Spatial distribution of mercury in Puget Sound Sediments

Jill M. Brandenberger*

Dayna R. Hernandez**

**Senior Research Scientist in Coastal Biogeochemistry, Pacific Northwest National Laboratory, 1529 West Sequim Bay Road, Sequim, WA 98382*

***Intern, Pacific Northwest National Laboratory, 1529 West Sequim Bay Road, Sequim, WA 98382*

Abstract. Originating from anthropogenic and natural sources, mercury is abundant throughout the environment. In marine sediments, inorganic mercury can be converted into an organic form, methylmercury. Methylmercury is the more toxic and can accumulate in the food chain, which ultimately means that human health is potentially at risk. The Puget Sound Naval Shipyard's historical operations served as an input source of mercury into Sinclair Inlet, a body of

water that is a part of the greater Puget Sound. Project Environmental Investment (ENVVEST) is a cooperative project with the objective of improving the environmental quality of Sinclair Inlet and its surrounding areas. The main entities involved in the project include the Puget Sound Naval Shipyard and Intermediate Maintenance Facility, the U.S. Environmental Protection Agency, and Washington State Department of Ecology. Surface (0-5 centimeters of depth) sediment samples were collected from Sinclair Inlet and 42 other sites throughout the Puget Sound. The samples were analyzed for total mercury, and the results were utilized in two ways. The first approach was to determine the spatial distribution of mercury throughout the Puget Sound, and establish where mercury concentrations exceed Washington State Department of Ecology's sediment quality standards (0.41 parts per million). The second approach was to establish which bays have a greater potential to contain methylmercury. For this determination, data from previous studies were incorporated, as well as each sample's total organic carbon measurement. It is suggested that the amount of organic carbon might serve as one tool to suggest a higher potential for the formation of methylmercury. The data may contribute to the future mercury Total Maximum Daily Load plan for Sinclair Inlet, which is designed to mitigate water quality impacts, and to assist ENVVEST's partners in decision making for effective implementation of contaminant management for environmental protection.

INTRODUCTION

Mercury in the Environment

Because of its long residence time and potential for transportation, mercury (Hg) is considered a global pollutant and is ubiquitous throughout the environment. Its origins are from both anthropogenic and natural sources. Examples of potential anthropogenic sources of Hg dissemination include combustion of coal and production of chlorine, while potential natural sources of contamination are volcanoes and geologic depositions. Mercury persists in the environment in three forms, elemental, ionic, and methylmercury, the latter of which is the most toxic to biota, including humans. Toxic effects are associated with each form, and include damage to the brain, kidney, heart, and the immune system.

In aquatic ecosystems, inorganic Hg can be converted into its organic form, methylmercury (CH_3Hg^+), through the process known as methylation. Methylated Hg is more toxic to biota than their parent metal. Because methylated species are more soluble and volatile in lipids, biomagnification and bioaccumulation within the food web can be enhanced. Ultimately, this means that human health is potentially at risk.

Although it is not fully understood, the optimal environment for the formation of methylmercury is hypothesized to occur in anoxic (or sub-oxic) sedimentary conditions by microbial organisms that reduce sulfur.[1] Another factor to consider when discussing the toxicity of Hg is the amount of total organic carbon (TOC) that is present in the substrate. The TOC is important because mercury has an affinity to organic carbon. It is believed that if mercury binds to the carbon, then there is less Hg available to potentially methylate.[2] Thus, there is hypothesized to be a correlation between methylmercury concentrations and TOC levels.[3]

However, this correlation is heavily debated in the scientific literature and only used as a single line of evidence to estimate if methylmercury would be of concern in particular marine sediment.

Project ENVVEST

Established in 2000, Project ENVVEST (ENVironmental inVESTment) is a cooperative partnership that includes the Puget Sound Naval Shipyard and the Intermediate Maintenance Facility (herein referred to as the shipyard, for brevity), the U.S. Environmental Protection Agency (EPA), the Washington State Department of Ecology (Ecology), and other technical partners. The objective of ENVVEST is to improve the environmental quality of Sinclair and Dyes Inlets[4], which are the waterbodies that were mainly affected by the historical operations of

