

Macaulay and Clover Points

Wastewater and Marine Environment Program

Annual Report 2010

Environmental Sustainability

Environmental Protection



Prepared by:
Marine Programs

Capital Regional District
625 Fisgard Street, Victoria, BC V8W 2S6
T: 250.360.3000 F: 250.360.3079
www.crd.bc.ca

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**MACAULAY AND CLOVER POINTS
WASTEWATER AND MARINE ENVIRONMENT PROGRAM
2010 ANNUAL REPORT**

EXECUTIVE SUMMARY

Monitoring of wastewater discharges, surface waters and the seafloor environment in the vicinity of the Macaulay and Clover points outfalls has been conducted as part of the Wastewater and Marine Environment Program (WMEP) on a regular basis since the late 1980s. Additional investigations have also been undertaken to more clearly define the effects of the outfalls on the receiving environment. The program has undergone a number of changes over the years but is relatively unchanged since 2000.

In March 2003, the BC Ministry of Environment (MOE) approved the Capital Regional District (CRD) Core Area Liquid Waste Management Plan (LWMP). This LWMP outlined CRD's plans to manage liquid wastes for the next 25 years. Commitments made in this plan are designed to protect public health and the environment from the impacts of liquid waste discharges. On July 21, 2006, the CRD received a letter from the minister of environment requiring an amendment to the Core Area LWMP, detailing a schedule for the provision of sewage treatment. The minister also requested that the CRD continue the current monitoring program. Liquid Waste Management Plan amendment #7 was submitted to MOE in December 2009, with a follow-up amendment, #8, in June 2010. Both amendments outline plans to implement advanced sewage treatment for the core area (i.e., Greater Victoria and western communities). The amendments, and current status of ongoing treatment plans, can be found at www.wastewatermadeclear.ca.

The 2010 WMEP consisted of the following components:

- wastewater monitoring and analysis for a list of substances, including conventional parameters, metals, and other priority substances (conducted monthly for each outfall)
- surface water monitoring and analysis of fecal coliforms as indicators of potential for human exposure to pathogens reaching the marine environment via wastewater (conducted monthly at each outfall)
- seafloor monitoring for chemical (sediment and mussel tissue contaminant concentrations) and biological (health of seafloor communities-benthic organisms and mussels) parameters on a yearly basis
- additional investigations into wastewater, water column and seafloor monitoring components, which look into emerging scientific issues regarding wastewater discharges and environmental effects

The 2010 annual report presents results and updates for the different elements of the Macaulay and Clover points WMEP, including the routine monitoring components and additional investigations. Beginning in 2011, WMEP will shift from monitoring annually to monitoring based on a five-year cycle. Therefore, this will be the last full annual report. In the future, update reports will be issued annually, plus a comprehensive report at the end of each five-year monitoring cycle.

WASTEWATER MONITORING

Wastewater monitoring results for conventional parameters (i.e., pH, biochemical oxygen demand, total suspended solids and nutrients) indicated that the quality of the effluents from Macaulay Point and Clover Point outfalls in 2010 was similar to previous years. Ten chemicals were above applicable BC and CCME water quality guidelines (WQGs) in undiluted effluent. However, when a minimum initial dilution factor (based on oceanographic modeling) was applied to predict concentrations in the receiving environment within the initial dilution zone (IDZ), there were no exceedences.

Priority substances frequently detected in wastewater in 2010 were similar to previous years. Substances detected greater than or equal to 50% of the time included a number of conventional parameters, total and dissolved metals, organotins, two phenolic compounds, PAHs, two phthalates, a few miscellaneous volatile organics and terpenes.

Concentrations of all conventional parameters were within the expected range for fine-screened wastewater, and the estimated receiving environment concentrations, based on the predicted minimum initial dilution, did not exceed applicable British Columbia (BC) or Canadian Council for Ministers of the Environment (CCME) water quality guidelines (WQG). Flow volumes did not exceed the allowable daily maximums stipulated in the Operational Certificates for the outfalls.

Overall, the 2010 wastewater monitoring results were generally consistent with previous years. The Macaulay and Clover points wastewaters met all flow, TSS and BOD requirements stipulated under their draft operational certificates, indicating that wastewater plants were operating as expected. Some priority substances were above WQGs in undiluted wastewater, but all met guidelines once the minimum dilution factors were applied.

SURFACE WATER MONITORING

Macaulay Point

Results of the monthly surface fecal coliform monitoring for Macaulay Point indicated that the effluent plume behaved according to modeling predictions. Hydrodynamic modeling work conducted in 2006 (Lorax, 2006) predicted that during slack tide in winter, there is a 0–5% chance that the Macaulay Point effluent may reach the surface. When surfacing does occur, the plume is highly diluted (average dilution of 1580:1). On these occasions, fecal coliform concentrations above 200 CFU/100 mL may be detected. The fecal coliform stations geometric means were all an order of magnitude below 200 CFU/100 mL, indicating that the potential for human exposure to the Macaulay Point wastewaters in the marine environment was low. Nineteen individual measurements out of 456 (representing 4.2% of surface water samples) were above the value of 200 CFU/100 mL, mostly in October. The highest value measured was 12,490 CFU/100 mL, measured during a visible plume surfacing event within the IDZ in September. Plume surfacing events are also predicted in the summer, but less frequently than during the winter. While dilution and diffusion help to greatly reduce the concentration of E.coli at the surface, continued monitoring is important to better characterize the risk for human exposures in the area.

Additional sampling was undertaken in the summer of 2010 to collect five samples in 30 days, as per recommendations by the Marine Monitoring Advisory Group (MMAG) and MOE. This sampling was done to determine if fecal coliform levels exceed the BC MOE WQG for recreational primary contact, as they were defined, during the time of year when most recreational activity is expected around the outfalls. Geometric mean results were far below the BC MOE WQG, classifying the likely potential for human exposure as “low” according to these guidelines.

Clover Point

Geometric means for fecal coliforms at all Clover Point stations were approximately an order of magnitude below 200 CFU/100 mL in 2010, indicating that the potential for human exposure to the Clover Point wastewaters in the marine environment was low. All stations had geometric means of 50 CFU/100 mL or less. There were 23 individual measurements out of 455 (representing 5.0% of surface water samples) above the value of 200 CFU/100mL, with most occurring in December. The highest value measured was 2,300 CFU/100 mL, recorded in October at a station outside of the IDZ. Results were within expected concentrations predicted by hydrodynamic modelling. Recent modelling work predicted that during slack tide in winter, there is less than a 2% chance that the Clover Point effluent plume may be reaching the surface. Although the plume is highly diluted by the time it reaches the surface (average dilution of 1500:1), fecal coliform concentrations above 200 CFU/100 mL will sometimes be detected. Summer plume surfacing events are also predicted to occur, but at a lower frequency than in the winter.

Overall, the data indicated that the Clover Point effluent plume was predominantly trapped below the surface, with occasional surfacing events, as predicted by the model, and that the outfall diffuser was operating as expected during the majority of the year. The CRD undertook the additional five samples in 30 days pilot project at Clover Point in the summer. Similar to Macaulay Point, all geometric mean results were far below the BC MOE WQG, classifying the potential for human exposure as likely low.

SEAFLOOR MONITORING

Macaulay Point

Sediment Chemistry

Samples collected from the outfall station (M0) and the reference station PB1 were analyzed for a full list of priority substances. For the remaining stations at Macaulay Point and Parry Bay, samples were analyzed for a modified list of priority substances. Results were compared to various sediment quality guidelines (SQGs) designed to predict potential biological effects in the environment.

Comparison of Macaulay Point sediment data to SQGs showed exceedences at stations within 200 m of the outfall and included copper, mercury, some PAHs (acenaphthene, anthracene, benz(a)anthracene, benzo(a)pyrene, chrysene, fluoranthene, indeno(1,2,3-c,d)pyrene, phenanthrene, pyrene), 1,4-dichlorobenzene, 1,2,4-trichlorobenzene, and phenol.) High-resolution parameters (PCBs, PAHs, nonylphenols, OC pesticides, and PBDEs) were also analyzed in 2010, with no SQG exceedences for any of them. Overall, sediment chemistry data indicated that effects on the seafloor were primarily limited to within, but also outside, the stations 200 m east of the diffuser. A complete assessment of the results of SQG exceedences requires additional follow-up and confirmatory measures such as assessing the health of the biological communities living within the sediments.

Overall, 2010 results indicated demonstrable impacts of the outfall on sediment chemistry, as consistent with previous years. Recent reviews indicated that conditions are not deteriorating over time. However, because there were SQG exceedences, the 2010 data indicate that there is potential for the biological communities to be affected by substances in sediments, especially at stations within 200 m of the Macaulay Point outfall. As such, a detailed analysis of the benthic community at the Macaulay Point outfall was undertaken to assess if the sediment chemistry concentrations were linked to any observed effects in the biological communities.

Benthic Communities

A comprehensive multi-year trend assessment including the 2010 benthic community data indicated potential declining environmental conditions around the Macaulay Point outfall. Conclusions made in past assessments require revision because true changes are now occurring in the biological assemblages. The 2010 benthic community assessment indicates that broad spatial trends and summary metrics are similar to recent years. However, the more detailed analysis of the 1994 to 2010 data identified a number of significant changes in recent years relative to earlier in the 2000s. The most significant changes near the outfall included a lower total organism abundance, a modified benthic community with fewer types of species and lower numbers of individuals, reduced biological diversity that now extends beyond the IDZ (and in some cases beyond the near-field stations), a decreased abundance of sensitive species, and an increase in abundance of pollution-tolerant species. Although several species showed modestly increased growth likely due to increased organics at the mid-field distances from the outfall, there are fewer species showing strong growth responses to outfall-related exposures than in previous years.

In 2010 the benthic community data at the outfall terminus station were indicative of a “highly degraded” benthic community. Taxa richness at the outfall terminus has changed since the first comprehensive assessment was undertaken in 1994. From 1994 to 2008 taxa richness approximately doubled, but declined between 2008 and 2010. The 2010 assessment of the benthic community is also a change relative to 2008 and previous years, when a conclusion of a “moderately degraded” benthic community was reached. The near-field stations are now ranked as a “moderately degraded” benthic community, while the mid-field stations show a small negative response. Abundance of bivalves, gastropods, and some other taxa shows an increasing trend with distance from the outfall, indicative of a potential impairment to the functional status of communities near the outfall. Beyond the mid-field, impacts were considered to be net-neutral or positive. Patterns of total organic carbon and substrate composition can partially explain benthic community variation around the outfalls, but these variables alone cannot fully explain the patterns observed in 2010 and other recent years. Changes to benthic community structure could be caused by increased nutrients, cumulative effects, or new chemicals with undocumented effects.

The CRD will continue to monitor the Macaulay Point benthic community conditions around the outfall to assess trends over time.

Clover Point

Sediment Chemistry

At the Clover Point outfall terminus station, copper, mercury, acenaphthene, and bis(2-ethylhexyl) phthalate exceeded SQGs. In comparison, there were no exceedences at the reference station. In 2010 sediment samples were collected from the outfall station (C0) and the reference station CB1, and were analyzed for a full list of priority substances. Sediment chemistry data were compared to the same SQGs as for Macaulay Point.

Overall, the 2010 sediment chemistry data indicated that there was potential for the biological communities adjacent to the Clover Point outfall to be affected by contaminants in sediments due to SQG exceedences. As such, a detailed analysis of the mussel community at the Clover Point outfall was undertaken to assess if the sediment chemistry concentrations were linked to any observed effects in the biological communities.

Mussel Communities

Mussel mean lengths and weights for 2010 were greater at the majority of stations relative to the reference stations (i.e. increased growth). Mean ages for the outfall monitoring stations were similar to the reference stations, as were mean mussel ages in the near-field and far-field station groupings. No statistically significant negative relationships were identified between gonad index and reproductive timing index and either depth or distance from the outfall. Overall, the 2010 biological data revealed no discernible effect on a variety of routine/standard indicators in the mussel communities.

The CRD undertook a detailed assessment of the 2000 to 2010 mussel dataset. Results of the mussel community size, age and reproductive status over the period of the study indicate that the impacts of the Clover Point outfall appear stable over time and space.

Tissue Chemistry

In 2010 mussel tissue from all stations was analyzed for total metals, chlorinated hydrocarbons, semi-volatile organics, chlorinated phenolics, phthalate esters and PAHs. Seventeen of the 27 station composite samples were also analyzed for polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans. The metals that were detected in 2010 were found at similar concentrations to previous years. Average copper and lead concentrations were significantly higher near the outfall as compared to the reference area. There was also a significant difference between the concentrations of copper in the far-field in comparison with reference. This indicates that the outfall is one source of these metals in this area. Aluminum, iron, mercury, and nickel concentrations exhibited a reverse gradient (i.e., higher concentrations further away from the outfall). These results were similar to previous years and may be partly attributed to growth dilution (i.e., when tissue weight increases more rapidly than the rate of uptake of a particular substance and is usually the result of enhanced food availability). Other factors (e.g., physiological or seasonal) could also be contributing to the concentrations of substances in mussels.

Lead and zinc concentrations were lower in mussel tissue than relevant tissue effects threshold levels for the protection of wildlife and consumers of mussels. Copper levels were slightly elevated relative to tissue effects threshold levels in two samples at stations C0 and C1E. Concentrations of most organic substances were either below routine analytical detection limits or were rarely detected. All 2010 PAH concentrations were substantially lower than lethal- or sublethal-effects threshold concentrations. Overall, a comparison of the 2010 monitoring data to tissue benchmarks suggests that there is limited potential for adverse effects to the resident mussel communities or to higher trophic level organisms as a result of eating the mussels and the bioaccumulation and/or biomagnification of substances.

The detailed assessment of the 2000 to 2010 mussel dataset determined that mussel tissue chemistry has been relatively consistent over the period of study and, as a result, significant ecological harm is unlikely to occur in the near future, based on the current discharge regime.

ADDITIONAL INVESTIGATIONS

Additional investigations are important elements of the WMEP and are conducted to address specific questions or issues that pertain to the WMEP, to clarify aspects of the program and to provide concurrent data for the assessment of environmental effects. Some additional investigations are also requirements under the Core Area LWMP approval. Studies undertaken as part of the additional investigations component of the WMEP are recommended and reviewed by the MMAG on a regular basis. The following additional investigations were underway and/or completed in 2010:

- supplementing the high resolution chemical and PPCP analyses from previous years
- continuation of the collaborative study on the presence of PPCPs in wastewater and potential environmental effects on biological communities with the University of Victoria (UVic) (Royal Roads University was brought in as a collaborative partner in 2010)
- continuation of the collaborative project on potential toxicogenomic effects in marine fish of emerging chemicals in municipal wastewater with Environment Canada
- continuation of analysis of sediment core samples in collaboration with Fisheries and Oceans Canada and UVic, including the addition of complementary benthic invertebrate samples
- completion of a detailed PAH fingerprinting analysis in sediment and wastewater samples
- continuation of a collaborative project on potential mussel biomarker effects in mussels of municipal wastewater with Environment Canada

Macaulay and Clover Points Additional Investigations: High-Resolution Analyses

High resolution analyses were supplemented in 2010 with the analyses of methylmercury and tributyltin in wastewaters. Tributyltin levels exceeded Canadian interim and BC WQGs. Methylmercury concentrations were all well below relevant WQGs. Both methylmercury and tributyltin analyses in wastewater will be shifted to the routine WMEP to allow for long-term monitoring of concentrations, environmental loadings and potential for environmental toxicity.

Collaborative Study on Pharmaceuticals, Personal Care Products and Emerging Chemicals in Wastewater

The CRD initiated a collaborative research project with UVic in 2004 to assess pharmaceutical and personal care product (PPCP) concentrations in Macaulay and Clover point wastewaters. This type of investigation was included in the requirements of the LWMP approval. Staff collected additional PPCP characterization samples in November 2009 at Macaulay and Clover point outfalls and two upstream pump stations. In 2010 analyses of both sets of results were undertaken both by UVic and a new collaborative partner: Royal Roads University (RRU). UVic and RRU analyzed the samples.

For the November 2009 results, the UVic assessment determined that there were no differences in overall concentration profiles for the four sampling sites. However, differences in concentrations between sampling days were identified, likely due to variations in wastewater flow volumes following a rain event. Concentrations were compared to those of conventional wastewater parameters typically used to characterize bulk loading parameters of wastewater and determine treatment plant capacity requirements. Relatively few target analyte concentrations correlated with those of the conventional wastewater parameters, suggesting that designing treatment plants to efficiently reduce conventional parameter loadings may not lead to optimal reductions in the concentrations of all PPCPs assessed in this study.

A preliminary relative loading assessment confirmed that the target analyte concentrations were generally proportional to the “population equivalents” of a wastewater system catchment area. Population equivalents represent the base census population of an area plus estimates of additional population based on the amount of industrial, commercial and institutional land use in the area. Minor proportional deviations were observed and could have been a result of disproportional hospital loading inputs into one of the pump station catchment areas, as well as dilution due to wastewater system inflow and infiltration in the other pump station catchment area.

The RRU study was sponsored by the CRD Regional Source Control program. The study predicted partitioning and degradation behaviour of PPCPs following secondary treatment, as is planned for the core area. The assessment included a ranking matrix to determine which of the 125 PPCPs pose the greatest environmental risk from a biosolids land application perspective. The ranking matrix included assessments of various PPCP properties and, as a result, a PPCP top 10 priority list was generated. Six of the ten substances were antibiotic in nature, two were non-medicinal antibiotic bacteriostats, and one of each of the following types of medications were identified: analgesic, anti-anxiety, anti-lipid and diabetic. This report concluded that, even with secondary treatment, it is challenging to reduce all pharmaceuticals simultaneously. Source control (e.g. public education on proper pharmaceutical disposal) and secondary treatment could be of value in removing at least some PPCPs from the wastewater stream.

The 2005 University of Victoria collaborative project consists of two components.

1. Assessment of PPCPs in wastewater and the potential environmental and ecological relevance of the results, as well as the determination of potential correlations with prescription rates and demographic data

Wastewater samples from Macaulay and Clover points were collected from 2004 to 2006. Samples were analyzed for a select group of seven PPCP, chosen because of analytical constraints at the time. Concentrations and environmental loadings were compared to demographic and prescription data from the CRD outfall catchment areas to determine whether they could be used together as predictors of future PPCP concentrations. The environmental relevance of any observed pharmaceuticals relative to concentrations or effects data presented in the literature was also to be assessed.

Concentrations and environmental loadings of the seven pharmaceuticals were within the ranges observed by other jurisdictions, both in comparison to jurisdictions with wastewaters treated to the same level as well as those receiving more advanced treatment. Seasonal patterns were also observed, primarily driven by wastewater flow volume increases following heavy rain events. There did not appear to be any potential for acute effects of these pharmaceuticals in the environment around the outfalls. There did appear to be some potential for chronic effects on organisms based on the environmental concentrations predicted for ibuprofen. Wastewater concentrations and loadings were proportional to both prescription rates and population size, but the relationships were statistically weak or insignificant. As such, prescription rates and population size could not be used to accurately predict pharmaceutical wastewater concentrations and loadings on their own. Wastewater flow volumes, derived population equivalents and analytical method variability were also important factors to consider. No relationships were observed between wastewater PPCP concentrations and loadings and either population age or gender breakdown. This component of the project is now considered complete.

2. Analysis of potential toxicogenomic effects on mussels

Phase three of this Clover Point study was initiated in 2009 to verify earlier phases of this mRNA abundance profiling study by repeating the experiments using archived mussels collected from a greater number of stations. Several biological and chemical indicators of *Modiolus modiolus* health across 15 sampling sites organized into five geospatial groupings were assessed. Comparisons of tissue chemical contaminant concentrations with biological endpoints in animals located at the Clover Point outfall were explored to assess if any relationship existed between pollutant exposure and changes in *M. modiolus* biology.

Results suggest that potential biological effects extend further from the outfall than is apparent from gross mussel size metrics and the chemical concentrations detected within the *Modiolus* tissues. The concentrations of PAHs appear to have a minimal relationship to the mRNA transcript pattern whereas correlations were observed between some of the metals and mRNA transcripts and a strong negative correlation was observed with bis(2-ethylhexyl) phthalate and three mRNAs. The importance of this relationship is currently unclear, but it highlights the need for evaluating other emerging chemicals such as personal care products and pharmaceuticals. It is currently unknown if these relationships are causal, but their findings suggest that altered mRNA abundance patterns within the mussel transcriptome are a result of bioactive anthropogenic agents originating from the outfall. The chemicals responsible for the

effects are currently not known, but the expression pattern suggests dispersion around the outfall of substances that may accumulate in the south/south-easterly direction. Results require further research to confirm, but do reveal that effluent is altering the physiology of mussels, and that mussels may be more sensitive to diluted sewage than previously thought.

The future direction of this project is currently under review.

Collaborative Program on Potential Effects of Emerging Chemicals from Municipal Wastewaters

The CRD WMEP and Environment Canada's Pacific Environmental Science Centre initiated a collaborative study in 2004 to determine the potential toxicogenomic effects of wastewater on marine fish. This type of investigation was included as part of the requirements of the LWMP approval. As part of this study, effluent samples from the Macaulay and Clover points outfalls were collected on a regular basis from 2004 to 2006 and marine fish species were exposed to different environmentally relevant concentrations. The overall objective of the study was to determine if these exposures cause changes in gene expression using a gene chip array and other toxicogenomic tools.

The research used microarrays and other genomic tools to evaluate the effects of the sewage on liver gene expression in exposed juvenile Chinook salmon (*Oncorhynchus tshawytscha*), particularly with respect to xenoestrogens. Examination of genetic males and females indicated very few significant differences in the expression of female-specific genes between the sexes, indicating that gene expression alterations caused by sewage were unrelated to genetic sex in the underyearling fish. Gene expression patterns were examined for trends across time and sewage concentrations. All concentrations of sewage examined caused gene expression alterations, including the very low environmentally relevant concentrations. The environmental relevance of these results is still being assessed, and will be reported on at a later date.

Sediment Core Analyses

Sediment chemistry data collected as part of the WMEP have shown some variations from year to year. Variations in the measured surface concentration of a contaminant may not only reflect variations in the source: the local rates of sedimentation and mixing also affect the observed surface concentration. As such, collecting only surface sediment can potentially be misleading. A sediment core study was recommended as part of the additional investigations prioritized by the MMAG. Sediment cores record past contamination history, and rates of sediment accumulation and mixing can be interpreted from them.

The CRD initiated a sediment core study in 2006 in collaboration with Fisheries and Oceans Canada, Institute of Ocean Sciences (IOS), when three sediment cores were collected. Additional sediment cores were collected in 2010 for further analyses of individual PBDE and PCB congeners, and carbon:nitrogen ratios. In addition, benthic invertebrate tissue samples were collected for comparison. All results will be assessed as part of an expanded collaborative study that includes the DFO, UVic and Metro Vancouver. Results will be included in a future annual report.

PAH Fingerprinting Analyses

WMEP observations have shown high variability in PAH results in Macaulay Point sediment samples for a number of years. One suspected source of the variability was coal contamination from a nearby sunken collier, the SS San Pedro, which sank in 1891. Previous annual reports presented detailed results of a study begun in 2007. Additional assessments of the alkyl PAHs—a minor component of the total PAH sediment profiles—were undertaken in 2009/2010 to better quantify the contribution of the alkyl substituted PAHs from the coal to the sediments. A comprehensive suite of resolved and UCM (unresolved complex mixture) alkanes, tricyclic terpane, hopane and sterane biomarkers, and parent and alkyl polycyclic aromatic hydrocarbons (PAHs) in samples of coal, wastewater and sediments were analyzed. Results confirm that coal from the collier does not make a dominant contribution to any sediment sample. Overall, results suggest that PAHs in Macaulay and Clover Point sediments have predominant sources in wood combustion, coal and possibly coke, with a likelihood of much lower bioavailability than would be expected from wastewater dominated by oils and soot from vehicle combustion.

This project is now considered complete. A peer-reviewed paper on this project will be published by Organic Geochemistry in 2012.

Mussel Biomarker Assessment

Mussels were collected from Clover Point in September 2007 for the toxicogenomic method validation described above. Additional tissue types were collected from the same mussels and sent to the Aquatic Ecosystem Protection Research group of Environment Canada in Montréal. It was anticipated that these biopsy samples would be analyzed for a number of biomarker endpoints and that the results would be directly comparable to the University of Victoria toxicogenomic results. These analyses have been put on hold until further review of the UVic toxicogenomic results has taken place.

Investigations Planned for 2011

No new additional investigations or studies are planned for 2011. Studies that will be continuing include:

- Supplementing the high resolution chemical and PPCP analyses from previous years.
- Two collaborative projects on potential toxicogenomic effects of emerging chemicals in municipal wastewater with Environment Canada & UVic.
- The collaborative project on analysis of sediment core and benthic invertebrate tissue samples with Fisheries and Oceans Canada, the University of Victoria and Metro Vancouver.
- The collaborative project on potential mussel biomarker effects of municipal wastewater with Environment Canada.

Additional details on these investigations and results will be presented in future WMEP annual reports as they become available.

OVERALL CONCLUSIONS

Results of wastewater monitoring showed that some substances were above water quality guidelines in undiluted wastewater, but all guidelines were met once the minimum dilution factor was applied. Both the Clover and Macaulay plumes were predominantly trapped at depth, with occasional surfacing events occurring mostly in winter. The likelihood for human exposure to pathogens that have reached the marine environment via wastewater was low at both outfalls. Seafloor monitoring showed that some chemicals exceeded sediment quality guidelines around the Macaulay and Clover outfalls. Benthic invertebrate community health showed a significant decline relative to recent years, and is now classified as “highly degraded” at the Macaulay Point outfall terminus station, and “moderately degraded” within 200 m of the outfall. The reason for this decline is not known, but it may reflect population growth in the greater Victoria area, cumulative effects of all contaminants in wastewater, and/or the release of new chemicals. The health of mussel communities at the Clover Point outfall did not change in 2010 relative to recent years.

WASTEWATER AND MARINE ENVIRONMENT PROGRAM SAMPLING DESIGN CHANGES

CRD and BC Ministry of Environment staff have recently completed a review of the WMEP sampling program design, in light of comments and concerns raised in a number of previous program reviews (e.g. the Society for Environmental Toxicology and Chemistry review in 2006 and in ongoing Marine Monitoring Advisory Group reviews). As a result of the staff review, substantial changes to the WMEP will be implemented in 2011 to address these previous comments and concerns. In short, the WMEP will shift from an annual monitoring program to one based on a five-year cycle. A number of new monitoring endpoints will be added, which will be balanced by a reduction in sampling frequency and the number of stations. This will be the last year in which an “annual” report will be generated. In future years, there will be annual “update” reports, with an overall final report summarizing the results of the entire five-year cycle.

Macauley and Clover Points

Wastewater and Marine Environment Program

Capital Regional District | 2010



CRD

Making a difference...together

CRD Marine Programs

Wastewater and Marine Environment Program (WMEP) scientists, within the CRD's Environmental Protection division, monitor and assess the potential effects of discharges from CRD sewer systems to ensure the ocean environment and public health are safe today and into the future, and to meet regulatory requirements set out by the British Columbia Ministry of Environment (MOE).

Marine Program scientists, along with external support and advice, have studied the Macaulay and Clover Points outfalls since the late 1980s. They analyze the wastewater prior to discharge, and then both the seawater and seafloor near each outfall. Since 2000, they have added more detailed monitoring and data analysis following recommendations made by the Marine Monitoring Advisory Group (MMAG).

The MMAG is a voluntary advisory group of scientists from government and academia, with expertise in marine sciences, that has provided an independent review of the Marine Program sampling design and results since 1987.

Marine Programs also supports the CRD Regional Source Control Program (RSCP) by providing information about pollutants entering the environment. The RSCP uses this information to develop programs to minimize substances of concern from entering the sewer system, and ultimately the marine environment.

The WMEP Annual Report presents the monitoring results and scientific investigations conducted each year. This brochure summarizes the results of the 2010 WMEP monitoring efforts. A glossary of terms and abbreviations used in this brochure can be found on pages 16-17.

CRD and MOE staffs completed a collaborative and comprehensive review of the WMEP sampling design. As a result of this review, new monitoring components have been added. These additions have been balanced by a reduction in sampling frequency for some monitoring components, along with a reduction in the number of routine sampling stations. This revised WMEP is based on a five year cycle and was implemented in April 2011. Future reporting will no longer be on an annual basis, and this will be the last year for a comprehensive "annual" report until 2016. Data update reports will continue to be created annually, while comprehensive reports will only be completed at the end of each five year monitoring cycle.

The 2010 WMEP annual report can be found online at:
<http://www.crd.bc.ca/wastewater/marine/reports.htm>

Guidelines

The CRD uses accredited laboratories and follows established scientific protocols for sampling. This includes taking duplicate and triplicate samples to confirm sample validity. Their work meets guidelines established by the BC and Canadian governments and the U.S. Environmental Protection Agency.

Scientific standards

The annual monitoring and assessment follow a rigorous quality assurance and quality control regime both in the field and in the laboratory. For example, the CRD uses established scientific protocols for sampling, such as taking triplicate samples, to confirm accuracy. Their work meets guidelines established by the BC and Canadian governments and the US Environmental Protection Agency (EPA).

The WMEP is regularly reviewed and updated to reflect current science and knowledge. For example, the CRD retained the Society for Environmental Toxicology and Chemistry (SETAC) in 2006 to review the Core Area Liquid Waste Management Plan (LWMP). The panel found that the monitoring work being conducted is generally sound and consistent with best practices in other jurisdictions.

The SETAC report can be found online at:

<http://www.crd.bc.ca/wastewater/reviewpanel.htm>

The Ministry of Environment also reviews WMEP and the recent CRD/MOE review completed in 2010, and implemented in 2011, incorporates comments and recommendations raised in previous reviews, as well as current knowledge and understanding of the marine environment.

The MMAG also reviews all of the conclusions, and independent experts are often invited to conduct their own detailed analyses or to review the CRD data. In some cases, CRD scientists publish their findings in peer-reviewed scientific journals.

Moving Ahead with Advanced Treatment

In July 2006, the CRD received a letter from the BC Minister of Environment requesting that a detailed schedule for increasing the level of sewage treatment at Macaulay and Clover Points be provided. Treatment is mandated to be in place by 2016. Liquid Waste Management Plan amendment #7 was submitted to MOE in December 2009 with a follow up amendment #8 in June 2010. The current plans indicate a treatment plant will be built in a new location, and the Macaulay and Clover Points plants will only be used as pumpstations to the new facility and for overflow discharges during severe weather. The main focus of the marine monitoring program will be reviewed once this plan has been implemented, but the recent CRD/MOE program review included consideration of the move towards advanced treatment.



“The CRD’s marine monitoring program is one of the more comprehensive programs being implemented to evaluate the effects of sewage in marine environments.”

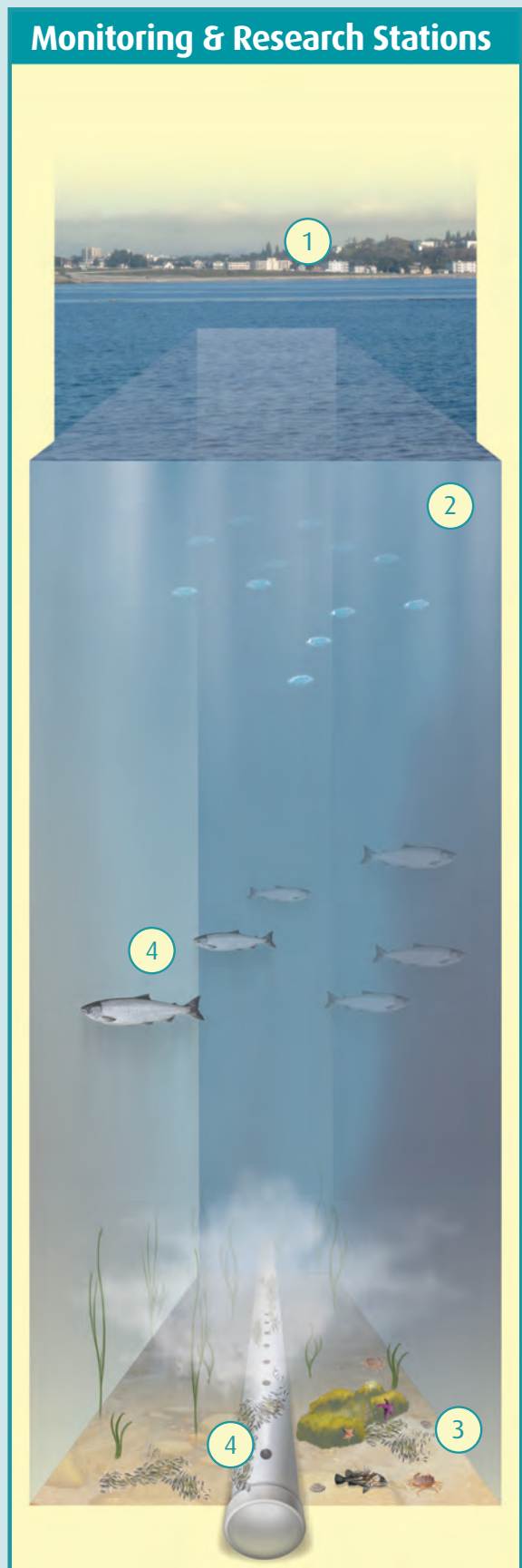
- SETAC Panel Report

What We Do

Monitoring and Research for the Macaulay and Clover Point outfalls includes:

- 1 Monitoring wastewater**
monthly for a list of substances including metals and priority substances before discharge into the marine environment and daily measurement of flows to make sure they do not exceed permitted levels. See page 5 for more details.
- 2 Monitoring surface water**
for fecal coliforms (an indicator of potential human exposure to wastewater) every month near the outfalls. See page 7 for more details.
- 3 Monitoring the seafloor**
and organisms living near each outfall every year. See page 9 for more details.
- 4 Conducting collaborative research projects**
such as estimating the proportion of persistent contaminants from wastewater dispersed far from the site versus the proportion that settle near the outfall. See page 13 for more details.

As well as assessing potential environmental and public health effects, this detailed scientific monitoring and analysis provides information to the CRD Regional Source Control Program, and scientific guidance to managers involved in the disposal of municipal wastewater.



Monitoring Wastewater

In 2010 WMEP monitored for over 170 substances in wastewater. This included measures of general wastewater quality, referred to as conventional parameters, such as fats, oil and grease, biochemical oxygen demand (BOD) and total suspended solids (TSS). Chemicals on a list of priority substances were also analyzed. These substances were selected from a list of priority chemicals originally identified by the EPA because they pose the most risk to the environment. Priority chemicals are part of many commonly used items and include metals, pesticides, hydrocarbons and others.

While Marine Programs scientists monitor for all of the substances on a priority list, they only expect to find a small percentage of them. Some substances that are detected may occur naturally, while others are produced by residents, businesses and industry. Others, such as DDTs and PCBs, were banned decades ago but continue to cycle in the environment worldwide because they do not readily break down. Many of the substances detected are found in wastewaters from any treatment plant, including those with secondary or tertiary treatment.

Findings in 2010

Substances that were detected frequently in 2010 included conventional parameters, metals, some PAHs, phthalates and phenols. Concentrations of these compounds in the ocean were predicted using dilution factors from a custom oceanographic computer model and then compared to BC Water Quality Guidelines (WQGs). Results were all below WQGs after the predicted environmental dilution was taken into account, with most concentrations below guidelines even in undiluted wastewater.



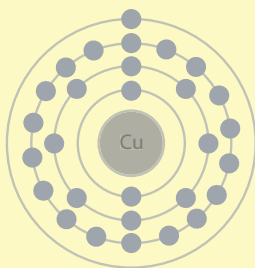
“There were 170+ substances analyzed in both discharges and more than half of these substances were never detected in 2010”

- 2010 Annual Report

General results for the eight main categories of priority substances measured in wastewater

Metals

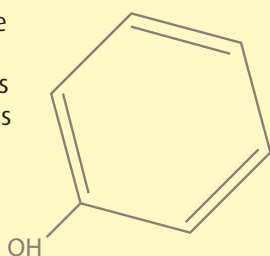
Tests have found that the concentrations of most metals of environmental concern have decreased over time in the Macaulay and Clover wastewaters.



Copper

Phenols

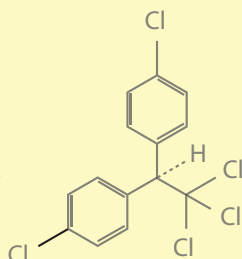
In general, there have been no observed increases or decreases of phenolic substances since 1990.



Phenol

Organochlorine Pesticides

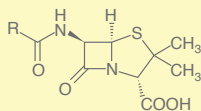
Organochlorine pesticides, such as DDT, are substances that are no longer used. However, they are still found at very low levels in the environment in water, air and soil. Levels in CRD wastewaters are consistently detectable, but low.



DDT

PPCPs (Pharmaceuticals and Personal Care Products)

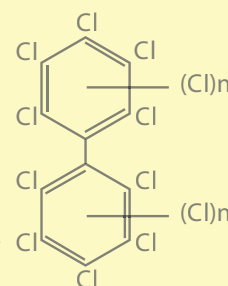
The fate and potential environmental effects of PPCPs are not yet fully understood. Studies have been done to characterize PPCP concentrations in CRD wastewaters and concentrations are similar to other jurisdictions. Effects assessment studies are ongoing.



Penicillin

PCBs (Polychlorinated Biphenyls)

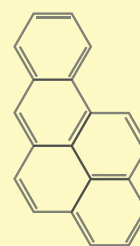
PCBs have been banned in North America since the 1970s. However, similar to organochlorine pesticides, they are still found at very low levels in the environment. Levels in CRD wastewaters are consistently detectable, but low.



PCBs

PAHs (Polycyclic Aromatic Hydrocarbons)

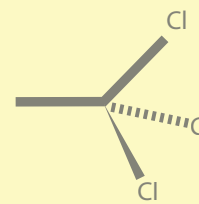
PAHs are consistently detected in wastewater, with the levels of some compounds increasing over time. As such, these compounds have been targeted by the RSCP to help reduce them at their source.



Benzo-a-pyrene

VOCs (Volatile and Semi-volatile Organics)

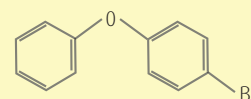
This category contains a range of compounds including solvents. While the majority of these have not been detected since 2005, there have been slight increases in a few VOCs since 1990. The RSCP is investigating potential source control options.



Trichloroethane

PBDEs (Polybrominated Diphenyl Ethers)

Flame retardants (PBDE) monitoring has only been undertaken in CRD wastewaters for a relatively limited period of time. Results are detectable, but are at levels that present negligible potential for ecological risks.



Bromophenyl Phenyl Ether

Monitoring surface waters

As well as monitoring wastewater, WMEP staff collect samples of surface water and evaluate them to ensure that the potential for human exposure to wastewater in the marine environment is low. The samples are collected by rapidly submerging sterile bottles to a depth of one metre, and testing for fecal coliform bacteria.

Findings in 2010

In 2010, monthly monitoring showed a small number of high fecal coliform concentrations in the winter, but average winter values were below water quality guidelines (WQGs), indicating that the overall risk to human health in winter is low. Winter sampling represents worst-case conditions, and is at a time when fewer people are likely to be using the water for recreational use. Summer conditions reflect the period when people are most likely to be in contact with surface water. The CRD undertook additional sampling in the summer of 2010 to collect 5 samples in 30 days, as per recommendations by the MMAG and MOE and for direct comparison to WQGs. Average concentrations of these sampling events were well below the WQGs, indicating that the risk to human health in summer is very low.

“The 2010 surface water fecal coliform results indicated that the risk to human health from the wastewater outfalls was low”

- 2010 Annual Report



Some Facts

The Macaulay and Clover Points long outfalls, in use since the early 1970s, discharge in deep water offshore.

At both outfalls, the wastewater currently passes through screens that remove solid objects larger than a thumbtack. These solids are taken to the Hartland Landfill. The remaining wastewater is jetted out through specially designed outfalls at least 60 metres below the surface. It mixes quickly with seawater and is dispersed by the strong tidal currents in Juan de Fuca Strait.

Plans are currently underway to provide advanced wastewater treatment for Greater Victoria.

The Macaulay Point Outfall

Average flow rate in 2010	45,112 m ³ /day
Distance from shoreline	1.7 km
Depth	60 m
Pipe diameter	0.91 m
Diffuser length	135 m
Number of operating diffuser ports	28

About the Reference Stations

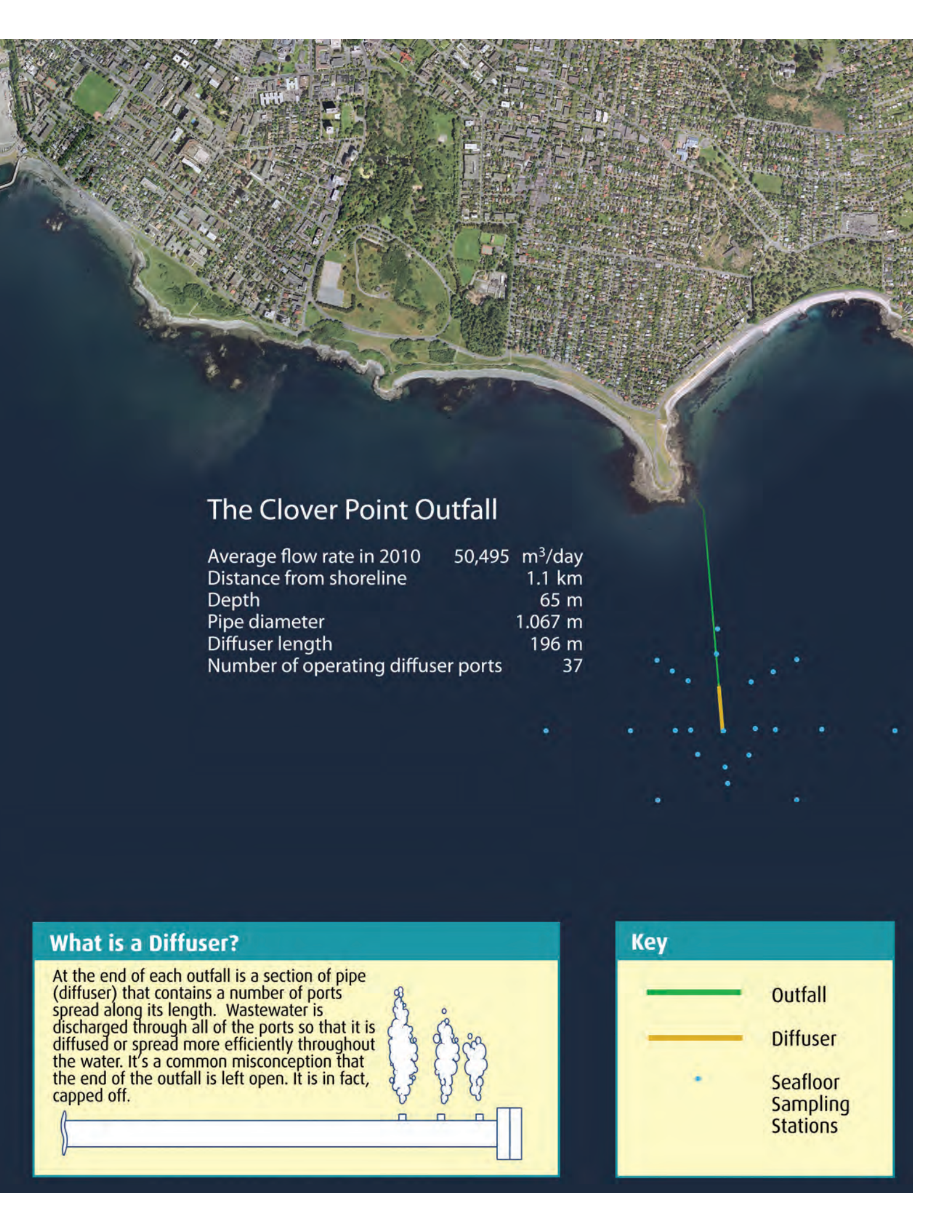
The CRD monitors areas immediately around the outfalls as well as reference stations further away.

The reference stations, situated well outside the areas of influence of the outfalls, have similar physical characteristics (e.g. depth, type of sea floor, sea life) to the outfall sampling stations and provide areas to compare observations and assess effects.

Reference stations for the Macaulay Point outfall are situated in Parry Bay.

Reference stations for the Clover Point outfall are situated at Constance Bank.



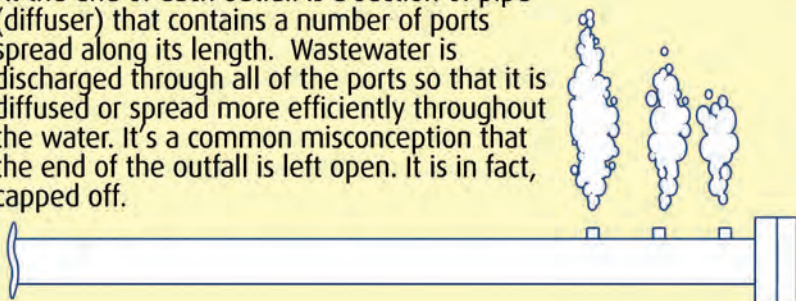
An aerial photograph of a coastal area with a dense residential neighborhood. A green line representing the outfall pipe extends from the shore into the ocean. At the end of the pipe, a yellow section represents the diffuser, with numerous blue dots indicating seafloor sampling stations.

The Clover Point Outfall

Average flow rate in 2010	50,495 m ³ /day
Distance from shoreline	1.1 km
Depth	65 m
Pipe diameter	1.067 m
Diffuser length	196 m
Number of operating diffuser ports	37

What is a Diffuser?

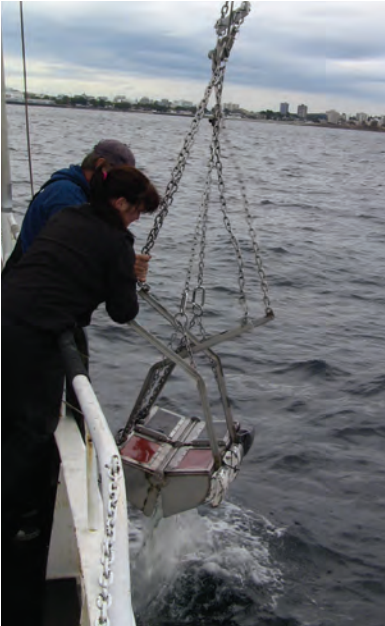
At the end of each outfall is a section of pipe (diffuser) that contains a number of ports spread along its length. Wastewater is discharged through all of the ports so that it is diffused or spread more efficiently throughout the water. It's a common misconception that the end of the outfall is left open. It is in fact, capped off.



Key

-  Outfall
-  Diffuser
-  Seafloor Sampling Stations

Monitoring the seafloor



“Benthic invertebrate community assessment indicate that conditions around the Macaulay Point outfall have declined significantly relative to the early to mid-2000s”

- 2010 Annual Report

Wastewater from Macaulay and Clover Points is discharged into the ocean through pipes on the seafloor with multiple discharge ports (diffusers). The wastewater mixes quickly with seawater and is dispersed by strong tidal currents. However, recent estimates indicate approximately 1% of the material settles to the bottom of the ocean. For this reason WMEP scientists monitor sediment quality within approximately 800 metres of both outfalls and at reference (comparison) stations five to 12 kilometres away.

In addition, there is a regular assessment of the health of organisms such as deep-sea horse mussels at Clover Point (where the seafloor is rocky) and benthic organisms such as shrimp, molluscs and sea worms in the sediment at Macaulay Point (where the seafloor is sandy or muddy).

Researchers use an apparatus called a Van Veen grab (see photo to left) to collect sediment and organism samples from the seafloor near the outfalls and the reference (comparison) stations.

Sediment samples are analyzed for priority substances that have the potential to be present in seafloor particles (based on what is measured in wastewater), including many of the metals, phenolic compounds, and PAHs. The results are compared with sediment quality guidelines (SQGs) that have been developed by various government agencies (such as BC Ministry of Environment, Canadian Council of Ministers of the Environment, and Washington State) to protect seafloor organisms.

Findings in 2010

The majority of substances in 2010 sediments were found at levels similar to previous years. Few substances exceeded SQGs, with concentrations above guidelines all limited to within 200 m of Macaulay Point, generally to the east of the diffuser. Regulatory requirements, however, are that SQG exceedences should not occur further than 100 m away from an outfall. Only four substances exceeded guidelines at Clover Point, all immediately at the outfall terminus. Sediment quality guidelines alone can only indicate the potential for effects on seafloor organisms. They are only one line of evidence in estimating risk to the environment. Biological community assessments of organisms actually living at or near the outfalls allow for a more direct assessment of biological effects near the outfalls.

With respect to the benthic community assessments, a detailed analysis of the 1994 to 2010 data from Macaulay Point identified a number of significant changes relative to recent years. In the early to mid-2000s there was a trend of improving benthic community health. However, since 2008, benthic community health has been declining to levels similar to (but not worse than) those observed in the 1990s. There is now a lower total number

of animals near the outfall, and the benthic community structure has changed, with fewer types of species and more pollution-tolerant species. Reduced biological diversity (the number of different species) now extends beyond 100 m from the outfall and in some cases beyond 200 m. In the early to mid-2000s, there were a number of species that exhibited strong positive responses to outfall-related exposures; they benefited from outfall exposure. In recent years, the number of species positively responding to the outfall has decreased.

As a result of these findings, the 2010 data indicate that true changes have been occurring in the biological assemblages adjacent to the Macaulay Point outfall in recent years. The benthic community data for the outfall terminus station are now indicative of a “highly degraded” benthic community for the first time since 2000. Stations within 200 m south-east of the outfall (the “near-field” stations) are now considered “moderately degraded”. Mid-field stations (up to 400 m south-east of the outfall) showed a small negative response, while beyond the mid-field, impacts were considered to be net-neutral or positive. At this point in time it is not possible to confirm the cause of these declines. Concurrent declines in wastewater in sediment chemistry have not been observed. In addition, similar declines have been observed elsewhere in the Strait of Georgia, Puget Sound and Juan de Fuca Strait, suggesting broader environmental shifts (e.g. climate change or natural biological variability) could be occurring. Ongoing monitoring is required.

At Clover Point, the 2010 mussel data were similar to previous years. The mussels near the outfall were larger than those further away or at the reference areas. A detailed trend assessment of the 2000 to 2010 mussel results showed that mussel size, age and reproductive status have remained stable over time and the spatial extent of outfall related impacts has remained constant. Tissue chemistry results showed very low potential for harmful effects adjacent to the outfall.

Overall Conclusions

Overall, 2010 wastewater results were similar to previous years. After accounting for dilution, the levels of substances in the wastewater were below BC and national water quality guidelines. Surface water fecal coliform concentrations were generally low, with some exceptions in the winter, but overall potential for human exposure and health impacts were low. The few exceedences of sediment quality guidelines shown in the sediment chemistry results did not extend beyond 200 m from the outfalls. The benthic community from the last few years at Macaulay Point has indicated a shift towards a more degraded community and the extent of effects has expanded spatially. Mussel communities at Clover Point were healthy, and their condition has remained stable over time and space.

With the exception of the benthic community declines at Macaulay Point, these findings are consistent with previous years’ results, similar to those endorsed by the 2006 SETAC panel report. The revised WMEP will continue to be used to monitor and interpret these results.



Science and Research

Additional Investigations & Conducting Collaborative Research Projects

Marine Programs scientists are also involved in additional research, often in collaboration with universities and government agencies, to address issues related to wastewater and marine environment monitoring and assessment. . Most of these projects address Liquid Waste Management Plan requirements set out by the MOE, while others fill gaps identified by MMAG, SETAC and other program reviewers.

Six investigations were underway or completed in 2010:

1. WMEP has conducted high-resolution chemical analyses in the past. In 2010 these results were supplemented with the analyses of methylmercury and tributyltin in wastewaters. Methylmercury, formed through natural conversion of mercury, and tributyltin, present in anti-fouling paints used by boats, were both assessed because they are particularly toxic to marine organisms. Methylmercury concentrations were well below WQGs, while tributyltin levels exceeded some Canadian interim and BC WQGs. Both of these compounds will now be routinely analyzed in wastewater to monitor long-term trends.
2. The CRD and the University of Victoria initiated a collaborative research project in 2004 to analyze pharmaceuticals and personal care products (PPCPs) in wastewater in samples collected from 2004 to 2006. In 2009 additional samples were collected. Wastewater PPCP concentrations were similar to those observed in other jurisdictions, both in comparison to jurisdictions with wastewaters treated to the same level as well as those receiving more advanced treatment. Seasonal patterns, related to rainfall, were observed. The potential for acute environmental effects was low; the potential for more subtle chronic effects is still being assessed. Detailed prescription rates and population size estimates could not be used to predict PPCP concentrations in the wastewaters, and no relationships were observed between concentrations and population demographics such as age or gender breakdown. Few PPCPs were correlated with conventional parameters in wastewater. In 2010, Royal Roads University (RRU) undertook additional analyses of the 2009 results to assess the potential for environmental impacts if biosolids were to be applied to land. The RRU study



**University
of Victoria**

Department of Biology

CRD Collaborations

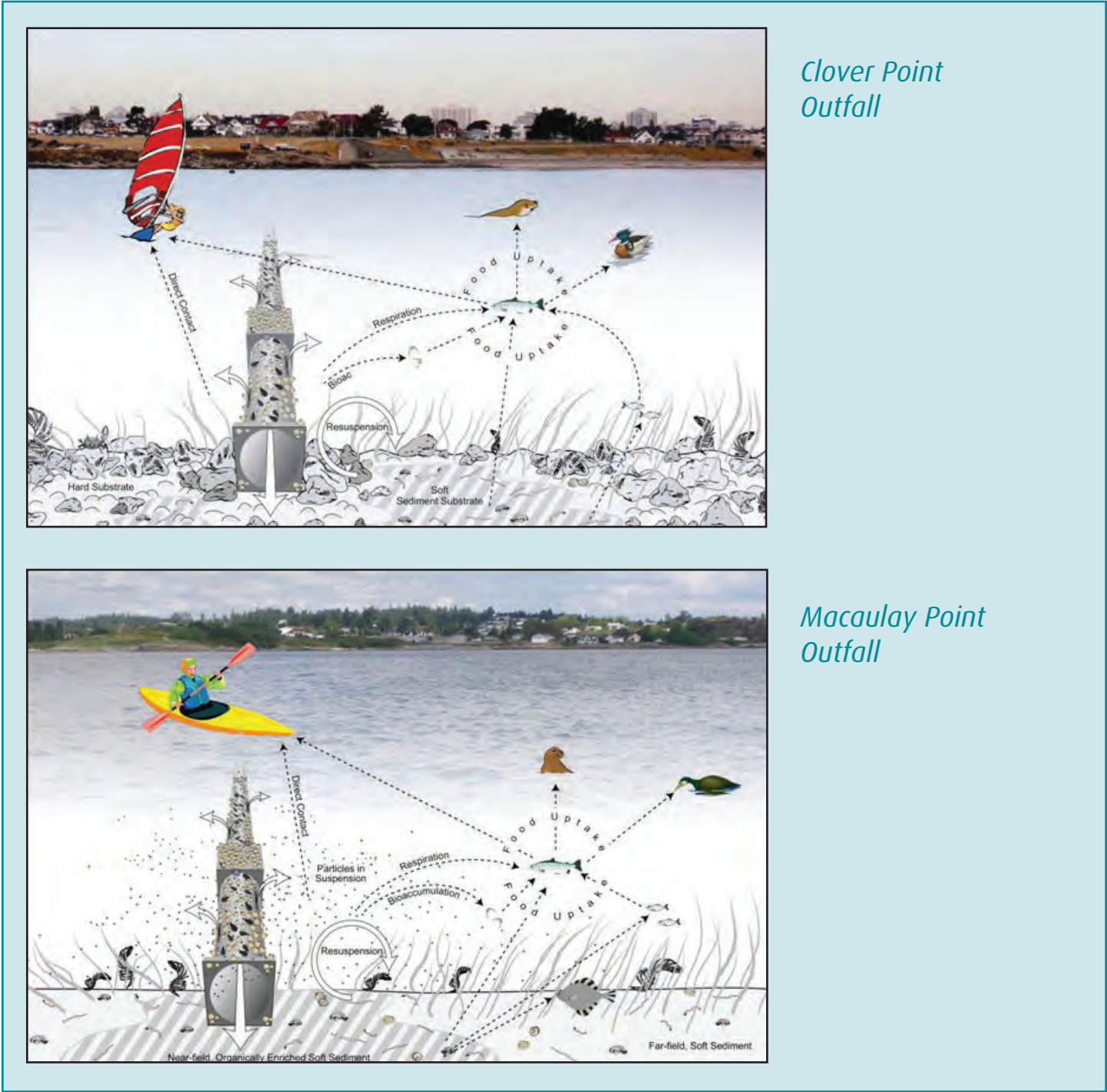
Studies with the University of Victoria and Environment Canada, are measuring pharmaceuticals in wastewater and studying potential effects on fish and mussels.



ranked the PPCPs for their potential environmental impact post-land application and the top 10 PPCPs of concern included antibiotics, analgesics, and anti-lipid medications. In addition, the report concluded that there is likely no easy way to completely eliminate all of the PPCPs found in municipal wastewater, either prior to discharge to the marine environment, or in biosolids prior to land application. The risks to human health were not assessed as part of this project.

3. Numerous collaborative studies have assessed mussels collected from Clover Point. In 2010, phase 3 of a project with the University of Victoria was completed. Results indicated that the potential impacts of the Clover Point outfall follow a different spatial pattern than the impacts detectable by the routine monitoring program. However, causal factors of these impacts could not be identified. The future direction of this project is under review, but could include additional biomarker assessments in collaboration with Environment Canada in Montreal. Results will be presented in a future report.
4. In 2004, a collaborative study between the CRD and the Environment Canada Pacific Environmental Science Centre was initiated to determine potential genetic effects of wastewater on marine fish. As part of this study, effluent samples from the Macaulay and Clover Points outfalls were collected on a regular basis from 2004 to 2006 and marine fish species were exposed to different concentrations. All concentrations of sewage examined caused gene expression alterations in fish. The environmental relevance of these results is still being assessed and results will be available in a future report.
5. A sediment core study that began in September 2006 in collaboration with Fisheries and Oceans Canada continued in 2010 with the University of Victoria and Metro Vancouver. Sedimentation rates and the deposition rates of flame retardants (PBDEs) were calculated using surface sediment samples collected near the Macaulay Point outfall. These results were used to estimate transport in the ocean of particles originating in wastewater. Results showed that 99% of particles from Macaulay Point outfall are dispersed into the wider ocean, with approximately 1% settling in the near-field. Very little of the persistent chemicals in sediment around the CRD outfalls can be accumulated by benthic invertebrates, as they are bound to organic carbon in the sediment and/or pore water.
6. In 2006, a research project to analyze the different types of PAH substances found near the Macaulay and Clover Points outfalls and identify their sources began. The project is now complete, and results confirm that coal from a nearby sunken coal barge is not the main source of PAHs, as previously thought. The PAHs found in sediments around the outfall come from wood combustion, coal and possibly coke. These types of PAHs are less bioavailable than those from oils and soot.

Potential Pathways for Outfall Environmental Effects



Glossary

BOD (Biochemical Oxygen Demand)

The amount of oxygen used by microorganisms in the breakdown or decay of organic matter in a water body.

Fecal coliform

A type of bacterium that comes from the intestines of warm-blooded animals, including humans and ducks. It is used as an indicator of potential for human health effects.

Metals

Includes total and dissolved metals such as aluminum, mercury, silver and zinc that occur naturally, or come from human sources (e.g. mercury from dental offices).

Nutrients

Any inorganic or organic substance needed by plants and animals for nutrition and growth (e.g. nitrogen, phosphorus).

Organic chemicals

Chemicals consisting primarily of carbon that are found in many household products such as cleaning, disinfecting, cosmetic, degreasing and hobby products.

Organochlorine Pesticides

Pesticides such as DDT and mirex that can remain in the environment long after application. Many have been banned because of concerns about environmental impacts and human health.

PPCPs (Pharmaceuticals and Personal Care Products)

Refers, in general, to any products used by individuals for personal health or cosmetic reasons, or used by agribusiness to enhance growth or health of livestock.

Phenolic Compounds

Compounds that occur naturally from the decomposition of aquatic vegetation or that are manufactured and used in disinfectants, biocides, preservatives, dyes, pesticides and medical and industrial products.

PBDEs (Polybrominated Diphenyl Ethers)

Chemicals that are used as flame retardants in a wide array of products including building materials, electronics, furnishings, motor vehicles, airplanes, plastics, polyurethane foams and textiles.

PCBs (Polychlorinated Biphenyls)

Industrial chemicals once widely used in electrical equipment, heat exchangers, hydraulic systems and several other specialized applications. PCBs are now banned in Canada, the US and Europe, but are still found widely in the environment.

PAHs (Polycyclic Aromatic Hydrocarbons)

Substances that occur through incomplete burning of organic substances such as gasoline, wood, tobacco or charbroiled meats, and are also manufactured and used in medicines, dyes, plastics and pesticides.

Priority substances

Substances, such as metals and organic chemicals, that were selected for monitoring based on numerous governmental agency lists of substances of potential concern.

TSS (Total Suspended Solids)

Solids in water that can be trapped by a filter. TSS can include a wide variety of organic and inorganic material, such as silt, and decaying plant and animal matter.

VOCs (Semi Volatile and Volatile Organic Compounds)

Compounds emitted as gasses from a wide array of products, including paints and lacquers, paint strippers, cleaning supplies, pesticides, building materials and furnishings, and glues and adhesives. This group includes compounds such as benzenes, phthalates and others.

Visit us online! For more information about these substances and other compounds, please visit the online glossary at:

<http://www.crd.bc.ca/wastewater/marine/index.htm>



Making a difference...together

Capital Regional District

625 Fisgard Street, PO Box 1000
Victoria, BC, Canada V8W 2S6

250.360.3000

info@crd.bc.ca

www.crd.bc.ca



**MACAULAY AND CLOVER POINTS
WASTEWATER AND MARINE ENVIRONMENT PROGRAM
2010 ANNUAL REPORT**

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Appendix E	Mussel and Benthic Community Monitoring

List of Acronyms and Abbreviations

- 1,4-DCB – 1,4-dichlorobenzene
- 2LAET – second-lowest apparent effects threshold
- 5-in-30 – a set of five sampling events within a 30 day period
- AET – apparent effects threshold
- ANOVA – analysis of variance
- ASTM – American Society for Testing and Materials
- AVS – acid volatile sulphide
- BCMELP – BC Ministry of Environment Land and Parks (now Ministry of Environment)
- BCWQG – BC Water Quality Guidelines
- BEHP – bis(2-ethylhexyl) phthalate
- BOD – biochemical oxygen demand
- BSG – Benthic Services Group
- C0 – Clover Point outfall terminus sampling station
- CB – Constance Bank reference sampling station
- CBOD – carbonaceous biochemical oxygen demand
- CCME – Canadian Council of the Ministers of the Environment
- CF – confidence factor
- CFU – colony forming units
- COD – chemical oxygen demand
- CRD – Capital Regional District
- DFO – Department of Fisheries and Oceans (now Fisheries and Oceans Canada)
- DO – Dissolved oxygen
- DQO – data quality objective
- EDC – endocrine disrupting compound/substance
- FOC – Fisheries and Oceans Canada
- GC-MS – Gas Chromatography-Mass Spectrometry
- IDZ – initial dilution zone
- IOS – Institute of Ocean Sciences (FOC)
- ISQG – Interim Sediment Quality Guideline
- ITI – Infaunal Trophic Index
- LAET – lowest apparent effects thresholds
- LC-MS – Liquid Chromatography-Mass Spectrometry
- LWMP – Liquid Waste Management plan
- M0 – Macaulay Point outfall terminus sampling station
- MMAG – Marine Monitoring Advisory group
- MoE – Ministry of Environment
- MWLAP – Ministry of Water, Land and Air Protection (now Ministry of Environment)
- NMDS – non-metric multidimensional scaling
- ND – non-detected
- NP – nonylphenol
- NSERC – National Scientific and Environment Research Council
- OC – organic carbon
- PA – polychaete abundance
- PAH – polycyclic aromatic hydrocarbon
- PB – Parry Bay reference sampling station
- PBDE – polybrominated diphenyl ether
- PBS – Pacific Biological Station (FOC)
- PCA – principle components analysis
- PCB – polychlorinated biphenyl
- PCR – polymerase chain reaction
- PEL – probable effects level

List of Acronyms and Abbreviations *continued*

- PESC – Pacific Environmental Science Centre (Environment Canada)
- POP – persistent organic pollutant
- PPCP – pharmaceuticals and personal care products
- PSAMP – Puget Sound Ambient Monitoring program
- QA/QC – quality assurance/quality control
- QPCR – quantitative polymerase chain reaction
- RSCP – Regional Source Control program
- RSD – Relative Standard Deviation
- ROV – remotely operated vehicle
- SCADA – Supervisory Control and Data Acquisition
- SDI – Swartz dominance index
- SEDQCSCS – sediment quality criteria-sensitive contaminated sites
- SEDQCTCS – sediment quality criteria-typical contaminated sites
- SEM – simultaneous extracted metals
- SETAC – Society of Environmental Toxicology and Chemistry
- SOI – substance of interest
- SQG – sediment quality guideline
- SRM – spiked reference material
- TA – total abundance
- TBOD – total biochemical oxygen demand
- TEF – toxic equivalent factor
- TEQ – toxic equivalent quotient
- TKN – total Kjeldahl nitrogen
- TOC – total organic carbon
- TR – taxa richness
- TRV – toxicity reference value
- TSS – total suspended solids
- USEPA – US Environmental Protection Agency
- UVic – University of Victoria
- VOC – volatile organic compound
- WMEP – Wastewater and Marine Environment program
- WQG – water quality guideline
- WSDOE – Washington State Department of Ecology

**MACAULAY AND CLOVER POINT
WASTEWATER AND MARINE ENVIRONMENT PROGRAM
2010 ANNUAL REPORT**

1.0 BACKGROUND

Wastewater has been discharged from the Macaulay and Clover points outfalls for approximately 100 years. The Macaulay Point outfall has been in use since 1915, with the initial discharge at low tide level. In 1971, to alleviate shoreline pollution, the point of discharge was moved offshore. The outfall is now approximately 1800 m long and terminates in a multiport diffuser at a depth of 60 m. The discharge of municipal wastewater at Clover Point began in 1894. Discharge was to the shoreline until 1981, when construction of an extended outfall was completed. The Clover Point outfall is now approximately 1160 m long and discharges through a multiport diffuser at a depth of approximately 65 m.

Wastewater from both of these outfalls is fine-screened to 6mm before release through the diffusers to the fast-moving waters of Juan de Fuca Strait. The freshwater wastewaters are then rapidly diluted as they mix with surrounding marine waters. As the wastewater plumes mix with the marine waters, they rapidly rise and trap at mean depths of 45 to 60 m, with some surfacing predicted during periods of slack tide, predominantly during the winter months (Hodgins, 2006).

In March 2003, the Capital Regional District (CRD) Core Area LWMP (CRD, 2000) was approved. This LWMP outlined the CRD's plans to manage liquid wastes for the next 25 years. Commitments made in this plan were designed to protect public health and the environment from the impacts of liquid waste discharges. On July 21, 2006, the CRD received a letter from the Minister of Environment requiring an amendment to the Core Area LWMP, detailing a schedule for the provision of sewage treatment. In his letter, the minister also requested that the CRD continue the current monitoring program. Liquid Waste Management Plan amendment #7 (CRD, 2009a) was submitted to MOE in December, 2009 with a follow up amendment #8 (CRD, 2010a) in June, 2010. Plans for the development of wastewater treatment for the Core Area (i.e., Greater Victoria and western communities) are currently underway.

The outfalls at Macaulay and Clover points operate under the long-term direction of the LWMP (see Section 1.1.1 for more detail), and under draft operational certificates on a day-to-day basis. The draft operational certificates for Macaulay (#ME-00270) and Clover (#ME-01877) were issued by the Ministry of Environment (MoE) under the 2004 BC Environmental Management Act (formerly the BC Waste Management Act (BCMoE, 2004)).

1.1 Wastewater and Marine Environment Program Components

1.1.1 Program History

Monitoring of wastewater discharges, surface waters and the seafloor environment in the vicinity of the Macaulay and Clover points outfalls has been conducted as part of the Wastewater and Marine Environment Program (WMEP) on a regular basis since the late 1980s. The program has undergone a number of changes over the years. Monitoring of wastewater, marine waters close to the outfalls, and benthic communities were conducted in the 1970s and 1980s in collaboration with the University of Victoria and independent consultants. In addition, special additional investigations were undertaken to more clearly define the effects of the outfalls on the receiving environment. In 1992, a detailed investigation of effects related to the outfalls was conducted by EVS (1992). This study included the analysis of wastewater and sediment chemistry, sediment toxicity, and the assessment of the health of biological communities near the outfalls. The 1992 study results were used to design a regular monitoring and assessment program in collaboration with the Marine Monitoring Advisory Group (MMAG) (see Section 1.2 for MMAG details).

From 1992 until 1999, the program consisted of monthly wastewater analysis for conventional parameters, quarterly wastewater analysis for priority substances, monthly surface water (<1m depth)

sampling for indicator bacteria, yearly sediment chemistry analysis and seafloor organisms monitoring on a three-year cycle. Starting in 2000, the WMEP was again revised in consultation with the MMAG. The major changes were not in the components of the program, but rather in the frequency of monitoring (i.e., monitoring frequency increased). Special, additional investigations continue to supplement the routine monitoring as necessary.

Toxicity testing also used to be a component of the WMEP, for both wastewater and sediment. Wastewater toxicity testing invariably failed, primarily due to the high ammonia concentrations in the Macaulay and Clover point wastewaters. Because ammonia is not typically a concern in the marine environment, it was agreed, in consultation with the MMAG and the MOE, that wastewater toxicity testing be dropped from the WMEP. Sediment toxicity testing was also a component of the WMEP and was dropped following the 1992 EVS study (EVS, 1992) due to confounding total organic carbon concentrations. Plans are in place to reintroduce both sediment and wastewater toxicity testing to the WMEP in 2011.

The Society of Environmental Toxicology and Chemistry (SETAC) completed a review of the CRD Core Area LWMP in 2006 (SETAC, 2006). This review panel commented that the WMEP was substantial and well designed and that continuing it would be appropriate for assessing the CRD wastewater discharge in the future. However, the panel made a number of recommendations to enhance the monitoring program, including considering more extensive monitoring with better spatial and temporal resolution in the far-field to provide a better understanding of the fate of the surfaced sewage plume. Since the review, the decision to move to advanced treatment was made. CRD and BC MOE staff have reviewed the objectives and design of the WMEP in light of the move to new treatment for Macaulay and Clover points, and a revised monitoring program based on a 5-year cycle will be implemented in 2011. Information about the revised WMEP will be presented for each monitoring component throughout this report. Further details about the revised WMEP will be provided in an upcoming report and are available upon request from the CRD Environmental Sustainability department.

1.1.2 Approach and Program Components

Wastewater and Marine Program Environmental program components were developed in conjunction with the MMAG. The current objectives of the WMEP contained in the Core Area LWMP (CRD, 2000) and updated in amendment #7 (CRD, 2009a) are as follows:

- Monitor and assess wastewater quality and quantity;
- Monitor and assess the potential effects of the wastewater discharges to the marine environment;
- Monitor and assess the potential effects of the wastewater discharges to human health;
- Provide information to the CRD Regional Source Control program (RSCP);
- Provide information to wastewater managers regarding treatment plant and outfall diffuser performance;
- Provide compliance monitoring results to regulatory agencies; and
- Provide scientific assessment to the general public regarding the use of the marine environment for the disposal of municipal wastewater.

The regular monitoring components of the WMEP are presented in Table 1.1 and Figure 1.1. The 2010 WMEP consisted of the following components:

- wastewater monitoring and analysis for a list of substances including conventional parameters, metals, and other priority substances (conducted monthly for each outfall)
- surface water monitoring and analysis of fecal coliforms as indicators of potential for human exposure to wastewater in the marine environment (conducted monthly at each outfall)
- seafloor monitoring for chemical (sediment and mussel tissue contaminant concentrations) and biological (health of seafloor communities-benthic organisms and mussels) parameters on a yearly basis

- additional investigations that address specific questions about wastewater, water column and seafloor monitoring components and that look into emerging scientific issues regarding wastewater discharges and environmental effects

An evidence-based approach is used to assess environmental effects. Wastewater is analysed on a regular basis to monitor the substances present in sewage. The potential effects of these substances on organisms in the water column are assessed by comparing the concentrations that are predicted in the marine environment to water quality guidelines (WQGs). Concentrations of substances present in the wastewater discharges are analysed in sediments off the two outfalls and at reference sites. Sediment chemistry results are compared to various sediment quality guidelines (SQGs) as a screening tool to predict potential effects on biological organisms in the marine environment. The organisms that have the potential for the most severe effects in the marine environment close to the outfalls are those that are continuously exposed to the wastewater discharges. These include benthic communities off the Macaulay Point outfall and mussel communities off the Clover Point outfall. The health of these communities is assessed by studying the organisms present and their abundance, growth and reproductive status. These biological indicators provide a direct assessment of environmental effects. Potential effects to higher trophic levels (e.g., fish and marine mammals) are assessed by measuring concentrations of substances present in wastewater, sediments and in mussel tissue. These regular components are supplemented by additional investigations.

Current additional investigations are also presented in Figure 1.1. Additional investigations are important elements of the WMEP. Some of these investigations are part of the requirements under the Core Area LWMP 2003 approval letter. Examples of such projects include the study of the potential effects of pharmaceuticals and personal care products (PPCPs) and polybrominated diphenyl ethers (PBDEs) (i.e., flame retardants) on the marine environment. Investigations undertaken between 2004 and 2010 and those planned for 2011 are discussed in Section 5. Results from these investigations are incorporated in the overall assessment of effects on the marine environment.

1.2 Marine Monitoring Advisory Group

In 1987, the CRD formed the MMAG to advise on and provide an independent assessment of CRD marine monitoring programs. The MMAG consists of university and government scientists with expertise in the fields of marine science, oceanography, toxicology, chemistry and environmental health. Since 1987, the MMAG has worked with the CRD to develop a comprehensive WMEP for the Macaulay and Clover points outfalls and has historically been required to submit an annual review of the WMEP to MOE. In September 2010, MOE waived all formal MMAG reporting requirements. The CRD, however, has retained the MMAG and has broadened the group's mandate to include the review of CRD Stormwater, Harbours and Watersheds marine monitoring activities, as well as expanded the group's membership to include members of the public with relevant expertise. The MMAG has given, and will continue to give, input into every aspect of the WMEP, including reviewing and commenting on the information presented in this report.

1.3 Data Presentation and Analysis

Until 2000, the results of the WMEP were tabulated in separate reports according to each component (e.g., wastewater monitoring results, etc.). Each of these reports presented a snapshot into the effects of the outfalls on the receiving environment. An overall view of the results was provided by compiling the data from the different components on a regular basis (i.e., once every three to five years). As the frequency of the seafloor components was increased from every three years to annually in 2000, and as additional elements were incorporated into the WMEP, it became evident that the program would benefit from the production of an annual report. Annual reporting began with the 2000/2001 report which was completed in 2002 (CRD, 2002).

The objective of this annual report is to present an integrated summary of the 2010 results for all the components of the Macaulay and Clover points WMEP, including additional investigations. Individual reports that include field and analytical methodologies and the quality assurance and quality control (QA/QC) measures for the WMEP are also completed for every component on an annual basis, along

with an overall methodology report that summarizes each component (CRD, 2010f). Results presented in this report include 2010 data and comparisons to previous years as they pertain to the overall analysis. Detailed statistical analyses for all monitoring components are conducted on an annual basis for some components and every three to five years for others, depending on the number of data points needed to conduct a meaningful analysis. All statistical analyses done that include the 2010 results have been summarized in this report.

Table 1.1 Monitoring Components of the 2010 Macaulay and Clover Points Wastewater and Marine Environment Program

Macaulay Point Outfall	Parameter	Monitoring Frequency
Wastewater	flow	daily
	conventional parameters ¹ and priority substances ¹	monthly
	priority substances ¹	quarterly (January, April, July and October)
Surface Water	indicator bacteria (fecal coliform) and dissolved oxygen	monthly sampling with a set of five sampling events in 30 days during summer (for fecal coliforms)
Seafloor	particle size analysis, TOC ² , AVS ² and sediment chemistry ¹ benthic community structure (including TA, SDI, TR, ITI, PA) ³	annually (September)
Clover Point Outfall	Parameter	Monitoring Frequency
Wastewater	flow	daily
	conventional parameters ¹ and priority substances ¹	monthly
	priority substances ¹	quarterly (January, April, July and October)
Surface Water	indicator bacteria (fecal coliform)	monthly sampling with five sampling events in 30 days during summer
Seafloor	particle size analysis, TOC ² , AVS ² and sediment chemistry ¹	annually (September) at C0 and CB, every three years at additional stations (2009, 2012, 2015, etc)
	deep-sea mussel (<i>Modiolus modiolus</i>) - tissue weight, shell length, age structure, reproductive state - tissue chemistry¹	annually (September)

Notes

¹ Appendix A1

² TOC—total organic carbon, AVS—acid volatile sulphide

³ TA—total abundance, SDI—Swartz dominance index, TR—taxa richness, ITI—Infaunal trophic index, PA—polychaete abundance

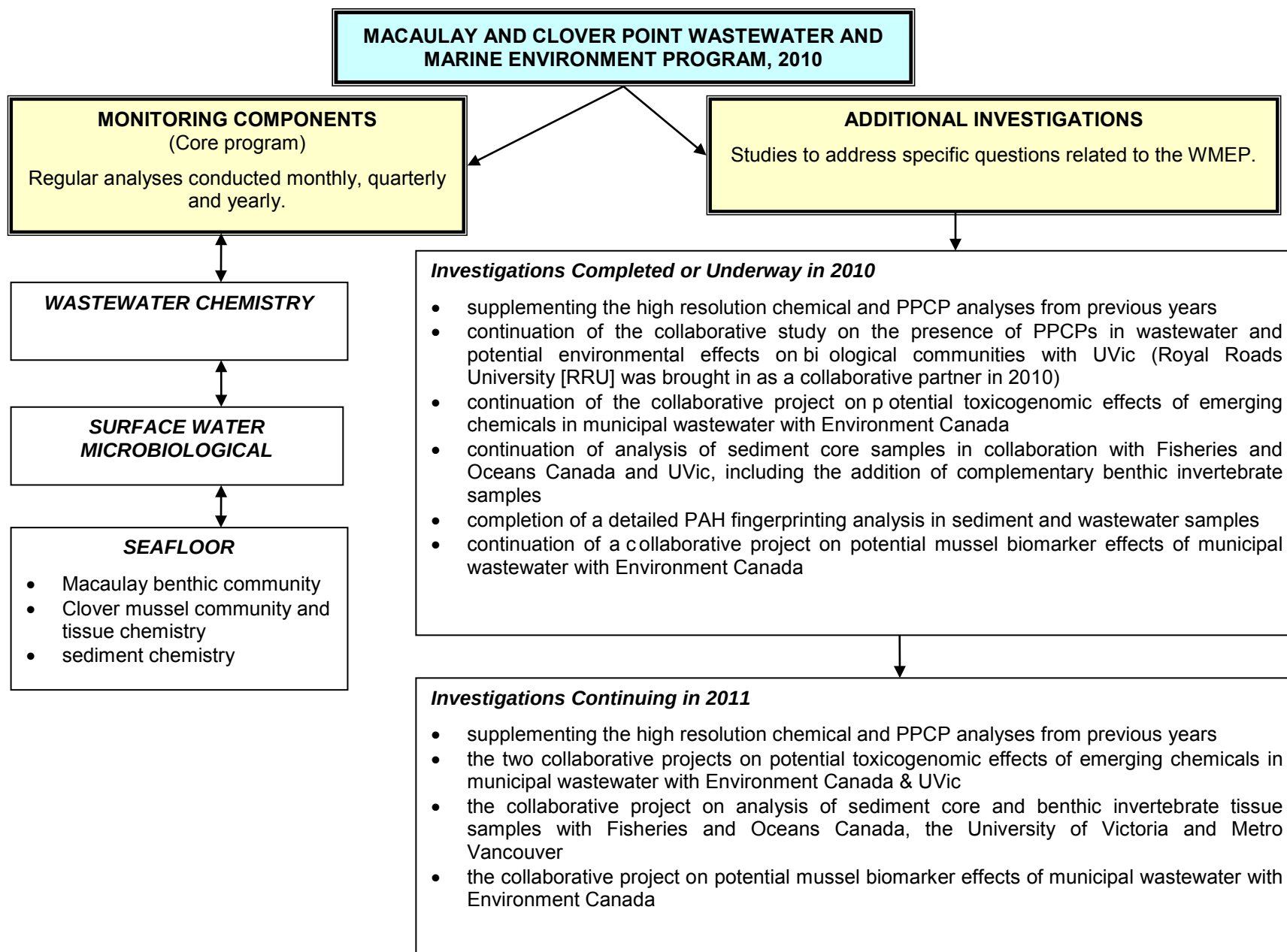


Figure 1.1 Elements of the 2010 Macaulay and Clover Points Wastewater and Marine Environment Program

2.0 WASTEWATER MONITORING

2.1 Introduction

Wastewater monitoring is conducted regularly at both Macaulay Point and Clover Point outfalls to assess compliance with the operating certificates (for flow, biochemical oxygen demand (BOD) and total suspended solids (TSS)) and to profile the chemical and physical constituents of wastewater before it is released to the marine receiving environment. Assessment of wastewater provides information on concentrations and loadings of wastewater components to the marine environment. These data provide an indication of which substances may be of concern in the receiving environment, and are used to direct the efforts of Marine Programs and of the RSCP.

