Heavy Metals in Utility Nesting Peregrine Falcons

Technical Report

Heavy Metals in Utility Nesting Peregrine Falcons

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REPORT SUMMARY

Peregrine falcons, a formerly endangered species, began nesting on utility stacks in 1989. First considered an anomaly, utility-nesting Peregrine falcons now comprise over one-third of the total falcon population in the Midwest, and over half of the total population in Minnesota and Wisconsin. However, concerns arose as to whether the physical or reproductive health of utility-nesting Peregrines might be jeopardized by mercury and other coal combustion by-products. This study tracked levels of mercury, selenium, chromium, nickel, and arsenic in utility-nesting Peregrines over a three-year period, yielded a profile of each site's contaminant levels, and provided a baseline against which the contaminant levels of future Peregrines may be measured.

Background

Utility nesting falcons are most successful in terms of number of young fledged. In fact, when compared against nests on buildings, cliffs, and bridges, utility nests have the highest rate of chick-to-fledgling survival and nest productivity. They also have very high year-to-year adult survivability and post-fledgling survival rates. By any standard, the Utility Peregrine Rescue Program of the Raptor Resource Project has been a resounding success in the Midwestern United States. In fact, Peregrine falcons currently nest at utilities in Minnesota, Iowa, Wisconsin, Kentucky, Kansas, Michigan, Indiana, and Ohio. The Raptor Resource Project, Xcel Energy, Wisconsin Electric Wisconsin Gas, and Dairyland Power wanted to ensure that Peregrine falcons nesting at fossil fuel plants were not accumulating levels of heavy metals hazardous to their physical or reproductive health. Such questions are not surprising in light of current emissions estimates, which indicate that coal-fired utility boilers are the single largest source of anthropogenic mercury emissions, contributing approximately 33% of the national inventory. Other metals produced by burning fossil fuels include chromium, selenium, arsenic, and nickel.

Objectives

- To establish whether Peregrine falcons nesting at fossil fuel plants were accumulating levels of heavy metals hazardous to their physical or reproductive health.
- To develop baseline metals data on wild Peregrine falcons.
- To explore the possibility of using Peregrine falcons as bio-sentinels to track mercury in wildlife within the near-site deposition area of a plant.

Approach

Investigators tested five groups of Peregrine falcons over a three-year period to determine their blood levels of methylmercury (MeHg), selenium, chromium, arsenic, and nickel. The groups consisted of fossil fuel nesting falcons, nuclear plant nesting falcons, urban nesting falcons, immature arctic falcons, and control falcons. Where possible, investigators tested adults and chicks, also testing adults from year to year at some locations. They compared blood data from all five groups, all three years, and within each group to develop a profile of metals exposure among each group and at each site. Using this data, they established whether Peregrine falcons nesting at fossil fuel plants had higher levels of metals exposure than did falcons nesting elsewhere. They also developed a profile of exposure for each site and each year. In all, they developed baseline exposure data for 15 utility plants spanning over 300 miles of the Mississippi river and its tributaries—from the river's headwaters at Minnesota Power and Light's Cohasset plant through Alliant Energy's Lansing plant in northeastern Iowa.

Results

Peregrines nesting at fossil fuel plants had higher blood MeHg levels than did those nesting at nuclear and urban locations. However, Peregrines nesting at fossil sites are not accumulating levels of heavy metals hazardous to their physical or reproductive health. The study found a stronger correlation between HgII output and blood MeHg levels in adults, suggesting adults would make better bio-sentinels than chicks. The adult group was very small, though, and further study would be warranted before beginning a full-scale bio-sentinel program. Fossil adults and chicks were also slightly more exposed to selenium and chromium—again, not at harmful levels—in all three years of the study. Urban nesting falcons had the highest exposure to arsenic, while all groups had minimal exposure to nickel. Based on the results, Peregrine falcons at fossil fuel burning utility sites do not appear to be at risk for significantly increased exposure to heavy metals when compared with nuclear, urban, and arctic Peregrines.

EPRI Perspective

The efforts of the Raptor Resource Project (RRP) have resulted in the recovery of the Midwest population of the Peregrine falcon and subsequently the removal of this species of raptor from the U.S. endangered species list. The success of this program has generated not only high praise and recognition for the RRP and utility participants, but also a growing interest among potential future participants. Before the program could move forward to involve other coal-fired facilities, the potential for exposure of birds to stack emissions had to be assessed. This study shows that birds nesting on utility stacks do not accumulate metals to hazardous concentrations. The next step in this project will be to produce a guidance document that can aid other organizations in installing Peregrine falcon nest boxes on utility stacks and buildings.

Keywords

Heavy metals
Fossil fuels
Utility nesting sites

ABSTRACT

Peregrine falcons, a formerly endangered species, began nesting on Midwestern utility stacks in 1989. Midwestern recovery efforts, however, began much earlier, in 1982, with the captive production and release of young birds. In 1987, MF-1—a falcon bred by the Raptor Resource Project for the Minnesota Falconers Association—became the first returned Peregrine to breed in the wild in the Midwest. Mae—the first Peregrine to produce young on a utility stack—fledged two chicks from Northern State Power's Alan King plant in 1990. From that point on, the utility Peregrine nesting program, first considered an anomaly, grew rapidly.

As of this writing, Peregrines fledged from utility sites comprise about 30% of the Midwest population. When compared against nests on buildings, cliffs, and bridges, utility nests have the highest rate of chick-to-fledgling survival and nest productivity. They also have very high year-to-year adult survivability and post-fledgling survival rates. Peregrine falcons currently nest at utilities in Minnesota, Iowa, Wisconsin, Kentucky, Kansas, Michigan, Indiana, and Ohio.

Although there is no a priori indication of metal toxicity based on behavioral data, Peregrine falcons nesting at fossil fuel plants were considered at risk for developing heavy metal toxicity over time. Organizers of the Utility Peregrine Rescue Program of the Raptor Resource Project are repeatedly asked whether the physical or reproductive health of utility-nesting Peregrines might be jeopardized by mercury and other coal combustion by-products. Such questions are not surprising in light of current emissions estimates, which indicate that coal-fired utility boilers are the single largest source of anthropogenic mercury emissions, contributing approximately 33% of the national inventory. Other metals produced by burning fossil fuels include chromium, selenium, arsenic, and nickel.

This study tracked levels of mercury, selenium, chromium, nickel, and arsenic in utility-nesting Peregrines over a three-year period, yielded a profile of each site's contaminant levels, and provided a baseline against which the contaminant levels of future Peregrines may be measured. Based on the results, Peregrine falcons at fossil fuel burning utility sites do not appear to be at risk for significantly increased exposure to heavy metals when compared with nuclear, urban, and arctic Peregrines.

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FOSSIL FUELS AND UTILITY PEREGRINES

The utility-peregrine program in the Midwestern United States is in its 12th successful year. When compared against nests on buildings, cliffs, and bridges, utility nests have the highest rate of chick-to-fledgling survival and nest productivity; they also have very high year-to-year adult survivability and post-fledgling survival rates. The program has been by any standard a resounding success; however, we have repeatedly been asked whether the physical or reproductive health of utility-nesting peregrines might be jeopardized by mercury and other byproducts of coal combustion. Current emissions estimates indicate that coal-fired utility boilers are the single largest source of anthropogenic mercury emissions, contributing approximately 33% of the national inventory [1]. Other metals produced by burning fossil fuels include chromium, selenium, arsenic, and nickel.

The Raptor Resource Project drew blood from five groups of falcons over a three-year period to determine whether falcons nesting at coal burning utilities are at higher risk for exposure to mercury and other metals than falcons nesting elsewhere. Chicks and adults from fossil fuel utilities, nuclear utilities, urban locations, and the Project's captive breeding program were sampled, as were immature tundrius falcons trapped on their first migration from the Arctic Circle. The blood was analyzed to determine mercury, selenium, chromium, nickel, and arsenic content in falcons from each group.

Sample Collection

Samples were collected from Peregrine chicks and one adult on site. A minimum of 1 ml of blood was drawn from the cutaneous ulnar (elbow of the wing) into a 3-cc container using a 25-gauge 5/8" syringe. This blood was transferred to a sterile sodium heparin vacutainer and frozen. Samples were kept frozen until tested.

