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EFFECT OF METHYLATED MERCURY ON THE DIVING FREQUENCY OF THE COMMON LOON

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ABSTRACT

Rising levels of atmospherically deposited mercury and its incorporation into aquatic food webs have long been a topic of concern for threatened populations of the common loon, *Gavia immer*, in the northeast. Although little is known about the effect of mercury on adult loon behavior, it has been shown that mercury inhibits heme production, and may affect the oxygen carrying capacity of loon blood. We examined the relationship between diving frequency and mercury concentration in common loons. We found a significant difference among the frequency of foraging dives in loons with different mercury burdens ($H = 8.75$, $df = 3$, $p = 0.033$) and a significant correlation between dive frequency and mercury level ($r = 0.136$, $N = 249$, $p = 0.032$). Additionally, the effect increased at higher concentrations ($H = 7.48$ $df = 1$, $p = 0.006$). This result prompts concern over contaminated loons' ability to forage for themselves and their offspring, especially in populations that are already stressed due to other anthropogenic disturbances.

INTRODUCTION

In recent decades the level of atmospherically deposited mercury in aquatic systems has been steadily rising (Swain et al. 1992). Since the largest source of mercury in aquatic systems is due to atmospheric deposition (Swain et al. 1992, Carpi 1997), the effects in the northeast have been greater than elsewhere, due to prevailing weather systems (Evers et al. 1998). The mobilization of mercury in biological systems is also noted to be far above what occurs naturally (U.S. EPA 1997, Vitousek et al. 1997). Because of this pattern, methylated mercury concentrations in common loons, *Gavia immer*, generally increase from west to northeast (Evers et al. 1998). Although the effects of this escalating contamination on reproductive productivity have already been noted in various aquatic birds (Barr 1986, Heinz 1976, 1979, Scheuhammer and Blancher 1994, Tejning 1967), little has been recorded in loons. Nocera and Taylor (1998) found that contaminated chicks tend to brood and preen less, and Evers (unpublished DEP Report, 1998) noted that males with high mercury loads incubate eggs less frequently. Little work has been done, however, to link lower levels of mercury with adult loon behavior. This deficiency is an important gap in our understanding of the anthropogenic effects on declining loon populations (Sutcliffe 1978, Blair 1992). It has been documented, however, that methylated mercury inhibits the production of heme (Marks, 1985; Matts, et al, 1991). We hypothesized that inhibited heme production would limit the oxygen carrying capacity of loon blood, thereby decreasing diving duration. We assumed that as diving duration decreased, loons would be required to dive more frequently per foraging interval to secure the same caloric needs. We tested the hypothesis that there was no change in the diving frequency of loons at different mercury contamination concentrations.

METHODS AND MATERIALS

Field sites

We collected data from a total of nine loon territories on six lakes in Franklin and Somerset Counties, Maine from May until August, 1999. The lakes are located in the upper drainage basins of the Androscoggin and Kennebec rivers. Both Rangely and Flagstaff lakes are dam controlled, but only Flagstaff's water level fluctuates widely. The majority of all shorelines are wooded with mixed evergreen and deciduous forest.

Approach

Loon territories were divided into four risk categories according to levels of blood mercury: extra high (> 4.0 ppm), high (3.0-4.0ppm), moderate (1.0-3.0 ppm), and low (0-1.0 ppm). We gathered diving time observations in one hour time blocks for up to 4 hours/day using one or two 15-45X spotting scopes and 10X binoculars. Observers monitored behavior continually through a spotting scope and relayed behaviors to a recorder, who noted times from a digital stopwatch and recorded observations. We gathered data from early May until late August in order to incorporate data from pre-nesting, nesting, and post-nesting intervals. Observations time were not stratified throughout the day in accordance with Evers (1994), Gostomski and Evers (1998), Mager (1999), and Paruk (1999), who found minimal or no significant relationships between time of day and behavior. During observations, we concealed ourselves as much as possible from a distance (up to 300m) to avoid any possible change in behavior due to our presence. Bradley (1985) found that this bias can influence data significantly. We collected 6 cc of blood from each loon through the methods described by Biodiversity Research Institute (Unpublished, 1999) and determined mercury concentration through cold vapor atomic absorption (CVAA).

Statistical Analysis

We calculated diving frequency as the number of dives per second foraging. We determined foraging to be a behavior state as defined by Altmann (1974), Tacha et al. (1985), and Nocera and Taylor (1998) in their time activity budget protocols. We calculated differences among treatments with the Kruskal Wallace test (Sokal and Rohlf, 1995) and Mann Whitney U (Sokal and Rohlf, 1995), and also used Pearson's Product Moment to investigate correlations between dive frequency and mercury risk category (Sokal and Rohlf, 1995). We used an alpha level of 0.05 and considered differences to be significant at $p < 0.05$.

RESULTS

Non-parametric testing determined that there was a significant difference among diving frequencies of common loons which have different levels of mercury contamination ($H = 8.75$, $df = 3$, $p = 0.033$) (Fig. 1).

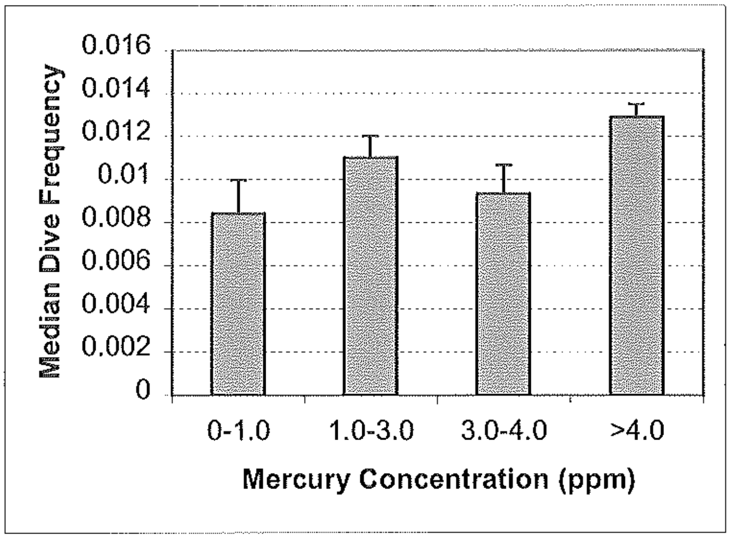

Figure 1. Median frequency of Common loon dives (+SE) among four categories of Hg contamination in loon blood during the summer of 1999 in Maine.