Statistical trend assessments are conducted with the wastewater data. The last trend assessment was conducted using data up to 2008 (Golder, 2009e). The purpose of this study was to conduct an assessment of trends with the 1990–2008 Macaulay and Clover points effluent data, in order to determine temporal trends in detection frequencies, concentrations and loadings of wastewater parameters. Trend assessments are generally conducted every three years, with the next trend scheduled for 2012 using 1990–2011 data.

Based on the recent WMEP review by CRD and BC MOE staff, plans are in place to revise the wastewater component of the WMEP in 2011. Revisions include minor changes to the target analyte list, along with the introduction of regular wastewater toxicity testing. Further details about these changes will be provided in a future report and are available upon request from the CRD Environmental Sustainability department.

2.2 Methods

Wastewater samples were collected on a monthly basis in 2010 and analysed for over 20 conventional parameters (such as TSS and nutrients) and a comprehensive list of priority substances (Appendix A1). These included metals, aldehydes, phenolic compounds, polycyclic aromatic hydrocarbons (PAHs), semi-volatile organic compounds, volatile organic compounds (VOCs) and terpenes. The list of priority substances was adapted from the US Environmental Protection Agency (USEPA) National Recommended Water Quality Criteria; Priority Toxic Pollutants list (US EPA, 2002). The CRD's list is reviewed on a periodic basis to determine the need to delete or add substances depending on new developments in terms of analytical techniques, potential presence in wastewaters and potential effects on the receiving environment. The CRD's entire priority substance list (i.e., over 170 substances—see Appendix A1) was analysed quarterly (January, April, July and October) in 2010. A modified list of these substances (i.e., over 110 substances; Appendix A1) was analysed monthly throughout the rest of the year.

Wastewater samples were taken as 24-hour composites (400 mL effluent collected every 30 minutes for a 24-hour period and composited into one large sample) at the Macaulay and Clover points wet wells, with grab samples taken for a few substances. Substances that have very short hold times (e.g., fecal coliforms), substances that are volatile (e.g., sulphide and volatile organic substances) and substances that cannot be sampled correctly by composite sampling (e.g., oil and grease sits on the surface of the wastewater) are deemed unsuitable for composite sampling. Samples were immediately dispatched to qualified laboratories to conduct chemical analyses. Conventional parameters were analysed by the CRD Saanich Peninsula Wastewater Treatment Plant laboratory (Sidney, BC) and Maxxam Analytics Inc. (Victoria, BC); priority substance analyses were conducted by Maxxam Analytics Inc. (Burnaby, BC). Refer to Appendix A for a complete list of substances and the Wastewater Methodology Report (CRD, 2010e) (2009c)(2009c)(2009c)(2009c)(2009c)(2009c)(2009c)(2009c) for frequency of monitoring, method detection limits and technical and analytical sampling details. Substances were analysed using analytical methods capable of method detection limits suitable for comparison to applicable WQGs.

Wastewater flow volume was measured continuously (i.e., every few minutes) by a Supervisory Control and Data Acquisition (SCADA) system at the Macaulay and Clover points outfalls. Flow measurements

were compared to maximum daily and annual mean flow limits specified in the draft operating certificates for these facilities. These flows were also used for the calculation of loadings of conventional and priority substances to the marine receiving environment.

DATA QUALITY ASSESSMENT

A rigorous QA/QC assessment procedure was followed for both field sampling procedures and laboratory analyses for the WMEP routine wastewater monitoring program. Within each analytical batch (i.e., 12 monthly batches in 2010), one sample was randomly chosen for laboratory triplicate analysis and every quarter (i.e., January, April, July and October), one sample was randomly chosen for field triplicate analysis. In addition, one sample each month was analysed as a matrix spike and trip and field blanks were tested once in 2010. The analytical laboratories also conducted internal QA/QC analyses, including method analyte spikes, method blanks and standard reference materials.

All 2010 results were assessed against the data quality objectives (DQOs) of the revised CRD QA/QC assessment procedure (Appendix A4). The original CRD DQOs were developed with the MMAG in the early 1990s, following established laboratory analytical standards. The CRD updated these DQOs in 2007 based on a comparison to established QA/QC procedures used by the US EPA, Ontario and BC governments and other relevant jurisdictions and then updated again in 2009 following a year of application (Golder, 2009c). The revised procedure is consistent with, and in some cases more rigorous than, procedures used by the other jurisdictions. The MMAG reviewed and provided comments on the new QA/QC assessment procedure and agreed on its use to assess wastewater, sediment and mussel tissue chemistry data. A description of the CRD QA/QC assessment procedure is presented in Appendix A4; a brief summary is included in this section.

The revised procedure involved an initial screen of the data to ensure that they fell within expected ranges of results (0.5th to 99.5th percentiles of the historic results). Any data that fell outside of expected ranges were discussed with the laboratory to ensure their internal QA/QC requirements were satisfied and to determine whether reanalysis was necessary.

Following the initial screening, the data were evaluated (Figure 2.1) for precision (based on variability in lab or field replicates), bias (based on recoveries of spikes, surrogate standards or certified reference materials), and representativeness (based on blank sample contamination), using specific criteria for each analytical group (Table 2.1). The extremity of precision, bias or representativeness failures were determined (Table 2.2), and data with marginal failures were flagged, while data with severe failures were rejected. Analytical batch data, if available, were used to link associated samples to specific blanks, spikes, replicates, etc. All data that exhibited failures were questioned and a determination of the potential causes was undertaken. Most failures were due to uncertainty regarding the quantity detected. Therefore, rejected results were not presented in this report and were not used for further analyses (e.g., statistical analyses), except for frequency of detection calculations, which only need to have the presence of the analyte confirmed.

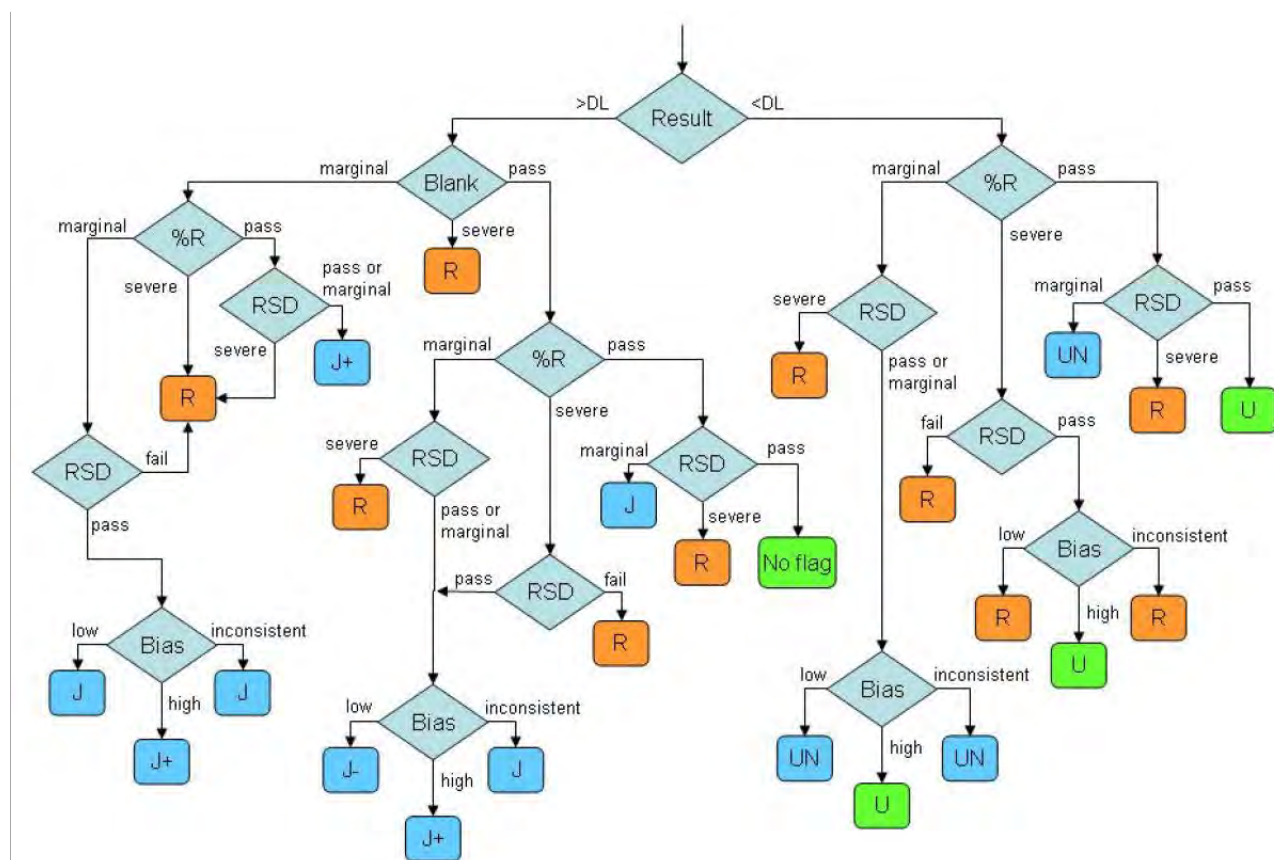


Figure 2.1 Decision Criteria for Assigning Data Flags to CRD Chemistry Data (Golder, 2007d)

2.3 Results and Discussion

2.3.1 Compliance Monitoring

Wastewater compliance monitoring is undertaken to ensure compliance with the draft operational certificates issued for the Macaulay and Clover points outfalls by the Ministry of Environment under the Environmental Management Act. Among other day-to-day operation requirements, the operational certificates stipulate maximum operating levels for flow, and effluent concentrations of TSS and BOD (Table 2.3).

Wastewater compliance monitoring results are summarized in Table 2.3; the complete monthly results are included in the CRD Wastewater Monitoring Data Report (CRD, 2010d; CRD, 2011g). Flow data for 2010 are presented in Appendices B1 and B2. Flows did not exceed the allowable daily maximum or daily mean for either the Macaulay or Clover discharges (Table 2.3). The mean daily flow at Macaulay Point was 45,112 m³/day in 2010, slightly lower (3.4%) than the daily average flow in 2009 (i.e., 46,708 m³/day). The mean daily flow at Clover Point was 50,495 m³/day in 2010, which is slightly lower (4.8%) than in 2009 (i.e., 53,050 m³/day).

Compliance monitoring annual average results for TSS and BOD are presented in Table 2.3. Appendix B3 presents monthly TSS and BOD results. Results indicate that the quality of the effluents from Macaulay and Clover points outfalls in 2010 were similar to 2009 and 2008 results. Concentrations of all conventional parameters were within the expected range for fine-screened wastewater (Tchobanoglous *et al.*, 1991), and therefore met regulatory requirements. The predicted environmental concentrations (taking estimated minimum initial dilution into consideration) did not exceed BC WQG.

Table 2.1 Criteria Used to Differentiate Between Moderate and Severe QA/QC Failures (Golder, 2009c)

Objective/DQO	Analyte Group	Proposed Criteria		
		Pass	Marginal Failure	Severe Failure
Precision: Laboratory or Field ^b Replicate RSD [or SD] ^c	Oil & Grease	RSD<20% [SD<DL]	RSD=20-30% [SD=DL-1.5×DL]	RSD>30% [SD>1.5×DL]
	Metals (except silver)	RSD<20% [SD<DL]	RSD=20-40% [SD=DL-2×DL]	RSD>40% [SD>2×DL]
	Silver	RSD<20% [SD<DL]	RSD=20-70% [SD=DL-3.5×DL]	RSD>70% [SD>3.5×DL]
	Organics	RSD<50% [SD<2.5×DL]	RSD=50-75% [SD=2.5×DL-5×DL]	RSD>75% [SD>5×DL]
	NH ₃ , TKN, NO ₂ ⁻ , NO ₃ ⁻	RSD<10% [SD<0.5×DL]	RSD=10-15% [SD=0.5×DL-DL]	RSD>15% [SD>DL]
	TSS, BOD, SO ₄ ²⁻ , Hardness, COD	RSD<15% [SD<DL]	RSD=15-25% [SD=DL-1.5×DL]	RSD>25% [SD>1.5×DL]
	S ²⁻ , CN ⁻ , Phenolics, TOC, lipid	RSD<25% [SD<DL]	RSD=25-40% [SD=DL-1.5×DL]	RSD>40% [SD>1.5×DL]
Bias: Matrix Spike, Reference Sample or Surrogate Recovery	Metals, S ²⁻ , CN ⁻ , phenolics, TOC	75-125%	60-75% or 125-140%	<60% or >140%
	Organics	50-150%	25-50% or 150-175%	<25% or >175%
	NH ₃ , NO ₂ ⁻ , NO ₃ ⁻ , SO ₄ ²⁻ , Hardness, Oil & Grease	80-120%	70-80% or 120-130%	<70% or >130%
	BOD, COD, TKN	85-115%	75-85% or 115-125%	<75% or >125%
Representativeness Lab or Field/Trip Blank Contamination	All (Sample-based)	<10% of sample	10-20% of sample or >10% but NDR ^d	>20% of sample

Notes

RSD = Relative Standard Deviation; i.e. of triplicates, $RSD = \frac{SD}{\sqrt{X}}$

Separate precision criteria given for results ≥5x DL (RSD-based) and [results <5x DL, SD-based].

Blank criteria based on DL (CRD) and sample concentrations (US ACE, 2005).

Table 2.2 Definitions of Flags Assigned to CRD Data During the QA/QC Assessment Process (Golder, 2009c)

Flag	Description
R	The datum is rejected. This qualifier indicates that the presence of the analyte is unknown, and the reported value is completely unusable because of multiple and/or severe DQO failures.
J	The analyte has been positively identified (i.e., qualitative uncertainty is low), but the reported concentration is an estimated value (i.e., significant quantitative uncertainty exists) and the direction of bias is unknown.
J(-)	The analyte has been positively identified, but the reported concentration is an estimate that is believed to be <i>biased low</i> (i.e., the actual concentration in the sample is likely greater than the reported value).
J(+)	The analyte has been positively identified, but the reported concentration is an estimate that is believed to be <i>biased high</i> (i.e., the actual concentration in the sample is likely less than the reported value).
U	The analyte was not detected above the sample detection limit. The associated value is the sample detection limit.
UN	The analyte was not detected above the sample detection limit, but significant quantitative uncertainty exists and the method may not have been able to accurately measure the analyte in the sample.

Table 2.3 Macaulay and Clover Points Compliance Monitoring Results for 2010

Parameter	Macaulay Point	Clover Point	Allowable Maximums
Maximum Daily Flow ^a	166,180 m ³ /day	166,292 m ³ /day	Macaulay = 200,000 m ³ /day Clover = 300,000 m ³ /day
Mean Daily Flow ^a	45,112 m ³ /day	50,495 m ³ /day	Macaulay = 56,000 m ³ /day Clover = 73,000 m ³ /day
Maximum Biochemical Oxygen Demand (BOD) <i>n</i> =12	266 mg/L	245 mg/L	Equivalent or better than screened municipal wastewater range (110–400 mg/L) ^b
Maximum Total Suspended Solids (TSS) <i>n</i> =12	286 mg/L	298 mg/L	Equivalent or better than screened municipal wastewater range (100–350 mg/L) ^b

Note

a daily mean flow is presented in Appendix B1 and B2

b Tchobanoglous (1991)

2.3.2 Priority Substances

Wastewater samples were analysed for the priority substances listed in Appendix A1. Appendix B4 summarises the list of substances that were analysed in wastewater in 2010 that had DQO failures. Most failures were due to uncertainty regarding the quantity detected. Therefore, each time a substance was rejected due to failing DQOs, that value was excluded from the monthly data set and was not used for further analyses (e.g., annual average concentration and loading calculations), except for frequency of detection calculations, which only need the presence of the analyte to be confirmed.

The analytical parameters and groups that had the most DQO failures in 2010 were conventional parameters (TOC, oil and grease, sulfide), metals (total and dissolved), organotins, phenolics and some organics. The most common causes of severe DQO failures in the 2010 data set were bias (i.e., spike recovery failures), followed by representativeness (lab blank contamination). In some cases, spike failures were attributable to elevated detection limits in the spiked sample, introducing uncertainty in the evaluation of bias. All other data quality objectives (i.e., spike recoveries, lab and field blanks and lab replicates) were met for wastewater analyses in 2010. A complete description of QA/QC results is

presented in the CRD Wastewater Data Report (CRD, 2011g). Trends in DQO failures will be assessed in the future to determine whether there are consistent analytical issues that are not obvious when only looking at a single year's results.

The frequencies of detection of all substances analysed in wastewater are included in Appendix B5. There were 170+ substances analysed in both discharges and more than half of these substances were never detected in 2010 (at detection limits chosen for comparison to the applicable WQGs). Substances frequently detected in wastewater (i.e., greater than or equal to 50% of the time) in 2010 were similar to previous years and included a number of conventional parameters, total and dissolved metals, organotins, two phenolic compounds, PAHs, two phthalates, a few miscellaneous volatile organics and terpenes.

The mean annual concentration, standard deviation, annual loading and frequency of detection of each substance are included in Appendices B6 (Macaulay) and B7 (Clover). Concentrations of the substances that were frequently detected (greater than or equal to 50% of sampling events) in Macaulay and Clover points wastewaters are presented in Table 2.4 and 2.5, respectively. Concentrations of most substances in 2010 were variable (i.e., some increased and some decreased throughout the year) similar to previous years. These variations in concentrations are typical of municipal wastewater discharges. The only way to effectively measure the trends in concentrations and loadings of substances is to monitor on a regular basis and periodically conduct robust statistical analyses. The next statistical analysis is planned for 2012 and will incorporate the 1990 to 2011 data.

To determine the potential for effects of the wastewater discharges on the receiving environment, maximum wastewater concentrations of frequently detected substances (Tables 2.4 and 2.5) were compared to the BC (BCMoe, 2006a; BCMoe, 2006b) and CCME WQG (CCME, 2003a) developed to protect aquatic life. Estimated minimum initial dilution factors (245:1 for Macaulay Point and 175:1 for Clover Point) (Hodgins, 2006), which are conservative estimates of the minimum initial dilution of the effluents in receiving waters off the outfalls, were applied to maximum wastewater substance concentrations from both discharges to predict concentrations in the marine environment.

Before application of minimum dilution factors, there were ten substances (at either or both outfalls) that exceeded applicable WQGs in undiluted wastewater prior to discharge. These substances included fecal coliforms, WAD cyanide, ammonia, sulphide, cadmium, copper, iron, manganese, zinc, and trichloromethane at Macaulay (Table 2.4), and fecal coliforms, WAD cyanide, ammonia, sulphide, copper, iron, zinc and trichloromethane at Clover (Table 2.5). A summary of potential anthropogenic sources of these substances can be found in Appendix A1. These exceedences were similar in frequency and magnitude to those observed in 2008 and 2009 (CRD, 2009b; CRD, 2010b). The CRD will continue to monitor these substances to determine whether the exceedences of BC and CCME WQG are changing in frequency over time, or whether concentrations of these substances are increasing over time.

After application of minimum dilution factors there were no substances exceeding applicable WQGs, indicating that receiving environment concentrations are also not likely to exceed WQGs and that the potential for effects on aquatic life are likely limited to within the outfall IDZs only.

OVERALL ASSESSMENT

The 2010 wastewater monitoring results were generally consistent with previous years. Some substances in the Macaulay and Clover points wastewaters exceeded guidelines in undiluted effluent, but all met applicable WQGs in the marine receiving environment following the application of estimated minimum initial dilution factors. All flow, TSS, and BOD requirements stipulated under Macaulay and Clover points draft operational certificates, indicating that wastewaters, from an operational and regulatory compliance perspective, were as expected. The use of estimated minimum initial dilution factors allows for a conservative (i.e., highly protective) estimation of potential effects because the predicted average (mean) initial dilution factors are actually much higher in the marine receiving environments around each outfall (647:1 and 894:1 for the Macaulay and Clover points outfalls, respectively). However, it should be noted that the above dilution factors assume fully functioning outfall diffusers. Recent outfall inspections (2005 and 2009) indicate that encrusting sea life has blocked some

of the diffusers and that there may be minor cracks in the outfalls. These factors could be reducing the dilution efficiency of the outfalls. The CRD is planning outfall repair in 2012. However, even if the clogged ports caused a decrease of 50% in the minimum initial dilution factor, all parameters would still be below WQGs.

Table 2.4 Annual Mean Concentrations of Frequently Detected Substances (>50%), Macaulay Point Wastewater (2010)
(Shaded values indicate exceedences of water quality guidelines (WQG))

Parameters	Units	2008	2009	2010						BC	CCME
				Mean	St Dev	n	Max	Min	1:245 Dilution*		
Conventionals											
alkalinity	mg/L	185.5	197.9	186.1	22.19	12	223	155	n/a		
biochemical oxygen demand	mg/L O ²	208	214	233	28	12	266	178	n/a		
carbonaceous biochemical oxygen demand	mg/L O ²	161	178	185	26	12	226	121	n/a		
chemical oxygen demand	mg/L O ²	446	439	481	74	12	611	400	n/a		
chloride	mg/L	56.8	88.7	100.4	53.5	12	219	39	0.41		
conductivity	µS/cm	619	751	801	218	12	1,286	498	n/a		
SAD cyanide	mg/L	0.006845	0.003856	0.003208	0.000555	12	0.0041	0.0018	0.00001		
WAD cyanide	mg/L	0.001233	0.00127	0.001386	0.000336	12	0.0019	0.0009	0.00001	0.001b	
fecal coliform	CFU/100 mL	6,758,000	5,058,000	5,744,000	1,500,000	12	7,966,667	3,700,000	23,445		
hardness (as CaCO ₃)	mg/L	57.95	71.99	71.7	23.71	11	133.7	48.23	n/a		
N - NH ₃	mg/L	31.84	33.31	34.14	5.69	12	47	23.9	0.14	19.7e	
N - NO ₂	mg/L	0.00883	0.03297	0.02044	0.02081	12	0.05	0.003	0.0001		
N - NO ₃	mg/L	0.0261	0.1082	0.08331	0.08028	12	0.233	0.02	0.0003		
N - TKN	mg/L	47.29	51.08	52.71	6.118	9	63.2	46	0.22		
oil & grease, mineral	mg/L	2.36	2.81	5.81	3.77	12	16	2	0.02		
oil & grease, total	mg/L	29.39	19.72	22.71	6.05	7	31	13.67	0.09		
total organic carbon	mg/L	50.56	62.55	57.2	9.277	10	69	45.3	0.23		
P - PO ₄	mg/L	---	---	5.769	1.772	9	9.28	3.8	0.02		
pH	pH	7.2	7.2	7.3	0.27	12	7.9	7	n/a		
sulfide	mg/L	0.3062	0.2333	0.1621	0.05536	11	0.3	0.08	0.001	0.002cf	
sulphate	mg/L	---	---	23.58	11.45	12	52	7.3	0.096		
total suspended solids	mg/L	232	236	234.5	29.08	12	286	186	0.96		

continued

Table 2.4 continued

Parameters	Units	2008	2009	2010						BC	CCME
				Mean	St Dev	n	Max	Min	1:245 Dilution*		
Total Metals											
aluminum	mg/L	0.7083	0.03785	0.4609	0.1306	12	0.809	0.30167	0.002		
antimony	mg/L	0.0007364	0.0002708	0.0002891	0.0001376	11	0.00059	0.00014667	0.0000012		
arsenic	mg/L	0.0006817	0.0004383	0.0005403	0.0001599	12	0.00087	0.00036	0.000002	0.0125 ^{cg}	0.0125
barium	mg/L	0.02874	0.008963	0.0223	0.003432	11	0.0287	0.0159	0.00009	0.5 ^{ac}	
cadmium	mg/L	0.0005249	0.0001184	0.0003077	0.0001482	12	0.000695	0.0001443	0.0000013	0.00012 ^c	0.00012
calcium	mg/L	18.48	18.33	18.62	4.527	12	31.07	13.4	0.076		
chromium	mg/L	0.003453	0.0023	0.001872	0.000644	12	0.00297	0.0008	0.000008		
cobalt	mg/L	0.001046	0.0009973	0.0009814	0.0004984	12	0.00206	0.000296	0.000004		
copper	mg/L	0.1151	0.05455	0.1249	0.02448	11	0.169	0.0842	0.0005	0.003 ^{bh}	
iron	mg/L	0.7427	0.2886	0.5385	0.1032	12	0.697	0.352	0.002	0.05 ^{ac}	
lead	mg/L	0.004533	0.001045	0.004455	0.001119	11	0.00718	0.00345	0.00002	0.14 ^{bh}	
magnesium	mg/L	5.81	7.632	8.681	3.664	12	15.57	3.757	0.035		
manganese	mg/L	0.07857	0.06157	0.06128	0.01946	11	0.10533	0.04217	0.00025	0.1 ^c	
mercury	mg/L	0.0000624	0.0000164	0.0000233	0.0000267	11	0.00008	0.00001	0.00000010	0.002 ^b	
molybdenum	mg/L	0.002448	0.001348	0.002254	0.002634	11	0.00981	0.000617	0.000009		
nickel	mg/L	0.005333	0.004152	0.004943	0.001901	11	0.00992	0.00287	0.000020	0.075 ^{ci}	
phosphorus	mg/L	5.553	3.708	5.79	0.9967	3	6.557	4.663	0.024		
potassium	mg/L	14.38	14.67	14.89	2.699	12	18.43	9.80	0.061		
selenium	mg/L	0.0007283	0.0002283	0.0003525	0.0001313	12	0.00066	0.0002	0.0000014		
silver	mg/L	0.0009993	0.0001799	0.0002399	0.0003284	12	0.00115	0.000068	0.000001	0.003 ^{bh}	
thallium	mg/L	0.00000627	---	0.00000561	0.00000095	12	0.000007	0.000004	0.00000002		
tin	mg/L	0.003128	0.000845	0.001448	0.001059	11	0.00395	0.00074	0.000006		
zinc	mg/L	0.0854	0.02864	0.09684	0.0136	11	0.112	0.070333	0.00040	0.01 ^b	
Metals - Other											
dibutyltin	mg/L	n/a	n/a	0.00000542	0.00000796	4	0.00002	0.000001	0.00000002		
dibutyltin dichloride	mg/L	n/a	n/a	0.000 002	0	1	0.000 002	0.000 002	0.00000001		
tributyltin	mg/L	n/a	n/a	0.00000522	0.00000386	3	0.0000097	0.00000267	0.000000021		
tributyltin chloride	mg/L	n/a	n/a	0.00000483	0.00000118	2	0.000006	0.000004	0.00000002		
Phenolic Compounds											
total phenols	mg/L	0.03124	0.03658	0.04464	0.00963	11	0.059	0.028	0.00018		
Non Chlorinated Phenolics											

Table 2.4 continued

Parameters	Units	2008	2009	2010						BC	CCME
				Mean	St Dev	n	Max	Min	1:245 Dilution*		
phenol	mg/L	0.02383	0.01344	0.02627	0.01451	10	0.058	0.012	0.00011		
Polycyclic Aromatic Hydrocarbons											
2-methylnaphthalene	mg/L	---	0.0001515	0.0001045	0.000046	11	0.00017	0.00006	0.0000004		
acenaphthene	mg/L	---	0.0001292	0.000124	0.0000397	10	0.0002	0.00007	0.0000005	0.006 ^b	
chrysene	mg/L	---	0.0001067	0.0000664	0.0000541	11	0.0002	0.00002	0.0000003		
fluoranthene	mg/L	0.000135	0.0000848	0.0001397	0.0000816	11	0.00035	0.00007	0.0000006		
fluorene	mg/L	---	0.0001119	0.0002947	0.0003365	12	0.00097	0.00005	0.0000012	0.012 ^{bh}	
naphthalene	mg/L	---	0.001338	0.0002855	0.0002039	11	0.00072	0.0001	0.0000012		
phenanthrene	mg/L	---	0.0001597	0.0002081	0.0000432	12	0.00030	0.00013	0.0000008		
total LMW-PAH's	mg/L	---	0.0002845	0.0002617	0.0001841	10	0.00073	0.00008	0.0000011		
total HMW-PAH's	mg/L	---	0.001574	0.0008847	0.0004972	12	0.0017	0.0002	0.0000036		
total PAHs	mg/L	---	0.001821	0.001078	0.0006583	11	0.0021	0.0002	0.0000044		
SEMIVOLATILE ORGANICS-PHTHALATES											
bis(2-ethylhexyl)phthalate	mg/L	---	0.01127	0.01644	0.01054	9	0.042	0.009	0.00007		
diethyl phthalate	mg/L	---	0.003878	0.001667	0.001459	7	0.0039	0.000367	0.000007		
Volatile Organics											
toluene	mg/L	---	0.001703	0.002917	0.004305	12	0.01633	0.000667	0.000012	0.33 ^{bh}	0.215
Trihalomethanes											
trichloromethane	mg/L	---	0.001703	0.002917	0.004305	12	0.01633	0.000667	0.000012	0.0018 ^c	
Ketones											
dimethyl ketone	mg/L	0.00403	0.00342	0.00361	0.00098	12	0.006	0.002	0.000015		
Terpenes											
alpha-terpineol	mg/L	0.0723	0.0766	0.0773	0.0692	12	0.29	0.032	0.0003		

*dilution calculated from maximum concentration, a. these are "minimum risk" guidelines. There are also "hazard" guidelines for these substances (which are higher concentrations), b. approved, c. working, d. inorganic, e. maximum concentration at 7.0 pH and 15°C, f. as H₂S, g. interim, h. maximum, i. chronic, --- not detected ≥50%, n/a not analysed or not applicable

Table 2.5 Annual Mean Concentrations of Frequently Detected Substances (>50%), Clover Point Wastewater (2010)
(Shaded values indicate exceedences of water quality guidelines (WQG))

Parameters	Units	2008	2009	2010						BC	CCME
				Mean	St Dev	n	Max	Min	1:175 Dilution*		
Conventionals											
alkalinity	mg/L	143.9	145.9	149.5	11.83	12	181	135	n/a		
biochemical oxygen demand	mg/L O2	201.9	188.3	209.5	27.67	12	245	149	n/a		
carbonaceous biochemical oxygen demand	mg/L O2	167.2	152.9	172.4	26.92	12	204	110	n/a		
chemical oxygen demand	mg/L O2	378.3	357.4	406.6	57.43	12	530	323.3	n/a		
chloride	mg/L	50.57	49.06	44.97	4.88	12	51.67	38.33	0.3		
conductivity	µS/cm	505.3	510.2	515.9	32.44	12	588.7	463	n/a		
SAD cyanide	mg/L	0.005718	0.002657	0.002928	0.000506	12	0.003433	0.002167	0.00002		
WAD cyanide	mg/L	0.001136	0.001144	0.001306	0.000397	12	0.002067	0.000567	0.00001	0.001b	
fecal coliform	CFU/100 mL	7,069,000	5,188,000	5,308,000	2,104,000	12	10,000,000	2,633,000	30,331		
hardness (as CaCO3)	mg/L	57.97	65.81	59.61	11.24	11	86.47	46.07	n/a		
N - NH3	mg/L	22.9	21.56	24.79	4.36	12	31.67	16.23	0.1	19.7e	
N - NO2	mg/L	0.01431	0.04967	0.05478	0.05268	12	0.17	0.004	0.0003		
N - NO3	mg/L	0.04263	0.1622	0.1095	0.07374	12	0.2	0.02	0.001		
N - TKN	mg/L	38.15	36.05	36.94	6.045	10	46.13	25.83	0.2		
oil & grease, mineral	mg/L	2.56	3.44	5.27	2.27	11	9	2.67	0.03		
oil & grease, total	mg/L	29.08	20.81	21.76	3.72	7	26.67	18	0.1		
total organic carbon	mg/L	50.89	58.38	52.34	10.58	10	75.33	37.33	0.3		
P - PO4	mg/L	---	---	3.772	0.6567	9	5.09	3.093	0.02		
P - PO4	mg/L	---	---	4.532	0.7218	9	5.3	3.43	0.03		
pH	pH	7.1	7.2	7.2	0.29	12	7.9	6.8	n/a		

Table 2.5 continued

Parameters	Units	2008	2009	2010						BC	CCME
				Mean	St Dev	n	Max	Min	1:175 Dilution*		
sulfide	mg/L	0.1871	0.1133	0.1568	0.06023	11	0.2267	0.015	0.001	0.002cf	
sulphate	mg/L	---	---	15.62	3.304	12	19	7.433	0.1		
total suspended solids	mg/L	176.6	182.4	209.1	46.9	12	298.7	134	1.2		
Total Metals											
aluminum	mg/L	0.6089	0.03948	0.4054	0.05446	12	0.502	0.324			
antimony	mg/L	0.0004331	0.0002611	0.0003309	0.0002913	11	0.00116	0.00012	0.0023		
arsenic	mg/L	0.000765	0.0004133	0.0005494	0.0001315	12	0.00084	0.00045	0.000002	0.0125cg	0.0125
barium	mg/L	0.02397	0.007881	0.02054	0.003143	11	0.0251	0.01553	0.000003	0.5ac	
cadmium	mg/L	0.0002192	0.00003733	0.0002013	0.00005405	12	0.000346	0.000126	0.0000012	0.00012c	0.00012
calcium	mg/L	16.9	16.8	16.67	2.953	12	24.1	12.63	0.095		
chromium	mg/L	0.002219	0.000597	0.001269	0.000528	12	0.0026	0.000767	0.000007		
cobalt	mg/L	0.0004068	0.0002228	0.0003998	0.0001192	12	0.000706	0.0002973	0.000002		
copper	mg/L	0.1162	0.05826	0.1244	0.01513	11	0.144	0.08413	0.00071	0.003bh	
iron	mg/L	0.7758	0.2492	0.5778	0.1138	12	0.741	0.3753	0.0033	0.05ac	
lead	mg/L	0.005386	0.001158	0.005031	0.001089	11	0.00756	0.00352	0.00003	0.14bh	
magnesium	mg/L	5.706	5.641	5.876	1.511	12	9.25	3.727	0.034		
manganese	mg/L	0.04436	0.03111	0.04506	0.009221	11	0.0671	0.03433	0.00026	0.1c	
mercury	mg/L	0.0000814	0.0000188	0.000018	0.0000157	11	0.0000567	0.0000083	0.0000001	0.002b	
molybdenum	mg/L	0.00263	0.00122	0.001846	0.001122	11	0.00442	0.00057	0.000011		
nickel	mg/L	0.002757	0.001813	0.003483	0.001595	11	0.00689	0.00228	0.000020	0.075ci	
phosphorus	mg/L	4.649	3.084	4.381	0.8583	3	5.01	3.403	0.025		
potassium	mg/L	10.78	9.534	10.86	2.312	12	17	8.01	0.062		
selenium	mg/L	0.0006264	0.0002131	0.0003181	0.000086	12	0.0004967	0.00025	0.000002		
silver	mg/L	0.0008464	0.0001942	0.0001831	0.0001267	12	0.0004977	0.000062	0.0000010	0.003bh	
thallium	mg/L	0.00000627	---	0.000006	0.00000091	12	0.00000733	0.000004	0.00000003		
tin	mg/L	0.002513	0.0006394	0.001102	0.0007201	11	0.0026	0.0006	0.0000063		

Table 2.5 continued

Parameters	Units	2008	2009	2010						BC	CCME
				Mean	St Dev	n	Max	Min	1:175 Dilution*		
zinc	mg/L	0.06945	0.02864	0.08486	0.01373	11	0.109	0.06263	0.00048	0.01b	
Metals - Other											
dibutyltin	mg/L	n/a	n/a	0.00000267	0.00000271	4	0.00000667	0.000001	0.00000002		
tributyltin	mg/L	n/a	n/a	0.00000189	0.00000069	3	0.00000267	0.00000133	0.00000001		
tributyltin chloride	mg/L	n/a	n/a	0.0000035	0.00000259	2	0.00000533	0.00000167	0.00000002		
Phenolic Compounds											
total phenols	mg/L	0.02527	0.0335	0.03203	0.00848	11	0.04267	0.02067	0.00018		
Non Chlorinated Phenolics											
phenol	mg/L	0.02338	0.00633	0.02123	0.02226	10	0.08167	0.007	0.00012		
Organochlorine Pesticides											
2,4-DDD	mg/L	---	---	0.00003011	0.00001983	3	0.00005	0.00001033	0.0000002		
POLYCYCLIC AROMATIC HYDROCARBONS											
2-methylnaphthalene	mg/L	---	0.0001424	0.0000973	0.0000651	11	0.00024	0.00004	0.0000006		
acenaphthene	mg/L	---	0.0001136	0.0000997	0.0000433	10	0.00021	0.0000533	0.0000006	0.006b	
benzo(a)anthracene	mg/L	---	---	0.000053	0.0000304	10	0.0001033	0.00002	0.0000003		
chrysene	mg/L	---	0.0001088	0.0000618	0.0000608	11	0.0002333	0.0000267	0.0000004		
fluoranthene	mg/L	---	0.0000867	0.0001288	0.0000534	11	0.00024	0.0000567	0.0000007		
fluorene	mg/L	---	0.0001097	0.0002469	0.0003519	12	0.001	0.00005	0.0000014	0.012bh	
naphthalene	mg/L	---	0.001327	0.0001815	0.0000806	11	0.0003033	0.0001	0.0000010		
phenanthrene	mg/L	---	0.0001553	0.0001922	0.0000473	12	0.00024	0.0000967	0.0000011		
pyrene	mg/L	---	0.000147	0.00012	0.0000504	10	0.0002033	0.0000633	0.0000007		
total LMW-PAH's	mg/L	---	0.0005114	0.000336	0.0003441	10	0.001	0.0000967	0.0000019		
total HMW-PAH's	mg/L	---	0.001538	0.0009594	0.001259	12	0.0049	0.0003	0.0000055		
total PAHs	mg/L	---	0.001923	0.00131	0.001328	11	0.0051	0.0004667	0.0000075		

Table 2.5 continued

Parameters	Units	2008	2009	2010						BC	CCME
				Mean	St Dev	n	Max	Min	1:175 Dilution*		
Phthalates											
bis(2-ethylhexyl)phthalate	mg/L	0.01738	0.0137	0.01207	0.00177	9	0.01467	0.00967	0.000069		
diethyl phthalate	mg/L	0.003742	0.002811	0.001392	0.001295	7	0.0032	0.0002433	0.0000080		
Volatile Organics											
toluene	mg/L	0.001283	0.001521	0.001389	0.00064	12	0.0025	0.0005	0.0000079	0.33bh	0.215
Trihalomethanes											
trichloromethane	mg/L	0.00478	0.00456	0.00369	0.00097	12	0.005	0.002	0.000021	0.0018c	
Ketones											
dimethyl ketone	mg/L	0.1413	0.0776	0.0624	0.0301	12	0.1133	0.029	0.00036		
Terpenes											
alpha-terpineol	mg/L	0.01764	0.01331	0.01775	0.00508	12	0.029	0.009	0.00010		

*dilution calculated from maximum concentration, a. these are "minimum risk" guidelines. There are also "hazard" guidelines for these substances (which are higher concentrations), b. approved, c. working, d. inorganic, e. maximum concentration at 7.0 pH and 15°C, f. as H₂S, g. interim, h. maximum, i. chronic, --- not detected ≥50%, n/a not analysed or not applicable

3.0 SURFACE WATER MONITORING

3.1 Introduction

Receiving waters at Macaulay and Clover points outfalls have been monitored for indicator bacteria concentrations since the early 1980s. The indicator that has been used at both outfalls is fecal coliforms. This indicator is used as a surrogate to assess the potential for human exposure to wastewaters in the marine environment related to the bacterial content of the wastewater.

Macaulay and Clover points surface fecal samples have been collected monthly since the 1980s. However, sampling stations have changed over time. From 1990 to 1999, stations were sampled both around each outfall (i.e., 8 Macaulay stations and 13 Clover stations) and along the shoreline (11 Macaulay stations and 8 Clover stations). The sampling stations were updated in 2000 with the addition of more stations around each outfall and the elimination of the shoreline stations. Potential effects at the shoreline have been attributed to stormwater discharges which are currently monitored by the Vancouver Island Health Authority and the CRD Stormwater, Harbours and Watersheds Program.

The SETAC panel recommended a review of this monitoring component (SETAC, 2006). Their recommendations included an evaluation of enterococci as a human health indicator near the outfalls and a review of the monitoring frequency and station spatial distribution. A review of this program component was also suggested in the 2007 MMAG letter report to the MoE. To partially address these recommendations, a pilot study was conducted in 2010 which increased sampling frequency to five samples in 30 days during the summer months. This pilot will allow the CRD to determine if fecal coliform levels exceed BC MOE WQG for recreational primary contact, as they were defined (see Section 3.2), during the time of year when the most recreational activity is expected around the outfalls. Upon recommendation from the MMAG, the CRD began collecting measurements of dissolved oxygen (DO) in surface water in February 2010, at the same time as fecal coliform samples. The goal of these measurements was to test for potential impacts of the plume on oxygen levels in surface waters, by testing for a correlation between higher fecal coliform counts and lower DO.

As mentioned previously, CRD and MOE staff recently completed a review of the entire WMEP, including the surface water monitoring component. As a result of this review, a substantially revised surface water monitoring program will be implemented in 2011, and it will include quarterly five-in-30 sampling, samples collected at various depths in the water column, and analysis of enterococci. The use of enterococci as an indicator has been recommended by the MMAG and Health Canada for use in assessing recreation use of waters. Enterococci are now considered ideal to assess recreational quality because they survive longer than fecal coliforms in marine waters, and are therefore preferred when there is considerable time or distance between the source of fecal pollution and the bathing area (Health Canada, 1992). Since fecal coliforms do not survive well in marine waters, the use of the fresh water maximum limit may increase the risk of illness (Health Canada, 1992). The revised monitoring program is intended to address all of the concerns identified by SETAC, MOE and the MMAG. Additional details about the revised monitoring program will be presented in an upcoming report and are available upon request from the CRD Environmental Sustainability department.

3.2 Methods

Surface water samples were collected monthly in 2010 in the vicinity of the Macaulay and Clover points outfalls using a 6m research vessel positioned by differential global positioning system. Sampling stations are presented in Figure 3.1. The extensive sampling grid (total of 37 stations per outfall) is used to ensure that a broad area above each outfall is covered. In addition to these stations, a current drogue was released at the onset of each sampling event and a sample was collected at the location to which the drogue travelled during the sample collection process. Samples were collected in sterile, wide-mouth bottles by rapidly submerging open, upright bottles to 1m depth. Dissolved oxygen (DO) measurements were simultaneously made with an YSI DO meter. Sampling was scheduled for periods of slack or low current (i.e., potential worst case scenario); however, weather delays occasionally resulted in sampling

during moderate to high currents. Refer to CRD (CRD, 2011f) for comprehensive descriptions of sampling techniques, station codes and location coordinates.

Fecal coliforms were enumerated using 0.45µm membrane filters on mFC medium at 44.5°C for 24 hours. Results were evaluated against those developed by Warrington (1988) for MoE (2006a; BCMoE, 2006b) for recreational primary contact. The BC MoE guideline is based on the geometric mean of five samples collected in 30 days not exceeding 200 CFU/100mL. Re-sampling is recommended when any sample exceeds 400 CFU/100mL. It is important to note that the monthly CRD results cannot be compared to the guideline as it was defined because CRD sampling frequency (i.e., once per month) was not adequate for a direct comparison. Comparisons to the 200 CFU/100 mL value were conducted only to evaluate whether the fecal coliform concentrations in surface waters were above benchmarks for potential effects on recreation and for comparison to historical results. Re-sampling when a single sample exceeded 400 CFU/100 mL did not occur due to time and cost restraints.

The summer pilot study was conducted at Clover Point between June 15 and July 14 and at Macaulay Point between June 16 and July 13. Samples were collected weekly for a total of five samples in 30 days. The pilot study used the same sampling and analytical methods as the routine surface water sampling program. Unlike the monthly monitoring results, the results of this pilot study could be compared to the primary contact recreation guidelines as they are defined.

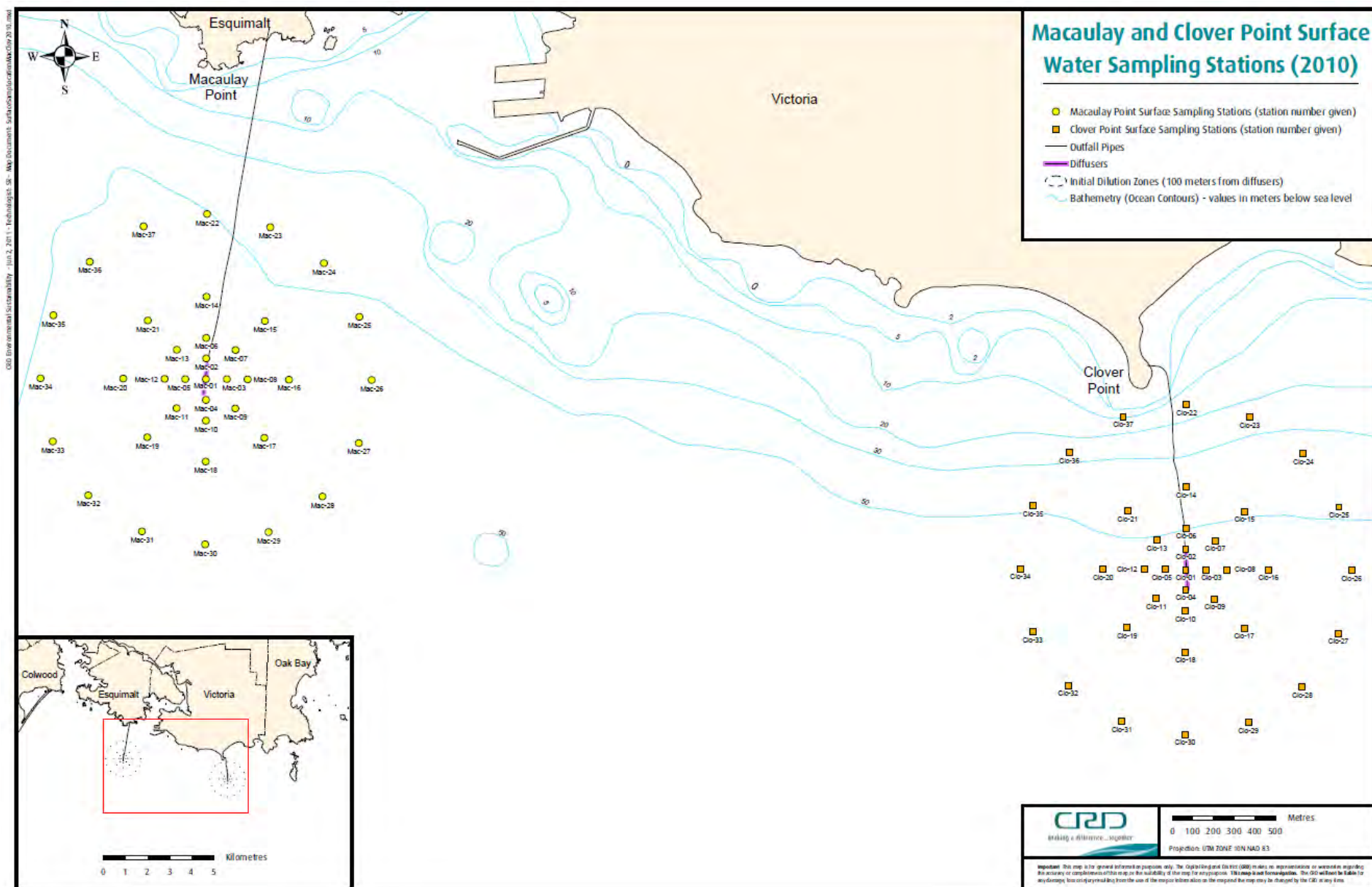


Figure 3.1 Surface Water Sampling Stations

3.3 Results and Discussion

3.3.1 Macaulay Point

Fecal coliform results for each sampling event at Macaulay Point (including station geometric means) are presented in Appendix C1. All station geometric means were an order of magnitude below 200 CFU/100 mL, indicating that the potential for human exposure to the Macaulay Point wastewaters in the marine environment was likely low. All individual stations had geometric means of 26 CFU/100 mL or less. Nineteen individual measurements out of 456 (representing 4.2% of the surface water samples) were above the value of 200 CFU/100 mL (Appendix C1), occurring mostly in October, suggesting that diluted effluent was surfacing during these sampling events. The maximum fecal coliform concentration measured in 2010 was 12,490 CFU/100 mL measured during a visible plume surfacing event within the IDZ on September 14. Figure 3.2 provides an indication of the spatial distribution and frequency of individual fecal coliform results for 2010 and denotes instances where results were over 200 CFU/100 mL.

Overall, results were within the concentrations predicted by hydrodynamic modeling (Hodgins, 2006). Recent modeling work predicted a less than 5% chance that the Macaulay Point effluent may reach the surface during slack tide in winter and an even lower chance during other times of the year (as seen in September and October). Although the plume is highly diluted by the time it reaches the surface on these occasions (average dilution of 1580:1), fecal coliform concentrations above 200 CFU/100 mL could sometimes be detected (Hodgins, 2006). Summer plume surfacing events are also predicted at both outfalls, associated with the morning flush in the wastewater system, weak water column stratification and slack tide (Lorax, 2009). These events are predicted to be less frequent than in winter. During summer, the core of the plume is predicted to be trapped at depth, but the diluted edge of the plume is predicted to occasionally surface.

Overall, the data indicate that the Macaulay Point effluent plume was predominantly trapped below the surface as predicted by the model, and that the outfall diffuser was resulting in adequate dilution. Had the effluent plume not been predominantly trapped, more frequent high fecal coliform concentrations would have been observed, particularly at stations approximately 100m from the outfall near which the plume is predicted most likely to surface (Hodgins, 2006). For example, surface water fecal coliform concentrations of approximately 3,635 CFU/100 mL would be expected if the 1580:1 dilution factor was applied to the 2010 mean wastewater fecal coliform concentration (5,744,000 CFU/100 mL; Table 2.4).

Figures 3.3 and 3.4 present the monthly and annual fecal coliform geometric means of all stations over time. Fecal coliform concentrations have varied over the years with some small increases or decreases observed. A small increase in fecal coliform concentrations was observed from 2000 to 2003, with a decrease in 2004. A visual inspection of the outfall by a submersible, remotely operated vehicle (ROV) during the summer of 2003 revealed a large crack in the diffuser. This crack was not present during the previous inspection in 2000. During the scheduled repair work in September 2004, the repair crew identified a second large crack. Both cracks were repaired and the diffuser ports were cleaned. The data in Figure 3.3 suggests that the cracks may have initially occurred in 2001 and gotten worse over time until the repair in September 2004.

Subsequent data in 2008 to 2010 shows a higher percentage of values above 200 CFU/100 mL in comparison to 2004 and 2005. The increased frequency of relatively high values could be related to overall outfall performance. As discussed in Section 2, recent outfall inspections (2005 and 2009) indicate that encrusting sea life has blocked some of the diffusers and there may be minor cracks in the outfalls. These factors could reduce the dilution efficiency of the outfalls, but additional data are needed to confirm these conclusions. The CRD is planning outfall repairs in 2012.

Figure 3.5 and Appendix C3 present the results of the pilot study (sampling five times in 30 days). The results indicate that the geometric means of the five summer sampling events were less than 8 CFU/100 mL at all stations, which is less than the BC MoE water quality guideline for recreational primary contact of 200 CFU/100 mL. There were no individual results above 400 CFU/100 mL.

Appendix C6 presents DO measurements taken over each sampling period except for Jan 13, August 4 and November 25 when the DO meter was unavailable. The results indicate lower DO measurements in the summer months when the surface temperatures were warmer (i.e., Jun, July, Aug, Sept and October) and higher measurements in the colder months (i.e., Feb, March April, May and Dec). DO levels did not correlate with fecal coliforms, suggesting that the sewage plume does not impact DO in surface waters near Macaulay Point.

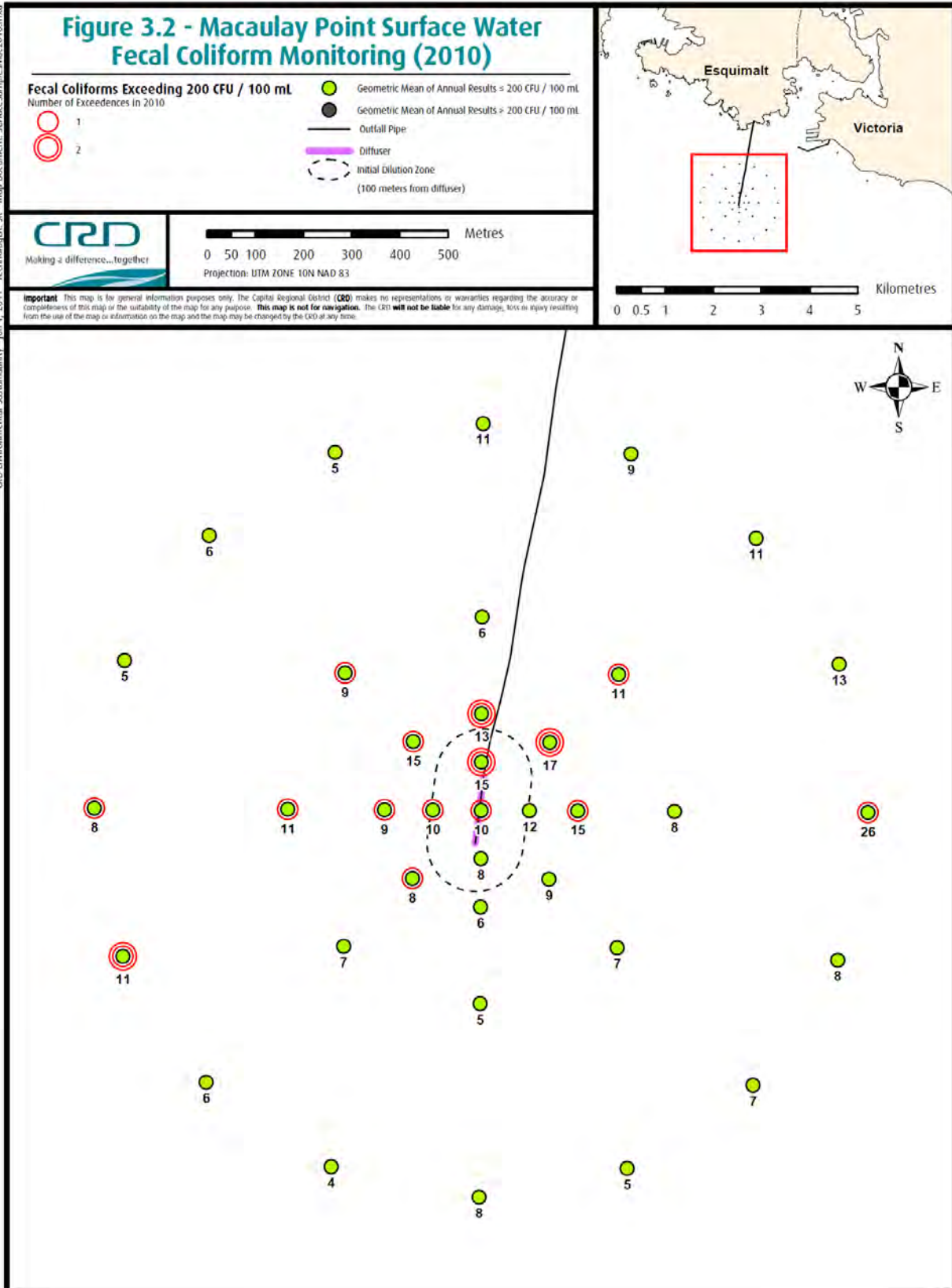


Figure 3.2 Macaulay Point Surface Water Fecal Coliform Monitoring (2010)

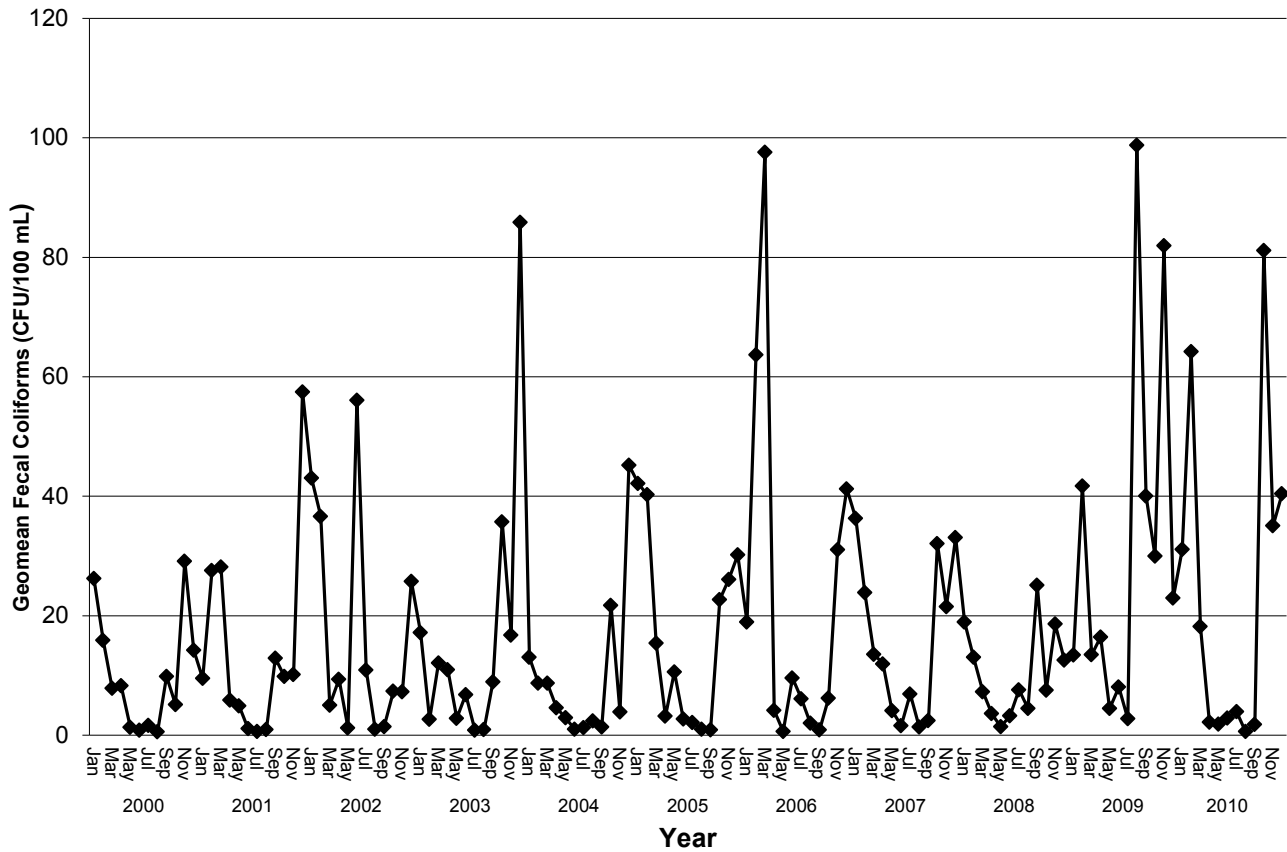


Figure 3.3 Macaulay Point Fecal Coliform Time Series 2000-2010 (Geometric Means of All Stations)

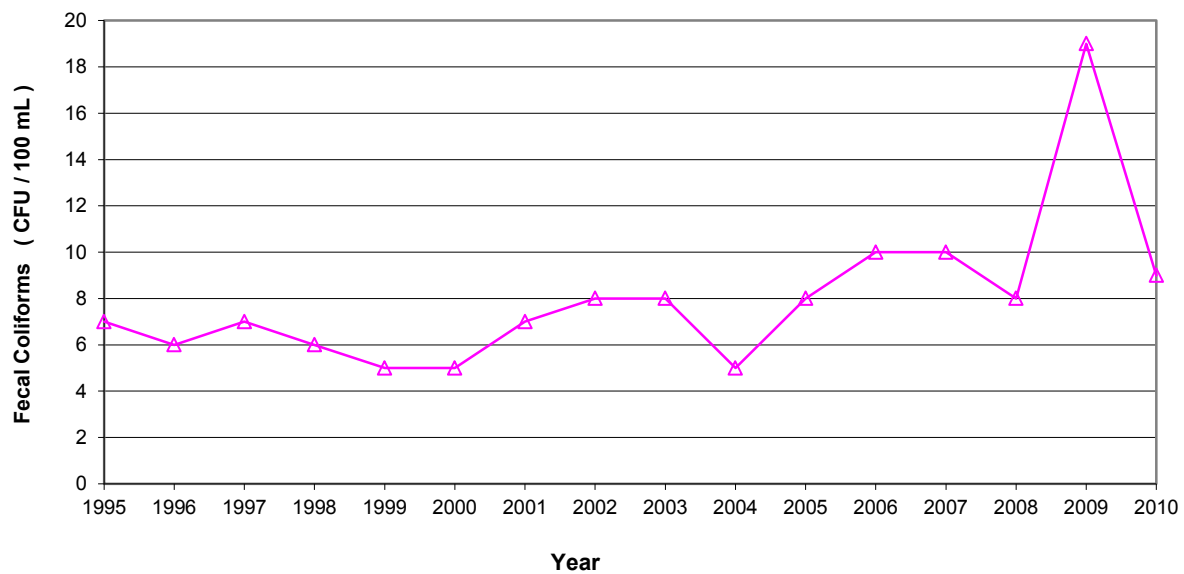


Figure 3.4 Macaulay Point Annual Fecal Coliform Time Series (Geometric Means of All Stations)

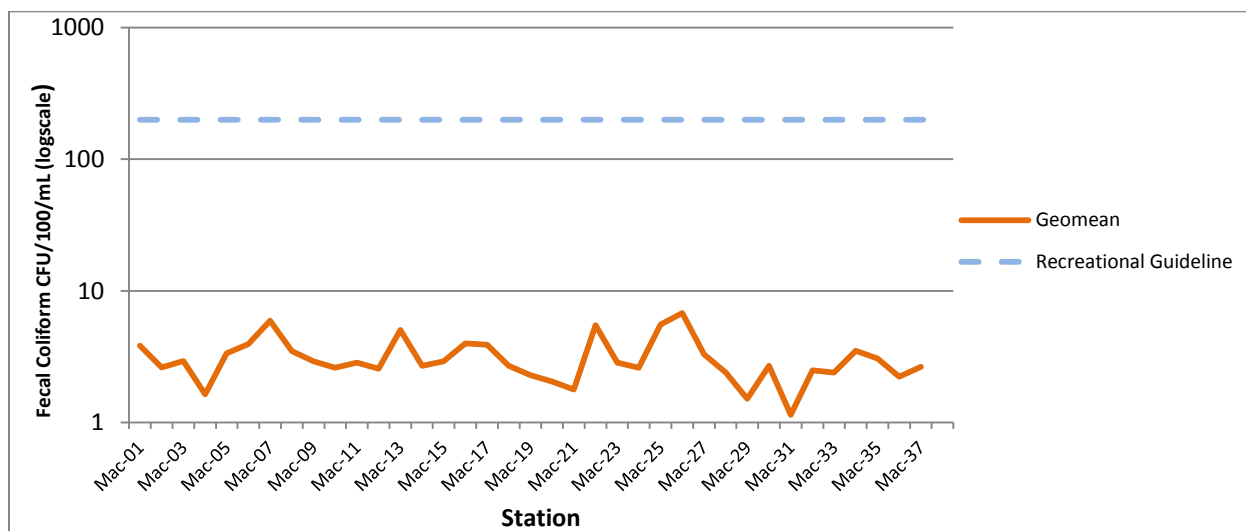


Figure 3.5 Macaulay Point Outfall Five in 30 Day Sampling Fecal Coliform

3.3.2 Clover Point

Fecal coliform results for each sampling event at Clover Point (including station geometric means) are presented in Appendix C2. Fecal coliform station geometric means were approximately an order of magnitude below the value of 200 CFU/100 mL, indicating that the potential for human exposure to Clover Point wastewaters in the marine environment was likely low. All stations had geometric means of 50 CFU/100 mL or less. There were 23 individual results out of 455 (representing 5.0% of surface water samples) above the value of 200 CFU/100 mL. Most of these 23 results occurred in December, suggesting the effluent was surfacing during this sampling event. The maximum fecal coliform concentration measured in 2010 was 2,300 CFU/100 mL during October at a station located outside of the IDZ. Figure 3.5 provides the spatial distribution and frequency of individual fecal coliform results and denotes instances where results were over 200 CFU/100 mL in 2010.

Results were within the expected concentrations predicted by hydrodynamic modeling (Hodgins, 2006). Recent modeling work predicted a less than 2% chance that the Clover Point effluent plume may reach the surface during slack tide in winter, and an even lower chance during other times of the year (Hodgins, 2006). Although the plume is highly diluted by the time it reaches the surface (average dilution of 1500:1), fecal coliform concentrations above 200 CFU/100 mL could sometimes be detected (as seen in December). Summer plume surfacing events are also predicted at both outfalls, associated with the morning flush in the wastewater system, weak water column stratification and slack tide (Lorax, 2009). Events are predicted to be less frequent in summer than in winter. During summer, the core of the plume is predicted to be trapped at depth, but the diluted edge of the plume is predicted to occasionally surface.

Overall, the data indicate that the Clover Point effluent plume was predominantly trapped below the surface as predicted by the model, and that the outfall diffuser was operating as expected during the majority of the year. Had the effluent plume not been predominantly trapped, more frequent high fecal coliform concentrations would likely have been observed, particularly at stations approximately 100m from the outfall near which the plume is predicted most likely to surface (Hodgins, 2006). For example, it is expected that surface water fecal coliform concentrations greater than 3,538 CFU/100 mL would be observed if adequate dilution was not being achieved and the 1500:1 dilution factor was applied to the 2010 mean wastewater fecal coliform concentration (5,308,000 CFU/100 mL; Table 2.5).

Figures 3.6 and 3.7 present the monthly and annual fecal coliform geometric mean of all stations over time. Fecal coliform concentrations have varied over the years. Concentrations increased from 2004 to

2008 (with the exception of 2006), and decreased slightly in 2009 and 2010. More data is required to determine if these variations constitute a trend. As discussed in Section 2, recent outfall inspections (2005 and 2009) indicate that encrusting sea life has blocked some of the diffusers and there may be minor cracks in the outfalls. These factors could be reducing the dilution efficiency of the outfalls, but additional data are needed to confirm these conclusions. The CRD is planning another outfall inspection in 2012. However, any necessary maintenance on the Macaulay and Clover points outfalls will only be undertaken if it is confirmed that they will continue to be part of the future sewage treatment system.

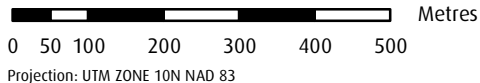
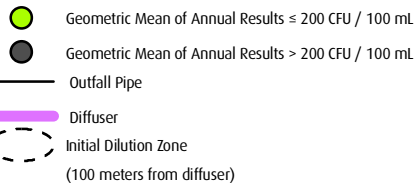
Figure 3.8 and Appendix C4 present the results of the pilot study (sampling five times in 30 days). The results indicate that the geometric means of the five summer sampling events were less than 14 CFU/100mL at all stations, which is considerably less than the BC MoE working water quality guideline for recreational primary contact of 200 CFU/100 mL. There were no individual results above 400 CFU/100 mL.

Appendix C5 presents DO measurements taken over each sampling period except for January 14, August 5 and November 24, when the DO meter was unavailable. The results indicate lower DO measurements in the summer months when the surface temperatures were warmer (i.e., June, July, August, September and October) and higher levels in the colder months (i.e., February, March, April, May and December). There was no correlation between DO and fecal coliform levels, suggesting that the plume does not impact dissolved oxygen in surface waters surrounding the Clover Point outfall.

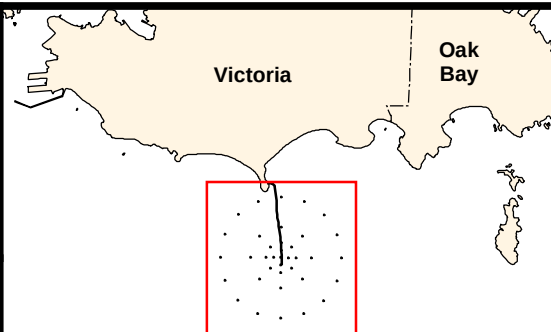
Figure 3.6 - Clover Point Surface Water Stations Fecal Coliform Exceedences (2010)

Fecal Coliforms Exceeding 200 CFU / 100 mL

Number of Exceedences in 2010

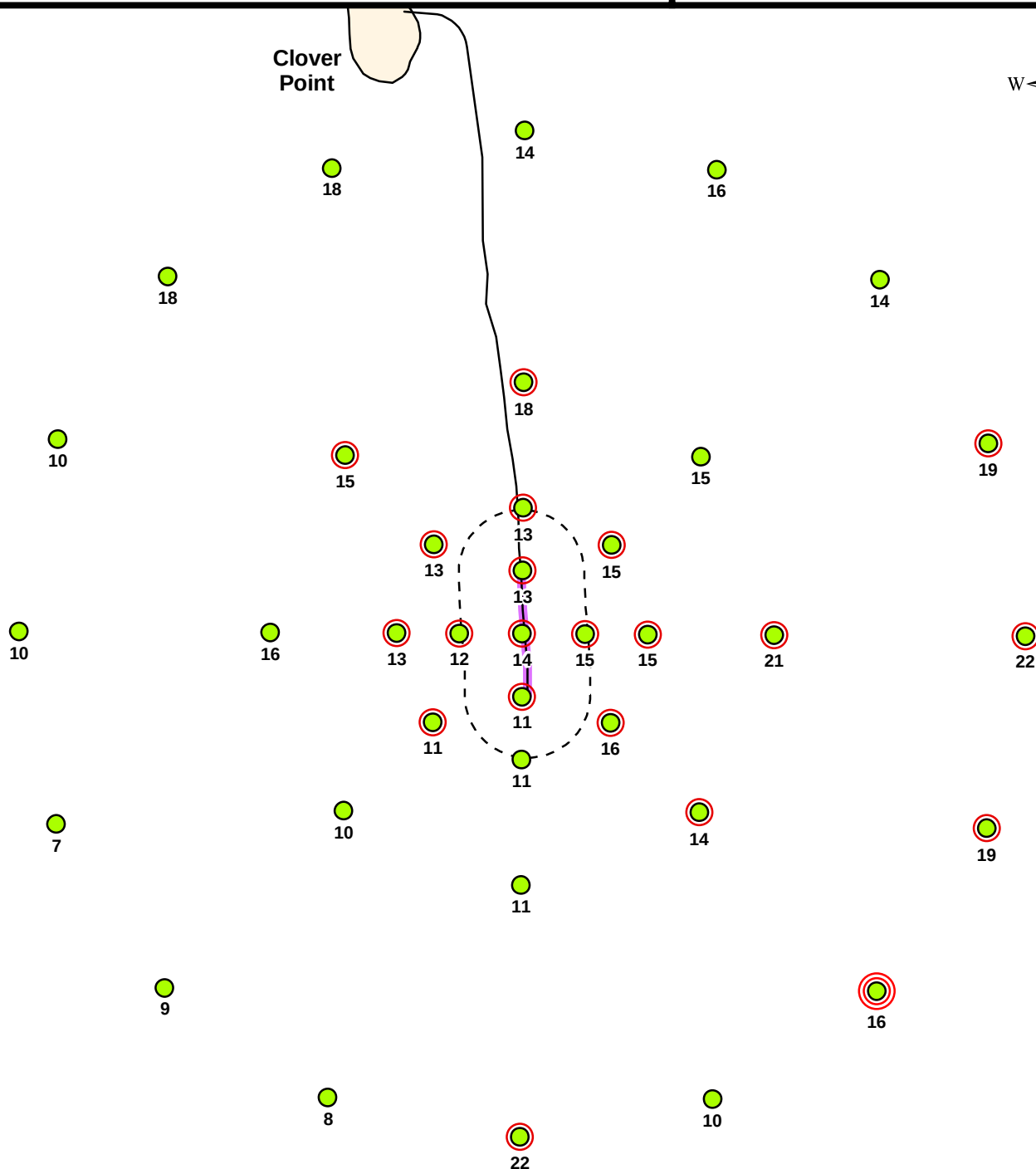
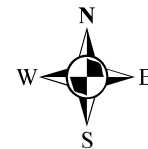


Projection: UTM ZONE 10N NAD 83



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Clover Point



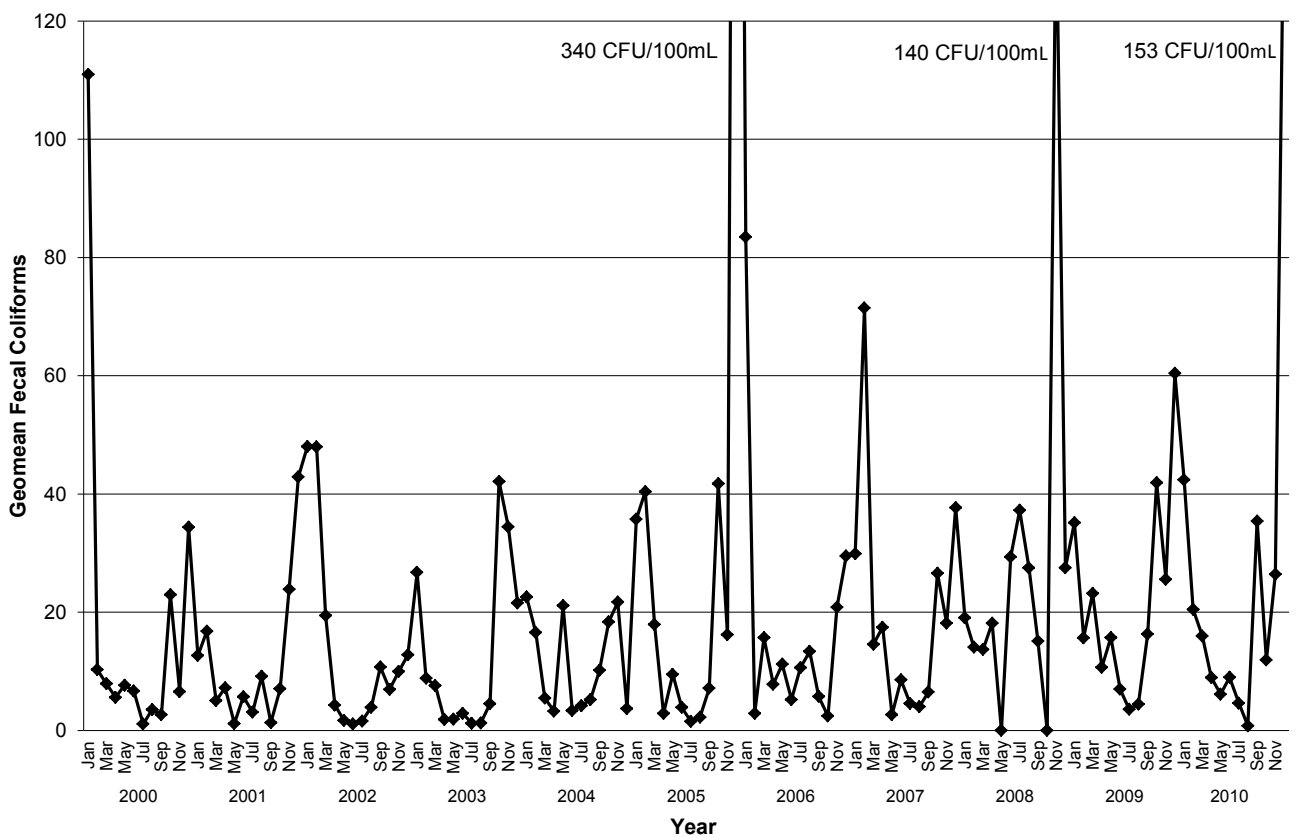


Figure 3.7 Clover Point Fecal Coliform Time Series 2000-2010 (Geometric Means of All Stations)



Figure 3.8 Clover Point Annual Fecal Coliform Time Series (Geometric Means of All Stations)

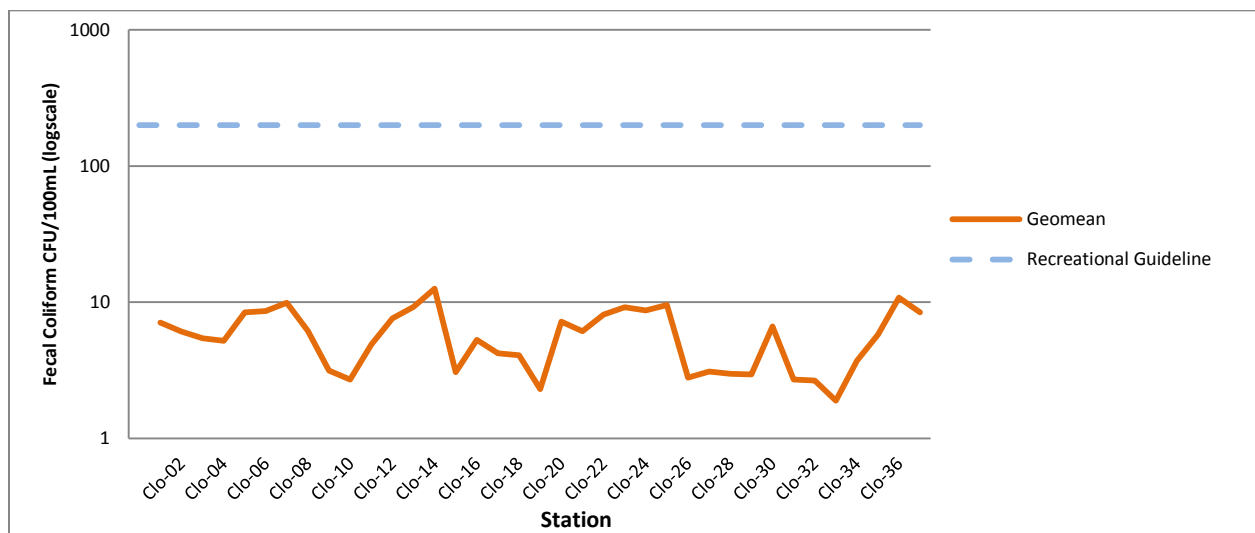


Figure 3.8 Clover Point Outfall Five in 30 Day Sampling Fecal Coliforms

OVERALL ASSESSMENT

Overall, the 2010 fecal coliform results indicated that the outfall plumes were predominantly trapped below the ocean surface and the diffusers were working as expected for most of the year. In addition, the potential for human exposure to high fecal coliform concentrations from the wastewaters was also likely low around the outfalls, as all geometric mean results were below thresholds used to assess potential human health risks in surface waters, including the results from the Five-in-30 summer sampling event.

