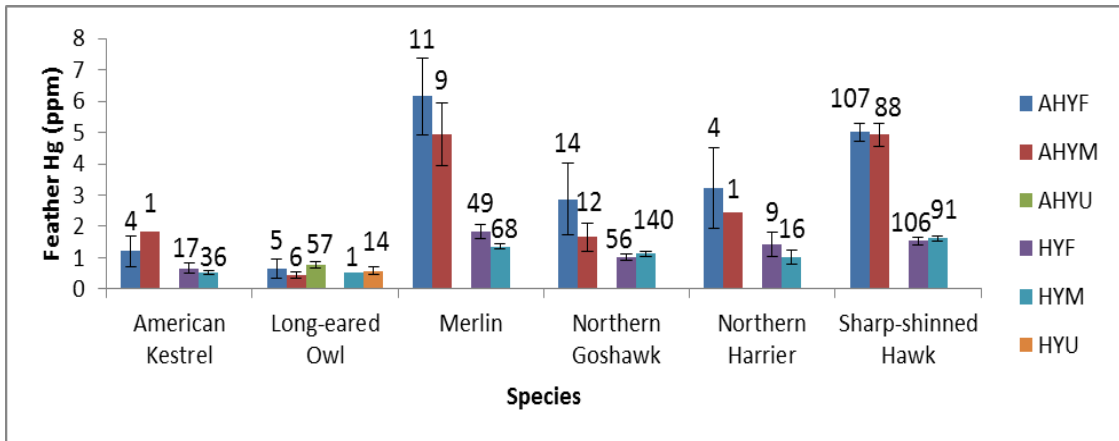


Figure 2. Mean mercury (Hg) accumulation in birds of prey by cohort. Mercury (ppm) concentrations in all age and sex combinations of raptors banded at Hawk Ridge, Duluth, MN from 2009-2012 with total individual species sample size >20. Sample size for each cohort is listed above each bar and error bars represent one standard error. AHYF = after hatch year female, AHYM = after hatch year male, AHYU = after hatch year unknown sex, HYF = hatch year female, HYM = hatch year male, and HYU = hatch year unknown sex.

Table 2. Analysis of variance comparisons of log-transformed Hg concentrations in feathers by species' sex, age and all sex and age combinations (cohort) including sample size. The p-values are shown and the level of significance indicated by asterisk. All samples are from Hawk Ridge, Duluth, MN, USA from 2009-2012. Sex is either male or female, Age is either hatch year (HY) or after hatch year (AHY), and Cohort is all possible Sex and Age combinations.

Species	Scientific Name	N	Sex	Age	Cohort
Northern Harrier	<i>Circus cyaneus</i>	30	0.1	0.01*	0.04*
Sharp-shinned Hawk	<i>Accipiter striatus</i>	392	0.91	<0.01***	<0.01***
Cooper's Hawk	<i>Accipiter cooperii</i>	11	0.47	0.42	0.42
Northern Goshawk	<i>Accipiter gentilis</i>	222	0.26	<0.01***	<0.01***
Long-eared Owl	<i>Asio otus</i>	88	0.52	0.26	0.66
American Kestrel	<i>Falco sparverius</i>	71	0.47	0.01**	0.02*
Merlin	<i>Falco columbarius</i>	137	0.03*	<0.01***	<0.01***
All	-	966	<0.01***	<0.01***	<0.01***

\*significant at < 0.05, \*\* significant at < 0.01, \*\*\* significant at < 0.001

Table 3. AIC, Wt, and adjusted  $R^2$  values for Merlin banded at Hawk Ridge, Duluth, MN, USA from 2009-2012. Calendar is ordinal day from 1 – 365, year ranges from 2009-2012, sex is either male or female, age is either hatch year (HY) or after hatch year (AHY), K is the number of factors in each model, Wt is the relative likelihood of the model. Minimum  $AIC_c$  value was 210.93 and all  $\Delta AIC_c$  terms were compared against it.

Candidate Models	K	$\Delta AIC_c$	Wt	$R^2_{adj}$
Calendar + Sex * Age	6	0.00	0.37	0.45
Calendar * Age	5	0.42	0.30	0.44
Calendar * Year + Sex * Age	8	0.65	0.26	0.46
Calendar + Age	4	3.57	0.06	0.43
Sex + Age	4	8.19	0.01	0.41
Year + Sex * Age	6	10.12	0.00	0.41
Sex * Age	5	10.31	0.00	0.40
Year * Age	5	11.46	0.00	0.40
Age	3	12.04	0.00	0.38
Year + Age	4	12.13	0.00	0.39
Calendar + Sex	4	29.99	0.00	0.30
Calendar * Sex	5	31.79	0.00	0.30
Year + Calendar	4	36.63	0.00	0.27
Calendar	3	37.70	0.00	0.26
Year * Calendar	5	38.03	0.00	0.27
Sex	3	72.82	0.00	0.04
Year + Sex	4	73.35	0.00	0.04
Year * Sex	5	75.48	0.00	0.04
Year	3	78.23	0.00	0.00

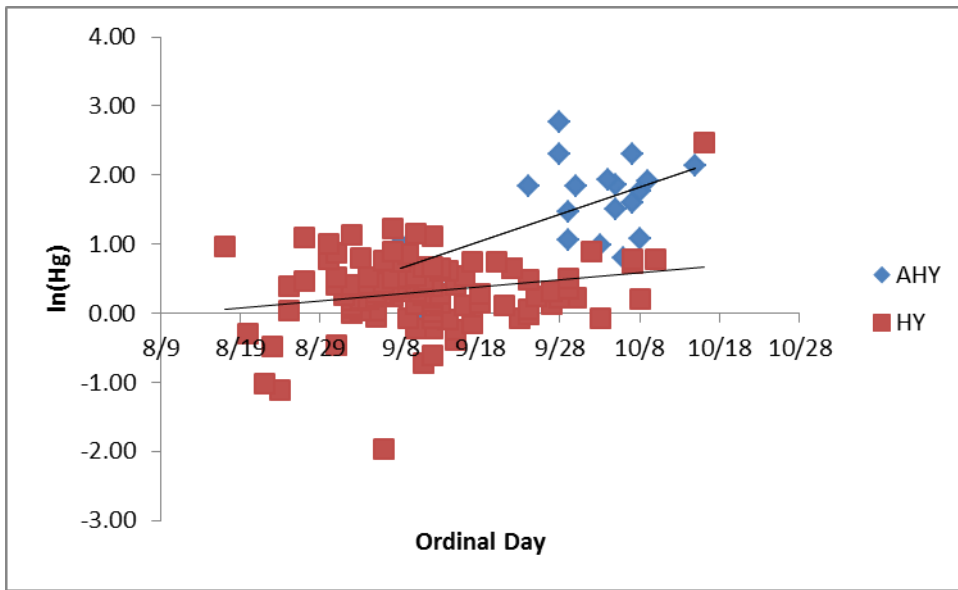


Figure 3. The relationship between Merlin ln(Hg) and ordinal day by age. All feathers were collected at Hawk Ridge, Duluth, MN, USA from 2009-2012. After hatch year (AHY; diamonds) increased significantly ( $\beta=0.039$ , SE= 0.014,  $p=0.011$ ,  $R^2=0.30$ ) as did hatch year (HY; squares;  $\beta=0.010$ , SE= 0.004,  $p=0.016$ ,  $R^2=0.05$ ).

Table 4.  $AIC_c$  values for Sharp-shinned Hawk banded at Hawk Ridge, Duluth, MN, USA from 2009-2012. Calendar is the ordinal day from 1 – 365, year ranges from 2009-2012, Sex is either male or female, Age is either hatch year (HY) or after hatch year (AHY) K is the number of factors in each model, Wt is the relative likelihood of the model. The minimum  $AIC_c$  value was 520.85 and all  $\Delta AIC_c$  terms were compared against it.

Candidate Models	K	$\Delta AIC_c$	Wt	$R^2_{adj}$
Year + Age	4	0.00	0.52	0.59
Year * Age	5	1.90	0.20	0.59
Year + Sex * Age	6	3.16	0.11	0.59
Calendar * Year + Sex * Age	8	3.56	0.09	0.59
Calendar * Age	5	5.27	0.04	0.59
Calendar + Age	4	5.94	0.03	0.59
Calendar + Sex * Age	6	8.55	0.01	0.59
Age	3	9.98	0.00	0.58
Sex + Age	4	11.27	0.00	0.58
Sex * Age	5	12.48	0.00	0.58
Calendar * Sex	5	289.46	0.00	0.15
Calendar + Sex	4	293.39	0.00	0.14
Year + Calendar	4	297.21	0.00	0.13
Calendar	3	297.88	0.00	0.13
Year * Calendar	5	298.73	0.00	0.13
Year	3	350.46	0.00	0.00
Sex	3	351.72	0.00	0.00
Year * Sex	5	352.10	0.00	0.00
Year + Sex	4	352.34	0.00	0.00

Table 5. Sharp-shinned Hawk sample size, mean ordinal day, mean ln(Hg) and standard error by year for each age class. The top rows are for after-hatch-year (AHY) birds and the bottom are for hatch-year (HY) birds.

Year	N	Mean Ordinal	Mean ln(Hg)
2009	27	3-Oct	1.80 ( $\pm$ 0.09)
2010	13	30-Sep	1.10 ( $\pm$ 0.08)
2011	81	24-Sep	1.43 ( $\pm$ 0.06)
2012	78	1-Oct	1.45 ( $\pm$ 0.06)
Total AHY	199	28-Sep	1.47 ( $\pm$ 0.04)
2009	35	2-Oct	0.67 ( $\pm$ 0.09)
2010	69	12-Sep	0.25 ( $\pm$ 0.04)
2011	37	19-Sep	0.31 ( $\pm$ 0.06)
2012	59	16-Sep	0.29 ( $\pm$ 0.06)
Total HY	200	18-Sep	0.35 ( $\pm$ 0.03)

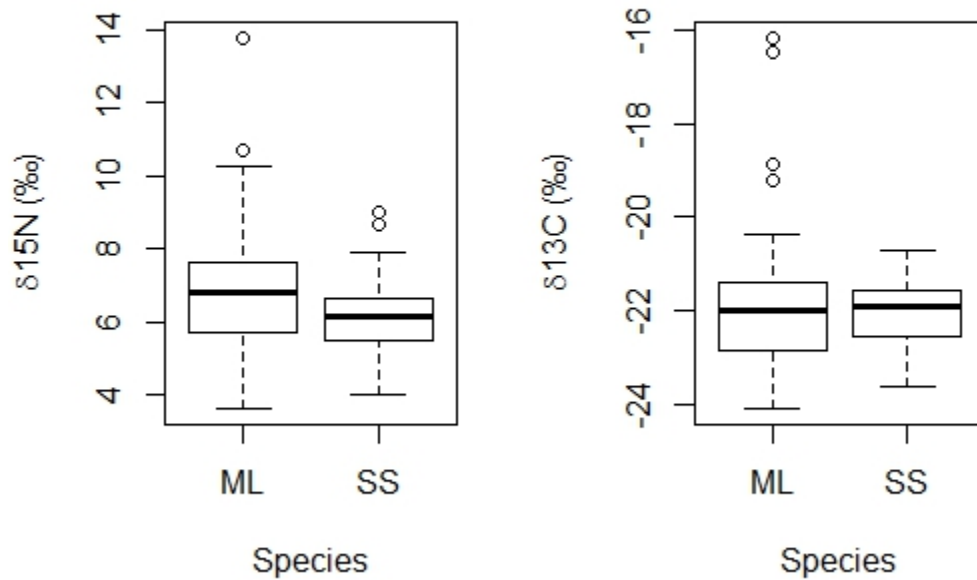


Figure 4. Boxplots of  $\delta^{15}\text{N}$  and  $\delta^{13}\text{C}$  for Sharp-shinned Hawk (SS) and Merlin (ML) caught at Hawk Ridge, Duluth, MN, USA. The center line represents the median, the bottom and top of the box are the 25<sup>th</sup> and 75<sup>th</sup> quartiles respectively. The whiskers correspond to ~95% confidence interval and the circles are outliers.