Analysis

Frontier GeoSciences (Seattle, WA) processed the samples using ultra-clean sample handling techniques in class-100 clean areas known to be low in atmospheric trace metals. Reagents, gases, and deionized water were all reagent or ultra-pure grade, and previously were analyzed for trace metals to ensure very low blanks. Total Hg analysis was performed using cold vapor atomic fluorescence spectrometry (CVAFS) as a detector (EPA Method 1631 modified). Cr, Ni, and As were analyzed using inductively coupled plasma-mass spectrometry (ICP-MS) with a Perkin-Elmer Elan 6000 (EPA Method 1638 modified). Total Se was determined by hydride generation - atomic fluorescence spectrometry (HG-AFS).

In 1999, a discrepancy between MeHg and total Hg was revealed in the first set of tests. It was determined that different digests were used to measure Hg and MeHg, making it difficult to compare both forms of the metal since measurements were not done on the same samples at the same time. The samples were retested for MeHg and Hg (II) (inorganic mercury), using one digest. Subsequent samples were tested using this method. The samples taken in 1998 were corrected for the process used and can be considered accurate. Dr. Nicholas Bloom (Frontier Geosciences) assessed year-to-year variability of all samples and determined that samples were comparable.

Fossil Fuel Nesting Falcons

83 blood samples were collected between 1998 and 2000 from chick and adult falcons nesting at 13 fossil fuel generating plants in Minnesota, Iowa, and Wisconsin. With very few exceptions, the falcons were nesting in unpainted wooden nest boxes placed on utility smokestacks. Chicks were sampled at between an estimated 10 and 30 days of age: adults were sampled either at the same time as chicks or while egg sitting prior to hatching. Eleven of the sites had multiple-year falcon nesting histories. Adults and chicks appeared physically healthy, the sites have histories of successful reproduction, and falcons at seven sites have produced one or more chicks that survived into adulthood.

Nuclear Nesting Falcons

18 blood samples were collected between 1998 and 2000 from falcon chicks nesting at the Prairie Island and Monticello nuclear power generating plants in Minnesota. The Prairie Island falcons were nesting in a wooden nest box on top of the containment dome, and the Monticello falcons in a wooden nest box on the off-gas stack. Both sites have multiple-year falcon nesting histories. Adults and chicks appeared physically healthy, the sites have histories of successful reproduction, and falcons at both sites have produced one or more chicks that survived into adulthood.

Urban Nesting Falcons

4 samples were collected in 1998 from falcon chicks nesting in unpainted wooden nest boxes on non-industrial buildings in urban Des Moines and Cedar Rapids. Both sites have successful multiple-year falcon nesting histories. Adults and chicks appeared physically healthy, the sites have histories of successful reproduction, and falcons at both sites have produced one or more chicks that survived into adulthood.

Tundrius (Arctic) Falcons

7 samples were collected between 1999 and 2000 from wild unbanded immature and adult. *Peregrinus tundrius* falcons migrating through Decorah, Iowa; Cedar Grove, Wisconsin; and Virginia. We identified these falcons as members of the *tundrius* subspecies, which breeds in the tundra regions of Canada, Alaska and Greenland, based on their “blond” heads (since *P. tundrius*

falcons have very narrow mallar stripes, their heads appear lighter or blonder than the heads of other subspecies), their migratory periods (*P. tundrius* falcons migrate through the northern United States from approximately the last week of September through the first week of October), their appearance on known *P. tundrius* migration routes, and their lack of bands. The immature falcons were identified by their brown and white plumage; immature falcons lack the slate backs and barred breasts of adults.

Control Falcons

Ten samples were collected between 1998 and 2000 from chick and adult falcons at the Raptor Resource Project. The adult falcons are captive breeding stock and ate a controlled diet of ground quail and chicken. The chicks were released into the wild shortly after sampling: like the adults, they were fed a controlled diet of quail and chicken. The adult falcons have histories of successful reproduction and several released chicks survived into adulthood.

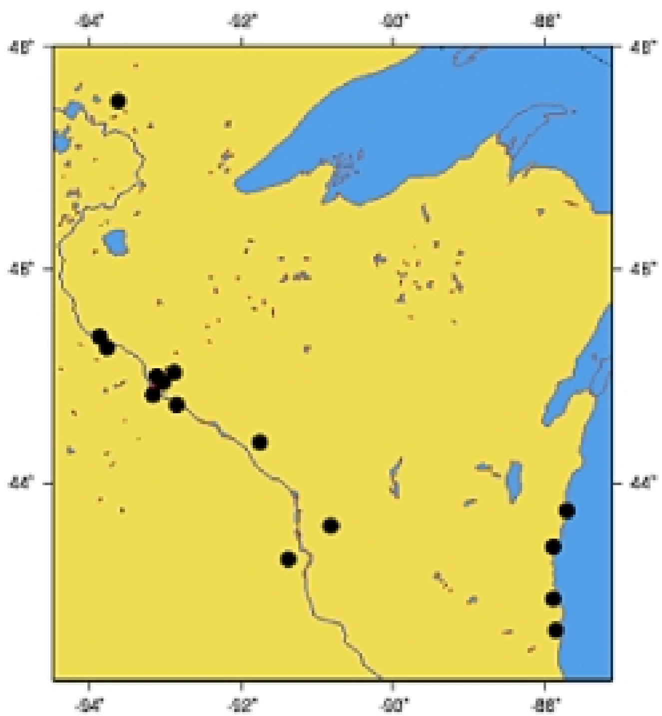

Figure 1-1
Fifteen Utility Locations at which Nesting Peregrine Falcons were Sampled

2
MERCURY

Mercury Toxicology

Methylmercury (MeHg) has harmful effects on survival, reproduction, behavior, and cell development, and is teratogenic. Reproduction is one of the most sensitive endpoints and MeHg causes reproductive impairment in birds at lower exposure levels than those required to produce other pathological effects: outcomes include impaired territorial fidelity and egg laying, reduced hatching success, and impaired chick survivability [2, 3, 4].

Mercury toxicity to birds can vary with species, age, sex, physiological condition, route of administration and dose; it may also vary with external factors such as water pH and levels of antagonists. In a study of adult loons carried out between 1991 and 1996, mean adult whole-blood Hg concentration was 1.72 (± 1.17) ppm across North America and 1.58 (± 0.92) ppm in the Great Lakes Region. Loon chick whole-blood concentration was 0.14 ppm across North America and 0.23 ppm in North Central Wisconsin [5]. Fossil, nuclear, and urban falcon adults and chicks collected as part of this study had MeHg blood levels roughly a factor of 10 lower than that of loons collected in the same region; less exposure in peregrines is likely a function of a terrestrial diet vs. an aquatic diet [6].

A number of thresholds have been suggested for toxic effects. These include [7, 8, 9, 10]:

- 2 ppm liver: reproductive and behavioral deficiencies in domestic mallards and pheasants.
- 3-14 ppm liver: abnormal feather loss in tern chicks.
- 3-13.7 ppm liver: decreased hatchability of eggs of the common loon.
- 5 ppm liver: conservative threshold for major toxic effects in waterbirds.
- 11+ ppm liver: high embryo/duckling mortality, brain lesions.
- 17+ ppm liver: mortality in red-tailed hawks.

If we assume blood Hg was slightly lower than liver Hg [11], none of the fossil, urban, nuclear, or control chicks that were tested contained levels of MeHg known to be detrimental to the chicks' physical or reproductive health. Year-to-year comparisons of chick and adult blood MeHg reveal what in most cases are slight fluctuations likely tied to changes in Hg emissions, prey MeHg levels, age (in chicks) and other factors. At the Kenosha and Oak Creek plants, one chick in each of the two nests had elevated mercury levels in 1999, while their brood brothers and sisters all had lower levels. These two chicks had mercury levels higher than those of adults, indicating direct exposure.

On average methylmercury comprised 95% of total falcon blood mercury: the remaining 5% was present as Hg(II). MeHg has a biological half-life of 2-3 months in avian tissues [12]. Since blood MeHg reflects short-term dietary exposure, the blood samples used in this study are indicative of mercury levels in the immediate environment over a short period of time. The Peregrine falcon is a high trophic level predator that feeds on small to medium-sized birds including jays, cardinals, bluebirds, pigeons, sparrows, ducks, gulls, terns, plovers, finches, orioles, blackbirds, grosbeaks, nuthatches, and many others. The primary mode of mercury accumulation in falcons is through the ingestion of contaminated prey.