Over the last five to seven years, there has been an increased frequency of fecal coliform observations greater than 200 CFU/100 mL. This could be an indication of reduced outfall diffuser efficiency as overall flow volumes and wastewater fecal concentrations have not changed substantially over this time period. Reduced dilution efficiency is likely due to the blockage of some diffuser ports and some minor cracks in the outfalls as observed during recent outfall inspections. The CRD is planning outfall repairs in 2012.

Finally, the CRD intends to implement a substantially revised surface water monitoring program in 2011 to address various concerns about the sampling design that have previously been identified by SETAC, MOE and the MMAG.

4.0 SEAFLOOR MONITORING

The effects of the wastewater discharges on the seafloor adjacent to the Macaulay Point and Clover Point outfalls are measured in a variety of ways as part of the WMEP. The seafloor is monitored by analyzing the sediments at and near the two outfalls for a series of chemical substances. The health of two different groups of organisms living on and in the seafloor are also assessed: benthic organism community structure analyses are used at the Macaulay Point outfall while deep-sea mussel chemical, morphological, reproductive and community structure analyses are conducted at the Clover Point outfall. Appendices A1 through A3 present the parameters and stations included in the 2010 seafloor monitoring component of the WMEP.

The reason for the different biological indicators at each outfall is related to the nature of the respective seafloor substrates. The seafloor at the Macaulay Point outfall is composed of soft, muddy and sandy sediments; benthic organisms (i.e., living in the sediments) are numerous in this type of environment. The seafloor at the Clover Point outfall is composed of pebbles, rocks, boulders and coarse-grained sediments. This type of environment is ideal for epibenthic organisms (i.e., living on the seafloor) such as deep-sea mussels.

Seafloor sampling follows established protocols and guidelines that have been developed to standardize marine sampling techniques and help to reduce variability between sampling events.

4.1 Macaulay Point

4.1.1 Sediment Chemistry

4.1.1.1 Introduction

Sediments are collected annually from stations at the Macaulay Point outfall and Parry Bay (PB) reference stations to assess the concentrations of a variety of substances (Appendix A2) and for comparison to relevant sediment quality guidelines.

It should be noted that, based on the recent review of the WMEP by CRD and BC MOE staff, significant changes to the sediment monitoring program are planned for 2011. These changes will include the addition of comprehensive sediment toxicity assessments and a revision of the target analyte list, including expanded high resolution analyses. These WMEP additions will be balanced (from a financial perspective) by a reduction in both sampling frequency (from annual to twice in a five year cycle) and the number of stations. Further details about the revised WMEP will be provided in a future report and are available upon request from the CRD Environmental Sustainability department.

4.1.1.2 Methods

Seafloor sampling followed the PSAMP (2002) protocols and guidelines. Sampling was conducted off the 20 m research vessel Richardson Point, using a 0.1m² Van Veen grab sampler (Picture 4.1).

Sediment samples were collected from 23 stations located in the near- and far-fields of the Macaulay Point outfall in August and September, 2010 (Figure 4.1). Samples were also collected from five associated reference stations at Parry Bay, located approximately 10km SW of the outfall; two of which were added in 2005 to improve statistical power. The area 100 m around the diffuser section of the outfall is defined as the initial dilution zone (IDZ). Stations are designated as follows:

- M (for Macaulay)
- 1 (for stations at or just outside the IDZ) or 2, 4 and 8 respectively (for the stations situated approximately 200 m, 400 m and 800 m from the outfall terminus)
- E, N, etc. (for the compass direction from the outfall terminus)



Picture 4.1 Seafloor Sampling Van Veen Grab

Three replicate grabs were collected and composited into one sample representing each station using methods consistent with previous monitoring years (i.e., collecting sediments only from the top 2 cm of each grab). Additional samples were collected at M1SE, M2E, M8E and PB1 from which composites were collected representing the top 10 cm of each sediment grab. These additional top 10 cm samples were collected in conjunction with sediment toxicity samples required as part of the pre-discharge monitoring program for the proposed advanced wastewater treatment facility at McLoughlin Point. The sediment chemistry results for the top 10 cm samples are presented in this report whereas the sediment toxicity test results will be presented in a future report to be generated to satisfy Environment Impact Study requirements under the BC Municipal Sewage Regulation. CRD (CRD, 2011e) contains more details about the sampling methodologies along with target station coordinates. A list of substances analysed can be found in Appendix A1. Sediments from the outfall terminus (M0) and the PB1 reference station were analysed for approximately 151 priority substances. Sediments from the remaining outfall and reference stations were analysed for a subset of 78 priority substances that were selected based on their frequency of detection in wastewater and in sediments from the outfall station M0.

Ten percent of the sediment samples were randomly chosen for additional laboratory and field triplicate analyses. The analytical laboratory, ALS Environmental (Vancouver, BC), also conducted internal QA/QC analyses including method analyte spikes, method blanks and standard reference materials. Appendix A4 contains a summary of the sampling and analytical QA/QC program. Additional information can be found in CRD (CRD, 2011e).

DATA QUALITY ASSESSMENT

All 2010 priority substance results were screened using the CRD analytical data QA/QC assessment procedure (Appendix A4). This procedure is based on DQOs that were originally developed with the MMAG in the early 1990s, following established laboratory analytical standards, and were re-evaluated and updated in 2007, and revised again in 2009 (Golder, 2007d; Golder, 2009c).

Application of the revised DQOs involved procedures that evaluated the data for precision (based on variability in laboratory or field replicates), bias (based on recoveries of spikes, surrogate standards or certified reference materials) and representativeness (based on blank sample contamination), using specific criteria for each analytical group (Figure 2.1, Table 4.1 and 2.2). The extremity of precision, bias or representativeness failures was determined, and data with marginal failures were flagged, while data with severe failures were rejected. All data that exhibited failures were reviewed and a determination of the cause(s) was undertaken. Except for frequency of detection calculations, rejected results were not used for further analyses (e.g., statistical analyses) and are not presented in this report.

COMPARISON TO SEDIMENT QUALITY GUIDELINES

Sediment quality guidelines (SQGs) are frequently used to evaluate the potential for adverse biological effects associated with contamination of sediments as part of monitoring, source control, cleanup and dredging programs. There are multiple SQGs in use in North America today, varying considerably in the substances that are included, levels derived for the substances, and methods of derivation. In 2007, Avocet Consulting conducted an evaluation of the reliability of select marine SQGs to determine which ones should be most applicable for monitoring at the Macaulay and Clover points outfalls (Avocet, 2007). A detailed description of this review was presented in the 2006 WMEP Annual Report (CRD, 2007).

Based on the results of the reliability analysis, the following SQGs were determined to be the most relevant and reliable, specifically for the Macaulay Point results, and therefore were used in the assessment of sediment quality data in this report: the WSDOE 2LAET (WSDOE, 1991); the BC SedQCtcs (BCMWLAP, 2003), and the CCME PEL (CCME, 2002).

DETAILED STATISTICAL ANALYSIS

A detailed statistical analysis of sediment data is undertaken every three to five years, with the most recent assessment completed in 2010. An analysis of the spatial and temporal trends for the entire period of record available at that point (i.e., 1990–2009) using the traditional distance groups (e.g. 100 m, 200 m, etc.) and the newer distance-direction groupings (i.e. near-field, far-field, etc.) was conducted by Golder (2010c). Methodologies were similar to previous trend reports (Golder, 2007c; Golder, 2008a; Golder, 2008b; Paine, 2004b). In addition, decision rules were applied in the sediment trend assessment to identify substances of interest in sediments. The decision rules were intended to distinguish substances that reflected localized contamination due to point source discharges rather than regional contamination and/or background concentrations of substances. The results of this trend assessment were presented in last year's annual report CRD (2010) and more details can be found in Golder (2010c). The next trend assessment will be undertaken after the collection of three more years of sediment chemistry data.

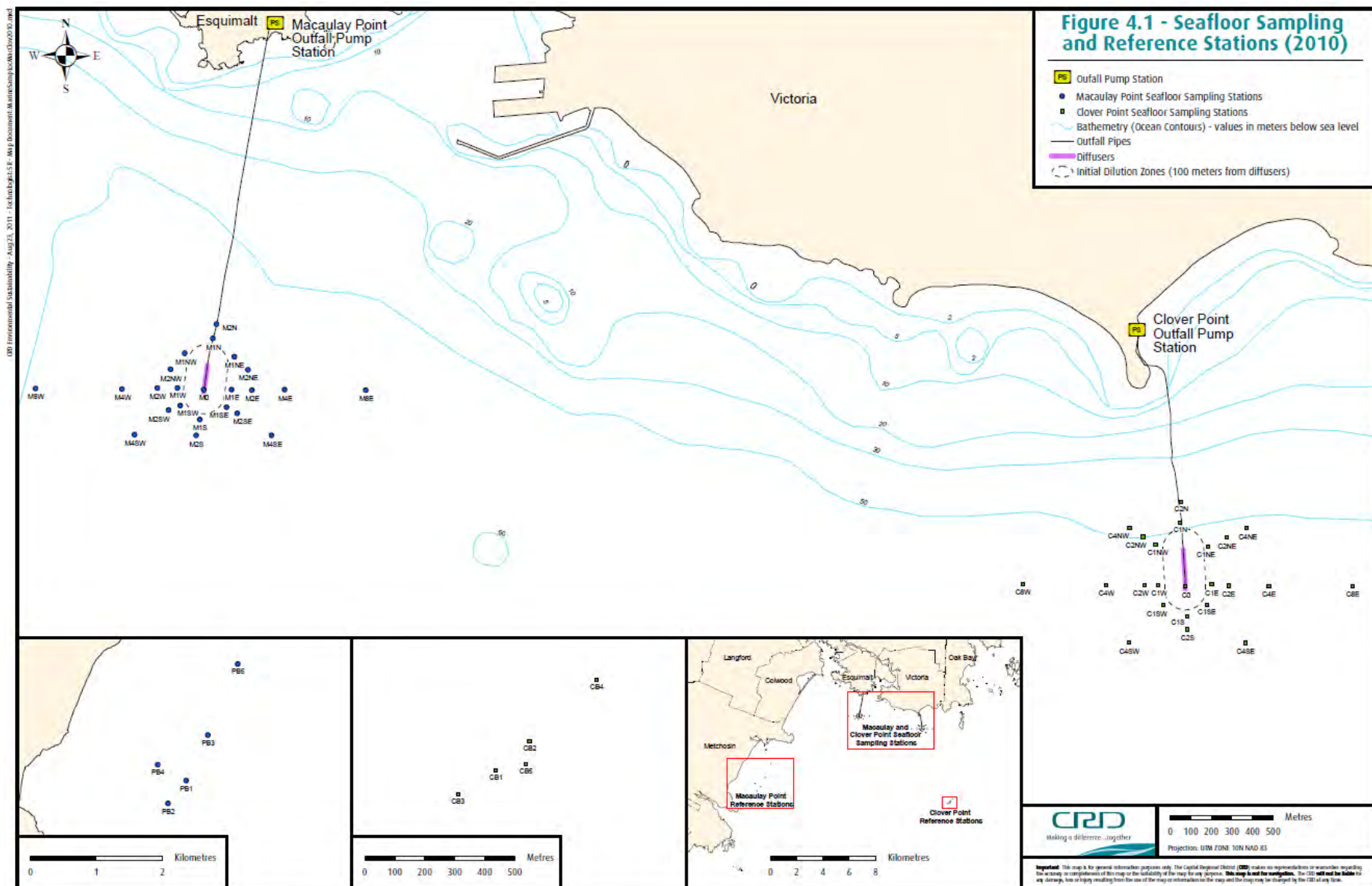


Figure 4.1 Macaulay and Clover Points Seafloor Sampling and Reference Stations

4.1.1.3 Results and Discussion

DATA QUALITY ASSESSMENT

Appendix D1 contains a summary of the 2010 data QA/QC assessment results. Sediment analytical results for 2010 are presented in Appendix D2 and summarized in this section. Individual data points that did not meet the CRD DQOs and therefore were rejected were not included in further analyses or presented in this report.

The substances with severe failures, resulting in rejection of data in at least one batch in 2010 were some metals and extractable metals (e.g. antimony, lead, silver, extractable copper), phenols, six PAHs (acenaphthene, anthracene, benz(a)anthracene, chrysene, fluoranthene and pyrene), bis(2-chloroethyl)ether and 2,4-dinitrophenol (Appendix D1).

High-resolution sediment analyses were also screened against the CRD DQOs. Two batch-wide DQO failures were identified for PCBs (PCB 11 and PCB TEQ [ND=1/2 DL]) and five batch-wide failures were identified for OC pesticides (e.g. 1,3-dichlorobenzene and Mirex).

All remaining sediment results passed both laboratory and CRD QA/QC DQOs (i.e., analyte spikes, method blanks, laboratory triplicates, field triplicates and standard reference materials) (CRD, 2011d).

COMPARISON TO SEDIMENT QUALITY GUIDELINES

The comparison of 2010 sediment chemistry results to the BC, CCME and WSDOE SQGs is presented in Table 4.1 and Appendix D2. Table 4.1 only shows those substances that exceeded at least one SQG.

The comparison of Macaulay Point sediment data to SQGs showed similar results to previous years. SQG exceedences were limited to the 200m stations. Outside of 100m IDZ, numerous PAHs (i.e., acenaphthene, anthracene, benz(a)anthracene, benzo(a)pyrene, chrysene, fluoranthene, ideno(1,2,3-c,d)pyrene, phenanthrene, pyrene), 1,4-dichlorobenzene, 1,2,4-trichlorobenzene, and phenol exceeded SQGs. Substances that had concentrations above at least one SQG within the 100 m IDZ were copper, mercury, acenaphthene, phenanthrene, and 1,4-dichlorobenzene. Overall, sediment chemistry data indicated that effects of the outfall on the seafloor were primarily limited to within the stations 200 m east of the diffuser.

One of the substances which was above the CRD SQGs in 2010 was 1,4-DCB, which is commonly used as an air freshener, a deodorizer in urinals and as a moth and bird repellent. Results for 1,4-DCB from 1990 to 2009 have also periodically been above the SQGs both within and just outside the IDZ. The most likely source of this substance in the region is the use of deodorizing and disinfectant tablets in urinals. Although 1,4-DCB is not persistent in air or surface waters, it has been found to accumulate in sediment (McPherson et al., 2002). The CRD RSCP is continuing to promote the use of products that do not contain this substance by providing educational materials aimed at business sectors and large organizations that frequently use urinal deodorizers.

In addition, the RSCP has developed a mass balance of priority contaminant discharges to the sanitary sewer (Golder, 2009d). The results of this research found that 1,4-DCB was frequently detected in Hartland Landfill leachate, but was infrequently or never detected in other sources and wastewater treatment plants. At Macaulay Point, 1,4-DCB was not detected in wastewater but was slightly above the MDL in some inputs. This could indicate that there may be some 1,4-DCB in the inputs that are potentially being removed in some unidentified sinks or that the imprecision close to the MDL is reflecting false positive values (Golder, 2010c).

Table 4.1 Comparison of Macaulay and Clover Points 2010 Sediment Concentrations to SQGs (Mean ± Standard Deviation for Replicates)

Grey highlighting indicates that concentration exceeds at least one of the criteria. All results expressed on a dry weight basis.

Sample ID	Total Metals	Total Metals	Polycyclic Aromatic Hydrocarbons									Chlorinated Hydrocarbons		Phthalate Esters	Non-Chlorinated Phenolics
	Cu Copper	Hg Mercury	Acenaph-thene	Anthracene	Benz(a)-anthracene	Benzo(a)-pyrene	Chrysene	Fluoran-thene	Indeno(1,2,-3-c,d)pyrene	Phenan-threne	Pyrene	1,4-Dichloro-benzene	1,2,4-Trichloro-benzene	Bis(2-ethylhexyl) phthalate	Phenol
units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
MDL	1	0.005	0.005	0.005	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.1	0.02
BC CSR Typical ¹	130	0.84	0.11	0.29	0.83	0.92	1	1.8		0.65	1.7				
CCME PEL ²	108	0.7	0.08890	0.245	0.693	0.763	0.846	1.494		0.544	1.398				
WSDOE 2nd Lowest AET ³	390	0.59	0.50000	0.96	1.6	1.6	2.8	2.5	0.69	1.5	3.3	0.11	0.051	1.9	1.2
C0	155	9.5	0.384	0.0893	0.139	<0.15	0.206	0.264	<0.11	0.455	0.247	0.08	<0.050	8.9	0.025
CB1	11±3	0.02±0	<0.0050	<0.0040	<0.010	<0.010	<0.010	<0.010	<0.010	0.01±0	<0.010	<0.010	<0.010	<0.10	<0.020
M0	224	1.66	0.0386	0.149	0.685	0.733	0.612	1.36	0.341	0.364	1.07	0.216	<0.050	<0.50	0.021
M100N	30.3±9.83	QA	QA	QA	QA	0.18±0.12	QA	QA	0.1±0.07	0.26±0.16	QA	<0.010	<0.010	<0.10	<0.030
M100NE	19.6	QA	QA	QA	QA	QA	QA	QA	0.117	0.342	QA	0.016	<0.010	0.16	<0.10
M100E	50.3±15.63	QA	QA	QA	QA	0.52±0.35	QA	QA	0.29±0.21	0.36±0.22	QA	0.11±0.05	0.01±0	1.66±0.35	<0.030
M100E (Top 10 cm)	45.3	1.12	0.106	0.216	0.485	0.415	0.465	0.914	0.216	0.737	0.811	0.101	<0.010	0.39	0.32
M100SE	238	QA	QA	QA	QA	QA	QA	QA	QA	8.7	QA	0.098	<0.010	0.19	<0.10
M100S	50.4	QA	QA	QA	QA	0.055	QA	QA	0.019	0.06	QA	0.065	<0.010	<0.10	<0.050
M100SW	109.3±14.5	0.86±0.2	0.05±0.02	0.13±0.06	0.35±0.1	0.67±0.21	0.32±0.08	0.68±0.33	0.39±0.12	0.42±0.25	0.73±0.15	0.21±0.04	<0.010	0.96±0.52	<0.040
M100W	67.7±12.19	0.32±0.22	0.01±0	0.05±0.02	0.1±0.07	0.11±0.05	0.09±0.06	0.18±0.09	0.05±0.04	0.18±0.1	0.16±0.1	0.06±0.01	<0.010	0.3±0.13	<0.030
M100NW	19.6	QA	QA	QA	QA	0.046	QA	QA	0.025	0.111	QA	<0.010	<0.010	<0.10	<0.10
M200N	25.2	0.056	0.0113	0.0246	0.068	0.082	0.062	0.152	0.048	0.086	0.129	<0.010	<0.010	<0.10	<0.020
M200NE	55.3	0.061	<0.010	0.0191	0.06	0.063	0.056	0.098	0.034	0.094	0.095	0.047	<0.010	0.1	<0.020
M200E	32.4	0.296	0.13	0.368	1.26	1.47	1.13	3.03	0.904	1.22	2.69	0.017	<0.010	<0.20	<0.020
M200E (Top 10cm)	43.4	0.114	0.211	0.3±0.32	1.41±1.71	1.57±1.87	1.3±1.55	2.74±3.33	1±1.26	0.95±0.89	2.46±2.91	0.058	0.173	<0.10	1.84±0.17
M200SE	59.9±27.1	0.56±0.33	0.07±0.05	0.17±0.1	0.38±0.22	0.41±0.24	0.34±0.19	0.70±0.39	0.22±0.13	0.58±0.28	0.59±0.34	0.11±0.01	<0.020	0.63±0.4	<0.22
M200S	14.5	0.0728	<0.0050	<0.0040	<0.010	<0.010	<0.010	0.013	<0.010	0.045	0.013	<0.010	<0.010	<0.10	0.023
M200SW	19.7	0.0522	<0.0050	0.0104	0.035	0.03	0.039	0.06	0.015	0.06	0.05	<0.010	<0.010	0.12	0.022
M200W	17	0.118	0.0069	0.0114	0.026	0.033	0.029	0.058	0.014	0.069	0.048	0.016	<0.010	<0.10	0.022
M200NW	19.3	0.0512	<0.0050	0.0044	<0.010	<0.010	<0.010	0.015	<0.010	0.047	0.015	<0.010	<0.010	QA	<0.020
M400E	73.5±12.6	0.07±0.03	0.01±0	0.01±0.01	0.04±0	0.04±0	0.05±0	0.06±0.01	0.03±0	0.07±0.03	0.06±0	0.01±0.01	<0.010	0.22±0.17	0.08±0.01
M400SE	36.4	0.151	<0.0050	0.0044	<0.010	<0.020	0.013	0.017	<0.010	0.04	0.018	0.015	<0.010	0.16	0.133
M400SW	13.6	0.0396	<0.0050	0.0051	0.013	<0.020	0.017	0.027	<0.010	0.049	0.03	<0.010	<0.010	<0.10	<0.020
M400W	15.5±0.99	0.05±0.01	0.004±0	0.02±0.01	0.04±0.05	0.04±0.05	0.05±0.05	0.08±0.09	0.02±0.03	0.07±0.02	0.07±0.07	<0.010	<0.010	<0.10	0.02±0.01
M800E	12.9	0.247	<0.0050	0.0074	<0.010	<0.020	0.014	0.026	<0.010	0.053	0.03	<0.010	<0.010	<0.10	<0.020
M800E (Top 10cm)	21.6	0.0525	<0.015	0.0391	0.224	0.198	0.216	0.218	0.084	0.09	0.234	<0.010	<0.010	<0.10	0.473
M800W	14.1	0.039	<0.0050	<0.0040	<0.010	<0.020	<0.010	0.019	<0.010	0.045	0.019	<0.010	<0.010	0.26	0.024
PB1	12.4±0.35	0.03±0	<0.0050	<0.0040	<0.010	<0.010	<0.010	<0.010	<0.010	0.03±0	<0.010	<0.010	<0.010	<0.10	0.01±0.01
PB1 (Top 10 cm)	11.4±1.65	0.03±0	<0.0050	<0.0040	<0.010	<0.010	<0.010	<0.010	<0.010	0.03±0	<0.010	<0.010	<0.010	<0.10	0.03±0
PB2	9.8±1.13	0.03±0	<0.0050	<0.0040	<0.010	<0.010	<0.010	<0.010	<0.010	0.03±0	<0.010	<0.010	<0.010	<0.10	<0.020
PB3	13	0.0358	<0.0050	0.0065	0.018	0.022	0.022	<0.010	0.012	0.051	0.027	<0.010	<0.010	<0.10	0.02
PB4	13.7	0.0396	<0.0050	<0.0040	<0.010	<0.010	0.014	<0.010	<0.010	0.057	0.023	<0.010	<0.010	<0.10	<0.020
PB5	16.1	0.0421	<0.0050	<0.0040	<0.010	<0.010	0.013	<0.010	<0.010	0.049	0.012	<0.010	<0.010	<0.10	<0.020

Note

QA" denotes that value has failed the data quality objective (DQO) screening, and has been rejected for use in statistical analyses.

For stations with multiple results (i.e., lab replicates or field replicates), average and standard deviation are presented

¹BC Contaminated Sites Regulation Typical Contaminated Site Criteria (BCMWLAP, 2003)

²Canadian Council of Ministers of the Environment Probable Effects Level (PEL) (CCME, 2002)

³Washington State Department of Ecology, 2nd lowest AET (WSDOE, 1991)

Sediment concentrations of phthalates around the Macaulay Point outfall are also variable from year to year, with some results above SQGs within and just outside the IDZ in one year and none the next. Phthalates are used in many different kinds of plastics and other products. Consequently, they are ubiquitous and are often present as laboratory contaminants. This results in a high degree of variability in the analysis of these chemicals. Analytical laboratories are working on developing methodologies that will reduce contamination of samples and increase the reliability of results.

In 2010, copper and mercury exceeded SQGs at Macaulay Point. Both metals exceeded SQGs within the IDZ (M0 and M1SW for both metals, plus M1E for mercury). In 2009 only mercury exceeded SQGs (M0, M2E and M2SE), and in 2008 mercury was rejected due to DQO at M0, with the highest retained concentrations found at M2SE and M2SW. Metal concentrations above SQGs vary from year to year and this can be partly attributed to the inherent difficulties with collecting representative sediment samples. There is potential to collect samples that contain particles of historically dumped municipal refuse, which can lead to difficulty when homogenizing samples and to episodic spikes in metal concentrations. This could lead to a confounding effect. However, since measurements over time are generally consistent, with only the occasional episodic spike, staff believe this outside influence will be identifiable. Copper, mercury and zinc have all exceeded SQGs at least once since 2000.

Historically, phenol has also exceeded SQGs in sediments from Macaulay Point both within and outside the IDZ and at the reference stations, particularly in 2006 (CRD, 2007). In 2010, phenol exceeded SQGs at M2E only. In 2009 phenol exceeded SQGs at multiple Macaulay Point stations (M0, M1E, M1N, M1S, M1SE, M1SW, M1W, M2N, M2SE), and in 2008 phenol exceeded SQGs at two stations.

When examining the trends in the SQG exceedences from previous years (i.e., 1990 to 2009) (Figure 4.2; (Golder, 2010c), the overall frequencies of exceedences for metals were low (<40%). The frequency of exceedence for lead appeared to have decreased over time with lower frequencies (0 to 10%) observed in the most recent years. The previous trend assessment (Golder, 2007c) also identified an apparent decline in the frequency of exceedences for copper, mercury and zinc. However, recent results showed frequencies that were in the range of some of the earlier years, resulting in no clear temporal trends for these parameters. No clear temporal trends were observed in the frequency of SQG exceedences for organic substances of interest due, in part, to the reduced period of record and greater variability of data (Golder, 2010c). The exceedence frequency in 2010 was similar to previous years.

According to Golder (2007c), the screening of Macaulay Point (and Clover Point) sediment chemistry against generic SQGs (i.e., those not developed specifically for Macaulay and Clover points) is likely to overstate the potential for adverse biological effects associated with SQG exceedences. The degree of over-protection is likely to be greatest for sediments containing elevated TOC concentrations. It is generally accepted that SQGs should only be applied as a conservative screening step, and exceedences should not necessarily be interpreted as equating with adverse biological effects (Chapman *et al.*, 1999). In addition, it is recommended that any SQGs used for screening purposes be paired with, or followed up by, confirmatory biological testing, in accordance with the frameworks described by CCME and BC MoE (Avocet, 2007). The CRD incorporates assessments of the benthic invertebrate community (Section 4.1.2) around Macaulay Point to confirm whether any SQG exceedences are leading to effects on biological communities.

OVERALL ASSESSMENT

The 2010 results were generally consistent with previous years and recent reviews (Golder, 2007c; SETAC, 2006). These findings concluded that, although there were demonstrable impacts of the outfall on sediment chemistry, this does not indicate that conditions are deteriorating over time. However, because there were SQG exceedences, the 2010 data do indicate that there is potential for the biological communities (within 200 m of the Macaulay Point outfall) to be affected by substances in sediments.

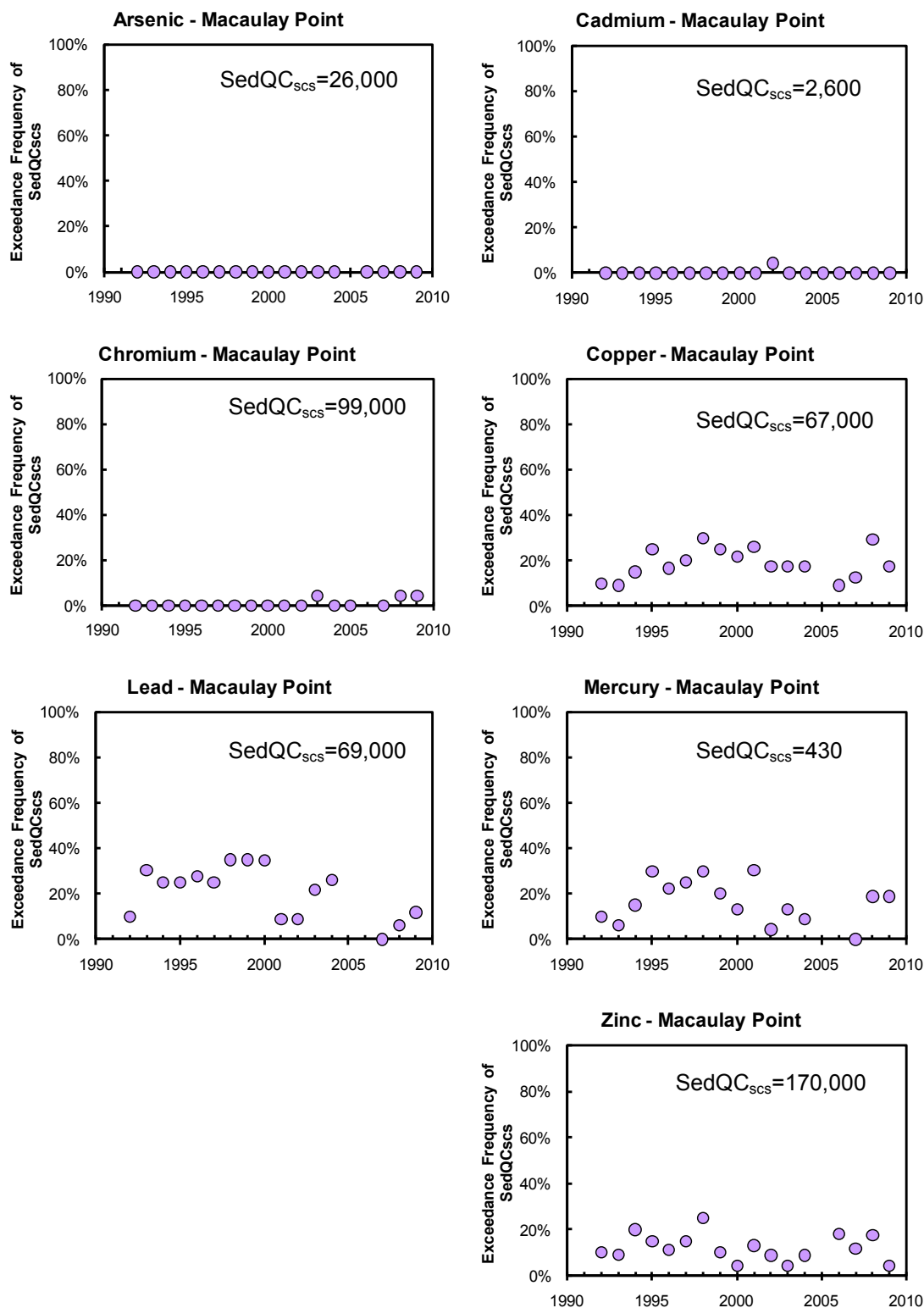


Figure 4.2 Temporal Trends in SQG Exceedences at Macaulay Point (Golder, 2010c)
a) Metals (all SQC values in ug/kg dry weight (BCM WLAP, 2003)) continued

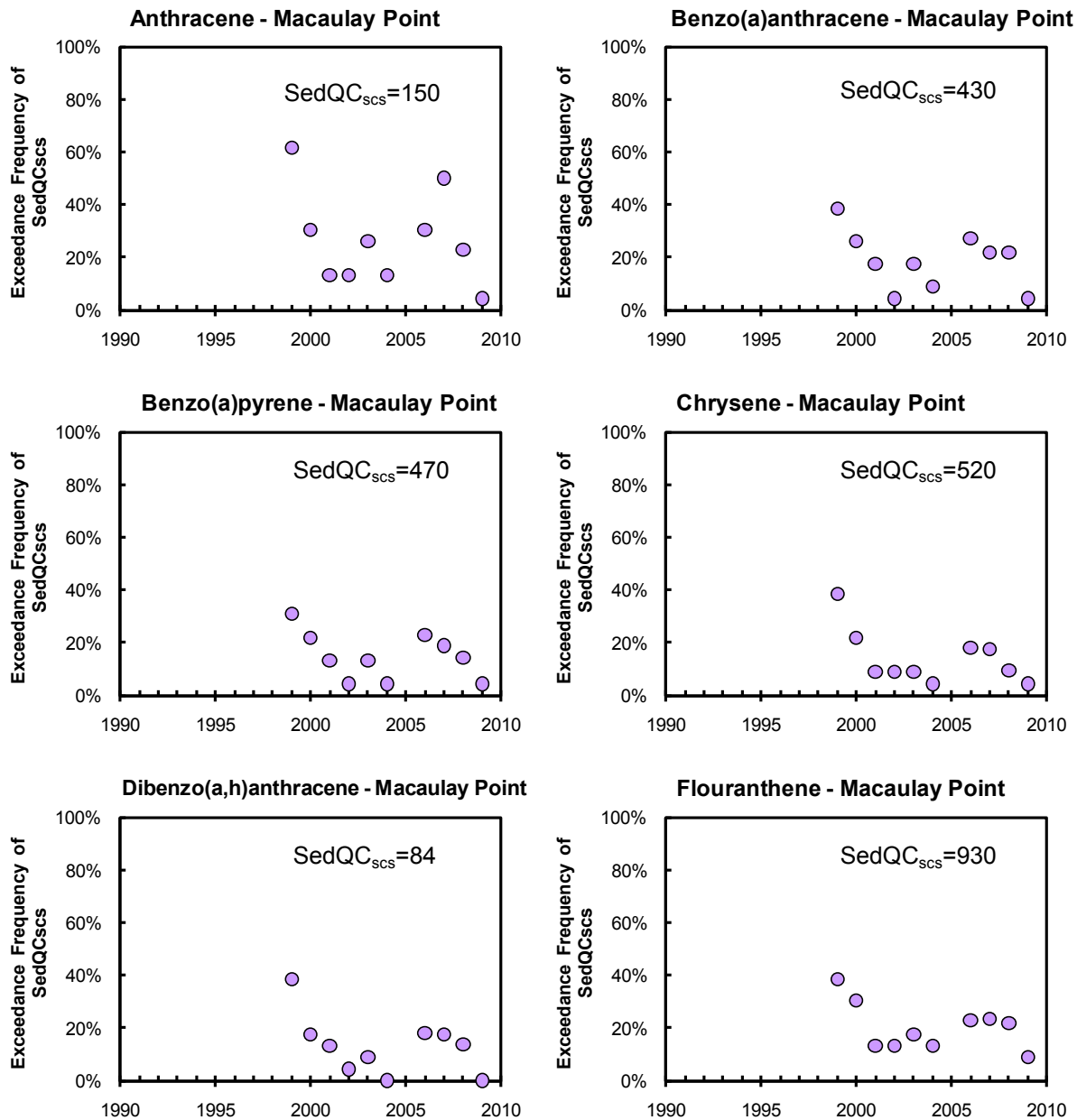


Figure 4.2, continued

b) Organics (all SQC values in ug/kg dry weight (BCMWLAP, 2003))

continued

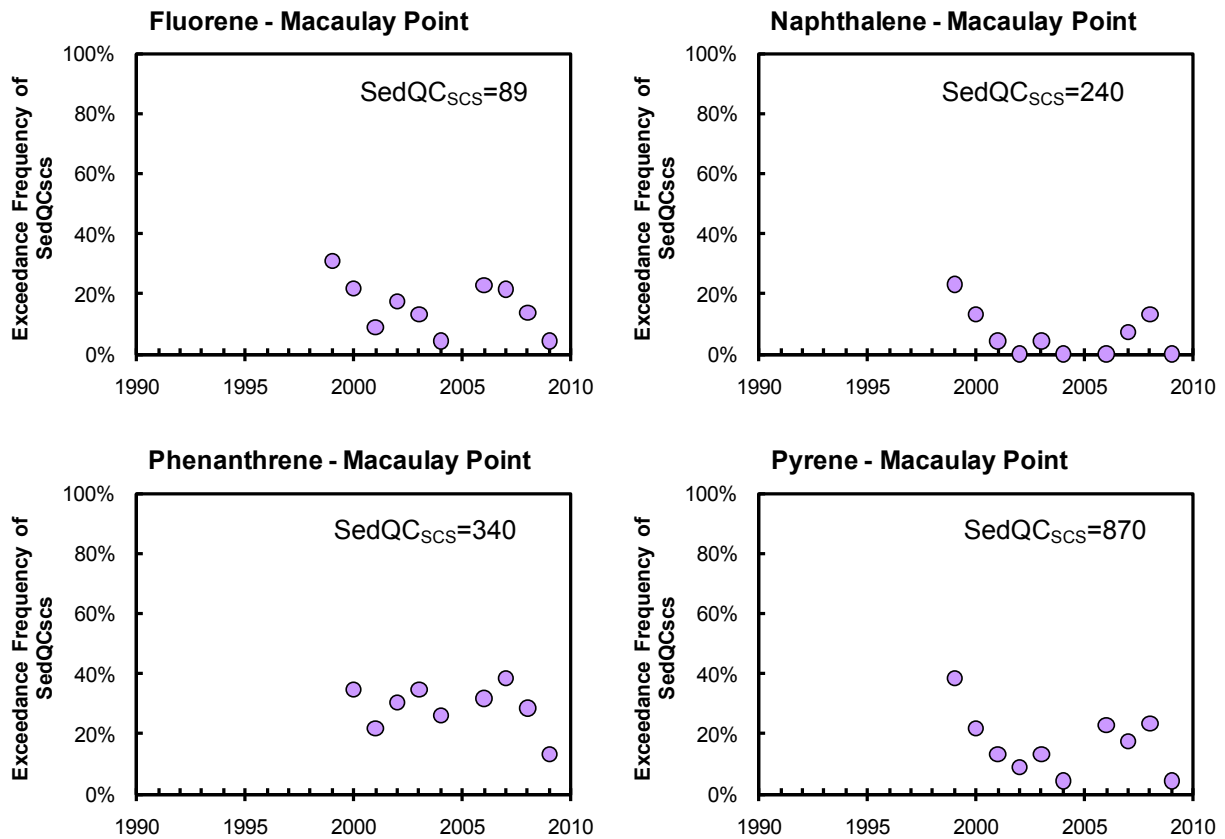


Figure 4.2, continued (Organics)

4.1.2 Benthic Communities

4.1.2.1 Introduction

Native communities of benthic invertebrates at and around the Macaulay Point outfall have been used as indicators of potential wastewater discharge effects since the late 1970s. Monitoring efforts were increased in the early 1990s to a frequency of once every three years. Since 2000, monitoring has been conducted annually, establishing a large database of information to assess potential effects on seafloor organisms related to the discharge of wastewater at Macaulay Point, both spatially and temporally.

The use of benthic invertebrate organisms as indicators of potential environmental effects is extensive. Measurements of change in benthic communities have been widely used in identifying and monitoring effects from coastal discharges, chemical contamination of sediments, commercial dredging, oil exploration and introduced species (OzEstuaries, 2006). Together with sediment toxicity and chemistry, benthic infaunal community studies are considered the “gold standard” in terms of determining whether or not alterations in benthic communities are occurring and whether or not such changes are due to toxic contaminants in the sediments (Chapman, 2007). Benthic organisms are a component of various environmental monitoring programs including the Canadian Pulp and Paper and Metal Mining Environmental Effects Monitoring programs and are proposed as part of the upcoming federal Wastewater Systems Effluent Regulation.

Biological communities provide a direct measure of effects whereas sediment chemistry can only provide a screening-level assessment of potential effects. Benthic community studies do have some limitations. For example, they are based on correlation, not causation, so cannot be used to definitively determine the causes of changes in community structure (Pinto *et al.*, 2009). Also, interpretation of these studies can be confounded by sediment characteristics such as grain size, TOC, depth, currents etc. Finally, benthic community data can be highly variable, leading to low statistical power to detect pairwise differences vs references (McPherson *et al.*, 2008). Despite these limitations, properly analysed benthic community data remain the most ecologically relevant line of evidence regarding possible impacts on the benthos (McPherson *et al.*, 2008).

The regulatory programs and guidance documents that accompany the various sets of SQGs included in the most recent reliability analysis (Avocet, 2007) recommend bioassay and/or benthic community assessments to confirm sediment chemical predictions of adverse effects, for the purposes of regulatory decision-making. In addition, a SETAC Pellston workshop recently discussed the limitations of SQGs and cautioned on their appropriateness for sole use in decision-making (Wenning *et al.*, 2005). In a recent review of the environmental effects of the Macaulay and Clover points outfalls, the SETAC panel chose to look at the biological communities around the outfalls, noting the inherent variability in sediment chemistry data (SETAC, 2006). Benthic community health is often used in conjunction with sediment chemistry and sediment toxicity data in a weight-of-evidence approach to assess environmental effects.

Studies have found that relying solely on sediment toxicity and chemistry data, without considering the full weight of evidence, could provide misleading evidence (McPherson *et al.*, 2008). Sediment chemistry only provides information on contaminants present, not on their bioavailability or toxicity (Chapman, 2007). Sediment toxicity testing used to be a component of the WMEP, but was dropped following the 1992 study by EVS. At that time, sediment toxicity testing methodology was limited and results were often confounded by the CRD sediments that contained high total organic carbon concentrations (i.e. typical around the Macaulay Point outfall). The best assessment was evaluated by giving highest weight to resident benthic community structure, followed by the results of laboratory toxicity tests, then chemical analyses (McPherson *et al.*, 2008). The SETAC panel has noted that while the health of the seafloor and seafloor communities is assessed around Macaulay Point (SETAC, 2006), the monitoring program does not thoroughly address other important groups within the marine ecosystem (e.g., organisms higher up in the food chain and/or water column).

Based on the recent WMEP review by CRD and BC MOE staff and improvements in sediment toxicity methodologies, plans are in place to reintroduce sediment toxicity testing to the WMEP in 2011. To balance the addition of sediment toxicity assessments, there will be a reduction in the benthic invertebrate

sampling frequency from annually to twice in a five year cycle. There will also be a reduction in the number of benthic invertebrate sampling stations. It should also be noted that fish surveys are also planned sometime in the next few years, most likely in 2015. Further details about the changes to the WMEP will be provided in a future report and are available upon request from the CRD Environmental Sustainability department.

Benthic community effects are typically determined through comparisons of potentially exposed stations to stations that are outside the exposure area (i.e., reference stations). A number of different indicator metrics can be used to assess the health of benthic communities. A healthy benthic community generally consists of a number of different taxa (different kinds of organisms). The types of taxa found at a particular location and the abundance of organisms partly depend on the physical characteristics of the habitat (i.e., grain size, type of substrate, etc.). Other physical factors that can influence the composition of the community and the number of organisms are water temperature, depth, and salinity. Biological factors that can influence benthic communities include primary productivity, competition and acclimatization. Benthic communities can also change in response to nutrients, organic matter and contaminants. Some changes in the benthic community can also be due to flexible life history strategies, rather than tolerance of pollution or adverse environmental conditions. Overall, an evaluation of benthic community structure needs to consider more than just toxicity testing (Gray, 1979).

In general, as the concentration of organic matter in sediment increases, the number of taxa in marine benthic communities decreases and the abundance of organisms increases (Pearson *et al.*, 1978). Abundance will eventually decline when organic matter begins to overwhelm the community. This is a typical pattern observed near wastewater outfalls and involves an increase in abundance and a reduction in the total number of taxa with proximity to the source (Pearson *et al.*, 1978). Therefore, important indicator tools or metrics to assess potential effects from wastewater discharges include measures of total abundance and taxa richness (SEA *et al.*, 1999). The assessment of the Macaulay Point benthic communities in 2010 included the use of the following indicators:

- **Total Abundance (TA):** Benthic abundance helps provides an indication of the health of the community.
- **Taxa Richness (TR):** The total number of individual taxa provides a measure of the biodiversity in the benthic community.
- **Mean Abundance:** of all species of major taxa including polychaete abundance (PA) and other major taxa such amphipods, molluscs, echinoderms, etc. These measures provide additional information on biodiversity.
- **Swartz Dominance Index (SDI):** The minimum number of species accounting for 75% of the abundance. This measure gives an indication of whether the abundance at a station is evenly spread across taxa or dominated by only a few taxa. Low SDI values indicate that the abundance is dominated by only a few taxa. The SDI metric has been interpreted with caution, as it is strongly influenced by the pattern of organic concentrations in the vicinity of the outfall, such that increases in abundances of opportunistic taxa result in reduced SDI values irrespective of the responses of other taxonomic groups. SDI is considered an indicator of benthic alteration but should not be interpreted as an indicator of degradation (negative ecological response) without other supporting lines of evidence.
- **Abundances of Individual Indicator Organisms** and their changes in abundance with distance and direction from the outfall.
- **Infaunal Trophic Index (ITI):** A quantitative measure of the distribution of dominant feeding groups of the benthic fauna. The ITI is based on the principle that with increasing organic enrichment, the dominant feeding type changes from those species that feed at the interface of the sediment and water to those species that predominantly deposit feed (Golder, 2007a). Organisms are classified into one of four feeding groups and then the relative abundance of these feeding groups is calculated using the ITI formula. Values of the index range from 0–100, with low values indicative of potentially altered conditions. As the metric is based solely upon feeding strategies, it cannot be used alone to distinguish between alterations that are net-positive, neutral, or that negatively affect overall

ecosystem function (i.e., cause impairment), but is more effective when used as part of a total mass of evidence approach (Maurer et al., 1999). The ITI can give a good indication of the overall conditions that are prevalent and, in conjunction with other benthic invertebrate indices and species presence/absence information, can be used to assess levels of ecosystem function impairment. However, ITI values have been successfully used by some investigators to classify areas of seabed into either 'normal' (values 100–60), 'changed' (60–30) or 'degraded' (30–0) (Bascom, 1979), particularly in areas where there are anthropogenic disturbances such as organic enrichment from outfalls. It should be noted that the thresholds between these classifications were determined somewhat arbitrarily and it is the direction of change (+/-) around these thresholds over time and space that is more important in assessing ITI in long-term monitoring programs.

Detailed spatial and temporal statistical analyses of the benthic data are conducted on a regular basis. These analyses help in the determination of the potential effects related to the outfall, what factors (such as specific contaminants, natural variability, etc.) may be causing any effects, and if the effects are ecologically significant now or could be in the future. An additional community analysis tool involves the use of multivariate statistics that take many, or all, of the above indicators into account simultaneously. These statistical tools are helpful in identifying differences among stations or groups of stations. More comprehensive statistical trend assessments are conducted every three to five years. The last trend assessment was conducted using the 1994 to 2006 data (Golder, 2008b) and was summarized in the 2007 annual report (CRD, 2008). An updated trend assessment was completed in 2011 incorporating the 1994 to 2010 benthic data; results of this trend assessment are presented later in this report.

4.1.2.2 Methods

Benthic community samples were collected at the 23 Macaulay Point outfall stations and five PB reference stations (i.e., the same stations that were sampled for sediments) (Figure 4.1). Four replicate grabs were taken at each site (except for M0 where five replicates were collected to increase statistical power at that location), sieved to 1.0 mm, preserved in formalin solution and transported to the taxonomic laboratory of Benthic Services Group (BSG) (Seattle, USA). The sieve used for the sampling is shown in Picture 4.2.



Picture 4.2 Benthic Sampling Sieve

Benthic invertebrates were sorted, enumerated and identified to the lowest practicable taxonomic level using Puget Sound Protocols (PSAMP, 2002). The same taxonomic laboratory was used from 2002 to 2010 and will be used again in future sampling years. The use of consistent methods (i.e., laboratory and sampling) has served to increase confidence in inter-annual comparisons. In 2001, the same field sampling methods were used, but the overall effort in sample sorting was greater. Animals lodged in holes on the rocks, as well as fragmented animals, were identified in 2001, which was not done in 2002 to 2010 or in previous years. This resulted in the 2001 dataset being incomparable to the 2002 to 2010 data.

The decision to identify organisms from three or four replicates per station was based on the variability in abundances of organisms in the first three replicates sorted for each station. The fourth replicate was

only sorted and identified if the imprecision of abundances of the first three replicates exceeded 20%. In 2010, the fourth benthic community replicate was analyzed at seven (7) of the 22 remaining outfall monitoring stations. At M0 all five replicates were analysed to increase statistical power, as recommended by Golder (2009a). At least 10% of the submitted samples were re-sorted by another person to ensure that no more than 5% of a given sample was missed by the sorter (i.e., a sample sorting efficiency of 95%). Five percent of all samples were re-identified by a second taxonomist. These quality control measures ensured that identifications were correct and consistent. A reference collection was collated for the 2001 to 2010 data and was preserved for future comparisons. Detailed sampling and analytical methodologies are presented in CRD (CRD, 2011a), while details of how the different indicators (i.e., TA, PA, TR, SDI, and ITI) were calculated for the 2010 data analysis are presented in Golder (Golder, 2011a).

The subdivision of TA into major taxa followed standard criteria (Golder, 2011a). Nine major taxa groupings were evaluated as part of the overall assessment:

- **Amphipoda:** Order of organisms within the class Crustacea consisting of numerous small, shrimp-like crustaceans. Amphipods are considered the most efficient scavengers of sea bottoms and shorelines, where they likely clear up and recycle more organic nearshore debris than any other animal group (Schmitt, 1968).
- **Bivalvia:** Class of organisms within the phylum Mollusca, consisting of shelled organisms comprised of two hinged valves, including mussels, oysters, scallops, and clams.
- ***Capitella capitata* complex:** The *Capitella capitata* represents a complex (Grassle *et al.*, 1976) of over 10 sibling species of polychaetes (Gamenick *et al.*, 1997). It is a widely-occurring, opportunist species complex that is particularly associated with organically enriched sediments (Pearson *et al.*, 1978).
- **Crustacea** [not including amphipods]: Class of arthropods that includes water fleas, shrimps, copepods, barnacles, lobsters, and crabs. Amphipods were excluded from this category because they were considered as a separate group.
- **Echinodermata:** Phylum that includes starfish, brittle stars, sea cucumbers, sea urchins, and sand dollars.
- **Gastropoda:** Class of organisms within the phylum Mollusca, consisting mostly of shelled organisms with a ventral foot, and including snails and slugs.
- **Miscellaneous:** Other combined taxa having generally low organism counts.
- **Polychaeta Errantia:** Class of annelid segmented worms; the Errantia are active and mobile polychaetes.
- **Polychaeta Sedentaria** [not including *Capitella capitata* complex]: Class of annelid segmented worms; the Sedentaria are immobile (sedentary), spending their entire lives burrowed in sediment.

Mean abundance values by station and by distance group, as well as percent relative to reference, were calculated for each of these taxonomic indicator groups.

All statistical analyses were conducted using SPSS version 14.0 software, with the exception of the non-metric multidimensional scaling (NMDS), which was conducted using Systat version 11.0. Descriptive statistics were calculated for each summary metric (i.e., arithmetic mean, median, standard deviation, minimum, and maximum) for general use. Spatial patterns in benthic parameters were assessed using two complementary approaches: distance (i.e., 100 m, 200 m, etc.) and distance-direction (i.e., near-field, far-field, etc.).

In a previous trend assessment (Golder, 2005b), multivariate analysis of the sediment and benthic data collected from 2000 to 2004 was used to group sampling stations based on their pattern of contamination, without requiring that the stations within a group represent the same distance from the outfall. The Golder (2005b) analysis identified three groups of stations: near-field, far-field, and reference. Following consultation with the MMAG, the value of the distance-direction analysis was recognized, given that the

influence of currents is highly directional (i.e., to the southeast) in the vicinity of the Macaulay Point outfall. However, there was concern that the broad groupings of stations could mask smaller-scale patterns in biological metrics; consequently, it was recommended that the grouping analysis be repeated and evaluated for potential presence of additional station groups. After more detailed multivariate analyses of the benthic community and the sediment chemistry data from 2000 to 2007 (Golder, 2009a), the following “distance-direction” groupings were identified:

- outfall: station M0
- near-field: stations M1E, M1SE, M2SE
- mid-field: stations M1W, M1SW, M1S, M2E, M2NE, M4SE, M4E
- far-field: stations M2S, M2SW, M4SW, M4W, M8W, M2W, M2NW, M1NW, M1N, M2N, M1NE, M8E
- reference: all five Parry Bay stations

Groupings were identified initially based on similarities in benthic community data, and then confirmed and refined using the sediment chemistry data. In the previous two assessments, the outfall terminus station (M0) was combined with near-field stations in order to increase sample size for the statistical tests. However, following inspection of the univariate and multivariate results in the 2008 assessment, M0 was identified as being substantially different from the near-field station in terms of benthic community composition. As a result, it was recommended that M0 be handled as a separate treatment for statistical tests (e.g., ANOVAs and pairwise contrasts), rather than lumped with near-field stations. Therefore, based on these recommendations, M0 was assessed separately for the detailed statistical analyses in the 2010 assessment. Although separation of M0 from the near-field group results in weakened statistical power through the use of a single station with five replicates, the discrimination of M0 will assist in the evaluation of finer-scale spatial trends near the outfall. The 2010 sampling data confirmed the importance of evaluating M0 as a distinct exposure unit along the gradient of wastewater influence. Figure 4.3 illustrates the Macaulay Point sampling stations categorized by the distance-direction groups.

DETAILED STATISTICAL ANALYSIS

Non-metric multidimensional scaling (NMDS) was used to derive summary measures of the benthic invertebrate data. NMDS takes a pair-wise similarity matrix among multiple original variables and calculates a few key components that serve to reduce the multidimensional nature of the data (Zar, 1984). Station scores along the dimension axes provide a means of assessing the overall structure of the benthic community at a particular station, as well as identifying any spatial patterns among stations. Abundances of major taxa for sample replicates were used as the input variables into NMDS.

Differences in the benthic community metrics between the individual distance groups (outfall, 100 m, 200 m, 400 m, and 800 m) and the reference area and among distance-direction groups (near-field, mid-field, far-field and reference) were made using one way analysis of variance (ANOVA) if the data met the assumptions of a normal distribution and homogeneity of variance. Where an ANOVA identified significant differences among treatments, post hoc comparisons between each group and the reference area were made using Dunnett's test (distance groups) or Tukey's test (distance-direction groups)¹. Data transformations (e.g., log transformation) were used where required to meet the assumptions of ANOVA. Where a data transformation was not sufficient to meet the above assumptions, a non-parametric version of the ANOVA, the Kruskal-Wallis test, was used to identify differences between stations grouped by distance. Comparisons between distance groups were made using individual sample replicates (Golder, 2011a).

¹ Dunnett's test compares individual groups to a control group (reference stations in this case), whereas Tukey's test assesses all pairwise differences.

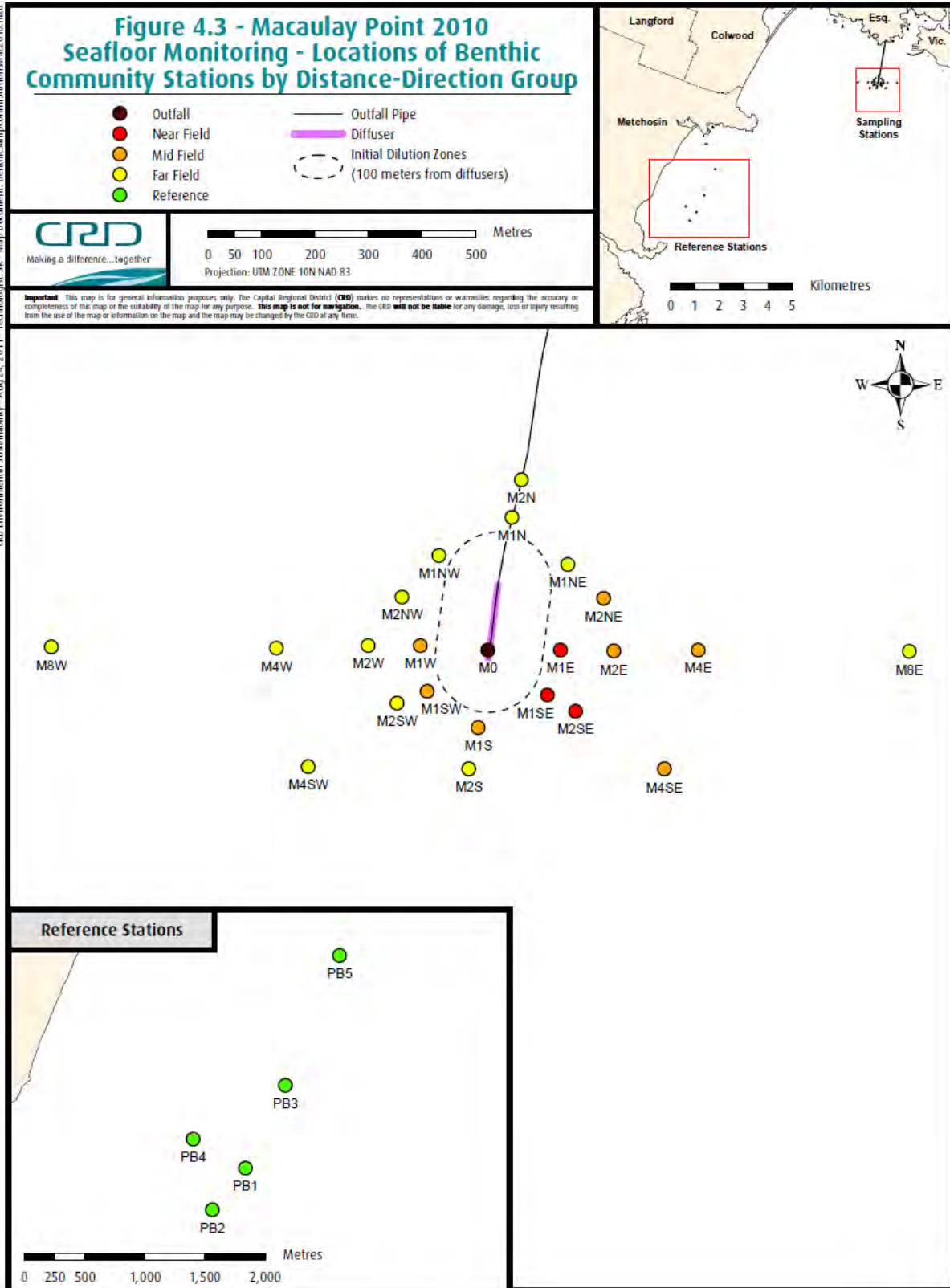


Figure 4.3 Macaulay Point 2009 Seafloor Monitoring, Locations of Benthic Community Stations by Distance-Direction Group

NMDS was also used to investigate the spatial distribution of monitoring stations based on the 2010 benthic data. Abundance counts of the nine major taxa of each station replicate were used as input variables and values were $\log_{10}(x+1)$ transformed prior to analysis. Transformation was done to better elucidate subtle trends in the analyses by down-weighting the influence of highly abundant taxa (Golder, 2011a). Station scores along the dimension axes provided a means of assessing the overall structure of the benthic community at a particular station, as well as identifying any spatial patterns among stations. Graphical analyses conducted with the 2006 through 2009 sediment chemistry and benthic community data consistently show that the increased sample size using the new reference stations, combined with acceptable variability among replicates, have improved the statistical design of the monitoring program. The variability in 2010 summary metrics appears to be sufficiently low to enable meaningful statistical contrasts between outfall monitoring stations and the reference area (Golder, 2011a).

The effects of physical and chemical sediment parameters on benthic community parameters were assessed by identifying statistical relationships among these variables. Sediment data collected as part of the 2010 monitoring program (Section 4.1.1) were used in this assessment. Spearman rank correlations were computed to identify significant relationships. Station means (i.e., means of individual replicate values) were used in this analysis for both the sediment substrate/chemistry and benthic community variables.

The 2010 benthic community data were compared to previous years (1994–2009). Plots of the reference-normalized metrics (grouped by distance and distance-direction from the outfall) were used to qualitatively assess broad temporal trends.

Multi-Year Trend Assessment

To the extent possible, the multi-year trend assessment technical approach was designed to be consistent with previous trend reports (e.g. Golder 2005b, Golder 2008) in order to facilitate the integration of new findings with those previously reported. Additional methods of data presentation and analysis have been considered where such analyses augment and are complementary to the approaches used in previous investigations.

Benthic metrics included in the trend assessment were total abundance, total polychaete abundance, total taxonomic richness, abundances of major taxa, infaunal trophic index and Swartz dominance index. Summary statistics, including means, medians, standard deviations, minima and maxima were computed for the 2000-2010 (excluding 2001) benthic data. Summary statistics were computed separately for the 2000-2010 (excluding 2001) and 2008-2010 time periods, and are categorized using both distance groups and distance-direction groups.

Spatial trends in the Macaulay Point benthic community data were assessed relative to distance from outfall and among spatial groups of stations using methodologies similar to previous trend reports (Paine 1999, 2004; Golder 2005a, 2005b, Golder 2008). Benthic data trends were conducted using the full period of record (2000-2010; excluding 2001), and also separately for the three most recent years' data alone (2008-2010). A comparison of the results of these two analyses was intended to evaluate whether recent spatial patterns are consistent with the broader historical trends.

Distance gradients were assessed using non-parametric Spearman rank correlations of benthic parameters as a function of distance from the outfall. Spearman rank correlations were calculated for both the distance groups and the distance-direction groups. Differences in benthic community metrics between each distance group (outfall, 100 m, 200 m, 400 m, and 800 m) and the reference area were made using one-way analysis of variance (ANOVA) followed by *post hoc* multiple comparisons. Differences between distance-direction groups (outfall, mid-field, near-field and far-field) and the reference area were made using the same approach.

Temporal trends in benthic community metrics were assessed using methodologies similar to previous trend reports (Paine 1999, 2004; Golder 2005a, 2005b; Golder 2008). The formal quantitative analyses were conducted for the period of 2000 to 2010 (excluding 2001), whereas the qualitative assessment (i.e., graphical analysis) also included the years 1994, 1997 and 1999.

Plots of the reference-normalized benthic community metrics (grouped by distance-direction and by distance) were used to qualitatively assess temporal trends. These temporal plots are used following each year of monitoring to discern broad trends. Because the 2010 program included a formal statistical trend assessment, the graphical evaluation was included as a complementary technique for evaluating trends over the last decade (Golder, 2011a).

Rank correlations were compared among stations using a modified version of the van Belle test for homogeneity of trends, as outlined in Paine (2004). Separate van Belle test statistics were calculated once for all monitoring stations combined (including reference) and once for all stations except references. A comparison of the results of these two analyses was intended to assess the extent to which any significant heterogeneity identified by the van Belle tests was due to:

- differences between reference stations and the other distance groups (*i.e.*, potentially indicating regional-scale variability in trends); or,
- differences among the non-reference distance groups (*i.e.*, potentially indicating local scale variability in trends with distance from the outfall).

See Golder (2011) for complete details on the data analysis.

4.1.2.3 Results and Discussion

Summary statistics for 2010 benthic community metrics are presented in Table 4.2. Results are presented by individual stations (e.g., M0, M8E), by distance group (e.g., outfall, 100 m, 200 m) and by distance-direction groupings (*i.e.*, outfall, near-field, mid-field, far-field and reference). Correlations with distance and distance-direction from the outfall are presented in Table 4.3 and Table 4.4. Cumulative abundance of the major taxa by distance and distance-direction group is presented in Figure 4.4, and Figure 4.5 graphically shows the comparison of TOC to benthic community parameters. More detailed results are presented in Golder (2011).

BENTHIC COMMUNITY INDICATORS AND SPATIAL PATTERNS

Total Abundance: Total abundance in individual replicates ranged from 152 individuals in a Station M8E replicate to 2,342 individuals in an outfall (Station M0) replicate (Table 4.2). The mean abundance at reference stations was 438 individuals. Ten (10) of the twenty-three (23) outfall monitoring stations exhibited mean abundances below this reference level; station averages for these locations ranged from 42% to 98% of the reference mean). The remaining individual station averages ranged from 101% to 410% of reference. A statistically significant difference was identified between the outfall and the reference area ($p < 0.01$), indicating that total abundance was greater at the outfall relative to reference (Table 4.3 and Table 4.4; Figure 4.6). No other statistically significant differences in total abundance were identified between the reference area and either of the distance or distance-direction groups. The correlations between total abundance and each of the distances from the outfall (and all distance-direction groups) were not significant (Golder, 2011a).

The pattern of total abundance in the current assessment (2010 data) is similar to the pattern from the 2008 data, in that abundances at near-field stations are considerably lower than at station M0, and not significantly different from reference. Therefore, the general profile in total abundance observed in 2010 is not unique. However, in most sampling events over the last decade, the near-field total abundance has been higher than observed in 2010. For example, in last year's assessment (2009 monitoring data, (Golder, 2010a), total abundance at near-field stations was similar to that of M0 and was significantly greater than at the reference stations.

Whereas the mean total abundance at near-field stations was lower in 2010 than in 2009, the most conspicuous difference between these two sampling events was the higher total abundance at Station M0 in 2010 (1,799 individuals), which was approximately 2.5 times greater than the total abundance at the outfall station in 2009 (693 individuals) (Golder, 2010a). The contrasting patterns observed in the last few years illustrate the high variability in total abundance that has been observed in the benthic community monitoring program. In general, the pattern of total abundance exhibits a decreasing trend with increased

distance from the outfall. However, in any individual sampling year, deviations from this broad trend can be observed. In 2008, some near-field stations were atypically low in abundance, whereas in 2009 the outfall station M0 was atypically low (*i.e.*, M0 usually has the highest abundance, but was similar to near-field stations in 2009). In 2010, the total mean abundance at M0 (1,799 individuals) was high in comparison to the previous two assessments, which had a combined average total abundance of approximately 700 individuals (Golder, 2011a).

Polychaete Abundance: Total polychaete abundance ranged from 74 individuals in a Station M8E replicate to 1,603 individuals in an outfall station (M0) replicate (Table 4.2). Mean polychaete abundance was greater than the reference area mean for all outfall monitoring stations, with the exception of the two 800 metre stations (M8E and M8W), which had station averages that were 75% and 81% of the reference mean, respectively. The remaining twenty-one (21) stations had station averages that ranged from 108% to 1082% of the reference mean. Statistically significant differences were identified between each of the outfall, 100 m, 200 m, 400 m and 800 m distance groups relative to the reference area ($p < 0.05$), indicating that total polychaete abundance was greater than the reference stations for each of these distance groups, with the exception of the 800 m group, which had lower abundance counts (Table 4.3; Figure 4.7). Significant differences were also observed between each of the distance-plus-direction groups and the reference area ($p < 0.01$) (Table 4.4; Figure 4.7). Polychaete abundance was greatest near the outfall, particularly at the outfall terminus (M0) and to the south east of the outfall (*i.e.*, M1SE and M2SE). The correlation between distance from the outfall and polychaete abundance was statistically significant ($r_s = -0.671$, $p < 0.01$) and negative, indicating that this metric decreases with distance from the outfall (Table 4.3). Polychaete abundance significantly ($r_s = -0.758$, $p < 0.01$) decreased with distance-direction from the outfall as well (Table 4.4) (Golder, 2011a).

Taxonomic Richness: Taxonomic richness ranged from a minimum of 25 taxa in a replicate at Station M0 and at Station M1SE to a maximum of 96 taxa at a Station M4W replicate (Table 4.2). Mean taxonomic richness was equal to or greater than the reference area mean at only two (M2N and M4W) of the 23 Macaulay Point outfall monitoring stations, compared to eight (8) stations in both 2009 and 2008, seven (7) stations in 2007 and fifteen (15) stations in 2006. Station averages ranged from 44% to 115% of reference richness. The majority of stations exhibited richness values that were within 25% of reference, with six exceptions (M0, M1E, M1S, M1SE, M1SW, and M2SE) near the zone of greatest outfall influence. In the previous assessment, a similar pattern was observed although the majority of stations were within 10% of reference. Statistically significant differences ($p < 0.05$) were identified between each of the outfall, 100 m, 200 m and 800 m distance groups relative to the reference area indicating that taxonomic richness was less than the reference stations for each of these distance groups (Table 4.3; Figure 4.8). The correlation between distance from the outfall and taxonomic richness was statistically significant and positive ($r_s = 0.61$; Table 4.3). Statistically significant differences ($p < 0.05$) were also identified between each of the outfall and distance-direction groups and the reference area (Table 4.4; Figure 4.8). The correlation between distance-direction groups and taxonomic richness was also statistically significant and positive ($r_s = 0.69$; Table 4.4; (Golder, 2011a)).

As with previous monitoring events, the mean taxonomic richness at the outfall (36 at M0 in 2010) was lower than the mean reference station value (68 in 2010). However, the 2010 sampling results (Golder, 2011a) differ from most other sampling events in that the outfall station M0 did not exhibit the lowest mean taxonomic richness, which was instead observed at Station M1SE (30 in 2010). Accordingly, the spatial extent of the reduced richness is greater in 2010 than has been observed in other recent sampling events. The five lowest mean richness values (30 at M1SE, 36 at M0, 40 at M1E, 42 at M2SE, 43 at M1SW) were all observed near the outfall and generally in the direction of the predominant currents (*i.e.*, near-field stations). The occurrence of reduced richness in the area of greatest outfall influence is suggestive of an adverse response due to wastewater-related effects. The degree to which richness was reduced at M0 was less in 2010 than in 2009 (53% and 39% of reference, respectively). Historically, the richness at M0 has been variable, with some years exhibiting richness similar to reference, and other years exhibiting richness reduced by more than a factor of 2. The 2010 monitoring event falls somewhere in between the two extremes, which is an improvement on the observations of 2009 (Golder, 2010a) when richness fell at the lower end of the historically observed range for M0.

At far-field stations, relative richness was similar to previous years of monitoring with values ranging from 93% to 105% of reference. Overall, the data demonstrates a reduction in species richness near the outfall terminus and at other near-field stations (oriented generally to the southeast of the diffuser) (Golder, 2011a).

Swartz Dominance Index: The Swartz Dominance Index (SDI) ranged from 0.9 taxa at a Station M1SE replicate to 29 taxa at a Station M2N replicate (Table 4.2). Mean SDI was lower than the reference area mean for the majority of stations (18 out of 23 stations), with values below reference ranging from 6% to 87% of reference. The remaining five stations with SDI values above reference ranged from 106% to 154% of reference (M1N, M2N, M2NE, M4E and M8E). Statistically significant differences were identified for each of the outfall, 100 m and 200 m distance groups relative to the reference area ($p < 0.05$), indicating that the SDI was lower at these stations relative to the reference stations (Table 4.3; Figure 4.9). The outfall, near-field, mid-field and far-field distance groups were also identified to have statistically significantly lower SDI values compared with the reference group ($p < 0.05$) (Table 4.4; Figure 4.9).

The correlation between SDI and distance from the outfall was significant and positive ($r_s = 0.62$), indicating that SDI increased with increasing distance from the outfall (Table 4.3). The correlation between SDI and distance-direction groups was also significant and positive ($r_s = 0.59$; Table 4.4).

The spatial patterns in SDI were stronger in the last three monitoring events (2008-2010) relative to previous years (Golder, 2011a). Figure 4.9 illustrates the systematic increase in SDI with distance from the outfall exposure source. The previous monitoring study (Golder, 2010a) indicated that the 2009 and 2008 datasets both showed an increased effect size (*i.e.*, the most affected groups are 3- to 4-fold lower than reference, compared to a two-fold difference in 2007). This increase in effect size is still apparent, with the most affected groups approximately 5-fold lower than reference. The last three years of data also suggest an increased spatial zone of influence in comparison to 2007 and previous years. In 2007, large reductions in SDI (relative to reference) were observed only at M0 and near-field stations. In contrast, the 2008-2010 data indicate reductions in SDI across all distance-plus-direction groups (Golder, 2011a).

Overall, the SDI data reconfirm the general trend of decreasing SDI with increased outfall exposure (*i.e.*, south-east of the outfall, following the direction of prevailing currents). This spatial pattern is consistent with the distribution of enhanced polychaete abundance and reduced taxonomic richness described above. In the most recent years (2008-2010), the pattern of SDI was clearer and more pronounced than in previous monitoring events.

Infaunal Trophic Index: In 2010 ITI was calculated using two methods (Golder, 2011a), ITI-standard and ITI-regional. ITI-standard is comparable to the ITI classifications designated in previous monitoring studies (e.g. Golder 2006, 2007, 2008, 2009, 2010, 2011), while ITI-regional is based on a 2010 study (Macdonald *et al.* 2010), and extends the standardization of taxa to include ecological attributes such as feeding mode, food type/source and life habit.

ITI-standard ranged from a minimum of 9 in a replicate at Station M1SE to a maximum of 63 at a Station M8E replicate. ITI-regional ranged from a minimum of 4 at a Station M1SE replicate to 58 at a Station M8W replicate (Table 4.2). The mean ITI-standard values were lower than the reference area mean for 14 out of 23 outfall monitoring stations, with values ranging from 22% to 99% of reference. The nine stations with mean ITI-standard values greater than reference ranged from 100% to 106% of reference. The mean ITI-regional values were lower than the reference area mean for all but one of the 23 outfall monitoring stations, with values ranging from 12% to 96% of reference. Only Station M8W had a mean ITI-regional value above the reference area mean (115% above reference; Table 4.2). Statistically significant differences in ITI-standard were identified between each of the outfall and 100 m distance groups in comparison with the reference area ($p < 0.05$); significant differences in ITI-regional were identified between each of the outfall, 100 m, 200 m and 400 m distance groups in comparison with the reference area ($p < 0.05$). These results indicate that the ITI-standard and ITI-regional values were lower at these distance groups relative to the reference area (Table 4.3; Figure 4.10 and Figure 4.11).

The correlations with distance from the outfall and both ITI-standard and ITI-regional were significant and positive, indicating that ITI scores increased with increasing distance from the outfall (Table 4.3). The correlation between distance from the outfall and ITI-regional was stronger than the correlation between ITI-standard and distance from the outfall ($r_s = 0.60$ and 0.70 , respectively).

When distance-direction groups were compared, significant differences in ITI-standard were identified for each of the outfall, near-field and mid-field groups in comparison with the reference area; significant differences in ITI-regional were identified for each of the outfall, near-field, mid-field and far-field groups in comparison with the reference area (Table 4.4; Figure 4.10 and Figure 4.11). A significant difference in ITI-standard values was not identified between the far-field distance-direction group and the reference area.

Both the ITI-standard and ITI-regional metrics were significantly positively correlated with distance-direction, indicating that ITI scored increased with increasing distance-direction from the outfall (Table 4.4; Figure 4.11). Both correlation coefficients indicated a stronger relationship between the ITI metrics and distance-direction in comparison with the correlations with distance alone (Golder, 2011a).

An increase in ITI scores with increasing distance from the outfall is consistent with that expected for an area with elevated organic matter adjacent to a point source discharge (Maurer et al., 1999). The change in dominance of organisms from those feeding on suspended materials to those that feed on deposited materials is indicative of increases in the amount of organic material in the sediment. The largest reductions in the ITI metrics (relative to reference) were observed at the outfall and in the near-field group (*i.e.*, M1SE, and M2SE) that are in the region of greatest influence of the outfall discharge (*i.e.*, south and east of the outfall, following the direction of prevailing currents) (Golder, 2011a).

In Golder (2009a), recommendations were made for the site-specific interpretation of ITI, specifically that the ITI narrative consider the Parry Bay reference condition. Values within 20% of the mean reference condition may be defined as “normal”, reductions of 20% to 49% relative to reference would be considered “changed”, and reductions of 50% or more would be considered “degraded”. The resulting classifications using ITI-standard are (Golder, 2011a):

Normal: M1N, M1NE, M1NW, M1S, all 200 m stations with the exception of M2SE, all 400 m stations, all 800 m stations;

- Changed: M1E, M1SW, M1W; and
- Degraded: M0, M1SE, and M2SE.

The resulting classifications using ITI-regional are:

- Normal: M1N, M1NE, M2NW, M2S, M2SW, M2W, M4E, M4SW, M4W, M8W;
- Changed: M1NW, M1S, M2E, M2N, M2NE, M4SE, M8E; and
- Degraded: M0, M1E, M1SE, M1SW, M1W and M2SE.

The magnitude of effects relative to reference was greater in 2010 in comparison with previous years, particularly at station M0, where ITI-standard averaged only 16% of reference. In 2009, ITI-standard was 19% of reference at M0, whereas in 2008, ITI values in M0 replicates were similar to those at the other near-field stations (at approximately 30 to 40% of reference). The very low ITI-standard scores observed at station M0 in 2010 and 2009 is attributable to the high relative abundance of the polychaete *Capitella capitata* complex (a group IV deposit feeder), which contributed greater than 60% of total abundance at this station. The spatial extent of ITI response in 2010 was similar to previous years, with significant reductions observed in near-field and mid-field stations, and levels at far-field resembling those at the reference stations (Golder, 2011a).

Echinodermata: Mean abundance of echinoderms was low in all Macaulay Point outfall monitoring stations and reference stations (Table 4.5). A statistically significant difference was identified between each of outfall and distance groups and the reference area, with the exception of the 400 m distance group (Table 4.3; Figure 4.12). The correlation between echinoderm abundance and distance from the

outfall was significant and positive ($r_s = 0.54$; Table 4.5), indicating that echinoderm abundances increased with distance from outfall. A statistically significant difference was identified between each of the outfall, near-field, and far-field distance-direction groups and the reference area. The correlation between echinoderm abundance and distance-plus-direction groups was significant but weak ($r_s = 0.31$; Table 4.4) indicating that only a small proportion of the variance was explained by the distance-plus-direction groups. The results from 2010 differ from the previous monitoring event in that there were no significant differences observed between distance groups and the reference in 2009 (Golder, 2011a).

Bivalvia: A statistically significant difference was identified between the outfall and the reference area; the correlation between bivalve abundance and distance from the outfall was significant and positive ($r_s = 0.29$; Table 4.3), though weak. When analyzed in terms of distance-plus-direction groups, bivalve abundance was statistically significantly lower in each of the outfall, near-field and mid-field groups, and significantly higher in the far-field group, relative to the reference area (Table 4.4; Figure 4.13). The correlation between abundance and distance-direction group was significant and positive ($r_s = 0.65$; Table 4.4), indicating that bivalve abundances increased with distance-direction from outfall. The analysis of bivalve abundances in previous sampling years has suggested that bivalves tend to be less abundant at near-field locations relative to reference, supporting the 2010 results (Golder, 2011a).

Gastropoda: Mean gastropod abundance was lower at the outfall station in comparison with the other monitoring stations (Figure 4.14). Statistically significant differences were identified between each of the outfall and distance groups and the reference area with the exception of the 800m group (Table 4.3; Figure 4.14). The correlation between gastropod abundance and distance from the outfall was significant ($r_s = 0.69$; Table 4.2). When analyzed by distance-direction, gastropod abundance was statistically significantly lower at the outfall and all distance-direction groups relative to the reference area and the correlation between abundance and distance-plus-direction group was significant and positive ($r_s = 0.72$; Table 4.4) (Golder, 2011a).

Crustacea (Amphipoda): A statistically significant difference was identified between each of the outfall and the 200 m distance group, and the reference area, and the correlation between amphipod abundance and distance from the outfall was significant and negative but weak in strength ($r_s = -0.24$; Table 4.3). In 2009, the highest mean abundance of amphipods occurred at stations south and east of the outfall (Stations M1SE, M2E, M1E and M1S). Conversely, in 2010, the mean abundance of amphipods at Stations M1E, M1S, and M1SE were the lowest of the outfall monitoring stations, ranging from 56% to 76% of reference. The correlation between amphipod abundance and distance-direction was not significant (Golder, 2011a).

Crustacea (Other): Mean abundances of other crustaceans were variable, but were below the reference area mean for the majority of stations (Table 4.5). Stations M0 and M8W were the only stations with a mean abundance of other crustaceans greater than the reference area mean, at 287% and 152% of reference, respectively. All other station averages ranged from 7% to 72% of reference. A statistically significant difference was identified between each of the outfall, 100 m, 200 m and 400 m station groups and the reference area stations (Table 4.3), with the reference stations exhibiting greater mean abundance for all groups except the outfall. The correlation between abundance of other crustaceans and distance from the outfall was significant and positive; however, the correlation coefficient ($r_s = 0.37$; Table 4.3), indicates a weak association. The graphical pattern of the 2010 data suggests that the outfall (M0) contained substantially more crustaceans than at all other distance and distance-plus-direction groups (Figure 4.15). This pattern is in agreement with the findings of 2007 and 2008, and suggests that the low relative abundance observed at M0 in 2009 was an anomaly. Statistically significant differences were identified between each of the outfall and distance-direction groups relative to the reference area, and the correlation between abundance of other crustaceans and distance-plus-direction groups was positive and significant ($r_s = 0.50$; Table 4.4) (Golder, 2011a).