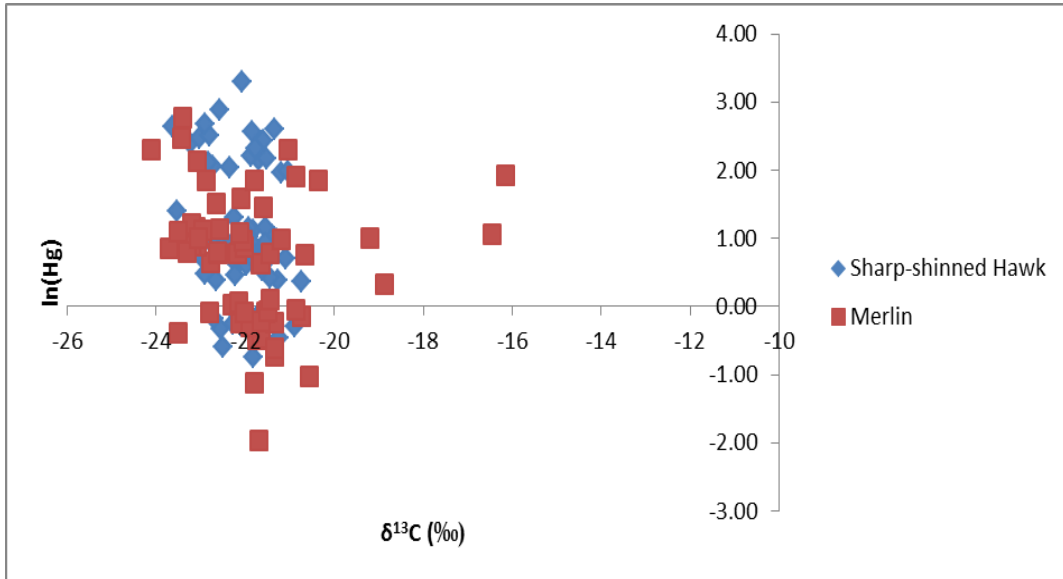


Figure 5. Values for  $\delta^{13}\text{C}$  against  $\ln(\text{Hg})$  concentrations for Sharp-shinned Hawks (diamonds) and Merlin (squares) caught at Hawk Ridge, Duluth, MN, USA.



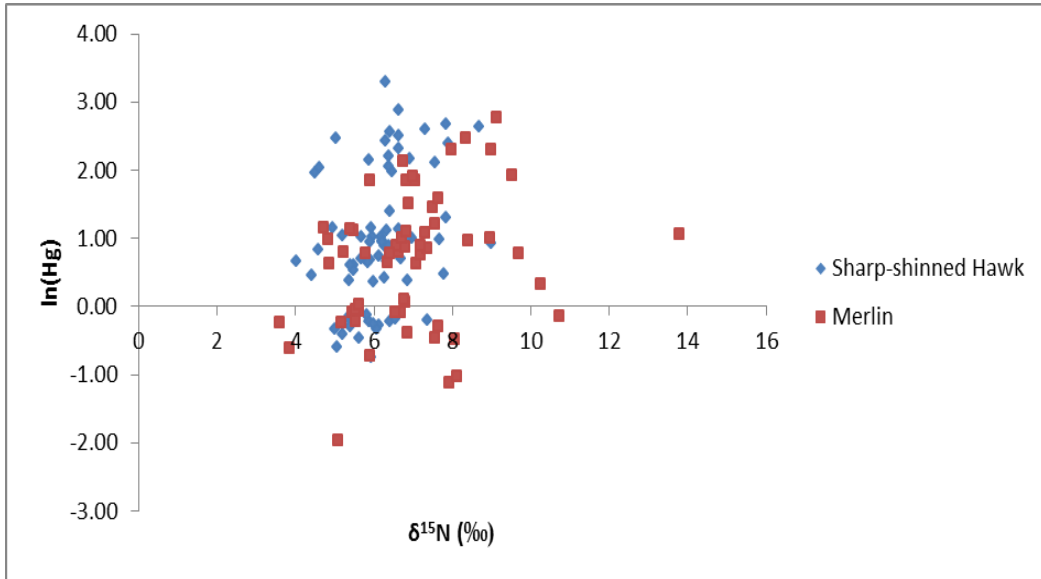


Figure 6. Values for  $\delta^{15}\text{N}$  against  $\ln(\text{Hg})$  concentrations for Sharp-shinned Hawks (diamonds) and Merlin (squares) caught at Hawk Ridge, Duluth, MN, USA.

## **Bibliography**

- Akearok, J.A. et al. (2010). Inter-and intraclutch variation in egg mercury levels in marine bird species from the Canadian Arctic. *Sci. of the Tot. Env.* 408: 836-840.
- Albers, P.H., M.T. Koterba, R. Rossman, W.A. Link, J.B. French, R.S. Bennett, and W.C. Bauer. (2007). Effects of methylmercury on reproduction in American Kestrels. *Env. Tox. and Chem.* 26: 1856-1866
- Atwell, L., K.A. Hobson, and H.E. Welch. (1998). Biomagnification and bioaccumulation of mercury in an arctic marine food web: insights from stable nitrogen isotope analysis. *Can. J. Fish. Aq. Sci.* 55: 1114-1121.
- Barkay, T. and I. Wagner-Doebler. (2005). Microbial transformations of mercury: potentials, challenges, and achievements in controlling mercury toxicity in the environment. *Adv. In App. Micro.* 57: 1-54
- Barnes, J.G., S.L. Gerstenberger. (2015). Using feathers to determine mercury contamination in Peregrine Falcons and their prey. *J. Raptor Res.* 49: 43-58.
- Bearhop, S. S. Waldron, S.C. Votier, and R.W. Furness. (2002). Factors that influence assimilation rates and fractionation of nitrogen and carbon stable isotopes in avian blood and feathers. *Physiological and Biochemical Zoology* 75: 451-458.
- Bennett, R.S., JB. French, R. Rossmann, and R. Haebler. (2009). Dietary toxicity and tissue accumulation of methylmercury in American Kestrels. *Arch. Env. Cont. Tox.* 56: 149-156.

- Bildstein, K.L. and K. Meyer. (2000). Sharp-shinned Hawk (*Accipiter striatus*). *In* The Birds of North America, no. 482 (A. Poole, Ed.). Birds of North America, Philadelphia.
- Bowerman IV, W.W., E.D. Evans, J.P. Giesy, and S. Postupalsky. 1994. Using feathers to assess risk of mercury and selenium to Bald Eagle reproduction in the great lakes region. *Arch. Env. Cont. Tox.* 27: 294-298.
- Buehler, D.A. (2000). Bald Eagle (*Haliaeetus leucocephalus*). *In* The Birds of North America, no. 506 (A. Poole Ed.). Birds of North America, Philadelphia.
- Burger, J and M. Gochfeld. (2009). Comparison of arsenic, cadmium, chromium, lead, manganese, mercury and selenium in feathers of bald eagles (*Haliaeetus leucocephalus*), and comparison with common eider (*Somateria mollissima*), glaucous-winged gull (*Larus glaucescens*, pigeon guillemot (*Cephus columba*), and tufted puffin (*Fratercula cirrhata*) from the Aleutian chain of Alaska. *Environ. Monit. Assess.* 152: 357-367.
- Butler, T.J., M.D. Cohen, F.M. Vermeulen, G.E. Likens, D. Schmeltz, and R.S. Artz. (2008). Regional precipitation mercury trends in the eastern USA, 1998-2005: declines in the northeast and midwest, no trend in the southeast. *Atm. Env.* 42: 1582-1592.
- Burnham, K.P. and D.R. Anderson. (2002). Model selection and multimodel inference: a practical information-theoretic approach. Springer Science & Business Media, New York, New York, USA.
- Compeau, G.C. and R. Bartha. (1985). Sulfate-reducing bacteria: principal

methylators of mercury in anoxic estuarine sediment. *App. and Env. Micro.* 50: 498-502.

Cristol, D.A., R.L. Brasso, A.M. Condon, R.E. Fovargue, S.L. Friedman, K.K.

Hallinger, A.P. Monroe, and A.E. White. (2008). The movement of aquatic mercury through terrestrial food webs. *Science* 320: 335.

Curtis, O.E., R.N. Rosenfield, and J. Bielefeldt. (2006). Cooper's Hawk (*Accipiter cooperii*). *In* *The Birds of North America*, no. 075 (A. Poole Ed.). Birds of North America, Philadelphia.

Devereux, R., M.R. Winfrey, J. Winfrey, and D.A. Stahl. (1996). Depth profile of sulfate-reducing bacterial ribosomal RNA and mercury methylation in an estuarine sediment. *FEMS Micro. Eco.* 20: 23-31.

Driscoll, C.T., Y.J. Han, C.Y. Chen, D.C. Evers, K.F. Lambert, T.M. Holsen, N.C. Kamman, and R.K. Munson. (2007). Mercury contamination in forest and freshwater ecosystems in the northeastern United States. *BioScience* 57: 17-28.

Evans, D.L., G.J. Niemi, and M.A. Etterson. (2012). Autumn raptor banding at hawk ridge, Duluth, Minnesota, USA, 1972-2009: An overview. *J. Raptor Res.* 46: 36-49.

Evers, D.C., N.M. Burgess, L. Champoux, B. Hoskins, A. Major, W.M. Goodale, R.J. Taylor, R. Poppenga, and T. Daigle. (2005). Patterns and interpretation of mercury exposure in freshwater avian communities in northeastern North America. *Ecotoxicology* 14: 193-221.

- Evers, D.C., Y. Han, C.T. Driscoll, N.C Kamman, M.W. Goodale, K.F. Lambert, T.M. Holsen, C.Y. Chen, T.A. Clair, and T. Butler. (2007). Biological mercury hotspots in northeastern United States and southeastern Canada. *BioScience* 57: 29-43.
- Evers, D.C., K.A. Williams, M.W. Meyer, A.M. Scheuhammer, N. Schoch, A.T. Gilbert, L. Siegel, R.J. Taylor, R. Poppenga, and C.R. Perkins. (2011a). Spatial gradients of methylmercury for breeding common loons in the Laurentian great lakes region. *Ecotoxicology* 20: 1609-1625.
- Evers, D.C., J.G. Wiener, N. Basu, R.A. Bodaly, H.A. Morrison, and K.A. Williams. (2011b). Mercury in the great lakes region bioaccumulation, spatiotemporal patterns, ecological risks, and policy. *Ecotoxicology* 20: 1487-1499.
- Evers, D.C., J.D. Kaplan, M.W. Meyer, P.S. Reaman, W.E. Braselton, A. Major, N. Burgess, and A.M. Schuehammer. (1998). Geographic trend in mercury measured in Common Loon feathers and blood. *Env. Tox. And Chem.* 17: 173-183.
- Fallacara, D.M., R.S. Halbrook, J.B. French. (2011a). Toxic effects of dietary methylmercury on immune system development in american kestrels (*Falco sparverius*). *Env. Tox. and Chem.* 30: 1328-1337.
- Fallacara, D.M., R.S. Halbrook, and J.B. French. (2011b). Toxic effects of dietary methylmercury on immune function and hematology in American Kestrels (*Falco sparverius*). *Env. Tox. and Chem.* 30: 1320-1327.
- Falk, K. Møller, and W.G. Mattox. (2006). A long-term increase in eggshell thickness

- of Greenlandic Peregrine Falcons *Falco peregrinus tundrius*. *Sci. of the Tot. Env.* 355: 127-134.
- Farmer, C. J., & Hussell, D. J. (2008). The raptor population index in practice. *State of North America's birds of prey. Series in Ornithology.* 3:165-178.
- French, J.B., R.S. Bennett, and R. Rossmann. (2010). Mercury in the blood and eggs of American Kestrels fed methylmercury chloride. *Env. Tox. And Chem.* 29: 2206-2210.
- Gann, G.L., C.H. Powell, M.M. Chumchal, and R.W. Drenner. (2015). Hg-contaminated terrestrial spiders pose a potential risk to songbirds at Caddo Lake (Texas/Louisiana, USA). *Env. Tox. And Chem.* 34: 303-306.
- Goodale, M.W., D.C. Evers, S.E. Mierzykowski, A.L. Bond, N.M. Burgess, C.I. Otorowski, L.J. Welch, C.S. Hall, J.C. Ellis, R.B. Allen, A.W. Diamond, et al. (2008). Marine foraging birds as bioindicators of mercury in the Gulf of Maine. *EcoHealth* 5: 409-425.
- Grier, J.W. (1982). Ban of DDT and subsequent recovery of Reproduction in Bald Eagles. *Science* 218: 1232-1235.
- Haney, A. and R.L. Lipsey. (1973). Accumulation and effects of methyl mercury hydroxide in a terrestrial food chain under laboratory conditions. *Environ. Pollut.* 5: 305-316.
- Hawley, D.M., K.K. Hallinger, and D.A. Cristol. (2009). Compromised immune competence in free-living tree swallows exposed to mercury. *Ecotoxicology* 18:499-503.