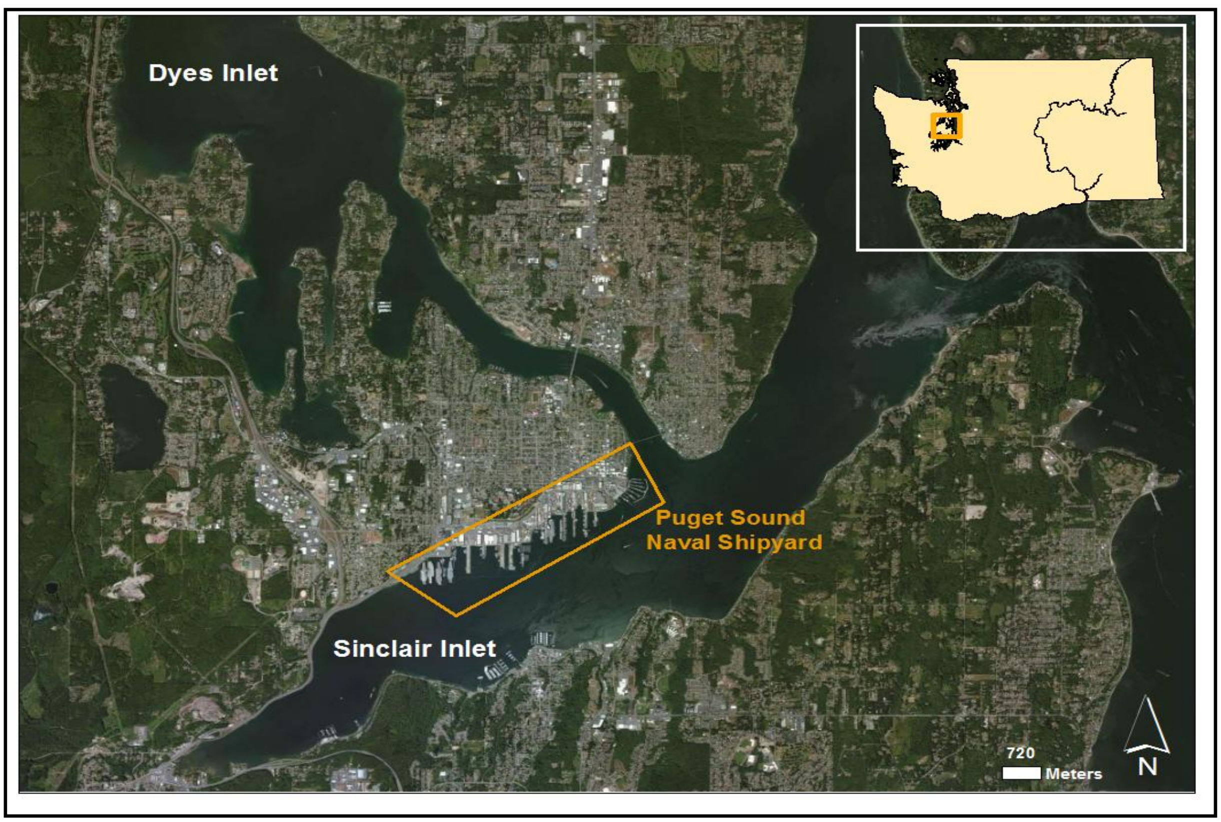

Fig. 1. The main map depicts the location of the Puget Sound Naval Shipyard (outlined in orange) in relation to Sinclair and Dyes Inlets; the inlay map shows the location of PSNS (outlined in orange) in Washington State.

shipyard, and have documented concerns for total Hg in sediment.[3] Although Sinclair Inlet houses the shipyard (see Fig. 1), the hydrology and spatial proximity of the inlets have rendered Dyes Inlet vulnerable to the contaminants disseminated from the shipyard.[5] One component of the ENVVEST project is to determine the concentration of total mercury (THg) found in the sediment in Sinclair Inlet, which is predominantly due to the operations of PSNS.[3]

Continuous studies of marine sediments in the Puget Sound since the 1980s suggest that there are elevated levels of total Hg in Sinclair Inlet when compared with other bays.[6] Although the introduction of Hg into the environment began in the late 19th century,[7] a prior study that analyzed Hg concentration in dated sediment cores revealed that mercury levels peaked during the World War II era, when the shipyard's war-related activities also peaked.[6] Activities stemming from the shipyard that introduced Hg into the environment include those associated with naval fleet services, such as "overhaul, maintenance, conversion, refueling, defueling, and repair."[8] However, a 1997 age-dated sediment core study by Lefkovitz, et al. (1997) revealed that Hg levels have steadily decreased since 1987[7] and Brandenberger et al.[9] (2008) verified similar trends for Sinclair Inlet. Although the combination of naval remedial actions and environmental regulations set forth in recent decades are responsible for curbing many environmentally-harmful behaviors and practices, the sediment of Puget Sound may still contain concentrations of Hg that pose a risk to human and/or ecological resources.

Therefore, a marine sediment study was conducted through ENVVEST. Mercury concentrations were determined in sediments that were collected throughout the Puget Sound by the University of Washington-Tacoma. The results were used to first establish the spatial distribution of Hg throughout the Puget Sound, and then to determine which sampling sites contained Hg concentrations which exceed Ecology's sediment quality standards (SQS).

Because of the results from prior data, and given the shipyard's activity history, it is hypothesized that Sinclair Inlet will continue to have higher concentrations of Hg in sediment than other urban bays. Putting the data into a regional (e.g. Puget Sound) context by comparing concentrations among urban, rural, and industrial bays to the SQS and ranging them as priority bays (exceeding SQS or higher potential to methylate Hg) or bays of concern (within a factor of 3 of the SQS) provides ENVVEST's decision makers with data to support a more effective Hg management plan.

MATERIALS AND METHODS

Sample collection and preparation

The University of Washington-Tacoma (UWT) collected 78 sediment samples from 45 different sites throughout Puget Sound. Samples were collected using either a Craib Corer or a Van Veen grab. The grab was used in substrates that were too hard for core penetration. Field duplicates were collected at two sites for Quality Assurance and Quality Control (QA/QC). Splits of all samples were obtained by Pacific Northwest National Marine Science Lab (PNNL/MSL), Sequim, Washington for analysis under the ENVVEST project. After the samples were received and logged-in, they were freeze dried and homogenized using a SPEX 8000 series mixer/miller instrument for two minutes to ensure homogeneity.