Polychaete Sedentaria (Capitella capitata complex): *Capitella* individuals were not identified in any of the five reference stations or in Stations M2N, M4SW, or M8W, and as a result, percent of reference could not be calculated (Table 4.5). The highest mean *Capitella* individuals were observed at the outfall station and in stations included in the near-field group (*i.e.*, M1E, M1SE and M2SE) that are in the region of greatest influence of the outfall discharge (*i.e.*, south and east of the outfall, following the direction of

prevailing currents). This spatial pattern is consistent with the distribution of enhanced polychaete abundance and marginally reduced taxonomic richness described above. A strong and significant negative correlation ($r_s = -0.76$; Table 4.3) was observed between *Capitella* abundance and distance from the outfall, indicating that abundance counts of this taxon decreased with increasing distance from the outfall (Figure 4.16). All distance-direction groups were significantly different from the reference area, and the correlation between *Capitella* abundance and distance-direction was strong and negative ($r_s = -0.86$; Table 4.4) (Golder, 2011a).

Polychaete Errantia: Mean abundances of mobile polychaetes were greater than the reference area mean for the vast majority of stations (Table 4.5). Stations M1SE and M8E were the only stations with a mean abundance of mobile polychaetes lower than the reference area mean, at 87% and 98% of reference respectively. The abundances of mobile polychaetes were significantly higher in each of the outfall, 100 m, 200 m and 400 m distance groups relative to reference. The correlation between abundance of mobile polychaetes and distance from outfall was significant and negative ($r_s = -0.39$; Table 4.3, Figure 4.17). The correlation between mobile polychaete abundance and distance-direction was also significant and negative ($r_s = -0.38$; Table 4.4). Both of the mid-field and far-field distance groups differed significantly from the reference area, but no significant difference was identified between the outfall or the near-field group and the reference area (Table 4.4; Figure 4.17). In 2010, mobile polychaetes were most abundant at the outfall monitoring stations, with lower abundances at the reference area and 800 m stations (Golder, 2011a).

Polychaete Sedentaria (Other): Mean abundance of non-capitellid sedentary polychaetes was greater than the reference area mean for the majority of stations (Table 4.5). Stations M0, M1S, M1SE, M1SW, M8E and M8W were the only stations with a mean abundance of other sedentary polychaetes less than the reference area mean, with relative abundance ranging from 48% to 86% of reference. Although the outfall had fewer sedentary polychaetes than the reference area the difference was not significant; statistically significant differences were identified between each of the 200 m and 800 m distance groups in comparison with reference (Table 4.3; Figure 4.18). The reduced abundances at M0 observed in 2010 and 2009 are not typical of other monitoring events in the last decade, as abundances of sedentary polychaetes have historically been close to reference or somewhat higher than reference. The correlation between abundance of other sedentary polychaetes and distance from the outfall was not significant. Abundance in the far-field distance-direction group was statistically significantly higher than the reference area; however the correlation between abundance and distance-direction groups was not statistically significant (Table 4.4) (Golder, 2011a).

Miscellaneous Taxa: Mean abundance of miscellaneous taxa was less than the reference area mean at 21 of the 23 outfall monitoring stations, which ranged from 2% to 60% of reference. Mean abundance of miscellaneous taxa at Stations M0 and M8W were greater than the reference area mean, with abundances of 681% and 157% of reference, respectively. The outfall station was identified as having a significantly greater abundance of miscellaneous taxa relative to reference (Table 4.3; Figure 4.19), but although the correlation between abundance of miscellaneous taxa and distance from the outfall was significant and positive, it was weak in magnitude ($r_s = 0.32$; Table 4.3). Abundances of miscellaneous taxa were significantly lower in all of the distance groups and distance-direction groups relative to reference area. The correlation between abundance of miscellaneous taxa and distance-direction was significant and positive but weak in magnitude ($r_s = 0.33$; Table 4.4). The relatively high abundances at Station M0 suggest that the outfall terminus may provide habitat for specialized organisms that are suited to organically-enhanced sediments and the substrate/habitat conditions found at M0. Apart from this localized phenomenon, there are few strong trends in the abundances of miscellaneous taxa (Golder, 2011a).

Table 4.2 Summary Statistics for Macaulay Point 2010 Benthic Community Metrics

Station	Total Abundance						Polychaete Abundance						Taxonomic Richness					
	mean	median	SD	min.	max.	% ref.	mean	median	SD	min.	max.	% ref.	mean	median	SD	min.	max.	% ref.
M0	1799	1576	425	1441	2342	410%	1311	1251	267	1011	1603	1082%	36.4	41.0	8.38	25	44	53%
M1E	306	320	53.3	233	349	70%	261	273	44.1	200	298	215%	39.5	38.0	5.45	35	47	58%
M1N	330	349	61.3	261	379	75%	144	145	25.0	118	168	119%	64.7	66.0	2.31	62	66	95%
M1NE	605	612	59.8	542	661	138%	264	262	11.6	253	276	218%	62.3	63.0	2.08	60	64	91%
M1NW	718	716	114	605	833	164%	176	159	31.5	156	212	145%	67.3	64.0	9.45	60	78	98%
M1S	399	366	117	298	565	91%	235	228	61.6	167	316	194%	49.5	49.5	11.0	40	59	72%
M1SE	481	464	48.2	443	535	110%	444	422	40.4	420	491	367%	30.0	32.0	4.36	25	33	44%
M1SW	341	313	75.5	286	451	78%	236	227	46.0	194	295	194%	43.3	40.5	5.85	40	52	63%
M1W	443	413	104	353	591	101%	309	300	60.4	246	391	255%	52.3	51.5	8.30	43	63	76%
100 m stations	441	393	151	233	833	101%	259	251	90.2	118	491	213%	50.4	51.0	13.4	25	78	74%
M2E	383	395	110	246	497	87%	230	218	65.9	174	309	190%	52.0	52.5	7.16	44	59	76%
M2N	327	311	36.4	302	369	75%	163	165	17.1	145	179	134%	72.0	69.0	5.20	69	78	105%
M2NE	344	358	30.2	309	364	78%	214	245	56.9	148	248	176%	62.3	68.0	10.7	50	69	91%
M2NW	625	659	67.2	548	669	143%	199	203	24.2	173	221	164%	54.3	55.0	2.08	52	56	79%
M2S	520	572	98.3	407	582	119%	211	229	39.2	166	238	174%	63.7	66.0	4.93	58	67	93%
M2SE	557	577	112	403	670	127%	497	532	105	343	581	410%	41.8	43.5	11.0	27	53	61%
M2SW	623	662	69.0	543	663	142%	239	253	35.7	198	265	197%	60.3	62.0	2.89	57	62	88%
M2W	614	625	86.6	522	694	140%	257	257	36	221	293	212%	57.7	62.0	9.29	47	64	84%
200 m stations	497	533	140	246	694	113%	260	234	118	145	581	214%	57.2	57.5	11.0	27	78	84%
M4E	397	456	139	190	487	91%	188	198	75.9	94	260	155%	68.3	73.0	13.8	48	79	100%
M4SE	443	465	84.7	349	514	101%	300	306	33.9	264	331	248%	64.3	63.0	6.11	59	71	94%
M4SW	428	420	15.3	419	446	98%	130	130	0.577	130	131	108%	61.0	61.0	1.00	60	62	89%
M4W	663	622	71.3	621	745	151%	211	195	42.9	179	260	174%	78.7	71.0	15.0	69	96	115%
400 m stations	476	458	136	190	745	109%	206	195	75.6	94	331	170%	68.1	69.0	11.7	48	96	100%
M8E	185	167	44.8	152	236	42%	91.3	86	20.5	74	114	75%	57.0	55.0	5.29	53	63	83%
M8W	603	624	76.7	518	667	138%	98	92	14.9	87	115	81%	63.7	63.0	1.15	63	65	93%
800 m stations	394	377	236	152	667	90%	94.7	89.5	16.5	74	115	78%	60.3	63.0	5.01	53	65	88%
PB1	409	363	104	335	528	93%	130	121	18.6	117	151	107%	65.7	65.0	4.04	62	70	96%
PB2	408	422	73.6	328	473	93%	115	113	13.1	103	129	95%	74.3	73.0	5.13	70	80	109%
PB3	405	425	46.9	351	438	92%	139	133	12.7	131	154	115%	68.3	66.0	5.86	64	75	100%
PB4	541	524	50.1	501	597	123%	107	106	7.02	100	114	88%	65.7	64.0	2.89	64	69	96%
PB5	431	442	72.7	353	497	98%	115	116	4.04	111	119	95%	68.0	69.0	2.65	65	70	99%
Reference	438	438	81.5	328	597	100%	121	117	15.9	100	154	100%	68.4	69.0	4.90	62	80	100%
Near-field	445	443	135	233	670	101%	397	420	128	200	581	327%	37.7	36.0	8.64	25	53	55%
Mid-field	393	375	97.3	190	591	90%	243	247	66.7	94	391	201%	55.4	55.0	11.9	40	79	81%
Far-field stns.	520	560	170	152	833	119%	182	176	61.0	74	293	150%	63.6	63.0	8.45	47	96	93%

continued

Table 4.2, continued

Station	Swartz Dominance Index						ITI Group (Standard)						ITI Group (Regional)					
	mean	median	SD	min	max	% ref.	mean	median	SD	min	max	% ref.	mean	median	SD	min	max	% ref.
M0	1.62	1.59	0.249	1.29	1.97	10%	16.4	16.4	3.07	12.6	21.1	29%	13.9	13.9	4.06	9.22	20.2	28%
M1E	6.03	6.09	1.65	4.43	7.5	38%	37.9	39.0	5.03	31.1	42.4	67%	13.1	13.2	1.44	11.5	14.7	27%
M1N	18.6	19.3	1.32	17.1	19.4	116%	57.9	59.2	2.78	54.7	59.8	103%	41.6	41.6	3.45	38.1	45.0	84%
M1NE	10.9	12.0	1.95	8.64	12.1	68%	56.5	56.7	0.43	56.0	56.8	100%	42.8	43.1	1.20	41.5	43.8	87%
M1NW	6.88	5.83	2.16	5.43	9.37	43%	49.2	50.0	1.37	47.7	50.1	87%	37.9	37.2	2.42	35.9	40.6	77%
M1S	7.81	6.78	2.22	6.55	11.1	49%	47.1	46.2	2.47	45.3	50.6	84%	32.4	31.5	4.13	28.7	37.7	66%
M1SE	0.962	0.978	0.046	0.910	0.998	6%	12.2	11.9	3.18	9.22	15.5	22%	5.88	6.65	1.93	3.69	7.30	12%
M1SW	7.28	6.05	2.69	5.73	11.3	46%	36.4	35.6	4.41	31.8	42.4	65%	23.0	24.6	3.53	17.7	25.0	47%
M1W	7.85	7.88	0.43	7.31	8.35	49%	42.9	42.9	4.62	37.3	48.6	76%	24.4	24.0	2.36	22.4	27.2	50%
100 m	8.14	7.35	4.70	0.910	19.4	51%	42.3	44.2	13.3	9.22	59.8	75%	27.0	26.4	12.5	3.69	45.0	55%
M2E	11.7	12.0	0.931	10.4	12.5	74%	47.0	48.3	3.62	41.6	49.6	83%	31.0	32.4	5.41	23.6	35.5	63%
M2N	24.5	23.9	4.10	20.8	28.9	154%	55.4	56.0	1.25	54.0	56.3	98%	28.1	27.4	2.41	26.1	30.8	57%
M2NE	16.9	17.8	5.45	11.1	21.9	106%	49.8	48.2	3.43	47.4	53.7	88%	31.5	29.9	4.84	27.6	36.9	64%
M2NW	7.10	7.02	1.07	6.08	8.21	45%	57.2	57.5	1.74	55.3	58.7	101%	45.5	46.0	0.98	44.4	46.2	93%
M2S	11.4	11.3	0.712	10.75	12.2	72%	59.8	59.3	0.92	59.1	60.8	106%	43.8	42.9	1.70	42.7	45.7	89%
M2SE	2.87	3.17	1.36	0.955	4.17	18%	19.1	19.8	4.68	12.9	24.0	34%	7.78	7.72	2.14	5.60	10.1	16%
M2SW	7.67	7.85	0.580	7.02	8.14	48%	56.8	56.1	2.34	54.8	59.4	101%	43.1	43.6	1.10	41.9	43.9	88%
M2W	8.14	7.98	0.852	7.38	9.06	51%	55.6	54.6	2.28	54.0	58.2	99%	40.0	39.2	1.61	39.0	41.9	81%
200 m	11.0	9.72	6.73	0.955	28.9	69%	48.8	54.3	13.8	12.9	60.8	87%	32.7	36.2	12.8	5.60	46.2	66%
M4E	18.0	18.2	3.46	13.6	22.0	113%	56.7	56.6	1.96	54.6	59.3	101%	41.3	41.0	2.99	37.9	45.2	84%
M4SE	13.9	13.6	1.60	12.4	15.6	87%	49.7	49.8	1.00	48.7	50.6	88%	26.9	26.0	3.09	24.4	30.4	55%
M4SW	11.6	12.8	2.59	8.64	13.4	73%	59.5	59.0	2.26	57.6	62.0	106%	47.5	47.8	1.27	46.1	48.6	96%
M4W	12.6	11.2	3.16	10.4	16.2	79%	58.0	57.6	1.60	56.6	59.8	103%	45.1	44.9	1.82	43.4	47.0	92%
400 m	14.3	13.6	3.65	8.64	22.0	90%	56.1	57.0	4.08	48.7	62.0	99%	40.3	43.4	8.27	24.4	48.6	82%
M8E	22.7	21.6	1.99	21.5	25.0	142%	55.8	53.8	6.14	50.9	62.7	99%	39.1	39.9	2.58	36.2	41.2	79%
M8W	8.62	8.35	1.57	7.2	10.3	54%	59.8	59.6	2.40	57.5	62.3	106%	56.5	57.0	1.63	54.7	57.9	115%
800 m	15.7	15.9	7.88	7.2	25.0	98%	57.8	58.6	4.71	50.9	62.7	103%	47.8	48.0	9.74	36.2	57.9	97%
PB1	17.6	16.7	1.93	16.4	19.9	110%	54.6	53.3	2.91	52.6	57.9	97%	49.5	49.0	1.07	48.8	50.8	101%
PB2	18.2	19.3	2.97	14.8	20.4	114%	57.4	58.6	2.63	54.3	59.1	102%	51.2	52.6	2.68	48.1	52.9	104%
PB3	16.7	16.9	2.30	14.4	19.0	105%	52.4	52.5	2.37	50.1	54.8	93%	42.6	43.0	3.52	39.0	46.0	87%
PB4	12.2	12.4	0.863	11.3	13.0	77%	59.6	59.9	1.51	58.0	61.0	106%	53.8	53.9	0.66	53.1	54.3	109%
PB5	15.0	16.5	3.63	10.9	17.7	94%	57.7	57.6	1.39	56.3	59.1	102%	48.9	49.4	3.60	45.1	52.3	99%
Reference	16.0	16.5	3.08	10.9	20.4	100%	56.3	57.6	3.23	50.1	61.0	100%	49.2	49.4	4.41	39.0	54.3	100%
Near-field	3.50	3.19	2.45	0.910	7.5	22%	24.0	20.7	12.0	9.22	42.4	43%	9.20	9.07	3.60	3.69	14.7	19%
Mid-field	11.7	11.2	4.87	5.73	22.0	73%	46.9	48.3	6.81	31.8	59.3	83%	30.1	29.1	6.87	17.7	45.2	61%
Far-field	12.6	10.6	6.17	5.43	28.9	79%	56.8	57.1	3.48	47.7	62.7	101%	42.6	43.0	6.67	26.1	57.9	87%

Note: SD = standard deviation; Near-field includes M0, M1E, M1SE, M2SE; Mid-field includes: M1W, M1SW, M1S, M2E, M2NE, M4E, M4SE; Far-field includes M1NE, M1NW, M1N, M2N, M2W, M2NW, M2S, M2SW, M4W, M4SW, M8W, M8E; Reference (ref.) includes PB1–PB5

Table 4.3 Macaulay Point 2010 Benthic Community Metrics, Correlations with Distance from the Outfall and Statistical Comparisons to References

Metric	Spearman Rank Correlation (r_s) with Distance from Outfall ¹	P-values (by Distance Group) for Comparisons to Reference Stations ^{1,2}				
		Outfall	100m	200m	400m	800m
Total Abundance	-0.129	0.005	1.00	0.837	1.00	1.00
Polychaete Abundance	-0.671**	0.005	<0.001	<0.001	0.005	0.045
Taxonomic Richness	0.609**	0.005	<0.001	0.002	1.00	0.019
Swartz Dominance Index (SDI)	0.623**	0.005	<0.001	0.012	0.800	1.00
Infaunal Trophic Index (ITI), Standard	0.603**	0.005	<0.001	0.309	1.00	1.00
Infaunal Trophic Index (ITI), Regional	0.699**	0.005	<0.001	<0.001	0.005	1.00
Echinodermata	0.542**	0.009	<0.001	<0.001	1.00	0.023
Bivalvia	0.293**	0.005	0.264	1.00	1.00	1.00
Gastropoda	0.691**	0.005	<0.001	<0.001	0.001	0.161
Crustacea (Amphipoda)	-0.240*	0.005	1.00	0.038	1.00	1.00
Crustacea (Other)	0.370**	0.017	<0.001	<0.001	<0.001	1.00
Polychaeta Errantia	-0.389**	0.006	<0.001	<0.001	<0.001	0.878
Polychaeta Sedentaria (Other)	0.062	0.063	1.00	0.034	0.127	0.007
<i>Capitella capitata</i> complex	-0.760**	<0.001	<0.001	<0.001	<0.001	0.110
Miscellaneous Taxa	0.321**	0.005	<0.001	<0.001	0.019	1.00
Benthic Dim 1	0.774**	0.005	<0.001	<0.001	<0.001	0.025
Benthic Dim 2	-0.078	0.005	0.004	0.598	0.264	1.00
Total Organic Carbon (TOC)	-0.670**	-	-	-	-	-
Percent Gravel	-0.599**	-	-	-	-	-
Percent Fines	0.221	-	-	-	-	-

Note

¹ Statistical significance (2-tailed): ** = $p < 0.01$; * = $p < 0.05$. Significant results are shown in **boldface**.

² P-values shown include Bonferroni adjustments for multiple comparisons where applicable.

Table 4.4 Macaulay Point Benthic Community Metrics, Correlations with Distance-Direction from the Outfall and Statistical Comparisons to References

Metric	Spearman Rank Correlation (r_s) with Distance-Direction from Outfall ¹	P-values for Comparisons Among Distance-Direction Groups ^{1,2}			
		Outfall	Near-field	Mid-field	Far-field
Total Abundance	-0.004	0.004	1.00	0.561	0.155
Polychaete Abundance	-0.758**	0.004	<0.001	<0.001	0.002
Taxonomic Richness	0.691**	0.004	<0.001	0.002	0.010
Swartz Dominance Index (SDI)	0.586**	0.004	<0.001	0.018	0.044
Infaunal Trophic Index (ITI), Standard	0.762**	0.004	<0.001	<0.001	1.00
Infaunal Trophic Index (ITI), Regional	0.864**	<0.001	<0.001	<0.001	0.002
Echinodermata	0.312**	0.008	<0.001	0.211	<0.001
Bivalvia	0.649**	0.004	<0.001	0.003	0.018
Gastropoda	0.724**	0.004	<0.001	<0.001	<0.001
Crustacea (Amphipoda)	-0.114	0.004	1.00	0.383	0.058
Crustacea (Other)	0.502**	0.004	<0.001	<0.001	<0.001
Polycheata Errantia	-0.377**	0.082	0.406	<0.001	<0.001
Polycheata Sedentaria (Other)	0.199	0.051	1.00	1.00	0.048
<i>Capitella capitata</i> complex	-0.856**	<0.001	<0.001	<0.001	<0.001
Miscellaneous Taxa	0.326**	0.004	<0.001	<0.001	0.001
Benthic Dim 1	0.895**	0.004	<0.001	<0.001	<0.001
Benthic Dim 2	-0.086	<0.001	0.138	0.010	0.233
Total Organic Carbon (TOC)	-0.779**	-	-	-	-
Percent Gravel	-0.698**	-	-	-	-
Percent Fines	0.338	-	-	-	-
Total Abundance	-0.004	0.004	1.00	0.561	0.155

Notes

¹ Statistical significance (2-tailed): ** = $p < 0.01$; * = $p < 0.05$. Significant results are shown in **boldface**.

² P-values shown include Bonferroni adjustments for multiple comparisons where applicable.

Near-field includes: M1E, M1SE and M2SE. Mid-field includes: M1W, M1SW, M1S, M2E, M2NE, M4SE and M4E. Far-field includes: M1N, M1NE, M1NW, M2N, M2NW, M2S, M2SW, M2W, M4SW, M4W, M8W and M8E. Reference includes: PB1 to PB5.

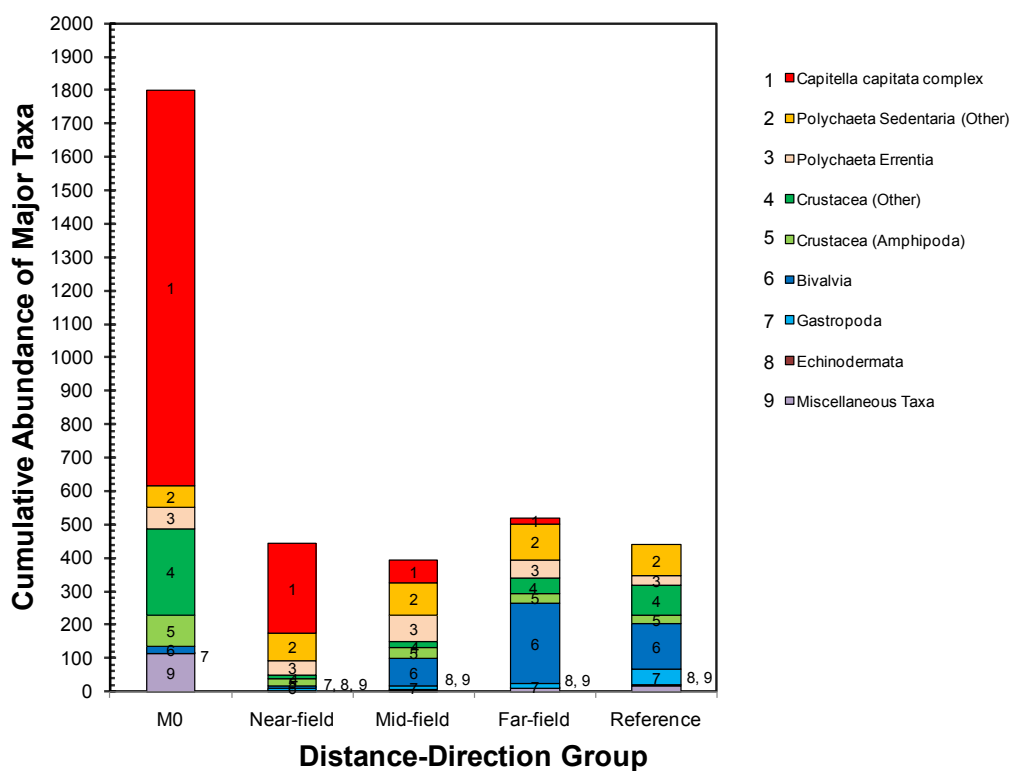
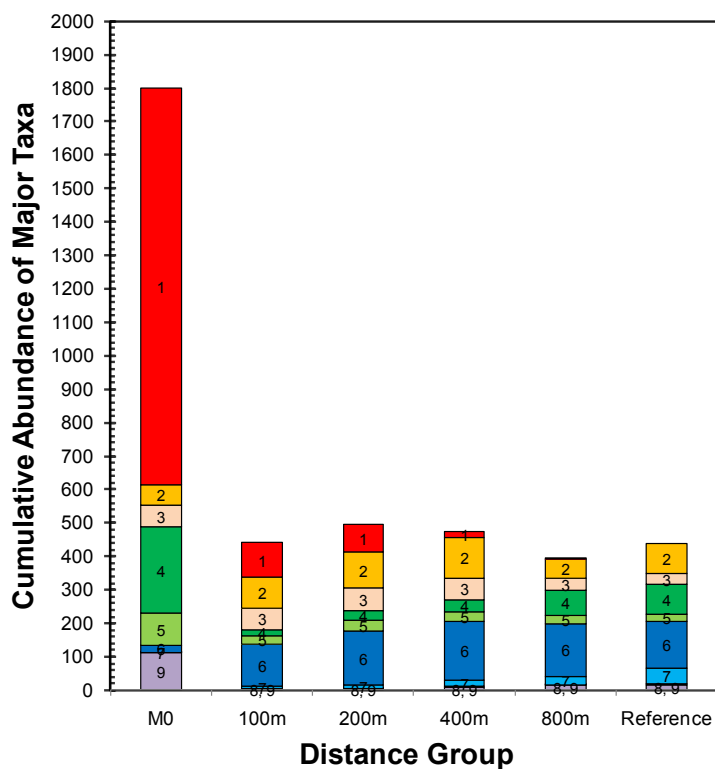


Figure 4.4 Cumulative Abundance of Major Taxa by Distance-Direction (top panel) and by Distance (bottom panel) from the Macaulay Point Outfall (2010)

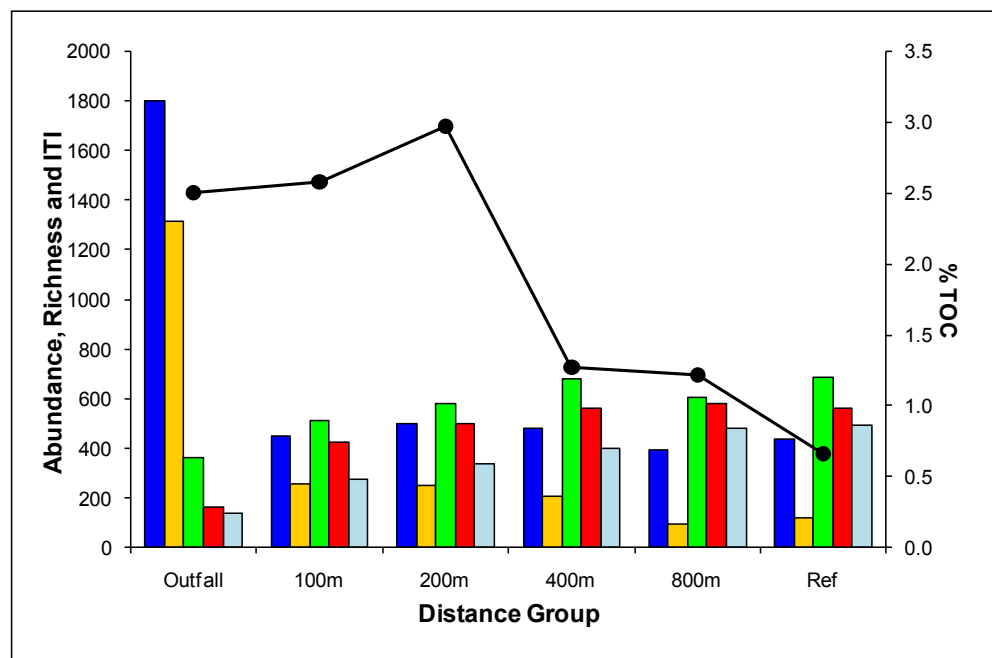
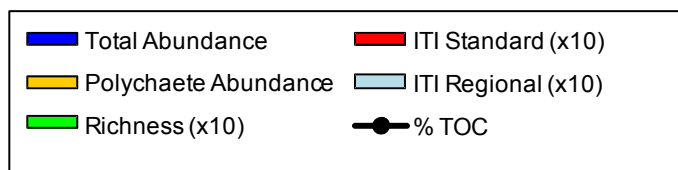
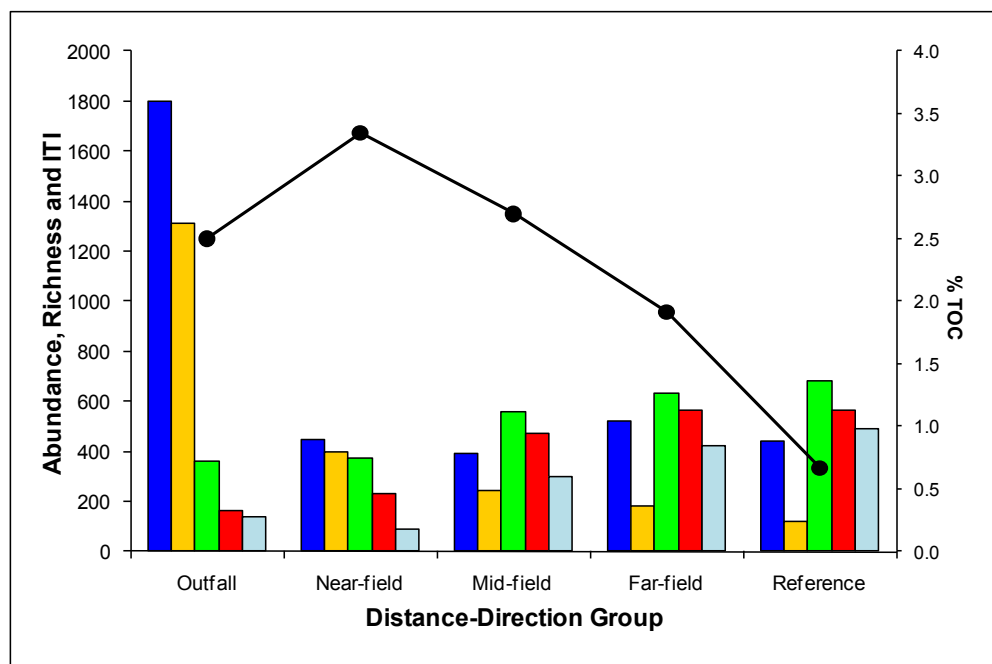


Figure 4.5 Comparison of TOC and Benthic Community Parameters among Distance and Distance-Direction Groups

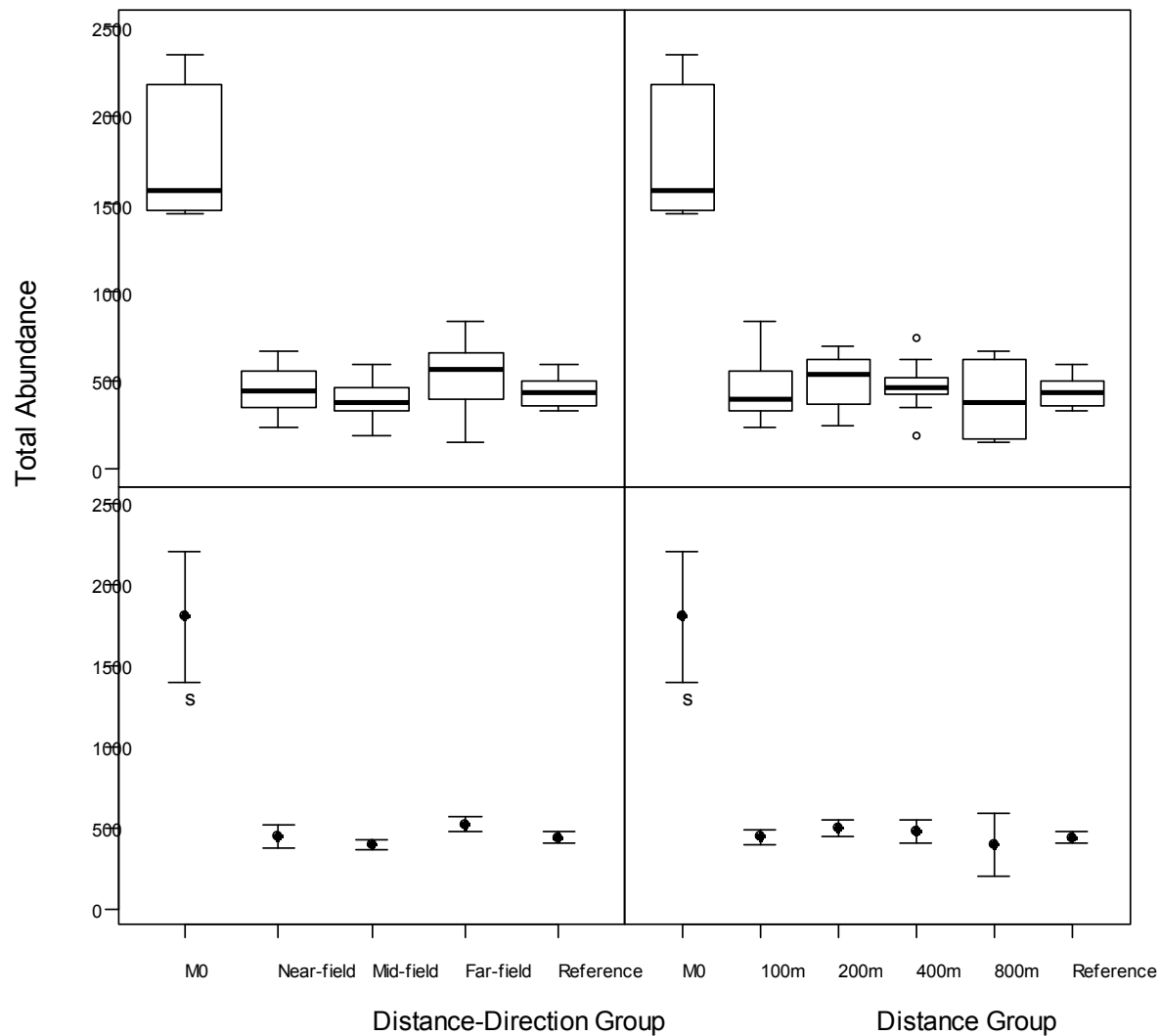


Figure 4.6 Box and Whisker Plots (Top Panel) and Means $\pm$ 95% Confidence Intervals (Bottom Panel) for 2010 Total Organism Abundance

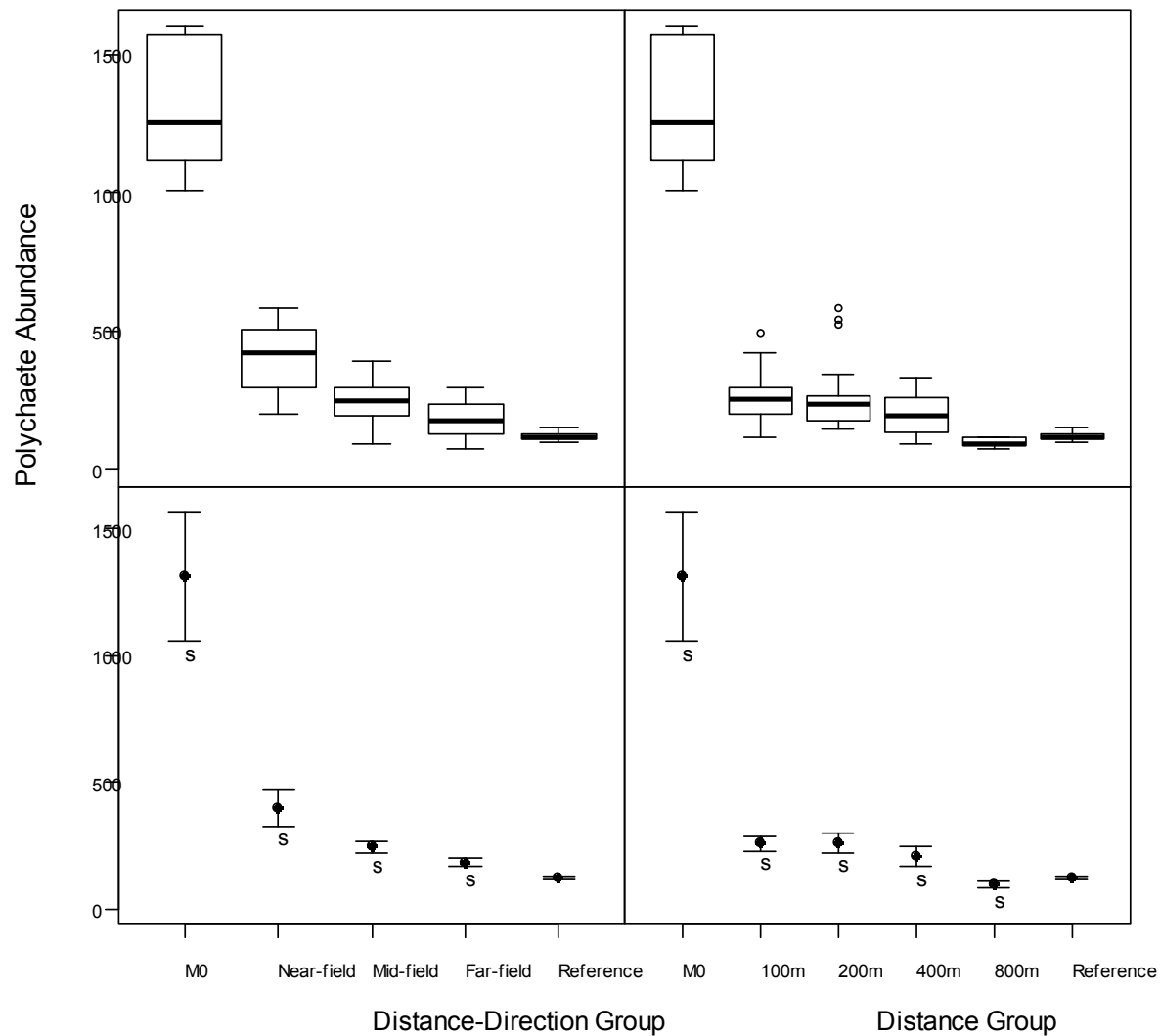


Figure 4.7 Box and Whisker Plots (Top Panel) and Means $\pm$ 95% Confidence Intervals (Bottom Panel) for 2010 Polychaete Abundance

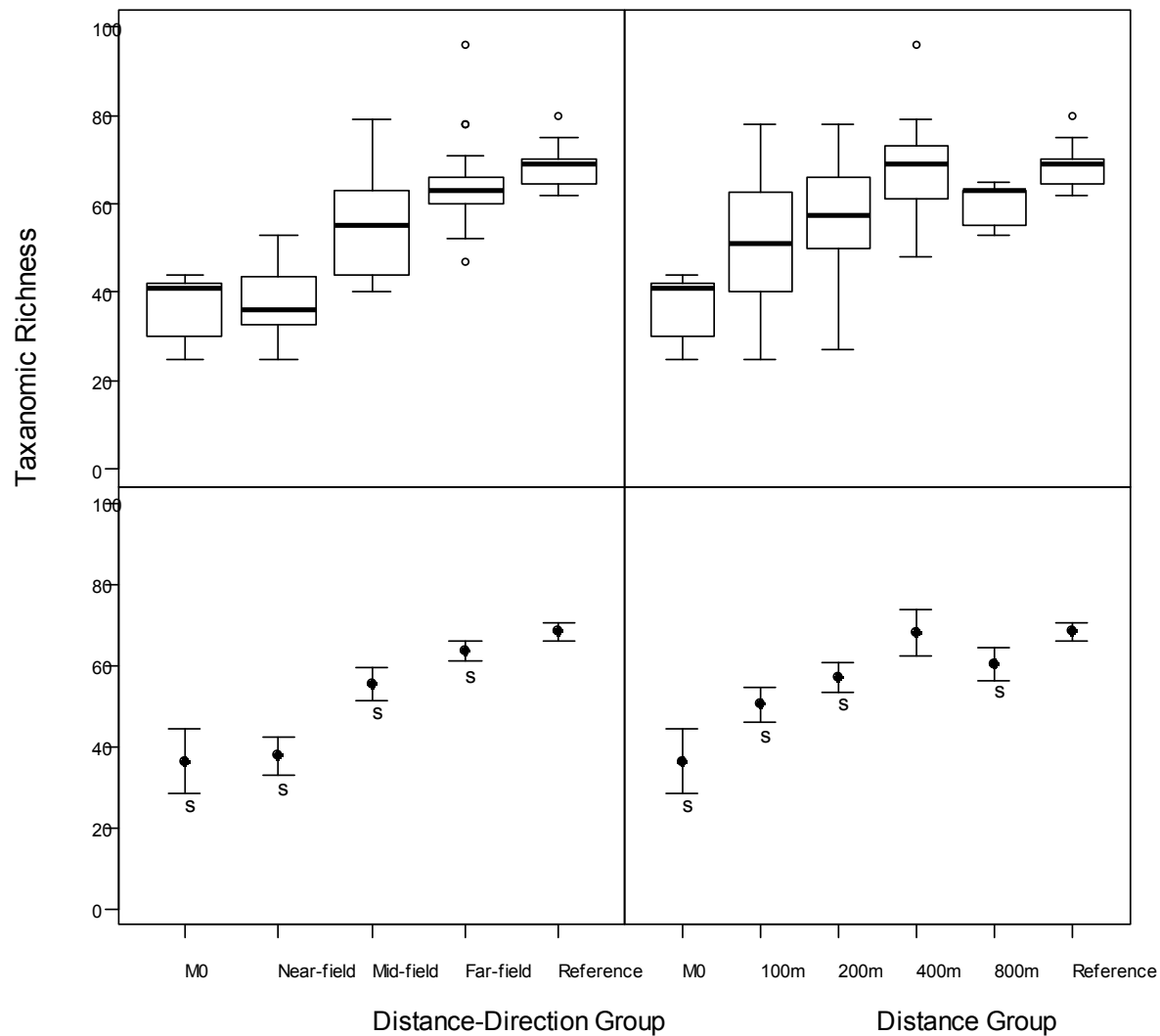


Figure 4.8 Box and Whisker Plots (Top Panel) and Means $\pm$ 95% Confidence Intervals (Bottom Panel) for 2010 Taxonomic Richness

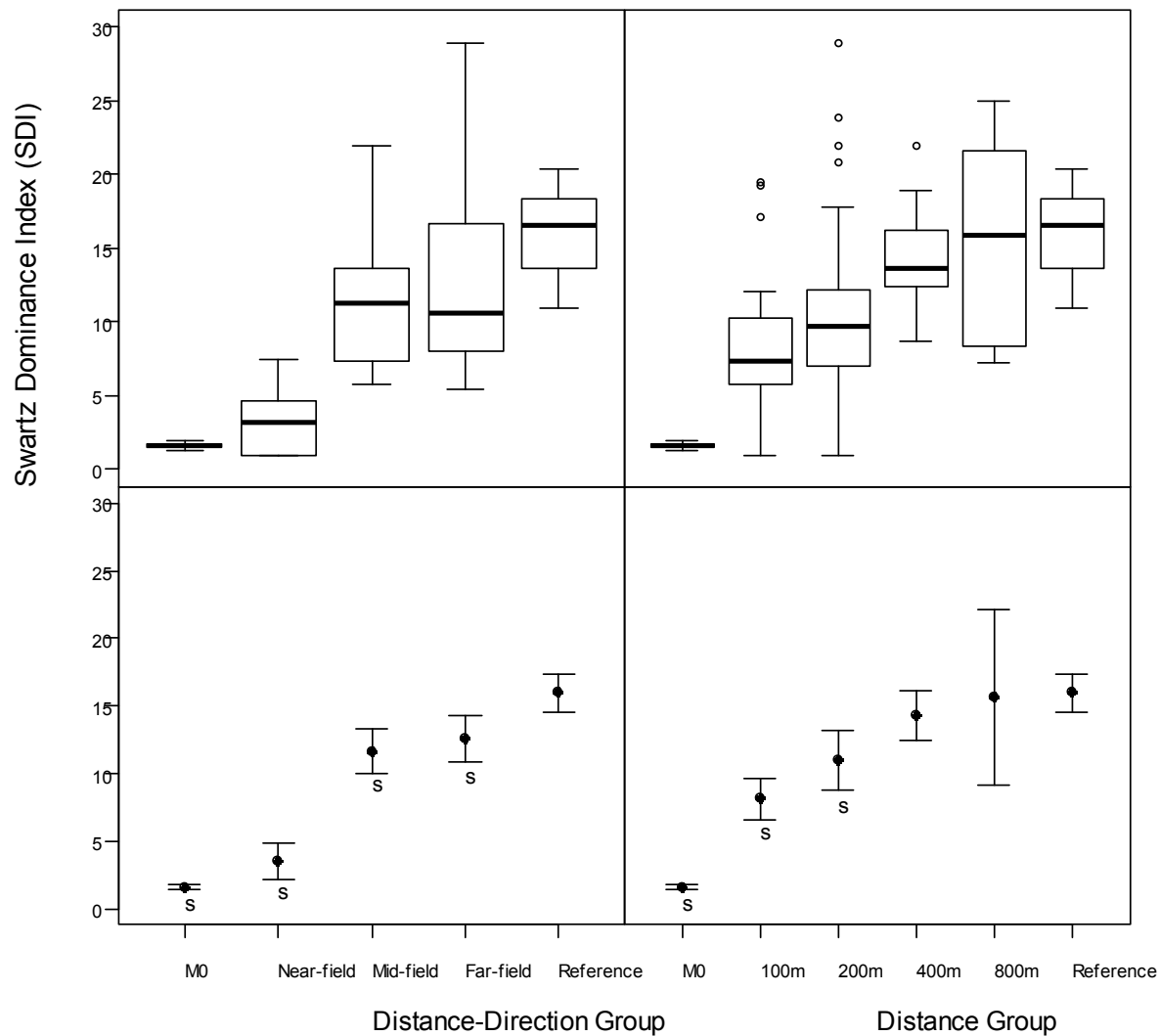


Figure 4.9 Box and Whisker Plots (Top Panel) and Means $\pm$ 95% Confidence Intervals (Bottom Panel) for 2010 Swartz Dominance Index

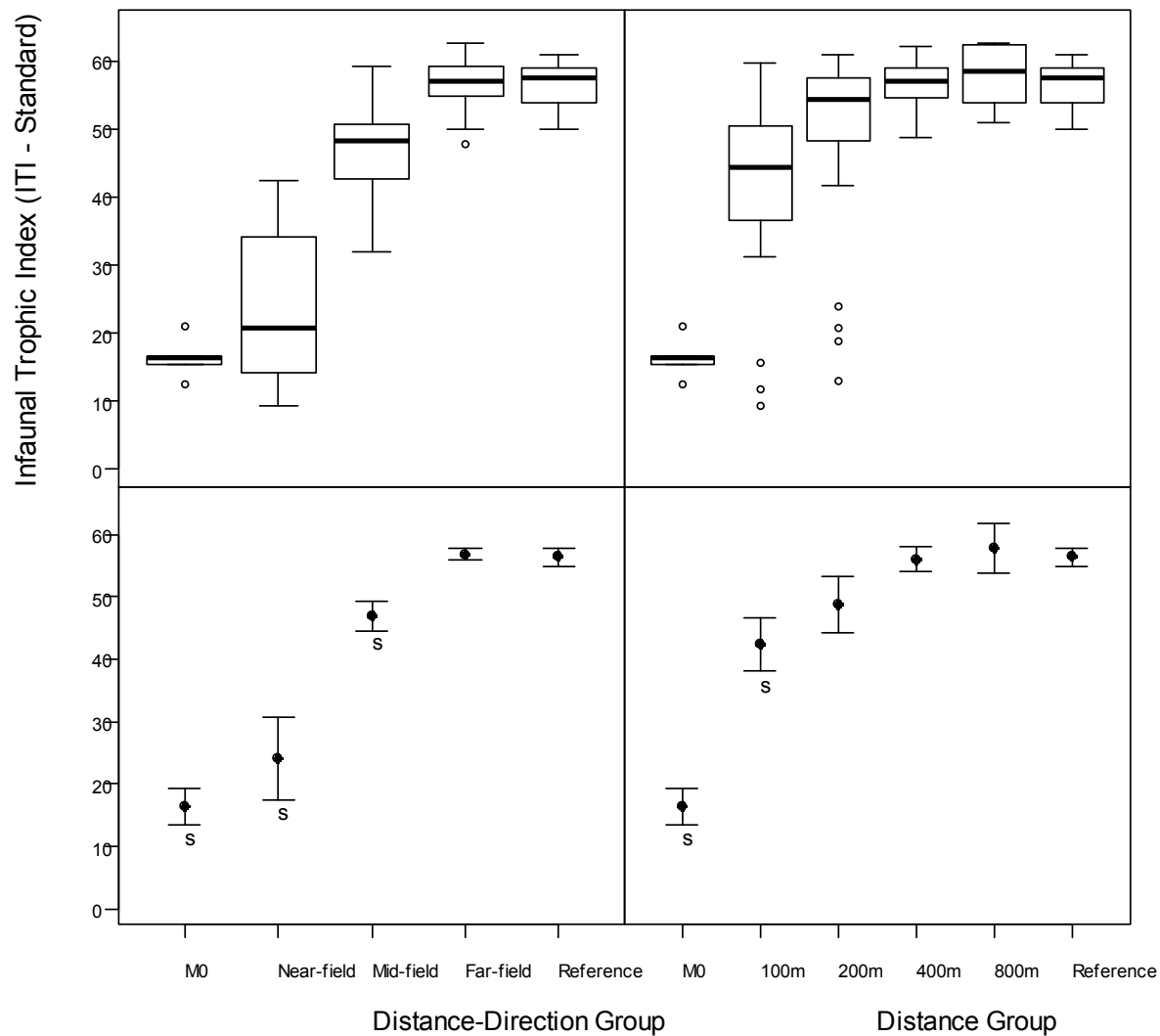


Figure 4.10 Box and Whisker Plots (Top Panel) and Means $\pm$ 95% Confidence Intervals (Bottom Panel) for 2010 Infaunal Trophic Index - Standard

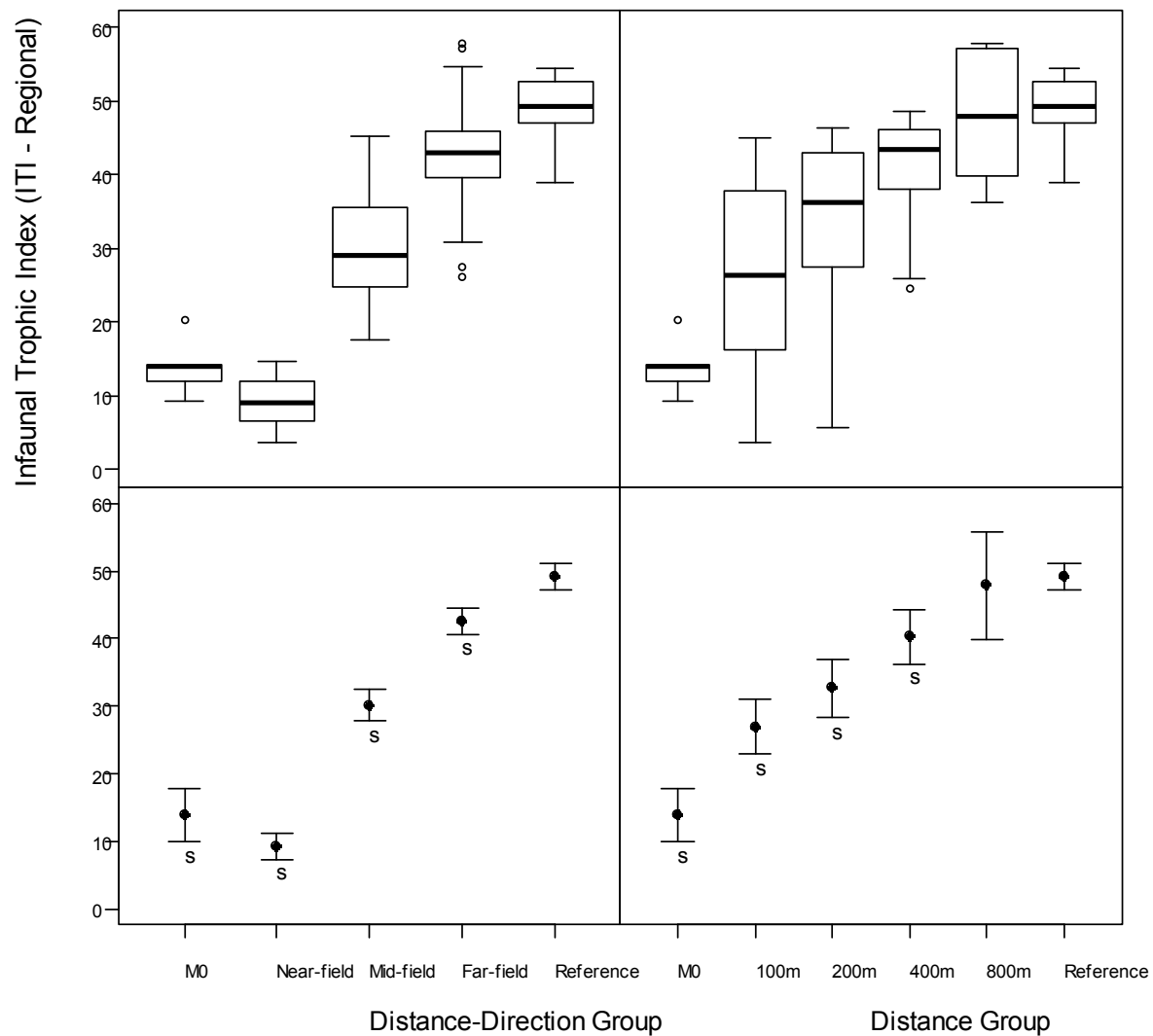


Figure 4.11 Box and Whisker Plots (Top Panel) and Means $\pm$ 95% Confidence Intervals (Bottom Panel) for 2010 Infaunal Trophic Index – Regional

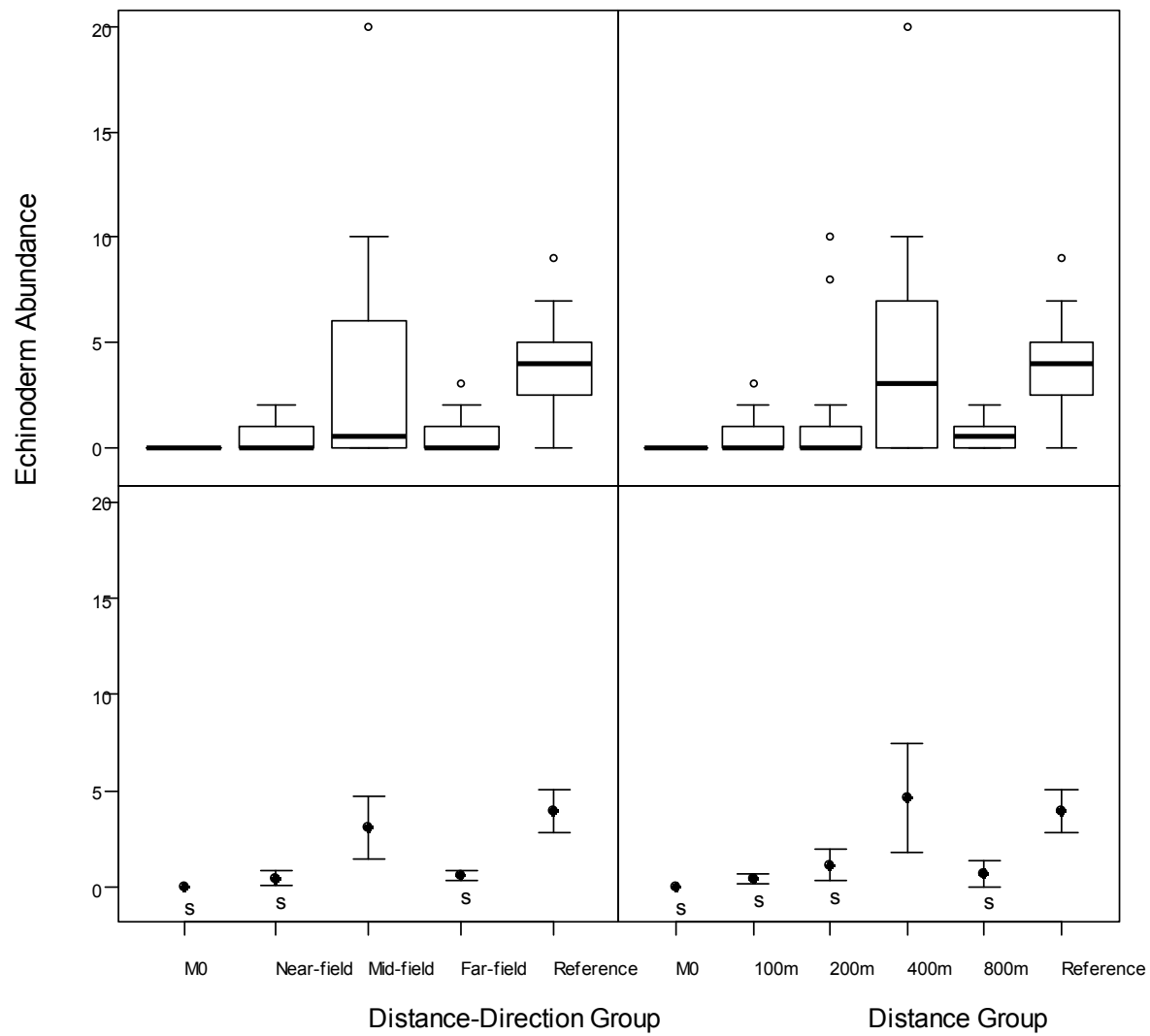


Figure 4.12 Box and Whisker Plots (Top Panel) and Means $\pm$ 95% Confidence Intervals (Bottom Panel) for 2010 Echinoderm Abundance

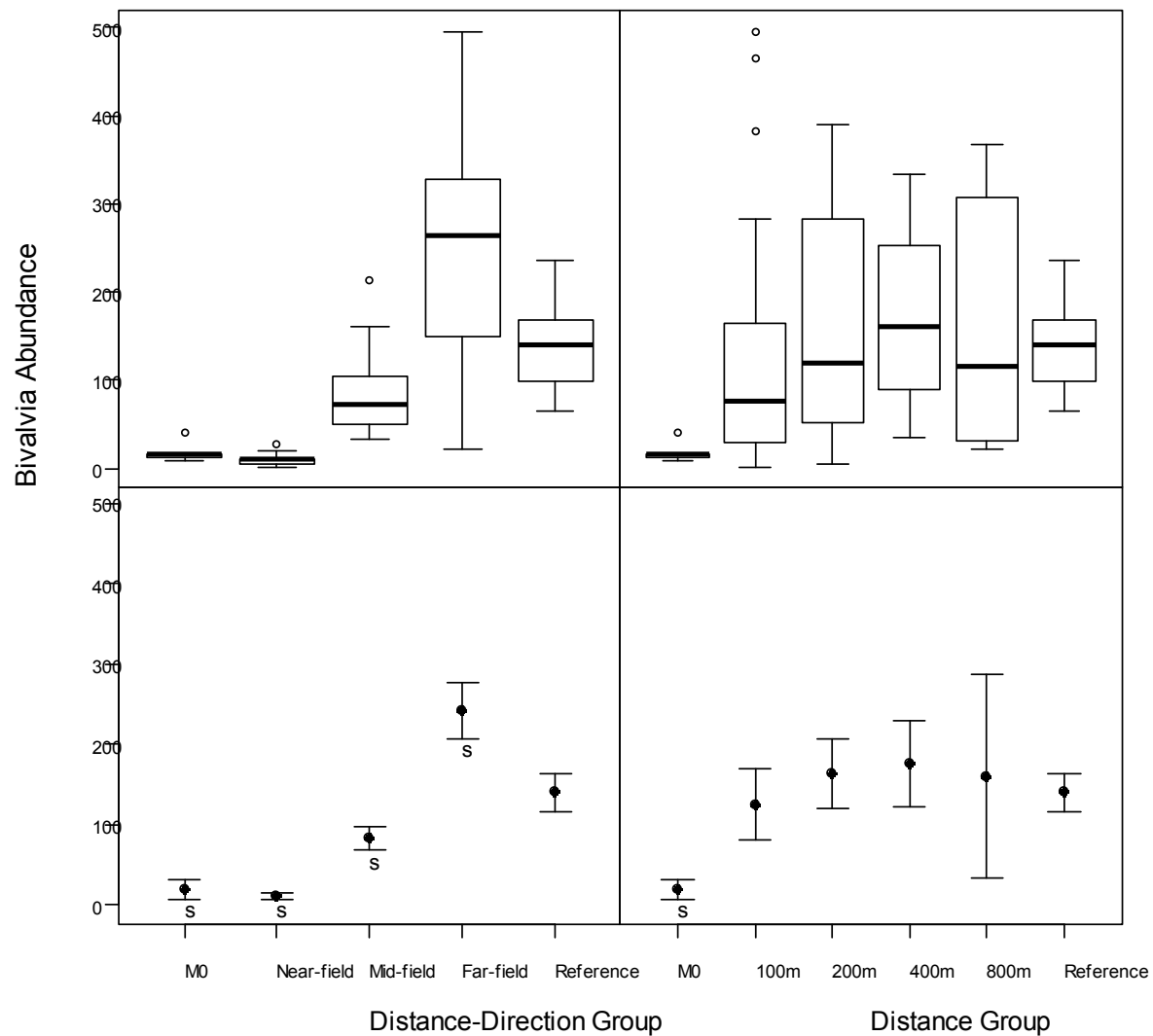


Figure 4.13 Box and Whisker Plots (Top Panel) and Means $\pm$ 95% Confidence Intervals (Bottom Panel) for 2010 Bivalve Abundance

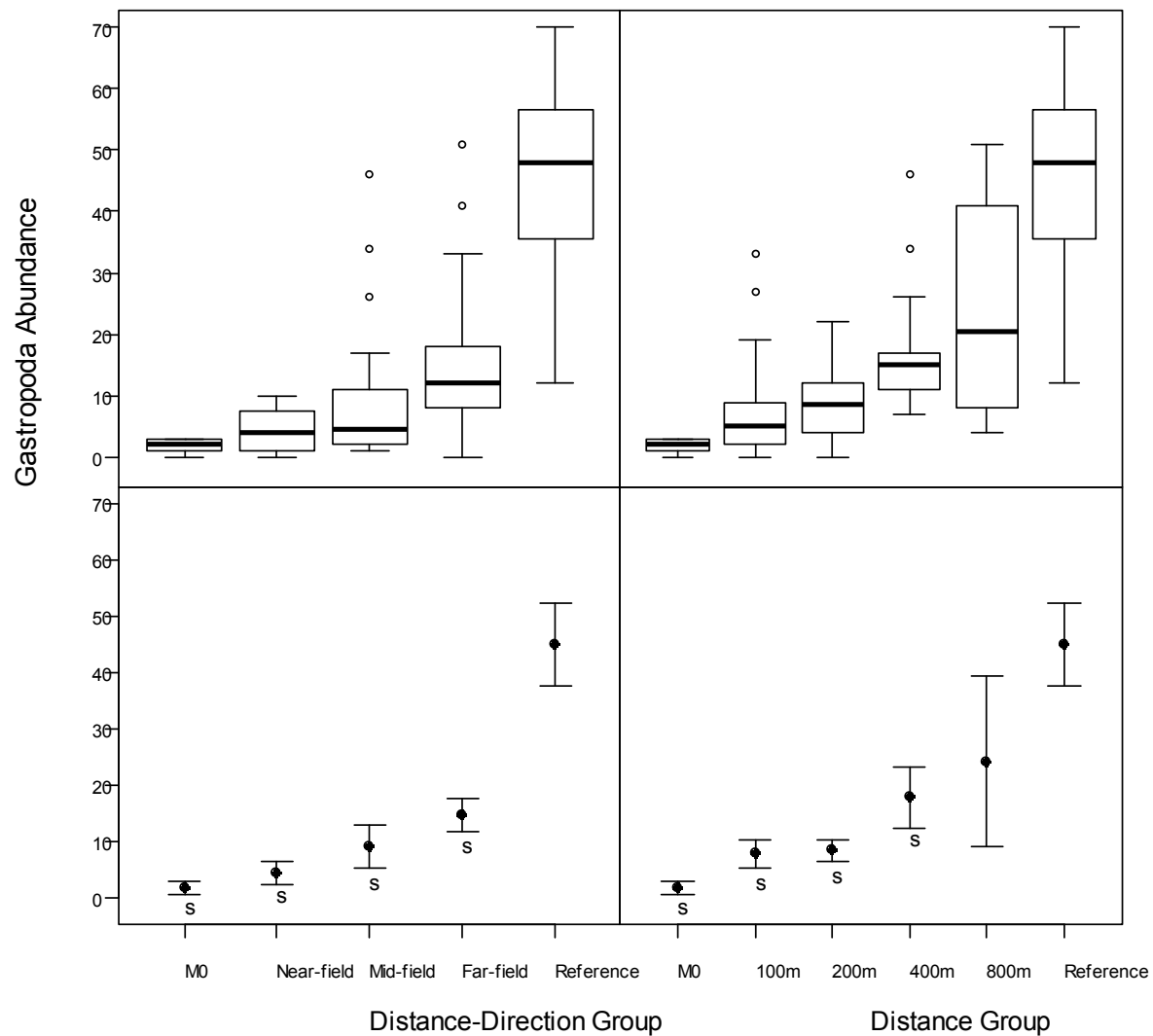


Figure 4.14 Box and Whisker Plots (Top Panel) and Means $\pm$ 95% Confidence Intervals (Bottom Panel) for 2010 Gastropod Abundance

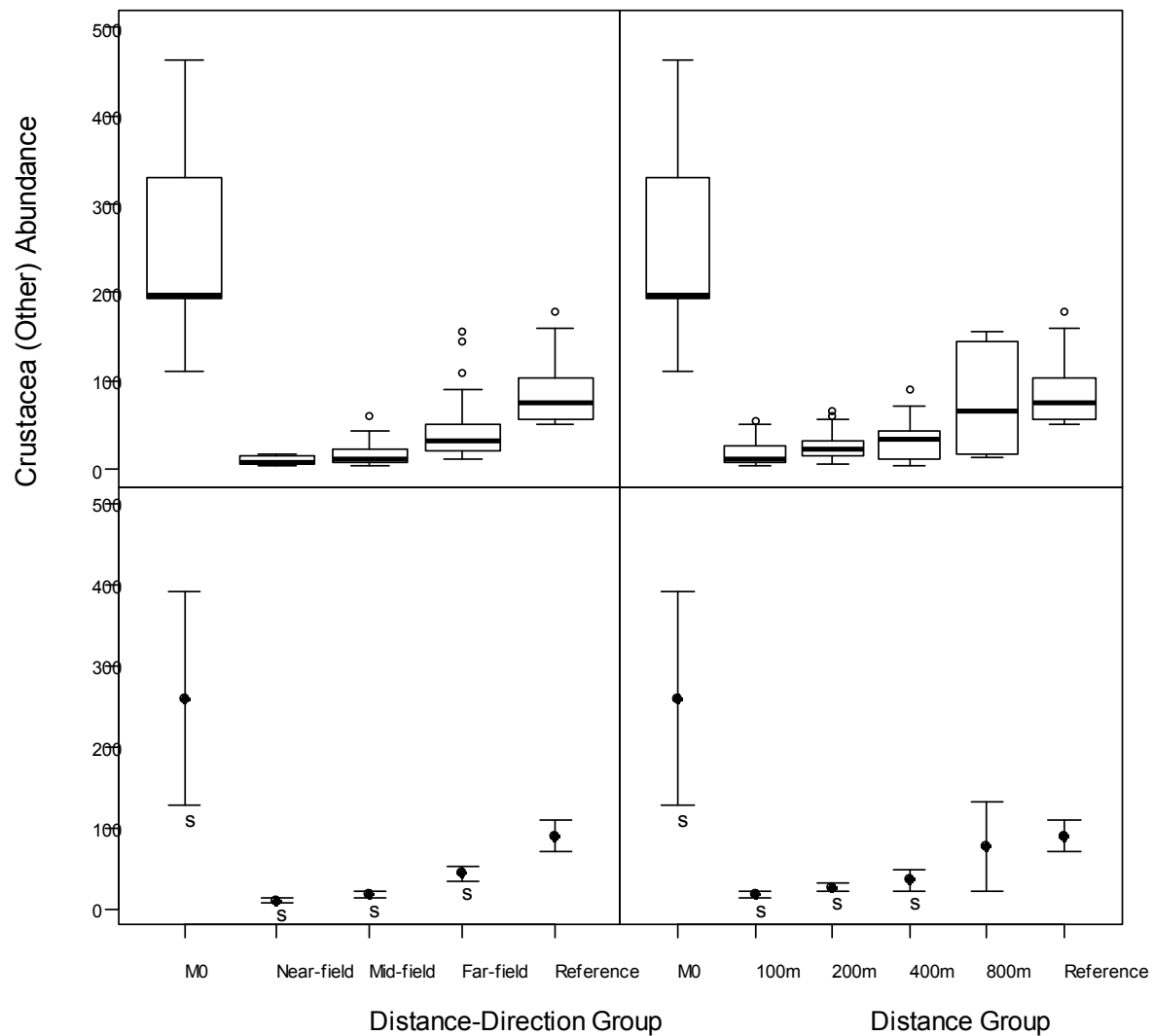


Figure 4.15 Box and Whisker Plots (Top Panel) and Means $\pm$ 95% Confidence Intervals (Bottom Panel) for 2010 Crustacean Abundance (non-amphipod only)

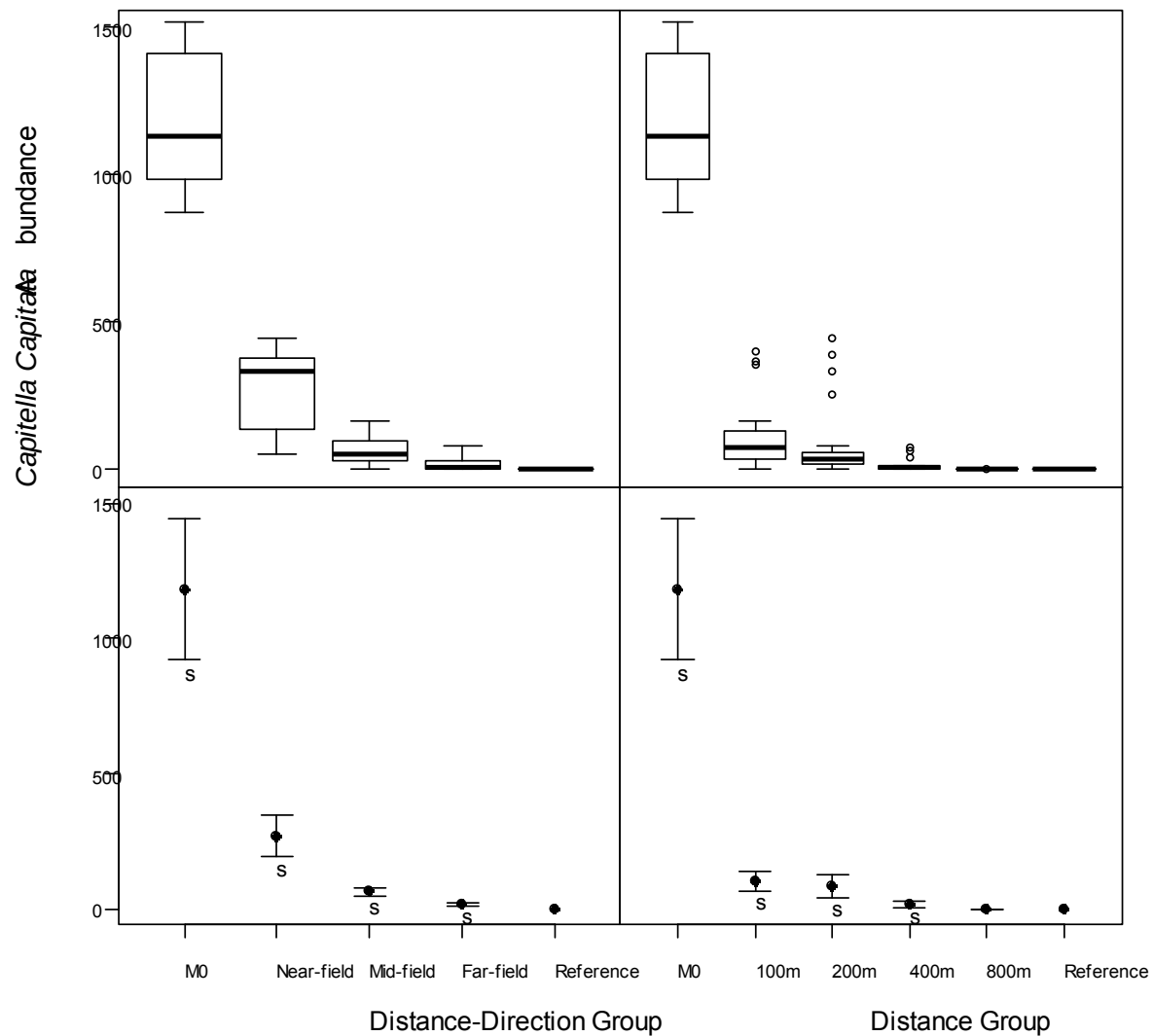


Figure 4.16 Box and Whisker Plots (Top Panel) and Means $\pm$ 95% Confidence Intervals (Bottom Panel) for 2010 *Capitella Capitata* Abundance

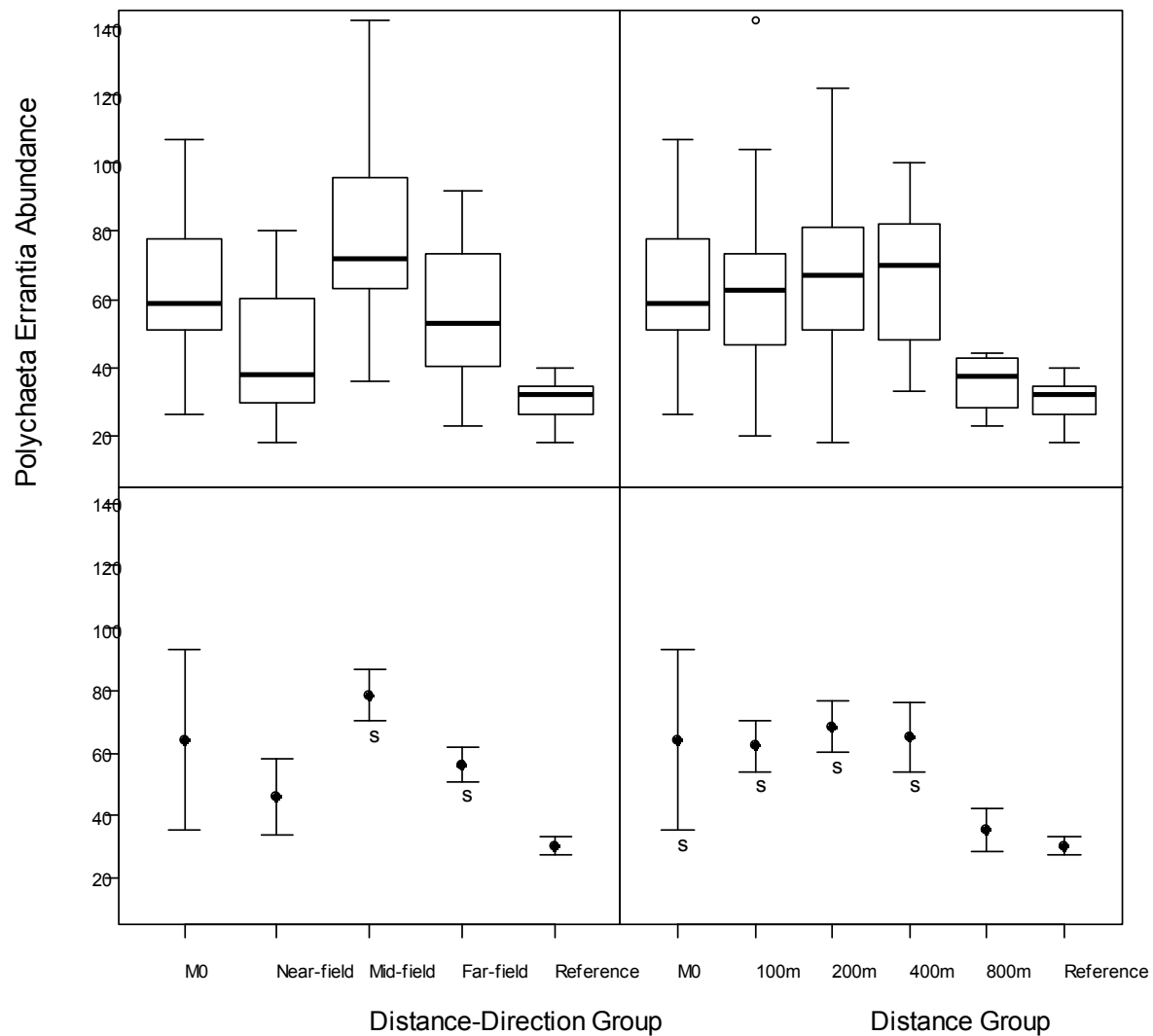


Figure 4.17 Box and Whisker Plots (Top Panel) and Means $\pm$ 95% Confidence Intervals (Bottom Panel) for 2010 Mobile Polychaete Abundance

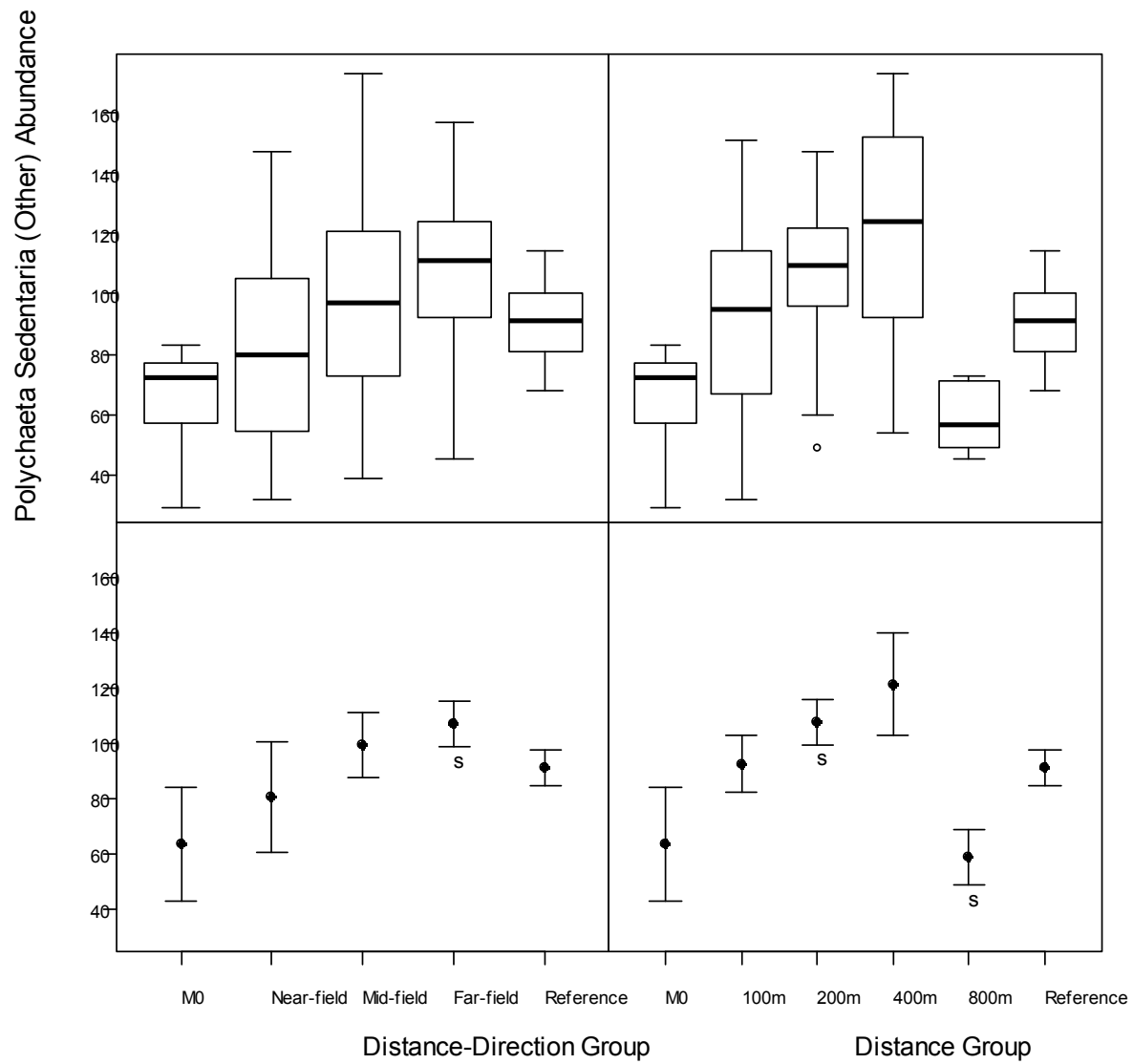


Figure 4.18 Box and Whisker Plots (Top Panel) and Means $\pm$ 95% Confidence Intervals (Bottom Panel) for 2010 Sedentary Polychaete Abundance (non-capitellid)

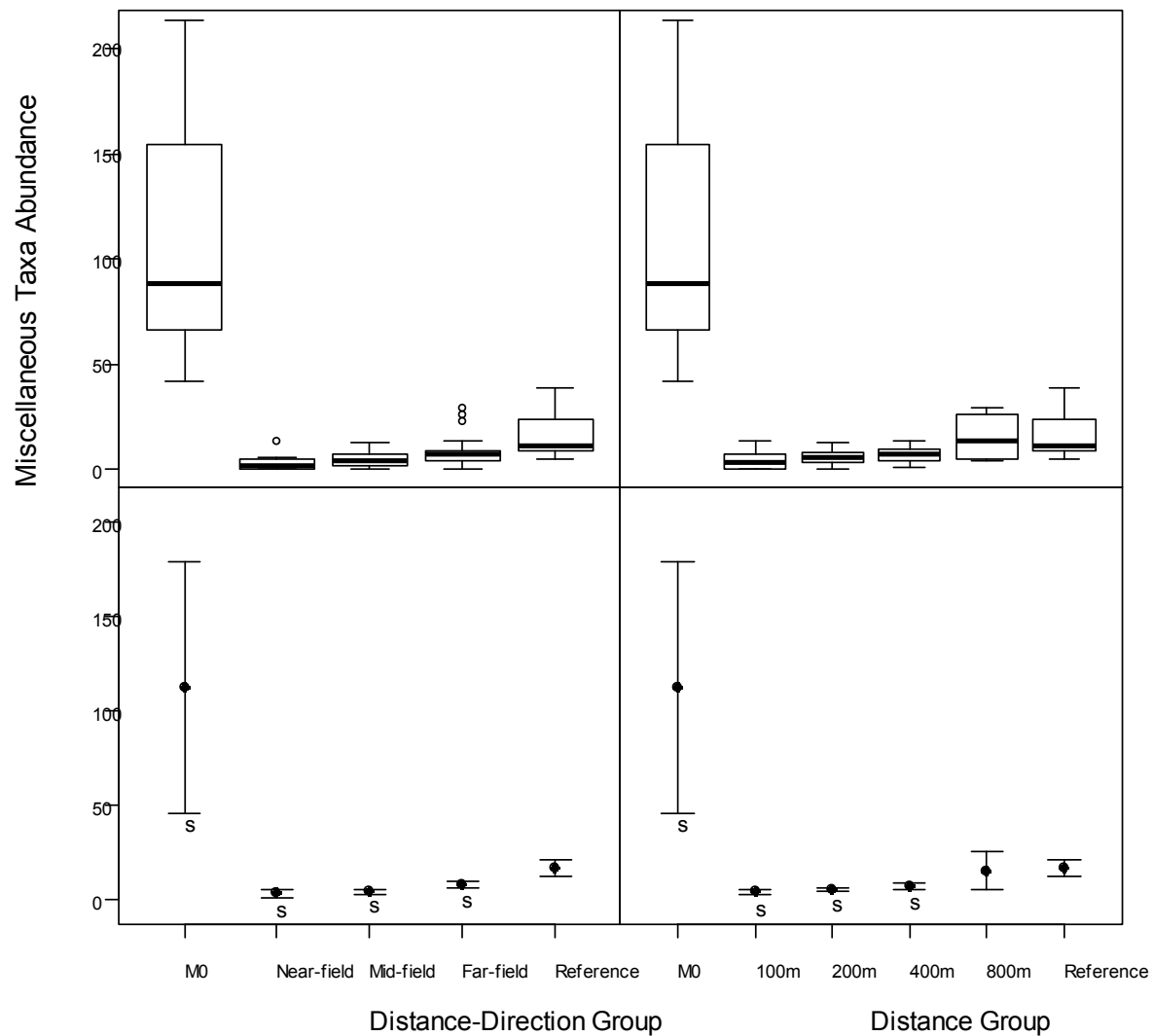


Figure 4.19 Box and Whisker Plots (Top Panel) and Means $\pm$ 95% Confidence Intervals (Bottom Panel) for 2010 Miscellaneous Taxa Abundance

Table 4.5 Mean Values and Percent of Reference for Macaulay Point 2010 Abundance of Major Taxonomic Groups

Station	Echinodermata		Bivalvia		Gastropoda		Crustacea (Amphipoda)		Crustacea (Other)	
	Mean	% Ref.	Mean	% Ref.	Mean	% Ref.	Mean	% Ref.	Mean	% Ref.
M0	0.00	0%	19.2	14%	1.80	4%	95.8	435%	259	287%
M1E	0.75	19%	13.3	9%	6.75	15%	12.3	56%	6.00	7%
M1N	0.33	8%	99.0	71%	7.67	17%	38.3	174%	34.3	38%
M1NE	0.00	0%	251	180%	23.0	51%	28.0	127%	32.7	36%
M1NW	0.33	8%	447	320%	16.3	36%	37.7	171%	33.7	37%
M1S	0.75	19%	129	92%	5.00	11%	16.5	75%	11.0	12%
M1SE	0.00	0%	3.67	3%	2.67	6%	16.7	76%	13.0	14%
M1SW	0.75	19%	52.3	37%	2.50	6%	37.3	169%	10.5	12%
M1W	0.25	6%	78.0	56%	3.00	7%	33.5	152%	15.0	17%
100 metre stations	0.43	11%	125	89%	7.79	17%	27.1	123%	18.3	20%
M2E	2.25	57%	68.8	49%	5.25	12%	44.5	202%	27.5	31%
M2N	1.00	25%	67.3	48%	15.7	35%	38.0	173%	35.7	40%
M2NE	3.33	85%	73.0	52%	3.00	7%	23.3	106%	22.0	24%
M2NW	0.33	8%	346	248%	13.7	30%	24.3	111%	34.3	38%
M2S	1.00	25%	231	165%	6.33	14%	36.0	164%	30.0	33%
M2SE	0.50	13%	12.0	9%	3.25	7%	28.8	131%	11.8	13%
M2SW	0.67	17%	317	227%	9.7	22%	28.0	127%	19.3	21%
M2W	0.00	0%	269	192%	13.0	29%	37.0	168%	37.3	41%
200 metre stations	1.15	29%	163	116%	8.38	19%	32.8	149%	26.7	30%
M4E	7.75	197%	112	80%	18.3	41%	39.5	180%	26.0	29%
M4SE	7.67	195%	61.7	44%	30.3	68%	27.0	123%	9.00	10%
M4SW	1.00	25%	220	158%	9.33	21%	17.3	79%	43.7	48%
M4W	1.00	25%	329	235%	13.0	29%	33.0	150%	65.3	72%
400 metre stations	4.62	117%	175	125%	17.8	40%	30.0	136%	35.2	39%
M8E	0.33	8%	29.3	21%	21.3	48%	20.7	94%	17.3	19%
M8W	1.00	25%	291	208%	27.0	60%	22.7	103%	137	152%
800 metre stations	0.67	17%	160	115%	24.2	54%	21.7	98%	77.2	86%
PB1	3.00	76%	102	73%	60.3	134%	20.3	92%	73.7	82%
PB2	6.33	161%	120	86%	53.3	119%	21.0	95%	80.3	89%
PB3	5.33	136%	112	80%	53.0	118%	26.3	120%	60.7	67%
PB4	3.00	76%	187	134%	28.3	63%	24.3	111%	161	179%
PB5	2.00	51%	179	128%	29.3	65%	18.0	82%	74.7	83%
Reference stations	3.93	100%	140	100%	44.9	100%	22.0	100%	90.1	100%
Near-field stations	0.45	12%	10.2	7%	4.36	10%	19.5	88%	10.0	11%
Mid-field stations	3.08	78%	83.2	60%	9.08	20%	32.2	146%	17.4	19%
Far-field stations	0.58	15%	242	173%	14.7	33%	30.1	137%	43.4	48%

continued

Table 4.5, continued

Station	Polychaeta Errantia		Polychaeta Sedentaria (Other)		Polychaeta Sedentaria (Capitella)		Miscellaneous Taxa	
	Mean	% Ref.	Mean	% Ref.	Mean	% Ref.	Mean	% Ref.
M0	64.2	212%	63.6	70%	1183	NC	113	681%
M1E	57.8	191%	97.3	107%	106	NC	5.50	33%
M1N	42.0	139%	97.3	107%	4.33	NC	6.33	38%
M1NE	78.0	258%	146	161%	39.7	NC	6.67	40%
M1NW	51.3	170%	116	128%	8.00	NC	7.00	42%
M1S	84.3	278%	78.5	86%	72.0	NC	1.50	9%
M1SE	26.3	87%	43.7	48%	374	NC	0.33	2%
M1SW	60.3	199%	59.3	65%	116	NC	2.00	12%
M1W	84.5	279%	109	120%	116	NC	3.75	23%
100 metre stations	62.1	205%	92.4	102%	104	NC	4.00	24%
M2E	83.0	274%	98.5	108%	48.3	NC	5.00	30%
M2N	48.0	159%	115	126%	0.00	NC	6.67	40%
M2NE	90.3	298%	98.7	109%	24.7	NC	5.33	32%
M2NW	58.3	193%	109	120%	32.0	NC	7.33	44%
M2S	71.0	235%	121	133%	19.0	NC	4.67	28%
M2SE	48.8	161%	91.3	100%	357	NC	3.25	20%
M2SW	72.3	239%	116	128%	50.3	NC	9.33	56%
M2W	77.0	254%	121	133%	59.0	NC	0.67	4%
200 metre stations	68.4	226%	108	118%	83.7	NC	5.19	31%
M4E	71.3	235%	105	115%	11.3	NC	6.25	38%
M4SE	79.7	263%	161	177%	60.0	NC	6.67	40%
M4SW	39.7	131%	90.7	100%	0.00	NC	6.33	38%
M4W	66.7	220%	134	147%	11.0	NC	10.0	60%
400 metre stations	64.8	214%	121	133%	19.8	NC	7.23	44%
M8E	29.7	98%	60.3	66%	1.33	NC	4.67	28%
M8W	41.3	137%	56.7	62%	0.00	NC	26.0	157%
800 metre stations	35.5	117%	58.5	64%	0.67	NC	15.33	93%
PB1	35.0	116%	94.7	104%	0.00	NC	19.7	119%
PB2	34.3	113%	80.7	89%	0.00	NC	11.67	71%
PB3	33.3	110%	106	117%	0.00	NC	8.33	50%
PB4	28.3	94%	78.3	86%	0.00	NC	30.3	183%
PB5	20.3	67%	95.0	104%	0.00	NC	12.67	77%
Reference stations	30.3	100%	90.9	100%	0.00	NC	16.53	100%
Near-field stations	45.9	152%	80.5	88%	270	NC	3.27	20%
Mid-field stations	78.6	260%	99.2	109%	65.6	NC	4.23	26%
Far-field stations	56.3	186%	107	118%	18.7	NC	7.97	48%

Note: NC = Not calculated; the mean abundance at reference stations was equal to zero and therefore the % Reference could not be calculated. Near-field includes: M1E, M1SE and M2SE. Mid-field includes: M1W, M1SW, M1S, M2E, M2NE, M4SE and M4E. Far-field includes: M1N, M1NE, M1NW, M2N, M2NW, M2S, M2SW, M2W, M4SW, M4W, M8W and M8E. Reference includes: PB1 to PB5.

