Predicting mercury levels in freshwater fish through biotic and abiotic factors: a case study of Nantucket Island

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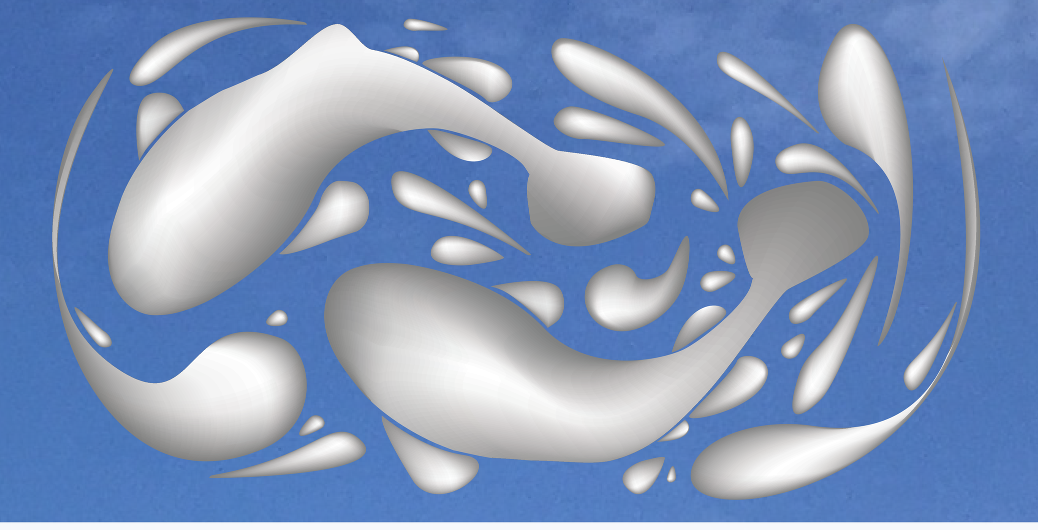


INTRODUCTION

Methylmercury (MeHg) is a neurotoxic pollutant that bioaccumulates and biomagnifies in food webs throughout aquatic systems, impacting the health of piscivorous wildlife and human consumers of predatory fish. Many of the lakes and streams in the US Northeast have been labeled "biological Hg hotspots," and elevated MeHg concentrations have been found even in fisheries of isolated island pond systems such as on Nantucket Island, MA. In this study, we investigated environmental modulators of MeHg bioaccumulation in fish of four genera (sunfish, yellow perch, white perch, and killifish) across six eutrophic to hyper-eutrophic freshwater pond systems of Nantucket to identify the strongest biotic and abiotic predictors of freshwater fish total mercury (THg) levels. By collecting a large sample of fish representing a wide range of lengths, we were able to develop simple linear regression models of ln-THg vs. fish length relating aqueous MeHg to THg bioaccumulation among fish within each pond system.