The frequency of diving was positively correlated with mercury load (r = 0.136, N = 249, p = 0.032) (Fig. 2).

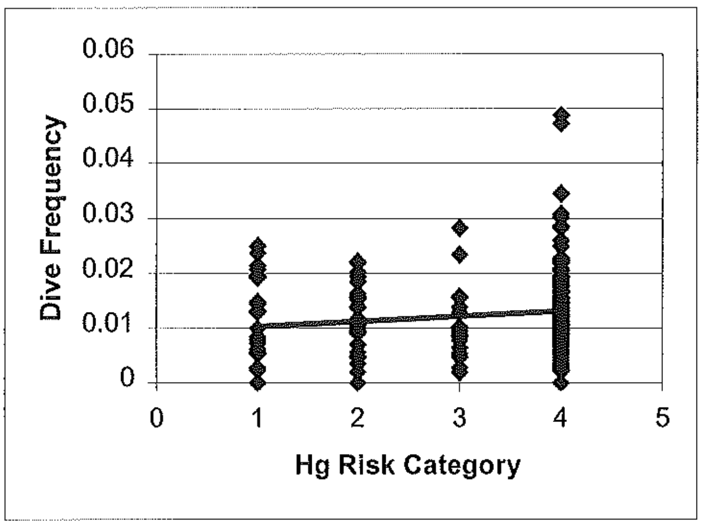

Figure 2. Frequency of common loon dives as a function of mercury contamination in the blood. Loon territories were divided up into 0-1.0 ppm , 1.0-3.0 ppm , 3.0-4.0ppm , and >4.0 ppm risk categories respectively.

This difference increases in significance as mercury loads reach the high risk category (>4.0ppm). When we pooled our first three risk categories to reduce the possible effect of low sample size, the significance of the difference increased (U = 151.0, N= 85, 164, p = 0.0063) (Fig. 3).

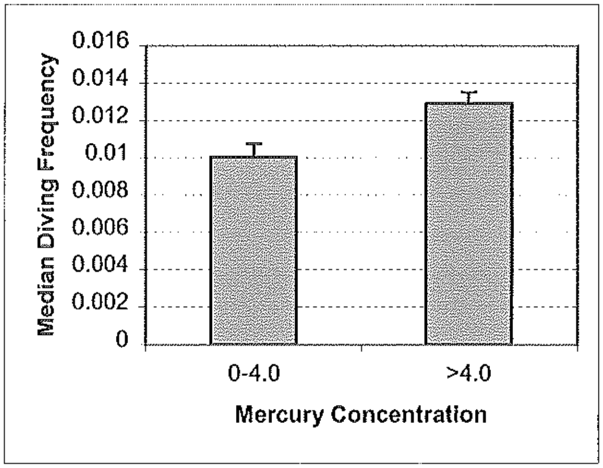

Figure 3. Median frequency of Common loon dives (+SE) of two categories of Hg contamination in loon blood during the summer of 1999 in Maine.

There was a highly significant positive difference between the diving frequencies of loons with blood concentration of 0-4.0 ppm and those with >4.0ppm.

DISCUSSION

Our findings support the supposition that there is a positive correlation between mercury contamination in loon blood and diving frequency. We hypothesize that mercury, a known heme inhibitor (Marks, 1985; Matts, et al, 1991), lowers the blood carrying capacity of the blood, thereby making it harder for loons to stay underwater as long. Shorter dives should lead to more frequent dives unless the loss in duration can somehow be compensated by foraging efficiency. In nearly exclusive piscivores such as loons, a shorter dive is presumably a less efficient dive. Thus, to meet daily caloric needs, a loon would have to dive more frequently. Although this study does not prove that mercury and dive frequency are linked, the correlation should raise sufficient concern to prompt further investigation. More frequent diving could conceivably have wide ranging effects on loon populations. Birds might have to spend more energy foraging, both because of a need for longer foraging duration, and more dives. Their ability to feed both themselves and their young might also be impacted by this effect. For many loon populations which are already under stress from shoreline development, lead poisoning, and other water quality issues, this added effect further inhibits the population's ability to rebound from disturbances and to thrive in currently established habitats.

Our conclusions are tentative, however, because of a low sample size. The moderate and high risk categories consist of only one territorial pair over the entire summer. The low category only consists of three pairs, and the extra high category consists of four territorial pairs. The high risk category's deviation from the overall pattern of increase may be because of this low sample size. However, since such a low sample size indicated a significant correlation, it is possible that further study with more sufficient sample sizes would discover a more significant relationship. It should be noted that although our correlation was not a strong one, it was a significant one. Although a number of other factors such as prey availability, water depth, and chick age may correlate more strongly with diving frequency, mercury concentration correlates significantly. Limitations of the parent data base restricted us to using diving frequency, but comparing exact diving times would yield a more direct result without further assumptions. Further study might also address the effect of increased diving frequency on foraging efficiency, caloric intake, chick feeding, and foraging duration as well as examining blood-porphyrin levels to connect the observed pattern directly to heme inhibition.

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