Site Influences on Exposure

Table 2-1
Mercury Exposure (ugHg/ml Whole Blood Wet Weight) in Fossil, Nuclear, Urban, Arctic, and Control Falcon Chicks and Adults

Chicks	Fossil	Nuclear	Urban	Control
1998	.025 (n=10)	.024 (n=4)	.018 (n=4)	.0003 (n=4)
1999	.049 (n=31)	.027 (n=6)	NA	.071 (n=2)
2000	.025 (n=34)	.043 (n=8)	NA	NA
Average	.033	.031	.018	.036
High	.182	.054	.035	.076
Adults	**Fossil**	**Arctic**	**Control**	
1998	.171 (n=1)	NA	.0005 (n=2)	
1999	.153 (n=4)	.570 (n=2)	NA	
2000	.350 (n=3)	.446 (n=5)	.029 (n=2)	
Average	.350	.508	.015	
High	.464	1.1	.029	

There is no statistically significant difference in the mean blood MeHg content of chicks regardless of site. Among adults, mean blood MeHg concentrations were 69% higher in immature arctic falcons than in fossil fuel nesting falcons, although arctic falcons still had blood MeHg concentrations approximately an order of magnitude lower than adult loons.

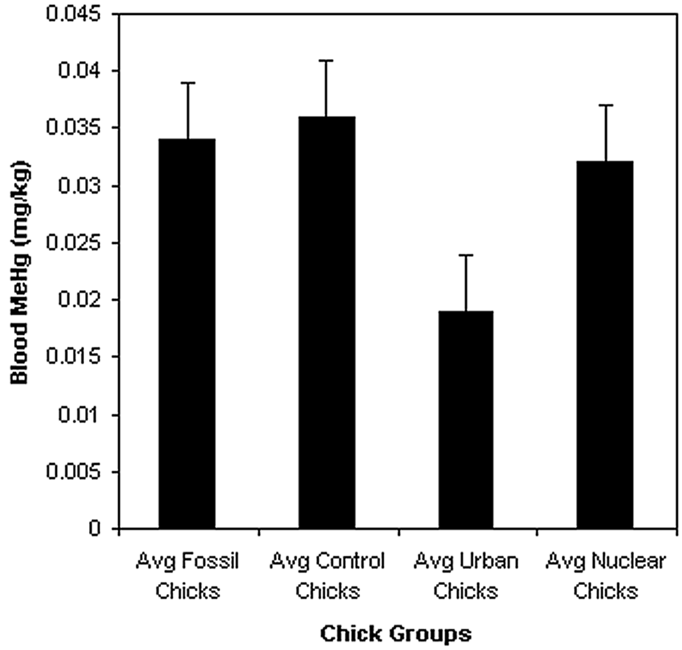

Figure 2-1
Falcon Chick Blood Hg Concentration by Group: 1998-2000

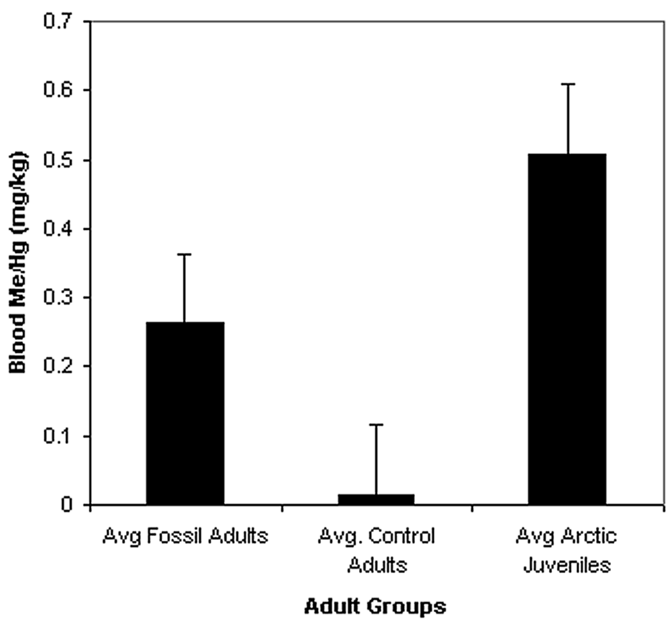

Figure 2-2
Falcon Adult and Arctic Juvenile Blood Hg Concentration by Group: 1998-2000

Recent investigation of the episodic depletion of elemental mercury from air over the arctic in springtime has identified a rapid chemical transformation of elemental mercury to oxidized forms that appear to deposit rapidly to the snowpack. This suggests that elemental mercury may be more efficiently deposited from the atmosphere at arctic locations [13]. Tundrius falcon blood

Hg averages and highs were roughly double those of fossil fuel averages and highs, although still within safe levels. It was suggested that arctic falcons might have higher MeHg blood levels due to a greater number of fish-eating birds in their diet, but studies of arctic and northern Canadian populations do not necessarily bear this conclusion out [14]. Although higher levels of blood MeHg in arctic falcons are consistent with the idea of greater mercury deposition in the north, we know nothing for certain of exact point of origin, dietary differences, and exposure during migration.

Sources of Mercury

Mercury is emitted from coal-fired generating plants in two forms: elemental mercury (Hg0), which remains aloft for up to one year before it oxidizes and deposits to the ground far from its original source, and oxidized mercury (HgII) [15], which deposits locally or regionally [16]. Once HgII is deposited in an aquatic environment, biotic and abiotic methylation produce methylmercury (MeHg), a potent neurotoxin that bioconcentrates in organisms and biomagnifies through food chains [17, 18].

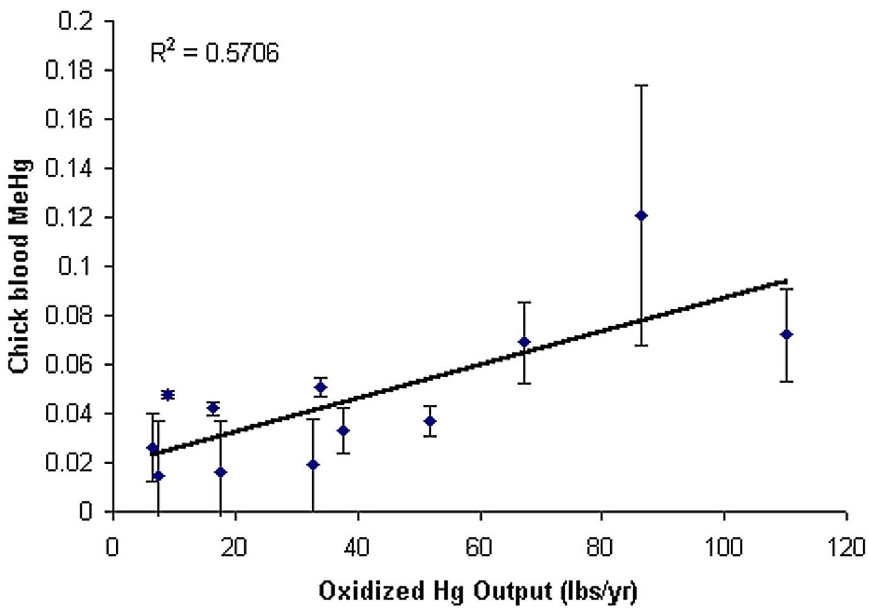

Figure 2-3
Chick Blood Methylmercury and Utility HgII Output

We calculated plant HgII output using total annual HgII-to-Hg0 estimates provided by the Electrical Power Research Institute [Appendix B]. The estimated annual total HgII output was derived as a percentage of each site's total annual Hg0 output: total Hg0 outputs were provided by Dairyland Power Company, Northern States Power Company (now Xcel Energy), Wisconsin Electric Power Company, and Alliant Energy. In some cases utilities had multiple outputs with different HgII/Hg0 profiles: in these cases, we developed data on each stack separately and added the outputs for a total plant profile. The resultant figure gave us an estimated annual HgII output based on the data provided by EPRI and the utility companies An analysis of samples using mean falcon blood MeHg levels collected from fossil fuel sites in 1999 and 2000 found a correlation between adult blood MeHg and HgII output (Figure 2-3; r^2=.796, $p<.05$, n=6) and between chick blood MeHg and utility Hg output (Figure 2-2; r^2=.571, $p<.01$, n=38).