Sample analysis

The sediment samples were analyzed for total Hg according to U.S. EPA Method 7473 by thermal decomposition, gold amalgamation, and cold vapor atomic absorption spectrometry (CVAAS); specifically, the Milestone Direct Mercury Analyzer (DMA)-80 instrument was used.

The DMA uses “controlled heating in a decomposition furnace flushed with oxygen [to] liberate mercury from solid…samples.”[10] A catalyst is used to remove halogens and nitrogen/sulfur oxides, and then flowing oxygen is used to rid the system of further gases or decomposition products. Finally, mercury vapor is freed from the sediment when the gold amalgamator is heated. This allows the vapor to travel through two different cells, one being ten times longer than the other, so that the concentration to be calculated at two different sensitivities,[10] which leads to more accurate concentration results.

Each day, the DMA was calibrated using four standards with known concentrations: 1) Initial Calibration Verification (ICV) standard, with a concentration of 1.56 parts per million (ppm), 2) two Continuing Calibration Verification (CCV) standards, with concentrations of 1.0 and 0.1 ppm, and 3) International Atomic Energy Agency’s marine sediment standard IAEA-433 with a certified concentration of 0.168 micrograms per gram (μg/g).

The PNNL/MSL QA/QC protocol was adhered to maintain the data quality. Each batch of 20 samples included a method blank, a Laboratory Control Standard (LCS) with a known concentration, IAEA-433, the ICV, a matrix spike (MS), and a matrix spike duplicate (MSD). Additionally, a CCV was analyzed with every ten samples to ensure the instrument did not drift beyond 10% of the calibrated concentration. Those completed standards were acceptable if they were within a certain range of error. If the acceptance criterion was not met, analysis ceased until recalibration occurred prior to analyzing any further samples.

The sediment samples were analyzed once the DMA’s calibration curves were created and the acceptance criterion were met. A duplicate sediment sample was analyzed for QA/QC purposes for every ten samples. A duplicate was also analyzed for any samples that produced unexpected results, or results that were much greater or much less than the other samples taken from the same bay.

RESULTS

Mercury was detected in 100% of the study sediment samples, with concentrations ranging from 0.00123 to 1. 35 µg/g on a dry-weight basis. QA/QC sample results were within the acceptance criterion, which are summarized in Table 1. Sinclair (SI) and Dyes (DI) Inlets have four out of five of the highest concentrations (along with Quartermaster Harbor (QH)); these values (all values reported in units of µg/g) were: SI- 0.331 and 1.35, DI- 0.469 and 0.536, and QH- 0.405. Conversely, samples from Holmes Harbor (HH), the Main Basin (MB), Commencement Bay (CB), and Discovery Bay (DB) had the lowest five concentrations; these values (all values reported in units of µg/g) were: HH- 0.00923, MB- 0.0126 and 0.0161, CB- 0.0171, and DB- 0.0194.

Table 1. The acceptable amount of error is detailed for each QA/QC sample. If the criterion was not met, analysis ceased until recalibration occurred prior to analyzing any further samples.

QA/QC Sample	Acceptable Variation	Analysis Results (Averaged)
Method blank	< 5x MDL	0.000264 µg./g
IAEA-433 (% difference)	± 20%	0.933%
Replicates (RPD or RSD)	± 10%	3.80%
MS/MSD (% Recovery)	± 20%	99.5%

*MDL= method detection limit; the MDL is 0.00219 µg/g. RPD = Relative percent difference or Relative standard deviation.

DISCUSSION AND CONCLUSIONS

Part I

Analysis. The concentrations for the UWT field replicates and samples that were analyzed more than once were averaged and reported as one value. The relative standard deviations (RSD) for the duplicated samples were also calculated, and the averaged concentrations were accepted if the RSDs were ± 20%. Once the concentrations for each UWT sample were determined, the data was classified into three categories. The first category (green) was defined as less than 0.41µg/g Hg. The second category (yellow) was concentrations between 0.150 (factor of three below the SQS) and 0.400 µg/g. The third category (red) was concentrations greater than 0.410 µg/g Hg (Ecology's SQS). The data were categorized to gage where the mercury hotspots are within the Puget Sound (Fig. 2).