- Heinz, G.H., D.J. Hoffman, J.D. Klimstra, K.R. Stebbins, S.L. Kondrad, and C.A. Erwin. (2009). Species differences in the sensitivity of avian embryos to methylmercury. *Arch. Env. Cont. Tox.* 56: 129-138.
- Heinz, G.H., D.J. Hoffman, J.D. Klimstra, and K.R. Stebbins. (2010). Reproduction in mallards exposed to dietary concentrations of methylmercury. *Ecotoxicology* 19:977:982.
- Hobson, K.A. and R.G. Clark. (1992). Avian diets using stable isotopes II: Factors influencing diet-tissue fractionation. *The Condor* 94: 189-197.
- Hobson, K.A. (1999a). Tracing origins and migration of wildlife using stable isotopes: a review. *Oecologia* 120: 314-326.
- Hobson, K.A. (1999b). Stable-carbon and nitrogen isotope ratios of songbird feathers grown in two terrestrial biomes: implications for evaluating trophic relationships and breeding origins. *The Condor* 101: 799-805.
- Hrabik, T.R., and C.J. Watras. (2002). Recent declines in mercury concentration in a freshwater fishery: isolating the effects of de-acidification and decreased atmospheric mercury deposition in Little Rock Lake. *Sci. of the Tot. Env.* 297: 229-237.
- Jackson, A.K., D.C. Evers, M.A. Etterson, A.M. Condon, S.B. Folsom, J. Detweiler, J. Schmerfeld, and D.A. Cristol. (2011). Mercury exposure affects the reproductive success of a free-living terrestrial songbird, the Carolina Wren (*Thryothorus ludovicianus*). *The Auk* 128: 259-769.
- Jaeger, I., H. Hop, and G.W. Gabrielsen. (2009). Biomagnification of mercury in

selected species from an Arctic marine food web in Svalbard. *Sci. of the Tot. Env.* 407: 4744-4751.

King, J.K, J.E. Kostka, M.E. Frischer, F.M. Saunders, and R.A. Jahnke. (2001). A quantitative relationship that demonstrates mercury methylation rates in marine sediments are based on community composition and activity of sulfate-reducing bacteria. *Environ. Sci. Technol.* 35: 2491-2496.

Krabbenhoft, D.P., J.G. Wiener, W.G. Brumbaugh, M.L. Olson, J.E. DeWild, and T.J. Sabin. (1997). A national pilot study of mercury contamination of aquatic ecosystems along multiple gradients. USGS.

Lavoie, R.A., C.E. Hebert, J.F. Rail, B. M. Braune, E. Yumvihoze, L.G. Hill and D.R.S. Lean. (2010). Trophic structure and mercury distribution in a Gulf of St. Lawrence (Canada) food web using stable isotope analysis. *Sci. of the Tot. Env.* 408: 5529-5539.

Lavoie, R.A., T.D. Jardine, M.M. Chumchal, K.A. Kidd, and L.M. Campbell. (2013). Biomagnification of mercury in aquatic food webs: a worldwide meta-analysis. *Env. Sci. and Tech.* 47: 13385-13394.

Lewis, S.A., P.H. Becker, and R.W. Furness. (1993). Mercury levels in eggs, tissues, and feathers of Herring Gulls *Larus argentatus* from the German Wadden Sea coast. *Env. Poll.* 80: 293-299.

Lindberg, P. 1984. Mercury in feathers of Swedish Gyrfalcons, *Falco rusticolis*, in relation to diet. *Bul. Env. Cont. Tox.* 32: 453-459.

Marks, J.S., D.L. Evans and D.W. Holt. 1994. Long-eared Owl (*Asio otus*). *In* The



Birds of North America, no. 133 (A. Poole Ed.). Birds of North America, Philadelphia.

- Marvin-DiPasquale, M., J. Agee, C. McGowan, R.S. Oremland, M. Thomas, D. Krabbenhoft, and C.C. Gilmour. (2000). Methyl-mercury degradation pathways: a comparison among three mercury-impacted ecosystems. *Env. Sci. Tech.* 24: 4908-4916.
- Mora, M., R. Skiles, B. McKinney, M. Paredes, D. Buckler, D. Papoulias, and D. Klein. (2002). Environmental contaminants in prey and tissues of the Peregrine Falcon in the Big Bend Region, Texas, USA. *Env. Pol.* 116: 169-176.
- Morel, F.M. and A.M. Kraepiel. (1998). The chemical cycle and bioaccumulation of mercury. *Annu. Rev. Ecol. Syst.* 29: 543-566.
- Mueller, H.C., N.S. Mueller, D.D. Berger, G. Allez, W. Robichaud, and J.L. Kaspar. 2000. Age and sex differences in the timing of fall migration of hawks and falcons. *Wilson Bul.* 112: 214-224.
- Mueller, H.C., D.D. Berger, N.S. Mueller, W. Robichaud, and J.L. Kaspar. (2004). Temporal changes in size of Sharp-shinned Hawks during fall migration at Cedar Grove, Wisconsin. *J. Field Ornithol.* 75: 386-393.
- NADP-3. (2007). National Atmospheric Deposition Program. NADP Program Office, Illinois State Water Survey, Champaign, IL.  
[http://nadp.sws.uiuc.edu/maplib/pdf/mdn/hg\\_Conc\\_2013.pdf](http://nadp.sws.uiuc.edu/maplib/pdf/mdn/hg_Conc_2013.pdf)
- Newton, I. (1979). Population ecology of raptors. Buteo Books, Vermilion, South

Dakota, USA.

- Nichols, J., R.S. Bennett, R. Rossman, J.B. French, and K.G. Sappington. (2010). A physiologically based toxicokinetic model for methylmercury in female American Kestrels. *Env. Tox. And Chem.* 29: 1854-1867.
- Peterson, B.J. and Fry, B. (1987). Stable isotopes in ecosystem studies. *Ann. Rev. Ecol. Syst.* 18: 293-320.
- Pyle, P. (2008). *Identification Guide to North American Birds. Part 2.* Slate Creek Press, Point Reyes Station, CA, USA.
- R Development Core Team. (2013). *R: A language and environment for statistical computing.* R Foundation for Statistical Computing, Vienna, Austria.  
[Online.] Available at [www.R-project.org](http://www.R-project.org).
- Rimmer, C.C., K.P. McFarland, D.C. Evers, E.K. Miller, Y. Aubry, D. Busby, and R.J. Taylor. (2005). Mercury concentrations in bicknell's thrush and other insectivorous passerines in montane forests of northeastern North America. *Ecotoxicology* 14: 223-240.
- Rodriguez-Estrella, R., J.A. Donazar, and F. Hiraldo. (1998). Raptors as indicators of environmental change in the scrub habitat of Baja California Sur, Mexico. *Conservation Biology* 12: 921-925.
- Rolfhus, K.R., B.D. Hall, B.A. Monson, M.J. Paterson, and J.D. Jeremianson. (2011). Assessment of mercury bioaccumulation with the pelagic food web of lakes in the western Great Lakes region. *Ecotoxicology* 20: 1520-1529.
- Rutkiewicz, J., D. Nam, T. Cooley, K. Neumann, I. Bueno Padilla, W. Route, S.

- Strom, and N. Basu. (2011). Mercury exposure and neurochemical impacts in bald eagles across several great lakes states. *Ecotoxicology* 20: 1669-1676.
- Scheuhammer, A.M., M.W. Meyer, M.B. Sandheinrich, and M.W. Murray. (2007). Effects of environmental methylmercury on the health of wild birds, mammals, and fish. *Ambio* 36: 12-18.
- Smallwood, J.A. and D.M. Bird. 2002. American Kestrel (*Falco sparverius*). *In* The Birds of North America, no. 602 (A. Poole, Ed.). Birds of North America, Philadelphia.
- Smith, K.G., S.R. Wittenberg, R.B. Macwhirter, and K.L. Bildstein. 2011. Northern Harrier (*Circus cyaneus*). *In* The Birds of North America, no. 210 (A. Poole Ed.). Birds of North America, Philadelphia.
- Snyder, N.F.R. and J.W. Wiley. (1976). Sexual size dimorphism in hawks and owls of North America. *Ornithological Monographs* 20.
- Squires, J.R. and R.T. Reynolds. 1997. Northern Goshawk (*Accipiter gentilis*). *In* The Birds of North America, no. 298 (A. Poole Ed.). Birds of North America, Philadelphia.
- Swain, E.B., D.R. Engstrom, M.E. Brigham, T.A. Henning, and P.L. Brezonik. (1992). Increasing rates of atmospheric mercury deposition in midcontinental North America. *Science* 257: 784-787.
- Tan, S.W., J.C. Meiller, and K.R. Mahaffey. (2009). The endocrine effects of mercury in humans and wildlife. *Crit. Rev. in Tox.* 39:228-269.
- Tavares, P.C., J.C. Xavier, R.A. Phillips, M.E. Pereira, and M.A. Pardal. (2009).

Relationships between carbon sources, trophic level and mercury exposure in generalist shorebirds revealed by stable isotope ratios in chicks. *Waterbirds* 32: 311-321.

Thompson, D.R. and R.W. Furness. Stable-isotope ratios of carbon and nitrogen in feathers indicate seasonal dietary shifts in Northern Fulmars. *The Auk* 112: 493-498.

Warkentin, I. G., N. S. Sodhi, R. H. M. Espie, Alan F. Poole, L. W. Oliphant and P. C. James. 2005. Merlin (*Falco columbarius*). *In* *The Birds of North America*, no. 044 (A. Poole, Ed.). *Birds of North America*, Philadelphia.

Yu, X., C.T. Driscoll, M. Montesdeoca, D. Evers, M. Duron, K. Williams, N. Schoch, and N.C. Kamman. (2011). Spatial patterns of mercury in biota of Adirondack, New York lakes. *Ecotoxicology* 20: 1542: 1554.

Zillioux, E.J., D.B. Porcella, and J.M. Benoit. (1993). Mercury cycling and effects in freshwater wetland ecosystems. *Environmental Toxicology and Chemistry* 17: 2245-2264.

Zolfaghari, G., A. Esmaili-Sari, S.M. Ghasempouri, and B.H. Kiabi. 2007.

Examination of mercury concentration in the feathers of 18 species of birds in southwest Iran. *Env. Research* 104: 258-265.

Appendix A: Mercury Data

Feather_Hg_ppm	Year	Date	Species	Sex	Age
3.32	2010	9/10/2010	AMKE	F	HY
2.19	2011	9/29/2011	AMKE	F	AHY
1.85	2009	10/9/2009	AMKE	F	AHY
1.84	2012	10/10/2012	AMKE	M	AHY
1.76	2011	9/19/2011	AMKE	M	HY
1.52	2010	9/18/2010	AMKE	M	HY
1.41	2011	9/5/2011	AMKE	F	U
1.20	2012	9/15/2012	AMKE	M	HY
1.03	2012	9/20/2012	AMKE	M	HY
0.97	2011	9/17/2011	AMKE	M	HY
0.95	2011	9/14/2011	AMKE	F	U
0.85	2012	9/12/2012	AMKE	F	HY
0.78	2011	9/5/2011	AMKE	M	HY
0.76	2011	9/11/2011	AMKE	F	HY
0.75	2011	9/26/2011	AMKE	M	HY
0.70	2011	9/7/2011	AMKE	M	HY
0.69	2011	8/27/2011	AMKE	F	U
0.67	2012	9/12/2012	AMKE	F	HY
0.66	2012	9/12/2012	AMKE	M	HY
0.66	2011	9/19/2011	AMKE	F	U
0.65	2012	9/11/2012	AMKE	F	HY
0.64	2010	9/18/2010	AMKE	M	HY
0.64	2012	9/6/2012	AMKE	M	HY
0.63	2010	9/13/2010	AMKE	M	HY
0.62	2011	9/13/2011	AMKE	M	HY
0.62	2012	9/6/2012	AMKE	M	HY
0.58	2011	9/10/2011	AMKE	M	HY
0.57	2010	9/14/2010	AMKE	M	HY
0.56	2010	9/12/2010	AMKE	F	HY
0.56	2011	9/17/2011	AMKE	F	U
0.54	2012	9/7/2012	AMKE	F	HY
0.54	2010	9/5/2010	AMKE	F	HY
0.53	2012	9/12/2012	AMKE	F	HY
0.49	2012	9/12/2012	AMKE	F	HY
0.49	2011	8/29/2011	AMKE	M	HY
0.48	2010	9/4/2010	AMKE	F	HY
0.48	2011	9/14/2011	AMKE	M	HY