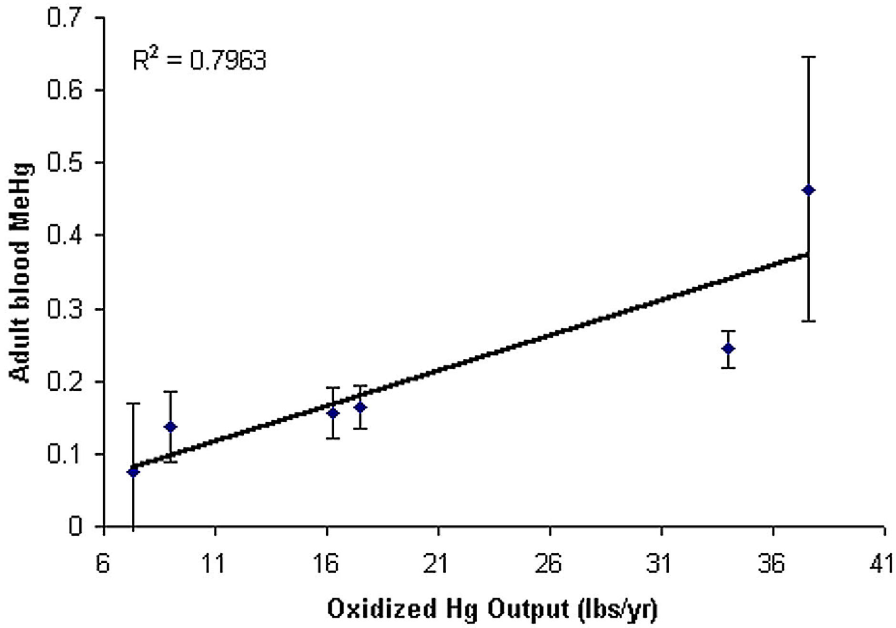

Figure 2-4
Adult Blood Methylmercury and Utility HgII Output

Atmospheric deposition of mercury from the global pool plays a role in the levels of MeHg found in utility nesting falcons [Appendix C]: otherwise, falcons nesting at nuclear plants and in urban locations would have markedly lower MeHg blood levels than those at fossil fuel plants. If local deposition is occurring, its effects are relatively minor since the increase in exposure is very small in the fossil falcons; however, the correlation between estimated HgII output and falcon blood MeHg is interesting. Our test group was small and we had output data for one year only. If the relationship between HgII and blood MeHg in biota near utilities is to be looked at in the future, we recommend, if possible:

- Using a larger test group.
- Testing biota at several trophic levels.
- Developing HgII output data based on sampling rather than estimates or estimating data based on HgII output for the three months prior to the testing period rather than the entire year.
- Sampling biota at different times of the year to observe whether seasonal atmospheric deposition fluctuations are reflected in MeHg concentrations of biota.

Age and Diet

Adult falcons have blood MeHg levels approximately an order of magnitude higher than chicks. Falcon age and blood MeHg levels are positively correlated – as falcon chicks mature, blood MeHg rises. By four months of age, the immature arctic falcons we sampled had blood MeHg levels comparable with those of fossil fuel adults.

Geographic Trends

In a study of loons sampled in several northern counties in Minnesota, live juvenile loons had significantly higher mercury levels in feathers than loons in the northwestern region: the same study found a significant correlation between Hg in feathers and Hg in blood [20]. In a larger study conducted across the northern United States and southern Canada, a similar trend was found, with juvenile concentrations of Hg increasing significantly from west to east [5]. Both studies involved groups of juveniles exposed through atmospheric (non-point source) deposition.

We found no significant increase in blood MeHg from west to east (r^2=.322), or north to south. Xcel's Sherco facility at Becker, Minnesota, was the most westerly of plants sampled (93.87339) and the Alliant Edgewater plant in Sheboygan, WI, was the most easterly (87.73007).

Mercury and Eggs

Nine addled eggs were also tested for MeHg. There was not a correlation between egg mercury and chick mercury levels and too few eggs were collected from sites with sampled adults to draw conclusions about adult/egg mercury levels. There was a very strong correlation between plant HgII output and eggs collected at fossil fuel sites (r^2=.995, p=<.05) however the sample size was small (n=4). Control eggs had the lowest levels of MeHg, followed by nuclear and then fossil fuel eggs. Egg MeHg concentrations at all sites are far below levels associated with embryo toxicity.

Year-To-Year, Adult to Chick, and Gender Comparisons

Adult falcons had approximately an order of magnitude higher blood MeHg concentration than chicks in all three years of the study. MeHg levels in retested adults fluctuated between years however no trend was apparent. There was no relationship between MeHg levels and gender in chicks. Sample size was not sufficient to test for a gender difference in adults.

3
SELENIUM

Selenium is a semi-metallic trace element that occurs in both organic and inorganic forms. An essential nutrient in trace quantities, there is a comparatively narrow concentration range separating effects of selenium deficiency from those of selenosis [20]. Selenium, like mercury, occurs in several forms: the most toxic to birds of which is the organic selenomethionine [21]. Samples were tested for total selenium.

Coal-fired utility plants and the irrigation of high-selenium soils for agricultural production are the most widespread sources of selenium mobilization in the United States. Se released as a result of anthropogenic activities poses the greatest threat of poisoning to fish and wildlife [20]. Overflow or leachate from coal fly and bottom ash storage basins may run, leach, or drip into lakes, rivers, and streams, where it bio-accumulates directly into biota. When selenium becomes available to fish, birds, and mammals, it may bio-concentrate in tissues to several orders of magnitude higher than that of the food source. Even though concentrations of selenium in water may be low, predatory fish, birds, and mammals can still receive toxic levels of selenium from their diet [23]. In body tissues, selenium is quickly accumulated upon exposure and is also rapidly eliminated once dietary exposure has ceased [21]. Overexposure to selenium is linked to deformities, reproductive impairment, alocepia, and death [21, 22]. Hatchability of fertile eggs is considered the most sensitive measure of selenium toxicity: although fertility is not affected, selenium causes high rates of embryo mortality and developmental abnormalities in birds [22]. Thresholds suggested for toxic effects include [20, 21]:

- 3 ppm liver: reproductive impairment in laying females.
- 3 ppm eggs: threshold level for reproductive impairment.
- 5-14 ppm blood: mortality in mallards.
- 10 ppm liver: threshold for health-related toxic effects in young and adult birds.
- 20 ppm liver: mortality in a variety of species.

Selenium in Falcons

All of the falcons tested had selenium levels well below those known to negatively impact reproductive and physical health. Falcon chicks at fossil fuel plants were more exposed to selenium than were nuclear, urban, or control chicks: adult falcons at fossil plants were less exposed than were arctic and control falcons.

Table 3-1
Selenium Exposure in Fossil, Nuclear, Urban, Arctic, and Control Falcon Chicks and Adults

Chicks	Fossil	Nuclear	Urban	Control
1998	.846 n=10	.688 n=4	.815 n=4	.385 n=4
1999	.689 n=31	.520 n=6	NA	.245 n=2
2000	.607 n=34	.682 n=8	NA	NA
Average	.714	.630	.815	.315
High	1.460	.700	.94	.46
Adults	**Fossil**	**Arctic**	**Control**	
1998	.640 n=1	NA	.805 n=2	
1999	.415 n=4	.585 n=2	NA	
2000	.658 n=4	.814 n=5	.460 n=2	
Average	.571	.700	.632	
High	.880	1.78	1.18	

In general, blood selenium showed few patterns. Chick and adult blood selenium, gender, age, year-to-year data, and MeHg/Se variance did not correlate well. Fossil fuel chicks had higher levels of selenium than fossil fuel adults: control adults had higher levels of selenium than control chicks. There was a correlation between blood MeHg and selenium levels as discussed in the next section.

Selenium and Mercury

Selenium and mercury are antagonists; high selenium levels help ameliorate the effect of high mercury levels [10, 20, 21, 22]. Co-accumulation of Hg and Se is believed to result in the formation of a toxicologically inert Hg/Se protein complex with a long half-life (24). Studies of Hg and Se in birds have produced a variety of results, with some finding a positive correlation, some a negative correlation, and some no correlation at all. Our study found a weak positive correlation between blood MeHg and selenium in adults (r^2=.367, n=16) and eggs (r^2=.164, n=9), and no correlation in chicks (r^2=.086, n=38). Sheuhammer states that if Hg exposure is below some as-yet undetermined level, the biochemical processes that initiate the association of Hg with Se in the liver are not brought into play [10]. MeHg/Se levels in adults support this, since we found that the higher blood MeHg, the better the correlation between MeHg and Se. In a group of seven adult falcons with blood MeHg levels over .3 ppm, r^2=.346, while in a group of nine adult falcons with blood levels under .3 ppm, r^2=.100. The falcon with the highest blood MeHg levels, an immature arctic falcon on its first migration, also had the highest selenium levels: MeHg=1.13 ppm and Se=1.78 ppm.