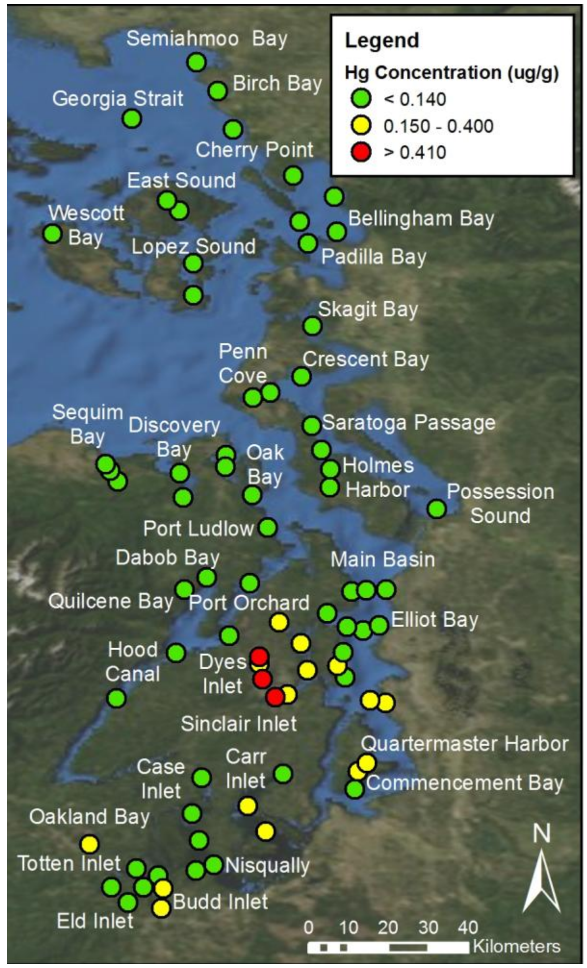

Fig. 2. The mercury concentrations of the sediment samples were categorized into ranges based on Ecology's mercury sediment quality standard of 0.41 parts per million; their locations within the Puget Sound are shown in the map above.

Descriptive statistics were performed on this data, which are summarized in Table 2. The types of statistics that were calculated include the average, standard deviation, relative standard deviation, 25th percentile, 50th percentile, 75th percentile, the number of samples included in the calculations, the minimum, and the maximum.

Table 2. A summary of the descriptive statistics of the mercury concentrations in the marine surface sediment samples collected by the University of Washington-Tacoma.

Site	Mean Conc. (µg/g)	Ave. Conc. (when n<3) (µg/g)	Conc. Std. Dev. (µg/g)	RSD (%)	25th Percentile	50th Percentile	75th Percentile	n	Min. Hg Conc. (µg/g)	Max. Hg Conc. (µg/g)
Bellingham Bay	0.094		0.034	35.9	0.085	0.10	0.11	4	0.050	0.13
Birch Bay		0.035						1		
Blakely Harbor		0.074						1		
Budd Inlet	0.14		0.028	19.7	0.13	0.15	0.16	3	0.11	0.17
Carr Inlet	0.14		0.074	52.6	0.12	0.18	0.18	3	0.055	0.19
Case Inlet	0.10		0.045	46.0	0.08	0.11	0.12	3	0.047	0.13
Cherry Point		0.044						1		
Commencement Bay		0.017						1		
Cresent Bay		0.083						1		
Dabob Bay		0.037						1		
Discovery Bay		0.050						2		
Dyes Inlet	0.39		0.20	52.6	0.31	0.47	0.50	3	0.15	0.54
Eagle Harbor		0.28						1		
East Sound		0.081						2		
Eld Inlet		0.12						2		
Elliott Bay	0.10		0.006	5.8	0.10	0.10	0.10	3	0.10	0.11
Georgia Strait		0.062						1		
Henderson Bay		0.11						1		
Holmes Harbor	0.061		0.055	89.6	0.032	0.055	0.087	3	0.009	0.12
Hood Canal Bridge		0.027						1		
Hood Canal-Hamma Hamma		0.085						1		
Hood Canal-Seabeck		0.064						1		
Liberty Bay		0.21						1		
Lopez Sound		0.052						2		
Main Basin	0.082		0.066	80.1	0.028	0.073	0.13	6	0.013	0.17
Murden Cove		0.020						1		
Nisqually Reach		0.071						1		
Oak Bay		0.062						1		
Oakland Bay		0.16						1		

Padilla Bay		0.064						1		
Penn Cove		0.10						2		
Port Ludlow		0.051						1		
Port Madison		0.037						1		
Port Orchard Bay		0.25						2		
Port Townsend		0.075						2		
Possession Sound		0.11						1		
Quartermaster Harbor		0.37						2		
Quilcene Bay		0.031						1		
Saratoga Passage		0.10						1		
Semiahmoo Bay		0.079						1		
Sequim Bay	0.089		0.025	28.6	0.075	0.076	0.10	3	0.073	0.12
Sinclair Inlet		0.84						2		
Skagit Bay		0.056						1		
Totten Inlet		0.080						2		
Wescott Bay		0.028						1		

Results. There are three sampling sites that were categorized as *red* within the study area (all in Sinclair and Dyes Inlets). The areas with this rating exceed Ecology's SQS for Hg. There are 14 yellow sites which are the Main Basin, Budd Inlet, Dyes Inlet, Oakland Bay, Carr Inlet, Liberty Bay, Port Orchard, Eagle Harbor, Quartermaster Harbor, and Sinclair Inlet. These sites do not exceed Ecology's SQS, but are within a factor of three below the SQS. Finally, the remaining sites were *green* and include Holmes Harbor, the Main Basin, Commencement Bay, Murden Cove, Hood Canal, Wescott Bay, Quilcene Bay, Birch Bay, Port Madison, Dabob Bay, Lopez Sound, Cherry Point, Case Inlet, Bellingham Bay, Port Ludlow, Carr Inlet, Skagit Bay, Georgia Strait, Oak Bay, Padilla Bay, Port Townsend Bay, Nisqually, Sequim Bay, Semiahmoo Bay, East Sound, Discovery Bay, Crescent Bay, Totten Inlet, Elliot Bay, Eld Inlet, Penn Cove, Saratoga Passage, Possession Sound, Budd Inlet, and Henderson Inlet. This show spatially that the red sites are all located in industrial or urban bays while yellow sites are urban, rural, and industrial

Purpose. Historically, some areas may have higher concentrations of Hg depending on the land use surrounding the area. In the case of Dyes and Sinclair Inlets, this is likely the case, due to the past activities of the shipyard. However, the high concentration of Hg in Quartermaster Harbor was unexpected since it is not an urban or industrial bay. The area, although close in proximity to Commencement Bay, is dominated by rural land use. A statement regarding an explanation of why the harbor may have high Hg cannot be made definitively, but it is recommended that the area be the center of a study in the future.