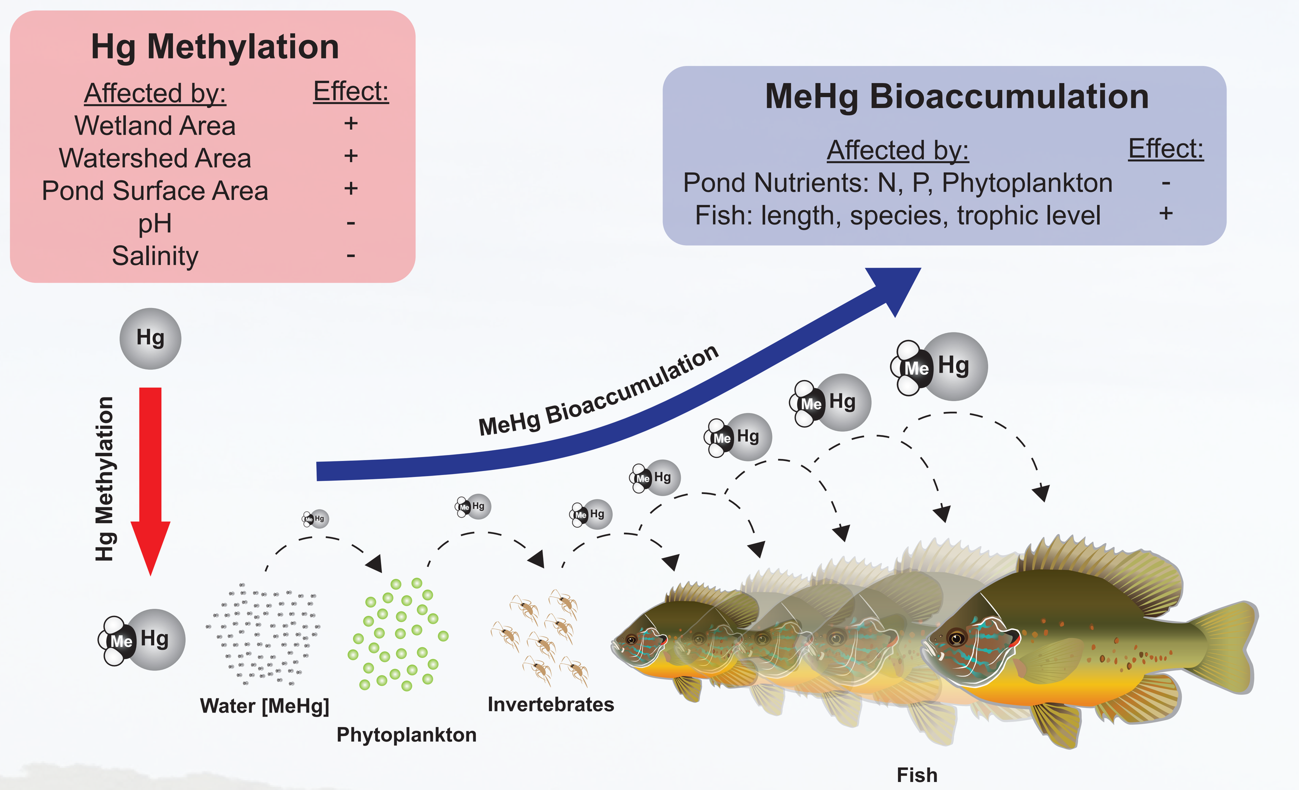


Figure 1. A depiction of the MeHg contamination pathway, divided into its two main components: Hg methylation (i.e., the source of bioavailable MeHg), and MeHg bioaccumulation (i.e., the extent to which MeHg is then accumulated in progressive trophic levels of the food web). The modulators of each process are listed under each component. "Invertebrates" are included as an example of a primary consumer prey item for larger organisms higher in trophic level, such as pond fish.

METHODS

Field Collection:

- Sample sites: 6 eutrophic to hyper-eutrophic ponds across Nantucket Island (see Fig. 2).
- **Nutrient Data**: samples collected in July and August.
  - o Water column measurements of pH, conductivity, dissolved oxygen, and temperature across depths
- **Fish Data**: Multiple collections at the same ponds, in the July-August time interval between the nutrient collections.
  - o By seine net, captured a total of 318 fish of 4 genera: yellow perch, white perch, killifish, and sunfish
  - o From each pond, collected 35-129 total fish of at least 2 different genera, with a range of juvenile age/size classes in each genus

Analysis

- o Water Samples sent to the Darrin Freshwater Institute of Rensselaer Polytechnic Institute, Troy, NY for analysis of Total N, Total P, NO_3^-, NH_3, and Chl. a
- o Measured total mercury (THg) levels in all fish using a Direct Mercury Analyzer (DMA-80)
- o Measured watershed area, pond surface area, and watershed wetland area of each study pond using ArcGIS Software.