Spatial Assessment

Non-metric multidimensional scaling (NMDS) was performed using the nine major taxa (Figure 4.20). The purpose of this exercise was assess the spatial distribution of recently added reference stations (PB4 and PB5) in comparison to the other reference stations (PB1 through PB3), and to investigate the spatial distribution of monitoring stations based on the 2010 benthic data (Golder, 2011a).

These results are specific to the 2010 monitoring event. Two dimensions were derived from the benthic community data (Golder, 2010a), which together accounted for 93% of the variance in the original nine variables. NMDS dimension 1 (Benthic Dim1) was strongly negatively correlated with the polychaete *Capitella capitata* complex ($r_s = -0.95$) and negatively correlated with mobile polychaetes ($r_s = -0.39$) (Table 4.6). In addition, Benthic Dim1 was significantly positively correlated with echinoderms ($r_s = 0.44$), bivalves ($r_s = 0.55$) and gastropods ($r_s = 0.78$), non-amphipod crustaceans ($r_s = 0.60$), and miscellaneous taxa ($r_s = 0.50$) (Table 4.6). Therefore, Benthic Dim1 can be considered a general measure of the abundance of several major taxa, in particular the sedentary polychaete *Capitella capitata* complex; as Benthic Dim1 scores increase, abundances of capitellids decrease and the abundances of non-polychaete taxa (e.g. bivalves, gastropods and amphipods) increase. NMDS dimension 2 (Benthic Dim2) exhibited a strongly significant negative correlation with abundances of miscellaneous taxa ($r_s = -0.73$) and non-amphipod crustaceans ($r_s = -0.71$), and was also significantly negatively correlated to amphipod crustaceans ($r_s = -0.56$) (Table 4.6; (Golder, 2011a)).

Table 4.6 Rank Correlations between the Benthic Dimensions From NMDS Analysis of 2010 Data and the Abundance Counts of the Nine Major Taxa

Taxonomic Group	Correlation (r_s) with ¹ :	
	Benthic Dim 1	Benthic Dim 2
Echinodermata	0.439**	-0.123
Bivalvia	0.553**	-0.179
Gastropoda	0.780**	0.091
Crustacea (Amphipoda)	-0.095	-0.563**
Crustacea (Other)	0.600**	-0.708**
Polychaeta Errantia	-0.391**	-0.055
Polychaeta Sedentaria (Other)	0.119	-0.025
<i>Capitella capitata</i> Complex	-0.948**	0.033
Miscellaneous Taxa	0.502**	-0.729**

Notes

¹ Statistical significance (2-tailed): ** = $p < 0.01$; * = $p < 0.05$.
Significant results shown in **boldface**.

A plot of Benthic Dim1 against Benthic Dim2, categorized by the distance-direction groups, is presented in Figure 4.20. Clear separation among the distance-direction groups is visible in multivariate space, with minimal overlap occurring among groups. Similar to the 2008 and 2009 results, station M0 exhibits a clear separation from the near-field stations, suggesting that the biological assemblages are distinct from near-field stations in spite of similar levels of organic enhancement. The degree of separation between far-field and reference stations is low, indicating that some of the stations removed from the directional influence of the predominant currents (i.e., outfall exposure) closely resemble the reference stations in term of benthic composition.

A spatial gradient is apparent along Dim 1, with near-field stations falling on the left and far-field and reference stations occupying the right portion of the plot. The spatial trend in Dim 1 scores is associated with the relative abundances of the polychaete *Capitella capitata* and non-polychaete taxa (especially gastropods), which exhibit significant monotonic increases (gastropods) and decreases (*Capitella*) with distance from the outfall.

Additional variability among distance-direction groups is apparent along Dim 2. In general, Dim 2 scores are highest for the near-field, mid-field and far-field groups and lowest at M0 stations. Dim 2 was significantly associated with abundances of crustaceans (both amphipods and other Crustacea) and miscellaneous taxa. These individual taxa groups all exhibited a similar spatial pattern (Figures 4.6 through 4.19), with high abundances near the outfall terminus, declining with distance [or distance-direction] from the Macaulay Point outfall.

Statistical comparisons of benthic community structure were conducted using Benthic Dim 1 and Dim 2 scores as the parameters of interest and station grouping (both distance groupings and distance-direction groupings) as the treatment (Table 4.3 and Table 4.4). Tests for normality were conducted with the Shapiro-Wilk test. NMDS scores were not normally distributed within the traditional distance groups. Benthic Dim 1 scores were also not normally distributed within the distance-direction groups but Benthic Dim 2 scores were normally distributed. Non-parametric methods (*i.e.*, Kruskal-Wallis test and Mann-Whitney multiple comparisons) were used for station grouping comparisons of non-normal parameters, whereas normally distributed parameters were analyzed using parametric methods (*i.e.*, ANOVA and Dunnett's *post hoc* test):

- **Distance-based groups:** Significant differences ($p < 0.05$) were identified between each of the outfall and all distance groups relative to the reference stations for Benthic Dim 1 (Table 4.3). Figure 4.21 (top right panel) shows that Dim1 scores are lowest at M0 and increase with distance from the outfall, a reversal of the pattern displayed by the polychaete *Capitella capitata*, which was strongly negatively correlated to Dim 1. Dim 1 scores were significantly positively correlated with distance from the outfall ($r_s = 0.77$). Dim 2 scores were significantly different ($p < 0.01$) at the outfall and 100 m distance groups compared to reference stations; Dim 2 scores at the outfall terminus (M0) were significantly lower than those at the reference stations, with significantly higher values present at 100 m stations. The spatial distribution of Benthic Dim 2 scores follows Pattern C which exhibits a low abundance in the vicinity of the outfall but rapidly plateaus to reference levels in the near-field.
- **Distance-direction groups:** Significant differences ($p < 0.01$) in Benthic Dim1 scores were identified between each of the outfall, near-field, mid-field and far-field groups in comparison with the reference area. Figure 4.21 (top left panel) shows that Dim1 scores were lower at the near-field stations compared with the outfall stations, but outfall stations were lower than mid-field stations, with a pronounced increase from mid-field to far-field to reference (in that order). Dim 1 scores were strongly and significantly positively correlated with distance-direction from the outfall ($r_s = 0.90$). Dim 2 scores were significantly lower at outfall stations and significantly higher at mid-field stations relative to reference; the correlation between Benthic Dim 2 scores and distance-direction was not significant.

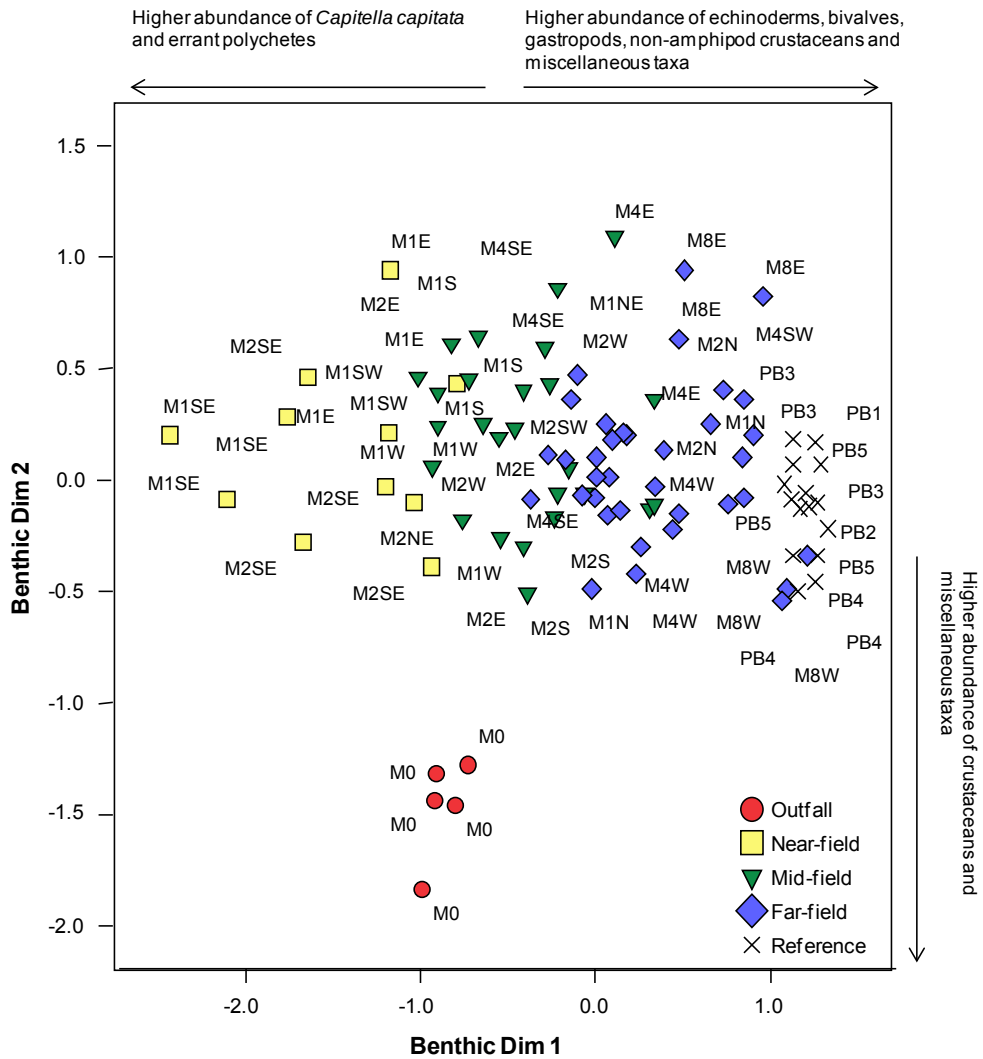


Figure 4.20 Multidimensional Scaling of 2010 Benthic Community Major Taxonomic Abundances Coded Based on Distance-Direction Categories

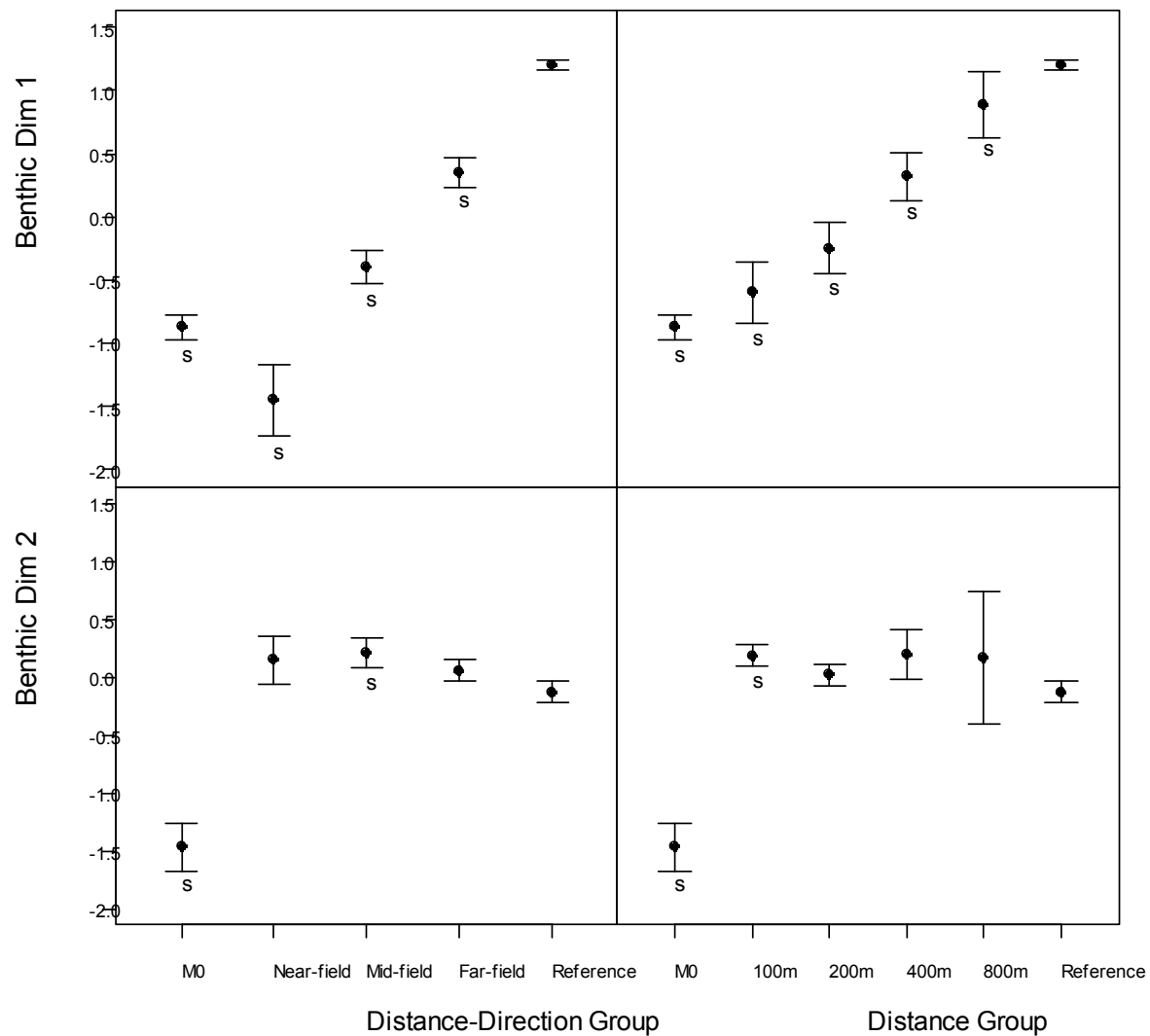


Figure 4.21 Means + Confidence Intervals for NMDS Benthic Dimension 1 Scores (top panel) and Benthic Dimension 2 Scores (bottom panel)

Environmental Response Distributional Patterns

From the distribution of taxa among the six distributional patterns (Table 4.7; Appendix E3), it is evident that proximity to the wastewater outfall terminus does not correspond to uniform changes to abundances of invertebrates. Instead, the spatial response is highly species-specific. The observed benthic trends depend on the life-history and preferences of the organisms, the magnitude of the outfall-related disturbance, the sensitivity of the organisms in question, and other confounding factors (natural disturbances, substrate type, etc.). Although some taxa appear to respond positively to conditions at or adjacent to the outfall (which include greater exposure to wastewater influence and associated organic matter), other taxa respond adversely (i.e., cannot survive and/or are out competed), and some taxa exhibit more complex responses (Golder, 2011a).

Table 4.7 Patterns of Environmental Response

Pattern	Outfall/Near-Field	Mid-Field	Far-Field	Net Response
A	⬆	⬆	⬆	⬆
B1	• / ⬇	⬆ / ⬆	⬆ / ⬆	⬆
B2	⬇ / ⬆	• / ⬆	⬆ / ⬆	• / ⬆
C	⬆	•	•	⬇
D	⬆	⬇	• / ⬇	⬇ / ⬆
E	⬆	⬆	⬇ / ⬆	⬆
F	•	•	•	•

Notes:

Symbols represent pattern of abundance by station-group (normalized to reference):

⬆ pronounced increase; ⬇ pronounced decrease; ⬆ moderate increase; ⬇ moderate decrease; • no clear trend identified

Three of the patterns (A, B1, B2) are net positive (beneficial), because they result in overall increased abundance of an organism across the study area. Three patterns (C, D, E) are considered net negative (adverse), although the adverse responses of pattern C are spatially localized. The sixth pattern (F) is considered net neutral (Golder, 2011a).

Distance-Based Groups: By comparing the numbers of taxa that correspond to each type of spatial trends, some inferences regarding the influence of the wastewater discharge can be made. When data are categorized based on distance from the outfall, Pattern A (11 species) is one of the most readily identifiable patterns (Golder, 2011a), representing the taxa that respond most favourably to wastewater exposures.

Pattern B1 (6 species) and B2 (12 species) collectively form the most common spatial pattern, and follows a “hump-shaped” pattern consistent with the model of organic carbon enhancement discussed by Pearson and Rosenberg (1978) and Nilsson and Rosenberg (2000). The disturbance-gradient model predicts that at high levels of disturbance, reductions in species abundance are common. However, at low to intermediate levels of disturbance, particularly in the case of enhanced organic carbon loadings, there are often increases in benthic abundance. In the context of the Macaulay Point wastewater discharges, such an intermediate level of disturbance is found where the benefits of organic carbon contributions (e.g., increased food supply) outweigh the potential negative aspects (e.g., contaminant responses or modification of substrate). The site-specific data suggest that for many taxa, net positive effects are observed at intermediate distances from the outfall, but not at stations immediately adjacent to the outfall terminus.

Patterns C, D, and E represent indications of adverse responses of taxa to outfall influence. Pattern E (4 species) represents the taxa that appear most poorly suited to the influence of the discharges. Pattern D (11 taxa) also provides a profile suggestive of organism sensitivity to proximity to wastewater influence; for these taxa the abundances increase as exposures to wastewater discharges decrease. This pattern

may be due to factors associated with wastewater discharge, although other factors such as substrate type may also be important. Pattern C (9 taxa) provides a profile suggestive of localized alterations only; outside the near-field area the pattern suggests no response (negative or positive) to distance-related factors (whether outfall-related or not) (Golder, 2011a).

The distance-based analysis indicate 29 taxa that respond net positively to proximity to outfall, and 24 taxa that respond net negatively. Of the negative responses, 15 of 24 of the affected species were affected over a large spatial range; the remaining taxa (Pattern C) were affected only within 200 metres of the outfall M0. More than half of the positive responses (18 of 29) reflected the response of taxa to a moderate enhancement of organic matter, in which increases in organism abundance occurred at intermediate distance stations. The remaining positive responses reflected a more pronounced positive response to organic matter enhancement, with elevated abundance near the outfall and decreasing abundance with distance from the outfall. Five additional taxa showed an unclear pattern or no linkage between abundance and proximity to the outfall (Golder, 2011a).

Distance-Direction Groups: When data are categorized based on distance-direction groups, Pattern D (14 taxa) represents the most common spatial pattern, indicating that these taxa are negatively influenced by the outfall. The distance-direction groups showed a higher number of strong negative effects (Pattern E; 8 taxa) relative to the distance only groups (4 taxa). An additional 8 taxa responded negatively within close proximity to the outfall (Pattern C). Of the net positive spatial trends, Pattern A (10 taxa) represents the most common pattern when data are categorized based on distance-direction groups, which is similar to observations of distance only groups (11 taxa). The number of species that are represented by Pattern B1 are similar when grouped by distance (6 taxa) and distance-direction (5 taxa), however the positive influence of outfall exposure at intermediate distance is not as evident when data is categorized based on distance-direction groups, owing largely to the decrease in taxa exhibiting Pattern B2 (8 taxa) compared with distance groups (12 taxa).

The distance-direction analysis indicates 23 taxa that respond net positively to proximity to the outfall, and 30 taxa that respond net negatively. Of the negative responses, most of the affected species (22 of 30) are affected over a large spatial range; the eight remaining taxa (Pattern C) were affected only in the near-field area. Five (5) taxa showed an unclear pattern or no linkage between abundance and proximity to the outfall (Golder, 2011a).

Relationships Between Substrate and Sediment Chemistry

Relationships between 2010 biological metrics and sediment variables were examined using rank correlations. In general, correlation results are similar to those in recent sampling years. In 2010, the strongest positive correlations were observed between the capitellid polychaetes and SOI concentrations in sediment and the strongest negative correlations were observed between ITI and SOI concentrations. Table 4.8 presents the results of rank correlations between 2010 biological metrics and sediment variables. For organic parameters (e.g. PAHs), correlations were repeated with organic carbon (OC) normalized concentrations.

Total richness was significantly negatively correlated with all of the metals (except aluminum, chromium and nickel), total phenols, and 12 of 13 of the individual PAHs (Table 4.8). Significant correlations were generally moderate in strength (r_s values ranging from -0.43 to -0.73). Among the SOIs, the strongest negative correlations were observed for the priority metals antimony ($r_s = -0.73$), cadmium ($r_s = -0.68$), mercury ($r_s = -0.73$) and silver ($r_s = -0.68$). In 2008 and 2009, significant negative correlations were observed for several metals and for most or all of the PAHs (Golder, 2011a).

The number of significant correlations of both the standard and regional Infaunal Trophic Index (ITI) results was similar to those for total richness (Table 4.8). ITI (both standard and regional versions of the metric) was significantly negatively correlated with 11 of 13 metals, total phenols, and 12 of 13 of the individual PAHs. In all cases with significant correlations, the regional ITI was more strongly correlated with the sediment SOIs. The Swartz Dominance Index (SDI) was significantly negatively correlated to 8 of 13 metals, total phenols, and 3 of 13 PAHs, with significant correlation coefficients ranging from -0.38

to -0.63. The magnitude of the correlations observed between ITI (standard) and SDI and the SOIs are similar in 2010 to those observed in the previous year (Golder, 2011a).

Several significant positive correlations were observed between polychaete abundances (total polychaetes, mobile polychaetes and *Capitella capitata* complex) and SOIs. Significant correlations for at least one of the polychaete parameters were observed for all SOIs with the exception of aluminum and chromium. The strongest correlations were observed for the *Capitella capitata* complex (23 SOIs with $r_s > 0.6$). No significant correlations were observed between the non-capitellid sedentary polychaetes and SOIs in 2010, which was also observed in the previous assessment (Golder, 2011a).

Significant negative correlations were observed between bivalve abundances and most of the metals (10 of 13) and PAHs (12 of 13) with r_s values ranging from -0.40 (nickel) to -0.74 (selenium) (Table 4.8). These results are similar to those observed in 2009 but differ from 2008, when only a few metals exhibited significant correlations and most of the individual PAHs did not exhibit significant correlations. Correlations between bivalve abundance and SOIs for the 2008 data were mostly negative; however, fewer correlations were significant, indicating an increase in the magnitude of the relationship between these parameters in the last two monitoring events (Golder, 2011a).

Some negative correlations (Table 4.8) were observed between abundances of echinoderms, gastropods, and non-amphipod crustaceans and the concentrations of SOIs in sediment. For echinoderms, significant negative correlations were identified for four of the metals (r_s of -0.50 to -0.73), total phenols, and three PAHs (r_s of -0.39 to -0.53). Gastropods exhibited significant negative correlations with all SOIs (r_s of -0.55 to 0.92), with the exception of aluminum, chromium, and 2-methylnaphthalene. This differs considerably from 2009 when only lead ($r_s = -0.49$) and phenol ($r_s = -0.45$) were significantly correlated with gastropod abundance. Non-amphipod crustaceans were negatively correlated to all metals (r_s of -0.41 to -0.68) except aluminum and chromium, and 9 of 13 PAHs (r_s of -0.39 to -0.77). In 2009, non-amphipod crustaceans were negatively correlated to antimony (r_s of -0.54) and 2-methylnaphthalene ($r_s = -0.43$) only. Thus the number and magnitude of significant correlations for these groups was generally higher than those observed in 2009 (Golder, 2011a).

The magnitudes of correlations were similar for many of the SOI groups in 2010 (i.e., among PAHs and among several metals including arsenic, cadmium, copper, mercury and zinc). This indicates high covariation in the spatial distributions of the contaminants. Due to this covariation, it is difficult, if not impossible, to discern the potential causal agent(s) responsible for the changes in the biological trends using only a simple empirical correlation analysis. Furthermore, the correlations of most biological metrics with total organic carbon (TOC) and particle size parameters were very strong (discussed further in the following section), such that the influence of physical and habitat factors cannot be distinguished from possible SOI effects on the benthic communities.

Organic carbon (OC)-normalized PAH concentrations in sediment generally exhibited weaker correlations with biological parameters than the dry weight concentrations, and the frequency of significant correlations was reduced when data were OC-normalized. The absolute magnitudes of the decreases in correlation strength were relatively small, indicating that differences in sediment OC content have some influence on the correlation results but only partially explain the relationships observed using dry-weight sediment concentrations (Golder, 2011a).

In general, correlation results are similar to those in recent sampling years. In 2010, the strongest positive correlations were observed between the capitellid polychaetes and SOI concentrations in sediment and the strongest negative correlations were observed between ITI and SOI concentrations.

Statistical (Spearman rank correlations and ANOVA comparisons) and graphical analyses were used to explore the effect of substrate type (i.e., organic carbon content and particle size) on the spatial distribution of the benthic community parameters (Table 4.8). TOC was positively correlated to total polychaete abundance ($r_s = 0.68$), mobile polychaetes ($r_s = 0.49$) and *Capitella capitata* abundance ($r_s = 0.77$), and negatively correlated to ITI (r_s of -0.61 and -0.80 for standard and regional, respectively) and richness ($r_s = -0.64$) metrics (Table 4.8). Abundances of bivalves, echinoderms, gastropods, non-amphipod crustaceans and miscellaneous taxa were also negatively correlated to TOC. These broad

findings are similar to the previous investigation; however, more significant correlations were observed in 2010 relative to previous years, and SDI was not significantly correlated to TOC (statistical significance was marginal for SDI). As in 2008 and 2009, total abundance did not correlate strongly with TOC, mainly because the major components of abundance exhibited trends in opposite directions (which cancelled each other out). This is observed in Figure 4.4, which shows that the distribution of total abundance changes between near-field and far-field stations, whereas the total numbers of organisms remain similar.

Percent gravel was positively correlated to polychaete abundance and *Capitella capitata* abundance and negatively correlated to ITI (standard and regional) and richness metrics (Table 4.8). Taxonomic richness was lower at the outfall, and in some near-field stations, relative to those at distance from the outfall (Figures 4.8, 4.5). Although the magnitude of the difference is not large at most stations, the region of decreased richness is coincident with sediment that contains elevated TOC and/or elevated gravel content. Figure 4.4 illustrates the cumulative abundance of each major taxa across distance groups and distance-direction groups. When compared to the organic enrichment model of Nilsson and Rosenberg (2000), there are some indications of conditions in near-field sediments that are indicative of pronounced environmental disturbance. The impacts were most pronounced at station M0 in 2010, with a considerable increase in the relative abundance of most taxonomic groups, particularly the polychaete *Capitella capitata*, relative to reference. The trends observed in 2010 were similar to those seen in 2008, but were more pronounced due to the greater abundance of capitellid polychaetes at the outfall. Although not as pronounced as at the outfall, there is evidence of modest impairment in the near-field zone, with no change in overall abundance, but a relative increase in the abundance of the opportunistic *Capitella capitata* (Golder, 2011a).

In stations beyond the near-field, the data generally indicate negligible to low net impairment of the benthic community. The TOC concentrations and percent gravel are slightly elevated relative to reference, but significant influence on benthic community metrics is not apparent. Figure 4.4 and Figure 4.5 indicate that in mid-field and far-field areas, overall abundances and major taxa abundances are similar to reference conditions. Taxonomic richness and ITI gradually increase with distance from the outfall. Overall, the mid-field and far-field distance groups show signs of increased community health as a result of decreased influence of the environmental disturbance (Golder, 2011a).

Table 4.8 Macaulay Point Rank Correlations between 2010 Benthic Community Indicators and Sediment Chemistry Parameters

Metric	AVS	TOC	% Gravel	% Fines	Aluminum	Antimony	Arsenic	Cadmium	Chromium
Total Abundance	-0.170	-0.251	-0.260	-0.255	0.346	-0.199	-0.257	-0.098	0.166
Total Richness	-0.675**	-0.642**	-0.383*	0.345	0.140	-0.726**	-0.620**	-0.683**	-0.218
Polychaete Abundance	0.744**	0.677**	0.457*	-0.411*	-0.025	0.776**	0.591**	0.846**	0.312
SDI	-0.449*	-0.350	-0.175	0.473*	-0.128	-0.439*	-0.375*	-0.546**	-0.294
ITI (Standard)	-0.751**	-0.608**	-0.587**	0.547**	0.183	-0.682**	-0.651**	-0.768**	-0.267
ITI (Regional)	-0.887**	-0.802**	-0.739**	0.302	0.186	-0.860**	-0.778**	-0.856**	-0.197
Echinodermata	-0.382*	-0.410*	-0.367	0.119	0.117	-0.606**	-0.232	-0.341	-0.087
Bivalvia	-0.619**	-0.529**	-0.624**	0.276	0.327	-0.599**	-0.675**	-0.569**	-0.091
Gastropoda	-0.773**	-0.784**	-0.542**	0.045	0.046	-0.921**	-0.624**	-0.758**	-0.281
Crustacea (Amphipoda)	0.308	0.229	0.151	0.077	-0.010	0.282	0.041	0.248	0.113
Crustacea (other)	-0.650**	-0.653**	-0.451*	0.148	0.189	-0.624**	-0.668**	-0.657**	-0.134
Polychaeta Errantia	0.412*	0.488**	0.133	-0.012	0.080	0.570**	0.240	0.525**	0.244
Polychaeta Sedentaria	-0.028	-0.039	-0.249	0.234	0.016	-0.054	-0.219	-0.019	-0.182
<i>Capitella capitata</i> complex	0.797**	0.769**	0.520**	-0.462*	-0.062	0.826**	0.712**	0.872**	0.354
Miscellaneous Taxa	-0.602**	-0.775**	-0.409*	-0.081	0.459*	-0.608**	-0.640**	-0.528**	0.137
Metric	Copper	Lead	Mercury	Nickel	Phosphorus	Selenium	Silver	Zinc	
Total Abundance	-0.056	-0.150	-0.029	-0.090	-0.112	-0.314	0.020	-0.201	
Total Richness	-0.581**	-0.654**	-0.734**	-0.363	-0.515**	-0.620**	-0.681**	-0.460*	
Polychaete Abundance	0.776**	0.675**	0.729**	0.604**	0.656**	0.650**	0.852**	0.583**	
SDI	-0.490**	-0.480*	-0.445*	-0.242	-0.445*	-0.329	-0.630**	-0.328	
ITI (Standard)	-0.703**	-0.541*	-0.685**	-0.516**	-0.652**	-0.761**	-0.698**	-0.581**	
ITI (Regional)	-0.819**	-0.782**	-0.891**	-0.609**	-0.682**	-0.867**	-0.827**	-0.698**	
Echinodermata	-0.315	-0.510*	-0.497*	-0.149	-0.256	-0.276	-0.727**	-0.246	
Bivalvia	-0.516**	-0.471*	-0.605**	-0.400*	-0.470*	-0.743**	-0.408	-0.533**	
Gastropoda	-0.747**	-0.751**	-0.732**	-0.628**	-0.554**	-0.614**	-0.851**	-0.647**	
Crustacea (Amphipoda)	0.330	0.133	0.673**	0.374*	0.174	0.134	0.161	0.260	
Crustacea (other)	-0.592**	-0.621**	-0.619**	-0.408*	-0.508**	-0.679**	-0.605**	-0.478*	
Polychaeta Errantia	0.483**	0.376	0.557**	0.477*	0.374*	0.267	0.551**	0.303	
Polychaeta Sedentaria	-0.063	-0.136	0.038	0.034	-0.125	-0.184	-0.001	-0.161	
<i>Capitella capitata</i> complex	0.814**	0.783**	0.867**	0.620**	0.681**	0.732**	0.864**	0.611**	
Miscellaneous Taxa	-0.48**	-0.568**	-0.611**	-0.385*	-0.253	-0.507**	-0.545**	-0.309	

continued

Note

OC = organic carbon normalized concentration.

Bolded values are statistically significant: ** = $p < 0.01$; * = $p < 0.05$

Table 4.8, continued

Metric	Phenols	2-Methyl-naphthalene	Anthracene	Benzo[a]pyrene	Benzo[b]fluoranthene	Benzo[g,h,i]perylene	Benzo[k]fluoranthene
Total Abundance	-0.053	-0.003	-0.130	-0.248	-0.263	-0.212	-0.200
Total Richness	-0.628**	-0.238	-0.533*	-0.511**	-0.512**	-0.434*	-0.510**
Polychaete Abundance	0.785**	0.271	0.692**	0.636**	0.626**	0.621**	0.652**
SDI	-0.443*	-0.129	-0.306	-0.336	-0.328	-0.322	-0.369
ITI (Standard)	-0.507*	-0.052	-0.748**	-0.721**	-0.698**	-0.678**	-0.699**
ITI (Regional)	-0.658**	-0.110	-0.847**	-0.824**	-0.826**	-0.755**	-0.785**
Echinodermata	-0.468*	-0.201	-0.373	-0.364	-0.362	-0.336	-0.389*
Bivalvia	-0.417	0.162	-0.539**	-0.556**	-0.563**	-0.483*	-0.514**
Gastropoda	-0.705**	-0.309	-0.746**	-0.740**	-0.750**	-0.649**	-0.774**
Crustacea (Amphipoda)	0.214	0.326	0.694**	0.514**	0.513**	0.545**	0.527**
Crustacea (other)	-0.390	-0.291	-0.458*	-0.434*	-0.438*	-0.387*	-0.390*
Polychaeta Errantia	0.612**	0.548**	0.541**	0.474*	0.458*	0.436*	0.485*
Polychaeta Sedentaria	0.132	0.236	0.051	-0.053	-0.046	0.033	-0.044
<i>Capitella capitata</i> complex	0.693**	0.273	0.667**	0.637**	0.625**	0.602**	0.658**
Miscellaneous Taxa	-0.381	-0.396*	-0.495*	-0.432*	-0.445*	-0.385*	-0.402*
Metric	Phenols (OC-normalized)	2-Methyl-naphthalene (OC-normalized)	Anthracene (OC-normalized)	Benzo[a]pyrene (OC-normalized)	Benzo[b]fluoranthene (OC-normalized)	Benzo[g,h,i]perylene (OC-normalized)	Benzo[k]fluoranthene (OC-normalized)
Total Abundance	0.401	0.257	-0.091	-0.155	-0.160	-0.091	-0.097
Total Richness	-0.086	0.557**	-0.376	-0.293	-0.302	-0.177	-0.262
Polychaete Abundance	0.293	-0.573**	0.483*	0.454*	0.447*	0.366	0.400*
SDI	-0.266	0.250	-0.274	-0.310	-0.313	-0.241	-0.306
ITI (Standard)	0.054	0.553**	-0.630**	-0.614**	-0.595**	-0.496**	-0.566**
ITI (Regional)	0.018	0.762**	-0.615**	-0.616**	-0.631**	-0.454*	-0.511**
Echinodermata	-0.194	0.363	-0.236	-0.190	-0.178	-0.169	-0.192
Bivalvia	0.177	0.582**	-0.448*	-0.450*	-0.462*	-0.362	-0.403*
Gastropoda	-0.036	0.683**	-0.549**	-0.526**	-0.538**	-0.342	-0.485*
Crustacea (Amphipoda)	0.193	-0.201	0.505*	0.466*	0.471*	0.490**	0.446*
Crustacea (other)	0.280	0.520**	-0.252	-0.227	-0.255	-0.085	-0.145
Polychaeta Errantia	0.272	-0.338	0.249	0.221	0.215	0.101	0.170
Polychaeta Sedentaria	0.311	0.093	-0.093	-0.107	-0.092	-0.046	-0.160
<i>Capitella capitata</i> complex	0.102	-0.660**	0.423*	0.412*	0.410*	0.296	0.379
Miscellaneous Taxa	0.294	0.657**	-0.149	-0.076	-0.088	0.056	0.006

continued

Note

OC = organic carbon normalized concentration.

Bolded values are statistically significant: ** = $p < 0.01$; * = $p < 0.05$

Table 4.8, continued

Metric	Chrysene	Fluoranthene	Fluorene	Indeno[1,2,3-c,d]pyrene	Naphthalene	Phenanthrene	Pyrene
Total Abundance	-0.144	-0.075	-0.156	-0.171	-0.303	-0.062	-0.099
Total Richness	-0.457*	-0.534*	-0.580**	-0.451*	-0.571**	-0.551**	-0.532*
Polychaete Abundance	0.643**	0.629**	0.647**	0.643**	0.680**	0.634**	0.623**
SDI	-0.274	-0.356	-0.438*	-0.345	-0.380*	-0.462*	-0.346
ITI (Standard)	-0.702**	-0.629**	-0.703**	-0.672**	-0.694**	-0.655**	-0.639**
ITI (Regional)	-0.785**	-0.764**	-0.781**	-0.748**	-0.870**	-0.750**	-0.772**
Echinodermata	-0.275	-0.376	-0.512**	-0.360	-0.333	-0.525**	-0.376
Bivalvia	-0.540**	-0.477*	-0.515**	-0.466*	-0.592**	-0.466*	-0.483*
Gastropoda	-0.719**	-0.788**	-0.676**	-0.672**	-0.717**	-0.721**	-0.786**
Crustacea (Amphipoda)	0.686**	0.692**	0.379*	0.563**	0.291	0.390*	0.700**
Crustacea (other)	-0.347	-0.360	-0.486**	-0.386*	-0.771**	-0.399*	-0.369
Polychaeta Errantia	0.465*	0.506*	0.266	0.460*	0.389*	0.251	0.507*
Polychaeta Sedentaria	-0.009	-0.044	-0.072	0.036	-0.037	-0.095	-0.047
<i>Capitella capitata</i> complex	0.582**	0.608**	0.674**	0.627**	0.736**	0.646**	0.610**
Miscellaneous Taxa	-0.386	-0.408	-0.526**	-0.368	-0.652**	-0.462*	-0.415
Metric	Chrysene (OC-normalized)	Fluoranthene (OC-normalized)	Fluorene (OC-normalized)	Indeno[1,2,3-c,d]pyrene (OC-normalized)	Naphthalene (OC-normalized)	Phenanthrene (OC-normalized)	Pyrene (OC-normalized)
Total Abundance	-0.063	0.008	0.167	-0.059	0.198	0.196	-0.004
Total Richness	-0.247	-0.382	-0.121	-0.201	0.286	-0.287	-0.384
Polychaete Abundance	0.462*	0.394	0.211	0.404*	-0.106	0.281	0.404
SDI	-0.235	-0.374	-0.284	-0.264	-0.082	-0.445*	-0.373
ITI (Standard)	-0.556**	-0.456*	-0.333	-0.501**	0.014	-0.345	-0.467*
ITI (Regional)	-0.547**	-0.504*	-0.257	-0.463*	0.119	-0.285	-0.517*
Echinodermata	-0.091	-0.261	-0.325	-0.209	0.074	-0.341	-0.251
Bivalvia	-0.453*	-0.365	-0.193	-0.349	0.232	-0.242	-0.372
Gastropoda	-0.482*	-0.579**	-0.157	-0.372	0.256	-0.258	-0.581**
Crustacea (Amphipoda)	0.493*	0.486*	0.302	0.483*	0.046	0.208	0.502*
Crustacea (other)	-0.143	-0.124	0.101	-0.092	0.056	0.034	-0.144
Polychaeta Errantia	0.167	0.158	-0.260	0.149	-0.269	-0.226	0.180
Polychaeta Sedentaria	-0.098	-0.208	-0.075	-0.032	0.130	-0.221	-0.201
<i>Capitella capitata</i> complex	0.345	0.340	0.136	0.327	-0.216	0.246	0.355
Miscellaneous Taxa	-0.016	-0.028	0.121	0.053	0.277	0.098	-0.036

Note

OC = organic carbon normalized concentration.

Bolded values are statistically significant: ** = $p < 0.01$; * = $p < 0.05$

MULTI-YEAR TREND ASSESSMENT

Table 4.9 presents the multi-year trend assessment summary statistics for the selected benthic community metrics by distance and by distance-direction from the outfall, over the relevant period of record. The computed summary statistics include mean, median, standard deviation, minima, maxima and percent of reference.

Distance gradients, assessed using Spearman rank correlations between each benthic community metric and distance from the outfall, are presented in Table 4.10, while distance-direction gradients are presented in Table 4.11. Spearman rank correlations were calculated for all years combined (2000-2010), for recent years only (2008-2010) and for each individual year. Reference stations were also included in the calculations (Golder, 2011a).

Total Abundance and Polychaete Abundance

Both total abundance and polychaete abundance metrics exhibited significant negative correlations with distance from the outfall for all years (2000-2010 [excluding 2001]), recent years (2008-2010), and individual years up to 2005 (Table 4.10). After 2005, total abundance has not exhibited a significant negative relationship with distance from the outfall during each individual year. However, the negative correlation of polychaete abundance with distance appears to have become stronger in the last five years ($r_s > -0.72$ from 2006-2010). Correlations between polychaete abundance and distance were stronger than those for total abundance, and were stronger in 2008-2010 ($r_s = -0.73$) than in 2000-2010 ($r_s = -0.57$). The highest correlation was observed between polychaete abundance and distance in the year 2009, with a correlation coefficient (r_s) of -0.79.

From 2000-2010 the correlation between total abundance and distance-direction was significant but weak ($r_s = -0.23$) as was the correlation between abundance and distance alone ($r_s = -0.36$). From 2003 to 2010, correlations between total abundance and distance-direction were not statistically significant, with the exception of weak correlations in 2005 and 2009 (Table 4.11). Polychaete abundance, however, was generally more strongly correlated to distance-direction than to distance alone. Strong negative correlations between polychaete abundance and distance-direction ($r_s > -0.6$) were observed in all individual years with the exception of 2004.

Overall, the above trends indicate a change in the benthic community over the last five years, with increased numbers of polychaetes observed at stations near the outfall. These increases have not been accompanied by similar increases in other taxa, however. As the correlations for polychaete abundance have strengthened, the correlations for total abundance have weakened, indicating a change to a near-field community that is more dominated by polychaetes, and with reduced diversity (Golder, 2011a).

Richness and SDI

Total taxa richness was positively correlated to distance from the outfall for all years combined (2000-2010); however, the strength of the relationship was very weak ($r_s = 0.27$). From 2000 to 2006, the year 2000 was the only individual year that exhibited a significant correlation between richness and distance. Significant correlations existed between richness and distance for each individual year from 2007 to 2010, with moderate to strong correlations (r_s of 0.41 to 0.64). Swartz Dominance Index (SDI) was positively correlated with distance from the outfall, with a moderate strength correlation coefficient for all years combined ($r_s = 0.58$) and moderate-to-strong correlations in each individual year.

Relationships between richness distance-direction from the outfall were generally stronger than those for distance alone, although the correlation coefficient for all years combined was the same ($r_s = 0.27$) (Table 4.11). The number of significant correlations between richness and distance-direction for combined years and individual years was the same as that for richness and distance. There were fewer and generally weaker statistically significant correlations between SDI and distance-direction compared with SDI and distance, with an all years combined correlation coefficient of 0.45.

Overall, the above trends are suggestive of a change in the near-field benthic community, with movement toward a community that has lower taxonomic richness (a measure of genetic and functional diversity) and increased dominance by fewer species. Whereas the middle part of the last decade indicated relatively constant richness values across most of the study area, recent years of sampling have documented a change in richness gradients (Golder, 2011a).

Abundances of Major Taxa

No significant correlations were observed between bivalve abundances and distance from the outfall, with the exception of one weak correlation ($r_s = 0.38$) in 2009 (Table 4.10). Similarly, there had been no significant correlations between gastropod abundances and distance in individual years until 2010, which exhibited a strong positive correlation ($r_s = 0.77$). Echinoderm abundance was positively correlated to distance in all years combined ($r_s = 0.30$) and recent years ($r_s = 0.58$). The correlation coefficient for recent years (2008-2010) has increased since the last trend assessment ($r_s = 0.34$ for 2005-2007) due to the moderate to strong significant and positive correlations in the last three years. Amphipods exhibited a weak negative correlation with distance from the outfall for all years ($r_s = -0.21$) and moderate negative correlations in 4 of 10 individual years (r_s ranging from -0.42 to -0.59). The abundances of non-amphipod crustaceans exhibited a weak positive correlation with distance ($r_s = 0.21$ for all years) and only two moderate significant correlations in individual years. Miscellaneous taxa abundances were also weakly significantly correlated to distance in all years combined ($r_s = 0.15$), but were not correlated in recent years. Abundances of polychaete sub-groups (i.e., mobile polychaetes, sedentary polychaetes and *Capitella capitata* complex) were negatively correlated with distance from the outfall, although only capitellid polychaetes exhibited a strong correlation ($r_s = -0.74$). Among the three polychaete groups, capitellid polychaetes showed the strongest relationship with distance, with r_s values greater than 0.6 in all time periods. Correlations between the other two polychaete groups and distance from the outfall were weak for all years combined and in recent years, with some moderate strength correlations identified in individual years.

Relationships between the abundances of gastropods and non-amphipod crustaceans and distance-direction were similar to those for distance alone. Bivalves, however, showed a much stronger correlation with distance-direction, with moderate-to-strong positive correlations observed in all time periods (r_s ranging from 0.41 to 0.62). Echinoderm abundances exhibited no significant correlations with distance-direction in any of the individual years, although it showed a weak correlation in the 2008-2010 time period ($r_s = 0.35$). Relationships between polychaete groups and distance-direction were also generally stronger than for distance alone, with the strongest negative correlations observed between *Capitella* sp. and distance-direction (r_s ranging from -0.82 to -0.92 in individual years). Correlations between amphipods and distance-direction were generally slightly stronger than those for distance alone.

Overall, the above findings are indicative of relatively consistent negative correlations for taxa that are well suited to organic enhancement (such as many species of polychaetes and amphipods) but also a strengthening of the positive correlations for numerous groups of taxa. In recent years, and particularly in 2010, the spatial trends for bivalves, gastropods, non-amphipod crustaceans, and miscellaneous taxa have become more apparent. As the positive correlations for the latter organisms mean reduced abundances at stations near the outfall, these correlations are indicative of a potential impairment to the functional status of these communities (Golder, 2011a).

Table 4.9 Summary Statistics for Benthic Community Parameters (2000-2010 and 2008-2010)

A. Total Abundance														
Distance Group	2000-2010 station means							2008-2010 station means						
	n	Mean	Median	SD	Min	Max	%Ref	n	Mean	Median	SD	Min	Max	%Ref
Outfall	10	1539	1496	963	559	3662	399	3	1070	719	631	693	1799	251
100 m stations	80	638	541	414	249	3293	165	24	533	506	175	249	1027	125
200 m stations	80	593	529	289	207	2374	154	24	513	524	142	246	766	120
400 m stations	40	542	492	182	279	995	141	12	579	492	192	397	995	136
800 m stations	20	490	548	225	185	796	127	6	470	456	249	185	796	110
Near-field stations	30	762	541	666	207	3293	197	9	496	481	187	249	731	116
Mid-field stations	70	502	458	201	242	1534	130	21	488	448	110	341	735	114
Far-field stations	120	600	587	221	185	1309	155	36	560	577	196	185	1027	132
Reference stations	42	386	358	147	209	832	100	15	426	409	115	256	702	100
All Stations	272	594	509	398	185	3662	154	84	530	484	219	185	1799	124
B. Polychaete Abundance														
Distance Group	2000-2010 station means							2008-2010 station means						
	n	Mean	Median	SD	Min	Max	%Ref	n	Mean	Median	SD	Min	Max	%Ref
Outfall	10	1040	1012	624	391	2043	878	3	768	597	481	397	1311	678
100 m stations	80	365	268	341	102	2679	308	24	285	268	82.8	144	444	251
200 m stations	80	288	219	219	90.0	1538	243	24	256	239	91.8	163	541	225
400 m stations	40	216	191	118	68.3	594	183	12	223	210	66.1	129	368	197
800 m stations	20	176	131	132	91.3	554	149	6	134	134	36.7	91.3	180	118
Near-field stations	30	582	439	504	139	2679	491	9	377	385	113	205	541	333
Mid-field stations	70	297	252	139	110	851	251	21	281	269	58.2	188	402	247
Far-field stations	120	218	163	157	68.3	858	184	36	199	206	52.5	91.3	324	175
Reference stations	42	118	102	57.8	60.3	362	100	15	113	115	22.0	72.7	145	100
All Stations	272	293	203	306	60.3	2679	248	84	243	219	158	72.7	1311	215

continued

Table 4.9, continued

C. Total Richness														
Distance Group	2000-2010 station means							2008-2010 station means						
	n	Mean	Median	SD	Min	Max	%Ref	n	Mean	Median	SD	Min	Max	%Ref
Outfall	10	47.2	46.9	11.9	29.6	68.0	70	3	37.5	36.4	8.45	29.6	46.4	53
100 m stations	80	63.5	65.3	13.4	30.0	95.0	94	24	57.9	57.5	16.7	30.0	95.0	82
200 m stations	80	66.1	69.8	11.5	39.3	87.5	98	24	60.5	59.5	11.2	39.3	81.7	86
400 m stations	40	74.3	72.8	11.2	54.0	96.7	110	12	72.4	70.7	9.29	60.7	89.7	103
800 m stations	20	75.2	73.8	10.9	57.0	102	111	6	71.8	73.8	9.77	57.0	82.3	102
Near-field stations	30	50.3	49.3	12.0	30.0	76.0	74	9	40.1	39.5	7.47	30.0	54.3	57
Mid-field stations	70	70.1	71.8	12.5	43.3	96.7	104	21	61.8	60.7	11.1	43.3	89.7	88
Far-field stations	120	70.2	70.7	9.58	49.0	102	104	36	69.0	67.5	10.8	49.0	95.0	98
Reference stations	42	67.6	67.1	8.64	50.3	87.8	100	15	70.3	68.3	5.28	61.3	79.0	100
All Stations	272	66.7	68.0	12.8	29.6	102	99	84	63.2	65.7	14.0	29.6	95.0	90
D. SDI														
Distance Group	2000-2010 station means							2008-2010 station means						
	n	Mean	Median	SD	Min	Max	%Ref	n	Mean	Median	SD	Min	Max	%Ref
Outfall	10	3.34	3.11	1.75	1.33	6.99	16	3	2.57	1.62	1.90	1.33	4.76	14
100 m stations	80	10.6	10.8	4.89	0.962	27.4	52	24	9.73	8.06	5.52	0.962	27.4	54
200 m stations	80	12.3	12.0	5.20	1.13	26.3	61	24	11.2	10.4	6.04	2.87	26.0	62
400 m stations	40	16.3	14.0	7.24	6.22	30.6	81	12	13.4	13.9	1.98	10.3	18.0	74
800 m stations	20	20.1	18.1	9.63	8.62	36.3	99	6	18.2	18.1	7.92	8.62	26.4	100
Near-field stations	30	5.93	4.79	3.43	0.962	12.8	29	9	4.58	4.36	2.23	0.962	8.26	25
Mid-field stations	70	15.2	13.9	6.12	5.04	30.6	75	21	11.2	10.8	3.41	5.65	18.0	62
Far-field stations	120	13.7	12.1	6.46	4.26	36.3	67	36	13.8	12.1	6.30	5.48	27.4	76
Reference stations	42	20.2	19.2	11.1	10.2	86.3	100	15	18.2	18.2	3.27	12.2	22.6	100
All Stations	272	13.9	12.6	8.10	0.962	86.3	68	84	12.5	11.9	6.26	0.962	27.4	69

continued

Table 4.9, continued

E. Echinodermata														
Distance Group	2000-2010 station means							2008-2010 station means						
	n	Mean	Median	SD	Min	Max	%Ref	n	Mean	Median	SD	Min	Max	%Ref
Outfall	10	0.942	0.433	1.13	0	3.00	31	3	0	0	0	0	0	0
100 m stations	80	1.63	0.667	2.19	0	11.0	54	24	0.410	0.333	0.518	0	1.67	15
200 m stations	80	1.66	1.00	2.07	0	10.0	55	24	0.740	0.583	0.903	0	3.33	26
400 m stations	40	2.37	1.33	2.44	0	10.0	78	12	2.28	1.00	2.79	0	7.75	81
800 m stations	20	3.30	1.50	4.33	0	16.7	109	6	1.22	1.17	0.720	0.333	2.33	43
Near-field stations	30	1.57	0.708	1.93	0	7.67	52	9	0.324	0.333	0.369	0	1.00	11
Mid-field stations	70	3.09	2.33	2.77	0	11.0	102	21	1.77	0.750	2.33	0	7.75	63
Far-field stations	120	1.34	0.667	2.22	0	16.7	44	36	0.620	0.667	0.575	0	2.33	22
Reference stations	42	3.04	3.00	1.83	0	8.00	100	15	2.82	3.00	1.75	0	6.33	100
All Stations	272	2.06	1.29	2.41	0	16.7	68	84	1.25	0.667	1.68	0	7.75	44
F. Bivalvia														
Distance Group	2000-2010 station means							2008-2010 station means						
	n	Mean	Median	SD	Min	Max	%Ref	n	Mean	Median	SD	Min	Max	%Ref
Outfall	10	68.3	56.8	56.5	19.2	188	46	3	20.0	20.4	0.69	19.2	20.4	13
100 m stations	80	177	125	170	3.67	850	120	24	146	100	148	3.67	607	95
200 m stations	80	228	217	162	12.0	629	155	24	173	118	131	12.0	446	113
400 m stations	40	237	157	192	26.0	697	161	12	237	171	184	45.7	626	154
800 m stations	20	212	178	196	18.5	580	144	6	194	167	181	23.7	412	127
Near-field stations	30	32.0	27.2	21.1	3.67	99.0	22	9	20.0	18.3	13.8	3.67	52.3	13
Mid-field stations	70	113	96.3	71.4	26.0	397	77	21	98.6	100	27.7	45.7	140	64
Far-field stations	120	310	316	171	18.5	850	211	36	261	260	159	23.7	626	170
Reference stations	42	147	125	77.2	54.3	349	100	15	153	120	77.1	54.3	349	100
All Stations	272	195	138	163	3.67	850	132	84	167	118	141	3.67	626	109

continued

Table 4.9, continued

G. Gastropoda														
Distance Group	2000-2010 station means							2008-2010 station means						
	n	Mean	Median	SD	Min	Max	%Ref	n	Mean	Median	SD	Min	Max	%Ref
Outfall	10	10.5	11.6	7.67	0.800	22.3	45	3	1.20	1.00	0.529	0.800	1.80	4
100 m stations	80	18.4	16.5	10.8	2.50	53.7	80	24	15.7	13.3	12.7	2.50	53.7	52
200 m stations	80	20.8	17.7	16.4	1.67	126	90	24	16.9	16.0	10.7	1.7	41.3	56
400 m stations	40	18.2	17.3	8.03	4.50	40.7	78	12	20.5	21.3	7.24	9.33	34.3	68
800 m stations	20	23.5	24.6	9.61	3.00	39.7	102	6	29.8	31.5	8.74	18.7	39.7	98
Near-field stations	30	11.5	9.00	8.30	1.67	31.0	50	9	8.19	6.75	8.26	1.67	28.0	27
Mid-field stations	70	21.1	20.0	11.2	2.50	57.7	91	21	18.9	18.3	12.5	2.50	53.7	62
Far-field stations	120	20.9	18.7	13.7	2.33	126	90	36	20.4	20.5	10.1	2.33	41.3	67
Reference stations	42	23.2	17.2	17.2	2.00	73.7	100	15	30.4	26.0	20.2	10.0	73.7	100
All Stations	272	19.9	17.5	13.5	0.800	126.0	86	84	19.8	17.8	14.3	0.800	73.7	65
H. Amphipoda														
Distance Group	2000-2010 station means							2008-2010 station means						
	n	Mean	Median	SD	Min	Max	%Ref	n	Mean	Median	SD	Min	Max	%Ref
Outfall	10	235	114	317	13.6	1076	582	3	75.5	95.8	37.3	32.4	98.2	171
100 m stations	80	76.5	55.3	89.5	5.33	623	190	24	56.6	38.0	44.2	12.3	167	128
200 m stations	80	68.0	47.6	84.1	12.7	712	169	24	44.6	31.7	34.6	12.7	164	101
400 m stations	40	69.8	62.7	44.2	17.3	235	173	12	55.5	40.8	35.8	17.3	141	125
800 m stations	20	50.9	47.0	21.6	20.7	94.8	126	6	42.3	34.5	25.5	20.7	88.7	96
Near-field stations	30	113	57.8	174	12.3	712	280	9	54.8	18.3	62.0	12.3	167	124
Mid-field stations	70	72.6	56.2	51.1	5.33	235	180	21	64.3	44.5	46.6	16.5	164	145
Far-field stations	120	57.5	50.0	35.7	17.3	242	142	36	41.8	37.3	17.9	17.3	88.7	94
Reference stations	42	40.3	35.0	33.1	11.0	216	100	15	44.2	45.0	22.1	18.0	99.0	100
All Stations	272	71.4	50.3	96.9	5.33	1076	177	84	50.5	37.8	35.4	12.3	167	114

continued

Table 4.9, continued

I. Crustacea (other)														
Distance Group	2000-2010 station means							2008-2010 station means						
	n	Mean	Median	SD	Min	Max	%Ref	n	Mean	Median	SD	Min	Max	%Ref
Outfall	10	264	163	270	14.6	825	463	3	146	157	119	22.4	259	209
100 m stations	80	26.7	16.0	27.4	2.33	152	47	24	25.6	14.0	31.4	2.33	147	37
200 m stations	80	19.6	17.8	13.2	1.67	70.0	34	24	17.3	19.2	12.1	1.67	37.3	25
400 m stations	40	24.4	18.5	17.6	4.67	79.7	43	12	33.4	24.3	26.7	4.67	79.7	48
800 m stations	20	40.9	26.5	38.7	5.33	137	72	6	57.6	29.3	58.8	5.33	137	82
Near-field stations	30	36.8	24.3	38.0	3.00	152	64	9	32.0	11.8	46.7	4.00	147	46
Mid-field stations	70	15.9	12.5	11.9	2.00	79.7	28	21	18.7	15.0	17.9	2.00	79.7	27
Far-field stations	120	27.3	21.2	22.3	1.67	137	48	36	30.4	20.0	31.0	1.67	137	43
Reference stations	42	57.1	45.5	38.3	10.3	161	100	15	69.9	63.0	44.0	11.0	161	100
All Stations	272	38.7	22.0	71.9	1.67	825	68	84	38.8	22.7	45.7	1.67	259	56
J. Polychaete Errantia														
Distance Group	2000-2010 station means							2008-2010 station means						
	n	Mean	Median	SD	Min	Max	%Ref	n	Mean	Median	SD	Min	Max	%Ref
Outfall	10	70.1	60.1	42.5	27.6	168	240	3	53.0	64.2	20.3	29.6	65.2	167
100 m stations	80	72.2	59.5	57.0	8.67	407	247	24	64.4	59.0	30.6	8.67	134	203
200 m stations	80	63.1	58.2	27.9	20.7	161	216	24	64.5	66.3	25.1	20.7	127	204
400 m stations	40	63.6	52.7	35.1	25.0	215	218	12	69.5	69.0	26.1	33.3	118	220
800 m stations	20	60.8	50.5	44.9	29.0	238	208	6	45.6	45.7	12.2	29.7	64.3	144
Near-field stations	30	59.4	43.5	70.4	8.67	407	203	9	41.2	43.7	23.4	8.67	87.0	130
Mid-field stations	70	81.2	71.0	39.2	36.3	249	278	21	79.8	79.7	26.4	36.3	127	252
Far-field stations	120	59.3	51.5	33.9	25.0	268	203	36	59.9	56.2	22.7	28.7	134	189
Reference stations	42	29.2	27.8	8.34	14.7	54.0	100	15	31.6	33.3	7.81	20.3	45.7	100
All Stations	272	60.7	52.0	42.0	8.67	407	208	84	57.6	50.5	27.1	8.67	134	182

continued

Table 4.9, continued

K. Polychaete Sedentaria														
Distance Group	2000-2010 station means							2008-2010 station means						
	n	Mean	Median	SD	Min	Max	%Ref	n	Mean	Median	SD	Min	Max	%Ref
Outfall	10	84.3	78.6	36.4	39.2	151	111	3	73.7	63.6	40.6	39.2	118	90
100 m stations	80	102	95.3	46.9	43.7	356	134	24	109	113	33.7	43.7	183	133
200 m stations	80	105	98.3	39.2	53.7	241	138	24	114	116	13.3	91.3	138	140
400 m stations	40	104	96.3	42.4	31.3	215	137	12	126	128	32.0	80.0	193	155
800 m stations	20	87.7	76.5	55.1	33.0	298	116	6	87.2	89.2	27.1	56.7	128	107
Near-field stations	30	98.8	97.3	29.3	43.7	180	130	9	86.2	96.3	30.2	43.7	130	106
Mid-field stations	70	111	102	44.8	52.0	310	147	21	120	118	28.8	59.3	193	147
Far-field stations	120	97.1	86.8	46.3	31.3	356	128	36	114	116	24.1	56.7	183	139
Reference stations	42	75.9	71.0	25.8	37.7	147	100	15	81.6	81.0	16.8	52.0	106	100
All Stations	272	97.2	91.6	42.6	31.3	356	128	84	105	106	29.7	39.2	193	129
L. Capitella capitata complex														
Distance Group	2000-2010 station means							2008-2010 station means						
	n	Mean	Median	SD	Min	Max	%Ref	n	Mean	Median	SD	Min	Max	%Ref
Outfall	10	748	656	505	208	1759	801907	3	642	528	495	213	1183	481300
100 m stations	80	159	93.5	288	0	2200	170303	24	112	111	95.7	4.3	374	83651
200 m stations	80	80.8	32.2	178	0	1304	86698	24	77.1	45.3	102	0	394	57820
400 m stations	40	17.0	11.0	20.4	0	67.3	18243	12	27.0	17.8	25.4	0	66.0	20286
800 m stations	20	1.02	0.583	1.65	0	7.25	1095	6	0.833	0.667	0.888	0	2.33	625
Near-field stations	30	403	298	444	42.3	2200	432234	9	250	251	111	106	394	187444
Mid-field stations	70	79.3	58.3	81.9	3.00	473	85039	21	80.8	72.0	50.3	11.3	190	60619
Far-field stations	120	18.6	6.13	32.1	0	234	19933	36	25.3	10.0	31.7	0	122	18958
Reference stations	42	0.093	0	0.337	0	2.00	100	15	0.133	0	0.516	0	2.00	100
All Stations	272	101	17.7	249	0	2200	107849	84	80.8	26.0	158	0	1183	60570

continued

Table 4.9, continued

M. Miscellaneous Taxa														
Distance Group	2000-2010 station means							2008-2010 station means						
	n	Mean	Median	SD	Min	Max	%Ref	n	Mean	Median	SD	Min	Max	%Ref
Outfall	10	58.3	47.5	45.2	7.750	137	661	3	59.1	45.4	48.1	19.4	113	612
100 m stations	80	5.82	4.58	5.41	0	35.3	66	24	4.99	5.58	2.80	0	10.3	52
200 m stations	80	5.97	4.83	5.05	0	28.5	68	24	4.65	4.83	2.24	0.667	9.33	48
400 m stations	40	6.18	6.29	3.55	0.667	14.0	70	12	6.97	6.50	2.87	1.00	10.7	72
800 m stations	20	8.92	9.13	6.26	2.00	26.0	101	6	9.50	5.33	8.98	2.33	26.0	98
Near-field stations	30	5.38	3.00	7.45	0	35.3	61	9	3.27	2.67	2.14	0.333	7.67	34
Mid-field stations	70	4.77	4.33	3.36	0	16.5	54	21	4.85	5.33	2.84	0	10.7	50
Far-field stations	120	7.28	6.00	5.05	0.667	28.5	83	36	6.69	6.33	4.26	0.667	26.0	69
Reference stations	42	8.82	7.50	5.16	0.333	30.3	100	15	9.67	8.00	7.26	0.333	30.3	100
All Stations	272	8.54	5.67	13.7	0	137	97	84	8.27	6.13	13.2	0	113	86
I. ITI (Standard)														
Distance Group	2000-2010 station means							2008-2010 station means						
	n	Mean	Median	SD	Min	Max	%Ref	n	Mean	Median	SD	Min	Max	%Ref
Outfall	5	24.7	16.4	14.5	12.0	41.0	42	3	22.8	16.4	15.1	12.0	40.1	38
100 m stations	40	46.1	46.7	11.8	12.2	63.7	78	24	44.9	44.6	12.5	12.2	63.7	76
200 m stations	40	52.5	55.7	10.0	19.1	69.0	89	24	52.0	55.7	12.2	19.1	69.0	87
400 m stations	20	57.5	58.4	3.69	49.7	62.1	97	12	57.8	58.8	3.88	49.7	62.1	97
800 m stations	10	58.3	59.4	4.21	48.2	63.2	98	6	60.1	60.3	2.53	55.8	63.2	101
Near-field stations	15	32.1	35.9	10.6	12.2	46.9	54	9	28.0	29.0	10.0	12.2	39.5	47
Mid-field stations	35	49.6	49.7	6.38	36.4	61.7	84	21	49.3	49.0	7.22	36.4	61.7	83
Far-field stations	60	57.7	58.0	4.33	45.6	69.0	97	36	58.1	58.4	4.64	45.6	69.0	98
Reference stations	25	59.3	59.2	3.19	52.4	66.0	100	15	59.5	59.2	3.87	52.4	66.0	100
All Stations	140	52.1	56.4	11.5	12.0	69.0	88	84	51.7	56.6	12.7	12.0	69.0	87

Table 4.10 Spearman Rank Correlations between Benthic Community Parameters and Distance from the Outfall (2000-2010)

Parameter	2000-2010 ¹	2008-2010	2000	2002	2003	2004	2005	2006	2007	2008	2009	2010
Total Abundance	<u>-0.355</u>	<u>-0.251</u>	-0.686	-0.586	-0.474	-0.530	-0.485	-0.298	-0.333	-0.361	-0.278	-0.092
Polychaete Abundance	-0.571	-0.733	-0.629	-0.677	-0.489	-0.565	-0.638	-0.731	-0.774	-0.740	-0.792	-0.720
Total Richness	<u>0.266</u>	0.487	0.541	0.183	0.126	0.017	0.098	0.205	0.436	0.597	0.411	0.635
Echinodermata	<u>0.302</u>	0.582	0.225	-0.053	0.258	0.156	0.141	0.341	0.546	0.647	0.432	0.711
Bivalvia	0.095	<u>0.234</u>	0.041	0.003	-0.090	-0.045	0.090	0.128	0.154	0.104	<u>0.375</u>	0.232
Gastropoda	<u>0.131</u>	0.442	-0.301	-0.237	-0.146	0.051	0.016	-0.074	0.232	0.271	0.232	0.772
Crustacea (amphipoda)	<u>-0.209</u>	-0.062	-0.466	-0.215	-0.286	-0.594	-0.487	0.206	-0.153	0.332	-0.417	-0.327
Crustacea (other)	<u>0.212</u>	<u>0.318</u>	0.131	0.132	0.317	-0.240	0.249	0.324	0.299	0.464	0.326	0.477
Polychaete Errantia	<u>-0.377</u>	<u>-0.360</u>	-0.477	-0.493	-0.231	-0.566	-0.454	-0.270	-0.411	-0.371	-0.362	-0.481
Polychaete Sedentaria (other)	<u>-0.185</u>	<u>-0.245</u>	0.057	-0.585	0.139	-0.356	-0.170	-0.465	-0.578	-0.408	-0.224	-0.062
<i>Capitella capitata</i> complex	-0.739	-0.755	-0.817	-0.740	-0.600	-0.751	-0.737	-0.792	-0.770	-0.788	-0.730	-0.753
Miscellaneous Taxa	<u>0.149</u>	0.182	-0.158	0.102	-0.024	-0.136	0.436	0.457	0.192	0.216	-0.220	0.470
SDI	0.544	0.618	0.604	0.624	0.549	0.514	0.449	0.498	0.402	0.696	0.560	0.620
ITI-Standard ²	0.577	0.595	NM	NM	NM	NM	NM	0.573	0.499	0.704	0.611	0.573

Note

¹ Excluding 2001 (due to anomalous invertebrate taxonomy)

² ITI-Standard data available only from 2006 through 2010

NM = parameter was not measured this year

Statistically significant correlations ($p < 0.05$) are **bolded**

Bold & underlined = weak ($|r_s| < 0.4$) but statistically significant correlation

X = strong correlation ($|r_s| > 0.6$) **X** = moderate strength correlation ($0.4 < |r_s| < 0.6$)

Table 4.11 Spearman Rank Correlations between Benthic Community Parameters and Distance-Direction Gradient (i.e. Outfall/Mid-field/Near-field/Far-field/Reference; 2000-2010)

Parameter	2000-2010 ¹	2008-2010	2000	2002	2003	2004	2005	2006	2007	2008	2009	2010
Total Abundance	<u>-0.225</u>	-0.145	-0.474	-0.488	-0.236	-0.290	<u>-0.377</u>	0.001	-0.215	-0.092	<u>-0.375</u>	0.072
Polychaete Abundance	-0.686	-0.824	-0.769	-0.914	-0.910	-0.311	-0.933	-0.828	-0.891	-0.829	-0.918	-0.782
Total Richness	<u>0.270</u>	0.576	0.561	-0.021	0.077	0.059	-0.022	0.219	<u>0.390</u>	0.624	0.579	0.734
Echinodermata	0.059	<u>0.349</u>	-0.089	-0.332	-0.151	0.005	-0.197	0.133	0.204	0.370	0.363	0.318
Bivalvia	0.492	0.543	0.621	0.413	0.449	0.443	0.520	0.572	0.458	0.422	0.589	0.596
Gastropoda	<u>0.186</u>	0.433	-0.367	<u>-0.394</u>	0.125	0.256	0.102	0.123	<u>0.393</u>	0.238	0.292	0.779
Crustacea (amphipoda)	<u>-0.251</u>	-0.044	-0.582	-0.178	-0.565	-0.512	-0.487	0.263	-0.319	0.406	-0.555	-0.184
Crustacea (other)	<u>0.243</u>	<u>0.311</u>	0.451	-0.134	0.240	0.074	0.370	0.371	0.186	0.414	0.161	0.656
Polychaete Errantia	-0.401	<u>-0.334</u>	-0.585	-0.480	-0.318	-0.504	-0.526	-0.311	-0.598	-0.353	-0.300	-0.495
Polychaete Sedentaria (other)	<u>-0.255</u>	-0.156	0.034	-0.775	-0.265	-0.510	-0.515	-0.471	-0.696	-0.457	-0.083	0.143
<i>Capitella capitata</i> complex	-0.849	-0.853	-0.817	-0.883	-0.895	-0.877	-0.918	-0.858	-0.864	-0.855	-0.867	-0.856
Miscellaneous Taxa	<u>0.246</u>	<u>0.284</u>	0.219	0.326	-0.072	-0.219	0.519	0.585	0.424	0.418	-0.182	0.549
SDI	0.450	0.649	0.426	0.419	0.271	0.430	0.293	0.211	0.401	0.720	0.692	0.550
ITI-Standard ²	0.716	0.698	NM	NM	NM	NM	NM	0.839	0.700	0.771	0.768	0.719

Note

¹ Excluding 2001 (due to anomalous invertebrate taxonomy)

² ITI-Standard data available only from 2006 through 2010

NM = parameter was not measured this year

Statistically significant correlations ($p < 0.05$) are **bolded**

Bold & underlined = weak ($|r_s| < 0.4$) but statistically significant correlation

X

= strong correlation ($|r_s| > 0.6$)

X

= moderate strength correlation ($0.4 < |r_s| < 0.6$)

Analysis of Variance

The analysis of variance was conducted once for all years of data and once for only the three most recent years, to investigate whether trends have remained consistent in recent years. Prior to analysis, data were tested for normality using the Kolmogorov Smirnov test and the Shapiro-Wilk tests (depending on the size of the data set), and for homogeneity of variance using Levene's test. Results of the ANOVA (or Kruskal-Wallis) and *post hoc* multiple comparisons are presented in Table 4.12 and Table 4.13. Figure 4.22 illustrates means and 95% confidence intervals (CI) by distance group and by distance-direction group for each parameter (Golder, 2011a).