0.47	2011	9/10/2011	AMKE	M	HY
0.47	2010	9/16/2010	AMKE	F	HY
0.45	2011	9/10/2011	AMKE	M	HY
0.44	2011	9/3/2011	AMKE	F	U
0.44	2010	9/18/2010	AMKE	F	HY
0.39	2011	9/3/2011	AMKE	F	HY
0.39	2011	9/1/2011	AMKE	F	AHY
0.38	2012	9/24/2012	AMKE	F	AHY
0.38	2011	9/11/2011	AMKE	M	HY
0.34	2011	9/8/2011	AMKE	M	HY
0.33	2011	9/1/2011	AMKE	F	U
0.31	2011	9/14/2011	AMKE	M	HY
0.29	2012	9/3/2012	AMKE	F	HY
0.28	2011	9/8/2011	AMKE	M	HY
0.28	2011	9/8/2011	AMKE	M	HY
0.27	2011	9/4/2011	AMKE	M	HY
0.27	2011	9/10/2011	AMKE	F	U
0.26	2011	9/14/2011	AMKE	F	U
0.25	2010	9/13/2010	AMKE	F	HY
0.24	2011	9/19/2011	AMKE	F	U
0.24	2010	9/13/2010	AMKE	M	HY
0.23	2011	9/14/2011	AMKE	M	HY
0.23	2012	8/26/2012	AMKE	M	HY
0.21	2011	9/3/2011	AMKE	M	HY
0.20	2010	9/13/2010	AMKE	M	HY
0.19	2011	9/17/2011	AMKE	F	U
0.19	2011	9/11/2011	AMKE	F	U
0.16	2011	9/15/2011	AMKE	M	HY
0.15	2011	9/2/2011	AMKE	F	U
0.15	2012	9/9/2012	AMKE	M	HY
0.13	2012	9/16/2012	AMKE	M	HY
0.13	2011	9/16/2011	AMKE	M	HY
0.09	2011	9/11/2011	AMKE	F	HY
0.03	2010	9/18/2010	AMKE	M	HY
0.80	2012	9/16/2012	BWHA	U	HY
0.50	2012	9/7/2012	BWHA	U	HY
0.49	2012	9/21/2012	BWHA	U	HY
0.42	2012	9/17/2012	BWHA	U	HY
0.36	2012	9/25/2012	BWHA	U	HY
2.65	2012	10/10/2012	COHA	M	AHY
1.77	2012	10/10/2012	COHA	F	ASY

1.36	2012	10/10/2012	COHA	M	SY
1.35	2012	10/9/2012	COHA	M	AHY
1.20	2012	10/6/2012	COHA	M	AHY
1.02	2012	9/12/2012	COHA	M	HY
0.97	2012	9/12/2012	COHA	F	HY
0.67	2012	9/21/2012	COHA	F	ASY
0.67	2012	10/6/2012	COHA	M	AHY
0.37	2012	9/12/2012	COHA	M	HY
0.17	2012	9/10/2012	COHA	F	HY
4.71	2012	10/13/2012	LEOW	U	AHY
1.81	2009	10/18/2009	LEOW	U	AHY
1.81	2009	10/24/2009	LEOW	U	AHY
1.80	2011	10/20/2011	LEOW	F	AHY
1.57	2009	10/17/2009	LEOW	U	HY
1.57	2009	10/25/2009	LEOW	U	AHY
1.55	2009	10/18/2009	LEOW	U	AHY
1.46	2009	10/24/2009	LEOW	U	AHY
1.45	2012	10/13/2012	LEOW	U	AHY
1.41	2009	10/17/2009	LEOW	U	AHY
1.39	2009	10/17/2009	LEOW	U	HY
1.29	2012	10/31/2012	LEOW	U	AHY
1.26	2012	10/27/2012	LEOW	U	AHY
1.24	2012	10/30/2012	LEOW	U	AHY
1.22	2012	10/27/2012	LEOW	U	AHY
1.22	2009	10/17/2009	LEOW	U	AHY
1.12	2009	10/24/2009	LEOW	U	AHY
1.00	2009	10/20/2009	LEOW	U	AHY
0.95	2012	10/13/2012	LEOW	U	HY
0.92	2012	10/13/2012	LEOW	U	AHY
0.92	2012	10/13/2012	LEOW	U	AHY
0.90	2009	10/17/2009	LEOW	U	AHY
0.88	2009	10/16/2009	LEOW	U	HY
0.84	2011	9/30/2011	LEOW	M	AHY
0.81	2009	10/24/2009	LEOW	U	AHY
0.79	2009	10/14/2009	LEOW	U	AHY
0.78	2012	10/27/2012	LEOW	U	AHY
0.76	2012	10/13/2012	LEOW	U	AHY
0.72	2012	10/12/2012	LEOW	U	AHY
0.65	2011	10/20/2011	LEOW	F	AHY
0.62	2012	10/13/2012	LEOW	U	AHY
0.57	2012	10/30/2012	LEOW	U	AHY

0.57	2012	10/12/2012	LEOW	U	AHY
0.56	2012	10/13/2012	LEOW	U	HY
0.56	2009	10/18/2009	LEOW	U	AHY
0.52	2011	10/20/2011	LEOW	M	HY
0.51	2011	10/20/2011	LEOW	M	AHY
0.50	2012	10/27/2012	LEOW	U	AHY
0.50	2011	10/20/2011	LEOW	U	AHY
0.49	2009	10/24/2009	LEOW	U	HY
0.47	2011	10/8/2011	LEOW	M	AHY
0.46	2012	10/13/2012	LEOW	U	AHY
0.46	2009	10/17/2009	LEOW	U	HY
0.45	2012	10/13/2012	LEOW	U	AHY
0.45	2012	10/13/2012	LEOW	U	HY
0.44	2009	10/17/2009	LEOW	U	AHY
0.44	2012	10/28/2012	LEOW	U	AHY
0.42	2012	10/12/2012	LEOW	U	AHY
0.42	2009	10/24/2009	LEOW	U	AHY
0.41	2012	10/13/2012	LEOW	U	AHY
0.41	2012	10/13/2012	LEOW	U	AHY
0.40	2012	10/13/2012	LEOW	U	AHY
0.40	2012	10/13/2012	LEOW	U	AHY
0.40	2009	10/24/2009	LEOW	U	AHY
0.39	2012	10/29/2012	LEOW	U	AHY
0.38	2009	10/14/2009	LEOW	U	AHY
0.38	2011	10/20/2011	LEOW	U	AHY
0.37	2011	10/20/2011	LEOW	M	AHY
0.36	2012	10/27/2012	LEOW	U	HY
0.35	2011	10/20/2011	LEOW	F	U
0.34	2011	9/30/2011	LEOW	M	AHY
0.33	2012	10/13/2012	LEOW	U	AHY
0.33	2011	10/20/2011	LEOW	U	U
0.33	2009	10/17/2009	LEOW	U	HY
0.32	2009	10/17/2009	LEOW	U	AHY
0.31	2012	10/13/2012	LEOW	U	AHY
0.30	2012	10/13/2012	LEOW	U	AHY
0.30	2012	10/13/2012	LEOW	U	AHY
0.30	2011	10/20/2011	LEOW	U	U
0.30	2012	10/12/2012	LEOW	U	AHY
0.29	2012	10/13/2012	LEOW	U	AHY
0.28	2012	10/19/2012	LEOW	U	AHY
0.27	2011	10/20/2011	LEOW	F	U



0.27	2011	10/20/2011	LEOW	F	AHY
0.27	2011	10/20/2011	LEOW	F	AHY
0.24	2011	10/20/2011	LEOW	F	AHY
0.24	2011	10/20/2011	LEOW	U	U
0.23	2012	10/13/2012	LEOW	U	AHY
0.23	2009	10/24/2009	LEOW	U	HY
0.22	2012	10/13/2012	LEOW	U	AHY
0.22	2012	10/13/2012	LEOW	U	AHY
0.20	2012	10/13/2012	LEOW	U	AHY
0.20	2012	10/13/2012	LEOW	U	AHY
0.19	2012	10/13/2012	LEOW	U	AHY
0.18	2012	10/13/2012	LEOW	U	HY
0.17	2011	10/20/2011	LEOW	M	AHY
0.14	2012	10/13/2012	LEOW	U	HY
0.09	2009	10/16/2009	LEOW	U	HY
15.95	2011	9/28/2011	MERL	F	AHY
11.77	2011	10/16/2011	MERL	F	HY
9.98	2011	10/7/2011	MERL	M	SY
9.96	2012	9/28/2012	MERL	F	AHY
8.47	2011	10/15/2011	MERL	M	SY
6.87	2012	10/4/2012	MERL	F	AHY
6.74	2012	10/9/2012	MERL	F	AHY
6.37	2011	10/5/2011	MERL	F	AHY
6.30	2012	9/30/2012	MERL	M	SY
6.30	2011	9/24/2011	MERL	M	AHY
5.79	2011	10/8/2011	MERL	F	SY
4.93	2012	10/7/2012	MERL	F	AHY
4.51	2011	10/5/2011	MERL	F	SY
4.31	2012	9/29/2012	MERL	M	AHY
3.38	2011	9/7/2011	MERL	M	HY
3.15	2011	9/10/2011	MERL	M	HY
3.13	2010	9/2/2010	MERL	F	HY
3.04	2012	9/12/2012	MERL	F	HY
2.99	2011	8/27/2011	MERL	F	HY
2.93	2011	10/8/2011	MERL	M	SY
2.87	2011	9/29/2011	MERL	F	AHY
2.73	2011	9/8/2011	MERL	F	AHY
2.72	2010	8/30/2010	MERL	F	HY
2.67	2012	10/3/2012	MERL	M	AHY
2.61	2012	8/17/2012	MERL	F	HY
2.44	2011	10/2/2011	MERL	F	HY

2.43	2011	9/7/2011	MERL	M	HY
2.39	2012	8/31/2012	MERL	M	HY
2.36	2011	9/9/2011	MERL	F	HY
2.23	2011	10/6/2011	MERL	M	ASY
2.23	2011	9/3/2011	MERL	M	HY
2.19	2011	10/7/2011	MERL	M	HY
2.19	2011	10/10/2011	MERL	M	HY
2.18	2010	8/30/2010	MERL	F	HY
2.13	2012	9/6/2012	MERL	F	HY
2.11	2011	9/20/2011	MERL	F	HY
2.10	2012	9/8/2012	MERL	F	HY
2.09	2010	9/17/2010	MERL	F	HY
2.05	2012	10/7/2012	MERL	F	HY
1.96	2012	9/12/2012	MERL	F	HY
1.95	2012	9/11/2012	MERL	F	HY
1.93	2011	9/22/2011	MERL	F	HY
1.92	2012	9/22/2012	MERL	M	HY
1.92	2011	9/13/2011	MERL	F	HY
1.87	2012	9/13/2012	MERL	M	HY
1.86	2010	9/14/2010	MERL	M	HY
1.85	2011	9/13/2011	MERL	M	HY
1.72	2011	9/10/2011	MERL	M	HY
1.70	2012	9/16/2012	MERL	M	HY
1.70	2012	8/31/2012	MERL	F	HY
1.68	2012	9/4/2012	MERL	M	HY
1.67	2012	9/9/2012	MERL	F	HY
1.66	2012	9/7/2012	MERL	M	HY
1.66	2012	9/8/2012	MERL	F	HY
1.66	2010	9/29/2010	MERL	M	HY
1.63	2012	9/11/2012	MERL	F	HY
1.62	2012	9/24/2012	MERL	M	HY
1.59	2011	8/27/2011	MERL	M	HY
1.56	2010	9/6/2010	MERL	M	HY
1.55	2011	9/4/2011	MERL	F	HY
1.52	2012	9/11/2012	MERL	F	HY
1.52	2011	9/2/2011	MERL	M	HY
1.50	2012	9/15/2012	MERL	M	HY
1.50	2010	8/31/2010	MERL	M	HY
1.48	2010	8/25/2010	MERL	F	HY
1.48	2011	9/10/2011	MERL	M	HY
1.47	2011	9/12/2011	MERL	M	HY

1.47	2012	9/10/2012	MERL	M	HY
1.45	2011	9/3/2011	MERL	F	HY
1.44	2012	9/9/2012	MERL	F	HY
1.44	2012	9/7/2012	MERL	M	HY
1.43	2011	9/2/2011	MERL	F	HY
1.42	2011	9/7/2011	MERL	F	HY
1.42	2012	9/29/2012	MERL	M	HY
1.39	2011	9/13/2011	MERL	M	AHY
1.38	2010	9/8/2010	MERL	F	HY
1.38	2012	9/10/2012	MERL	M	HY
1.38	2012	9/27/2012	MERL	F	HY
1.33	2011	9/5/2011	MERL	M	HY
1.33	2011	9/6/2011	MERL	M	HY
1.33	2011	9/13/2011	MERL	M	HY
1.32	2011	9/18/2011	MERL	M	HY
1.31	2012	9/11/2012	MERL	F	HY
1.30	2012	9/1/2012	MERL	F	HY
1.29	2012	9/11/2012	MERL	M	HY
1.28	2012	9/7/2012	MERL	M	HY
1.28	2012	9/5/2012	MERL	M	HY
1.28	2011	9/5/2011	MERL	M	HY
1.27	2012	9/12/2012	MERL	M	HY
1.26	2012	9/25/2012	MERL	F	HY
1.25	2011	9/28/2011	MERL	M	HY
1.25	2012	9/12/2012	MERL	F	HY
1.24	2012	9/30/2012	MERL	F	HY
1.24	2011	9/4/2011	MERL	F	HY
1.23	2011	9/3/2011	MERL	M	HY
1.22	2011	10/8/2011	MERL	M	HY
1.20	2012	9/3/2012	MERL	M	HY
1.19	2011	9/2/2011	MERL	M	HY
1.18	2012	9/12/2012	MERL	F	HY
1.16	2012	9/13/2012	MERL	M	HY
1.15	2012	9/18/2012	MERL	M	HY
1.15	2012	9/10/2012	MERL	F	HY
1.15	2011	9/27/2011	MERL	M	HY
1.13	2010	9/21/2010	MERL	M	HY
1.12	2012	9/12/2012	MERL	M	HY
1.11	2012	9/16/2012	MERL	M	HY
1.11	2011	9/2/2011	MERL	F	HY
1.09	2012	9/17/2012	MERL	M	HY