Part II

Analysis. Mercury concentrations from prior studies were obtained through Ecology's Environmental Information Management (EIM) database. A search was performed for all 45 bays that were targeted by UWT, but the database only contained results for 39 of them. Only data pertaining to surficial sediment was selected because it represents the most current conditions and comparable to the UWT data. For this study, surficial is defined as a depth no greater than 5 cm. Data that was deemed questionable, not obtained by accurate methods, or older than 1990, was excluded. The EIM data was combined with the UWT data, as well as data from ENVVEST (2011) (for brevity, the marriage of this data will be referred to as "combined data" from this point on). The Hg concentrations were then classified following the same categorization guidelines as Part I ($\leq$ 0.140 µg/g, 0.150-0.400 µg/g, and $\geq$ 0.410 µg/g), and a map was created in GIS to visually display the findings (Fig. 3). Descriptive statistics were performed on this data, which are summarized in Table 1 in the Appendix.

Results. Analysis of the combined data led to a greater number of sites that contained sediment with Hg concentrations greater than the SQS, as compared to analyzing the UWT mercury concentrations alone. The additional priority bays in the red category were Commencement Bay, Elliott Bay, and Possession Sound.

Purpose. The intention of part II's analysis was two-fold. Primarily, the purpose was to determine where Hg hotspots are throughout the Puget Sound when backed by the data of prior studies. This gives a more robust picture of Hg levels in the sound. This analysis was also important because it gave a greater number of samples to support this study. Scientifically speaking, one sample does not necessarily fairly represent an entire area, which is what the UWT data offered for 25/45 of the bays.

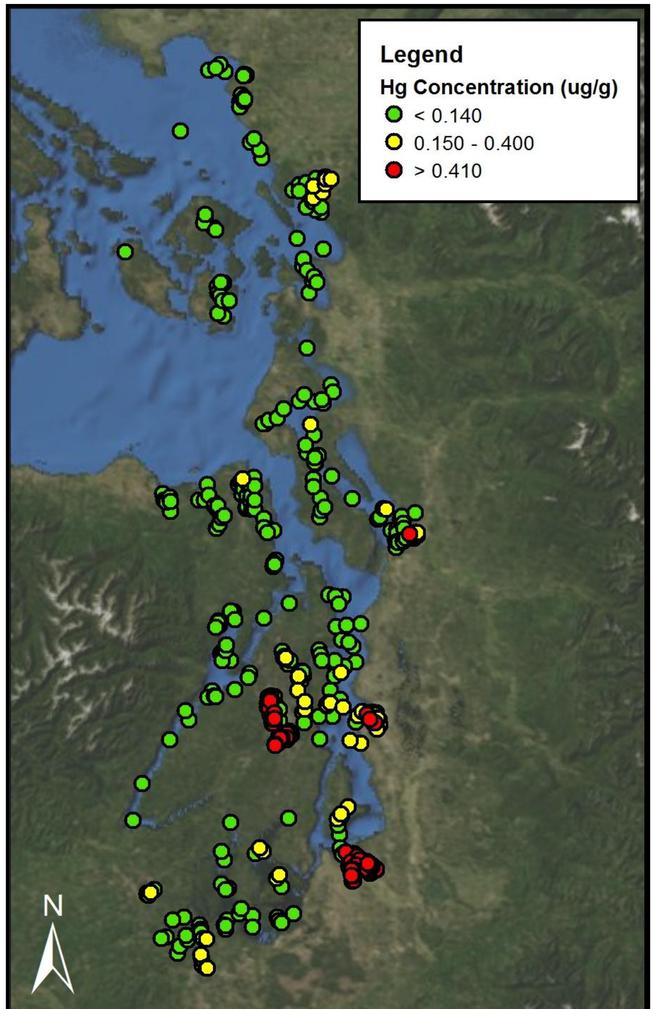

Fig. 3. The mercury concentrations of samples from prior studies were categorized into ranges based on Ecology's mercury sediment quality standard of 0.41 parts per million; their locations within the Puget Sound are shown in the map above.

Secondarily, the intention of part II was to compare the Hg concentrations in surface sediments of Sinclair Inlet to other bays throughout the Puget Sound, both urban and rural. The Navy has implemented numerous remedial efforts, and has made clean-up of Sinclair and Dyes Inlets a priority[11]. This part of the analysis could lend evidence to assist the Navy in their determination of the effectiveness of their efforts and a relative comparison to other bays. The analysis results support the alternative hypothesis that Sinclair Inlet has elevated Hg concentrations in the surface (0-5 centimeters of depth) sediment when compared to the other bays. However, it should be noted that this does not mean that Hg concentrations are not being reduced, since that type of comparison was not the focus of this study.