RESULTS

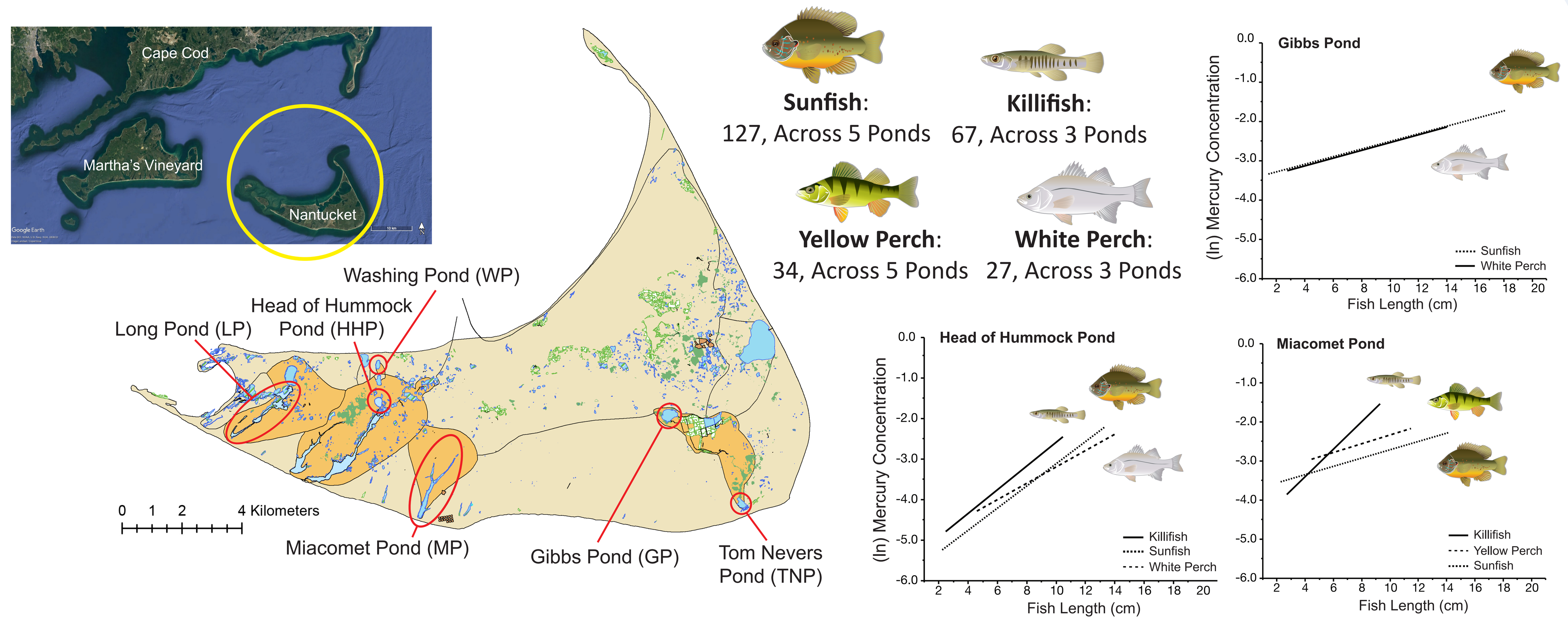


Figure 2. Left: Maps of Nantucket Island, both from Google Earth satellite imagery (upper left) and from ArcGIS software (bottom right). The watersheds relevant to this study's pond systems are denoted in orange. Right: Linear regressions of natural log-transformed fish THg, wet-weight (mg/kg) versus fish length (cm), by pond: Gibbs, Head of Hummock, and Miacomet. Each line denotes a separate genus from the labeled pond. Only those genera with significant linear regression lines are shown.

Result: In the same pond, recreationally fished species (i.e., sunfish, yellow perch, and white perch) appear to bioaccumulate MeHg at the same slope with increasing length.