Selenium in Eggs

The embryo is the avian life stage most sensitive to selenium poisoning [22]: given the rapid accumulation and loss of selenium in birds, eggs may also best represent contamination of the local environment [21]. Nine addled eggs were collected from fossil fuel nests, nuclear nests, and the control site during the three years of the study: all nine had selenium levels well below those known to negatively impact reproductive and physical health.

Table 3-2
Selenium and Methylmercury in Addled Eggs

Year/Location	Selenium	MeHg
1999 Prairie Island	2.37	.082
1999 Prairie Island	1.61	.062
1999 RRP control	2.28	.002
1999 RRP control	2.11	.004
1999 Sherco	1.8	.077
1999 Sherco	2.46	.045
2000 High Bridge	.280	.116
2000 Riverside	.666	.479
2000 RRP control	.279	.004

There was no correlation between selenium in surviving chicks and addled eggs. There were not enough eggs collected from sites with sampled adults to draw conclusions about adult/egg selenium levels.

4

ARSENIC

Arsenic is a semi-metallic element that can combine with other elements to form inorganic and organic arsenicals. Unlike selenium and mercury, inorganic derivatives are regarded as more toxic than the organic forms [24]. Anthropogenic arsenic sources include the combustion of fossil fuels, especially coal; wood preservation; smelting of sulphide minerals including copper, lead, and zinc; and from gold processing. Arsenic is bio-concentrated by organisms, but it is not biomagnified in the food chain [24].

Arsenic is one of the byproducts of fossil fuel combustion. It is emitted both in stack gas and coal fly ash: in 1999, electric utilities in the United States produced an estimated combined total of 835 pounds of arsenic via stack release and 21,404 pounds of arsenic via coal fly ash and other solid waste products [25]. Arsenic is also used in various pesticides and as a diet additive in chicken, cattle, and swine feed. Blood arsenic concentrations of one to three ppm are considered diagnostically significant indicators of dietary arsenic [27]: background arsenic concentrations are usually less than one ppm in terrestrial flora and fauna, birds, and freshwater biota [24]. Martin and Nickerson monitored starlings from 50 sites in the United States in 1971: except for one sample, all contained whole body arsenic levels of .04 ppm or less [26]. In another study, Stickle found that trapped male yearling cowbirds not exposed to arsenic had liver concentrations less than .41 ppm and kidney concentrations less than 1.48 ppm [27].

Falcons may be exposed to arsenic via prey, water, or air. All falcons sampled had blood arsenic concentrations consistent with background arsenic exposure: none of them had anywhere near the levels known to jeopardize physical or reproductive health. There was no correlation between falcon age or gender and arsenic exposure. Arsenic and selenium are antagonists: arsenic is known to reduce selenium poisoning. There was no correlation between blood selenium and blood arsenic in either chicks or adults.

Arsenic detection levels were biased higher in the first year of testing than in the following two years; however, chicks hatched at fossil fuel sites had lower blood arsenic levels than did chicks hatched at nuclear and urban sites in all years. The urban chicks in Cedar Rapids had blood levels of arsenic consistent with direct exposure: it is worth noting here that the Cedar River is contaminated with arsenic due to years of improperly stored waste material produced as a byproduct of animal pharmaceuticals. Further study of urban and wild birds in this area might yield worthwhile data; however, these falcons were not exposed to arsenic via the combustion of fossil fuels.

Blood arsenic levels in adults are higher in falcons nesting at fossil fuel plants during the first year, but drop in subsequent years. In the two years for which a direct comparison can be made, fossil fuel and arctic peregrines have very similar levels of arsenic exposure: however, average fossil levels are biased higher by the first year's results.

Table 4-1
Arsenic Exposure in Fossil, Nuclear, Urban, Arctic, and Control Falcon Chicks and Adults

Chicks	**Fossil**	**Nuclear**	**Urban**	**Control**
1998	.18 n=3	.19 n=2	.44 n=4	.12 n=4
1999	.034 n=7	ND n=6	NA	ND n=2
2000	.051 n=34	.058 n=8	NA	NA
Average	.088	.19	.44	.120
High	.18	.61	.67	.120
Adults	**Fossil**	**Arctic**	**Control**	
1998	.21 n=1	NA	.14 n=1	
1999	.05 n=1	.04	NA	
2000	.048 n=4	.06	.065 n=2	
Average	.102	.05	.103	
High	.21	.16	.14	

5
NICKEL

Environmental contamination by nickel occurs in local areas as a result of mining, smelting, combustion of fossil fuels, nickel plating and alloy manufacturing. The chemical and physical forms of nickel and its salts strongly influence bioavailability and toxicity. In wildlife, overexposure to nickel may result in respiratory disease, CNS disorders, testicular degeneration, immunological effects, and acute nickel poisoning [28, 29]. There is little data available on nickel levels in free-ranging bird populations. Nickel concentrations in the organs of most avian wildlife species in unpolluted ecosystems range from about 0.1 to 2.0 ppm, occasionally reaching 5.0 ppm [29, 30]. None of the falcons we sampled had anywhere near these amounts. At only three sites did all chicks have detectable levels of blood nickel: at several sites no chicks were exposed to nickel, although nickel occurred sporadically in every group tested.

Table 5-1
Nickel Exposure in Fossil, Nuclear, Urban, Arctic, and Control Falcon Chicks and Adults

Chicks	**Fossil**	**Nuclear**	**Urban**	**Control**
1998	.035 n=4	ND	ND	.07 n=1
1999	.02 n=14	.023 n=6	NA	.01 n=1
2000	.34 n=3	ND	NA	NA
Average	.13	.023	0	.04
High	.88	.07	ND	.07
Adults	**Fossil**	**Arctic**	**Control**	
1998	ND	NA	ND	
1999	.01 n=2	.01 n=1	ND	
2000	ND	ND	ND	
Average	.01	.01	ND	
High	.01	.01	ND	

There was an inverse correlation between age and nickel exposure: chicks had higher levels of nickel than adults. Our data indicates that nickel does not bioaccumulate in falcons: this is consistent with findings by Outridge and Schuehammer on nickel in mammals, although we were unable to locate similar references for birds. None of the falcons had levels of nickel higher than those consistent with background exposure.

6
CHROMIUM

Chromium emissions from electric utilities may occur into surface waters or air. Chromium is used as a corrosion inhibitor in cooling waters, where it takes the form of a Cr6 salt, and is also a byproduct of burning fossil fuels, where it takes the form of Cr3 released in stack gas. TRI data from 1999 indicates that more chromium was emitted into air than water. Compounds of both Cr(VI) and Cr(III) have induced developmental effects in experimental animals that include neural tube defects, malformations, and fetal deaths [31].

There is little data available on chromium levels in free-ranging bird populations. In a 1992 study, 20 laughing gulls taken from Raritan Bay in the Hudson river had a mean liver chromium concentration of .35 ppm [32]. Liver studies done in the same location in 1981 yielded mean liver chromium concentrations of 2.05 ppm for 20 Black ducks, 1.53 ppm for 16 Scaup, and 1.22 for seven Mallard ducks. A 1973 study of three Osprey from the Eastern United States yielded a mean liver chromium concentration of .11 ppm [33]. Chromium concentrations greater than 4 ppm in biota are considered elevated [34]. Chicks sampled at utility sites had slightly higher blood chromium levels than did chicks at nuclear sites or juvenile arctic falcons, but none of the peregrine falcons sampled had anywhere near elevated levels of chromium.

Table 6-1
Chromium Exposure in Fossil, Nuclear, Urban, Arctic, and Control Falcon Chicks and Adults

Chicks	Fossil	Nuclear	Urban	Control
1998	.113 n=7	.03 n=1	ND	.143 n=3
1999	.559 n=32	.238 n=6	NA	.125 n=2
2000	.27 n=3	.01 n=1	NA	NA
Average	.314	.093	0	.134
High	.69	.78	ND	.46
Adults	**Fossil**	**Arctic**	**Control**	
1998	.170 n=1	NA	.25 n=1	
1999	.338 n=4	.22 n=2	NA	
2000	.05 n=1	ND	ND	
Average	.186	.22	ND	
High	.69	.24	.25	

7
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A

EXPOSURE AT EACH UTILITY SITE

The following site exposure charts provide information on site type, size, history, and specific sampling data. Chicks are identified with a "c" – Alma 98: C1 is a chick sampled at Dairyland Power's Alma plant in 1998 – and adults are identified with an "a".

