Cadmium Resistance in *Limnodrilus hoffmeisteri* in Foundry Cove Following a Super Fund Cleanup

A Final Report of the Tibor T. Polgar Fellowship Program

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Abstract

I investigated the effects of the recent restoration of Foundry Cove on an evolved population of the tubificid oligochaete, *Limnodrilus hoffmeisteri*. The return of *L. hoffmeisteri* to the pre-contamination state in terms of population densities, resistance to cadmium, and body burdens of cadmium will indicate a successful restoration. The effects of the restoration on population densities, resistance to cadmium and cadmium body burdens were determined. Sediment concentrations of cadmium are greatly reduced compared to 1984 levels and are not significantly different from cadmium concentrations in the sediment of a control site, South Cove. Foundry Cove *L. hoffmeisteri* no longer differ in resistance to cadmium as compared with South Cove *L. hoffmeisteri*, and no longer exhibit higher cadmium body burdens. The return of cadmium resistance levels to pre-contamination levels is indicative of a Darwinian recovery. However, current population densities of Foundry Cove are slightly reduced as compared to 1984, while the population densities of the control site have increased significantly during the same time period.

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Introduction

Environmental contaminants can often have large detrimental effects on ecosystems. Populations in metal-polluted ecosystems, however, often undergo a variety of evolutionary adaptations allowing them to survive in metal-rich conditions. Cadmium, in particular, has been shown to be an effective agent of natural selection (Klerks and Levinton, 1989b). In the event of an environmental restoration, however, selection pressure is removed. In response to this removal of selection pressure, organisms that previously adapted to contamination may adapt again to new conditions. There are a number of possible responses to an environmental restoration, owing to the complexity of ecosystems. Therefore, different measures of success of environmental restorations are needed. One possible measure of success may be to examine the evolutionary response of organisms to the restoration. The return of organisms to their pre-contamination state of adaptation is one indication of a successful restoration. Such a response to a restoration would be an example of a Darwinian recovery.

The recent restoration of Foundry Cove, a freshwater tidal bay, located 86 kilometers north of Battery Park, on the Hudson River, provides a unique opportunity for evaluating the response of an evolved population to the reversal of the conditions under which natural selection took place. Foundry Cove was once the site of the Marathon Battery Factory, which produced nickel-cadmium batteries from 1953 until the factory closed in 1979. During this time, nickel cadmium waste was discharged into the Hudson River, and in particular into Foundry Cove. In total 179 metric tons of waste were released, 55 metric tons of which were discharged directly into the cove. This resulted in cadmium concentrations in Foundry Cove that ranged from 500 to 225,000 ppm (Knutson et al. 1987), making Foundry Cove the most highly metal-polluted cove at the time. In 1983, the EPA declared that Foundry Cove would be the site of a Super Fund cleanup. This cleanup began in 1994 and consisted of draining and dredging the entire cove, as well as the surrounding marsh, and removing sediment to a depth of 10-30 cm. Following the cleanup, cadmium concentrations in the sediment ranged from 10 to 100 ppm, a huge reduction compared to previous levels.

Prior to the cleanup, it had been found that population densities of *Limnodrilus hoffmeisteri*, the dominant oligochaete in Foundry Cove, were similar to those found in South Cove (Klerks and Levinton, 1989a). The high population densities found in Foundry Cover led researchers to believe that *L. hofffmeisteri* had evolved resistance to cadmium (Klerks, 1987). It was found that Foundry Cove worms were able to absorb more cadmium that South Cove worms, especially in the form of metal-rich granules and metals bound to protein (Klerks and Bartholomew, 1991). This mechanism of resistance has been shown to evolve over a relatively short period of time (Klerks and Levinton, 1989b). Currently, levels of cadmium are comparable to those of South Cove, where the evolution of resistance did not take place. According to evolutionary theory, when selective pressure is weakened, adaptations to special conditions may be lost. Thus, it is thought that after the restoration of Foundry Cove, there might be a decrease in cadmium resistance as compared to previous to the cleanup (Suatoni and Levinton, 1997). A return of resistance levels to those found in South Cove would indicate that a Darwinian recovery had taken place.