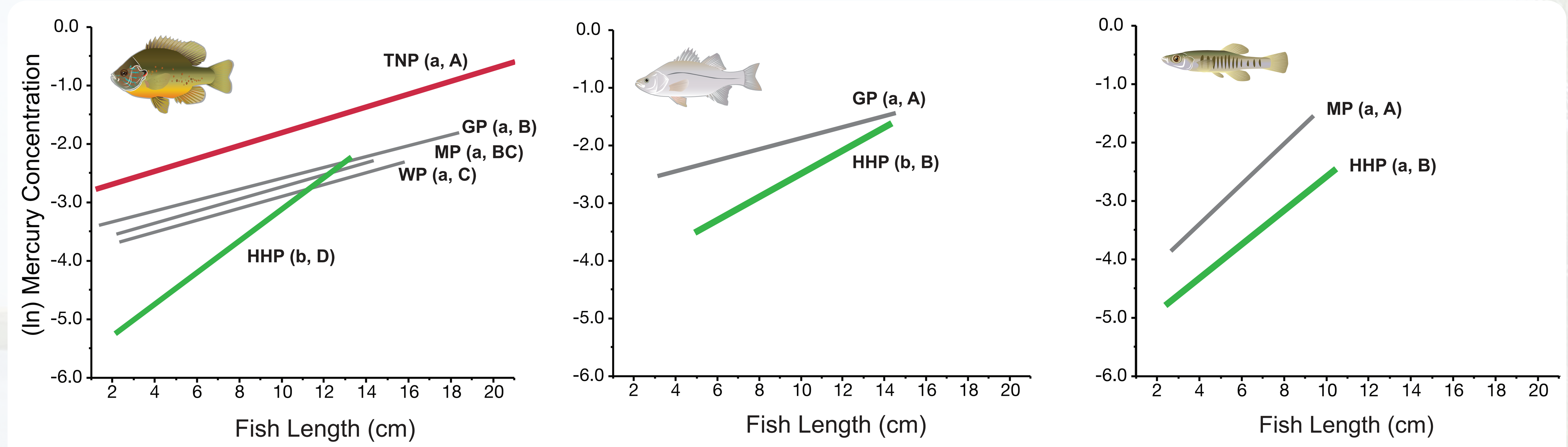
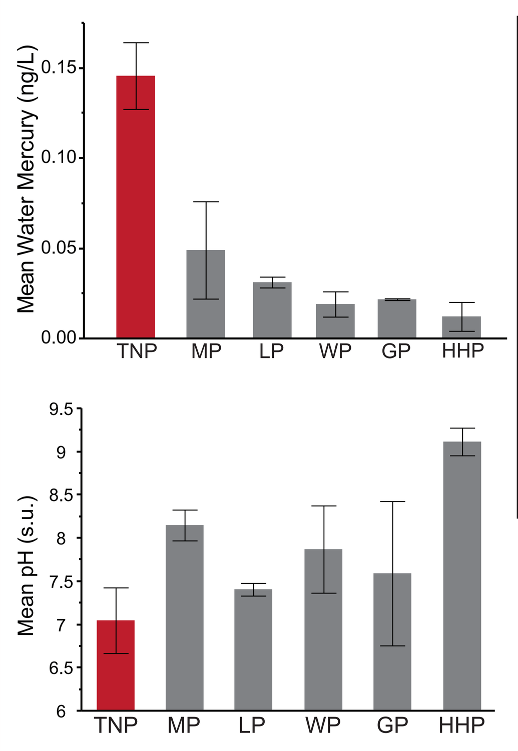
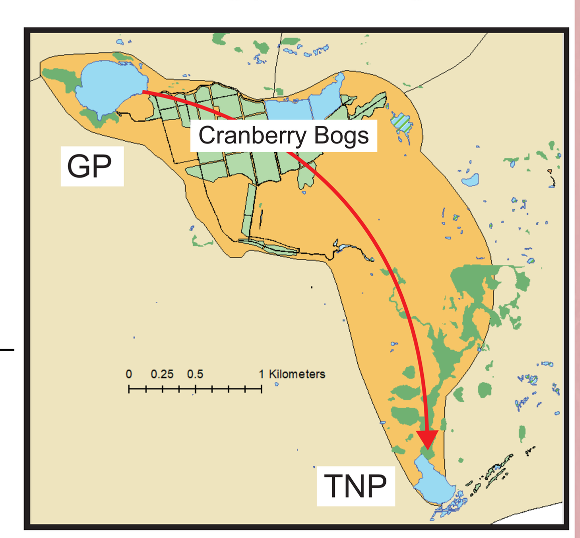