1.07	2011	9/2/2011	MERL	F	HY
1.06	2011	9/24/2011	MERL	M	HY
1.05	2010	9/3/2010	MERL	M	HY
1.04	2012	9/5/2012	MERL	M	HY
1.04	2010	8/25/2010	MERL	M	HY
1.03	2011	9/4/2011	MERL	M	HY
1.02	2012	9/12/2012	MERL	F	HY
1.00	2012	9/2/2012	MERL	M	HY
0.98	2012	9/24/2012	MERL	M	HY
0.94	2011	9/5/2011	MERL	F	HY
0.93	2010	9/9/2010	MERL	M	HY
0.93	2012	9/12/2012	MERL	F	HY
0.92	2011	9/23/2011	MERL	M	HY
0.92	2011	9/10/2011	MERL	F	AHY
0.92	2012	10/3/2012	MERL	M	HY
0.92	2010	9/14/2010	MERL	M	HY
0.86	2011	9/17/2011	MERL	F	HY
0.80	2011	9/10/2011	MERL	F	HY
0.79	2012	9/12/2012	MERL	M	HY
0.78	2012	9/15/2012	MERL	M	HY
0.75	2012	8/20/2012	MERL	F	HY
0.68	2012	9/15/2012	MERL	M	HY
0.63	2010	8/31/2010	MERL	M	HY
0.62	2012	8/23/2012	MERL	M	HY
0.54	2012	9/12/2012	MERL	F	HY
0.49	2011	9/11/2011	MERL	F	HY
0.36	2012	8/22/2012	MERL	M	HY
0.33	2012	8/24/2012	MERL	M	HY
0.14	2012	9/6/2012	MERL	M	HY
16.41	2012	11/1/2012	NOGO	F	SY
6.37	2010	10/29/2010	NOGO	M	ASY
6.14	2009	11/4/2009	NOGO	F	ASY
4.46	2011	10/7/2011	NOGO	M	HY
3.59	2012	10/15/2012	NOGO	M	HY
3.48	2012	10/30/2012	NOGO	M	HY
3.47	2012	10/13/2012	NOGO	F	SY
3.41	2011	10/12/2011	NOGO	M	HY
3.40	2012	10/4/2012	NOGO	M	HY
3.36	2010	10/18/2010	NOGO	F	HY
3.30	2012	10/9/2012	NOGO	F	HY
3.12	2009	10/23/2009	NOGO	F	HY

3.08	2009	10/17/2009	NOGO	F	HY
3.02	2011	10/14/2011	NOGO	M	HY
3.01	2012	10/31/2012	NOGO	F	SY
2.92	2011	10/10/2011	NOGO	M	HY
2.85	2011	10/5/2011	NOGO	F	HY
2.81	2010	9/30/2010	NOGO	M	HY
2.79	2011	10/14/2011	NOGO	F	SY
2.78	2009	9/21/2009	NOGO	M	HY
2.75	2012	10/28/2012	NOGO	M	HY
2.74	2011	10/6/2011	NOGO	M	HY
2.67	2012	9/21/2012	NOGO	M	HY
2.59	2012	10/16/2012	NOGO	M	HY
2.58	2009	11/17/2009	NOGO	M	HY
2.51	2010	9/28/2010	NOGO	M	HY
2.51	2010	11/4/2010	NOGO	F	HY
2.46	2012	10/29/2012	NOGO	M	HY
2.45	2009	10/22/2009	NOGO	M	HY
2.41	2011	10/18/2011	NOGO	F	SY
2.38	2011	11/23/2011	NOGO	M	ASY
2.23	2009	10/31/2009	NOGO	M	HY
2.07	2012	9/27/2012	NOGO	F	HY
2.04	2012	10/27/2012	NOGO	M	SY
2.03	2012	10/21/2012	NOGO	F	HY
1.98	2012	10/2/2012	NOGO	M	HY
1.91	2011	10/5/2011	NOGO	M	HY
1.88	2010	10/17/2010	NOGO	M	HY
1.86	2010	10/21/2010	NOGO	F	HY
1.83	2009	11/24/2009	NOGO	F	SY
1.77	2012	10/30/2012	NOGO	F	SY
1.77	2010	10/18/2010	NOGO	M	HY
1.70	2012	10/16/2012	NOGO	M	HY
1.70	2012	9/21/2012	NOGO	M	HY
1.68	2009	10/19/2009	NOGO	M	HY
1.62	2009	11/3/2009	NOGO	F	HY
1.60	2010	9/29/2010	NOGO	M	HY
1.60	2009	9/30/2009	NOGO	M	HY
1.57	2012	10/30/2012	NOGO	M	HY
1.57	2010	11/3/2010	NOGO	M	HY
1.51	2009	10/22/2009	NOGO	F	HY
1.51	2012	10/31/2012	NOGO	M	HY
1.50	2012	10/15/2012	NOGO	M	HY

1.47	2012	10/10/2012	NOGO	M	HY
1.47	2011	10/24/2011	NOGO	M	SY
1.44	2012	10/27/2012	NOGO	M	SY
1.44	2012	10/30/2012	NOGO	M	HY
1.44	2012	9/27/2012	NOGO	M	HY
1.43	2012	8/30/2012	NOGO	M	HY
1.42	2012	10/21/2012	NOGO	M	HY
1.41	2012	9/14/2012	NOGO	F	HY
1.40	2012	10/25/2012	NOGO	M	HY
1.39	2011	10/13/2011	NOGO	M	HY
1.35	2012	10/27/2012	NOGO	M	HY
1.35	2011	10/10/2011	NOGO	M	HY
1.32	2010	10/27/2010	NOGO	M	HY
1.29	2012	9/27/2012	NOGO	M	HY
1.28	2010	8/29/2010	NOGO	M	HY
1.26	2012	10/2/2012	NOGO	F	HY
1.25	2012	10/2/2012	NOGO	M	HY
1.24	2012	10/29/2012	NOGO	M	HY
1.24	2009	11/2/2009	NOGO	F	HY
1.23	2011	10/12/2011	NOGO	M	HY
1.21	2012	10/11/2012	NOGO	F	HY
1.19	2012	11/1/2012	NOGO	F	HY
1.18	2011	9/5/2011	NOGO	M	HY
1.18	2009	10/31/2009	NOGO	M	SY
1.17	2012	10/30/2012	NOGO	F	HY
1.17	2012	10/28/2012	NOGO	M	HY
1.16	2011	10/10/2011	NOGO	M	HY
1.15	2011	10/16/2011	NOGO	F	HY
1.15	2010	10/5/2010	NOGO	M	HY
1.15	2012	10/27/2012	NOGO	M	HY
1.12	2009	11/6/2009	NOGO	F	HY
1.11	2009	11/1/2009	NOGO	M	SY
1.10	2012	10/16/2012	NOGO	F	HY
1.09	2012	10/11/2012	NOGO	M	HY
1.07	2012	10/8/2012	NOGO	M	HY
1.07	2010	9/30/2010	NOGO	M	HY
1.07	2010	10/9/2010	NOGO	M	HY
1.07	2009	10/11/2009	NOGO	M	HY
1.06	2010	10/14/2010	NOGO	M	HY
1.05	2010	10/17/2010	NOGO	M	HY
1.05	2009	10/30/2009	NOGO	M	HY

1.05	2012	10/9/2012	NOGO	M	HY
1.04	2010	10/14/2010	NOGO	M	HY
1.04	2012	10/6/2012	NOGO	M	HY
1.02	2010	10/22/2010	NOGO	M	HY
1.01	2009	10/31/2009	NOGO	M	HY
1.01	2011	9/14/2011	NOGO	M	HY
1.00	2011	10/3/2011	NOGO	M	HY
0.97	2010	10/22/2010	NOGO	M	HY
0.96	2012	10/11/2012	NOGO	M	HY
0.96	2011	11/5/2011	NOGO	M	SY
0.95	2012	10/15/2012	NOGO	F	HY
0.94	2011	10/14/2011	NOGO	M	HY
0.94	2012	10/14/2012	NOGO	M	HY
0.94	2012	9/29/2012	NOGO	M	HY
0.93	2011	9/21/2011	NOGO	F	HY
0.92	2012	10/6/2012	NOGO	F	HY
0.92	2010	9/30/2010	NOGO	M	HY
0.92	2012	10/30/2012	NOGO	M	SY
0.91	2009	10/31/2009	NOGO	M	HY
0.91	2010	11/12/2010	NOGO	M	HY
0.89	2012	10/29/2012	NOGO	M	HY
0.87	2012	9/28/2012	NOGO	F	HY
0.87	2012	9/17/2012	NOGO	F	HY
0.86	2012	10/26/2012	NOGO	M	HY
0.86	2011	11/2/2011	NOGO	M	SY
0.86	2012	10/10/2012	NOGO	M	HY
0.86	2010	10/25/2010	NOGO	F	HY
0.85	2010	10/15/2010	NOGO	M	HY
0.85	2012	10/6/2012	NOGO	M	HY
0.83	2012	9/21/2012	NOGO	M	HY
0.83	2010	10/8/2010	NOGO	F	HY
0.82	2012	9/16/2012	NOGO	M	HY
0.82	2010	10/28/2010	NOGO	M	HY
0.81	2010	10/20/2010	NOGO	M	HY
0.80	2009	10/12/2009	NOGO	M	HY
0.80	2011	11/13/2011	NOGO	M	ASY
0.80	2011	10/25/2011	NOGO	F	HY
0.78	2011	10/10/2011	NOGO	M	HY
0.78	2012	10/31/2012	NOGO	M	HY
0.75	2011	9/25/2011	NOGO	F	HY
0.75	2012	10/28/2012	NOGO	M	HY

0.74	2011	10/16/2011	NOGO	F	HY
0.74	2012	10/21/2012	NOGO	M	HY
0.74	2010	10/31/2010	NOGO	M	HY
0.73	2012	10/26/2012	NOGO	M	HY
0.72	2011	10/15/2011	NOGO	F	HY
0.71	2012	9/21/2012	NOGO	M	HY
0.68	2012	10/13/2012	NOGO	M	HY
0.67	2012	10/19/2012	NOGO	M	HY
0.65	2012	10/13/2012	NOGO	M	HY
0.64	2011	10/18/2011	NOGO	F	HY
0.64	2009	10/20/2009	NOGO	M	HY
0.63	2011	10/11/2011	NOGO	F	HY
0.61	2012	10/27/2012	NOGO	F	HY
0.60	2011	10/3/2011	NOGO	M	HY
0.60	2012	10/28/2012	NOGO	M	HY
0.59	2012	10/13/2012	NOGO	M	HY
0.58	2012	10/13/2012	NOGO	M	HY
0.57	2011	10/14/2011	NOGO	F	HY
0.57	2012	10/12/2012	NOGO	M	HY
0.56	2011	11/10/2011	NOGO	F	SY
0.54	2010	10/14/2010	NOGO	M	HY
0.53	2012	10/14/2012	NOGO	F	HY
0.53	2012	9/29/2012	NOGO	M	HY
0.52	2011	10/20/2011	NOGO	F	HY
0.50	2012	10/25/2012	NOGO	M	HY
0.50	2010	11/4/2010	NOGO	M	HY
0.49	2010	9/13/2010	NOGO	F	HY
0.49	2012	10/30/2012	NOGO	M	HY
0.48	2009	9/22/2009	NOGO	F	HY
0.48	2012	10/28/2012	NOGO	M	HY
0.48	2011	11/10/2011	NOGO	M	SY
0.47	2011	10/11/2011	NOGO	F	HY
0.47	2012	10/29/2012	NOGO	F	HY
0.47	2012	10/25/2012	NOGO	F	HY
0.46	2010	10/20/2010	NOGO	M	HY
0.45	2009	11/6/2009	NOGO	F	HY
0.45	2012	10/25/2012	NOGO	M	HY
0.44	2012	10/11/2012	NOGO	M	HY
0.44	2012	10/30/2012	NOGO	M	HY
0.43	2012	10/28/2012	NOGO	F	SY
0.43	2009	10/31/2009	NOGO	M	HY