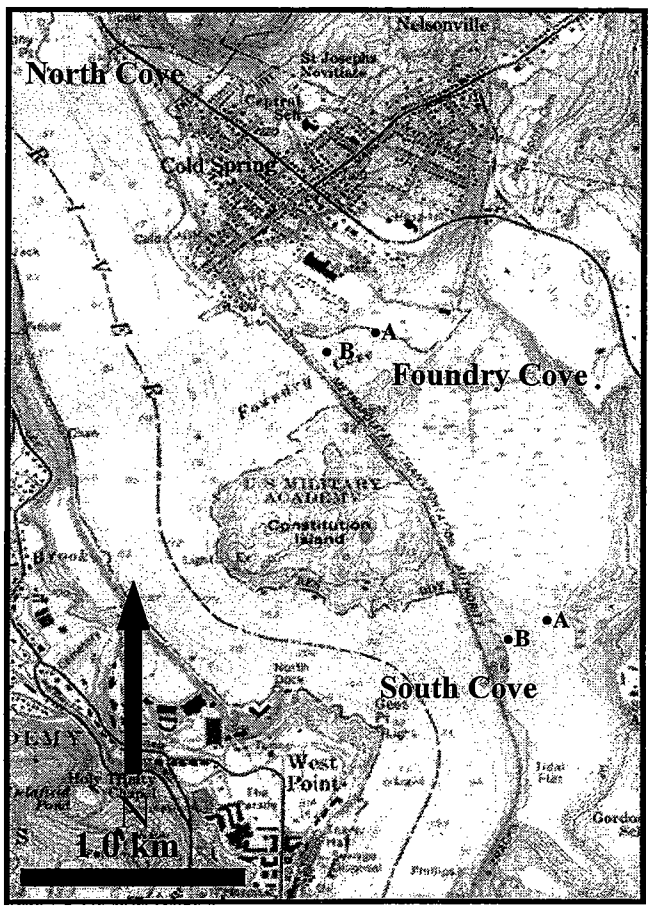
This project concludes a seven year study of the effects of the restoration on *L. hoffmeisteri,* and is one of the first to examine the loss of resistance as a measure of restoration success. We hypothesized that there would be a convergence between resistance levels of *L. hoffmeisteri* living in Foundry and South Coves and that there would be a reduction in body burdens of cadmium in Foundry Cove *L. hoffmeisteri* as compared to worms prior to the restoration.

Methods

Study site

Both sampling sites in Foundry Cove were chosen to roughly correspond with sites sampled in previous years to determine the change of resistance following the restoration (Suatoni and Levinton, 1997). However, previously only one South Cove site was sampled. This year two South Cove sites were sampled. These two sites correspond to those sampled in 2001 by Kelaher and Levinton in order to determine the relative species diversity and abundance in South Cove and Foundry Cove. The South Cove and Foundry Cove sites are indicated in Figure 1.

Figure 1. Map of Foundry Cove and South Cove, and the Locations Within these Sites.



Cadmium concentrations in sediment

Sediment was collected from Foundry and South Coves to a depth of approximately 5 cm. One sample of sediment from Foundry Cove and one sample from South Cove were analyzed for cadmium, using an atomic absorption spectrophotometer.

Resistance to cadmium

Toxicity bioassays were performed in order to determine resistance to cadmium in *L. hoffmeisteri*. Worms that were collected from two sites in Foundry Cove and two sites in South Cove were acclimated for 24 hours to reconstituted deionized fresh water and exposed to dissolved cadmium (8.9μM). Starting with a population of 96 worms, each kept in individual wells of a plastic fraction dish, the time to 50% survival was determined, and the survivorship curves of the worms was compared using Gehan's Generalized Wilcoxon test. The regression line indicating the change in time to 50% survival over the past seven years was determined.

Cadmium concentrations in Limnodrilus hoffmeisteri

Cadmium concentrations in *L. hoffmeisteri* were determined by direct measures of cadmium in an atomic absorption spectrophotometer. Worms were collected from Foundry and South Cove sediment to a depth of approximately 5 cm and were stored in the lab in their own sediment. Upon collection of worms from the sediment, they were placed in reconstituted deionized fresh water, and allowed to empty their gut contents for approximately two days. They were then frozen and stored at -80°C. Approximately 100 worms, or 0.1 gram/wet weight of tissues, were digested in hot nitric acid for analysis.

Population densities

L. hoffmeisteri population densities were determined using data collected in 2001, which examined the total benthic assemblages of Foundry Cove and South Cove following the restoration (Kelaher and Levinton, in preparation). Worms were collected from Foundry Cove and South Cove sediment using a 10 cm diameter core, to a depth of 5 cm, and were washed on a 500 micron sieve to separate them from the sediment. They were then preserved in formalin, tinted with Rose Bengal, and population densities were determined. These data were compared to those collected previous to the cleanup (Klerks, 1987). Comparisons of population densities were performed using a multi-way ANOVA.