A.1 Dairyland Power Genoa

Type: Coal-fired fossil fuel.
Generating capacity: 377 Mw.
Location: Genoa, Wisconsin (approximately 20 miles south of LaCrosse, WI). The Peregrine falcons in this location are nesting in a nestbox at the 400' level of the stack. Peregrine falcons have nested here since 1998, producing a total of eleven young.

Table A-1
Falcon Exposure at Dairyland Power Genoa

Plant & Year	Gender	MeHg	THg	Se	Cr	Ni	As
Gen 98: C1	F	.047	.052	1.06	ND	.08	.2
Gen 98: C2	M		.064	1.19	.05	ND	ND
Gen 99: C1	F	.048	.05	.39	.12	ND	ND
Gen 99: C2	F	.063	.065	.54	.17	.02	ND
Gen 99: C3	M	.053	.054	.49	.12	.01	ND
Gen 99: C4	M	.04	.039	.5	.18	.02	ND
Gen 00: C1	M	.037	.037	.74	ND	ND	.05
Gen 00: C2	M	.035	.035	.67	.07	.12	.03
Gen 00: C3	M	.033	.033	.64	ND	ND	.02
Gen 00: C4	F	.025	.025	.51	ND	ND	.02
Gen 99: A1	F	.244	.247	.73	.3	.01	ND
Gen 00: A1	F	.464	.47	.51	ND	ND	.02

A.2 Dairyland Power Alma

Type: Coal-fired fossil fuel.
Generating capacity: 584 MW total.
Location: Alma, Wisconsin. The Alma station consists of two separate generating stations and two stacks. The Peregrines are nesting on the Alma Station stack in a nest box at the 500' level. Peregrine falcons have nested here since 1997, producing a total of twenty-one young.

Table A-2
Falcon Exposure at Dairyland Genoa

Plant & Year	Gender	MeHg	THg	Se	Cr	Ni	As
Alma 98: C1	F		.023	1.21	0.05	0.01	ND
Alma 98: C2	F		.028	1.38	ND	ND	ND
Alma 98: C3	M		.024	1.15	ND	ND	ND
Alma 99: C1	F	0.042	0.042	.53	.1	ND	ND
Alma 99: C2	M	.045	.047	.66	.11	ND	ND
Alma 99: C3	M	.046	.045	.64	.12	.01	ND
Alma 99: C4	M	.055	.055	.47	.11	ND	ND
Alma 99; C5	M	.023	.025	.51	.13	ND	ND
Alma 00: C1	M	.012	.012	.59	.69	.88	.06
Alma 00: C2	M	.017	.017	.56	ND	ND	.05
Alma 00: C3	M	.018	.018	.48	ND	ND	.04
Alma 00: C4	F	.016	.016	.89	ND	ND	.04
Alma 99: A1	F	.156	.159	.62	.23	ND	.05
Alma 00: A1	F	.164	.168	.88	ND	ND	.04
Alma 00: A2	M	.325	.328	.72	ND	ND	.04

A.3 Xcel Energy Blackdog

Type: Coal-fired fossil fuel
Generating capacity: 512 MW
Location: Eagan, Minnesota (a metro-area suburb). The Peregrine falcons at this location are nesting in a nest box at the 400' level of the utility stack. Peregrine falcons have nested here since 1993. 23 young have fledged from this site.

Table A-3
Falcon Exposure at Xcel Energy Blackdog

Plant & Year	Gender	MeHg	THg	Se	Cr	Ni	As
Black 99: C1	F	.021	.024	.52	.1	.01	ND
Black 99: C2	M	.029	.019	.65	.16	ND	.06
Black 99: C3	M	.028	.027	.54	.11	.01	ND
Black 00: C1	F	.031	.033	.73	ND	ND	.07

A.4 Xcel Energy High Bridge Plant

Type: Coal-fired fossil fuel
Generating capacity: 343.8 MW
Location: St. Paul, Minnesota. The Peregrine falcons at this location are nesting in a nest box at the 400’ level of the utility stack. Peregrine falcons nested and fledged young here for the first time in 2000. Six young have fledged from this site.

Table A-4
Falcon Exposure at Xcel Energy High Bridge Plant

Plant & Year	Gender	MeHg	THg	Se	Cr	Ni	As
High 00: C1	M	.032	.032	.73	ND	ND	.05
High 00: C2	M	.04	.04	.63	ND	ND	.06
High 00: C3	F	.039	.039	.75	ND	ND	.07

A.5 Xcel Energy Alan S. King Plant

Type: Coal-fired fossil fuel
Generating capacity: 598 MW
Location: Oak Park Heights, Minnesota. The Alan S. King Plant is located along the St. Croix river just south of Stillwater, and was the first utility site to become a home for nesting falcons. The Peregrine falcons at this location are nesting in a nest box at the 400’ level of the stack. Mae, the first falcon to nest at a utility, has produced 32 young.

Table A-5
Falcon Exposure at Xcel Energy Alan S. King Plant

Plant & Year	Gender	MeHg	THg	Se	Cr	Ni	As
King 99: C1	F	.049	.05	.36	.1	ND	ND
King 99: C2	F	.049	.049	.29	1.2	ND	ND
King 99: C3	M	.046	.048	.48	.14	ND	ND
King 00: C1	M	.028	.028	.73	ND	ND	.05
King 00: C2	F	.024	.024	.55	.06	ND	.05
King 99: A1	F	.137	.137	.26	.69	.01	ND
King 00: A1	F	.098	.098	.52	.05	ND	.09

A.6 Xcel Energy Riverside Plant

Type: Coal-fired fossil fuel
Generating capacity: 370MW
Location: Minneapolis, Minnesota. NSP Riverside is located on the edge of an industrial area of North Minneapolis, just up the Mississippi River from downtown Minneapolis. The Peregrine falcons at this location are nesting in a nestbox at the top of the utility stack (600’). Peregrine falcons have nested here since 1998, producing ten chicks.

Table A-6
Falcon Exposure at Xcel Energy Riverside Plant

Plant & Year	Gender	MeHg	THg	Se	Cr	Ni	As
River 98: C1	M	.022	.029	.48	.14	ND	.18
River 98: C2	F		.022	.071	.1	ND	ND
River 98: C3	F		.054	.7	.08	.04	ND
River 99: C1	F	.019	.018	.37	.11	ND	ND
River 00: C1	M	.012	.012	.46	ND	ND	.04
River 00: C2	F	.012	.012	.46	ND	ND	.05

A.7 Xcel Energy Sherco Plant

Type: Coal-fired fossil fuel
Generating capacity: 2330 MW
Location: Becker, Minnesota (approximately 80 miles north of Minneapolis, MN). The Peregrine falcons at this location are nesting in a nestbox at the 400’ level of the utility stack. 36R, the adult female captured and sampled at this site, produced 22 young in seven years. 36R was killed in a territorial battle in 1999 and no young were produced here in 2000.

Table A-7
Falcon Exposure at Xcel Energy Sherco Plant

Plant & Year	Gender	MeHg	THg	Se	Cr	Ni	As
Sherco 98: C1	F	.007	.009	.37	.28	ND	.16
Sherco 98: C2	F		.008	.4	.09	.01	ND
Sherco 99: C1	F	.022	.02	.31	.1	ND	ND
Sherco 99: C2	M	.016	.015	.4	.11	ND	ND
Sherco 99: C3	M	.008	.007	.31	.41	.02	ND
Sherco 98: A1	F	.168	.171	.64	.17	ND	.21
Sherco 99: A2	F	.076	.079	.05	.13	ND	ND

A.8 Xcel Energy Monticello Plant

Type: Nuclear
Generating capacity: 536 MW
Location: Monticello, Minnesota. The Monticello plant is located approximately 5 miles from the Sherco plant. The Peregrine falcons at this location are nesting in a nest box on the turbine building. Peregrines have nested here since 1995, producing twenty-three young.