Distance Groups versus Reference Stations

Most benthic community parameters exhibited significant differences among distance groups ($p < 0.05$) with the exception of bivalves and amphipods in recent years (2008-2010) (Table 4.12).

Post hoc comparisons for all years of data revealed that total abundance, total polychaete abundance and abundances of amphipods, crustaceans (non-amphipod), mobile polychaetes and *Capitella capitata* complex were significantly higher at all distance groups compared to reference group, with the exception of total abundance, amphipod abundance and crustacean (non-amphipod) abundance at 800 m stations, which was not significantly different from reference. A decrease in abundance from the outfall to the reference stations is apparent for all of these parameters (Figure 4.22). Abundances of other sedentary polychaetes were significantly higher in 100 m, 200 m and 400 m distance groups compared to the reference area, but no significant differences were observed between each of the outfall and 800 m groups and the reference area. The lack of statistical significance is likely due to the lower sample sizes and higher variability in these groups, particularly at the outfall and 800 m stations, as is evident in Figure 4.22 (Golder, 2011a).

Total richness was significantly lower at the outfall than at the reference stations, whereas richness was significantly higher at the 400 m stations compared to the reference. Figure 4.22 shows that average richness increases from the outfall to 800 m and then decreases slightly (to the level of the 100 m and 200 m stations) at the reference area. The results of *post hoc* comparisons also indicate that ITI (standard) and SDI values are lower at each of the outfall, 100 m and 200 m stations than at the reference stations. Figure 4.22 illustrates this trend, showing increasing ITI (standard) and SDI values with distance from the outfall.

Echinoderm abundance was significantly lower than reference at the outfall, 100 m and 200 m stations. Average echinoderm abundance increases from the outfall to reference, although the average abundance at the 800 m stations is slightly higher than reference (Figure 4.22). Bivalve and gastropod abundances both exhibited significant differences among distance groups; however only bivalve abundance at the outfall was significantly different from the reference. Figure 4.22 suggests a negative influence of outfall exposure to both bivalves and gastropods, but only within close proximity to the outfall.

Non-amphipod crustaceans were found to be significantly less abundant at each of the 100 m, 200 m, and 400 m distances compared to the reference stations, and significantly more abundant at the outfall compared to the reference stations. Figure 4.22 shows an elevated (and variable) average abundance of non-amphipod crustaceans at the outfall with a large decrease at the 100 m stations and a gradual increase from 200 m toward the reference. Abundances of miscellaneous taxa were significantly higher at the outfall compared to the reference, and significantly lower at the 100 m and 200 m stations compared to the reference area. Miscellaneous taxa display a spatial pattern similar to that of the non-amphipod crustaceans, with high and variable abundances at the outfall and slightly lower abundances at the intermediate distances compared to the reference (Figure 4.22). Crustaceans (amphipod and other) and miscellaneous taxa at the outfall vary dramatically from year to year (Figure 4.22), whereas lower but more consistent abundances are observed at the other distance groups.

Results for multiple comparisons among distance groups and the reference were similar for tests conducted using the recent data only; however, fewer significant differences were identified for some distance groups (e.g., outfall and 800 m in particular). The reduction in statistical significance in recent

years is likely attributable to the smaller sample sizes (especially for the outfall, with only 3 values from 2008 to 2010). Using recent data only, total abundance, bivalve and amphipod abundances were not significantly different between each of the distance groups and the reference area (Table 4.12). The negative influence of outfall exposure is more apparent in gastropod abundances from recent years with significantly lower averages at the outfall and 100 m stations (Golder, 2011a).

Differences among Distance-Direction Groups

All benthic community parameters exhibited significant differences ($p < 0.001$) among distance-direction groups in all years combined (2000-2010), and all but amphipods were significantly different for recent years only (2008-2010) (Table 4.13). *Post hoc* comparisons were conducted between each of outfall, near-field, mid-field and far-field versus the reference stations using all years of data (2000-2010) and once for recent years only (2008-2010).

Total abundances, polychaete abundances, and abundances of mobile polychaetes and *Capitella capitata* complex were significantly higher ($p < 0.05$) at near-field, mid-field and far-field stations relative to reference stations (Table 4.13). Other sedentary polychaetes were also more abundant at near-field, mid-field and far-field groups relative to reference, but were not significantly more abundant at the outfall stations. Amphipod abundances were significantly greater than reference stations at all distance-direction group stations except the near-field stations. These results are similar to those observed for the distance-only based analysis; however, Figure 4.22 generally shows a clearer separation between individual distance-direction groups than for the traditional distance groups (Golder, 2011a).

Total richness was significantly lower ($p < 0.001$) at the outfall and near-field stations relative to reference stations (Table 4.13). These results are similar to those observed for the distance groups; however, a clearer separation is evident between the near-field and other distance-direction groups (Figure 4.22). The SDI was significantly lower at each of the outfall and distance-direction groups relative to reference. Figure 4.22 shows differing spatial patterns between the distance and distance-direction groupings, with the distance-direction plot displaying a clearer separation between higher SDI values in the mid-field, far-field, and reference areas. The steady increase of SDI with distance observed in the distance-based plot is likely a result of a smoothing artefact, in which stations in the 100 m and 200 m distance groups include stations that are qualitatively different. ITI (standard) values were significantly lower at each of the outfall and distance-direction groups relative to reference, which is similar to the observations for distance groups (Figure 4.22).

Echinoderm, bivalve and gastropod abundances exhibited a clearer spatial separation among distance-direction groups relative to the distance-only analysis (Figure 4.22), resulting in more statistically significant differences for the distance-direction groups (Table 4.13). Echinoderms were significantly less abundant at the outfall, near-field and far-field stations compared to reference stations. Bivalve abundances were significantly lower at the outfall, near-field and mid-field stations relative to reference stations, and significantly higher at far-field stations compared to reference. Gastropod abundances were significantly lower at near-field stations relative to reference stations, but there were no significant differences between any of the other distance-direction groups and the reference stations.

When grouped into distance-direction categories, non-amphipod crustaceans and miscellaneous taxa showed similar spatial patterns to those of the distance-only groupings. Miscellaneous taxa and non-amphipod crustacean abundances were significantly higher at the outfall and lower at each of the near-field, mid-field and far-field groups than at the reference stations or other distance direction groups (Table 4.13).

Statistical comparisons among distance-direction groups using only recent data (2008-2010) yielded similar results to those using all years. Statistically significant *p*-values were generally higher (*i.e.*, lower significance) and fewer for the recent years due to reduced sample size (*i.e.*, only 3 years of data vs. 10 years). Amphipod abundances were not significantly different among distance-direction groups when only recent data was analyzed and only the outfall was statistically different to the reference for total abundances (Table 4.13) (Golder, 2011a).

Table 4.12 Results of Analysis of Variance (ANOVA or Kruskal-Wallis) and Post hoc Statistical Comparisons to Reference for Macaulay Point Distance Groups (2000-2010)

Parameter	All Years (2000-2010) ¹						Recent Years (2008-2010)					
	ANOVA/ Kruskal- Wallis	Comparison with Reference					ANOVA/ Kruskal- Wallis	Comparison with Reference				
		Outfall	100 m	200 m	400 m	800 m		Outfall	100 m	200 m	400 m	800 m
Total Abundance	<0.001	<0.001	<0.001	<0.001	<0.001	1.00	0.044	0.054	0.217	0.391	0.179	1.00
Polychaete Abundance	<0.001	<0.001	<0.001	<0.001	<0.001	0.027	<0.001	0.038	<0.001	<0.001	<0.001	1.00
Total Richness	<0.001	<0.001	0.806	1.00	0.034	0.063	<0.001	0.038	0.027	0.023	1.00	1.00
Echinodermata	<0.001	0.005	<0.001	<0.001	0.163	0.584	<0.001	0.096	<0.001	0.001	0.851	0.192
Bivalvia	0.007	0.005	1.00	0.158	1.00	1.00	0.088	NC	NC	NC	NC	NC
Gastropoda	0.041	0.163	1.00	1.00	1.00	1.00	<0.001	0.038	0.039	0.216	1.00	1.00
Crustacea (amphipoda)	<0.001	0.007	0.001	0.004	<0.001	0.057	0.558	NC	NC	NC	NC	NC
Crustacea (other)	<0.001	0.048	<0.001	<0.001	<0.001	0.066	<0.001	1.00	0.002	<0.001	0.096	1.00
Polychaete Errantia	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.548	<0.001	<0.001	<0.001	0.079
Polychaete Sedentaria (other)	<0.001	1.00	<0.001	<0.001	0.012	1.00	<0.001	1.00	0.011	<0.001	0.004	1.00
<i>Capitella capitata</i> complex	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	0.034
Miscellaneous Taxa	<0.001	<0.001	<0.001	<0.001	0.051	1.00	0.001	0.075	0.057	0.015	1.00	1.00
SDI	<0.001	<0.001	<0.001	<0.001	0.118	1.00	<0.001	0.038	<0.001	0.002	0.003	1.00
ITI-Standard2	<0.001	0.003	<0.001	0.002	0.965	1.00	<0.001	0.038	<0.001	0.090	1.00	1.00

Note

¹ Excluding 2001 (due to anomalous invertebrate taxonomy)

² ITI-Standard data available only from 2006 through 2010

Significant differences relative to references ($p < 0.05$) are **bolded**.

NC = Not calculated; no comparison made as ANOVA (or non parametric Kruskal-Wallis test if applicable) was not significant.

Table 4.13 Results of Analysis of Variance (ANOVA or Kruskal-Wallis) and Post hoc Statistical Comparisons to Reference for Macaulay Point Distance-Direction Groups (2000-2010)

Parameter	All Years (2000-2010) ¹					Recent Years (2008-2010)				
	ANOVA/ Kruskal- Wallis	Comparison with Reference				ANOVA/ Kruskal- Wallis	Comparison with Reference			
		Outfall	Near-field	Mid-field	Far-Field		Outfall	Near-field	Mid-field	Far-Field
Total Abundance	<0.001	<0.001	<0.001	<0.001	<0.001	0.015	0.043	1.00	0.577	0.056
Polychaete Abundance	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.031	<0.001	<0.001	<0.001
Total Richness	<0.001	<0.001	<0.001	0.858	0.509	<0.001	<0.001	<0.001	0.040	0.976
Echinodermata	<0.001	0.004	0.002	1.00	<0.001	<0.001	0.077	0.005	0.155	<0.001
Bivalvia	<0.001	0.004	<0.001	0.022	<0.001	<0.001	0.031	<0.001	0.091	0.126
Gastropoda	<0.001	0.131	0.005	1.00	1.00	<0.001	0.031	0.003	0.526	0.651
Crustacea (amphipoda)	<0.001	0.005	0.232	<0.001	<0.001	0.276	NC	NC	NC	NC
Crustacea (other)	<0.001	0.038	0.015	<0.001	<0.001	<0.001	0.818	0.011	<0.001	0.003
Polychaete Errantia	<0.001	<0.001	0.006	<0.001	<0.001	<0.001	0.438	1.00	<0.001	<0.001
Polychaete Sedentaria (other)	<0.001	0.945	0.007	<0.001	0.004	<0.001	0.969	0.981	<0.001	<0.001
<i>Capitella capitata</i> complex	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001
Miscellaneous Taxa	<0.001	<0.001	<0.001	<0.001	0.045	<0.001	0.060	0.011	0.029	0.321
SDI	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.031	<0.001	<0.001	0.015
ITI-Standard ²	<0.001	0.002	<0.001	<0.001	0.540	<0.001	0.031	<0.001	<0.001	1.00

Note

¹ Excluding 2001 (due to anomalous invertebrate taxonomy)

² ITI-Standard data available only from 2006 through 2010

Significant differences relative to references ($p < 0.05$) are **bolded**.

NC = Not calculated; no comparison made as ANOVA (or non parametric Kruskal-Wallis test if applicable) was not significant.

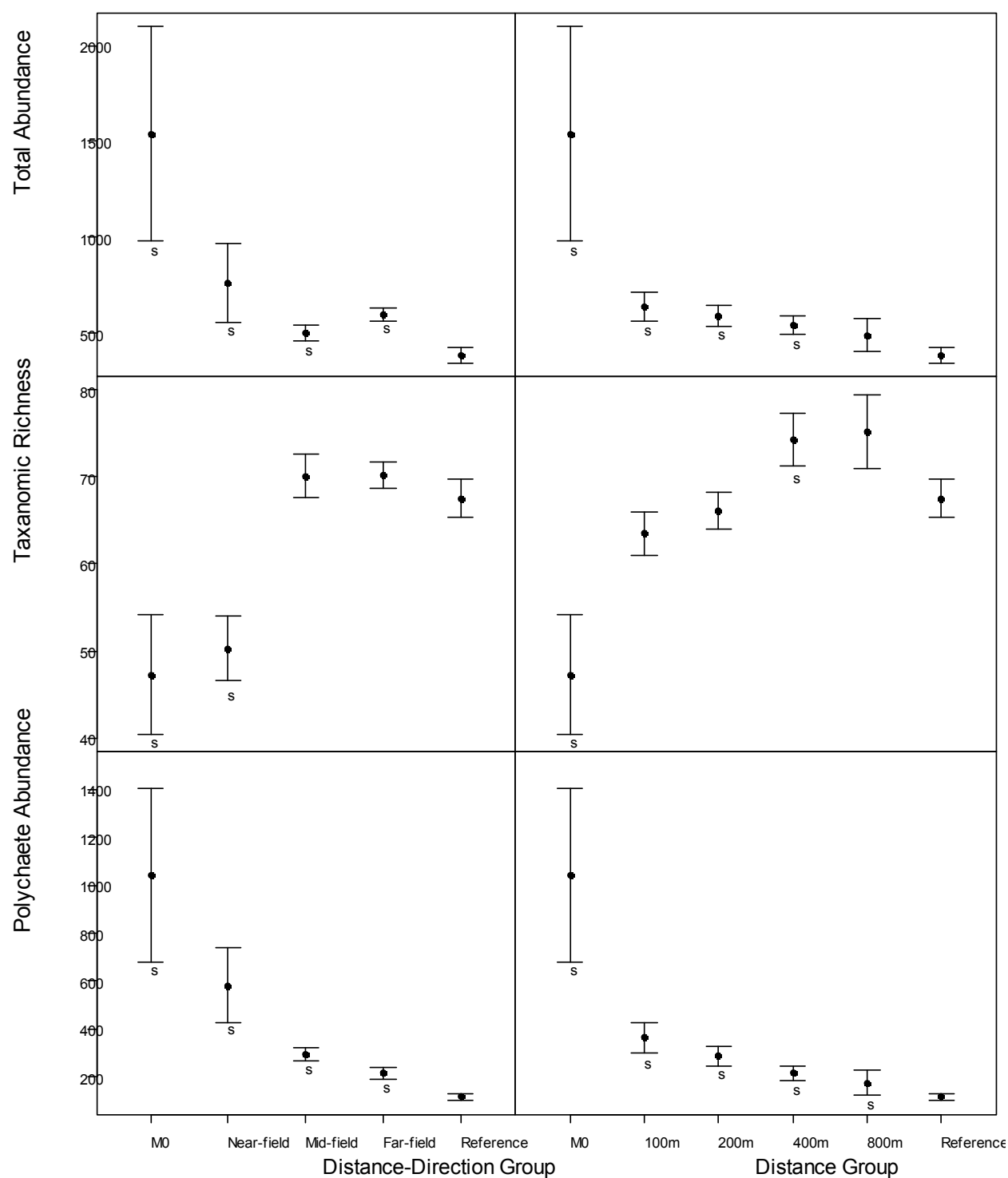


Figure 4.22 Means ± 95% Confidence Intervals for Macaulay Point Benthic Community Parameters (2000-2010)

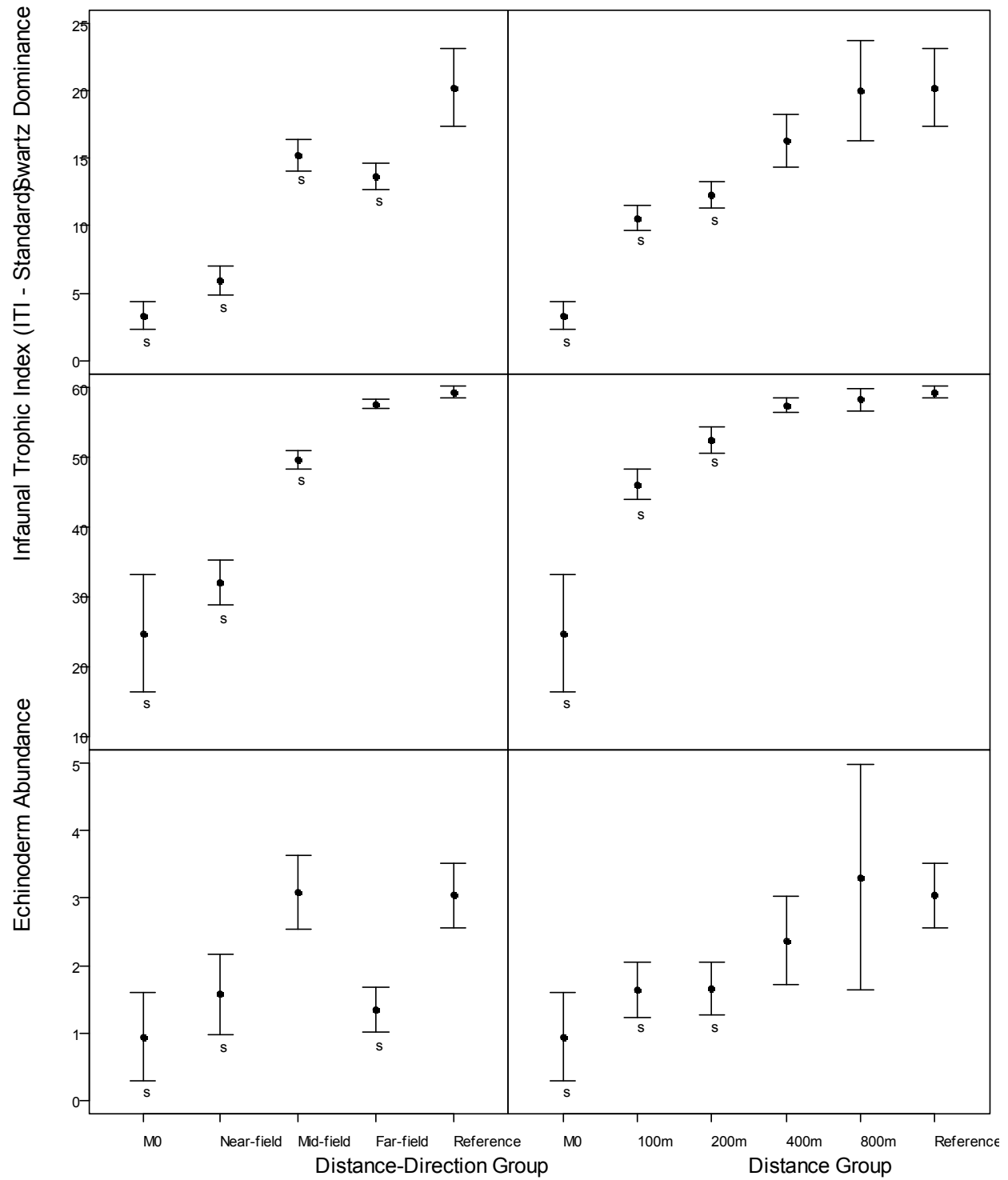


Figure 4.22, continued

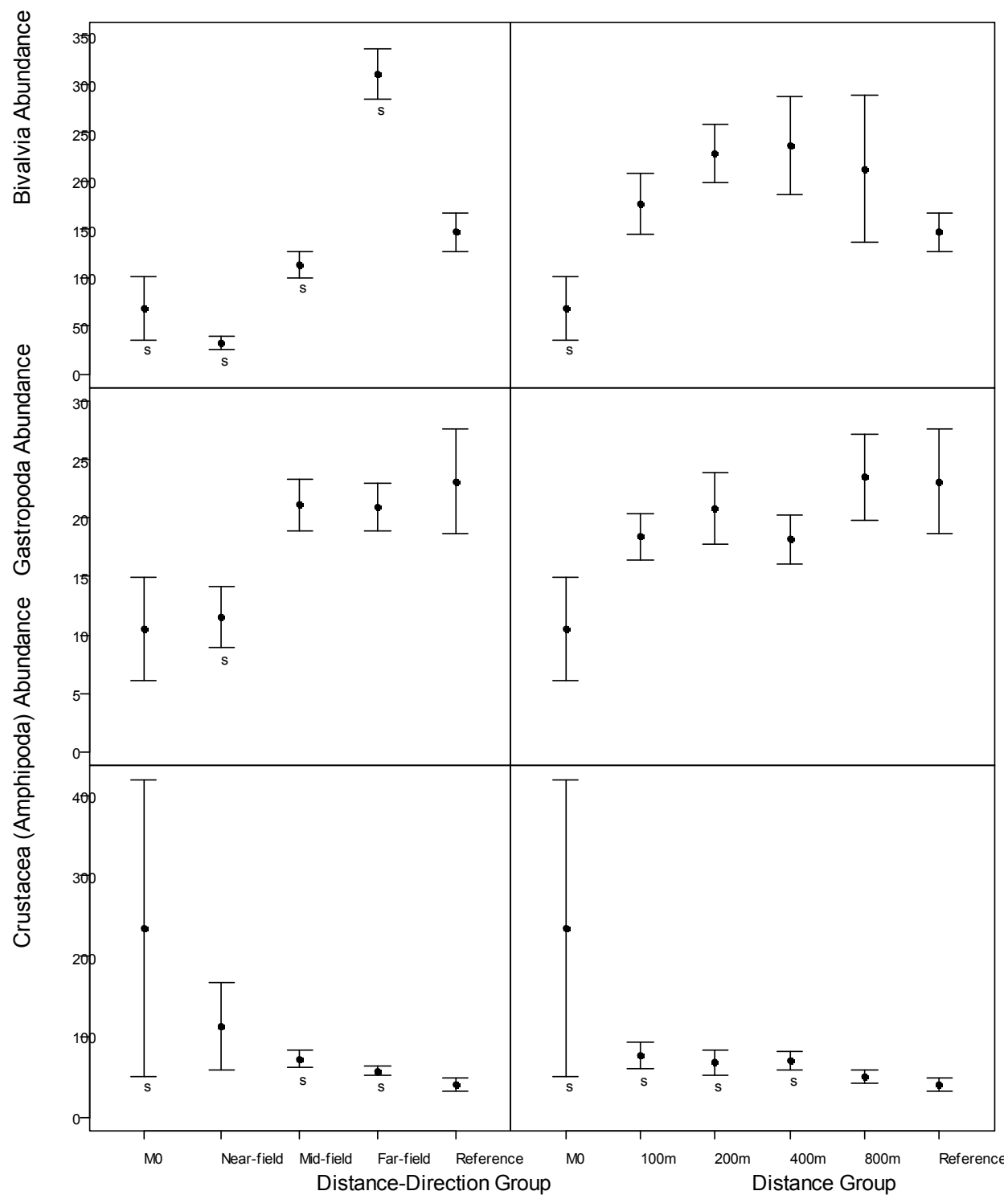


Figure 4.22, continued

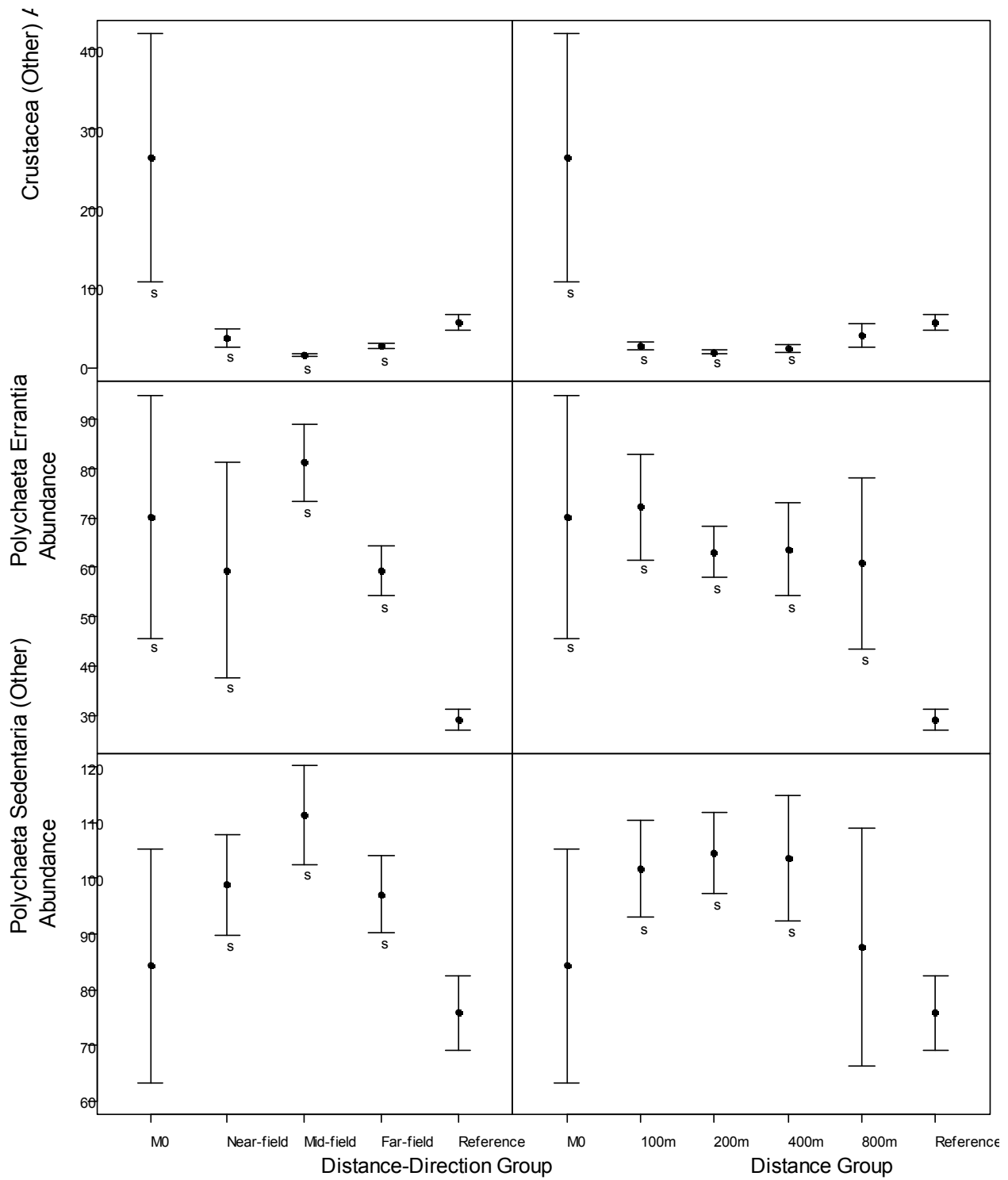


Figure 4.22, continued

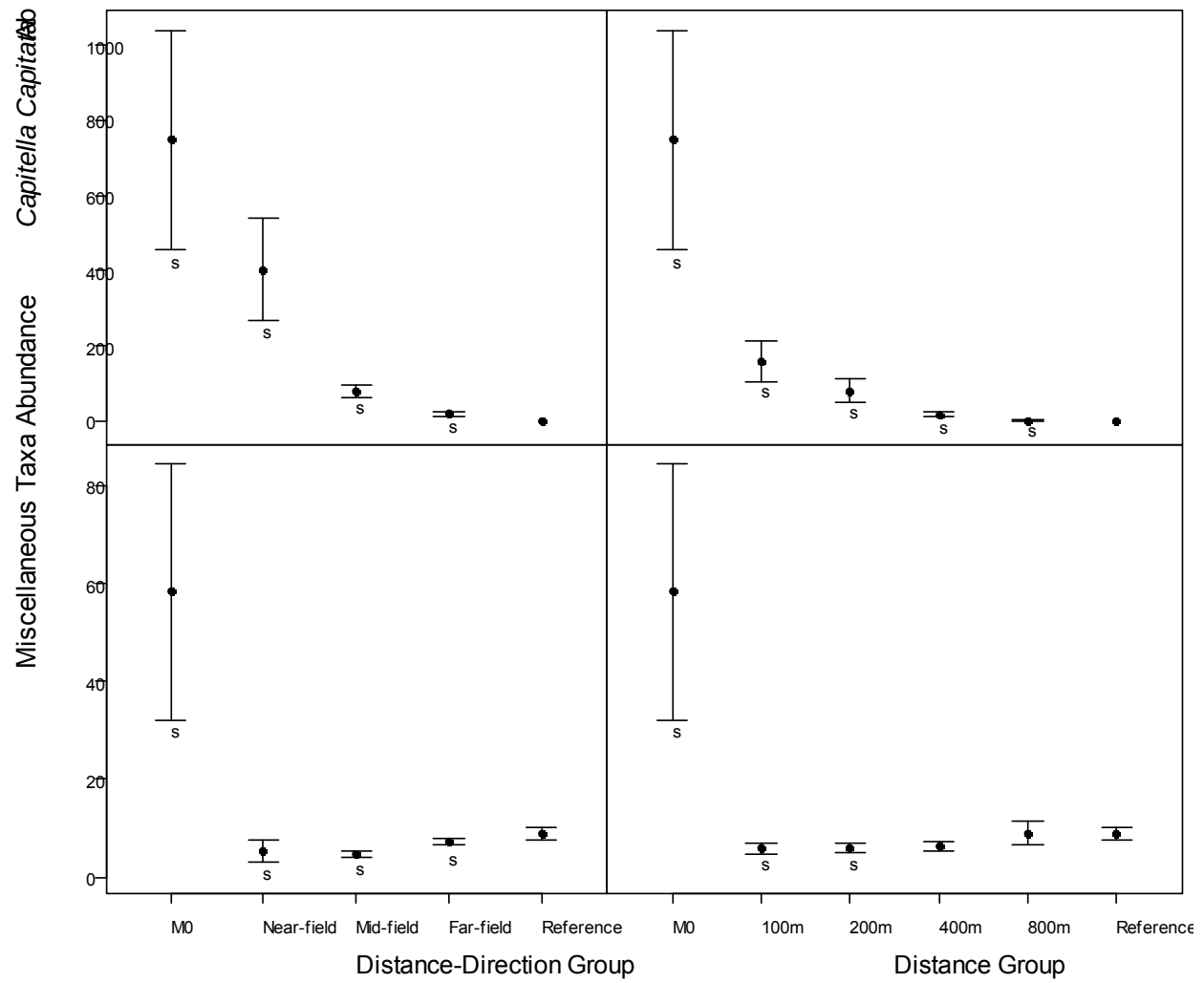


Figure 4.22, continued

Temporal Trends

Plots of the reference-normalized distance-group, and distance-direction means over time for the benthic parameters are presented in Figure 4.23 and 4.24 respectively. Data from 1994, 1997 and 1999 were included in these plots; however, these were not included in the quantitative assessments provided above due to inconsistency in sampling plans (*i.e.*, number and location of stations, splitting of samples) relative to 2000-2010 data. Data from 2001 are also presented in the temporal trend graphs but were not included in the quantitative analyses, as these data were strongly influenced by the higher level of effort applied during taxonomic enumerations in this year. Following 2001, the same benthic taxonomist has been contracted and methods have been standardized (e.g. samples are no longer split) resulting in elimination of numerous sources of analytical variability. Some observations from the graphs include (Golder, 2011a):

- In general, there is a greater temporal variability at the outfall than at any of the other distance and distance-direction groups. This is most evident for total abundance, polychaete abundance, crustaceans, miscellaneous taxa and *Capitella capitata* complex;
- The abundances of some taxa are more variable from 1994 to 1999 than in later years (e.g., errant polychaetes, echinoderms, and miscellaneous taxa). At least part of this variability may be explained by the reduction in sources of analytical variability in recent sampling years;
- In the last decade, total abundance of organisms has exceeded reference levels for all distance groups and distance-direction groups. However, over the last decade, the degree to which the exposed stations exceed reference abundances has decreased. In the early 2000s, the magnitude of the difference was approximately a factor of two (for all groups except M0), but in recent years the difference has become small;
- Over the period of record, total abundance levels have been generally higher at outfall terminus compared to the remaining distances; however, a reduced relative abundance at the outfall is apparent from 2006-2009 compared to earlier years. This difference is due primarily to a general reduction in polychaete abundances, which have decreased over the last decade. However a marked increase in polychaete abundance at the outfall from 2009 to 2010 has resulted in an increase in total abundance at M0 in 2010;
- Abundance counts for echinoderms and gastropods appear to vary in a random manner over the period of record. However, the counts of these organisms in 2010 (relative to reference) are among the lowest observed over the period of record, and counts were particularly low at stations near the outfall;
- Average values for SDI and ITI (standard) are also variable, although the average outfall values are consistently lower than the rest of the distance groups and values tend to increase with distance from the outfall;
- Taxonomic richness appears to gradually decline from 2002-2010, with the outfall and near-field averages consistently lower than the rest of the distance group averages. Whereas richness at mid-field and far-field stations was greater than reference for the time period of 2002-2005, we have observed a steady decline in richness since that time, such that richness at mid-field and far-field stations is now similar to reference, but not greater;
- Bivalve abundances varied randomly prior to 2002, but have generally declined at all distance groups from 2002 to 2010, with the lowest abundances consistently present near the outfall (M0 and near-field stations);
- No clear temporal trends are apparent in crustacean abundance. Whereas the average abundances of most distance groups do not appear to change dramatically relative to each other, the outfall averages are extremely variable. The 2010 data indicate a return to elevated crustacean abundances at the outfall (similar to the pattern observed approximately one decade ago); however, it is unknown whether this reflects a meaningful change to the benthic community composition or merely a transient response; and,

- The average abundances of miscellaneous taxa do not appear to change dramatically from 2002 to 2010 for all distance groups with the exception of the outfall, which varies substantially over time.

Spearman Rank Correlations

Temporal trends, assessed using Spearman rank correlations between each benthic community metric and year, are presented in Table 4.14. Significant trends are bolded and coded based on the strength of the relationship (Golder, 2011a).

Significant negative trends (*i.e.*, a decrease over time) were identified for total abundance, total richness, and the abundances of echinoderms, bivalves, gastropods, crustaceans, mobile polychaetes and miscellaneous taxa, when all stations were analyzed together, although all of these relationships were quite weak, with correlation coefficients (r_s) ranging from -0.17 to -0.40 (Table 4.14).

When correlation coefficients were calculated for individual distance groups, stronger trends were identified for most parameters, with the strongest temporal trends occurring at the outfall (Table 4.14). Five strong negative temporal trends ($p < 0.05$) were identified at the outfall for total abundance, and abundances of echinoderms, bivalves, gastropods and amphipods (r_s ranging from -0.69 to -0.93).

When stations were subdivided into distance-direction groups, temporal trends were qualitatively similar to those in the distance groups, with the strongest trends appearing at near-field stations (Table 4.14). The observed increases in statistical significance is likely attributable to higher sample size in the near-field group ($n = 30$) in comparison to the outfall ($n = 10$) and the reduction in spatial variability within groups for some parameters. More significant correlations were identified in the near-field groups than at the outfall alone.

Results were generally similar to those from the 2007 multi-year trend assessment, including the presence of significant negative trends for total abundances, the abundances of gastropods and the strongest trends at the outfall. Some notable differences in results included (Golder, 2011a):

- In the 2007 trend assessment, there were no significant temporal trends for total richness, whereas total richness was significantly negatively correlated at 100 m and 200 m from the outfall and at all distance-direction groupings in the current trend assessment. This change reflects the more pronounced decreases in richness that have been observed at near-field stations in recent years. Whereas in the middle part of the last decade, richness reductions were observed only at the outfall terminus, in the last few years the richness reductions have also been observed at several other stations within a few hundred metres of M0;
- In the current assessment there was an increase in the number of significant negative correlations (*e.g.*, echinoderms, bivalves and amphipods) at the outfall monitoring stations, compared with the 2007 trend assessment. As negative correlations indicate a decrease in biological metric over time, this is indicative of a potential worsening of environmental conditions; and,
- In the 2007 trend assessment, strong negative temporal trends were identified for polychaete abundances and *Capitella capitata* complex at the outfall and the near-field group, whereas negative trends were generally weaker or non-significant in the current assessment. This is likely due to the increases in *Capitella capitata* observed in recent years. There was also a general decrease in the strength of the negative temporal trends observed in mobile polychaetes in the current trend assessment compared with 2007. The changes indicate a potential trend toward benthic communities that are more dominated by polychaete taxa.

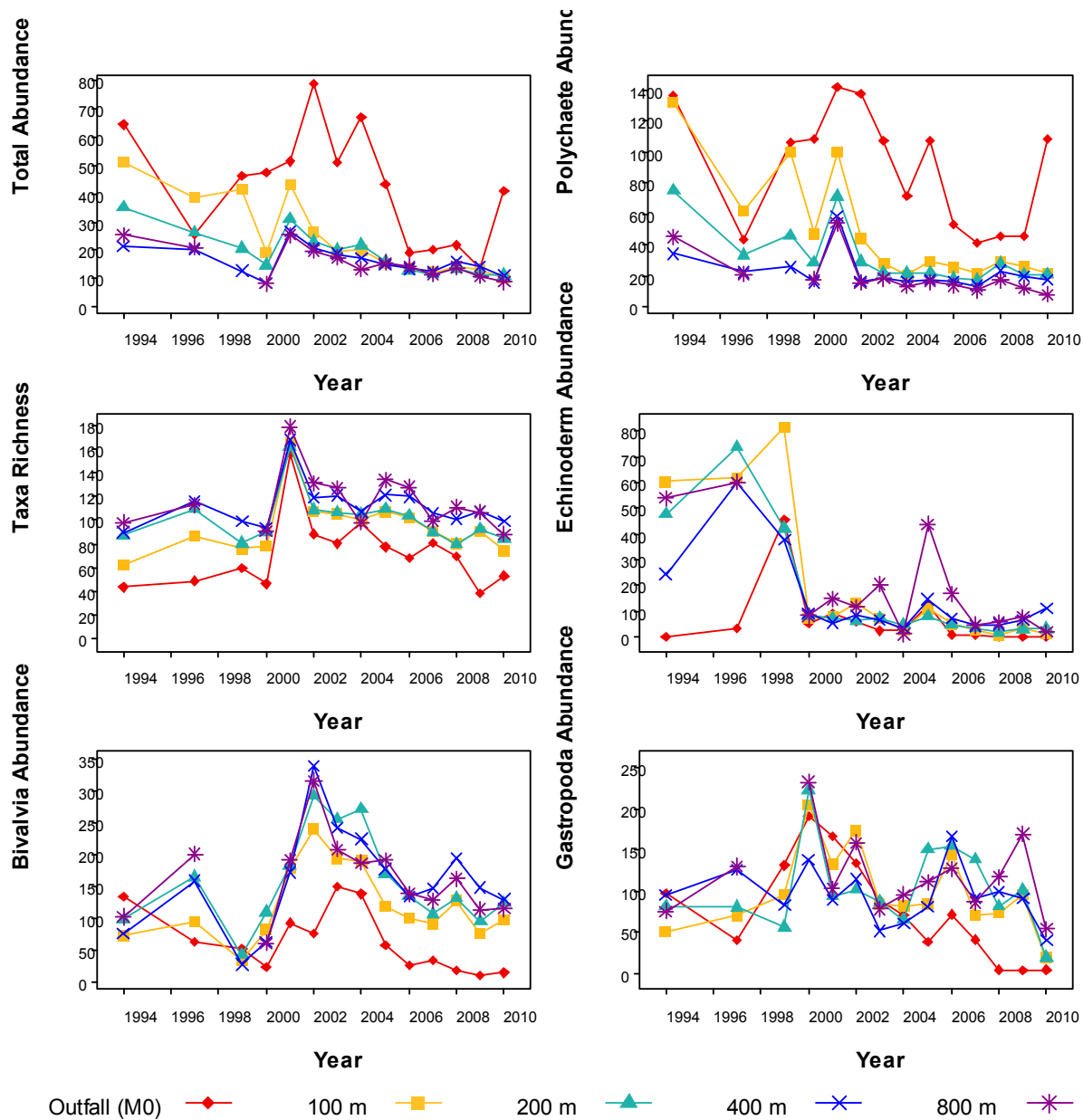


Figure 4.23 Plots of Normalized Benthic Community Metrics over Time, Grouped by Distance from M0

Note:
Benthic community metrics were normalized to reference area.
Vertical axis represents percent of reference.
No 800 m stations were sampled in 1999.

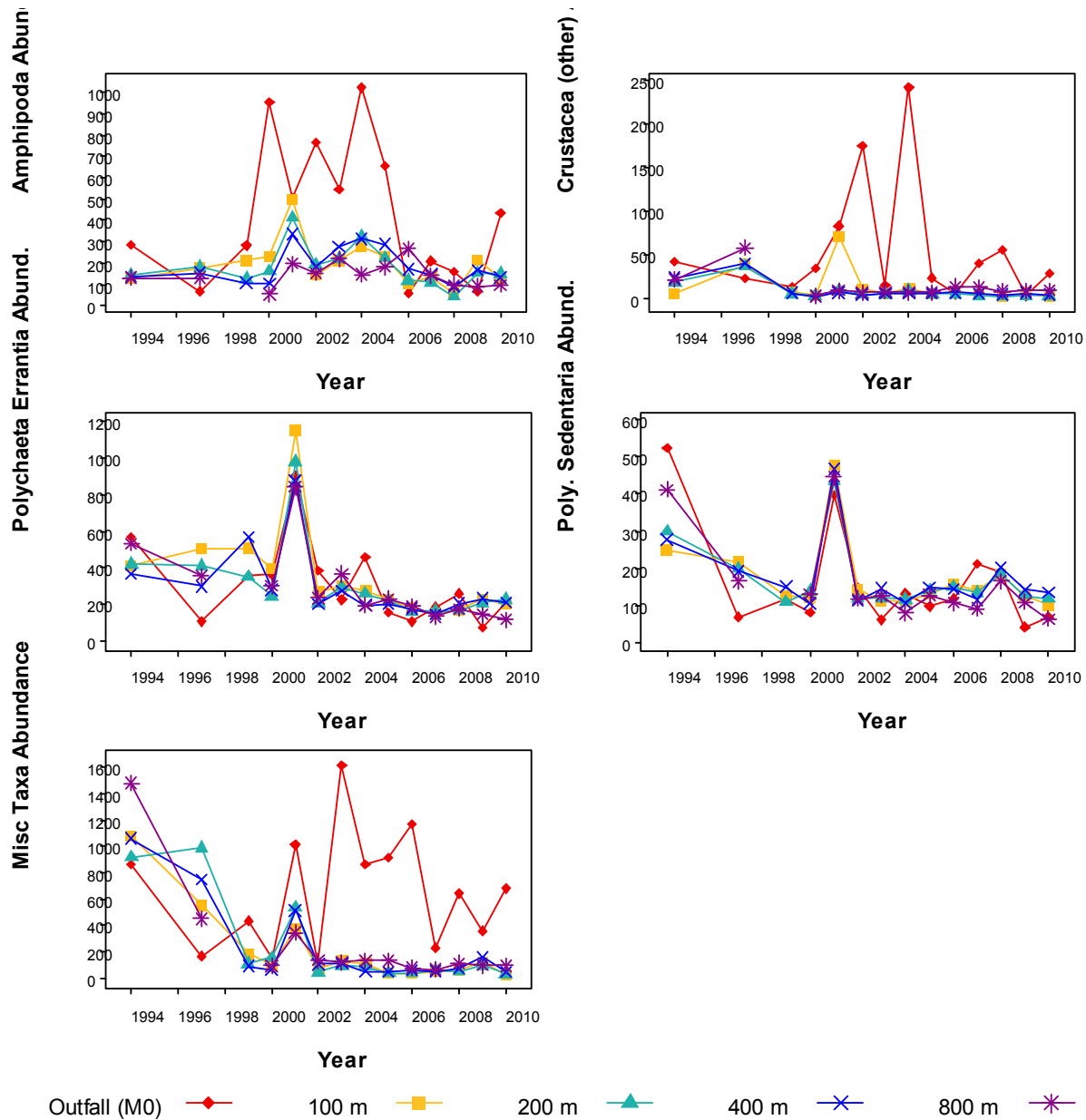


Figure 4.23, continued

Note: Benthic community metrics were normalized to reference area
 Vertical axis represents percent of reference
 No 800 m stations were sampled in 1999

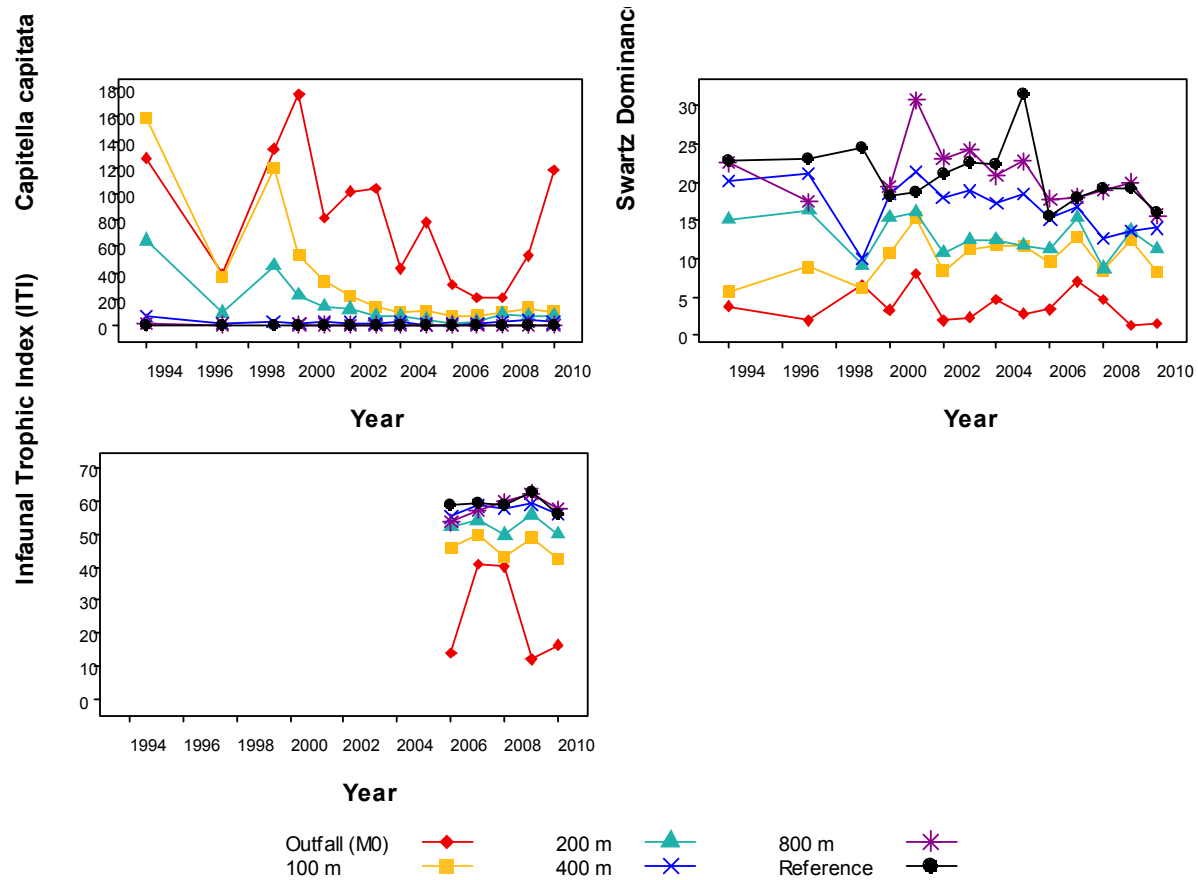


Figure 4.23, conclusion

Note *Capitella capitata* abundance, SDI and ITI were not reference normalized.
No 800 m stations were sampled in 1999.

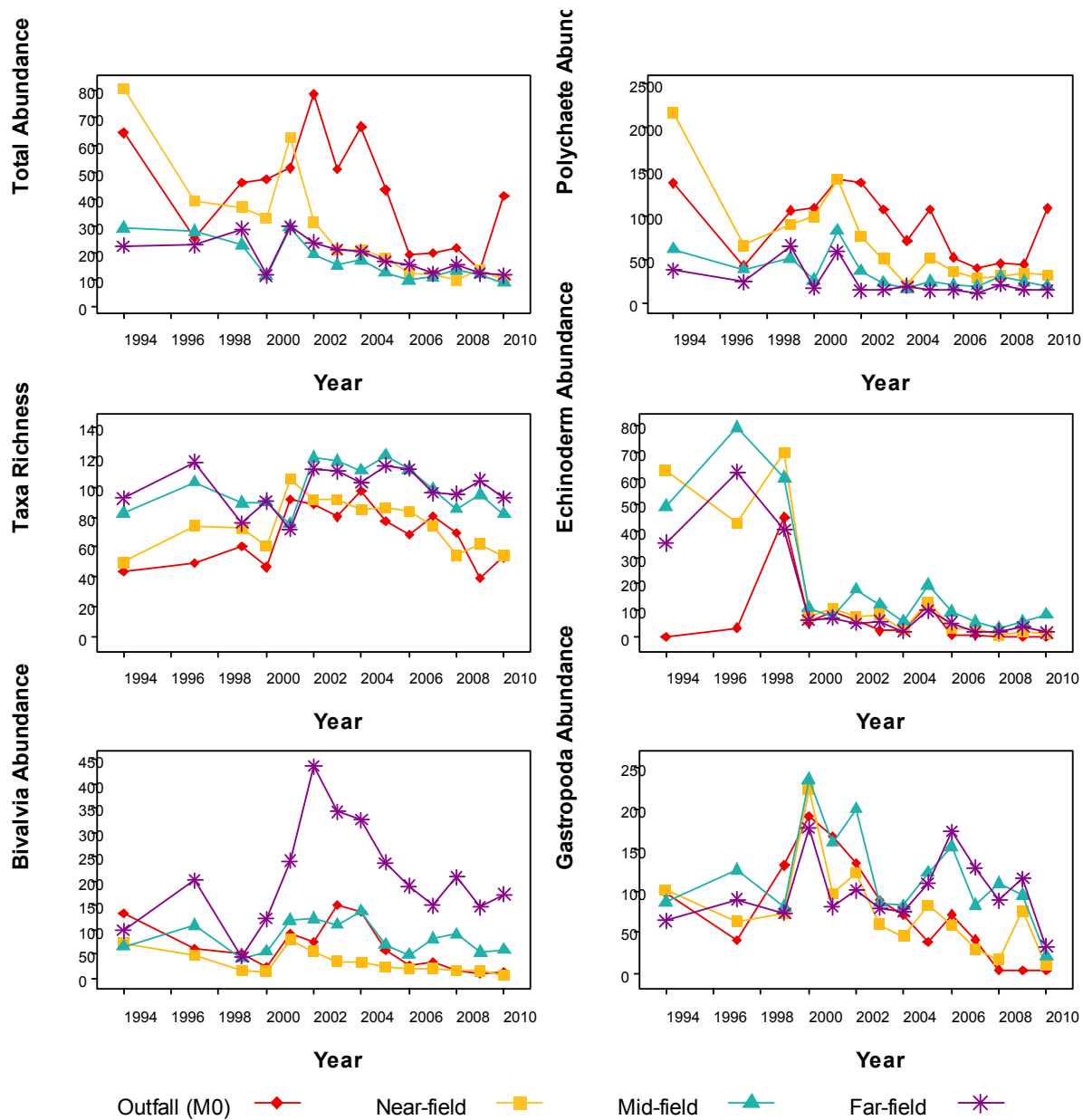


Figure 4.24 Plots of Normalized Benthic Community Metrics over Time, Grouped by Distance-Direction

Note Benthic community metrics were normalized to reference area
Vertical axis represents percent of reference

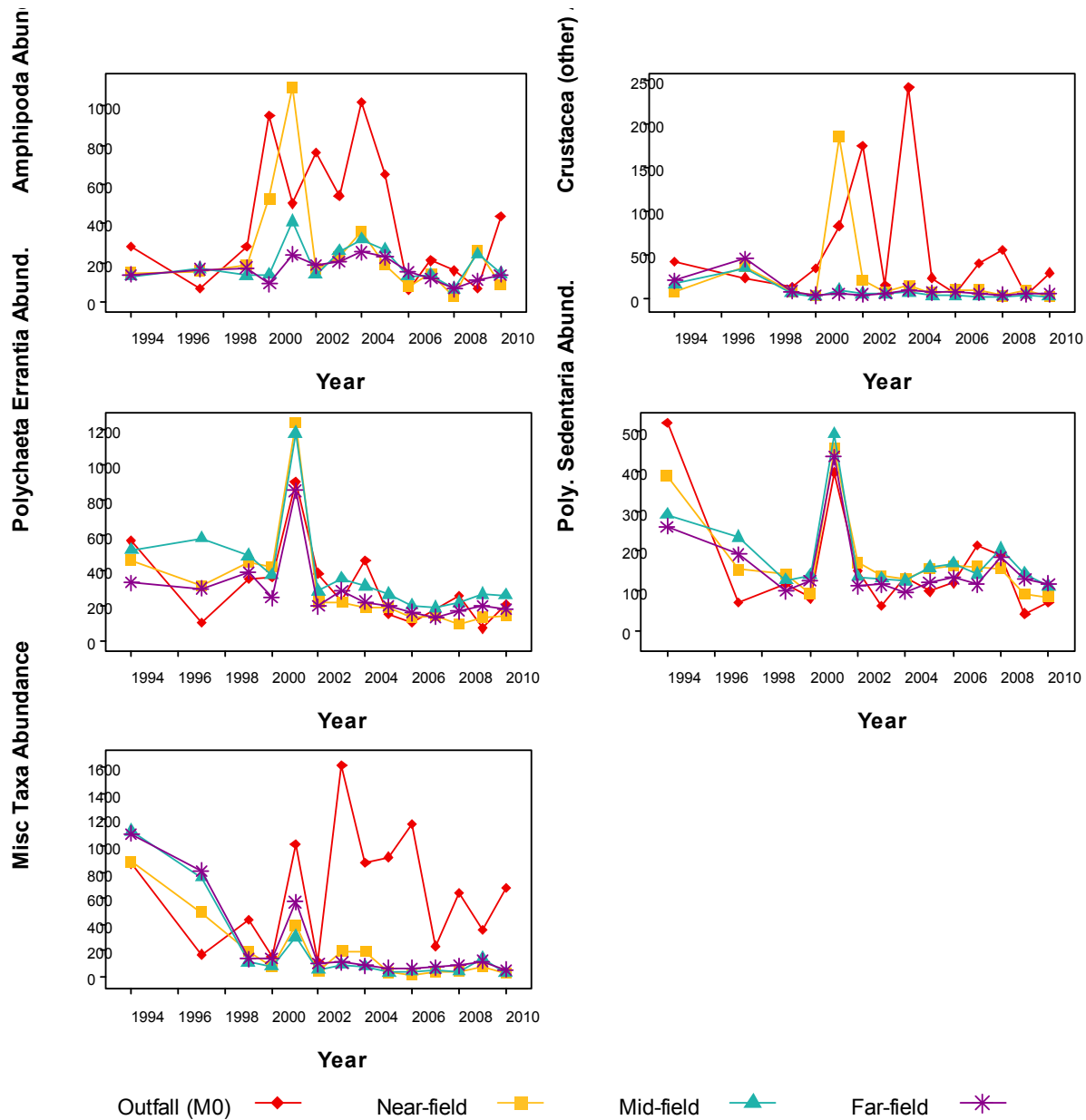


Figure 4.24 (continued)

Note Benthic community metrics were normalized to reference area
Vertical axis represents percent of reference

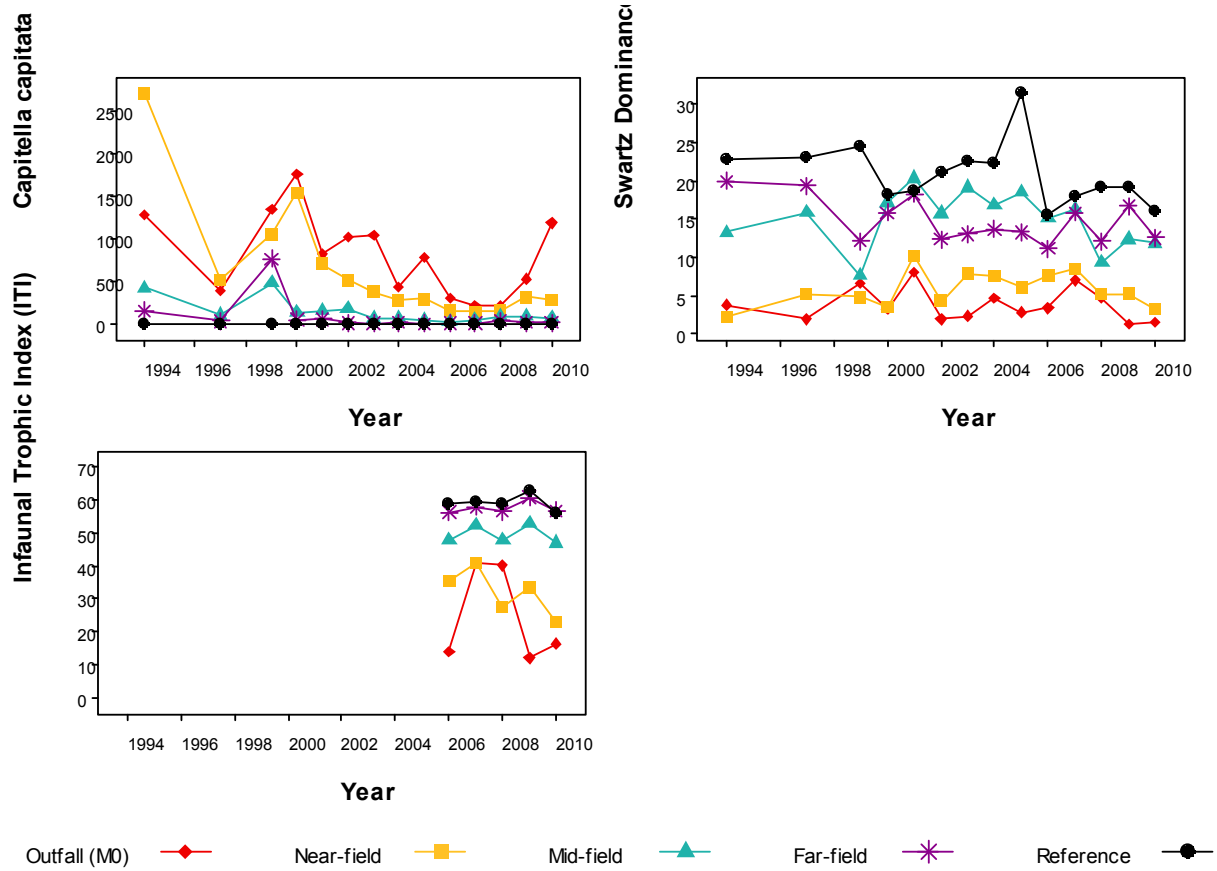


Figure 4.24, conclusion

Note: Capitella capitata abundance, SDI and ITI were not reference normalized

Table 4.14 Spearman Rank Correlations for Temporal Trends in Benthic Community Parameters (2000–2010)¹

Parameter	All Outfall Monitoring Stations	By Distance Group						By Distance-Direction Group		
		Outfall	100 m	200 m	400 m	800 m	Reference (untransformed)	Near-field	Mid-field	Far-field
Total Abundance	<u>-0.393</u>	-0.745	-0.570	-0.502	-0.085	-0.229	0.279	-0.843	-0.415	<u>-0.324</u>
Polychaete Abundance	-0.039	-0.576	-0.102	-0.059	0.161	-0.347	0.047	-0.549	-0.098	0.016
Total Richness	<u>-0.258</u>	-0.394	<u>-0.280</u>	-0.415	-0.095	-0.178	0.073	-0.489	-0.418	<u>-0.188</u>
Echinodermata	<u>-0.350</u>	-0.841	-0.456	-0.402	-0.072	-0.139	-0.115	-0.573	<u>-0.378</u>	<u>-0.289</u>
Bivalvia	<u>-0.170</u>	-0.685	-0.189	<u>-0.280</u>	-0.002	-0.133	0.062	<u>-0.384</u>	-0.171	<u>-0.261</u>
Gastropoda	<u>-0.399</u>	-0.927	-0.543	<u>-0.385</u>	-0.134	-0.057	0.436	-0.631	-0.526	<u>-0.252</u>
Crustacea (amphipoda)	<u>-0.296</u>	-0.709	<u>-0.307</u>	<u>-0.297</u>	-0.249	-0.235	-0.067	-0.584	-0.145	<u>-0.299</u>
Crustacea (other)	<u>-0.180</u>	-0.309	<u>-0.227</u>	<u>-0.308</u>	0.152	0.057	0.260	-0.223	<u>-0.281</u>	-0.113
Polychaete Errantia	<u>-0.294</u>	-0.588	<u>-0.345</u>	-0.219	-0.155	-0.534	0.201	<u>-0.372</u>	-0.436	<u>-0.241</u>
Polychaete Sedentaria (other)	0.116	-0.079	0.102	0.168	0.249	-0.160	0.117	-0.203	0.082	<u>0.272</u>
<i>Capitella capitata</i> complex	-0.088	-0.394	-0.126	-0.087	0.099	-0.207	-0.132	-0.488	-0.101	-0.041
Miscellaneous Taxa	<u>-0.198</u>	0.127	<u>-0.222</u>	<u>-0.354</u>	-0.045	-0.175	0.099	-0.159	-0.167	<u>-0.287</u>
SDI	-0.074	-0.103	-0.099	-0.151	-0.151	-0.205	<u>-0.308</u>	-0.023	<u>-0.356</u>	-0.013
ITI-Standard ²	0.023	-0.200	-0.086	0.119	0.049	0.394	-0.122	-0.436	-0.026	0.122

Note:

¹ Excluding 2001 (due to anomalous invertebrate taxonomy)

² ITI-Standard data available only from 2006 through 2010

Statistically significant correlations ($p < 0.05$) are **bolded**

Bold & underlined = weak ($|r_s| < 0.4$) but statistically significant correlation

X = strong correlation ($|r_s| > 0.6$) **X** = moderate strength correlation ($0.4 < |r_s| < 0.6$)

OVERALL ASSESSMENT

The evaluation of 2010 benthic community data suggests that broad spatial trends in 2010 were qualitatively similar to recent years (i.e., 2002 through 2009). The summary metrics (abundance, richness, SDI, etc.) yielded similar numbers to previous years across most of the site, and many patterns related to proximity to the outfall were reconfirmed in 2010. However, more detailed analysis of the 2010 data identified a number of deviations relative to other recent monitoring events. The most significant of those findings are as follows (Golder, 2011a):

- **Flat spatial response for organism abundance** – As has been observed in most other recent years, the total organism abundance at the M0 station was significantly elevated relative to other outfall monitoring stations. However, unlike previous monitoring events, the pattern of organism abundance was very weak for other distance and distance-direction groups. Whereas most other monitoring events have yielded a clear spatial trend of declining total abundance with distance from the outfall, the spatial pattern in 2010 was weaker than all other monitoring events in the 2000s decade. In 2010, M0 exhibited a high total abundance due to the dominance of *Capitella capitata*, but stations close to the outfall had abundances that were not significantly different from the reference. Earlier in the 2000s decade, the increased abundance of TOC-tolerant species compensated for slightly lower abundances of some taxonomic groups (e.g., bivalves, gastropods). In the last three years, however, and particularly in 2010, the increases in a few taxonomic groups have not been sufficient to outweigh the reductions of other taxa at some stations close to the outfall.
- **Altered pattern of impairment at M0** – The benthic communities at M0 have exhibited substantial interannual variability, and 2010 was no exception. In 2010, as in previous monitoring events, station M0 exhibited a modified benthic community, with elevated total abundance but reduced richness and lower abundances of several major taxonomic groups. The increased abundance in 2010 relative to 2009 is attributed in large part to the contribution of *Capitella*, but also to increased abundances of crustaceans and miscellaneous taxa (Figure 4.4). In 2009, total abundance was similar to other outfall monitoring stations (no enhancement as with previous years), and the composition of the community was less diverse than in 2010. The combination of low abundances for most taxa and the dominance of the *Capitella* group had resulted in increased impairment of benthic community health in 2009, as indicated by metrics such as richness, SDI, and ITI. In 2010, the community health metrics had marginally increased at the outfall, which may be a result of increased abundances of capitellids, crustaceans and miscellaneous taxa. In years previous to 2009, most taxonomic groups were reasonably well represented at M0, with suppression of only some specific taxa that were less suited to conditions of organic enrichment. The results from 2010 are intermediate between data from 2009 and previous years, with a marginal improvement of community health compared with 2009, but greater impairment relative to most monitoring events conducted over the last decade.
- **Separation of M0 from near-field group** – Related to the findings above, the 2010 data confirmed the findings from 2008 and 2009 that M0 no longer groups strongly with the other near-field stations. In the last three years, the multivariate profiling of the benthic community, combined with the univariate assessments, strongly indicated that the biological assemblages sampled at M0 differed from those at near-field stations M1E, M1SE, and M2SE. The pattern observed in the last three years contrasts with earlier investigations which indicated greater correspondence of M0 with other near-field stations. The separation is not explainable on the basis of only organic carbon or particle size differences. It is possible that concentrations of substances of concern are responsible for the observed pattern, but the constituent(s) influencing biology are difficult to discern given the high inter-correlations among substances of concern.
- **Broader richness response** – In most monitoring events conducted over the last decade, reduced richness relative to reference has been quite limited in spatial extent, generally limited to outfall and near-field stations. However, recent monitoring events have suggested a change in the distribution of reduced richness values, along with other metrics that measure biological diversity. In 2008, some of the mid-field stations exhibited lower richness values, and raised an important question as to whether the atypical richness response observed in 2008 would be repeated. The 2009 data exhibited a

weaker richness response than was observed in 2008, but not a complete return to the pattern observed earlier in the decade. The data from 2010 was similar to 2008 and exhibited a strong spatial trend of increasing richness with distance from the outfall. The previous monitoring report (Golder 2007a) stated that “the consistency in taxonomic richness across the majority of the study area indicates that biodiversity is not significantly affected by Macaulay Point discharge beyond the IDZ (i.e., 100 m) or outside the near-field region”. This conclusion requires revision in light of the data collected from the last three years. Based on the results from 2008-2010, the depression of richness now extends beyond the IDZ, and in some cases beyond the near-field stations.

- **Broader SDI response** – The spatial extent and magnitude of the decrease in normalized SDI was greater in 2008 and in 2009 than in previous sampling years, and this pattern was repeated in 2010. This is consistent with the pattern in richness, indicating alteration toward a less diverse benthic community at outfall monitoring stations.
- **Decrease of gastropod abundances** – While there was a slight recovery of gastropod abundances at all distance groups in 2009 after a period of decline, the numbers of gastropods decreased further in 2010, with the lowest numbers observed at the outfall, 100 m and 200 m stations. Based on the effect of this outfall on their abundance, gastropods appear to be a sensitive indicator of benthic community alteration.
- **Increase in localized major taxa abundances** – Capitellid polychaetes, crustaceans and miscellaneous taxa have all increased at the outfall in 2010 (Figure 4.23). These taxa, although variable in abundance between years, seem to be more abundant in the organically enriched sediment surrounding the outfall, and appear to be more tolerant to this enrichment. Their increased abundance in 2010 may therefore reflect their ability to outcompete more sensitive taxa in conditions of organic enhancement.

As a result of the above findings, the revised multi-year trend assessment represents a departure from findings presented in earlier trend assessments (Golder 2005a,b, 2006, 2007a, 2008). The 2009 results were equivocal with respect to whether the changes observed in 2008 represent stochastic temporal variations, or alternatively were indicative of a change in broad environmental condition in the Macaulay Point receiving environment. The results of the 2010 study suggest that the apparent changes in broad community composition reflect true changes in the biological assemblages (Golder, 2011a).

At a broad level, the analysis of individual taxa in 2010 produced generally similar results to last year’s assessment (Golder, 2011a), with common taxa displaying different spatial patterns, each dependent on a number of factors, including the preferences of organisms for increased concentrations of organic carbon in sediment and the particle size distributions of sediment. However, at a more refined level of analysis, the number of taxa that exhibited net-positive responses was somewhat diminished in 2010. Although several taxa appear to benefit from modest increases in organic carbon content at intermediate (or mid-field) distances from the outfall, fewer taxa exhibited strong positive responses to outfall-related exposures (Golder, 2011a).

In terms of overall environmental condition, the 2010 assessment indicates the following (Golder, 2011a):

- **M0** – Benthic community data are indicative of a highly degraded benthic community. The reduced taxonomic richness (approximately 50% of reference), combined with sharp decreases in abundances of sensitive taxa (e.g., bivalves and gastropods), and reduced summary metrics (SDI and ITI), are the main lines of evidence used to reach this conclusion. The assessment for M0 has changed in 2009 and 2010 relative to 2008 and previous years, when a conclusion of “moderately degraded benthic community” was rendered. The difference is attributable to the lower richness, very low SDI, and low ITI value. In 2010, total abundance at M0 was enhanced relative to reference, because of a significant increase in *Capitella capitata*, and other taxa that are well-suited to the higher TOC environment. However, these opportunistic species increased at the outfall at the expense of other taxa, which resulted in a reduction in species richness and other community health metrics (e.g., SDI, ITI). Substrate size has a large impact on taxa composition of benthic communities, and

therefore the elevated gravel content at station M0 observed in 2009 and 2010 (19%) may confound the conclusions reached above.

- **Near-field stations (not including M0)** – Similar to 2008 and 2009, community patterns are indicative of a moderately degraded benthic community. The reduced taxonomic richness (by approximately 55% relative to reference), combined with decreases in abundances of bivalves and gastropods, and reduced summary metrics (SDI and ITI), are the main lines of evidence used to reach this conclusion. The spatial pattern of these responses reconfirms the assignment of stations to the near-field group. In particular, the M2SE station grouped well with other near-field stations, confirming that the direction of outfall influence is predominantly to the southeast. The results from the past three years of monitoring have resulted in a reassignment of the level of alteration, as the reduced richness and responses to several major taxonomic groups indicate an increased degree of impairment relative to earlier years of sampling.
- **Mid-field stations** – The monitoring data collected for mid-field stations show a small negative response to the influence of the outfall. A general pattern of moderate biological alteration is evident in mid-field stations (more polychaetes, and fewer bivalves, crustaceans and gastropods), with significant declines in community health metrics compared with reference. Richness and ITI (standard) were reduced by 20% of the reference, whereas SDI was 75% of reference. In monitoring reports prior to 2008, the mid-field responses have been characterized as “neutral to slightly positive responses to outfall influence,” while the last assessment characterized the mid-field as “net neutral”. Therefore, the 2010 program reflects a change in the overall assessment of alteration. The enhancement of abundances and richness previously observed at mid-field stations were not observed in 2010, and instead a slight impairment of richness and other community health metrics led to the change of the characterization in 2010.
- **Far-field stations** – The 2010 data indicate a net neutral to positive response to the influence of the outfall, which is a minor change from the clearly net positive characterization that had been previously assigned to this grouping. The far-field stations exhibit summary biological metrics such as SDI and richness that are slightly less than reference, whereas ITI (standard) is similar to reference. In addition, these stations contain abundances of major taxonomic groups that exceed the reference condition (e.g., bivalves, amphipods and polychaetes). In these areas, the degree of exposure to outfall contamination is sufficiently limited to minimize any adverse effects, whereas a slight fertilization effect likely enhances the abundances of several taxa. The net effect in 2010 was that the functional status of far-field stations is considered equivalent to reference, but not enhanced as in previous monitoring events. The improvement in sediment quality with distance from M0 is most apparent from the abundances of bivalves. Whereas bivalve abundances are significantly reduced at near-field and far-field stations (and may be a sensitive indicator of outfall-related response), the bivalve abundances in the far-field areas are greater than reference. In summary, the far-field areas exhibit all the benefits of slightly increased TOC concentrations, without appreciable negative effects.

4.2 Clover Point

4.2.1 Sediment Chemistry

4.2.1.1 Introduction

Sediments are collected annually at the Clover Point outfall station (C0) and a reference station at Constance Bank (CB1) to assess the concentrations of a variety of substances. Additional outfall (i.e., 100 m, 200 m, 400 m, and 800 m stations) and reference stations (i.e., CB2 through CB5) are only sampled every three years due to the inconsistent nature and quality of the sediments surrounding the Clover Point outfall, which make it difficult to satisfy PSAMP sampling protocols (PSAMP, 2002). The three year sampling frequency for the additional Clover Point stations was approved by the MMAG in 2001. All Clover Point and Constance Bank stations were last sampled in 2009; therefore this sampling year (2010) consisted of C0 and CB1 only.

Similar to changes to the Macaulay Point sediment sampling program, significant changes are planned for the Clover Point sediment sampling program starting in 2011. These changes are a result of the recent review of the WMEP by CRD and BC MOE staff and include the addition of comprehensive sediment toxicity assessments and a revision of the target analyte list, including expanded high resolution analyses. These WMEP additions will be balanced (from a financial perspective) by a reduction in both sampling frequency (from annual to once in a five year cycle) and the number of stations. Further details about the revised WMEP will be provided in a future report and are available upon request from the CRD Environmental Sustainability department.

4.2.1.2 Methods

Sediment samples were collected from C0 and CB1 (Figure 4.1; Appendix A3) in August and September 2010, in conjunction with the sediment sampling conducted at and around Macaulay Point. Sampling was conducted off the 20 m research vessel Richardson Point, using a 0.1m² Van Veen grab sampler. All stations are coded following the same designation as those for Macaulay Point (i.e., C for Clover, etc.).

Three replicate grabs were composited into one sample representing each station sampled. Refer to CRD (CRD, 2011e) for sampling methodologies. Target station coordinates and substances analysed can also be found in CRD (CRD, 2011e) and Appendix A1, respectively. Station C0 and CB1 sediments were analyzed for the complete list of priority substances.

DATA QUALITY ASSESSMENT

The same analytical methods, QA/QC procedures and detection limits used for the Macaulay Point sediment chemistry analyses were followed for Clover Point (Section 4.1.1.2). Clover Point sediment chemistry data quality was also assessed against the revised CRD QA/QC assessment procedure (Appendix A4). Similar to Macaulay Point, Clover Point sediment chemistry results that were rejected and did not meet the data quality objectives were neither presented in this report nor included in further statistical analyses.

COMPARISON TO SEDIMENT QUALITY GUIDELINES

The Clover Point results were compared to the same SQGs as the Macaulay Point data, including WSDOE 2LAETs (WSDOE, 1991), BC SedQCtcs (BCMwLAP, 2003) and CCME PEL (CCME, 2002) SQGs (Appendix D2). As for Macaulay Point, the overall assessment of environmental effects also included additional direct measurements of Clover Point biological communities (see Section 4.1.1.2).

DETAILED STATISTICAL ANALYSIS

The last detailed statistical analysis of sediment trend data (Golder 2011) was conducted on Clover Point data up to 2009. Results of this assessment can be found in last year's annual report CRD (2010) and Golder (2011). The next detailed statistical analysis of sediment data is planned for after the collection of three more years of data.

4.2.1.3 Results and Discussion

DATA QUALITY ASSESSMENT

Sediment analytical results for 2010 are presented in Appendix D2 and summarized in this section. Those substances which did not meet the DQOs and were rejected are not included.

The substances with severe failures, resulting in rejection of data in at least one batch in 2010 were some metals and extractable metals (e.g. antimony, lead, silver, extractable copper), phenols, six PAHs (acenaphthene, anthracene, benz(a)anthracene, chrysene, fluoranthene and p yrene), bis(2-chloroethyl)ether and 2,4-dinitrophenol (Appendix D1).

High-resolution sediment analyses were also screened against the CRD DQOs. Two batch-wide DQO failures were identified for PCBs (PCB 11 and PCB TEQ [ND=1/2 DL]) and five batch-wide failures were identified for OC pesticides (e.g. 1,3-dichlorobenzene and Mirex).

All remaining sediment results passed both laboratory and CRD QA/QC DQOs (i.e., analyte spikes, method blanks, laboratory triplicates, field triplicates and standard reference materials) (CRD, 2011d).

COMPARISON TO SEDIMENT QUALITY GUIDELINES

The comparison of 2010 sediment chemistry results to BC, CCME and WSDOE SQGs is presented in Table 4.1 and Appendix D2. At C0, copper, mercury, acenaphthene, and bis(2-ethylhexyl)phthalate, exceeded SQGs. No exceedences were observed at CB1.

Figure 4.25 displays the trends in the percentage of lower-bound SQG exceedences observed in previous years (i.e., 1995 to 2009) at Clover Point for frequently-detected parameters (Golder 2011). The exceedence frequency in 2010 was similar to previous years. Overall, the frequencies of SQG exceedences were lower than for Macaulay Point (Figure 4.2); see the previous sediment trend assessment for full detail (Golder, 2011a).

As stated previously, comparing sediment concentrations to SQGs is only a preliminary tool for the assessment of receiving environment effects and should be done with caution (Wenning et al., 2005). Complete environmental assessments require additional study of biological communities and the use of other tools (Long et al., 2006) to evaluate and verify potential environmental effects.

