Supplementary Information
Indicator M: Toxics
State of Casco Bay 6th Edition

References

These references are data sources, sources of authoritative reference levels used to put local observations into context, and technical sources exploring methods for data analysis. Most were not referenced directly in the text, but they helped inform data analysis and data presentation, and so are appropriately referenced here.

Campbell Environmental Group, Inc. 2019. Bulk Chemistry Dredge Sediment Sampling and Harbor Assessment Report, Portland Harbor, Portland and South Portland, Maine. Report Prepared For Portland Harbor Commission, Maine Trade Center, Suite 105, Portland Fish Pier, Portland, ME 04101.

Department of Ecology, Washington State. 2013. Sediment Management Standards Chapter 173-204 WAC. Revised February 2013, Effective September 2013. Publication no. 13-09-055 (Available several places online, including: (https://www.epa.gov/sites/production/files/2014-12/documents/wa-chapter173-204.pdf)).

Leblanc, L.A., Krahforst, C.F., Aubé, J., Roach, S., Brun, G., Harding, G., Hennigar, P., Page, D., Jones, S., Shaw, S., Stahlnecker, J., Schwartz, J., Taylor, D., Thorpe, B., & Wells, P. (2009). Eighteenth Year of the Gulf of Maine Environmental Monitoring Program.

Maine Board of Pesticides Control, "Interim Report on the Environmental Risk Advisory Committee Study of Pesticides and Lobsters" (2015). Pesticides Control Documents. Paper 2. http://digitalmaine.com/bpc_docs/2

Maine Board of Pesticides Control. (2017). (rep.). *Update to the Maine Board of Pesticides Control Assessment Relative to the Risks of Pesticides to Marine Invertebrates*. Retrieved from https://www.cascobayestuary.org/wp-content/uploads/2021/01/BPC-2017-Risk-of-pesticides-to-marine-invertebrates-report.pdf.

Maine Center for Disease Control. 2001. Bureau of Health Fish Tissue Action Levels. <https://www.maine.gov/dhhs/mecdc/environmental-health/eohp/fish/documents/action-levels-writeup.pdf>. Accessed 11/10/2020.

Maine Department of Environmental Protection. 2019. Surface Water Ambient Toxics Monitoring Program. 2017-2018 Report to the Joint Committee on Environmental and Natural Resources. 129th Legislature, First Session.

Michelsen, Teresa C. 1992, Technical Information Memorandum. Organic Carbon Normalization of Sediment Data. Washington Department of Ecology Sediment Management Unit. December 1992. Publication No. 05-09-050 (https://apps.ecology.wa.gov/publications/SummaryPages/0509050.html)

National Oceanic and Atmospheric Association. (2019). (rep.). *Screening Quick Reference Tables*. Retrieved from https://response.restoration.noaa.gov/sites/default/files/SQuiRTs.pdf.

Further Reading

Casco Bay Estuary Partnership, & Ramboll Environ. (2017). Casco Bay Sediment Assessment 1991 – 2011. Portland, ME: University of Southern Maine, Muskie School of Public Service, Casco Bay Estuary Partnership. https://digitalcommons.usm.maine.edu/cgi/viewcontent.cgi?article=1001&context=cbep-toxic-pollution

Casco Bay Estuary Partnership commissioned Ramboll Environ to review two decades of sediment sampling in Caso Bay. The study reviewed several studies conducted at approximately 10-year intervals, allowing Ramboll Environ to analyze changes in metals, PAHs, PCBs, organochlorine pesticides, dioxins and furans, and organotins.

Casco Bay Estuary Project. (2007). *Toxic Pollution in Casco Bay Fact Sheet*. Available at: https://www.cascobayestuary.org/publication/toxic-pollution-in-casco-bay-sources-and-impacts/

A report on toxic contaminants in Casco Bay, reviewing multiple groups of contaminants, based on a variety of data sources. The report provides background information on major groups of contaminants, sources and consequences.

Maine Department of Environmental Protection. (n.d.). *Surface Water Ambient Toxics Monitoring Program (SWAT)*.Website accessed from https://www.maine.gov/dep/water/monitoring/toxics/swat/.

The Maine Department of Environmental Protection's Surface Water Ambient Toxics Monitoring Program monitors shellfish tissue, sediment, and the water column in all waters in Maine. The data is used to identify any environmental or public health risks. Annual reports to the legislature available from this webpage provide summaries of recent findings. SWAT data includes studies of toxics in both fresh water and marine areas.