0.43	2012	10/31/2012	NOGO	M	HY
0.42	2010	11/4/2010	NOGO	M	HY
0.42	2012	10/18/2012	NOGO	F	HY
0.41	2009	11/24/2009	NOGO	F	HY
0.41	2010	9/30/2010	NOGO	M	HY
0.41	2012	10/5/2012	NOGO	M	HY
0.40	2012	10/30/2012	NOGO	F	SY
0.40	2012	10/14/2012	NOGO	F	HY
0.39	2012	10/23/2012	NOGO	M	HY
0.37	2011	9/30/2011	NOGO	M	HY
0.37	2011	10/15/2011	NOGO	M	HY
0.36	2009	10/11/2009	NOGO	F	TY
0.36	2012	9/15/2012	NOGO	M	HY
0.36	2012	10/13/2012	NOGO	M	HY
0.35	2012	10/27/2012	NOGO	F	SY
0.34	2012	10/16/2012	NOGO	M	HY
0.33	2012	9/17/2012	NOGO	M	HY
0.32	2011	10/14/2011	NOGO	F	HY
0.32	2009	11/25/2009	NOGO	M	HY
0.32	2009	10/31/2009	NOGO	M	HY
0.32	2011	10/13/2011	NOGO	F	HY
0.31	2012	9/19/2012	NOGO	M	HY
0.31	2011	10/15/2011	NOGO	M	HY
0.30	2011	10/15/2011	NOGO	F	SY
0.30	2011	10/24/2011	NOGO	F	HY
0.30	2011	10/14/2011	NOGO	F	HY
0.29	2012	10/13/2012	NOGO	M	HY
0.28	2012	10/16/2012	NOGO	M	HY
0.27	2012	11/11/2012	NOGO	M	HY
0.27	2010	11/11/2010	NOGO	M	HY
0.26	2012	11/1/2012	NOGO	M	HY
0.26	2012	10/25/2012	NOGO	F	HY
0.25	2011	9/30/2011	NOGO	M	HY
0.25	2009	10/24/2009	NOGO	F	HY
0.24	2012	9/20/2012	NOGO	M	HY
0.21	2012	10/5/2012	NOGO	M	HY
0.20	2012	9/30/2012	NOGO	M	HY
0.20	2011	10/15/2011	NOGO	F	HY
0.20	2011	10/6/2011	NOGO	M	HY
0.19	2012	10/21/2012	NOGO	M	HY
0.19	2011	9/20/2011	NOGO	F	HY

0.18	2012	10/25/2012	NOGO	F	HY
0.16	2012	10/9/2012	NOGO	M	HY
0.16	2012	11/1/2012	NOGO	M	HY
0.16	2012	10/1/2012	NOGO	M	HY
0.15	2009	10/24/2009	NOGO	F	HY
6.18	2012	9/9/2012	NOHA	F	ASY
4.51	2012	10/4/2012	NOHA	F	SY
3.94	2012	9/12/2012	NOHA	F	HY
3.67	2012	9/12/2012	NOHA	M	HY
3.10	2012	9/20/2012	NOHA	M	HY
2.46	2012	9/23/2012	NOHA	M	ASY
2.14	2012	10/4/2012	NOHA	F	HY
2.00	2012	10/5/2012	NOHA	F	HY
1.43	2012	9/26/2012	NOHA	F	AHY
1.32	2012	9/11/2012	NOHA	F	HY
1.19	2012	10/1/2012	NOHA	M	HY
1.04	2012	9/28/2012	NOHA	M	HY
0.85	2012	9/7/2012	NOHA	M	HY
0.84	2012	10/4/2012	NOHA	M	HY
0.81	2012	9/19/2012	NOHA	F	HY
0.80	2012	9/16/2012	NOHA	M	HY
0.78	2012	9/11/2012	NOHA	M	HY
0.77	2012	9/21/2012	NOHA	F	HY
0.76	2012	9/7/2012	NOHA	F	HY
0.75	2012	9/7/2012	NOHA	M	HY
0.74	2012	9/23/2012	NOHA	F	ASY
0.70	2012	9/16/2012	NOHA	M	HY
0.60	2012	9/7/2012	NOHA	F	HY
0.55	2012	10/8/2012	NOHA	M	HY
0.53	2012	9/6/2012	NOHA	M	HY
0.49	2012	10/4/2012	NOHA	M	HY
0.46	2012	9/7/2012	NOHA	F	HY
0.39	2012	9/6/2012	NOHA	M	HY
0.37	2012	9/6/2012	NOHA	M	HY
0.32	2012	8/28/2012	NOHA	M	HY
2.76	2012	9/11/2012	PEFA	F	HY
2.45	2012	9/17/2012	PEFA	M	HY
2.16	2012	9/28/2012	PEFA	F	HY
1.34	2012	9/22/2012	PEFA	M	HY
0.99	2012	9/29/2012	PEFA	F	HY
0.74	2012	9/8/2012	PEFA	M	HY

0.65	2012	10/2/2012	PEFA	M	HY
0.40	2012	9/28/2012	PEFA	M	HY
1.09	2012	8/28/2012	RSHA	U	HY
27.18	2011	10/4/2011	SSHA	M	SY
17.95	2011	10/8/2011	SSHA	M	AHY
15.69	2009	9/22/2009	SSHA	F	AHY
14.70	2012	9/13/2012	SSHA	F	AHY
14.40	2009	9/28/2009	SSHA	F	ASY
13.98	2012	9/26/2012	SSHA	F	ASY
13.52	2009	9/22/2009	SSHA	F	HY
13.07	2011	9/29/2011	SSHA	M	AHY
12.23	2011	9/11/2011	SSHA	F	AHY
11.90	2011	9/10/2011	SSHA	F	SY
11.46	2012	10/8/2012	SSHA	M	SY
11.01	2009	10/19/2009	SSHA	M	SY
10.08	2009	9/20/2009	SSHA	F	ASY
9.13	2012	10/9/2012	SSHA	F	ASY
8.67	2011	9/12/2011	SSHA	F	SY
8.59	2012	9/9/2012	SSHA	F	ASY
8.31	2012	10/8/2012	SSHA	M	ASY
8.23	2009	9/27/2009	SSHA	F	SY
8.20	2011	9/10/2011	SSHA	F	AHY
8.15	2012	10/6/2012	SSHA	F	SY
8.11	2009	9/30/2009	SSHA	F	AHY
8.08	2009	9/24/2009	SSHA	F	ASY
7.97	2009	9/22/2009	SSHA	F	SY
7.86	2011	10/7/2011	SSHA	M	SY
7.69	2011	9/16/2011	SSHA	F	ASY
7.65	2012	10/8/2012	SSHA	F	ASY
7.60	2011	10/8/2011	SSHA	M	AHY
7.56	2012	9/18/2012	SSHA	F	SY
7.53	2012	9/21/2012	SSHA	F	SY
7.24	2009	9/29/2009	SSHA	M	AHY
7.17	2012	9/18/2012	SSHA	F	SY
7.12	2011	10/8/2011	SSHA	M	AHY
7.02	2012	9/19/2012	SSHA	F	SY
6.94	2012	10/8/2012	SSHA	M	SY
6.93	2011	10/5/2011	SSHA	F	ASY
6.78	2011	10/4/2011	SSHA	M	SY
6.73	2011	10/4/2011	SSHA	F	ASY
6.55	2012	9/16/2012	SSHA	F	ASY

6.46	2012	9/20/2012	SSHA	M	SY
6.44	2009	9/29/2009	SSHA	F	SY
6.41	2009	9/27/2009	SSHA	M	SY
6.41	2012	10/19/2012	SSHA	F	ASY
6.32	2009	10/8/2009	SSHA	F	SY
6.28	2011	10/4/2011	SSHA	M	SY
6.23	2012	10/6/2012	SSHA	M	AHY
6.11	2011	9/20/2011	SSHA	F	ASY
6.04	2012	10/3/2012	SSHA	F	SY
6.03	2011	9/13/2011	SSHA	M	SY
6.01	2011	10/4/2011	SSHA	M	SY
6.00	2012	10/2/2012	SSHA	F	SY
5.99	2009	10/8/2009	SSHA	M	HY
5.99	2012	10/8/2012	SSHA	M	ASY
5.93	2009	11/3/2009	SSHA	M	SY
5.90	2009	9/28/2009	SSHA	F	SY
5.87	2011	10/11/2011	SSHA	M	ASY
5.85	2012	10/23/2012	SSHA	M	ASY
5.77	2011	9/27/2011	SSHA	F	ASY
5.71	2012	10/2/2012	SSHA	M	AHY
5.70	2011	10/8/2011	SSHA	M	ASY
5.65	2012	9/18/2012	SSHA	F	SY
5.64	2009	9/22/2009	SSHA	F	ASY
5.53	2012	10/9/2012	SSHA	F	SY
5.49	2012	10/8/2012	SSHA	M	ASY
5.42	2009	10/4/2009	SSHA	F	ASY
5.42	2012	10/9/2012	SSHA	F	ASY
5.35	2011	10/4/2011	SSHA	M	AHY
5.33	2011	10/4/2011	SSHA	M	AHY
5.19	2012	10/9/2012	SSHA	M	SY
5.16	2012	9/21/2012	SSHA	F	SY
5.12	2011	9/22/2011	SSHA	F	ASY
4.96	2011	9/20/2011	SSHA	F	SY
4.84	2009	9/28/2009	SSHA	M	SY
4.80	2011	9/16/2011	SSHA	F	SY
4.74	2010	10/16/2010	SSHA	F	ASY
4.72	2011	10/11/2011	SSHA	M	ASY
4.58	2011	9/29/2011	SSHA	M	SY
4.58	2012	10/2/2012	SSHA	M	SY
4.56	2011	9/20/2011	SSHA	F	AHY
4.54	2012	10/16/2012	SSHA	F	ASY

4.52	2011	10/16/2011	SSHA	M	ASY
4.51	2011	10/8/2011	SSHA	M	AHY
4.50	2011	9/21/2011	SSHA	F	ASY
4.49	2011	8/27/2011	SSHA	F	SY
4.48	2012	10/8/2012	SSHA	M	ASY
4.46	2012	10/3/2012	SSHA	M	SY
4.44	2011	9/30/2011	SSHA	M	SY
4.43	2012	10/2/2012	SSHA	F	SY
4.41	2012	10/7/2012	SSHA	M	AHY
4.37	2011	9/20/2011	SSHA	F	SY
4.35	2011	9/13/2011	SSHA	F	SY
4.34	2012	10/14/2012	SSHA	M	ASY
4.31	2009	9/27/2009	SSHA	M	SY
4.28	2009	9/20/2009	SSHA	F	AHY
4.28	2011	10/7/2011	SSHA	M	ASY
4.27	2011	10/4/2011	SSHA	M	SY
4.25	2012	10/10/2012	SSHA	M	AHY
4.23	2009	11/3/2009	SSHA	F	ASY
4.19	2011	9/6/2011	SSHA	F	ASY
4.17	2012	9/16/2012	SSHA	F	ASY
4.14	2011	10/16/2011	SSHA	M	ASY
4.12	2012	10/10/2012	SSHA	M	AHY
4.08	2010	8/21/2010	SSHA	F	ASY
4.07	2011	9/16/2011	SSHA	F	SY
4.05	2012	10/8/2012	SSHA	F	ASY
4.04	2012	10/9/2012	SSHA	F	HY
4.03	2012	9/20/2012	SSHA	F	SY
4.01	2011	9/29/2011	SSHA	M	SY
4.01	2012	10/6/2012	SSHA	M	SY
3.98	2011	9/7/2011	SSHA	F	ASY
3.97	2009	9/27/2009	SSHA	F	SY
3.92	2012	9/28/2012	SSHA	F	AHY
3.91	2012	10/2/2012	SSHA	F	SY
3.91	2011	10/8/2011	SSHA	M	AHY
3.90	2010	9/24/2010	SSHA	F	SY
3.86	2010	10/8/2010	SSHA	M	SY
3.81	2011	10/15/2011	SSHA	M	ASY
3.78	2012	9/27/2012	SSHA	M	SY
3.77	2011	10/8/2011	SSHA	M	AHY
3.75	2012	10/10/2012	SSHA	M	AHY
3.73	2012	10/8/2012	SSHA	M	ASY