Part III

Analysis. Again using the EIM database, the TOC results from previous studies were gathered for all bays that were targeted by UWT. However, the search only yielded results for the same 39 bays found in part II. The TOC values were matched to the associated Hg concentrations, but those that could not be linked to corresponding Hg samples were excluded. This data were combined with ENVVEST (2011) data. The UWT data were not used for Part III because TOC results were not available. Finally, Hg concentrations were graphed against TOC values for each bay that received a *yellow* or *red* classification. The coupling of the Hg-TOC relationship and the comparison of Hg concentrations to sediment quality standards supported another line of evidence to use for prioritizing locations for future studies.

Results. Fig. 4 depicts the total Hg graphed against the TOC of each sample. The yellow box show which bays have high Hg concentrations and low TOC. For this study, low TOC was defined as values ≤ 1.5%. "High Hg" concentrations were based on the SQS of 0.41μg/g.

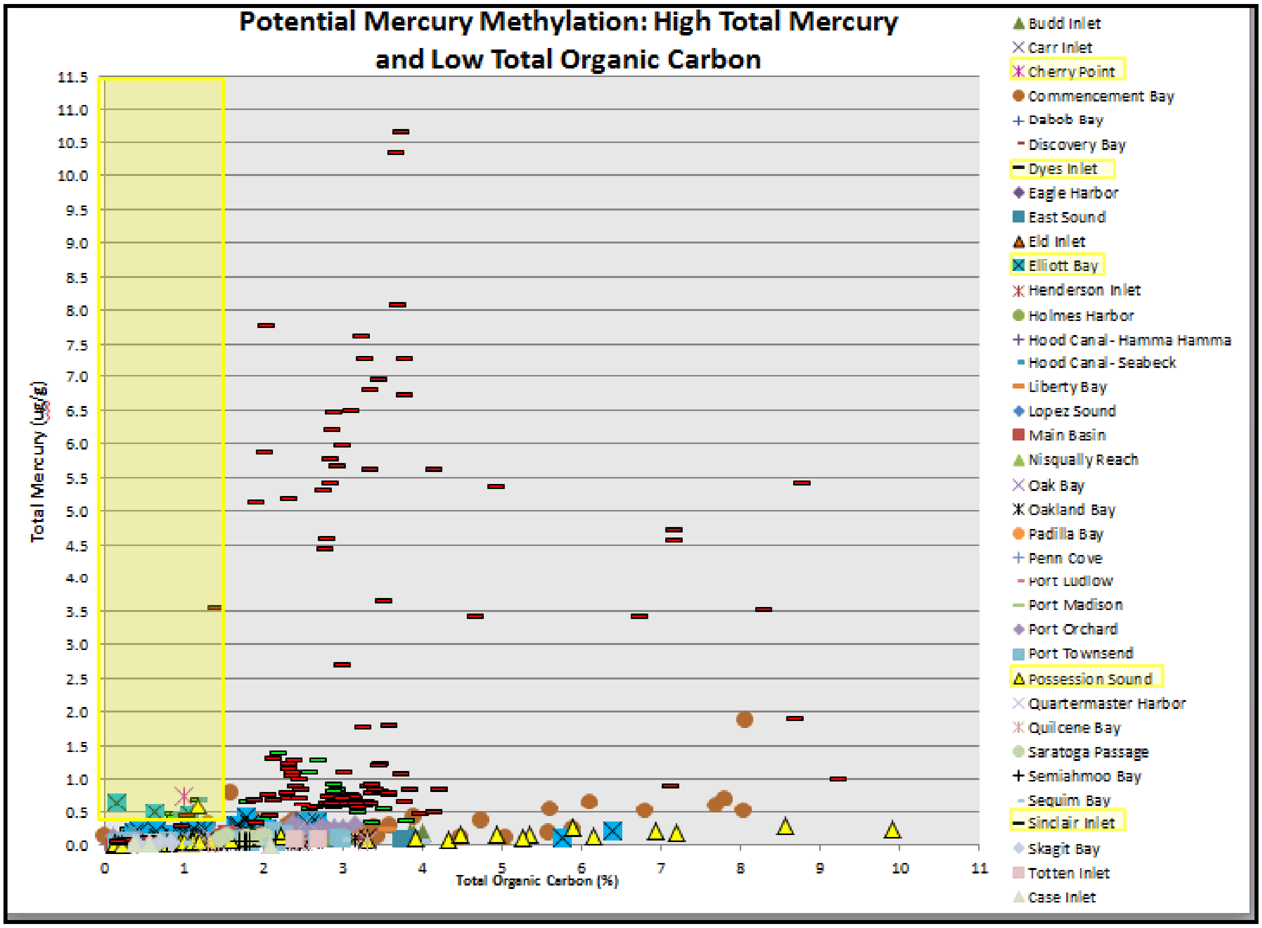

Fig. 4. The concentration of total mercury (ug/g) is graphed against total organic carbon (%) for all bays where data was available. The highlighted box depicts where high Hg and low TOC is present, which suggests high potential for mercury methylation.

Purpose. As previously mentioned, the relationship between Hg methylation and TOC in marine sediment is not yet fully understood. The reason for part III of the data analysis was to supply the idea with more information, regardless if the data supported or rejected the concept. No definitive statement can be made about the relationship based on this data. It was only used for prioritization.