Figure 3. Linear regressions of natural log-transformed fish THg, wet-weight (mg/kg) versus fish length (cm), by genus: sunfish (left), white perch (middle), and killifish (right). Each line denotes the set of fish from the labeled pond. Differences in lettered pairs assigned to each pond regression denote significant differences in slope (lowercase) or intercept (uppercase) between regressions. Slope and intercept letters assigned to comparisons of pond regressions are exclusive to each genus.

Result: Sunfish from TNP (red line) appear to have a higher magnitude of MeHg bioaccumulation over increasing fish length, while sunfish, white perch, and killifish from HHP (green line) appear to have a higher slope of MeHg bioaccumulation with increasing length.

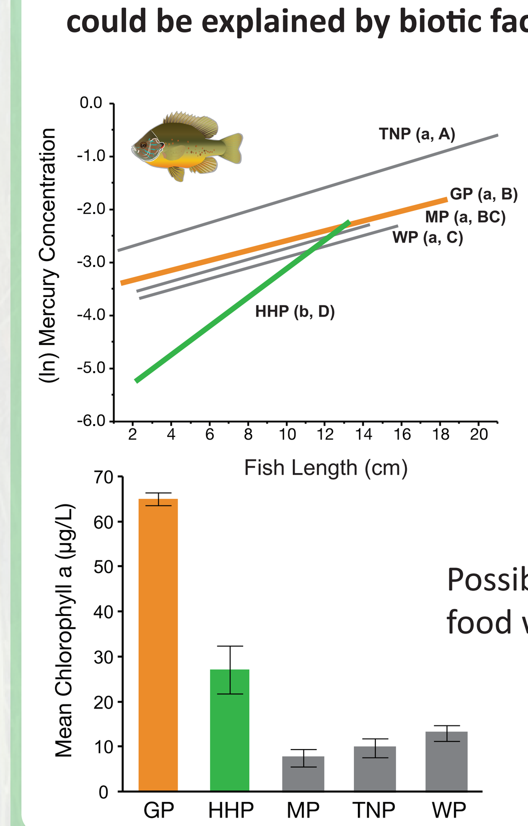
A higher magnitude of MeHg bioaccumulation in sunfish from TNP could be explained by abiotic factors increasing pond MeHg levels.





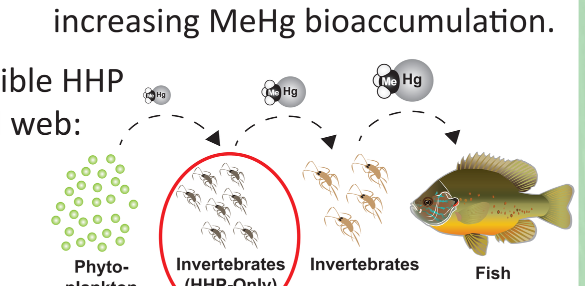
The exceptionally high surface water MeHg levels in Tom Nevers Pond (TNP) might be explained by the drainage of organic acids from the watershed's wetlands.

A higher slope of MeHg bioaccumulation across genera from HHP could be explained by biotic factors increasing fish trophic level.