3.73	2012	10/6/2012	SSHA	M	AHY
3.71	2012	9/18/2012	SSHA	F	ASY
3.69	2012	10/27/2012	SSHA	M	HY
3.66	2011	9/21/2011	SSHA	F	ASY
3.57	2012	10/2/2012	SSHA	M	AHY
3.57	2011	9/13/2011	SSHA	F	ASY
3.51	2011	10/8/2011	SSHA	M	SY
3.48	2011	9/14/2011	SSHA	F	SY
3.47	2011	9/11/2011	SSHA	F	SY
3.45	2011	10/7/2011	SSHA	F	ASY
3.45	2011	10/8/2011	SSHA	M	SY
3.44	2012	10/9/2012	SSHA	M	SY
3.41	2009	10/11/2009	SSHA	M	SY
3.35	2009	10/8/2009	SSHA	F	ASY
3.34	2011	9/22/2011	SSHA	M	SY
3.33	2012	10/6/2012	SSHA	M	AHY
3.33	2011	9/11/2011	SSHA	F	ASY
3.26	2009	9/29/2009	SSHA	F	SY
3.25	2011	9/22/2011	SSHA	M	SY
3.25	2012	10/16/2012	SSHA	F	SY
3.25	2012	9/15/2012	SSHA	F	SY
3.21	2009	11/15/2009	SSHA	M	SY
3.21	2011	9/27/2011	SSHA	F	ASY
3.19	2011	9/15/2011	SSHA	F	SY
3.18	2009	10/17/2009	SSHA	F	HY
3.18	2010	10/4/2010	SSHA	M	SY
3.17	2012	9/21/2012	SSHA	M	SY
3.17	2012	10/8/2012	SSHA	M	ASY
3.17	2011	10/15/2011	SSHA	M	ASY
3.14	2009	9/27/2009	SSHA	M	HY
3.14	2012	9/19/2012	SSHA	M	SY
3.13	2011	9/14/2011	SSHA	F	SY
3.12	2010	10/8/2010	SSHA	M	ASY
3.12	2010	10/16/2010	SSHA	F	SY
3.11	2009	10/19/2009	SSHA	M	SY
3.11	2012	10/2/2012	SSHA	M	AHY
3.11	2012	8/25/2012	SSHA	F	SY
3.11	2009	9/28/2009	SSHA	M	HY
3.04	2010	9/4/2010	SSHA	M	HY
3.00	2010	9/27/2010	SSHA	M	AHY
2.96	2011	9/3/2011	SSHA	F	ASY

2.94	2011	9/17/2011	SSHA	F	SY
2.91	2010	10/3/2010	SSHA	F	ASY
2.90	2012	10/9/2012	SSHA	M	AHY
2.87	2011	10/15/2011	SSHA	M	ASY
2.86	2012	10/10/2012	SSHA	M	SY
2.86	2011	9/20/2011	SSHA	F	SY
2.86	2011	9/13/2011	SSHA	F	AHY
2.85	2009	9/24/2009	SSHA	M	HY
2.82	2011	9/21/2011	SSHA	F	ASY
2.79	2012	9/6/2012	SSHA	F	HY
2.77	2009	9/26/2009	SSHA	F	HY
2.77	2012	10/6/2012	SSHA	M	AHY
2.76	2009	10/8/2009	SSHA	F	HY
2.74	2009	9/22/2009	SSHA	M	HY
2.73	2011	10/8/2011	SSHA	M	HY
2.70	2011	9/11/2011	SSHA	F	SY
2.69	2009	9/28/2009	SSHA	M	HY
2.67	2012	10/6/2012	SSHA	M	AHY
2.65	2012	10/30/2012	SSHA	M	HY
2.59	2012	10/8/2012	SSHA	M	ASY
2.56	2011	9/20/2011	SSHA	F	SY
2.56	2012	10/6/2012	SSHA	M	AHY
2.56	2010	9/26/2010	SSHA	F	ASY
2.56	2011	9/11/2011	SSHA	F	SY
2.54	2011	10/17/2011	SSHA	M	ASY
2.46	2012	10/13/2012	SSHA	F	SY
2.46	2012	10/8/2012	SSHA	F	ASY
2.45	2012	9/11/2012	SSHA	F	HY
2.43	2009	9/27/2009	SSHA	M	HY
2.43	2012	9/5/2012	SSHA	F	HY
2.42	2011	9/11/2011	SSHA	F	SY
2.38	2011	9/16/2011	SSHA	F	ASY
2.37	2009	9/26/2009	SSHA	M	HY
2.36	2011	10/4/2011	SSHA	M	SY
2.32	2011	9/21/2011	SSHA	M	HY
2.32	2012	9/22/2012	SSHA	F	SY
2.30	2011	9/21/2011	SSHA	M	HY
2.28	2012	10/3/2012	SSHA	M	ASY
2.27	2010	8/28/2010	SSHA	F	HY
2.25	2010	9/26/2010	SSHA	F	ASY
2.25	2009	9/25/2009	SSHA	M	HY

2.24	2009	10/8/2009	SSHA	M	HY
2.15	2010	9/29/2010	SSHA	M	HY
2.11	2010	9/30/2010	SSHA	F	AHY
2.09	2009	9/30/2009	SSHA	M	HY
2.08	2010	8/27/2010	SSHA	F	HY
2.08	2011	9/10/2011	SSHA	M	HY
2.06	2011	9/21/2011	SSHA	M	HY
2.05	2009	10/1/2009	SSHA	M	HY
2.05	2012	8/28/2012	SSHA	F	HY
2.03	2011	9/11/2011	SSHA	F	AHY
2.02	2011	9/14/2011	SSHA	F	SY
2.01	2012	10/15/2012	SSHA	M	ASY
2.00	2010	9/19/2010	SSHA	F	HY
1.98	2012	10/4/2012	SSHA	M	AHY
1.96	2012	9/15/2012	SSHA	F	ASY
1.95	2011	9/20/2011	SSHA	M	HY
1.94	2009	10/15/2009	SSHA	F	HY
1.94	2010	9/30/2010	SSHA	F	HY
1.93	2010	8/23/2010	SSHA	F	HY
1.93	2011	9/22/2011	SSHA	F	ASY
1.91	2012	9/15/2012	SSHA	M	HY
1.91	2012	9/19/2012	SSHA	F	HY
1.91	2010	8/26/2010	SSHA	F	HY
1.90	2012	9/13/2012	SSHA	F	HY
1.90	2011	9/16/2011	SSHA	F	SY
1.88	2012	9/15/2012	SSHA	F	HY
1.88	2011	9/29/2011	SSHA	M	HY
1.87	2012	10/9/2012	SSHA	F	HY
1.85	2012	10/8/2012	SSHA	M	AHY
1.84	2011	9/20/2011	SSHA	F	ASY
1.80	2010	9/4/2010	SSHA	F	HY
1.79	2010	9/29/2010	SSHA	F	HY
1.77	2012	9/13/2012	SSHA	M	HY
1.77	2009	10/7/2009	SSHA	M	HY
1.76	2010	8/30/2010	SSHA	M	HY
1.73	2009	10/8/2009	SSHA	M	HY
1.73	2012	9/15/2012	SSHA	M	HY
1.72	2011	9/28/2011	SSHA	M	HY
1.71	2009	10/4/2009	SSHA	M	HY
1.71	2009	10/7/2009	SSHA	F	HY
1.70	2010	9/7/2010	SSHA	F	HY



1.69	2011	9/14/2011	SSHA	F	ASY
1.68	2010	9/8/2010	SSHA	F	HY
1.67	2010	9/16/2010	SSHA	M	HY
1.65	2012	9/15/2012	SSHA	F	HY
1.65	2010	9/28/2010	SSHA	M	HY
1.63	2010	9/17/2010	SSHA	F	HY
1.61	2010	10/13/2010	SSHA	F	ASY
1.61	2011	9/20/2011	SSHA	M	HY
1.60	2011	10/8/2011	SSHA	M	HY
1.60	2010	9/17/2010	SSHA	M	HY
1.60	2009	9/27/2009	SSHA	F	HY
1.59	2011	9/22/2011	SSHA	M	HY
1.59	2010	9/16/2010	SSHA	M	HY
1.59	2009	10/9/2009	SSHA	M	HY
1.59	2010	9/7/2010	SSHA	M	HY
1.58	2011	10/6/2011	SSHA	M	HY
1.58	2011	8/30/2011	SSHA	F	HY
1.58	2012	10/11/2012	SSHA	F	HY
1.58	2011	9/13/2011	SSHA	F	SY
1.55	2012	8/20/2012	SSHA	F	HY
1.55	2009	10/11/2009	SSHA	M	HY
1.55	2009	10/1/2009	SSHA	F	HY
1.54	2011	9/13/2011	SSHA	F	HY
1.53	2011	9/21/2011	SSHA	F	ASY
1.53	2012	8/25/2012	SSHA	F	HY
1.52	2010	8/30/2010	SSHA	F	HY
1.52	2011	9/3/2011	SSHA	F	HY
1.51	2010	9/14/2010	SSHA	M	HY
1.50	2011	9/21/2011	SSHA	F	HY
1.50	2011	9/21/2011	SSHA	M	HY
1.49	2012	10/10/2012	SSHA	M	HY
1.48	2009	9/23/2009	SSHA	F	HY
1.48	2011	9/20/2011	SSHA	F	HY
1.48	2010	9/13/2010	SSHA	F	HY
1.48	2011	9/20/2011	SSHA	F	HY
1.47	2010	9/3/2010	SSHA	F	HY
1.47	2012	10/6/2012	SSHA	M	ASY
1.47	2012	8/20/2012	SSHA	F	HY
1.46	2012	10/10/2012	SSHA	M	SY
1.46	2012	9/5/2012	SSHA	F	HY
1.46	2011	9/21/2011	SSHA	F	HY

1.46	2012	9/13/2012	SSHA	F	HY
1.46	2009	9/28/2009	SSHA	F	HY
1.45	2012	9/21/2012	SSHA	F	SY
1.43	2012	9/19/2012	SSHA	M	HY
1.42	2011	9/20/2011	SSHA	F	HY
1.42	2010	9/13/2010	SSHA	M	HY
1.40	2012	9/17/2012	SSHA	F	HY
1.40	2012	9/1/2012	SSHA	F	HY
1.40	2010	9/24/2010	SSHA	F	HY
1.39	2009	10/27/2009	SSHA	F	HY
1.39	2011	9/20/2011	SSHA	M	HY
1.38	2010	8/27/2010	SSHA	F	HY
1.38	2010	9/15/2010	SSHA	M	HY
1.37	2010	9/14/2010	SSHA	M	HY
1.37	2010	9/13/2010	SSHA	M	HY
1.37	2010	9/7/2010	SSHA	M	HY
1.36	2010	9/13/2010	SSHA	F	HY
1.36	2012	9/13/2012	SSHA	F	HY
1.36	2010	9/20/2010	SSHA	M	HY
1.35	2009	9/22/2009	SSHA	F	HY
1.35	2012	9/21/2012	SSHA	M	HY
1.33	2012	9/21/2012	SSHA	M	HY
1.33	2011	9/20/2011	SSHA	F	HY
1.32	2012	10/27/2012	SSHA	F	HY
1.31	2010	9/8/2010	SSHA	M	HY
1.29	2010	9/30/2010	SSHA	M	HY
1.29	2010	9/12/2010	SSHA	F	HY
1.29	2010	8/25/2010	SSHA	F	HY
1.26	2010	9/18/2010	SSHA	M	HY
1.25	2010	9/13/2010	SSHA	M	HY
1.25	2011	8/30/2011	SSHA	M	HY
1.24	2012	9/1/2012	SSHA	F	HY
1.24	2012	8/28/2012	SSHA	F	HY
1.24	2011	10/5/2011	SSHA	F	HY
1.23	2012	9/13/2012	SSHA	F	HY
1.22	2012	9/30/2012	SSHA	M	HY
1.22	2010	9/8/2010	SSHA	F	HY
1.20	2010	9/17/2010	SSHA	M	HY
1.20	2012	9/21/2012	SSHA	F	HY
1.20	2010	9/30/2010	SSHA	F	HY
1.19	2010	9/14/2010	SSHA	M	HY