Table A-8
Falcon Exposure at Xcel Energy Monticello Plant

Plant & Year	Gender	MeHg	THg	Se	Cr	Ni	As
Monti 98: C1	M		.027	.93	.03	ND	.2
Monti 98: C2	F	.02	.026	.47	ND	ND	ND
Monti 99: C1	F	.02	.018	.51	.78	.07	ND
Monti 99: C2	F	.027	.027	.43	.15	.02	ND
Monti 99: C3	F	.036	.037	.8	.15	.01	ND
Monti 00: C1	M	.036	.036	.8	ND	ND	.06
Monti 00: C2	M	.03	.032	.68	ND	ND	.07
Monti 00: C3	F	.048	.048	.53	.01	ND	.05
Monti 00: C4	F	.025	.025	.77	ND	ND	.05

A.9 Xcel Energy Prairie Island Plant

Type: Nuclear
Generating capacity: 560 MW
Location: Red Wing, Minnesota (approximately 30 miles south of the Twin Cities).
The Peregrine falcons at this location are nesting in a nest box directly on the containment dome itself. Peregrines have nested here since 1997, producing eighteen young.

Table A-9
Falcon Exposure at Xcel Energy Prairie Island Plant

Plant & Year	Gender	MeHg	THg	Se	Cr	Ni	As
Prairie 98: C1	M		.023	.74	ND	ND	ND
Prairie 98: C2	F	.027	.028	.61	ND	ND	.18
Prairie 99: C1	F	.026	.026	.78	.13	.01	ND
Prairie 99: C2	F	.028	.029	.84	.12	.01	ND
Prairie 99: C3	F	.025	.027	.68	.10	.02	.61
Prairie 00: C1	M	.055	.055	.82	ND	ND	.06
Prairie 00: C2	M	.054	.054	.75	ND	ND	.06
Prairie 00: C3	M	.047	.047	.64	ND	ND	.06
Prairie 00: C4	F	.047	.047	.46	ND	ND	.05

A.10 Wisconsin Power and Light Edgewater Generating Station

Type: Coal-fired fossil fuel
Generating capacity: 770 MW
Location: Sheboygan, Wisconsin, along the shore of Lake Michigan. Peregrine falcons have nested here since 1991: over 27 chicks have been produced from this location.

Table A-10
Falcon Exposure at WI Power and Light Edgewater Generating Station

Plant & Year	Gender	MeHg	THg	Se	Cr	Ni	As
She 99: C1	F	.037	.033	1.03	.39	.07	ND
She 99: C2	M	.043	.045	.66	.12	ND	.06
She 99: C3	M	.032	.032	2.69	.42	.04	ND
She 00: C1	F	.031	.033	.52	ND	ND	.08
She 00: C2	F	.031	.034	.59	ND	ND	.07
She 00: C3	F	.059	.062	.62	ND	.02	.08
She 00: C4	M	.035	.036	.67	ND	ND	.04

A.11 Wisconsin Electric Power Company Pleasant Prairie Power Plant

Type: Coal-fired fossil fuel
Generating capacity: 1,235 MW
Location: Kenosha, Wisconsin, along the shore of Lake Michigan. Peregrine falcons have nested here since 1997: approximately 12 chicks have been produced from this location.

Table A-11
Falcon Exposure at WI Electric Power Company Pleasant Prairie

Plant & Year	Gender	MeHg	THg	Se	Cr	Ni	As
Ken 99: C1	F	.182	.198	.55	.23	ND	ND
Ken 99: C2	F	.06	.06	.73	.61	ND	ND
Ken 00: C1	M	.013	.015	.39	ND	ND	.05
Ken 00: C2	M	.015	.016	.38	ND	ND	.04
Ken 00: C3	?	.015	.015	.3	ND	ND	.05

A.12 Wisconsin Electric Power Company South Oak Creek Power Plant

Type: Coal-fired fossil fuel
Generating capacity: 1211 MW
Location: Milwaukee, Wisconsin, along the shore of Lake Michigan. Peregrine falcons have nested here since 1998, producing at least twelve chicks.

Table A-12
Falcon Exposure at WI Electric Power Company South Oak Creek

Plant & Year	Gender	MeHg	THg	Se	Cr	Ni	As
Oak 99: C1	F	.044	.046	.69	.09	ND	.06
Oak 99: C2	M	.105	.129	.59	.13	ND	.04
Oak 99: C3	M	.038	.042	.85	.13	.01	ND
Oak 00: C1	F	.03	.033	.66	ND	ND	.04
Oak 00: C2	F	.026	.027	.61	ND	ND	.02
Oak 00: C3	F	.03	.035	.54	ND	ND	.05
Oak 00: C4	F	.033	.033	.59	ND	ND	.03

A.13 Wisconsin Electric Power Company Port Washington Power Plant

Type: Coal-fired fossil fuel
Generating capacity: 339 MW
Location: Oak Creek, Wisconsin, along the shore of Lake Michigan. Peregrine falcons have nested here since 2000: six chicks have been produced from this location.

Table A-13
Falcon Exposure at WI Electric Power Company Port Washington

Plant & Year	Gender	MeHg	THg	Se	Cr	Ni	As
Wash 00: C1	F	.03	.031	.59	ND	ND	.08
Wash 00: C2	M	.023	.023	.49	ND	ND	.05
Wash 00: C3	M			.63	ND	ND	.09

A.14 Alliant Lansing Power Plant

Type: Coal-fired fossil fuel
Generating capacity: 340 MW
Location: Lansing, Iowa, along the Mississippi. Peregrine falcons have nested here since 1999: seven chicks have been produced from this location.

Table A-14
Falcon Exposure at Alliant Lansing Power Plant

Plant & Year	Gender	MeHg	THg	Se	Cr	Ni	As
Lan 99: C1	F	.069	.071	1.24	.2	ND	ND
Lan 99: C2	M	.061	.064	1.55	.1	ND	.02
Lan 99: C3	M	.076	.085	1.77	.12	ND	ND
Lan 00: C1	M	.011	.011	.607	ND	ND	.02
Lan 00: C2	M	.013	.013	.72	ND	ND	.02
Lan 00: C3	M	.013	.013	.345	ND	ND	.12
Lan 00: C4	F	.014	.014	1.29	ND	ND	.06

A.15 Minnesota Power and Light, Cohasset

Type: Coal-fired fossil fuel
Generating capacity: 1073 MW
Location: Lansing, Iowa, along the Mississippi. Peregrine falcons have nested here since 1993: twenty-eight chicks have been produced from this location.

Table A-15
Falcon Exposure at Minnesota Power and Light Cohasset

Plant & Year	Gender	MeHg	THg	Se	Cr	Ni	As
MPL 99: C1	F	.049	.051	.32	.3	.01	ND
MPL 99: C2	M	.051	.053	.77	.45	.01	ND

B

ESTIMATED Hg(II) OUTPUT PER UTILITY

The speciation estimates were provided by Rick Carlton from EPRI and Dave Michaud from Wisconsin Electric Power Company. The total Hg output was provided via Xcel Energy (formerly NSP) and Wisconsin Electric Power Company.

Table B-1
Hg0 and HgII Output at Ten Plants in 1999

	%Hg(0)/yr	%Hg(II)/yr	Total Hg (lbs/yr)	HgII (lbs/yr)
Pleasant Prairie	85	15	847.5	127
South Oak Creek	55	45	223.5	100
Alliant Lansing	29.5	60.5	111	67.18
Alliant Edgewater	70	30	179.9	53.97
Dairyland Genoa	22	77	43.6	33.6
Xcel Riverside	61	39	84.0	32.7
Dairyland Alma*				18.1
Xcel King	83	15	59.9	9
Xcel Sherco 1-3	98	2	364	7.3
Xcel Blackdog	85	15	43.9	6.58
*Alma	30%	70%	11	7.7
*JP Madgett	91%	9%	116	10.4

Note: Dairyland Alma consists of two separate units at one site: Alma and JP Madgett.

C
ATMOSPHERIC MERCURY DEPOSITION

The Mercury Deposition Network was charged with developing a national database of weekly concentrations of total mercury in precipitation and the seasonal and annual flux of total mercury in wet deposition. As stated earlier, atmospheric deposition of mercury from the global pool plays a role in the levels of MeHg found in utility nesting falcons: otherwise, falcons nesting at nuclear plants and in urban locations would have markedly lower MeHg blood levels than those at fossil fuel plants. The following map displays total atmospheric deposition at MDN sites in 1999. The three sites marked in black are closest to the study area.