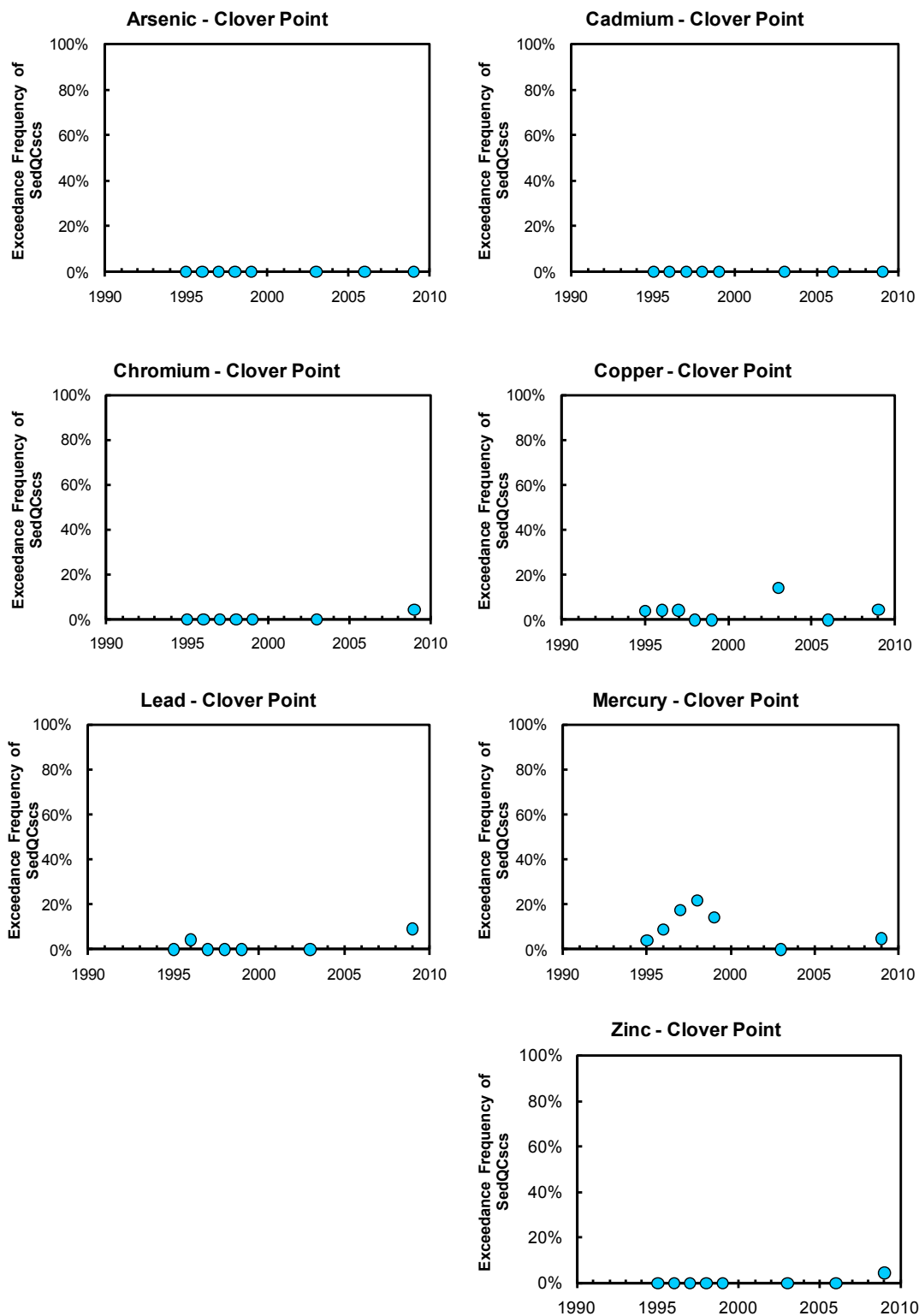


Figure 4.25 Temporal Trends in SQG Exceedences at Clover Point

a. Metals (note that some 2005 and/or 2006 data points were rejected due to DQU failure)

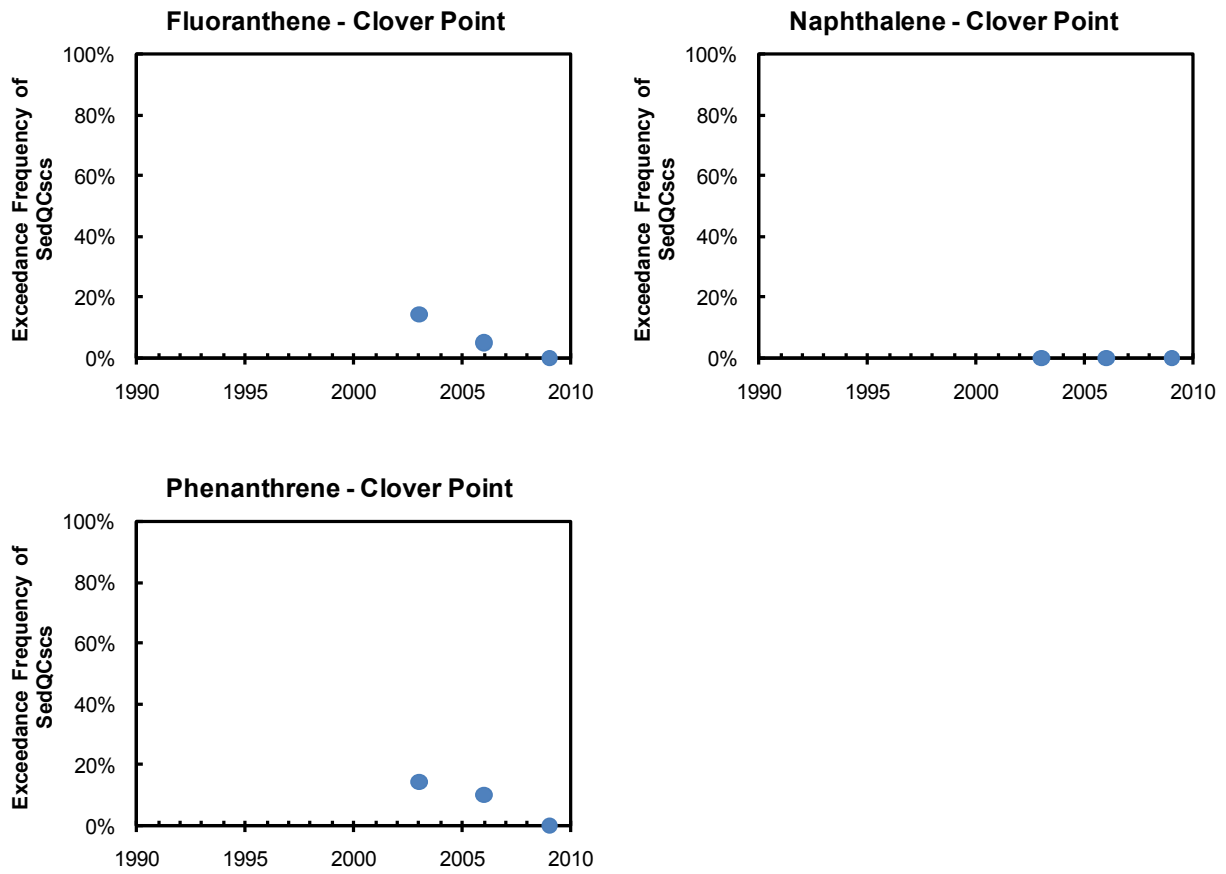


Figure 4.25, continued

b. Organics

OVERALL ASSESSMENT

The assessment of the sediment chemistry data by the SETAC panel (SETAC, 2006) found that while there has been considerable variation in the data, there is no reason to suggest that sediment quality around the Clover Point outfall is deteriorating over time. This assertion was supported by the 2010 results. However, the 2010 sediment chemistry data do indicate that there is slight potential for the biological communities immediately adjacent to the Clover Point outfall to be affected by contaminants in sediments based on comparison to SQGs. As such, a detailed analysis of the mussel community at all Clover Point stations was completed to assess any potential effects on biological communities off the outfall (Section 4.2.2).

4.2.2 Mussel Communities

4.2.2.1 Introduction

Native communities of deep-sea horse mussels (*Modiolus modiolus*) at and around the Clover Point outfall have been used as indicators of potential effects since the early 1990s. Since 2000, monitoring has been conducted annually, establishing a large database of information with which to assess potential effects on seafloor organisms related to the discharge of wastewater.

The use of bivalves as indicators of potential environmental effects is extensive (Acosta *et al.*, 2004; De Luca-Abbott *et al.*, 2000; Yusof *et al.*, 2004). Previous surveys have involved assessing native populations (Acosta *et al.*, 2003; Giguere *et al.*, 2003), installed populations (i.e., caged or transplanted) (Couillard *et al.*, 1995; Doyotte *et al.*, 1997; St-Jean *et al.*, 2003), or laboratory-based physiological impact analyses (Einady *et al.*, 1996; Hartl *et al.*, 2004). The most widely used bivalve genus in monitoring and research programs has been *Mytilus* sp., and more specifically, *Mytilus edulis*. *Modiolus* sp. mussels have been used less frequently in monitoring and research programs primarily due to their lack of commercial use, but also due to their infrequent occurrence at monitoring sites.

Bivalve growth and population age structure have proven to be very useful indicators in the monitoring programs of many other discharges (Anwar *et al.*, 1990; Applied Biomonitoring, 1998; Barille *et al.*, 1997; Ocana *et al.*, 1999; Prieto *et al.*, 2004; Seed *et al.*, 1978). In general, organisms such as mussels divide their energy between functions such as growth, reproduction, and survival. The amount of energy available for these functions is usually limited and when organisms are under stress from natural or anthropogenic sources, they generally respond by concentrating their energy into the most important function (i.e., survival). Therefore, a stressed community will show reduced growth and reproduction. For mussels, these potential effects can be assessed by measuring the length and weight of individuals (i.e., the growth for different age groups), the age structure, and the reproductive status (i.e., gonad index, timing index, and comparison between sexes) of the community. These biological metrics were used in the assessment of the 2010 Clover Point outfall mussel data as indicators of community health.

Effects on a community are usually assessed by comparing organisms in areas of potential exposure to reference sites outside these areas. For example, a 20% reduction in growth at monitoring sites, as compared to a reference area, has been used as an indication of stress (CRD, 2000; Ernst *et al.*, 1991). This percentage was included in the American Society for Testing and Materials (ASTM) monitoring protocol (ASTM, 2002; Salazar *et al.*, 1999) as the performance standard for monitoring in situ mussel populations.

Chemical concentrations in tissues are also used to assess the potential bioaccumulation of substances around the outfalls and their potential for subsequent transfer to organisms higher in the food chain (e.g., fish). Many studies have looked at the accumulation of metals in bivalve tissues (Adami *et al.*, 2002; Jiann *et al.*, 1997; Pip, 1995; Szefer *et al.*, 2004); the accumulation of organic contaminants is, in general, less studied (Ellis *et al.*, 1993; Lake *et al.*, 1995; Tavares *et al.*, 1999; Weston *et al.*, 2002). The CRD has participated in three peer-reviewed studies contributing to research on this topic (deBruyn *et al.*, 2009; Veldhoen *et al.*, 2009; Veldhoen *et al.*, 2011). The SETAC report (2006) commented that mussel tissue bioaccumulation provides a useful tool to evaluate exposure of the Clover Point invertebrate community to chemicals in the discharged sewage.

Detailed spatial and temporal statistical analyses of the mussel data are conducted on a regular basis, typically every three to five years. These analyses help in the determination of the potential effects related to the outfall, what factors (such as specific contaminants, natural variability, etc.) may be causing any effects, and if the effects are ecologically significant now or could be in the future. An additional community analysis tool involves the use of multivariate analyses that take many, or all, of the above indicators into account simultaneously. These statistical tools are helpful in identifying differences among stations or groups of stations. A detailed assessment was undertaken this year on the 2000-2010 dataset, the results of which are presented in this report.

Similar to changes to the other components of the WMEP, significant changes are planned for the Clover Point mussel sampling program starting in 2011. These changes are a result of the recent review of the WMEP by CRD and BC MOE staff and include a revision of the target tissue analyte list, including expanded high resolution analyses. These WMEP additions will be balanced (from a financial perspective) by a reduction in both sampling frequency (from annual to once in a five year cycle) and the number of stations. It should also be noted that benthic fish tissue assessments will also be added to the WMEP to further enhance the ability of the WMEP to assess impacts of the outfalls to organisms higher in the food chain. Further details about the revised WMEP will be provided in a future report and are available upon request from the CRD Environmental Sustainability department.

4.2.2.2 Methods

Mussels were collected from 22 stations off the Clover Point outfall and at five reference stations at Constance Bank in August and September 2010 (Figure 4.1; Appendix A3). Clover Point stations are located in a similar spatial pattern to Macaulay Point (i.e., there are stations at varying distances from the outfall in different compass directions). Detailed sampling and analytical methodologies are presented in CRD (2010c).

Samples were collected off the 20 m research vessel Richardson Point, using a 0.1m² Van Veen grab sampler. Twenty-four to 55 mussels were randomly selected from three benthic grabs collected at each station (Table 4.15). Because of the need to collect a minimum quantity of tissue for conducting chemical analyses, mussels smaller than 50 mm in length were discarded. This minimum size is similar to that required by other mussel monitoring programs with similar goals. For example, the United States National Status and Trends Mussel Watch program collects mussels of 50 to 80 mm in length. Golder conducted a review of mussel monitoring programs and, based on the goals of the WMEP, recommended that CRD Marine Programs continue to only collect mussels greater than 50 mm in size (Golder, 2007b). The mussels collected from the three grabs were composited to represent a single, 25 mussel sample, per station. Additional mussels (i.e. two additional samples of 15 mussels each) were collected for field replicates from stations C1S, C1S, C2E and C2NW. Mussels were randomly selected from the composite for biological and chemical analyses. Table 4.15 summarizes the number of mussels collected from each station and how they were allocated to the different analyses.

All statistical analyses were conducted using SPSS version 12.0 software. Descriptive statistics were calculated for each summary metric (i.e., arithmetic mean, median, standard deviation, minimum, and maximum) for general use. Spatial patterns in benthic parameters were assessed using two complementary approaches: linear distance from the outfall (i.e., 100 m, 200 m, etc.) and distance-direction (i.e., near-field, far-field, etc.).

In a previous trend assessment (Golder, 2005b), multivariate analysis of the sediment and tissue chemistry data collected from 2000 to 2004 was used to group sampling stations based on their pattern of contamination, without requiring that the stations within a group represent the same distance from the outfall. The Golder (2005b) analysis identified three groups of stations: near-field, far-field, and reference. Following consultation with the MMAG, the importance of the distance-direction analysis was recognized, given that the influence of currents is highly directional (i.e., to the east) in the vicinity of the Clover Point outfall. However, there was concern that the broad groupings of stations and the inclusion of sediment chemistry in station grouping identification could mask smaller-scale patterns in biological metrics; consequently, it was recommended that the grouping analysis be repeated with only mussel data, including both tissue chemistry and biological metrics. In addition, it was suggested that the data be

evaluated for the potential presence of additional station groupings. The detailed assessment of 2008 mussel data (Golder, 2009b) identified the following “distance-direction” groupings, consistent with those identified in 2007 (Figure 4.26). The groupings were re-assessed using the 2010 data and it was confirmed that they remain relevant. The groupings are as follows:

- outfall: station C0
- near-field: stations C1E and C2E
- far-field: stations C1S, C1SW, C1NW, C1NE, C2S, C2NW, C2N, C2NE, C4SE, C4SW, C4W, C4NW, C4NE, C4E, C8E, C8W
- reference: all five Constance Bank stations (CB1, CB2, CB3, CB4, CB5)

The 2010 mussel data was assessed using these groupings. Unlike the station groupings identified at Macaulay Point using benthic invertebrate data, there was no evidence of a mid-field grouping when the Clover Point mussel data was assessed.

Table 4.15 Mussel Allocation for Different Analyses, 2010

Number of Mussels Collected	Tissue Chemistry ¹	Mussel Biological Information			
		Age	Gonad Index	Shell Length, Width, Weight	Tissue Wet Weight
All Stations					
10 mussels	-	✓	✓	✓	✓
15 Mussels	✓	✓	-	✓	✓
Total (Minimum at All Stations) ¹	15	25	10	25	25

Note

¹ In 2010, an additional 30 mussels were collected at C1W, C4SW, C4W and C8E as field replicates.

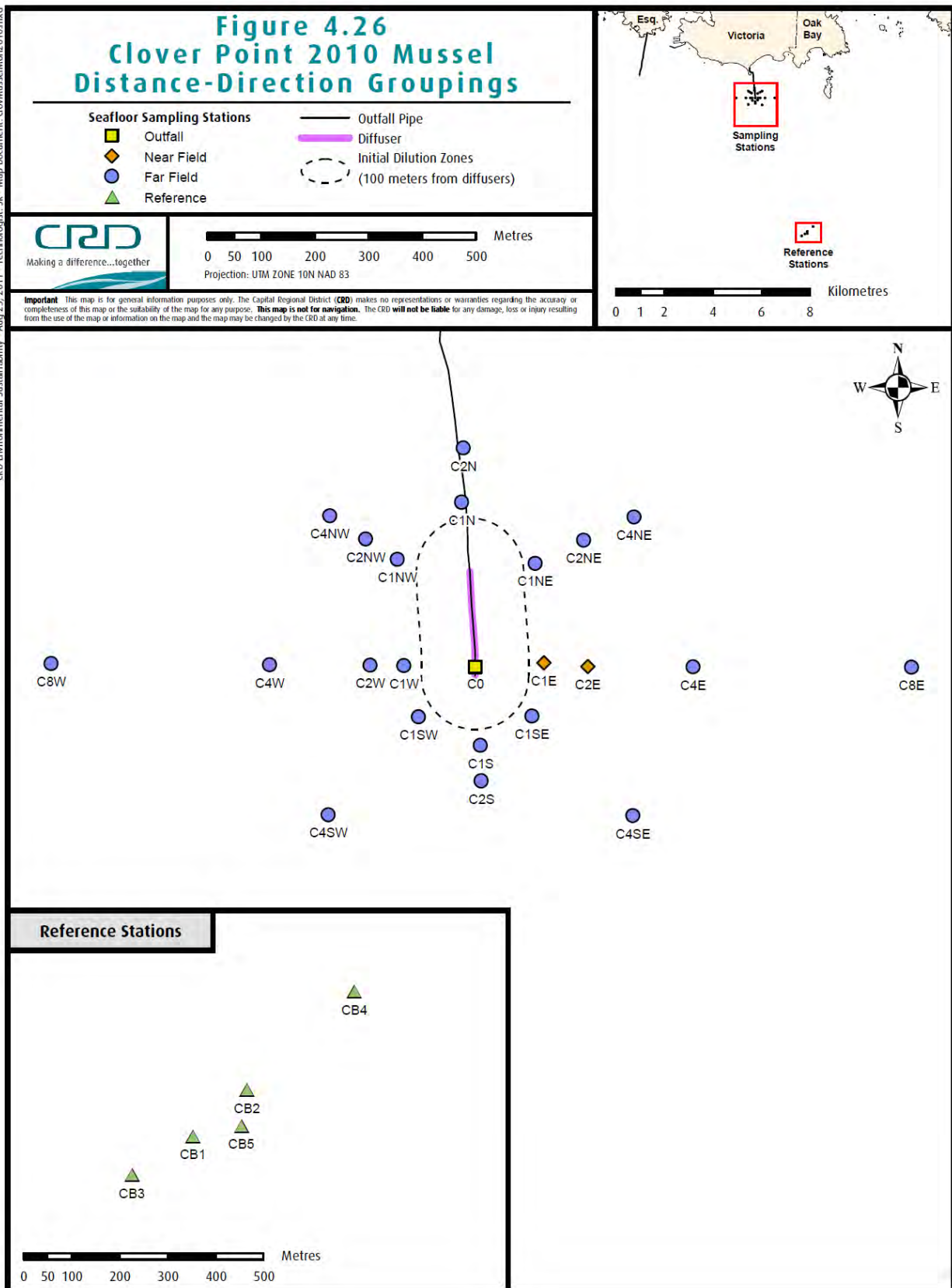


Figure 4.26 Clover Point Mussel Distance-Direction Groupings

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Detailed sampling and analytical procedures, as well as the QA/QC procedures, are presented in CRD (2010c). Biological parameters measured in 2010 included shell length, shell width, shell weight, tissue wet weight, age, gonad index (used to derive reproductive timing index) and sex. Aging methods were based on those used by Anwar et al. (1990) and involved cutting the mussel shells along the umbone, polishing the exposed surface and counting the annuli. Frequency distribution and box and whisker plots (box plots) were created for the above biological metrics. In the box plots,

- the solid black line through the box depicts the median value,
- the upper and lower ends of the box represent the 75th and 25th percentiles of the data, respectively;
- the “whisker” vertical lines represent 1.5 times the interquartile range; and
- the open circle and asterisk symbols represent outlier values that are 1.5 to three, and more than three, quartiles from the box edges, respectively.

Mussel reproductive status was assessed in tissue cross-sections (An, 2010a) using a gonad index developed by Seed and Brown (1975) and Brown and Seed (1977). This index has also been used by the United States National Status and Trends Program Mussel Watch Project (Ellis *et al.*, 1998; Hillman, 1993; Kim *et al.*, 2006) and by a number of other jurisdictions (Arrieche *et al.*, 2002; Brown, 1984; Jasim *et al.*, 1989). In addition to this gonad index, which uses index values between 0 and 5, an additional reproductive timing index, using values of 0 to 9, has been developed and utilized since 2004 to better differentiate between developing and spawning gonads. Mussels were processed at the Fisheries and Oceans Canada Pacific Biological Station (PBS) in Nanaimo, BC, and a comparison of gonad index and reproductive timing for stations around the outfall versus reference sites was done to determine relative reproductive health of the mussel communities. Refer to Figure 4.27 for a graphical representation of the gonad and reproductive timing indices. Males and females were also differentiated.

Stations means for male and female mussels were calculated for all biological metrics. The overall purpose of the comparison between the sexes was to determine if the outfall differentially affects mussels of either gender. Spearman rank correlations between the sexes for the biological metrics were also computed to determine if the different sexes showed any consistent spatial patterns.

As part of a collaborative research agreement, histopathological observations of parasites, symbionts and diseases in various tissues were made by Fisheries and Oceans Canada in conjunction with the gonad index assessment (An, 2010b). These observations were made on mussels from all stations including the reference areas and the results will help contribute to the overall understanding of shellfish health in British Columbia. A detailed temporal (1995 to 2007) assessment of these observations was completed in 2008 to determine the long-term health of the Clover Point and Constance Bank communities. Results of this assessment were presented in the 2007 WMEP annual report (CRD, 2008).

Mean and median values for all biological metrics were calculated for each station and distance group, as well as reference normalized means for some parameters. Age corrected lengths and tissue weights were also calculated to determine growth relative to reference (i.e., percent of reference) (Golder, 2011b). Age correction was done by first determining mean lengths and weights for each age group. These means were then log transformed and regressed against log transformed age. Residuals (i.e., the difference between the actual value and the one predicted from the regression equation) were calculated for each individual mussel and averaged within a station. The difference between each station average and the reference average were determined, anti-logged, and multiplied by 100 to get the growth metric as a percentage of reference (Golder, 2011b)

Spatial patterns in the mussel community indicators were investigated to assess potential effects of the discharge on the mussel community. Distance and depth gradients were assessed using non-parametric Spearman rank correlations. In addition, analyses using distance-direction groupings (i.e. near-field, far-field and reference) were conducted to determine whether these groupings would yield additional important information on trends. Differences in the metrics between the individual distance groups (i.e., 100 m and 200 m stations) and the reference stations were evaluated, primarily using the non-parametric

Kruskal-Wallis test (Golder, 2010b; Golder, 2011b). Principle components analysis (PCA) was used to derive summary metrics from the mussel size and weight metrics.

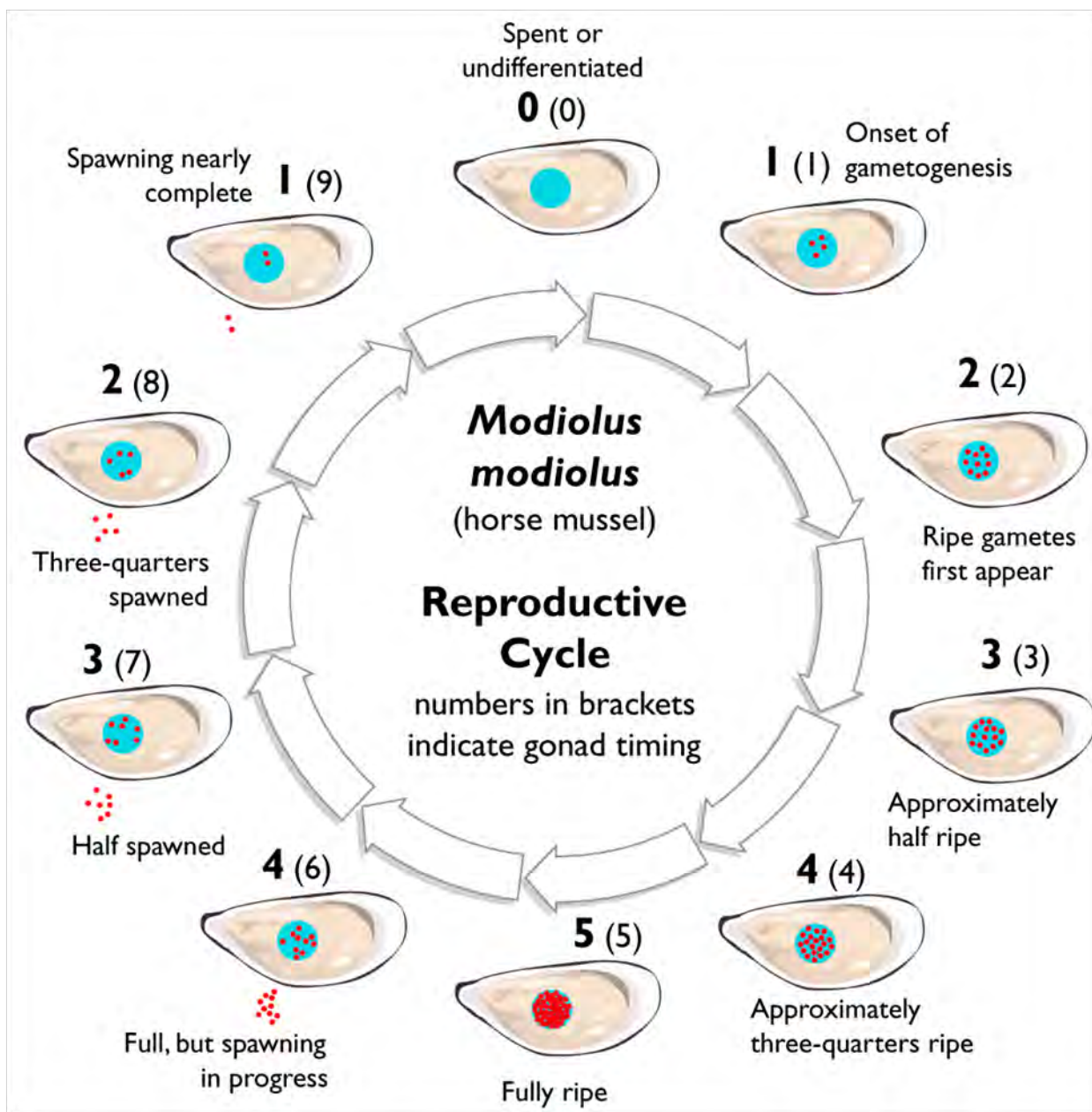


Figure 4.27 Graphical Representation of the Two Gonad Indices Used in 2010

Values presented are gonad index with reproductive timing index in brackets.

MUSSEL TISSUE CHEMISTRY

Tissue from 15 mussels from each station were homogenized and analysed for various inorganic and organic chemicals, including total metals, chlorinated hydrocarbons, semi-volatile organics, base-neutral extractables, chlorinated phenolics, PAHs, polychlorinated dibenzo-p-dioxins (PCDDs) and phthalates (Appendix A1). AXYS Analytical Services (Sidney, BC) measured shell length, width and weight after the tissue was thawed, removed, and homogenized. AXYS analysed the tissue for PAHs and PCDDs while the remaining tissue was subsampled and sent to ALS Environmental Ltd. (Vancouver, BC) for the remaining priority substances analyses. PCDDs were only analyzed in samples collected from 17 of the sampling stations.

Ten percent of all tissue samples were subjected to laboratory and field QA/QC protocols that included the analysis of field triplicates, laboratory triplicates, a method blank and a spiked reference material (SRM) analysis. A detailed description of analytical methods and all QA/QC procedures are presented in CRD (CRD, 2011c). Tissue chemistry data were assessed for overall quality by comparing them to the recently revised CRD QA/QC assessment procedure (see Section 2.2; Appendix A4). All data that exhibited failures were questioned and a determination of the potential causes was undertaken. Rejected results were not presented in this report and were not used for further analyses (e.g., statistical analyses).

Results were provided by the analytical laboratories on a dry weight basis (mg/kg). For comparison to effects threshold data from the literature and regulatory tissue guidelines for the protection of wildlife and consumers of mussels, dry weight values were converted to wet weight concentrations by multiplying concentrations by the percent dry weight of the particular sample (i.e., one minus the percent moisture) and then dividing by 100. Statistical analyses and temporal assessments were also performed using the wet weight converted concentrations, to remain consistent with previous mussel tissue statistical assessments (Golder, 2005a; Golder, 2005b; Golder, 2006; Golder, 2007b; Golder, 2009b; Golder, 2010b; Paine, 2003; Paine, 2004a). Statistics were only conducted for those parameters detected in at least 50% of the samples.

The literature and regulatory tissue guidelines for the protection of wildlife and consumers of mussels used for comparison were for copper, lead, zinc and PAHs. These substances were selected based on the following criteria:

- their high frequency of detection in CRD tissue samples
- the availability of relevant effects data
- recommendations from MMAG regarding substances of greatest concern for the mussel bioaccumulation pathway

Data were also compared to a food chain model (FCM) to estimate the substance doses associated with ingestion of outfall-related substances by fish-eating wildlife species. The FCM estimates the daily ingested dose based on species-specific parameters such as food ingestion rates, body weight, and dietary preferences (Golder, 2011b).

Spearman rank correlations between chemistry variables and distance from the outfall were calculated as a standard measure of the strength and direction of distance gradients (Golder, 2009b). Additional parametric and non-parametric statistics were also calculated, including PCA, which are described in detail in Golder (Golder, 2011b).

Broad temporal patterns were qualitatively assessed by comparing the 2010 biology and chemistry endpoints to those of previous years. To account for the natural temporal variability in the biological parameters, station means were normalized to the reference area mean within each year of data (Golder, 2011b).

DETAILED STATISTICAL ANALYSIS

A detailed statistical analysis of the mussel tissue chemistry and biology parameters was conducted in 2011 to assess spatial and temporal trends in the 2000 to 2010 data (Golder, 2008c; Golder, 2009b;

Golder, 2010b). Trend assessments are conducted approximately every three years, with the last one performed in 2008 on the 1995-2007 data (Golder, 2008c).

To the extent possible, the 2011 trend assessment was designed to be consistent with previous trend reports (e.g. Golder 2005b, 2007b, 2008c) in order to facilitate the integration of new findings with those previously reported (Golder, 2011b). Considering the relative consistency of the sampling design from 2000 to 2010, and following consultation with CRD, Golder determined that the 2000 to 2010 period of record was best suited to a formal evaluation of trends. Data compiled by Golder during the previous trend assessment (Golder, 2008a) were used, and the three most recent years' of data (including monitoring data from 2008 to 2010) were appended to the Golder (2008) dataset. Prior to beginning the statistical analyses, several data preparation steps were conducted, including formatting of files, data quality assessment, identification of frequently-detected parameters, and data reduction to a common unit of replication (Golder, 2011b).

Parameters that were detected in equal to or greater than 50% of samples (i.e., mean detection ≥ 0.50) were retained for statistical analysis. Tissue chemistry data collected from 2005 to 2010 have been evaluated using the data quality assessment process developed by Golder (2007). Historical data that were rejected based on this evaluation have previously been flagged in the working database and not included for subsequent statistical analyses. Because data collected prior to 2005 were not evaluated according to the same DQOs (that were unavailable at the time), there is the possibility that temporal trend analyses would be influenced by inconsistent screening of data. To address this concern, only those parameters that were analysed for and passed the DQO screening in at least two of the three recent years (2008-2010) were selected for further analyses as part of the trend assessment (Golder, 2011b).

Mussel biological and tissue chemistry data were reduced to one common unit of replication for subsequent analyses. The unit of replication was station-year (i.e. one value per station per year). Summary statistics, including means, medians, standard deviations, minimums and maximums were computed for the 2000-2010 mussel data. For data that were log-normally distributed (e.g. many of the metals concentrations and all of the PAH concentrations in tissue), geometric means and confidence factors were calculated instead of arithmetic means and standard deviations. Summary statistics were computed separately for the 2000-2010 and 2008-2010 time periods, and are categorized using both distance groups and distance-plus-direction groups. PAH data was only used from years 2006-2010, when high-resolution analytical methods were used (Golder, 2011b).

Spatial trends in Clover Point mussel biology and tissue chemistry metrics were assessed by Golder (2011b) relative to distance from outfall and among spatial groups of stations using methodologies similar to previous trend reports (Paine 1999, 2004; Golder 2005, 2008). Mussel data trends were conducted using the full period of record (2000-2010), and also separately for the three most recent years' data alone (2008-2010). A comparison of the results of these two analyses was intended to evaluate whether recent spatial patterns are consistent with the broader historical trends. This analysis is complementary to the analysis of multivariate groupings of parameters in that both approaches evaluate the consistency of spatial patterns over time. Descriptions of statistical tests and correlations can be found in Golder (2011b).

Golder (2011b) assessed mussel temporal trends using multiple combinations of spatial groupings, including:

- All stations excluding reference, to assess local trends (i.e. at all stations potentially influenced by the outfall);
- Each distance group treated separately (i.e. outfall, 100m, 200m, 400m, 800m, and reference groups), to assess variation in temporal trends as a function of linear distance from the outfall;
- Each distance-plus-direction grouping including near-field (which included the outfall station for chemistry parameters), far-field, and reference station groupings, to assess variation in temporal trends as a function of influence of the outfall; and

- Each individual station, to test for overall spatial homogeneity of temporal trends.

Rank correlations were compared among stations using a modified version of the van Belle test for homogeneity of trends, as outlined in Paine (2002). Separate van Belle tests were performed for biological and tissue chemistry parameters (Golder, 2011b). Test statistics were calculated once for all monitoring stations combined (including reference) and once for all stations except reference. A comparison of the results of these two analyses was intended to assess the extent to which any significant heterogeneity identified by the van Belle tests was due to:

- Differences between reference stations and the other distance groups (i.e. potentially indicating regional-scale variability in trends); or
- Differences among the non-reference distance groups (i.e. potentially indicating local scale variability in trends with distance from the outfall).

4.2.2.3 Results and Discussion

The comprehensive statistical analysis of the 2010 mussel community data can be found in Golder (Golder, 2011b). The following is a summary of the comprehensive analysis.

MUSSEL COMMUNITIES

Summary statistics for 2010 mussel size and age metrics, including mean and percent of reference for individual stations, distance groups and distance-direction groups are presented in Table 4.16 to Table 4.22. Individual mussel data are presented in CRD (CRD, 2011b).

Length and Weight

Mussel shell length and tissue wet weight sample distributions are presented in Figure 4.28. Station means of mussel lengths and tissue wet weights are presented in Table 4.16 and Table 4.18 and Figures 4.29 and 4.30, respectively. Mean shell lengths for the outfall monitoring stations were generally slightly greater than the reference area mean. Stations that exhibited mean shell lengths that were less than the reference area mean were stations C4E, C4SE and C8E, although the magnitudes of these differences were small (94% to 99% of reference) (Golder, 2011b). Distance group means ranged from 102% to 113% of reference. Both near-field and far-field average shell lengths were slightly greater than the reference stations at 111% and 107% of reference, respectively.

Statistically significant differences were identified between each of the outfall, 100 m, 200 m and 400 m distance groups and the reference area ($p < 0.001$, Table 4.23), indicating that shell length was significantly greater for these distance groups relative to reference (Golder, 2011b). Average shell length was also significantly higher in the near-field and far-field station groupings ($p < 0.001$) relative to the reference area (Table 4.24). There was a general decrease in shell length with distance from the outfall; however, the differences among distance groups were small relative to the variability within distance groups (Golder, 2011b).

Mean tissue wet weights for the outfall monitoring stations were greater than the reference area mean for most stations; station means that were greater than the reference area mean ranged from 104% to 159% of reference. The only stations that exhibited mean tissue wet weights lower than the reference area mean were Stations C2S, C4E, C4SE and C8E, which ranged between 86% and 97% of mean reference weight. Near-field and far-field mean tissue wet weights were 124% and 130% of reference respectively. Significant differences were identified between each of the outfall, 100m, 200m, and 400m distance groups and the reference area ($p < 0.001$, Table 4.23), with tissue wet weight significantly greater than the reference area for each of these distance groups (Golder, 2011b). Mean tissue wet weight was significantly higher in each of the distance-direction groups relative to the reference area (Table 4.24) (i.e., growth enhancement or stimulation occurred around the outfall).

Figure 4.30 (bottom panels) illustrates a general decrease in tissue wet weight with distance from the outfall. However, the differences among distance groups were small relative to the variability within

distance groups. When organized by distance-direction groupings tissue wet weights at all exposure distance-direction groups were elevated relative to the reference area. However, a systematic spatial pattern was not readily apparent (Golder, 2011b).

Overall, the 2010 data indicated a pattern very similar to previous sampling years, in that mussels collected from nearest the outfall were largest, and decreased slightly in size with distance from the outfall. This relationship has been consistently demonstrated over multiple sampling events, and although the absolute magnitude of the effect is small, it is a real effect that is attributable to proximity to the outfall (Golder, 2011b). The likely cause is the availability of an enhanced organic food source (discharged from the outfall) that diminishes with distance from the outfall. Additional research would be necessary to confirm this cause and effect relationship.

Table 4.16 2010 Summary Statistics for Mussel Shell Length

Distance Group	Station	Shell Length (mm)						
		N	Mean	Median	SD	Minimum	Maximum	% of Reference
Outfall	C0	25	85.3	86.4	8.2	68.6	100.9	113
100 m stations	C1E	25	83.2	82.7	6.3	68.8	94.8	111
	C1NE	25	81.1	78.0	11.6	62.3	102.0	108
	C1NW	25	80.1	79.8	10.6	64.9	101.3	107
	C1S	25	75.5	77.8	12.2	50.4	92.9	100
	C1SE	25	78.5	79.6	8.1	57.8	92.6	104
	C1SW	25	79.4	81.6	12.0	51.6	96.8	106
	C1W FR1	25	82.8	84.8	11.1	49.3	99.2	110
	C1W FR2	15	86.8	86.1	10.1	66.0	101.8	115
	C1W FR3	15	80.0	84.4	12.1	55.2	91.7	106
	C1W (all)	55	83.1	84.8	11.1	49.3	101.8	111
	100 metre stations	205	80.8	81.6	10.6	49.3	102.0	108
200 m stations	C2E	25	83.1	83.6	8.3	60.2	98.7	111
	C2N	22	75.9	79.3	15.0	45.2	94.4	101
	C2NE	25	83.5	83.5	10.1	59.4	100.8	111
	C2NW	25	84.5	88.8	13.2	54.5	101.3	112
	C2S	25	77.0	78.5	10.7	54.8	93.9	102
	C2W	25	88.5	88.3	8.4	75.3	107.6	118
	200 metre stations	147	82.1	83.5	11.1	45.2	107.6	109

continued

Table 4.16, continued

Distance Group	Station	Shell Length (mm)						
		N	Mean	Median	SD	Minimum	Maximum	% of Reference
400 m stations	C4E	25	71.1	71.0	9.9	54.2	87.7	95
	C4NE	25	82.3	83.5	12.2	60.2	98.0	110
	C4NW	25	81.7	81.0	13.9	53.8	108.4	109
	C4SE	25	74.3	75.9	8.0	53.3	88.1	99
	C4SW FR1	25	79.3	82.5	10.8	53.9	94.5	105
	C4SW FR2	15	81.1	82.1	8.0	67.4	93.8	108
	C4SW FR3	15	78.5	77.4	10.0	60.9	95.2	104
	C4SW (all)	55	79.6	82.1	9.9	53.9	95.2	106
	C4W FR1	25	83.3	83.3	7.8	68.1	95.9	111
	C4W FR2	15	87.2	89.2	7.8	71.2	97.1	116
	C4W FR3	15	85.4	85.5	7.4	68.5	97.7	114
	C4W (all)	55	84.9	85.5	7.7	68.1	97.7	113
	400 metre stations	210	80.4	82.3	10.1	53.3	108.4	107
800 m stations	C8E FR1	25	78.1	79.4	8.3	62.1	99.7	104
	C8E FR2	15	72.4	76.1	9.8	54.0	85.4	96
	C8E FR3	15	70.8	68.8	10.1	51.5	91.3	94
	C8E (all)	55	74.6	76.3	9.2	51.5	99.7	99
	C8W	24	85.1	85.4	9.2	67.5	100.8	113
	800 metre stations	79	76.6	77.7	9.2	51.5	100.8	102
Reference stations	CB1	25	71.8	70.8	9.2	50.2	88.6	96
	CB2	24	73.1	77.9	12.1	48.9	88.4	97
	CB3	25	77.7	79.5	8.1	57.6	89.7	103
	CB4	25	73.7	75.7	13.2	53.0	101.0	98
	CB5	25	79.5	78.3	7.1	63.4	90.9	106
	Reference stations	124	75.2	77.9	10.2	48.9	101.0	100
Distance-direction Groups	Near-field stations	50	83.1	83.2	7.4	60.2	98.7	111
	Far-field stations	591	80.2	81.6	10.6	45.2	108.4	107

Note

See Section 2.2.2 in the report for a description of how the summary statistics were calculated.

SD = standard deviation

Table 4.17 2010 Summary Statistics for Mussel Shell Width

Distance Group	Station	Shell Width (mm)						
		N	Mean	Median	SD	Minimum	Maximum	% of Reference
Outfall	C0	25	37.2	37.3	3.1	30.2	42.3	114
100 m stations	C1E	25	38.2	38.0	2.6	33.9	42.8	117
	C1NE	25	38.5	39.7	5.1	27.6	45.7	118
	C1NW	25	38.6	37.8	5.1	28.2	48.3	119
	C1S	25	35.0	35.5	3.9	26.6	42.9	108
	C1SE	25	35.8	36.8	3.5	26.9	41.3	110
	C1SW	25	37.1	37.3	5.3	25.1	50.4	114
	C1W FR1	25	39.0	40.3	4.0	27.4	44.6	120
	C2W FR2	15	39.5	39.5	3.6	32.9	46.1	121
	C1W FR3	15	37.7	38.2	4.6	29.9	44.4	116
	C1W (all)	55	38.8	39.4	4.1	27.4	46.1	119
	100 m stns	205	37.7	38.0	4.3	25.1	50.4	116
200 m stations	C2E	25	37.6	37.3	2.5	32.6	42.1	115
	C2N	22	35.7	35.0	6.0	25.2	45.8	110
	C2NE	25	39.5	41.1	4.2	31.5	45.2	121
	C2NW	25	39.4	41.2	5.4	29.0	46.4	121
	C2S	25	35.1	35.0	3.9	28.3	42.9	108
	C2W	25	40.3	40.2	2.6	35.4	46.5	124
	200 m stns	147	37.9	38.7	4.3	25.2	46.5	117
400 m stations	C4E	25	34.2	34.4	3.8	28.3	41.6	105
	C4NE	25	39.2	40.0	4.5	31.3	44.7	120
	C4NW	25	38.4	38.8	5.1	26.8	47.6	118
	C4SE	25	34.2	34.7	3.0	27.1	39.9	105
	C4SW FR1	25	37.3	38.1	3.8	28.5	43.5	115
	C4SW FR2	15	37.7	38.1	2.8	30.8	42.1	116
	C4SW FR3	15	37.1	37.0	3.6	30.0	42.7	114
	C4SW (all)	55	37.4	38.0	3.5	28.5	43.5	115
	C4W FR1	25	39.1	38.6	2.7	34.4	43.8	120
	C4W FR2	15	40.3	41.1	3.6	33.3	45.9	124
	C4W FR3	15	40.0	40.3	2.7	35.0	44.2	123
	C4W (all)	55	39.7	40.0	3.0	33.3	45.9	122
	C4W	210	37.7	38.3	3.7	26.8	47.6	116

continued

Table 4.17, continued

Distance Group	Station	Shell Width (mm)						
		N	Mean	Median	SD	Minimum	Maximum	% of Reference
800 m stations	C8E FR1	25	36.5	36.6	3.0	29.7	42.2	112
	C8E FR2	15	34.3	35.4	3.7	26.0	40.5	106
	C8E FR3	15	34.4	34.0	3.5	28.1	42.2	106
	C8E (all)	55	35.4	35.7	3.4	26.0	42.2	109
	C8W	24	39.7	40.0	3.4	30.9	45.3	122
	800 m stns	79	36.2	36.0	3.4	26.0	45.3	111
Reference stations	CB1	25	31.3	31.5	3.9	24.1	38.3	96
	CB2	24	32.5	32.9	3.6	25.0	37.8	100
	CB3	25	33.7	34.0	2.8	27.7	39.8	104
	CB4	25	32.2	30.3	5.1	25.0	45.2	99
	CB5	25	32.9	33.8	3.6	26.8	38.1	101
	Reference stations	124	32.5	32.9	3.9	24.1	45.2	100
Distance-direction Groups	Near-field stations	50	37.9	37.6	2.6	32.6	42.8	116
	Far-field stations	591	37.5	38.1	4.1	25.1	50.4	115

Note

See Section 2.2.2 in the report for a description of how the summary statistics were calculated.

SD = standard deviation

Table 4.18 2010 Summary Statistics for Mussel Tissue Wet Weight

Distance Group	Station	Tissue Wet Weight (g)						
		N	Mean	Median	SD	Minimum	Maximum	% of Reference
Outfall	C0	25	11.2	11.1	3.3	4.5	19.8	136
100 m stations	C1E	25	10.2	10.5	2.4	6.4	14.6	125
	C1NE	25	10.6	10.2	4.2	4.2	19.1	129
	C1NW	25	11.3	11.6	3.9	5.3	20.3	138
	C1S	25	8.8	9.4	2.6	3.8	13.7	107
	C1SE	25	10.2	10.0	2.5	4.5	14.6	124
	C1SW	25	10.2	10.5	3.5	3.5	18.2	124
	C1W FR1	25	11.7	11.5	3.7	3.8	19.1	143
	C2W FR2	15	15.1	13.5	5.1	8.6	23.9	185
	C1W FR3	15	11.9	13.4	3.9	5.2	18.0	146
	C1W (all)	55	12.7	11.9	4.2	3.8	23.9	155
	100 metre stations	205	11.1	10.5	3.5	3.5	23.9	136
200 m stations	C2E	25	10.1	10.1	2.0	5.1	13.7	123
	C2N	22	10.6	10.3	4.6	3.8	19.1	130
	C2NE	25	11.7	11.8	3.2	5.3	19.0	143
	C2NW	25	13.0	14.4	4.9	4.0	21.2	158
	C2S	25	7.9	8.1	2.5	3.4	11.4	97
	C2W	15	13.0	12.5	2.9	8.5	19.7	159
	200 metre stations	137	11.0	11.1	3.5	3.4	21.2	135
400 m stations	C4E	25	7.4	7.2	2.1	4.0	10.6	91
	C4NE	25	10.3	10.2	3.3	4.7	16.0	126
	C4NW	25	12.3	10.7	4.7	4.8	23.6	150
	C4SE	25	7.3	7.6	1.5	3.0	9.4	90
	C4SW FR1	25	10.5	11.3	3.9	3.8	16.6	129
	C4SW FR2	0	-	-	-	-	-	-
	C4SW FR3	0	-	-	-	-	-	-
	C4SW (all)	25	10.5	11.3	3.9	3.8	16.6	129
	C4W FR1	25	11.7	11.7	3.0	6.5	17.4	143
	C4W FR2	14	13.0	13.4	3.3	7.9	18.0	159
	C4W FR3	15	11.6	11.6	2.7	7.1	16.8	142
	C4W (all)	54	12.0	12.1	3.0	6.5	18.0	147
	400 metre stations	179	10.5	11.0	3.2	3.0	23.6	129

continued

Table 4.18, continued

Distance Group	Station	Tissue Wet Weight (g)						
		N	Mean	Median	SD	Minimum	Maximum	% of Reference
800 m stations	C8E FR1	25	8.5	8.2	2.5	3.8	13.7	104
	C8E FR2	15	7.5	7.1	2.2	3.8	11.9	91
	C8E FR3	14	7.1	7.0	1.8	4.8	11.1	86
	C8E (all)	54	7.8	7.7	2.2	3.8	13.7	96
	C8W	24	12.1	12.6	2.9	6.0	17.2	148
	800 metre stations	78	8.8	7.7	2.5	3.8	17.2	107
Reference stations	CB1	25	7.3	7.0	2.6	2.6	12.1	89
	CB2	25	7.7	7.7	2.6	3.5	13.1	94
	CB3	25	8.9	8.8	2.2	4.5	13.1	109
	CB4	25	8.0	7.9	3.3	3.8	17.4	98
	CB5	24	9.1	9.0	1.9	5.7	12.0	111
	Reference stations	124	8.2	7.9	2.6	2.6	17.4	100
Distance-direction Groups	Near-field stations	50	10.1	10.3	2.2	5.1	14.6	124
	Far-field stations	549	10.6	10.7	3.4	3.0	23.9	130

Note

See Section 2.2.2 in the report for a description of how the summary statistics were calculated.

SD = standard deviation

Table 4.19 2010 Summary Statistics for Mussel Shell Weight

Distance Group	Station	Shell Weight (g)						
		N	Mean	Median	SD	Minimum	Maximum	% of Reference
Outfall	C0	25	15.5	15.2	4.0	7.2	25.3	152
100 m stations	C1E	25	14.8	14.1	3.7	9.5	26.0	145
	C1NE	25	13.3	12.0	5.1	6.9	23.7	131
	C1NW	25	13.1	12.7	4.2	7.0	20.9	129
	C1S	25	13.1	13.6	5.5	3.8	22.2	128
	C1SE	25	13.7	14.6	3.5	6.8	19.4	134
	C1SW	25	13.6	13.9	5.0	4.0	22.1	133
	C1W FR1	25	15.9	15.8	5.8	3.8	27.4	156
	C2W FR2	15	16.7	15.1	6.5	7.8	31.0	163
	C1W FR3	15	14.2	14.8	5.2	4.8	25.1	139
	C1W (all)	55	15.7	15.1	5.9	3.8	31.0	153
	100 metre stations	205	14.3	14.1	4.9	3.8	31.0	140
200 m stations	C2E	25	15.6	16.3	5.3	1.7	26.8	153
	C2N	22	14.0	12.1	7.3	3.6	27.0	137
	C2NE	25	14.5	15.5	4.6	5.9	22.4	142
	C2NW	25	17.2	17.2	7.7	1.7	31.1	168
	C2S	25	12.7	12.9	4.8	5.0	21.0	124
	C2W	25	17.9	17.1	4.9	9.6	27.5	175
	200 metre stations	147	15.3	15.9	5.9	1.7	31.1	150
400 m stations	C4E	25	9.8	9.7	3.5	4.5	16.3	96
	C4NE	25	14.4	13.5	6.5	2.7	24.5	141
	C4NW	25	14.3	12.9	5.7	5.0	26.0	140
	C4SE	25	11.5	11.5	3.0	4.4	17.5	112
	C4SW FR1	25	12.5	12.7	3.9	4.2	20.2	122
	C4SW FR2	15	12.6	12.6	3.4	7.6	18.4	123
	C4SW FR3	15	11.9	11.2	3.5	6.4	17.8	116
	C4SW (all)	55	12.3	12.5	3.7	4.2	20.2	121
	C4W FR1	25	16.1	16.0	5.8	8.5	30.8	157
	C4W FR2	15	17.3	17.8	4.2	9.1	26.1	170
	C4W FR3	15	16.1	15.5	4.1	8.2	22.3	158
	C4W (all)	55	16.4	16.3	5.0	8.2	30.8	161
	400 metre stations	210	13.6	12.8	4.6	2.7	30.8	134

continued

Table 4.19, continued

Distance Group	Station	Shell Weight (g)						
		N	Mean	Median	SD	Minimum	Maximum	% of Reference
800 m stations	C8E FR1	25	12.8	11.8	5.0	6.4	30.9	125
	C8E FR2	15	12.0	11.5	5.6	5.0	25.0	118
	C8E FR3	15	9.9	9.4	4.9	4.1	25.0	97
	C8E (all)	55	11.8	11.0	5.2	4.1	30.9	116
	C8W	24	15.5	15.3	4.2	7.5	24.8	152
	800 metre stations	79	12.6	11.7	4.9	4.1	30.9	123
Reference stations	CB1	25	8.9	8.7	3.4	3.3	16.8	87
	CB2	24	9.4	9.7	4.0	2.6	15.5	92
	CB3	25	11.3	10.8	3.5	3.7	20.6	111
	CB4	25	9.5	9.0	4.1	4.0	17.4	94
	CB5	25	11.8	11.6	2.6	7.7	17.8	116
	Reference stations	124	10.2	9.7	3.6	2.6	20.6	100
Distance-direction Groups	Near-field stations	50	15.2	15.2	4.6	1.7	26.8	149
	Far-field stations	591	13.9	13.5	5.1	1.7	31.1	137

Note

See Section 2.2.2 in the report for a description of how the summary statistics were calculated.

SD = standard deviation

Table 4.20 2010 Summary Statistics for Mussel Age

Distance Group	Station	Age (Annuli)						
		N	Mean	Median	SD	Minimum	Maximum	% of Reference
Outfall	C0	25	8.4	8	0.8	7	10	110
100 m stations	C1E	24	8.3	8	0.8	7	10	109
	C1NE	25	7.8	8	1.1	6	10	101
	C1NW	25	6.4	7	1.1	4	8	83
	C1S	25	7.6	8	1.1	6	10	99
	C1SE	25	8.0	8	1.2	6	11	104
	C1SW	25	8.2	8	1.2	6	11	108
	C1W FR1	25	8.2	8	1.1	5	10	108
	C2W FR2	14	8.6	8	1.4	6	11	113
	C1W FR3	14	7.9	8	1.5	5	10	103
	C1W (all)	53	8.2	8	1.3	5	11	108
	100 metre stations	202	7.9	8	1.2	4	11	103
200 m stations	C2E	25	8.0	8	1.1	6	10	105
	C2N	22	7.7	8	1.8	4	10	100
	C2NE	25	8.7	9	1.1	7	11	114
	C2NW	25	8.2	9	2.0	5	11	107
	C2S	25	7.6	7	1.2	6	10	99
	C2W	23	8.9	9	1.3	6	12	116
	200 metre stations	145	8.2	9	1.5	4	12	107
400 m stations	C4E	24	6.0	6	1.0	4	8	78
	C4NE	25	8.0	8	1.4	5	11	104
	C4NW	25	7.8	8	1.7	4	11	102
	C4SE	23	7.4	8	1.0	5	9	97
	C4SW FR1	25	7.7	8	1.0	5	9	101
	C4SW FR2	15	8.1	8	1.3	6	11	105
	C4SW FR3	15	7.3	7	1.2	6	10	96
	C4SW (all)	55	7.7	8	1.1	5	11	101
	C4W FR1	25	8.4	9	0.9	7	10	110
	C4W FR2	15	8.8	9	0.9	7	11	115
	C4W FR3	15	8.7	9	0.9	7	10	114
	C4W (all)	55	8.6	9	0.9	7	11	112
	400 metre stations	207	7.8	8	1.2	4	11	102

continued

Table 4.20, continued

Distance Group	Station	Age (Annuli)						
		N	Mean	Median	SD	Minimum	Maximum	% of Reference
800 m stations	C8E FR1	25	8.0	8	1.0	6	11	104
	C8E FR2	15	7.0	7	1.0	5	8	91
	C8E FR3	14	7.0	7	1.0	6	9	91
	C8E (all)	54	7.4	8	1.0	5	11	97
	C8W	24	8.3	9	1.1	6	10	109
	800 metre stations	78	7.6	8	1.1	5	11	99
Reference stations	CB1	24	7.3	7	0.9	5	9	96
	CB2	24	7.4	8	1.2	5	10	96
	CB3	21	7.7	8	0.8	6	9	101
	CB4	24	7.5	8	1.2	5	10	98
	CB5	25	8.4	8	0.7	7	10	109
	Reference stations	118	7.7	8	1.0	5	10	100
Distance-direction Groups	Near-field stations	49	8.2	8	1.0	6	10	107
	Far-field stations	583	7.9	8	1.2	4	12	103

Note

See Section 2.2.2 in the report for a description of how the summary statistics were calculated.

SD = standard deviation

Table 4.21 2010 Summary Statistics for Mussel Growth Metrics

Distance Group	Station	Growth Metrics			
		Log growth (shell length [SL])	Log growth (wet weight [WW])	Growth (SL) (% of reference)	Growth (WW) (% of reference)
Outfall	C0	0.010	-0.009	107	122
100 m stations	C1E	0.001	-0.034	105	115
	C1NE	0.008	-0.002	107	124
	C1NW	0.056	0.139	119	171
	C1S	-0.020	-0.060	100	108
	C1SE	-0.011	-0.012	103	121
	C1SW	-0.018	-0.044	101	112
	C1W FR1	0.001	0.019	105	130
	C2W FR2	0.008	0.103	107	158
	C1W FR3	0.001	0.067	105	145
	C1W (all)	0.003	0.054	106	141
	100 metre stations	0.003	0.020	106	130
200 m stations	C2E	0.011	-0.018	108	120
	C2N	-0.019	0.005	101	126
	C2NE	-0.010	-0.003	103	124
	C2NW	0.016	0.066	109	145
	C2S	-0.009	-0.107	103	97
	C2W	0.014	-0.039	108	114
	200 metre stations	0.000	-0.016	105	120
400 m stations	C4E	0.015	-0.007	109	122
	C4NE	0.009	-0.014	107	121
	C4NW	0.012	0.072	108	147
	C4SE	-0.018	-0.108	101	97
	C4SW FR1	-0.002	-0.003	105	124
	C4SW FR2	0.000	-	105	-
	C4SW FR3	0.009	-	107	-
	C4SW (all)	0.002	-0.003	106	124
	C4W FR1	0.000	0.019	105	130
	C4W FR2	0.008	0.040	107	136
	C4W FR3	0.001	-0.001	105	124
	C4W (all)	0.002	0.019	106	130
	400 metre stations	0.003	0.000	106	124
800 m stations	C8E FR1	-0.014	-0.097	102	100
	C8E FR2	-0.015	-0.086	102	102
	C8E FR3	-0.023	-0.107	100	97
	C8E (all)	-0.017	-0.096	101	100
	C8W	0.012	0.040	108	136
	800 metre stations	-0.010	-0.062	103	108

continued

Table 4.21, continued

Distance Group	Station	Growth Metrics			
		Log growth (shell length [SL])	Log growth (wet weight [WW])	Growth (SL) (% of reference)	Growth (WW) (% of reference)
Reference stations	CB1	-0.030	-0.133	98	92
	CB2	-0.026	-0.102	99	98
	CB3	-0.009	-0.061	103	108
	CB4	-0.023	-0.092	100	101
	CB5	-0.019	-0.087	100	102
	Reference stations	-0.022	-0.095	100	100
Distance-direction Groups	Near-field stations	0.006	-0.026	107	117
	Far-field stations	0.000	-0.005	105	123

Note

See Section 2.2.2 in the report for a description of how the summary statistics were calculated.

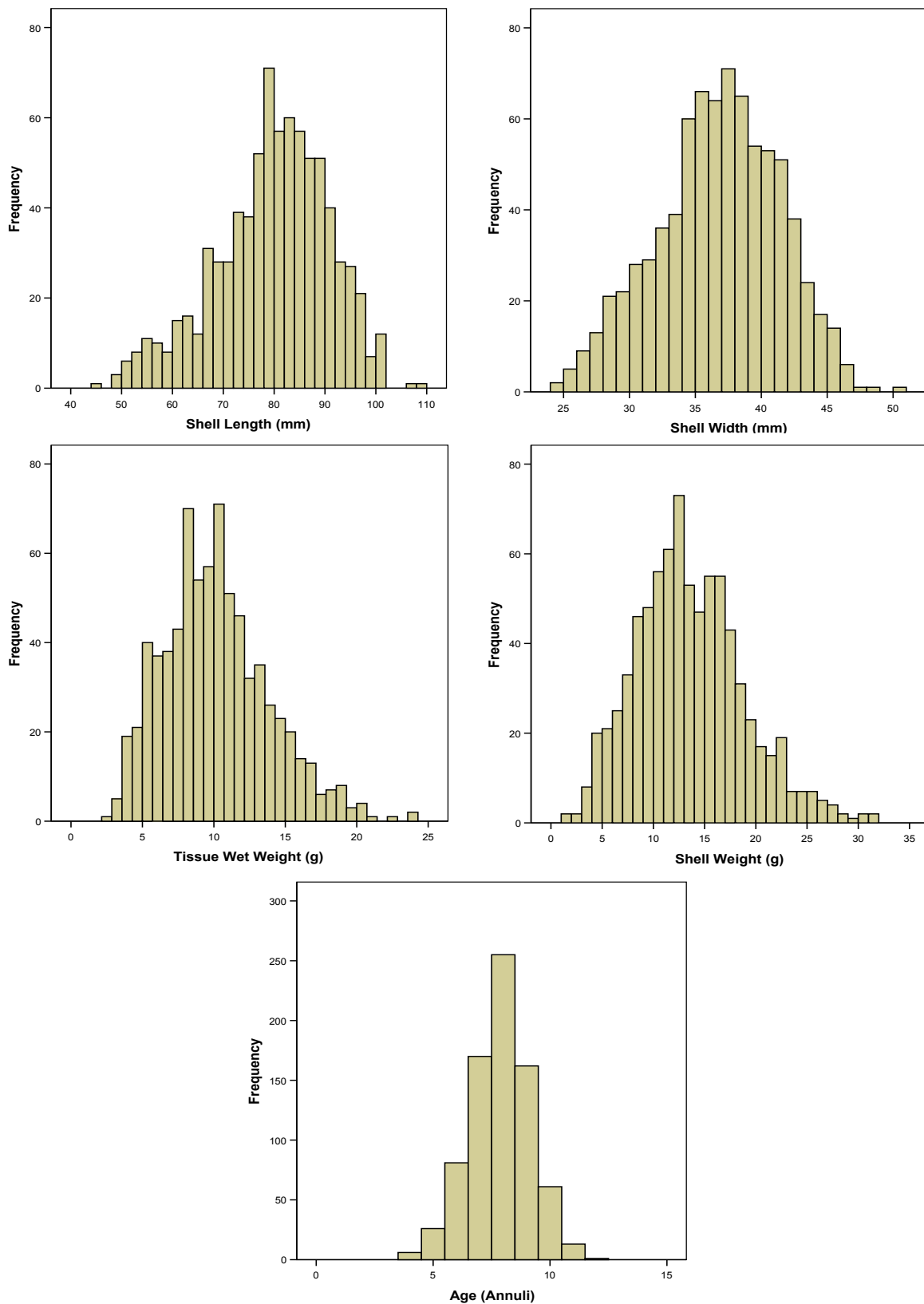


Figure 4.28 Frequency Distribution Plots for Mussel Size and Age Metrics (2010)

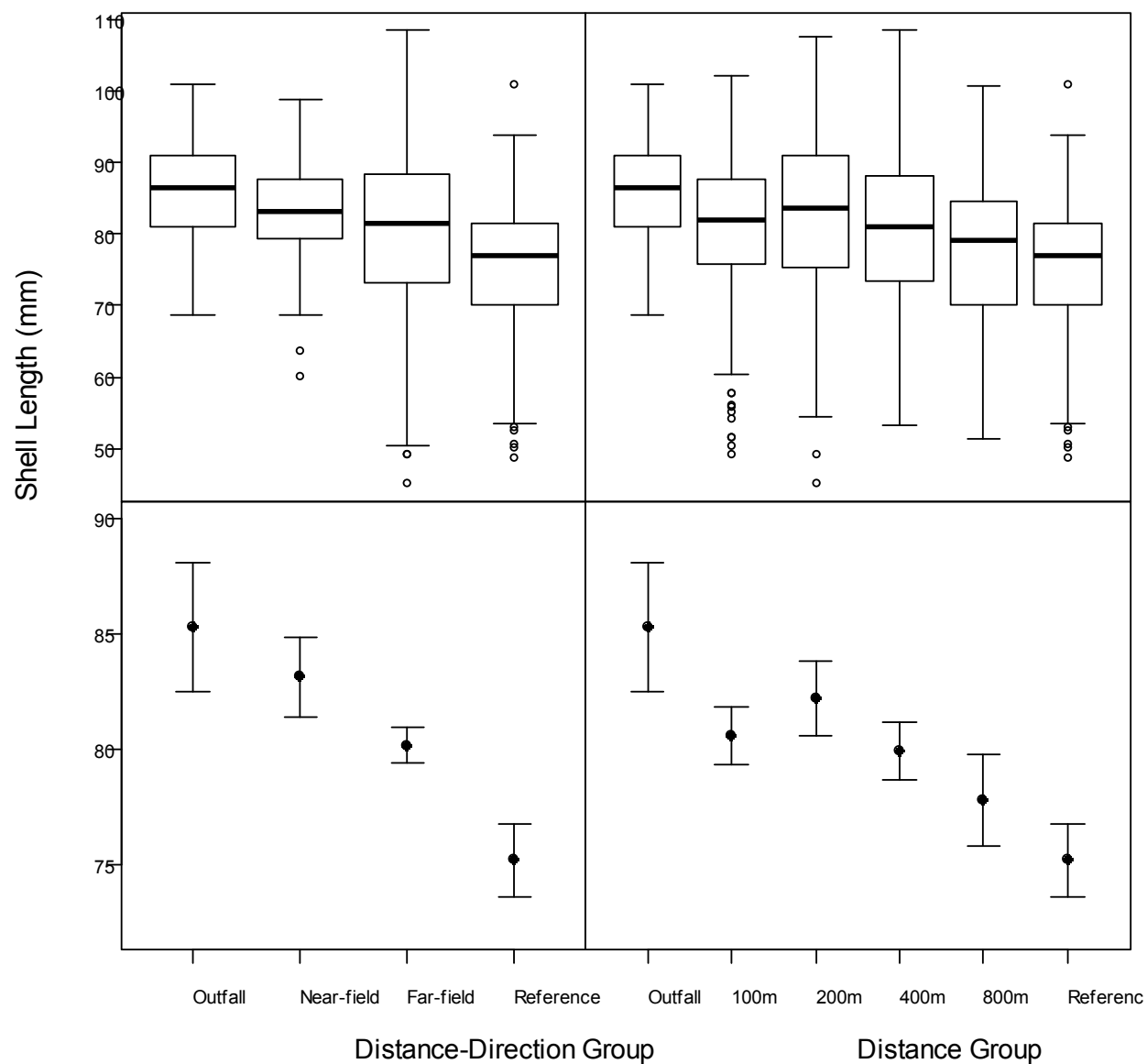


Figure 4.29 Box and Whisker Plots (Top Panel) and Means $\pm$ 95% Confidence Intervals (Bottom Panel) for 2010 Mussel Shell Length

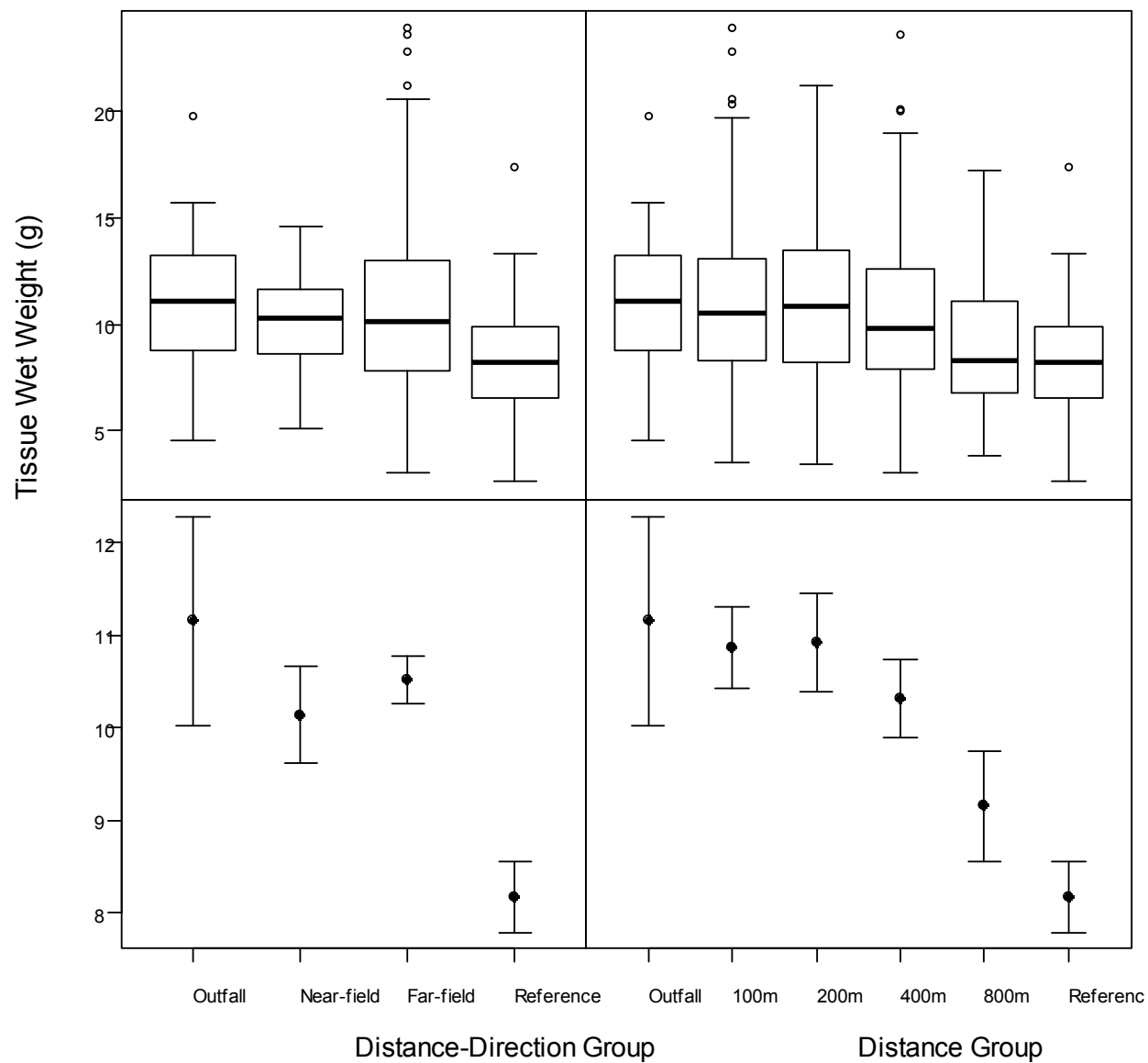


Figure 4.30 Box and Whisker Plots (Top Panel) and Means $\pm$ 95% Confidence Intervals (Bottom Panel) for 2010 Mussel Tissue Wet Weight

Population Age Structure

The age distribution is presented in Figure 4.31, with mean ages at each station and for distance groups presented in Table 4.20. Individual mussel ages ranged from four years (stations C1NW, C2N, C4E and C4NW) to 12 years at stations C2W (Table 4.20) (Golder, 2011b). Mean ages for the outfall monitoring stations were similar to the reference stations, ranging from 78% to 116% of reference. Mean mussel ages in the near-field and far-field station groupings were 107% and 103% of reference, respectively. Significant differences in mean mussel age were identified between each of the outfall and 200m distance groups and the reference area ($p < 0.05$, Table 4.23), with mussel age significantly greater than the reference area (Golder, 2011b). Mean mussel age was significantly higher in the outfall and near-field group relative to the reference area (Table 4.30) (Golder, 2011b)

Figure 4.31 illustrates slightly elevated mussel ages at each of the outfall and 200m distance groups relative to the 400 m, 800 m, and reference area distance groups. The magnitude of the age differences was very small (less than one year across all distance group means) and the 95% confidence intervals overlapped for most distance groups. When mussel age was plotted against distance-direction group, mussel ages appeared to decrease with distance-direction position, however there were large overlaps in the 95% CIs and the absolute magnitudes of the differences were small (less than 1 year difference across all distance group means) (Golder, 2011b).

Figure 4.31 illustrates slightly elevated mussel ages at C0 and the 200m stations relative to stations at 100m from the outfall and stations located greater than 200m from the outfall. There is the possibility that gradients in other biological parameters were influenced by age differences. However, the magnitude of the differences was small, with less than a one-year difference in mean age between the oldest and youngest station group means. In addition, other recent sampling data (e.g. 2006 mussel monitoring) has shown a flat response of age with distance, yet size and weight metrics still exhibited a decline with distance. These factors suggest that trends in size and weight of mussels are caused by factors other than age; previous reports have discussed the potential influence of increased food availability from the Clover Point outfall (i.e. nutrient enhancement) as a more plausible explanation for the long-term trends (Golder, 2011b)

Brown and Seed (1977) found that the size distribution of horse mussel populations in Northern Ireland consisted primarily of mussels greater than 50 mm in length. Similarly, Anwar et al. (1990) found that the size and age of horse mussels varied widely between locations around Great Britain, but in most instances the population size structures were between 35 mm and 80 mm in length (similar to the Clover Point mussels). The majority of horse mussels become sexually mature between 30 mm to 50 mm in length (Brown *et al.*, 1977; Seed *et al.*, 1977) and they have been observed to reach ages of up to 48 years old and sizes of up to 20 cm (Anwar et al., 1990). The vast majority of mussels collected by CRD staff were larger than 50 mm, suggesting that they were all sexually mature. Overall, the CRD horse mussel size and age characteristics were similar to those observed for other horse mussel populations around the world.

Reproduction

GI and R TI are summarized in Table 4.22 by station, distance group, and distance-direction group. Correlations with distance from outfall and depth, and with distance-direction groups, are presented in Table 4.23 and Table 4.24. No statistically significant relationships were identified between the sex ratio (i.e. percent female) at a particular station and distance from the outfall or water depth, and no significant differences were identified among the distance-direction groups (Golder, 2011b). The correlation between GI and distance from the outfall was not significant (Table 4.23), and no significant differences were identified between the reference area and the outfall monitoring stations. The correlation between GI and water depth was significant and negative; however the correlation coefficient was weak ($|r_s| = 0.28$, Table 4.23), indicating that only a small proportion of the variance was explained by the depth gradient. The correlation between GI and the distance-direction groupings was not significant and no significant differences were identified between the reference area and the distance-direction groups (Table 4.24) (Golder, 2011b).

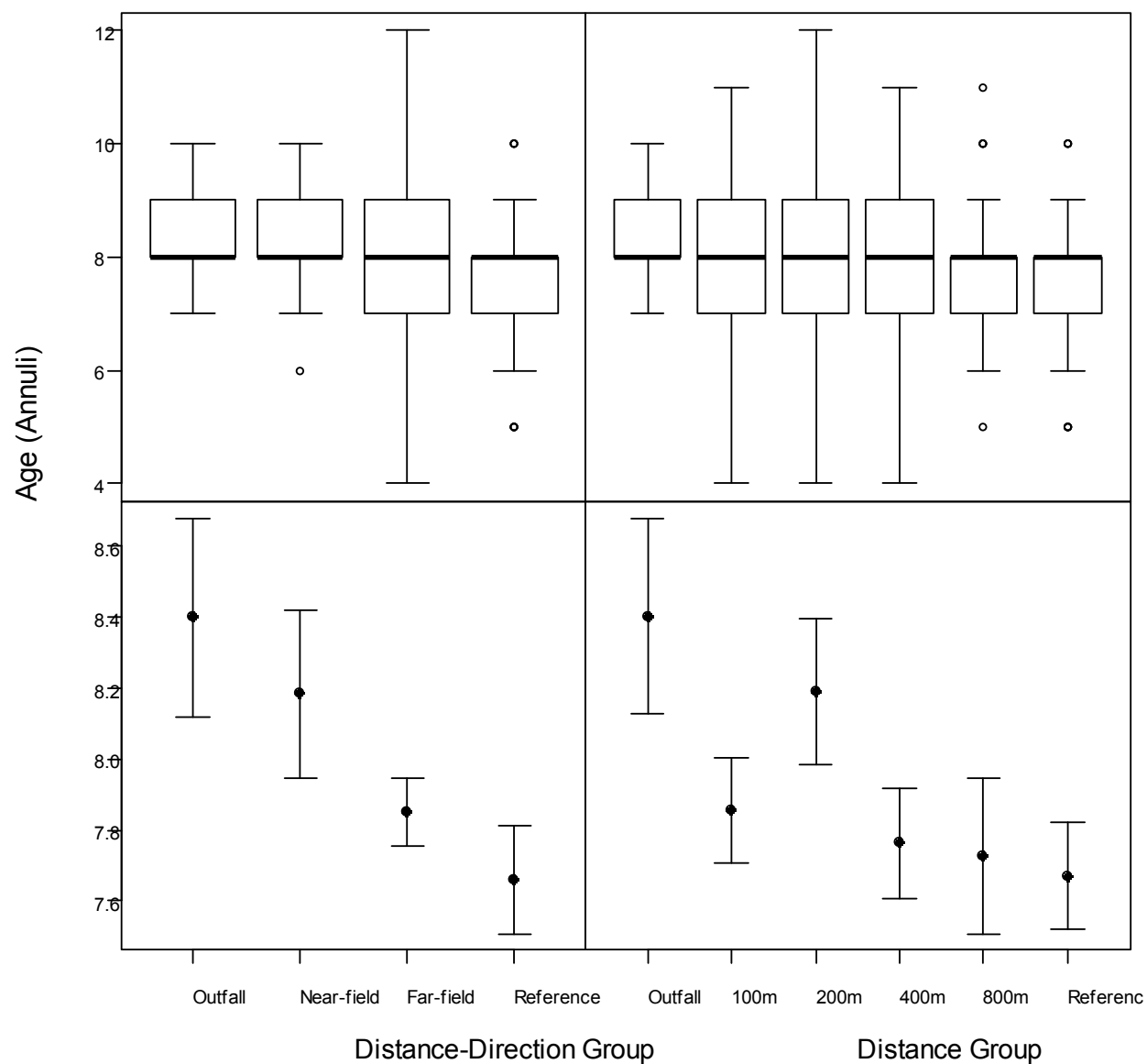


Figure 4.31 Box and Whisker Plots (Top Panel) and Means $\pm$ 95% Confidence Intervals (Bottom Panel) for 2010 Mussel Age

Reproductive Timing Index (RTI) values ranged from 0 to 8; however the majority of values were 6 or lower, suggesting that very few individuals were spawning or partially spent. The correlations between RTI and both distance from the outfall and distance-direction groupings were not significant (Table 4.23 and Table 4.24). No significant relationship was identified between RTI and water depth (Table 4.23). No significant differences were identified between the reference area and any of the distance or distance-direction groups (Table 4.23 and Table 4.24). No clear pattern with distance from the outfall was apparent in figures of mean GI (Figure 4.32) and RTI (Figure 4.33). The 2010 monitoring events and previous sampling events have exhibited either non-existent or weak relationships between reproduction metrics and proximity to the outfall. As with previous years, the 2010 data were not indicative of a biological effect that could be ascribed to outfall influences (Golder, 2011b).

In most sampling years, reproductive status was similar at all stations (Golder, 2005a; Golder, 2008c; Paine, 2004a); only 2003 sampling indicated that mussels were slightly more reproductively advanced near the discharge. There has been no consistent trend of reproductive status as a function of distance from the outfall (Golder, 2011b), an expected outcome since *M. modiolus* is known to have variable spawning. The slight variations from year to year that have been observed in Clover Point mussel GI values suggest that spawning might be occurring throughout the year rather than a discrete spawning event. Further sampling would be necessary to confirm this.

Brown (1984) and Comely (1978; Comely, 1981) found that horse mussel spawning patterns were highly variable among locations. In some populations, there were well-defined spawning events (June or July) followed either by redevelopment and further gamete release or no reproductive activity. In other populations, there were no defined spawning events; instead, the mussel populations had continuously ripe individuals with a constant release of gametes throughout the year. Seed and Brown (1975) found a very low proportion of spent mussels with most mussels in spawning stages. Brown (1984) attributed seasonal temperature variations as the determining process for the extent and duration of gametogenesis while spawning was dependent upon water temperatures exceeding certain minimal thresholds. Jasim and Brand (1989) studied a population of horse mussels around the Isle of Man and found the population had a clear seasonal gametogenesis cycle, but that spawning was slow and continuous with ripe gametes present throughout the year. Again, without additional sampling events covering other times of the year, the CRD WMEP cannot confirm whether the Clover Point populations are spawning year round. Additional sampling events could help to better characterize the seasonal reproductive patterns and determine whether any variation is natural or potentially outfall related, but there are no plans currently in place to undertake seasonal sampling.