Wade TL, Sweet ST, Klein AG. Assessment of sediment contamination in Casco Bay, Maine, USA. Environ Pollut. 2008 Apr;152(3):505-21. doi: 10.1016/j.envpol.2007.07.016. Epub 2007 Sep 5. PMID: 17804129.

An article showing the change in concentrations of toxics in sediments along Casco Bay over the course of 10 years.

Methods and Data Sources

Shellfish tissue data is derived from the EGAD database maintained by Maine's Department of Environmental Protection (DEP). We focused on toxic contaminants in blue mussels only because we have reported on blue mussels in prior state of Casco Bay reports. Recent data includes samples from other bivalves, especially soft-shell clams.

Portland Harbor sediment toxics data was sourced from Campbell Environmental, who led collection of samples to support a project to establish a Confined Aquatic Disposal cell in Portland harbor to dispose of potentially contaminated sediments. Samples represent composites from multiple depths along deep (~ 6 foot) sediment cores.

Pesticide sediment and stormwater sampling data were provided to CBEP by the Maine Board of Pesticides Control (BPC). BPC staff and volunteers conducted intertidal sediment and stormwater sampling in 2014 and 2015. We do not report on the more limited stormwater data here. The BPC sediment study looked at a relatively small number of pesticides, mostly pyrethroids. Most pyrethroids were never detected in Maine intertidal sediments. Bifenthrin was detected more frequently than any other pesticides. Bifenthrin is a widely used pesticide in urban areas, and it can be detected in sediments at comparatively low concentrations. Few other pyrethroids were detected, and none were detected often enough to enable analysis of spatial pattern or relationship to land use.

Analysis of data on toxic contaminants is complicated by the fact that many toxic compounds are found at such low concentrations that they cannot be reliably detected in environmental samples. "Non-detects" are neither missing data – we know the concentration was low – nor zeros – we only know the observation was below the detection limit.

Numerous different methods have been suggested for how best to address this. Some studies replace "non-detects" with a zero value, others with the "detection limit," the lowest concentration that can be reliably detected. Many other *ad hoc* approaches have been used over the years. None is fully satisfactory. For our analyses, we used a statistical method in which we replaced "non-detects" with a maximum-likelihood based estimate of the "most likely" value for samples below the detection limit. We used the distribution of observed samples to infer the likely distribution (under a lognormal distribution) of unobserved values below the detection limit, and then bootstraped the expected value of that truncated data distribution. The logic of this approach is embodied in a minimal R package we created, LCensMeans, available on the GitHub archive at https://github.com/CBEP-SoCB/LCensMeans. In practice, this method usually replaces the "non-detects" with a value well below ½ of the detection limit.

For the Blue Mussel toxics data, we modeled contaminant levels principally using linear models, after accounting for non-detects as just described. For the Portland Harbor toxics data, we present graphical data summaries, without statistical modeling beyond our treatment of non-detects.

For the BPC pesticide (bifenthrin) data, we used a median-based linear model to evaluate the relationship between local impervious surfaces and bifenthrin concentrations. That approach reduced the impact of the two outliers from 2014 on the trend line. The result is still statistically significant (although weaker) if based on simple linear models, or if the analysis is conducted based on organic-normalized bifenthrin concentrations, rather than raw concentration.

For the CBEP sediment data, we complemented linear models with mixed effects (hierarchical) models that treated sampling locations as random factors. While not originally based on a formal probability-based sapling design, sample locations can be thought of as a random selection of all possible sampling locations. Put another way, we expect samples collected at the same location at different times to be correlated.

Results reported in the figure legends on page 30 are based principally on full linear mixed effects models with both region and year as predictors of contaminant levels. For the metals data shown in the accompanying table, we report trend results from robust linear regression models (median-based linear models) but rely on linear mixed effects models to evaluate differences among regions of the Bay. While trend results for individual metals were generally similar with the mixed effects models, determination of statistical significance for some metals was highly model-dependent, and it proved difficult to summarize complex interactions for a public audience. We felt the robust regression results were less affected by outliers and non-detects, and thus likely to offer more robust data summaries.

Access to data and summary of data analysis can be found at https://github.com/CBEP-SoCB. For a full archive of data and all analyses steps head to https://github.com/CBEP-SoCB-Details.