1.18	2012	8/28/2012	SSHA	F	HY
1.18	2012	9/13/2012	SSHA	F	HY
1.18	2010	9/7/2010	SSHA	F	HY
1.16	2010	9/18/2010	SSHA	M	HY
1.16	2010	9/13/2010	SSHA	F	HY
1.15	2009	10/17/2009	SSHA	F	HY
1.13	2010	9/22/2010	SSHA	M	HY
1.13	2012	9/15/2012	SSHA	M	HY
1.12	2011	9/21/2011	SSHA	F	HY
1.12	2010	9/17/2010	SSHA	F	HY
1.11	2011	9/20/2011	SSHA	M	HY
1.11	2012	9/21/2012	SSHA	F	HY
1.11	2009	10/8/2009	SSHA	M	HY
1.11	2012	9/24/2012	SSHA	M	HY
1.09	2012	9/13/2012	SSHA	M	HY
1.08	2010	9/12/2010	SSHA	M	HY
1.07	2010	9/12/2010	SSHA	F	HY
1.07	2011	9/21/2011	SSHA	F	HY
1.06	2010	9/18/2010	SSHA	M	HY
1.04	2012	9/6/2012	SSHA	M	HY
1.04	2010	9/13/2010	SSHA	M	HY
1.04	2010	9/12/2010	SSHA	F	HY
1.03	2011	9/20/2011	SSHA	M	HY
1.03	2011	9/21/2011	SSHA	M	HY
1.02	2010	9/14/2010	SSHA	M	HY
1.01	2010	9/13/2010	SSHA	F	HY
1.00	2010	8/31/2010	SSHA	F	HY
1.00	2010	9/1/2010	SSHA	F	HY
1.00	2010	8/31/2010	SSHA	F	HY
0.99	2012	8/28/2012	SSHA	F	HY
0.98	2010	9/10/2010	SSHA	F	HY
0.98	2010	9/22/2010	SSHA	M	HY
0.98	2010	9/8/2010	SSHA	F	HY
0.98	2012	8/28/2012	SSHA	F	HY
0.98	2009	9/24/2009	SSHA	F	HY
0.98	2009	9/28/2009	SSHA	F	HY
0.97	2012	10/9/2012	SSHA	F	HY
0.97	2012	10/9/2012	SSHA	M	HY
0.96	2012	8/28/2012	SSHA	F	HY
0.94	2012	8/28/2012	SSHA	F	HY
0.94	2011	9/23/2011	SSHA	F	HY

0.93	2011	8/27/2011	SSHA	M	HY
0.92	2011	9/14/2011	SSHA	F	HY
0.91	2010	9/2/2010	SSHA	F	HY
0.90	2012	9/21/2012	SSHA	F	HY
0.90	2012	10/9/2012	SSHA	M	HY
0.89	2010	9/30/2010	SSHA	F	HY
0.89	2010	9/7/2010	SSHA	M	HY
0.84	2010	9/25/2010	SSHA	M	HY
0.83	2011	9/21/2011	SSHA	M	HY
0.83	2010	9/19/2010	SSHA	F	HY
0.83	2009	10/8/2009	SSHA	M	HY
0.82	2010	8/29/2010	SSHA	F	HY
0.82	2012	8/28/2012	SSHA	F	HY
0.80	2012	9/15/2012	SSHA	M	HY
0.80	2011	8/30/2011	SSHA	F	HY
0.77	2011	9/21/2011	SSHA	F	HY
0.77	2010	9/4/2010	SSHA	M	HY
0.76	2012	10/10/2012	SSHA	M	HY
0.75	2012	9/1/2012	SSHA	F	HY
0.72	2010	10/2/2010	SSHA	F	HY
0.71	2012	9/18/2012	SSHA	M	HY
0.66	2009	10/4/2009	SSHA	M	HY
0.63	2011	9/20/2011	SSHA	F	HY
0.55	2010	9/13/2010	SSHA	M	HY
0.48	2012	9/7/2012	SSHA	F	HY
0.40	2012	9/13/2012	SSHA	F	HY
0.11	2012	9/14/2012	SWHA	U	HY

Appendix B: Isotope Data

Cohort	Species	Age	Sex	ln(Hg)	15N	13C
SS_HY_M	SS	HY	M	-0.60	5.07	-22.51
SS_HY_M	SS	HY	M	-0.41	5.21	-21.63
SS_HY_M	SS	HY	M	-0.34	4.99	-21.67
SS_HY_M	SS	HY	M	-0.27	6.13	-22.1
SS_HY_M	SS	HY	M	-0.23	5.86	-21.43
SS_HY_M	SS	HY	M	-0.22	6.41	-21.68
SS_HY_M	SS	HY	M	-0.18	5.49	-21.82
SS_HY_M	SS	HY	M	-0.17	5.34	-21.74
SS_HY_M	SS	HY	M	-0.12	5.81	-22.16
SS_HY_M	SS	HY	M	0.97	6.2	-22.9
SS_HY_M	SS	HY	M	0.99	7.67	-21.29
SS_HY_M	SS	HY	M	1.00	6.98	-22.58
SS_HY_M	SS	HY	M	1.01	6.87	-22.93
SS_HY_M	SS	HY	M	1.05	5.19	-21.4
SS_HY_M	SS	HY	M	1.11	6.32	-21.81
SS_HY_M	SS	HY	M	1.13	6.63	-23.16
SS_HY_M	SS	HY	M	1.15	5.92	-21.93
SS_HY_M	SS	HY	M	1.31	7.84	-22.25
SS_HY_F	SS	HY	F	-0.74	5.94	-21.83
SS_HY_F	SS	HY	F	-0.47	5.61	-21.25
SS_HY_F	SS	HY	F	-0.33	6.07	-22.54
SS_HY_F	SS	HY	F	-0.29	5.41	-20.89
SS_HY_F	SS	HY	F	-0.26	5.99	-22.27
SS_HY_F	SS	HY	F	-0.20	7.35	-21.76
SS_HY_F	SS	HY	F	-0.19	5.51	-22.06
SS_HY_F	SS	HY	F	-0.18	6.56	-22.71
SS_HY_F	SS	HY	F	0.73	6.14	-21.82
SS_HY_F	SS	HY	F	0.89	6.26	-22.34
SS_HY_F	SS	HY	F	0.89	6.38	-21.58
SS_HY_F	SS	HY	F	1.01	5.67	-21.4
SS_HY_F	SS	HY	F	1.02	6.17	-22.04
SS_HY_F	SS	HY	F	1.03	5.97	-21.92
SS_HY_F	SS	HY	F	1.16	4.95	-21.54
SS_HY_F	SS	HY	F	1.40	6.41	-23.53
SS_HY_F	SS	HY	F	2.60	7.31	-21.33
SS_AHY_M	SS	AHY	M	0.38	6.86	-22.65
SS_AHY_M	SS	AHY	M	0.38	5.36	-21.27

SS_AHY_M	SS	AHY	M	0.61	5.48	-22.17
SS_AHY_M	SS	AHY	M	0.68	5.9	-21.96
SS_AHY_M	SS	AHY	M	0.70	6.68	-21.08
SS_AHY_M	SS	AHY	M	0.84	4.58	-21.5
SS_AHY_M	SS	AHY	M	0.93	8.99	-21.54
SS_AHY_M	SS	AHY	M	0.94	5.91	-22.78
SS_AHY_M	SS	AHY	M	0.95	6.22	-21.88
SS_AHY_M	SS	AHY	M	1.96	4.49	-21.18
SS_AHY_M	SS	AHY	M	1.98	6.47	-21.04
SS_AHY_M	SS	AHY	M	2.03	4.61	-22.35
SS_AHY_M	SS	AHY	M	2.06	6.39	-22.72
SS_AHY_M	SS	AHY	M	2.12	7.55	-22.83
SS_AHY_M	SS	AHY	M	2.40	7.89	-23.23
SS_AHY_M	SS	AHY	M	2.44	6.3	-21.6
SS_AHY_M	SS	AHY	M	2.57	6.41	-21.85
SS_AHY_M	SS	AHY	M	2.89	6.64	-22.57
SS_AHY_M	SS	AHY	M	3.30	6.3	-22.06
SS_AHY_F	SS	AHY	F	0.37	5.98	-20.73
SS_AHY_F	SS	AHY	F	0.43	6.26	-21.44
SS_AHY_F	SS	AHY	F	0.46	4.41	-22.22
SS_AHY_F	SS	AHY	F	0.48	7.78	-22.89
SS_AHY_F	SS	AHY	F	0.53	5.48	-21.62
SS_AHY_F	SS	AHY	F	0.61	5.4	-21.98
SS_AHY_F	SS	AHY	F	0.64	5.85	-22.76
SS_AHY_F	SS	AHY	F	0.66	4.03	-21.51
SS_AHY_F	SS	AHY	F	0.67	6.33	-21.77
SS_AHY_F	SS	AHY	F	0.70	5.68	-22.95
SS_AHY_F	SS	AHY	F	2.15	5.86	-21.7
SS_AHY_F	SS	AHY	F	2.16	6.9	-21.51
SS_AHY_F	SS	AHY	F	2.21	6.39	-21.87
SS_AHY_F	SS	AHY	F	2.31	6.64	-21.77
SS_AHY_F	SS	AHY	F	2.48	5.03	-23.04
SS_AHY_F	SS	AHY	F	2.50	6.62	-22.79
SS_AHY_F	SS	AHY	F	2.64	8.67	-23.64
SS_AHY_F	SS	AHY	F	2.67	7.85	-22.89
ML_HY_M	ML	HY	M	-1.97	5.09	-21.7
ML_HY_M	ML	HY	M	-1.12	7.92	-21.79
ML_HY_M	ML	HY	M	-1.03	8.12	-20.56
ML_HY_M	ML	HY	M	-0.48	8.06	-21.75
ML_HY_M	ML	HY	M	-0.47	7.57	-21.64
ML_HY_M	ML	HY	M	-0.38	6.87	-23.5

ML_HY_M	ML	HY	M	-0.24	5.17	-21.34
ML_HY_M	ML	HY	M	-0.23	3.61	-22.12
ML_HY_M	ML	HY	M	-0.09	5.46	-22.8
ML_HY_M	ML	HY	M	-0.08	6.68	-21.55
ML_HY_M	ML	HY	M	0.62	4.85	-21.68
ML_HY_M	ML	HY	M	0.63	7.08	-21.64
ML_HY_M	ML	HY	M	0.65	6.36	-22.78
ML_HY_M	ML	HY	M	0.78	5.79	-22.17
ML_HY_M	ML	HY	M	0.79	9.69	-22.59
ML_HY_M	ML	HY	M	0.80	6.63	-22.62
ML_HY_M	ML	HY	M	0.87	6.8	-22.01
ML_HY_M	ML	HY	M	0.89	6.57	-23.08
ML_HY_M	ML	HY	M	1.15	4.73	-23.1
ML_HY_M	ML	HY	M	1.22	7.57	-23.21
ML_HY_F	ML	HY	F	-0.72	5.9	-21.34
ML_HY_F	ML	HY	F	-0.62	3.85	-21.34
ML_HY_F	ML	HY	F	-0.29	7.65	-21.9
ML_HY_F	ML	HY	F	-0.23	5.55	-21.63
ML_HY_F	ML	HY	F	-0.15	10.73	-20.73
ML_HY_F	ML	HY	F	-0.07	5.61	-21.48
ML_HY_F	ML	HY	F	-0.06	5.55	-20.85
ML_HY_F	ML	HY	F	0.02	5.61	-22.3
ML_HY_F	ML	HY	F	0.07	6.81	-22.14
ML_HY_F	ML	HY	F	0.11	6.78	-21.45
ML_HY_F	ML	HY	F	0.76	7.19	-20.67
ML_HY_F	ML	HY	F	0.78	6.41	-21.44
ML_HY_F	ML	HY	F	0.86	7.37	-23.71
ML_HY_F	ML	HY	F	0.89	7.18	-23.21
ML_HY_F	ML	HY	F	0.96	8.4	-22.05
ML_HY_F	ML	HY	F	1.00	6.72	-19.2
ML_HY_F	ML	HY	F	1.10	6.83	-23.5
ML_HY_F	ML	HY	F	1.11	5.47	-22.96
ML_HY_F	ML	HY	F	1.14	5.39	-22.57
ML_HY_F	ML	HY	F	2.47	8.34	-23.42
ML_AHY_M	ML	AHY	M	0.33	10.26	-18.86
ML_AHY_M	ML	AHY	M	0.80	5.22	-23.31
ML_AHY_M	ML	AHY	M	0.98	4.84	-21.19
ML_AHY_M	ML	AHY	M	1.07	7.3	-22.12
ML_AHY_M	ML	AHY	M	1.46	7.5	-21.58
ML_AHY_M	ML	AHY	M	1.84	5.91	-22.88
ML_AHY_M	ML	AHY	M	1.84	6.84	-20.36

ML_AHY_M	ML	AHY	M	2.14	6.74	-23.09
ML_AHY_M	ML	AHY	M	2.30	7.97	-24.11
ML_AHY_F	ML	AHY	F	-0.08	6.54	-22.01
ML_AHY_F	ML	AHY	F	1.00	8.96	-23.06
ML_AHY_F	ML	AHY	F	1.06	13.8	-16.46
ML_AHY_F	ML	AHY	F	1.51	6.88	-22.64
ML_AHY_F	ML	AHY	F	1.60	7.64	-22.1
ML_AHY_F	ML	AHY	F	1.85	7.05	-21.79
ML_AHY_F	ML	AHY	F	1.91	7	-20.87
ML_AHY_F	ML	AHY	F	1.93	9.52	-16.15
ML_AHY_F	ML	AHY	F	2.30	9	-21.03
ML_AHY_F	ML	AHY	F	2.77	9.14	-23.41