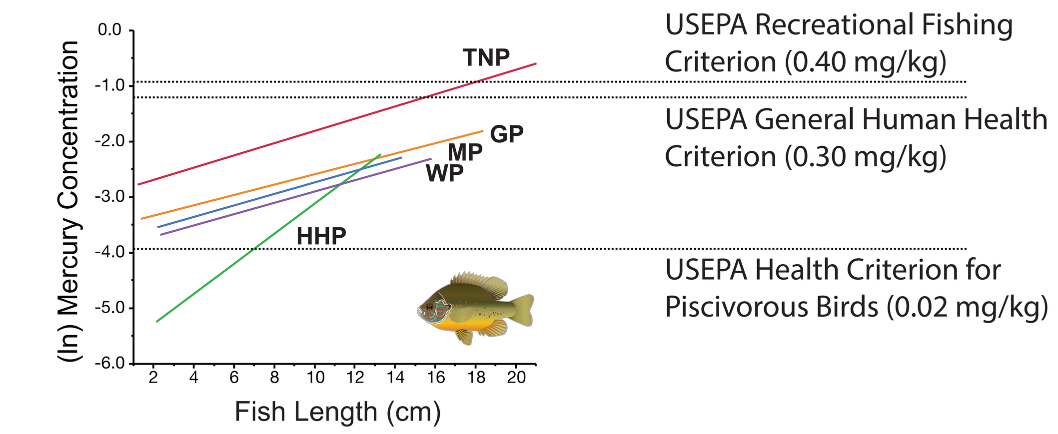
- Differences in the slope of fish ln-THg with increasing length do not correlate with differences in pond productivity (i.e., Chl. a).
- **Alternative**: biannual openings of HHP to the ocean might introduce exclusive prey sources. This addition might provide an extra link in the trophic web, increasing fish trophic level, and thus increasing MeHg bioaccumulation.

Possible HHP food web:



Implications for Environmental and Human Health

a.



b.

		Fish Length at Which THg Exceeds Health Criterion (cm)		
Genus	**Pond**	Piscivorous Birds (0.02 mg/kg)	General Human Health (0.30 mg/kg)	Recreational Human Fishers (0.40 mg/kg)
Sunfish	TNP	**0**	**15.4**	**18.0**
	GP	**0**	24.6	27.7
	MP	**0**	24.8	27.5
	WP	**0.08**	26.6	29.4
	HHP	**7.12**	17.1	18.1
W. Perch	GP	**0**	24.6	27.6
	HHP	**6.46**	19.9	21.4
Y. Perch	MP	**0**	20.5	23.1
Killifish	MP	**2.57**	N/A	N/A
	HHP	**5.46**	N/A	N/A

Figure 4. With the ln-THg vs. fish length regressions from each genus, we predicted lengths (cm) at which pond fish exceed EPA health criteria for piscivorous bird, general human health, and recreational fishing consumption (a, using sunfish regressions as example), tabulated in (b). Bold values indicate that the projected length limit is within the range of fish that we collected. All other projected lengths are within the known size ranges of each genus. Killifish criteria for human consumption are not listed because killifish are not fished recreationally.

Results (boxed in red): All study ponds appear to have fish mercury levels that are toxic for local piscivorous bird species, and fish from TNP and HHP appear to exceed EPA health criteria for human consumption at lower lengths.

CONCLUSIONS

- **Within-Pond**: All recreationally caught species shared similar mercury gain with increasing length.
- **Across-Pond**: Fish from TNP and HHP had heightened mercury levels related to hypothesized abiotic and biotic factors, respectively.
- **For Nantucket Island Policy**:
  - o All study ponds contained fish exceeding health limits for piscivorous birds.
  - o Smaller fish from TNP, HHP are of heightened concern for human consumption.

ACKNOWLEDGEMENTS

Funding from Dartmouth UGAR's Kaminsky Family Fund Award, Department of Biological Sciences Thomas B. Roos Memorial Fund and Dartmouth Superfund Research Program Grant P42ES007373.

Special Thanks to the Nantucket Land Council, the Town of Nantucket, the Dartmouth TEA Core Lab, and the Dartmouth Geography Department.