Part IV

Recognizing the bays that contain Hg levels above (red sites) and close to (yellow sites) Ecology's SQS, and combing that data with the TOC values, can assist in prioritizing bays according to the sediment's potential for Hg methylation. Based on this information, eleven bays are recommended for future studies. It is recommended that the bays evaluated for methylmercury concentrations and fish advisory evaluations.

The bays were divided into two tiers (Table 3). Tier 1 bays are considered Priority Bays based on the criteria that their mercury concentrations exceed the SQS, that they have low TOC levels, or both. Tier 1 bays are Cherry Point, Dyes Inlet, Elliott Bay, Possession Sound, and Sinclair Inlet. Tier 2 bays are considered Bays of Concern based on the criteria that their levels of mercury do not exceed the standard, but they are still higher than acceptable. The Tier 2 bays are Bellingham Bay, Budd Inlet, Liberty Bay, Oakland Bay, and Quartermaster Harbor. Close-up maps of each Priority Bay and Bay of Concern are referenced in Fig. 1 in the Appendix.

Table 3. A summary of the Priority Bays (Tier 1) and the Bays of Concern (Tier 2).

Tier 1: Priority Bays	Tier 2: Bays of Concern
Cherry Point	Bellingham Bay
Dyes Inlet	Budd Inlet
Commencement Bay	Liberty Bay
Elliott Bay	Oakland Bay
Possession Sound	Quartermaster Harbor
Sinclair Inlet	

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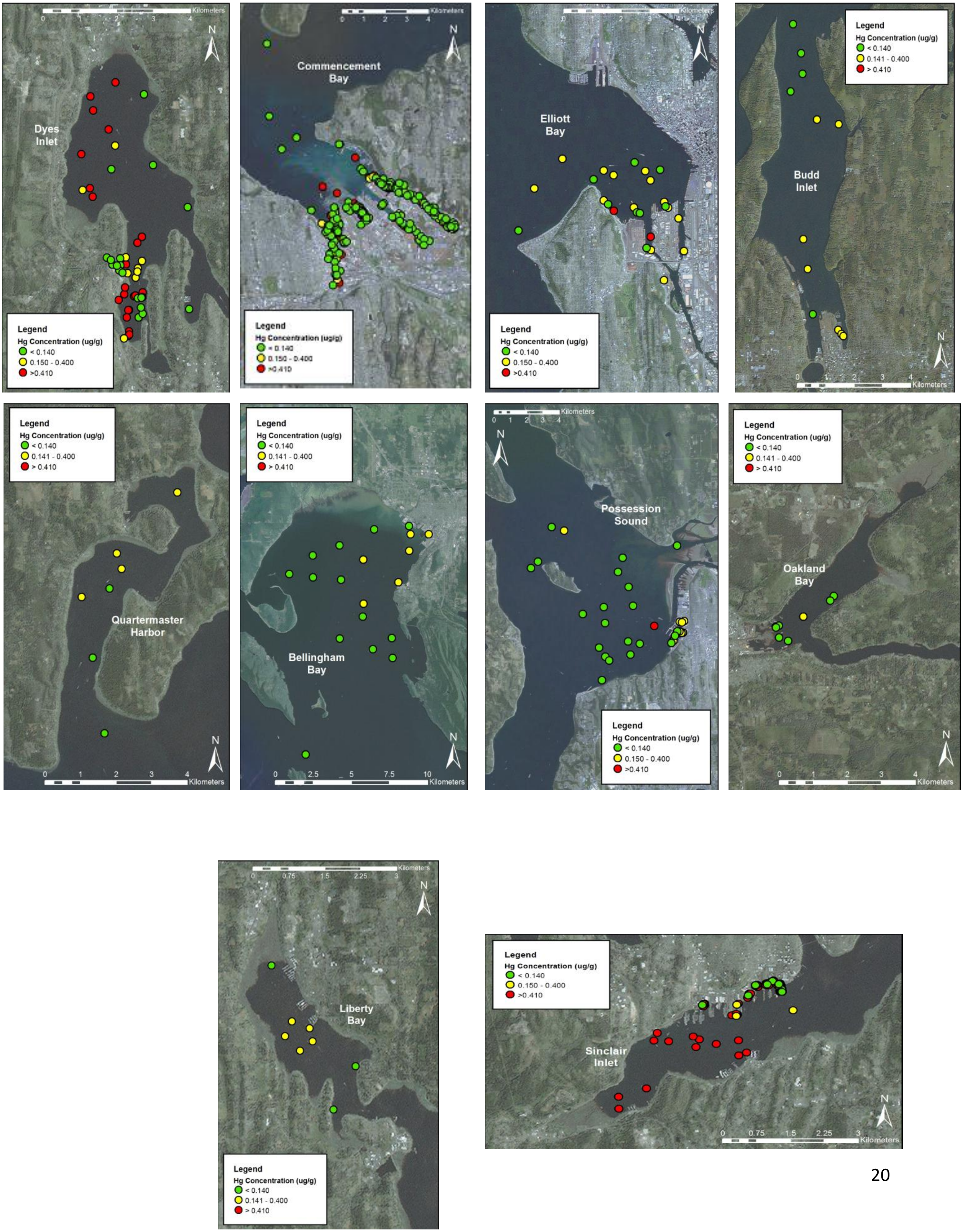
APPENDIX

Table 1. A summary of the descriptive statistics of the mercury concentrations in the marine sediment for the combined data.