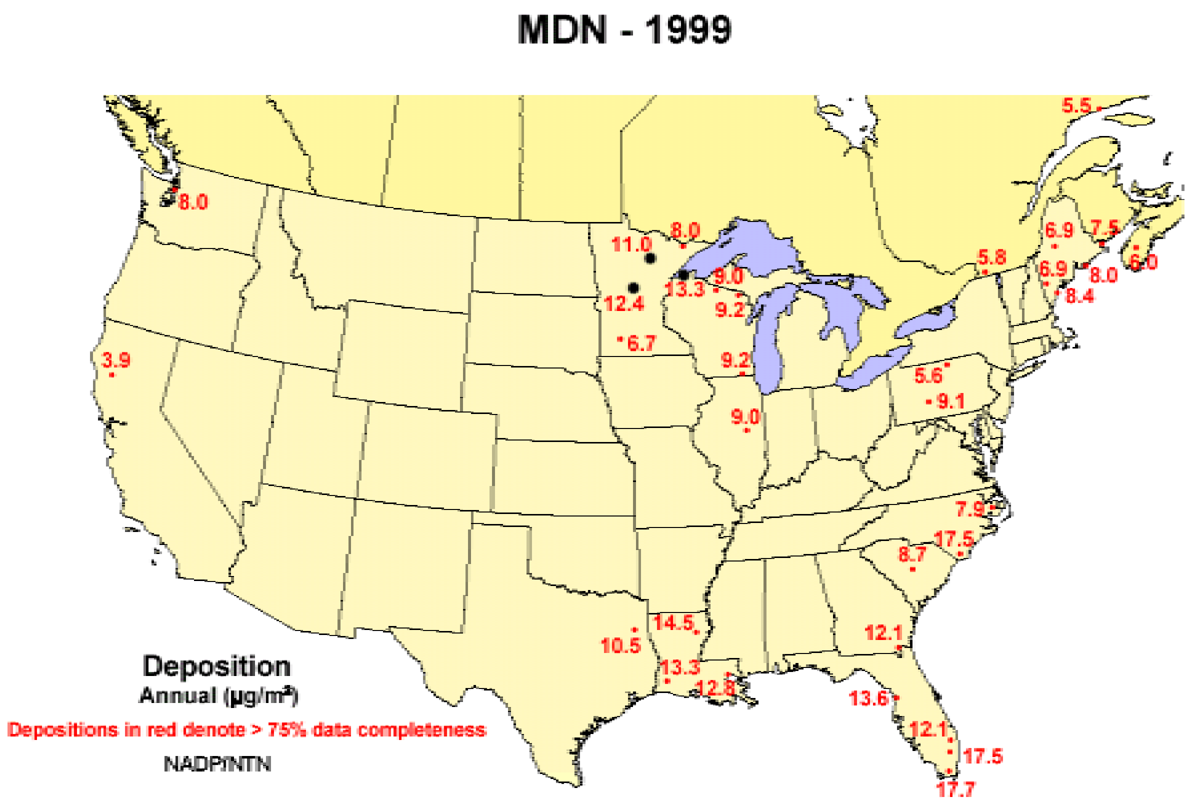

Figure C-1
United States Map Showing Atmospheric Mercury Deposition at MDN Sites in 1999 [35].

The following tables detail 1999 atmospheric mercury deposition at the three NADP sites nearest to the utility and urban locations where peregrine falcons were sampled. The time period begins in the first week of March, which is when falcons begin returning to the area to breed and nest. The time period ends in the middle of June, by which time all falcon chicks have been sampled. MeHg has a biological half-life of 2-3 months in avian tissues, so this time period reflects atmospheric deposition during the test period. Although the tables do not include information on Hg or MeHg in biota, they clearly indicate that atmospheric deposition is taking place in the region.

1999 Data Set for NADP/MDM Monitoring Location MN16

Location: Marcell Experimental Forest, Balsam Lake, Itasca County, Minnesota
Lat: 47 31 52 | Long: 93 28 07

Table C-1
1999 Dataset for NADP/MDM Monitoring Location MN16

Date On	Date Off	Subppt mm	Pptrec mm	HgConc ng/L	HgDep ng/m2	QR	Sample Type
03/02/99	03/09/99	13.2	13.2	2.3	30.6	A	W
03/09/99	03/16/99	0.0	0.0	--	0.0	A	D
03/16/99	03/23/99	3.8	3.8	6.8	25.7	A	W
03/23/99	03/30/99	22.1	22.1	8.7	193.2	B	W
03/30/99	04/06/99	42.2	42.2	7.6	321.1	B	W
04/06/99	04/13/99	1.9	1.9	19.1	35.9	B	W
04/13/99	04/20/99	3.7	3.7	10.6	39.0	B	W
04/20/99	04/27/99	.5	.5	28.3	14.4	B	T
04/27/99	05/04/99	2.0	2.0	--	--	C	W
05/04/99	05/11/99	68.3	68.3	14.0	957.3	B	W
05/11/99	05/18/99	24.9	24.9	12.0	298.7	B	W
05/18/99	05/25/99	17.5	17.5	30.3	531.7	B	W
5/25/99	06/01/99	5.6	5.6	18.3	101.9	A	W
06/01/99	06/08/99	25.4	25.4	30.1	763.4	A	W
06/08/99	06/15/99	23.9	23.9	10.4	249.0	B	W

1999 Data Set for NADP/MDM Monitoring Location MN23

Location: Camp Ripley, Belle Prairie, Morrison County, Minnesota
Lat: 46 14 58 | Long: 94 29 50

Table C-2
1999 Dataset for NADP/MDM Monitoring Location MN23

Date On	Date Off	Subppt mm	Pptrec mm	HgConc ng/L	HgDep ng/m2	QR	Sample Type
03/02/99	03/09/99	19.3	19.3	--	--	C	W
03/09/99	03/16/99	0.0	0.0	--	0.0	B	D
03/16/99	03/23/99	0.0	0.0	--	0.0	B	D
03/23/99	03/30/99	22.1	22.1	13.1	290.6	A	W
03/30/99	04/06/99	35.4	35.4	4.6	163.9	B	W
04/06/99	04/13/99	5.8	5.8	16.8	96.9	B	W
04/13/99	04/20/99	15.2	15.2	22.6	344.8	B	W
04/20/99	04/27/99	.2	--	71.8	10.8	B	T
04/27/99	05/04/99	4.8	4.8	30.9	149.1	A	W
05/04/99	05/11/99	93.7	93.7	10.9	1018.5	B	W
05/11/99	05/18/99	72.9	72.9	6.4	462.9	B	W
05/18/99	05/25/99	1.0	1.0	54.2	55.1	B	W
05/25/99	06/01/99	.8	.8	23.9	18.2	B	W
06/01/99	06/08/99	58.4	58.4	18.5	1083.6	B	W
06/08/99	06/15/99	34.8	34.8	21.7	756.8	B	W

1999 Data Set for NADP/MDM Monitoring Location WI08

Location: Brule River, Douglas County, Wisconsin
Lat: 46 45 00
Long: 91 30 00

Table C-3
1999 Dataset for NADP/MDM Monitoring Location WI08

Date On	Date Off	Subppt mm	Pptrec mm	HgConc ng/L	HgDep ng/m2	QR	Sample Type
03/02/99	03/09/99	6.1	6.1	--	--	C	W
03/09/99	03/16/99	0.0	0.0	--	0.0	B	D
03/16/99	03/23/99	0.0	0.0	--	0.0	B	D
03/23/99	03/30/99	6.4	6.4	5.7	36.4	A	W
03/30/99	04/06/99	82.6	82.6	5.7	472.7	B	W
04/06/99	04/13/99	11.9	--	15.0	178.0	B	W
04/13/99	04/20/99	7.6	7.6	31.8	242.2	B	W
04/20/99	04/27/99	0.0	0.0	--	0.0	B	T
04/27/99	05/04/99	0.0	0.0	--	0.0	B	D
05/04/99	05/11/99	47.3	47.3	9.7	456.1	B	W
05/11/99	05/18/99	7.6	7.6	17.4	132.9	B	W
05/18/99	05/25/99	12.7	12.7	14.3	181.1	A	W
05/25/99	06/01/99	8.9	8.9	15.4	137.1	A	W
06/01/99	06/08/99	67.3	67.3	23.6	1588.7	B	W
06/08/99	06/15/99	17.0	17.0	9.7	164.1	A	W

Target:
Environment

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