Site	Mean Concentration	Average Concentration	Concentration Standard	RSD (%)	25th Percentile	50th Percentile	75th Percentile	n	Minimum Hg Concentration	Maximum Hg Concentration
Bellingham Bay	0.14		0.068	48.8	0.098	0.12	0.15	25	0.050	0.33
Birch Bay	0.039		0.012	31.8	0.035	0.038	0.049	7	0.016	0.051
Blakely Harbor		0.074						1		
Budd Inlet	0.17		0.044	26.0	0.15	0.17	0.18	21	0.11	0.32
Carr Inlet	0.13		0.078	60.5	0.053	0.17	0.18	7	0.038	0.22
Case Inlet	0.06		0.050	81.8	0.025	0.04	0.096	6	0.014	0.13
Cherry Point	0.17		0.29	172.3	0.042	0.046	0.074	6	0.035	0.76
Commencement Bay	1.20		10.5	872.3	0.050	0.080	0.26	312	0.012	170
Cresent Bay		0.083						1		
Dabob Bay	0.06		0.031	49.0	0.038	0.069	0.078	9	0.01	0.11
Discovery Bay	0.071		0.043	61.0	0.047	0.072	0.089	16	0.016	0.19
Dyes Inlet	0.41		0.31	75.8	0.13	0.40	0.58	64	0.036	1.4
Eagle Harbor	0.15		0.13	85.6	0.057	0.14	0.22	7	0.01	0.37
East Sound	0.084		0.0045	5.4	0.0817	0.082	0.088	5	0.080	0.090
Eld Inlet	0.12		0.018	15.6	0.097	0.124	0.13	5	0.10	0.14
Elliott Bay	0.21		0.13	59.2	0.12	0.19	0.28	45	0.029	0.65
Georgia Strait		0.062						1		
Henderson Bay	0.11		0.0085	7.5	0.11	0.11	0.12	4	0.10	0.12
Holmes Harbor	0.064		0.045	70.3	0.029	0.063	0.10	6	0.0092	0.12
Hood Canal Bridge		0.027						1		
Hood Canal- Hamma Hamma	0.074		0.014	19.0	0.063	0.075	0.086	4	0.060	0.087
Hood Canal- Seabeck	0.16		0.19	120.7	0.029	0.11	0.18	58	0.005	0.84
Liberty Bay	0.13		0.092	72.0	0.040	0.15	0.21	18	0.014	0.24
Lopez Sound	0.07		0.025	35.9	0.052	0.062	0.087	9	0.043	0.12
Main Basin	0.074		0.054	73.5	0.019	0.079	0.11	24	0.0097	0.17
Murden Cove		0.020						1		

Site	Mean Concentration	Average Concentration	Concentration Standard	RSD (%)	25th Percentile	50th Percentile	75th Percentile	n	Minimum Hg Concentration	Maximum Hg Concentration
Nisqually Reach	0.041		0.021	50.5	0.0302	0.033	0.047	15	0.02	0.094
Oak Bay	0.040		0.026	64.6	0.022	0.044	0.062	4	0.012	0.063
Oakland Bay	0.092		0.033	36.1	0.070	0.074	0.111	9	0.053	0.16
Padilla Bay	0.048		0.017	35.7	0.037	0.055	0.059	8	0.018	0.064
Penn Cove	0.11		0.010	9.0	0.099	0.108	0.115	5	0.097	0.12
Port Ludlow	0.039		0.021	53.8	0.022	0.038	0.051	5	0.017	0.069
Port Madison	0.042		0.020	47.6	0.028	0.036	0.054	6	0.024	0.074
Port Orchard Bay	0.20		0.089	43.6	0.129	0.23	0.25	24	0.019	0.33
Port Townsend	0.065		0.040	61.3	0.04	0.05	0.081	35	0.018	0.209
Possession Sound	0.11		0.099	89.5	0.057	0.082	0.13	44	0.010	0.60
Quartermaster Harbor	0.23		0.16	71.2	0.078	0.25	0.36	6	0.048	0.41
Quilcene Bay	0.045		0.013	28.7	0.035	0.045	0.053	6	0.031	0.064
Saratoga Passage	0.10		0.033	33.0	0.094	0.11	0.12	12	0.038	0.14
Semiahmoo Bay	0.06		0.018	31.6	0.048	0.051	0.070	7	0.031	0.08
Sequim Bay	0.07		0.029	40.3	0.062	0.074	0.078	7	0.025	0.12
Sinclair Inlet	1.5		2.2	140.9	0.358	0.69	1.2	197	0.0000021	11
Skagit Bay	0.044		0.015	33.4	0.036	0.046	0.054	6	0.022	0.062
Totten Inlet	0.080		0.0048	5.9	0.079	0.081	0.082	4	0.074	0.085
Wescott Bay		0.028						1		

Fig. 1. The categorized mercury concentrations for Dyes Inlet, Commencement Bay, Elliott Bay, Budd Inlet, Bellingham Bay, Liberty Bay, Possession Sound, Oakland Bay, Quartermaster Harbor, and Sinclair Inlet.



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