Comparisons between Sexes

Horse mussels are usually dioecious and occasionally hermaphroditic (Jasim *et al.*, 1989). In 2010 results from the Wilcoxon signed rank test (Table 4.25) indicated mean RTI was significantly greater for male mussels than for female mussels ($p < 0.001$). However the magnitude of the difference between males and females was small. This small sex-specific difference in RTI is not expected to meaningfully affect the interpretation of trends in RTI across the study area (Golder, 2011b). No significant differences in mean shell length, shell width, tissue wet weight, shell weight, age or GI were identified between female and male mussels (Golder, 2011b).

Correlations between the male and female means for shell width, tissue wet weight, shell weight and age indicated significant positive relationships (Table 4.25). This indicated that for these metrics, there was a strong association between the spatial patterns observed for each sex. No significant relationship between RTI and distance from the outfall was identified, but a significant negative relationship was identified between RTI and water depth; indicating that as depth increased, the difference in the RTI values between male and female mussels decreased ($r_s = -0.42$; Table 4.25). Overall, the inter-sex comparisons revealed no ecologically significant differences in biological metrics between the sexes, and no relationships between the sexes and distance from the outfall were observed (Golder, 2011b).

Table 4.22 2010 Summary Statistics for Reproduction Metrics

Distance group	Station	N	Sex (% Female)	Gonad Index						Reproductive Timing Index					
				Mean	Median	SD	Min	Max	% of Ref	Mean	Median	SD	Min	Max	% of Ref
Outfall	C0	10	30%	4.2	4.0	0.7	3	5	105	4.7	5.0	1.0	3	6	106
100 m stations	C1E	10	40%	4.2	4.0	0.6	3	5	104	5.0	5.0	1.1	4	7	114
	C1NE	10	60%	4.4	4.0	0.5	4	5	108	4.6	4.5	0.7	4	6	105
	C1NW	9	56%	3.4	4.0	1.1	1	4	85	4.1	4.0	1.8	1	6	93
	C1S	10	30%	3.5	4.0	0.7	2	4	87	5.1	6.0	1.7	2	7	116
	C1SE	10	40%	3.5	4.0	0.7	2	4	87	5.1	6.0	1.7	2	7	116
	C1SW	10	20%	3.8	4.0	0.7	3	5	94	5.3	6.0	1.4	3	7	121
	C1W FR1	10	60%	4.3	4.0	0.5	4	5	107	4.6	4.0	0.7	4	6	104
	C2W FR2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C1W FR3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C1W (all)	10	60%	4.3	4.0	0.5	4	5	107	4.6	4.0	0.7	4	6	104
	100 m stations	69	44%	3.9	4.0	0.7	1	5	96	4.8	5.0	1.4	1	7	110
200 m stations	C2E	10	60%	4.0	4.0	1.2	1	5	99	4.4	4.5	1.4	1	6	100
	C2N	9	56%	3.8	4.0	1.5	1	5	94	4.2	5.0	1.8	1	6	96
	C2NE	10	70%	4.5	4.5	0.5	4	5	111	5.1	5.0	0.7	4	6	116
	C2NW	10	50%	4.2	4.5	1.0	2	5	104	4.2	4.5	1.0	2	5	95
	C2S	10	40%	3.5	4.0	1.4	0	5	87	4.1	4.0	1.9	0	6	93
	C2W	10	50%	4.0	4.0	0.5	3	5	99	6.0	6.0	0.5	5	7	136
	200 m stations	59	54%	4.0	4.0	1.1	0	5	99	4.7	4.8	1.3	0	7	106
400 m stations	C4E	10	50%	3.4	3.0	1.1	2	5	85	3.9	4.0	1.6	2	7	88
	C4NE	10	60%	4.3	4.0	0.7	3	5	106	5.1	5.0	1.0	3	6	116
	C4NW	10	30%	4.6	5.0	0.5	4	5	113	5.0	5.0	0.7	4	6	114
	C4SE	10	40%	3.5	4.0	1.6	0	5	87	4.3	4.5	2.1	0	8	98
	C4SW FR1	10	50%	3.7	4.0	0.9	2	5	92	5.3	6.0	1.6	2	7	120
	C4SW FR2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C4SW FR3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C4SW (all)	10	50%	3.7	4.0	0.9	2	5	92	5.3	6.0	1.6	2	7	120
	C4W FR1	10	40%	4.1	4.0	1.2	1	5	101	4.9	5.0	1.5	1	6	111
	C4W FR2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C4W FR3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C4W (all)	10	40%	4.1	4.0	1.2	1	5	101	4.9	5.0	1.5	1	6	111
	400 m stations	60	45%	3.9	4.0	1.1	0	5	97	4.7	5.0	1.5	0	8	108

continued

Table 4.22, continued

Distance group	Station	N	Sex (% Female)	Gonad Index						Reproductive Timing Index					
				Mean	Median	SD	Min	Max	% of Ref	Mean	Median	SD	Min	Max	% of Ref
400 m stations	C4E	10	50%	3.4	3.0	1.1	2	5	85	3.9	4.0	1.6	2	7	88
	C4NE	10	60%	4.3	4.0	0.7	3	5	106	5.1	5.0	1.0	3	6	116
	C4NW	10	30%	4.6	5.0	0.5	4	5	113	5.0	5.0	0.7	4	6	114
	C4SE	10	40%	3.5	4.0	1.6	0	5	87	4.3	4.5	2.1	0	8	98
	C4SW FR1	10	50%	3.7	4.0	0.9	2	5	92	5.3	6.0	1.6	2	7	120
	C4SW FR2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C4SW FR3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C4SW (all)	10	50%	3.7	4.0	0.9	2	5	92	5.3	6.0	1.6	2	7	120
	C4W FR1	10	40%	4.1	4.0	1.2	1	5	101	4.9	5.0	1.5	1	6	111
	C4W FR2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C4W FR3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C4W (all)	10	40%	4.1	4.0	1.2	1	5	101	4.9	5.0	1.5	1	6	111
	400 m stations	60	45%	3.9	4.0	1.1	0	5	97	4.7	5.0	1.5	0	8	108
800 m stations	C8E FR1	10	30%	3.9	4.0	0.6	3	5	97	5.5	6.0	1.2	3	7	125
	C8E FR2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C8E FR3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C8E (all)	10	30%	3.9	4.0	0.6	3	5	97	5.5	6.0	1.2	3	7	125
	C8W	10	50%	4.0	5.0	1.5	1	5	99	4.6	5.0	1.8	1	7	105
	800 m stations	20	40%	4.0	4.5	1.1	1	5	98	5.1	5.5	1.5	1	7	115
Reference stations	CB1	10	60%	3.9	4.0	1.2	1	5	97	4.1	4.0	1.4	1	6	93
	CB2	10	60%	3.8	4.0	1.5	0	5	94	4.0	4.5	1.7	0	6	91
	CB3	10	10%	3.8	4.0	1.1	1	5	94	4.6	5.0	1.6	1	6	105
	CB4	10	50%	4.0	4.5	1.3	1	5	99	4.4	5.0	1.6	1	6	100
	CB5	10	20%	4.7	5.0	0.5	4	5	116	4.9	5.0	0.6	4	6	111
	Reference stations	50	40%	4.0	4.0	1.2	0	5	100	4.4	5.0	1.4	0	6	100
Distance-direction Groups	Near-field stations	20	50%	4.1	4.0	0.9	1	5	101	4.7	4.8	1.3	1	7	107
	Far-field stations	188	46%	3.9	4.0	1.0	0	5	97	4.8	5.0	1.4	0	8	109

Note

See Section 2.2.2 in the report for a description of how the summary statistics were calculated.

SD = Standard Deviation

Table 4.23 Clover Point 2010 Mussel Metrics: Correlations with Distance from the Outfall and Statistical Comparisons to Constance Bank Reference

Metric	Sample Size	Rank Correlation with ¹ :		P-values (by Distance Group) for Comparisons to Reference ^{1,2}				
		Distance from Outfall	Water Depth	Outfall	100m	200m	400m	800m
Shell Length (mm)	790	-0.193**	-0.177**	< 0.001**	< 0.001**	< 0.001**	< 0.001**	0.774
Shell Width (mm)	790	-0.282**	-0.216**	< 0.001**	< 0.001**	< 0.001**	< 0.001**	< 0.001**
Tissue Wet Weight (g)	748	-0.255**	-0.276**	< 0.001**	< 0.001**	< 0.001**	< 0.001**	0.465
Shell Weight (g)	790	-0.260**	-0.137**	< 0.001**	< 0.001**	< 0.001**	< 0.001**	0.003**
Age (annuli)	775	-0.097**	-0.150**	0.005**	0.780	0.012*	1.000	4.079
Percent Female	27	-0.013	-0.268	NC	NC	NC	NC	NC
Gonad Index	260	0.098	-0.280**	NC	NC	NC	NC	NC
Reproductive Timing Index	260	-0.038	0.010	NC	NC	NC	NC	NC
Growth Shell Length	35	-0.391*	-0.243	0.716	0.068	0.088	0.016*	0.708
Growth Wet Weight	33	-0.467**	-0.582**	NC	NC	NC	NC	NC
Size/Weight PC1	747	-0.267**	-0.220**	< 0.001**	< 0.001**	< 0.001**	< 0.001**	0.002**
Size/Weight PC2	747	-0.087*	-0.217**	1.000	< 0.001**	0.339	< 0.001**	0.410

Notes

¹ Statistical significance (2-tailed): ** = $p < 0.01$; * = $p < 0.05$.

² P-values shown include Bonferroni adjustments for multiple comparisons where applicable.

NC = Not calculated; no comparison made as ANOVA (or non parametric Kruskal-Wallis test if applicable) was not significant.

Table 4.24 Clover Point 2010 Mussel Metrics: Correlations and Statistical Comparisons among Distance-Direction Groupings (Outfall, Near-field, Far-field and Constance Bank Reference

Metric	Sample Size	Rank Correlation (r_s) with ¹	P-values (by Distance-Direction Groupings) for Comparisons to Reference ^{1,2}		
		Distance-Direction Gradient	Outfall	Near-field	Far-field
Shell Length (mm)	790	-0.208**	< 0.001**	< 0.001**	< 0.001**
Shell Width (mm)	790	-0.324**	< 0.001**	< 0.001**	< 0.001**
Tissue Wet Weight (g)	748	-0.212**	< 0.001**	< 0.001**	< 0.001**
Shell Weight (g)	790	-0.284**	< 0.001**	< 0.001**	< 0.001**
Age (annuli)	775	-0.111**	0.003**	0.026*	0.364
Percent Female	27	0.015	NC	NC	NC
Gonad Index	260	0.035	NC	NC	NC
Reproductive Timing Index	260	-0.061	NC	NC	NC
Growth Shell Length	35	-0.530**	0.430	0.158	0.010*
Growth Wet Weight	33	-0.338	0.430	0.158	0.029*
Size/Weight PC1	747	-0.283**	< 0.001**	< 0.001**	< 0.001**
Size/Weight PC2	747	-0.013	1.000	1.000	< 0.001**

Notes

¹ Statistical significance (2-tailed): ** = $p < 0.01$; * = $p < 0.05$.

² P-values shown include Bonferroni adjustments for multiple comparisons where applicable.

NC = Not calculated; no comparison made as ANOVA (or non parametric Kruskal-Wallis if applicable) was not significant.

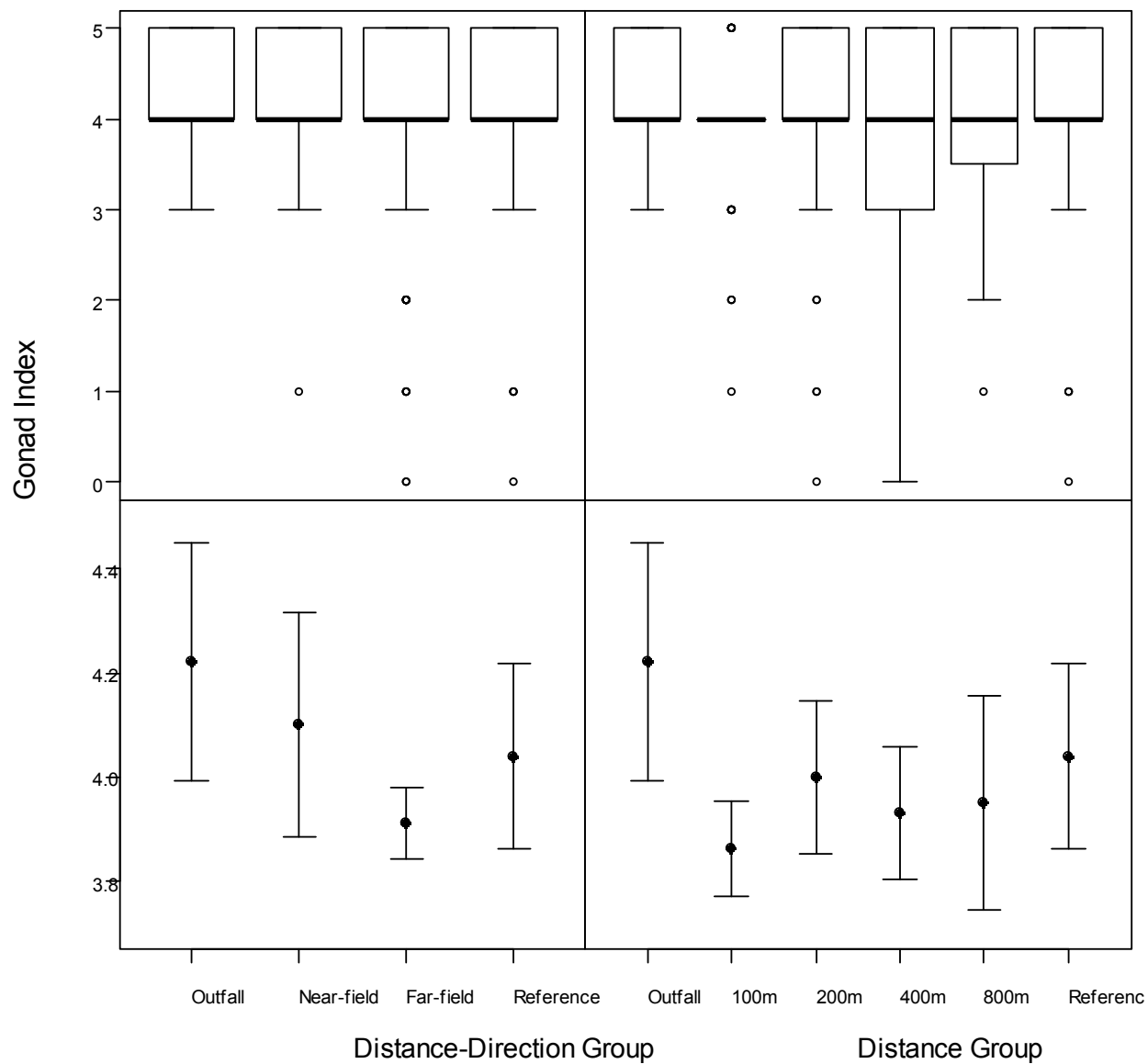


Figure 4.32 Distance Gradients (Top Panel) and Means $\pm$ 95% Confidence Intervals (Bottom Panel) for Mussel Gonad Index

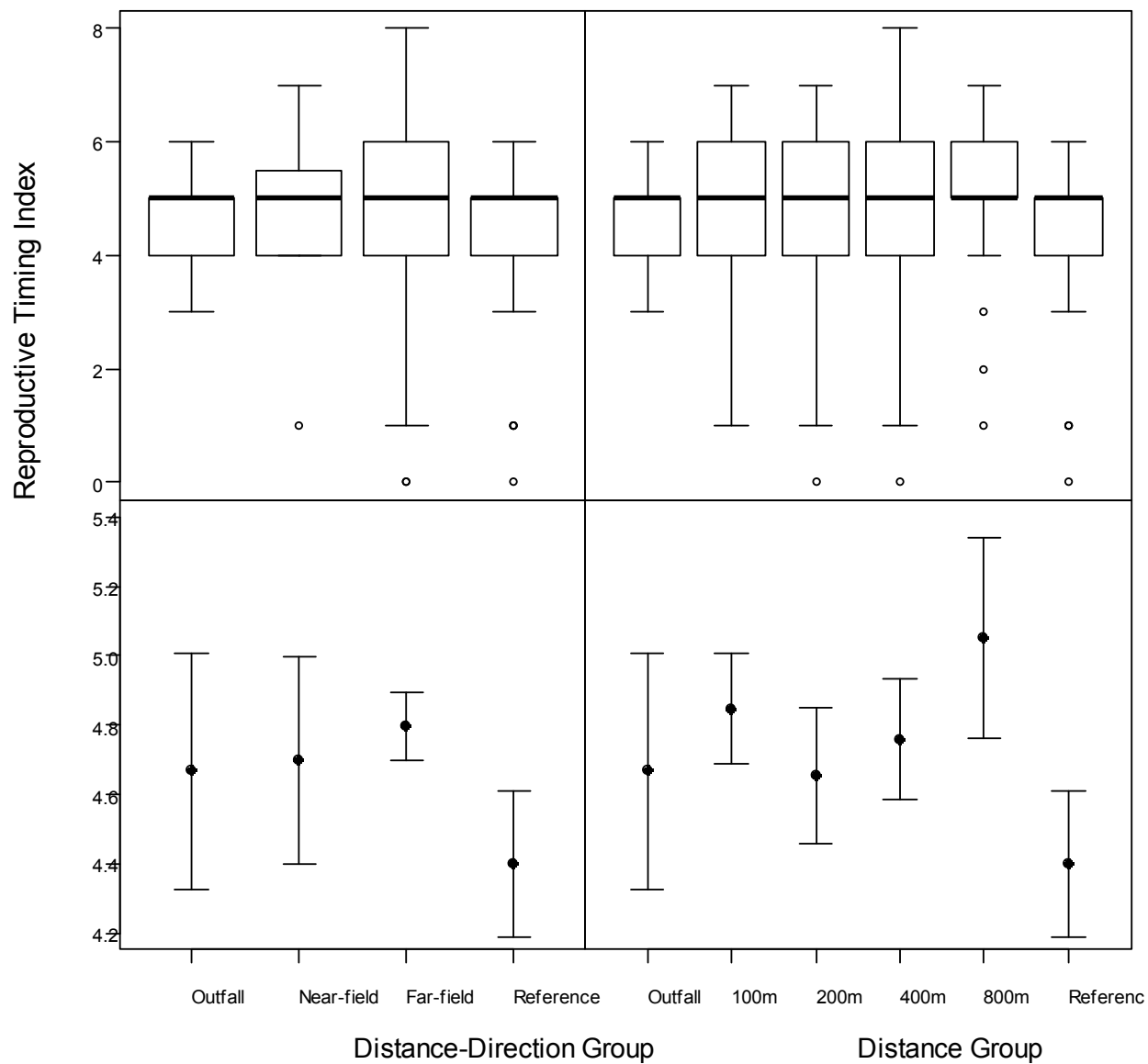


Figure 4.33 Distance Gradients (Top Panel) and Means $\pm$ 95 % Confidence Intervals (Bottom Panel) for Mussel Reproductive Timing Index

Table 4.25 Comparisons of the Biological Metrics between the Sexes

Metric	Wilcoxon Signed Rank Test Result (p-value)	Rank Correlations (r_s) Between Male and Female Station Means ¹	Rank Correlation (r_s) With ² :	
			Distance From Outfall	Depth
Shell Length (mm)	0.337	0.335	NC	NC
Shell Width (mm)	0.737	0.654**	NC	NC
Tissue Wet Weight (g)	0.501	0.519**	NC	NC
Shell Weight (g)	0.564	0.495**	NC	NC
Age (annuli)	0.248	0.395*	NC	NC
Gonad Index	0.271	-0.036	NC	NC
Reproductive Timing Index	< 0.001**	-0.087	0.314	-0.423*

Notes

¹ Statistical significance (2-tailed): ** = $p < 0.01$; * = $p < 0.05$.

² Spearman rank correlation of difference between the sexes (female station mean minus male station mean) with distance from outfall and sampling depth.

NC = Not calculated; no comparison made as Wilcoxon signed rank test was not significant.

Diseases and Parasites

The following mussel parasites, symbionts and pathological abnormalities were observed in mussels from some outfall and reference stations (An, 2010b):

- diffuse (2/268 incidences) and focalized (28/268 incidences) hemocyte infiltration
- diapedesis (migration of hemocytes through the intact epithelial wall) (19/268)
- metaplasia (changed shape of epithelial cells) (8/268 incidences)
- hemocyte neoplasia (7/268 incidences)
- gonad resorption (1/268)
- kidney concretions (22/268 incidences)
- hemocytes containing brown granules (16/268)
- Phagocytosis in male follicles, unknown kidney inclusion, and big size of brown colour deposition between gill and gonad (3/268, all males)
- inclusions of *Rickettsia*-like organisms (21/268)
- Unusual intracellular nest shape inclusions in gill epithelium. Pathogen is speculated to be a *Rickettsia*-like organism, but a different one from the cases reported in previous years (6/268).
- Hypertrophied sperm nuclei, determined to be viral gametocytic hypertrophy (VGH) (1/268)

Similar to previous years, no diseases of concern were observed in the Clover Point mussels in 2010 (An, 2010b). In previous years, the frequency or prevalence of symbionts, parasites and diseases of *M. modiolus* were below or similar to those reported in other mussel communities from around the world and were similar to those seen in other wild bivalve populations in B.C. (S. Bower, *pers. comm.*, 2007). A more detailed assessment of the 1998 to 2006 incidence of parasites, symbionts and pathological abnormalities was completed in 2007; results of this assessment were presented in the 2007 WMEP annual report (CRD, 2008). The 2010 frequency and prevalence of symbionts, parasites and diseases were qualitatively similar to previous years.

Comparison between Station Means and Individual Mussel Variation

The majority of the above discussions have focussed on distance or distance-direction group mean values of the mussel biological metrics rather than looking at individual mussels. Means are effective for determining overall inter-station changes over space and time, but are not as sensitive for determining

changes within a station or gaps within an individual station's biological metric sampling distribution. To ensure that there were no gaps in mussel population and sampling distributions, Golder looked at coefficients of variation and found that the variation in each biological metric was relatively constant across all distance groups and among stations within distance groups ((Golder, 2011b); Table 4.26). Exceptions were for reproductive metrics (GI and RTI), for which increased variability was observed. There was no discernible spatial pattern to the variability, and the highest variability for reproductive metrics was observed at station C4SE. As such, there do not appear to be any gaps in the biological metric sampling distributions and the use of distance or distance-direction group means were suitable for assessing the potential environmental effects of the Clover Point outfall on the horse mussel population.

Table 4.26 Coefficients of Variation (CVs) for 2010 Mussel Biological Metrics

Distance group	Station	Shell Length (mm)	Shell Width (mm)	Tissue Wet Weight (g)	Shell Weight (g)	Age (Annuli)	Gonad Index	Reproductive Timing Index
Outfall	C0	9.6%	8.4%	29.5%	25.8%	9.7%	15.8%	21.4%
100 metre stations	C1E	7.6%	6.8%	23.5%	25.0%	9.8%	15.1%	21.1%
	C1NE	14.3%	13.2%	39.6%	38.1%	14.5%	11.8%	16.1%
	C1NW	13.2%	13.2%	34.7%	32.1%	16.9%	32.8%	42.9%
	C1S	16.2%	11.1%	30.0%	42.0%	14.2%	20.2%	33.9%
	C1SE	10.4%	9.7%	24.9%	25.7%	15.6%	20.2%	33.9%
	C1SW	15.2%	14.2%	34.0%	37.2%	15.0%	17.6%	26.5%
	C1W FR1	13.4%	10.3%	31.8%	36.3%	13.7%	11.5%	15.9%
	C2W FR2	11.6%	9.1%	33.9%	39.3%	16.1%	-	-
	C1W FR3	15.2%	12.3%	32.4%	36.8%	18.6%	-	-
	C1W (all)	13.4%	10.5%	33.0%	37.4%	15.7%	11.5%	15.9%
	100 m stations	13.1%	11.3%	31.9%	34.7%	14.7%	18.4%	28.4%
200 metre stations	C2E	10.0%	6.7%	20.2%	34.1%	14.1%	28.9%	32.5%
	C2N	19.8%	16.9%	43.1%	52.1%	22.9%	39.2%	42.3%
	C2NE	12.1%	10.5%	27.4%	31.6%	13.0%	11.7%	14.5%
	C2NW	15.6%	13.8%	37.9%	44.5%	24.2%	24.6%	24.6%
	C2S	13.9%	11.2%	32.0%	37.9%	16.1%	38.7%	45.2%
	C2W	9.5%	6.5%	22.7%	27.6%	15.1%	12.5%	8.3%
	200 m stations	13.6%	11.3%	32.1%	38.3%	17.8%	26.7%	28.2%
400 metre stations	C4E	14.0%	11.1%	28.3%	35.6%	17.0%	32.8%	41.6%
	C4NE	14.8%	11.4%	32.4%	44.9%	17.9%	15.7%	19.5%
	C4NW	17.0%	13.3%	38.7%	39.8%	22.2%	11.6%	14.1%
	C4SE	10.7%	8.8%	20.8%	26.0%	14.0%	45.2%	49.1%
	C4SW FR1	13.7%	10.3%	36.6%	31.6%	12.7%	25.6%	30.9%
	C4SW FR2	9.9%	7.5%	-	26.7%	15.9%	-	-
	C4SW FR3	12.8%	9.7%	-	29.9%	16.0%	-	-
	C4SW (all)	12.5%	9.4%	36.6%	29.8%	14.6%	25.6%	30.9%
	C4W FR1	9.3%	6.9%	25.3%	35.9%	10.9%	29.2%	31.1%
	C4W FR2	8.9%	9.0%	25.4%	24.1%	10.7%	-	-
	C4W FR3	8.7%	6.7%	22.8%	25.6%	10.1%	-	-
	C4W (all)	9.0%	7.5%	24.7%	30.1%	10.6%	29.2%	31.1%
	400 m stations	12.5%	9.8%	30.6%	33.8%	15.2%	27.2%	31.7%

continued

Table 4.26, continued

Distance group	Station	Shell Length (mm)	Shell Width (mm)	Tissue Wet Weight (g)	Shell Weight (g)	Age (Annuli)	Gonad Index	Reproductive Timing Index
800 metre stations	C8E FR1	10.6%	8.3%	28.9%	39.0%	12.8%	14.6%	21.4%
	C8E FR2	13.5%	10.9%	29.6%	47.0%	14.3%	-	-
	C8E FR3	14.3%	10.1%	25.0%	49.7%	14.8%	-	-
	C8E (all)	12.4%	9.5%	28.4%	43.7%	13.7%	14.6%	21.4%
	C8W	10.8%	8.6%	24.1%	27.2%	13.6%	37.3%	38.6%
	800 metre stations	12.0%	9.3%	28.0%	39.0%	13.9%	28.6%	29.8%
Reference stations	CB1	12.8%	12.5%	35.4%	38.5%	11.8%	30.7%	33.4%
	CB2	16.6%	11.1%	34.0%	42.0%	16.4%	40.8%	42.5%
	CB3	10.4%	8.2%	25.0%	31.2%	10.2%	29.9%	35.8%
	CB4	17.8%	15.9%	41.0%	43.4%	15.7%	33.3%	35.9%
	CB5	8.9%	10.8%	20.7%	21.9%	8.4%	10.3%	11.6%
	Reference stations	13.6%	11.9%	31.3%	35.0%	12.7%	29.6%	32.6%
Distance-direction Groups	Near-field stations	8.9%	6.8%	21.9%	30.1%	12.1%	22.7%	26.7%
	Far-field stations	13.2%	10.9%	32.1%	36.6%	15.9%	24.9%	29.7%

Tissue Chemistry

Mussel tissue analyses for total metals, chlorinated hydrocarbons, semi-volatile organics, chlorinated phenolics and phthalate esters were conducted by ALS, and analyses for PAHs were conducted by AXYS. Seventeen of the 27 station composite samples were also analyzed by AXYS for tissue concentrations of PCDDs. Results of the DQO failures for the 2010 mussel tissue chemistry data are presented in Golder (2011b). The QA/QC assessment resulted in batch-wide severe failures for hexachloroethane in one batch, and for detected concentrations of bis(2-chloroethyl)ether in all four batches. No other batch-wide severe failures were identified. The substances that did not meet CRD DQOs in 2010 are summarized in Appendix E1. All remaining tissue analysis results passed both laboratory and CRD QA/QC criteria (i.e., analyte spikes, method blanks, laboratory triplicates, field triplicates and standard reference materials) and are presented in Appendix E2.

Several potential substances of interest (SOIs) were screened out based on evaluation of detection frequencies in tissue, e.g. chlorinated hydrocarbons and semi-volatile organics were not detected in any of the tissue samples. Bis(2-ethylhexyl)phthalate, di-n-butyl phthalate and di-n-octyl phthalate were detected at Station C2S only, 2-chlorophenol was detected at Station C4SW only. No other phthalates or phenolics were detected in any other samples.

Distance and Distance-Direction Gradients

Results of statistical comparisons between distance-direction groups (i.e. near-field and far-field) and distance from outfall groups (e.g. 100 m, 200 m) and the Constance Bank reference area are presented in Table 4.27 and Table 4.28 for the 2010 mussel tissue chemistry data. All frequently detected parameters were retained for the assessment, and included 14 metals, 12 PAH parameters, and one PCDD parameter: 1,2,3,4,6,7,8,9-octachlorodibenzodioxin (OCDD). For the PAHs and OCDD, statistical analyses were conducted on both wet weight concentrations and lipid-normalized concentrations. Conventional parameters were also assessed for spatial trends, including moisture and lipid content (both ALS and AXYS results). Spatial gradients are depicted graphically in Figure 4.34 (Golder, 2011b).

Significant differences among distance-direction groups ($p < 0.05$) were identified for all metals with the exception of manganese, selenium and zinc (Figure 4.34). Ten of the 12 PAHs (all PAHs with the exception of anthracene and naphthalene) exhibited significant differences among distance-direction groups on the basis of wet weight concentrations. On the basis of lipid-normalized concentrations, five of the twelve PAHs (acenaphthene, benz(a)anthracene, benzo(a)pyrene, chrysene and fluoranthene) were significantly different among distance-direction groups. For the conventional parameters, moisture content (from ALS data) and lipid content (from ALS and AXYS PAH data) exhibited a significant difference among stations. Neither wet weight nor lipid-normalized OCDD concentrations were significantly different between distance-direction groups and the reference.

Fewer significant differences were observed among distance groups in comparison to the distance-direction groupings (Figure 4.34). Significant differences among distance groups were identified for six metals (arsenic, cadmium, iron, mercury, nickel and silver), and six PAHs (acenaphthene, benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, chrysene, and fluoranthene). When PAHs were lipid-normalized, only one exhibited a significant difference among groups (benz(a)anthracene) (Golder, 2011b). OCDD was not significantly different among distance groups on the basis of wet weight concentrations, but there was a significant difference when the parameter was lipid-normalized. Statistically significant results are discussed in more detail below.

Table 4.27 Clover Point 2010 Mussel Tissue Chemistry: Rank Correlations with Distance-Direction from the Outfall and Statistical Comparisons among Distance-Direction Groupings

Parameter	Rank Correlation with Distance-Direction from Outfall (r_s) ¹	P-values (by Distance-Direction Group) for Comparisons to Reference ^{1,2,3}	
		Near-field	Far-field
Conventionals			
Moisture Content (%) - ALS	0.270	0.074	0.984
Moisture Content (%) - AXYS (PAHs)	0.251	NC	NC
Moisture Content (%) - AXYS (PCDDs)	0.342	NC	NC
Lipid Content (%) - ALS	-0.334	0.051	1.00
Lipid Content (%) - AXYS (PAHs)	-0.564**	0.049*	0.065
Lipid Content (%) - AXYS (PCDDs)	-0.522*	NC	NC
Metals (mg/kg ww)			
Aluminum	0.466*	0.008**	0.865
Arsenic	0.188	0.912	0.020*
Cadmium	0.330	0.359	0.003**
Chromium	0.516**	0.051	0.253
Copper	-0.739**	<0.001**	0.010**
Iron	0.677**	<0.001**	0.003**
Lead	-0.365	<0.001**	0.844
Magnesium	-0.035	0.527	0.132
Manganese	0.104	NC	NC
Mercury	0.442*	0.001**	<0.001**
Nickel	0.597**	0.004**	0.007**
Selenium	0.036	NC	NC
Silver	0.610**	0.051	0.023*
Zinc	-0.075	NC	NC

continued

Table 4.27, continued

Parameter	Rank Correlation with Distance-Direction from Outfall (r_s) ¹	P-values (by Distance-Direction Group) for Comparisons to Reference ^{1,2,3}	
		Near-field	Far-field
PAHs (µg/kg ww)			
Acenaphthene	-0.693**	<0.001**	0.057
Anthracene	-0.179	NC	NC
Benz[a]anthracene	-0.698**	0.068	0.019*
Benzo[a]pyrene	-0.733**	0.051	0.008**
Benzo[b]fluoranthene	-0.640**	0.051	0.050
Benzo[j,k]fluoranthenes	-0.513**	0.051	0.377
Chrysene	-0.599**	0.051	0.110
Fluoranthene	-0.682**	0.068	0.034
Fluorene	-0.302	0.005**	0.749
Naphthalene	-0.195	NC	NC
Phenanthrene	-0.712**	0.167	0.061
Pyrene	-0.666**	0.167	0.121
Total High Molecular Weight PAHs	-0.677**	0.051	0.023*
Total Low Molecular Weight PAHs	-0.547**	0.051	0.331
TOTAL PAHs	-0.649**	0.051	0.042*
PAHs (µg/kg lipid)			
Acenaphthene	-0.534**	0.068	0.251
Anthracene	-0.011	NC	NC
Benz[a]anthracene	-0.456*	0.068	0.931
Benzo[a]pyrene	-0.538**	0.051	0.341
Benzo[b]fluoranthene	-0.096	NC	NC
Benzo[j,k]fluoranthenes	-0.144	NC	NC
Chrysene	-0.249	0.105	1.00
Fluoranthene	-0.479*	0.068	0.789
Fluorene	0.076	NC	NC
Naphthalene	0.365	NC	NC
Phenanthrene	-0.417	NC	NC
Pyrene	-0.483*	NC	NC
Total High Molecular Weight PAHs	-0.431*	0.051	0.999
Total Low Molecular Weight PAHs	-0.059	NC	NC
TOTAL PAHs	-0.313	NC	NC
PCDDs (ng/kg ww)			
OCDD	-0.383	NC	NC
PCDDs (ng/kg lipid)			
OCDD	0.315	NC	NC

Notes¹ Statistical significance (2-tailed): ** = $p < 0.01$; * = $p < 0.05$.² P-values shown include Bonferroni adjustments for multiple comparisons applicable.³ NC = Not calculated; no comparison made as ANOVA (or non parametric Kruskal-Wallis test) was not significant.

Table 4.28 Clover Point 2010 Mussel Tissue Chemistry: Rank Correlations with Distance from the Outfall and Depth, and Statistical Comparisons to Constance Bank Reference

Parameter	Correlation with Distance from Outfall (r_s)	Correlation with Depth (r_s)	P-values (by Distance Group) for Comparisons to Reference ^{1,2,3,4}			
			100 m	200 m	400 m	800 m
Conventionals						
Moisture Content (%) - ALS	0.180	0.028	NC	NC	NC	NC
Moisture Content (%) - AXYS (PAHs)	0.178	-0.142	NC	NC	NC	NC
Moisture Content (%) - AXYS (PCDDs)	0.347	-0.231	NC	NC	NC	NC
Lipid Content (%) - ALS	-0.260	0.086	NC	NC	NC	NC
Lipid Content (%) - AXYS (PAHs)	-0.515**	-0.033	0.145	<0.001**	0.416	1.00
Lipid Content (%) - AXYS (PCDDs)	-0.477	-0.083	0.725	0.006**	0.624	1.00
Metals (mg/kg ww)						
Aluminum	0.421*	-0.246	NC	NC	NC	NC
Arsenic	0.199	0.093	0.205	0.986	0.010*	0.392
Cadmium	0.478*	0.153	0.018*	0.401	0.025*	0.211
Chromium	0.430*	-0.157	NC	NC	NC	NC
Copper	-0.594**	0.171	NC	NC	NC	NC
Iron	0.510**	-0.391*	0.012*	0.036*	0.054	0.155
Lead	-0.253	0.198	NC	NC	NC	NC
Magnesium	0.117	-0.238	NC	NC	NC	NC
Manganese	0.215	-0.281	NC	NC	NC	NC
Mercury	0.445*	0.437*	<0.001**	<0.001**	<0.001**	0.008**
Nickel	0.478*	-0.018	0.007**	0.255	0.006**	0.168
Selenium	0.075	0.186	NC	NC	NC	NC
Silver	0.495**	0.085	0.005**	0.030*	0.038*	0.088
Zinc	-0.002	0.026	NC	NC	NC	NC
PAHs (µg/kg ww)						
Acenaphthene	-0.608**	-0.061	0.027*	0.017*	0.384	0.807
Anthracene	-0.260	0.242	NC	NC	NC	NC
Benz[a]anthracene	-0.852**	0.046	0.033*	0.076	0.220	1.00
Benzo[a]pyrene	-0.800**	0.052	0.018*	0.036*	0.469	0.485
Benzo[b]fluoranthene	-0.718**	-0.040	0.018*	0.178	0.805	1.00
Benzo[j,k]fluoranthenes	-0.530**	0.138	NC	NC	NC	NC
Chrysene	-0.738**	-0.007	0.037*	0.178	1.00	1.00
Fluoranthene	-0.802**	-0.044	0.033*	0.042*	1.00	1.00
Fluorene	-0.208	0.149	NC	NC	NC	NC

continued

Table 4.28, continued

Parameter	Correlation with Distance from Outfall (r_s)	Correlation with Depth (r_s)	P-values (by Distance Group) for Comparisons to Reference ^{1,2,3,4}			
			100 m	200 m	400 m	800 m
Naphthalene	0.026	0.224	NC	NC	NC	NC
Phenanthrene	-0.787**	0.017	NC	NC	NC	NC
Pyrene	-0.744**	-0.095	NC	NC	NC	NC
Total High Molecular Weight PAHs	-0.802**	0.032	0.018*	0.042*	1.00	0.981
Total Low Molecular Weight PAHs	-0.504**	0.215	NC	NC	NC	NC
TOTAL PAHs	-0.779**	0.058	0.018*	0.178	0.577	1.00
PAHs (µg/kg lipid)						
Acenaphthene	-0.431*	0.176	NC	NC	NC	NC
Anthracene	-0.089	0.309	NC	NC	NC	NC
Benz[a]anthracene	-0.579**	0.179	0.056	1.00	1.00	1.00
Benzo[a]pyrene	-0.562**	0.309	NC	NC	NC	NC
Benzo[b]fluoranthene	-0.152	0.191	NC	NC	NC	NC
Benzo[j,k]fluoranthenes	-0.133	0.204	NC	NC	NC	NC
Chrysene	-0.230	0.254	NC	NC	NC	NC
Fluoranthene	-0.535**	0.154	NC	NC	NC	NC
Fluorene	0.152	0.191	NC	NC	NC	NC
Naphthalene	0.426*	0.359	NC	NC	NC	NC
Phenanthrene	-0.418	0.184	NC	NC	NC	NC
Pyrene	-0.568*	-0.020	NC	NC	NC	NC
Total High Molecular Weight PAHs	-0.520*	0.229	0.113	1.00	1.00	1.00
Total Low Molecular Weight PAHs	-0.044	0.330	NC	NC	NC	NC
TOTAL PAHs	-0.312	0.291	NC	NC	NC	NC
PCDDs (ng/kg ww)						
OCDD	-0.388	0.165	NC	NC	NC	NC
PCDDs (ng/kg lipid)						
OCDD	0.319	0.005	0.908	0.044*	0.990	0.193

Notes¹ Statistical significance (2-tailed): ** = $p < 0.01$; * = $p < 0.05$.² P-values shown include Bonferroni adjustments for multiple comparisons applicable.³ NC = Not calculated; no comparison made as ANOVA (or non parametric Kruskal-Wallis test) was not significant.⁴ Comparisons of C0 vs reference could not be made as only one sample was available at C0

Metals

Copper and lead exhibited significant differences ($p < 0.001$, Table 4.27) between near-field stations and the reference stations. Average copper and lead concentrations were significantly higher in the near-field in comparison to the reference area (Figure 4.34). There was also a significant difference between the concentrations of copper in the far-field in comparison with reference. No significant differences were observed in copper or lead concentrations when stations were grouped by distance alone. The spatial profiles of these metals were indicative of an exposure pattern attributable to the influence of the Clover Point outfall (i.e., the outfall is one source of these metals in the environment) (Golder, 2011b).

Aluminum, iron, mercury, and nickel were significantly lower in the near-field compared to reference ($p < 0.01$, Table 4.27). Concentrations of iron, mercury and nickel were also significantly lower at far-field stations compared to reference (Figure 4.34, Table 4.27), and were significantly lower than reference at several of the individual distance groups. Arsenic, cadmium and silver exhibited significantly lower concentrations at far-field stations compared to the reference stations. Arsenic concentrations at the 400m stations were significantly lower in comparison with the reference area. Cadmium concentrations were significantly lower than reference at each of the 100m and 400m distance groups, and silver concentrations were significantly lower at each of the 100m, 200m and 400m distance groups in comparison with reference (Table 4.28).

Reverse gradients (i.e., an increase in concentration with distance from the outfall) have been frequently observed in previous sampling years. They can be partly attributed to growth dilution, meaning that tissue weight increased more rapidly than the rate of uptake of a particular substance and is usually the result of enhanced food availability (Balogh *et al.*, 1994; Brix *et al.*, 1985).

Results were similar to those from previous assessments (Golder, 2009b; Golder, 2010b), with elevated copper and lead concentrations observed in the near-field in comparison to reference, and lower concentrations observed for silver in the near-field in comparison to far-field and reference.

Polycyclic Aromatic Hydrocarbons (PAHs) and Polychlorinated Dibenzo-p-dioxins (PCDDs)

Only four of twelve individual PAHs exhibited significant differences between at least one of the distance-direction groups and reference (acenaphthene, benz(a)anthracene, benzo(a)pyrene, and fluorene). Average concentrations of acenaphthene and fluorene were significantly higher in the near-field compared to reference ($p < 0.01$, Table 4.27), whereas benz(a)anthracene and benzo(a)pyrene were significantly higher in the far-field compared to reference ($p < 0.05$, Table 4.27). Figure 4.34 shows that concentrations of individual PAHs were generally highest at the near-field stations and lowest at the reference stations. A greater number of significant differences were observed when stations were grouped by distance from the outfall, and all significant differences occurred between the reference area and one or both of the 100m and the 200m distance groups (Table 4.28). In all cases, the PAH concentrations were significantly higher compared to the reference. This suggests that the influence of the outfall was associated more with distance rather than a combined effect of distance and direction. This conflicts with the observations of the previous assessment (Golder, 2010b), which found that the influence of the outfall was associated with both distance and direction from the outfall rather than distance alone (Golder, 2011b).

PAHs tend to partition to the lipid fraction of tissue samples. AXYS (PAH and PCDD) lipid content data and ALS lipid content data from the 2010 sampling event are depicted in a boxplot by distance groups in Figure 4.35. To further evaluate the effects of lipids on PAH concentrations, the same statistics were conducted on the lipid-normalized PAH concentrations (Figure 4.36, Table 4.27 and Table 4.28). No significant differences between distance-direction groupings and reference were observed for the lipid-normalized PAHs. Similarly there were no significant differences in lipid-normalized PAH concentrations between the distance groupings and reference. The lack of statistically significant differences is partly attributable to the trend in lipid content (Figures 4.34 D-F) with distance from the outfall. When the higher lipid contents near the outfall are taken into account, the trends in PAH gradients are much weaker than for wet weight data (Golder, 2011b).

No significant differences were identified between the distance-direction groupings and the reference area for concentrations of either OCDD or lipid-normalized OCDD (Table 4.27, and Figures 4.34 JJ and 4.36 P). Concentrations of lipid-normalized OCDD were significantly lower at the 200m distance grouping compared with the reference area (Table 4.28); no significant differences were identified between any of the distance groups and the reference area for OCDD concentrations before lipid normalization (Golder, 2011b).

Many factors (i.e., physiological or seasonal) can affect the concentrations of substances in mussels. Shulkin and Kavun (1995) found that tissue concentrations in various molluscs (*Mizuchopecten yessoensis*, *Crenomytilus grayanus* and *Modiolus kurilensis*) were dependent upon seasonal variations in filtration rates for some metals and on physiological state for other metals. Gutierrez-Galindo et al. (1999) found that concentrations were independent of horse mussel size and that some metals tended to accumulate in smaller organisms, while other metals had higher concentrations in medium to large organisms. Gutierrez-Galindo et al. (1999) also observed that horse mussels accumulated cadmium, copper and manganese at rates three times higher than *Mytilus californianus*. Growth dilution and seasonality are two factors that could explain the patterns of metal/organic distribution around the outfall.

Like those observed for the biological metrics, the tissue chemistry spatial patterns for distance-direction groupings were similar to those for distance groupings. However, in general, more significant spatial correlations were observed with the distance-direction groupings. These patterns confirm that the spatial extent of tissue contamination was limited, and was primarily constrained to 200 m from the Clover Point outfall in an easterly direction (i.e., the near-field group).

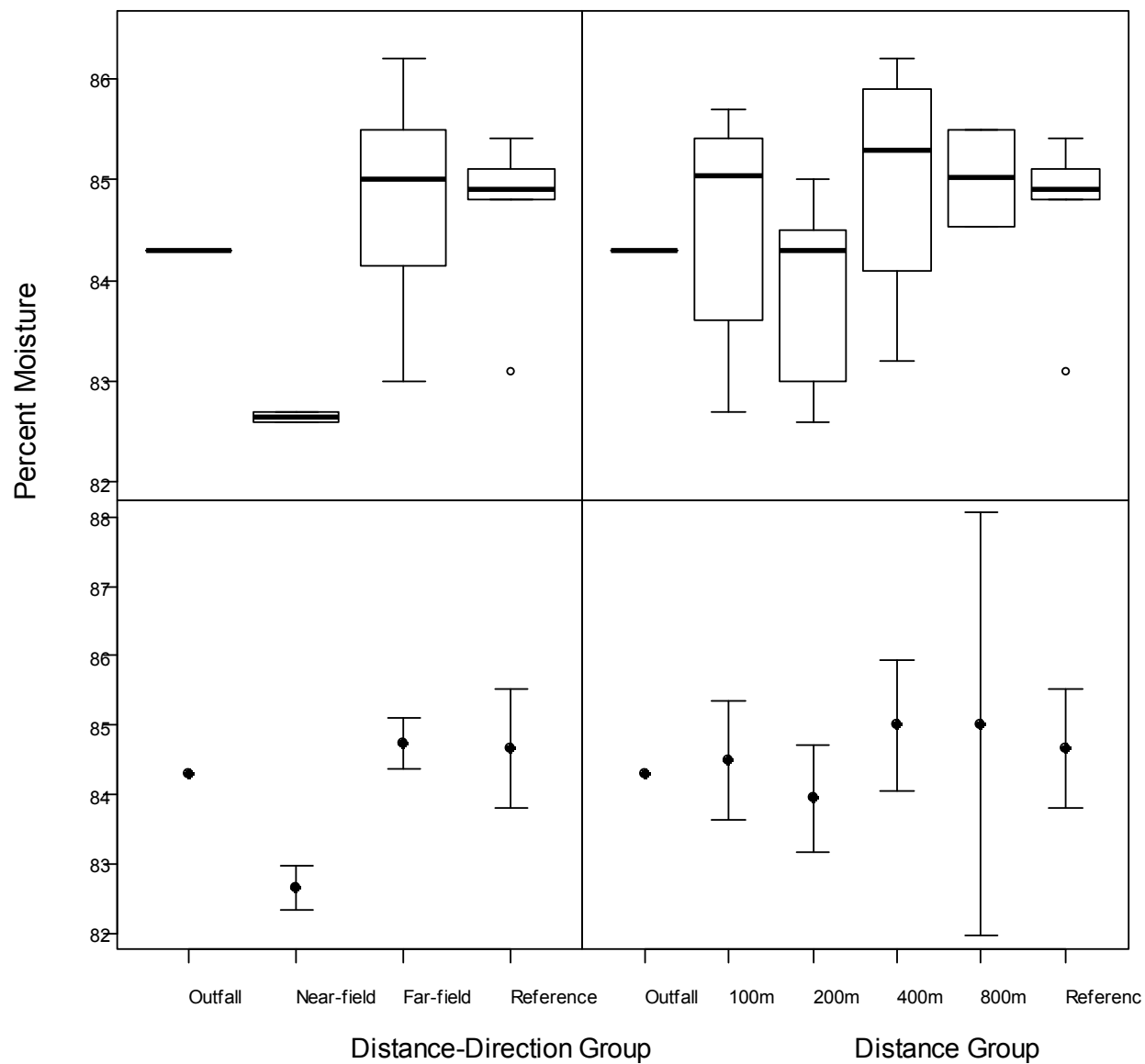


Figure 4.34 Box and Whisker Plots (Top Panel) and Means $\pm$ 95% Confidence Intervals (Bottom Panel) for 2010 Mussel Tissue Chemistry Parameters

a) Moisture (ALS)

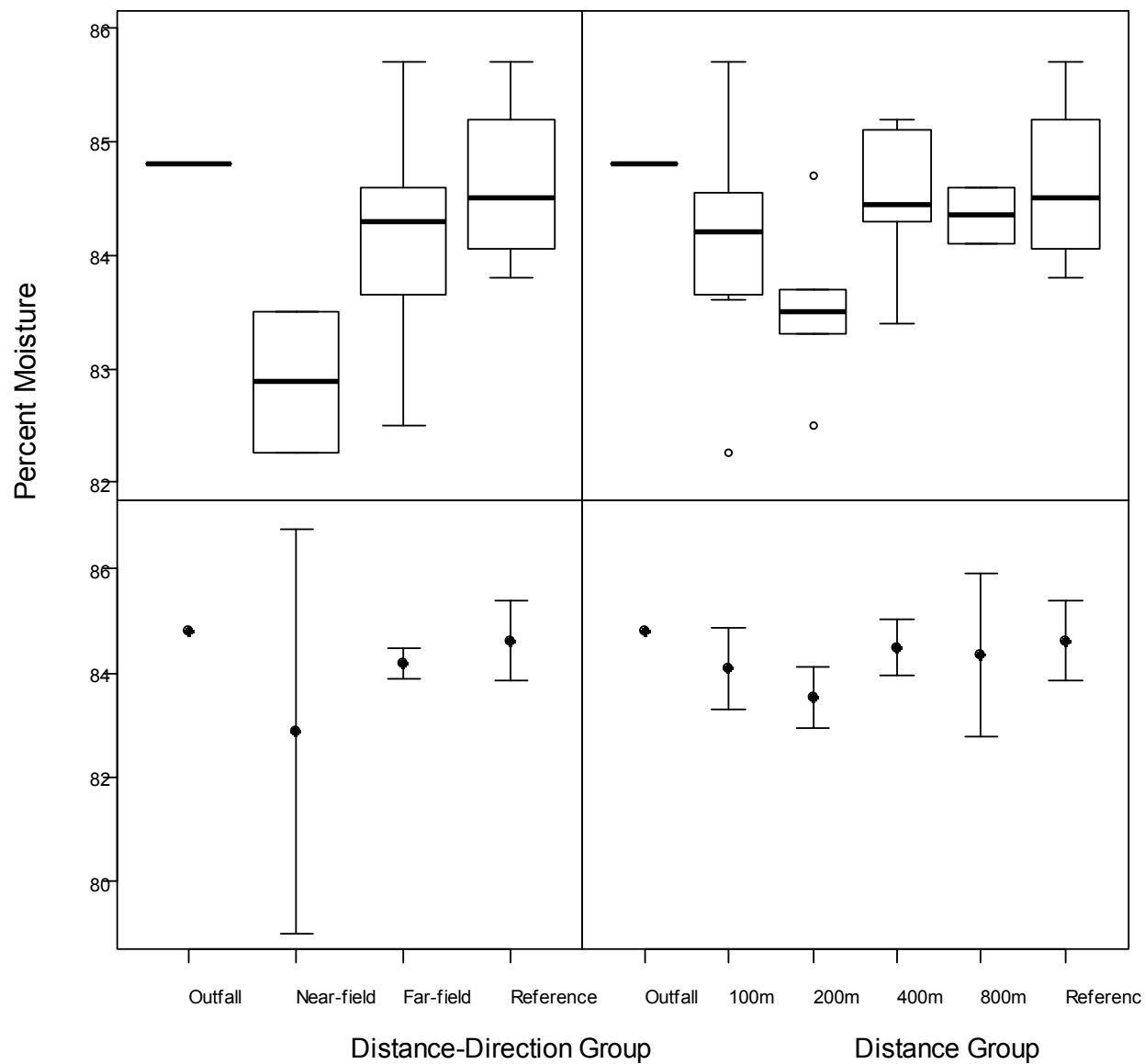


Figure 4.34, continued

b) Moisture (AXYS—associated with PAH analyses)

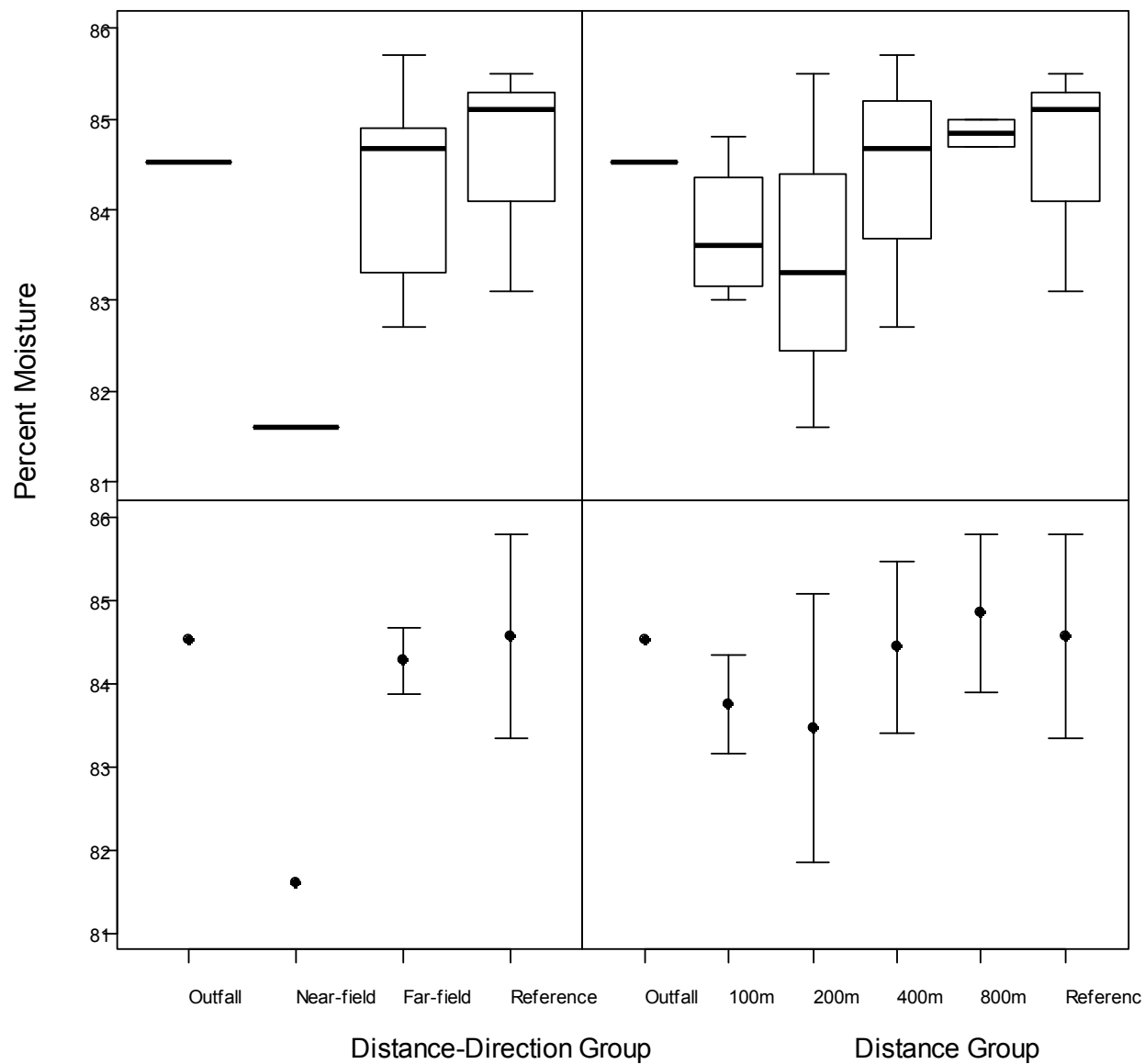


Figure 4.34, continued

c) Moisture (AXYS—associated with OCDD analyses)

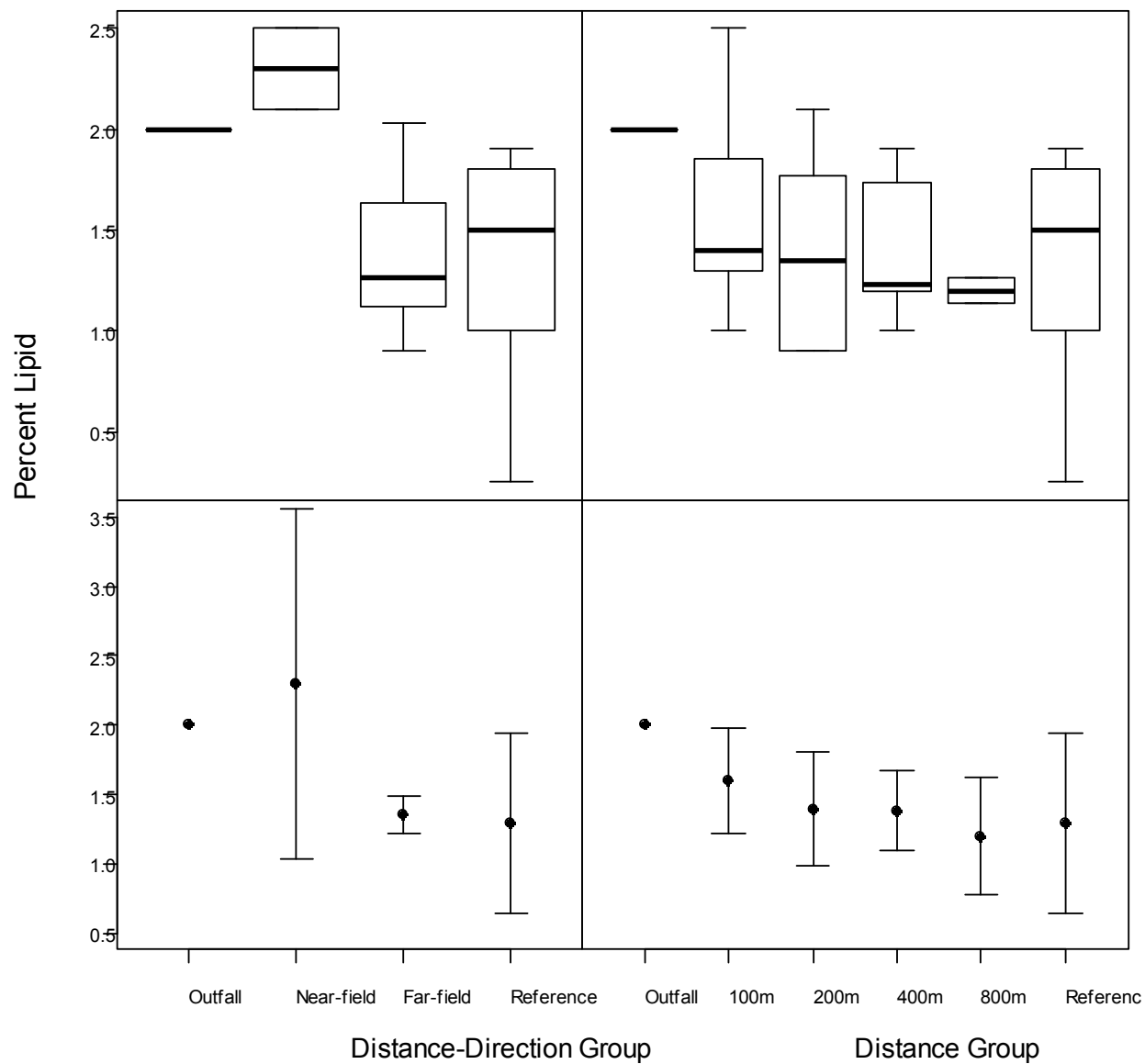


Figure 4.34, continued

d) Lipid (ALS)

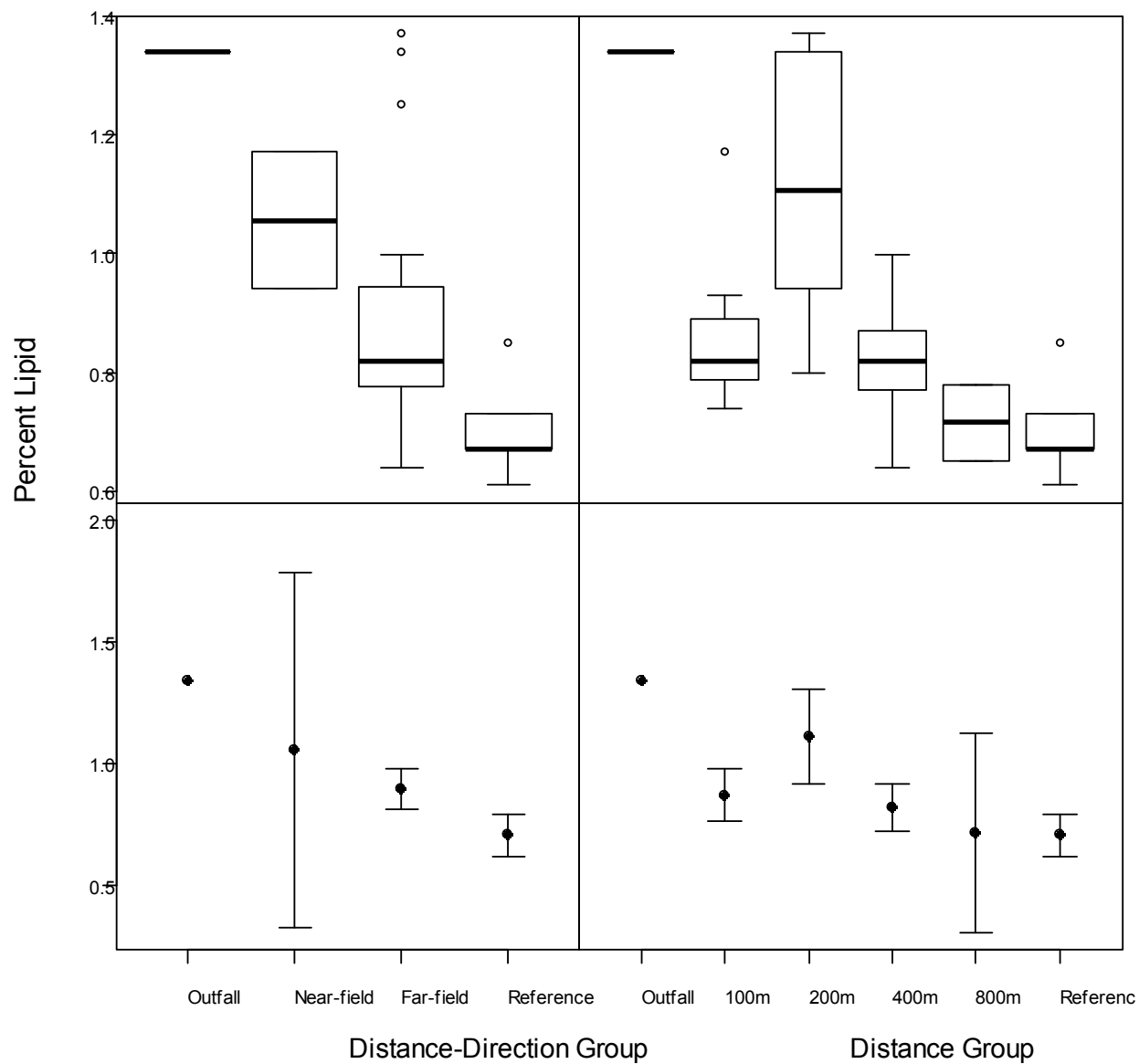


Figure 4.34, continued

e) Lipid (AXYS—associated with PAH analyses)

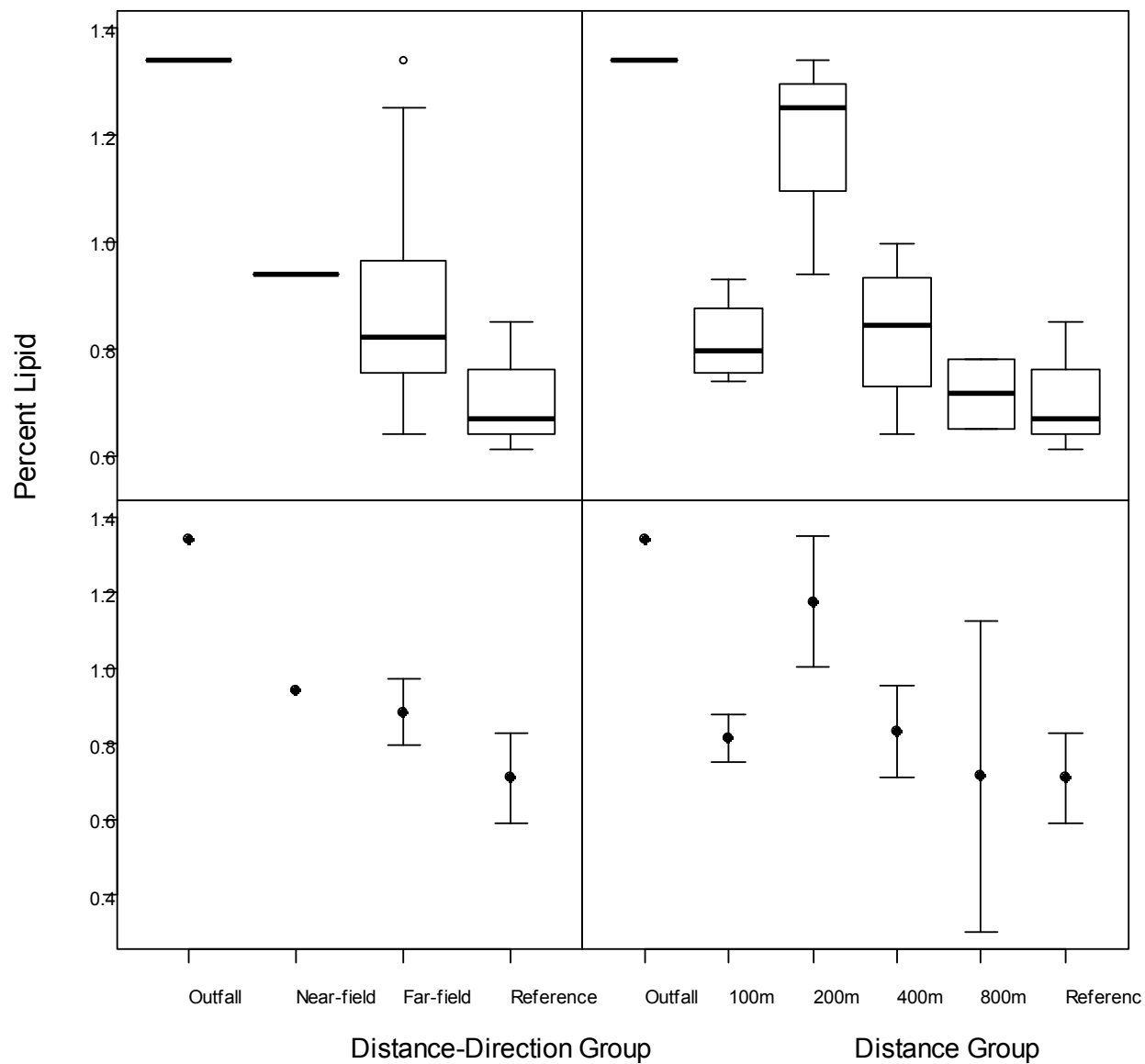


Figure 4.34, continued

f) Lipid (AXYS—associated with PCDD analyses)

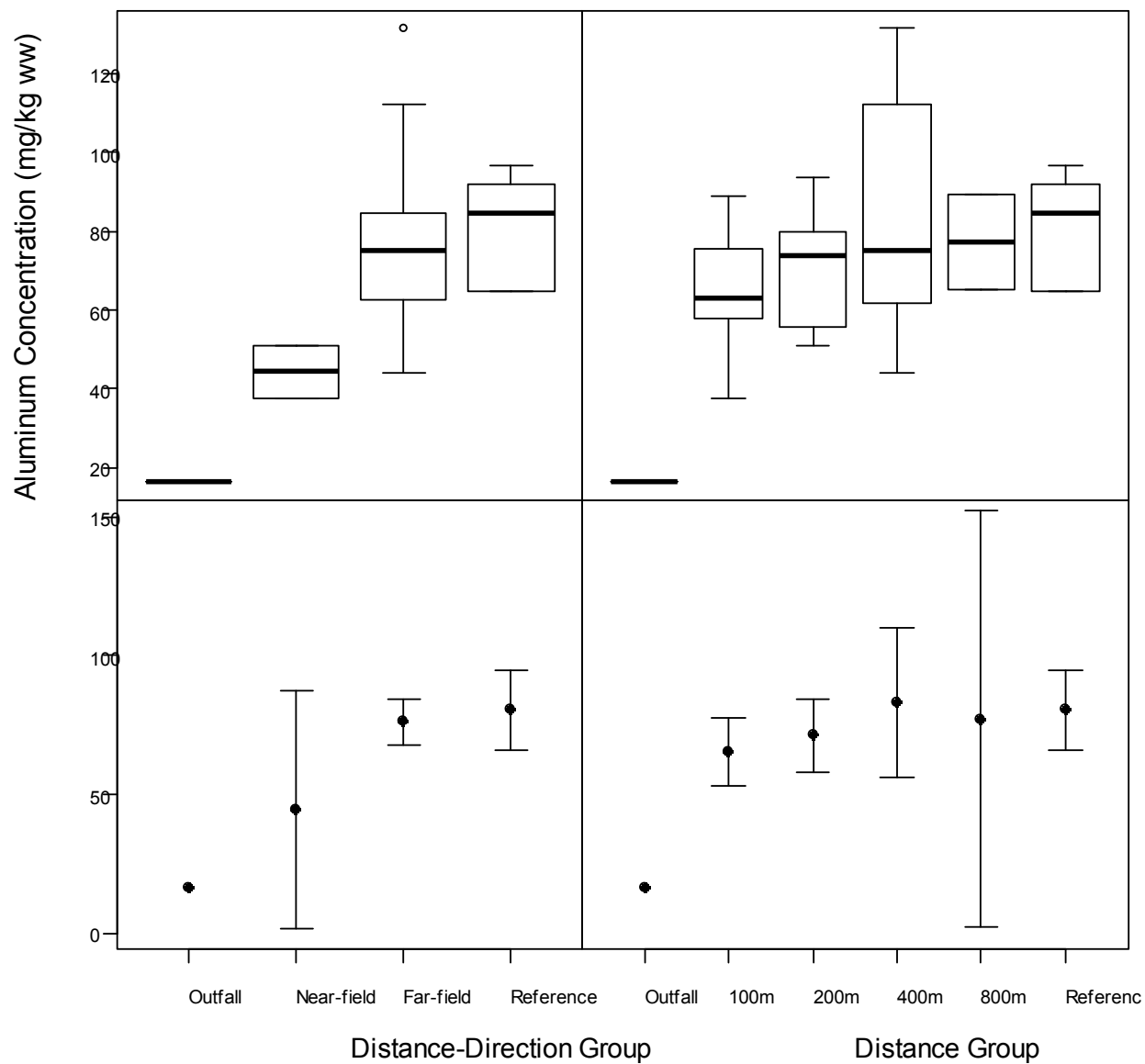


Figure 4.34, continued

g) Aluminum

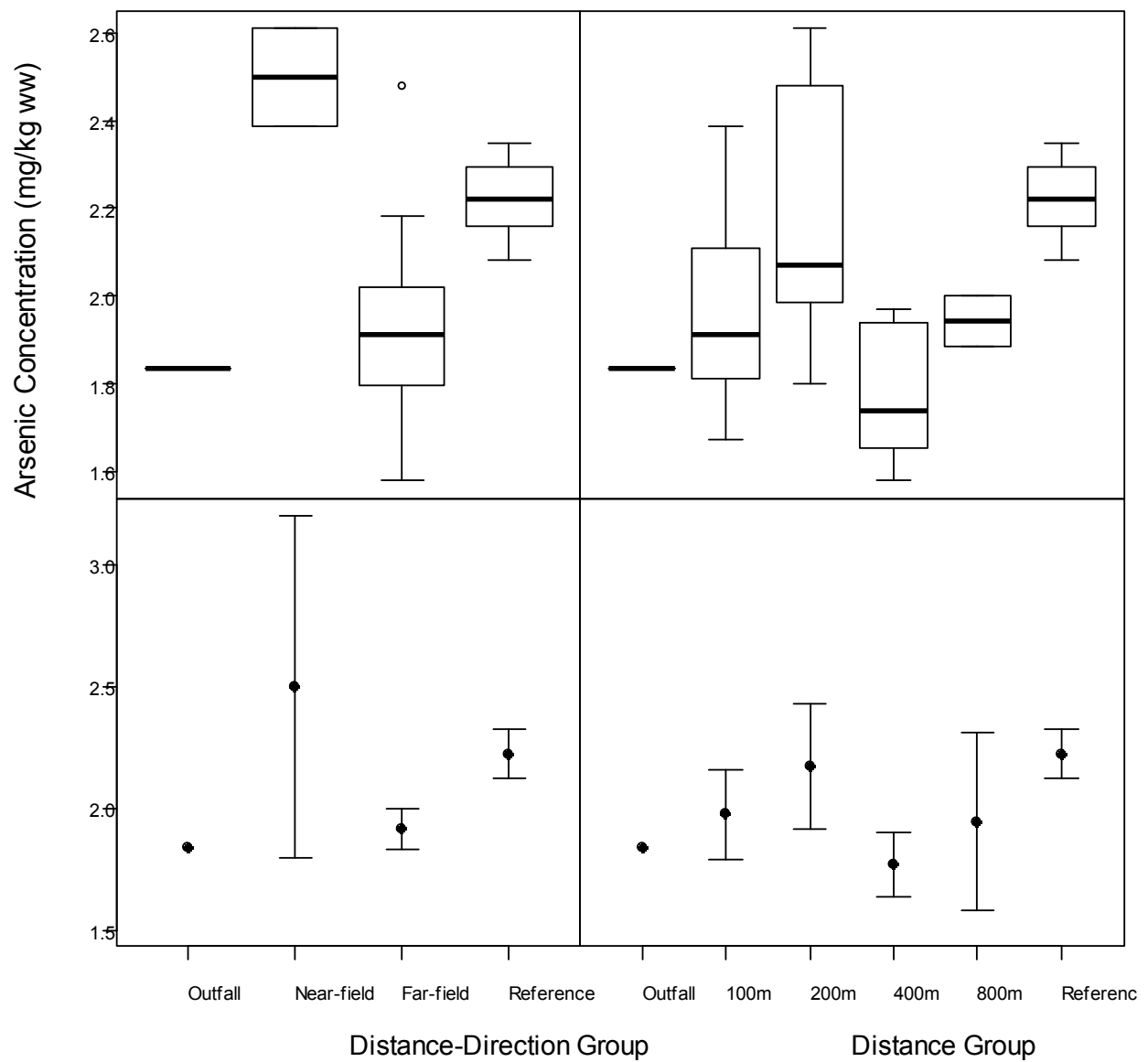


Figure 4.34, continued

h) Arsenic

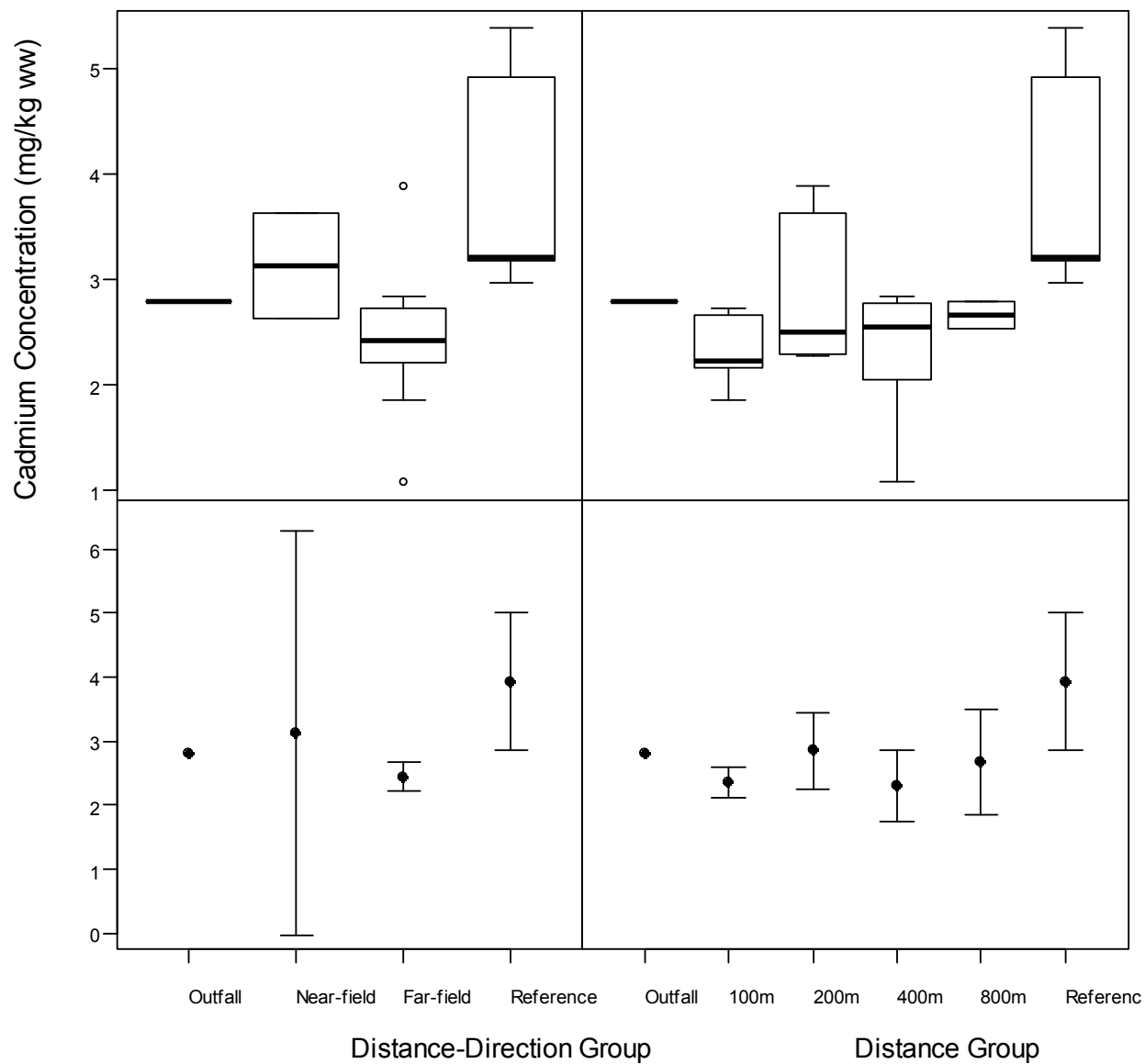


Figure 4.34, continued

i) Cadmium

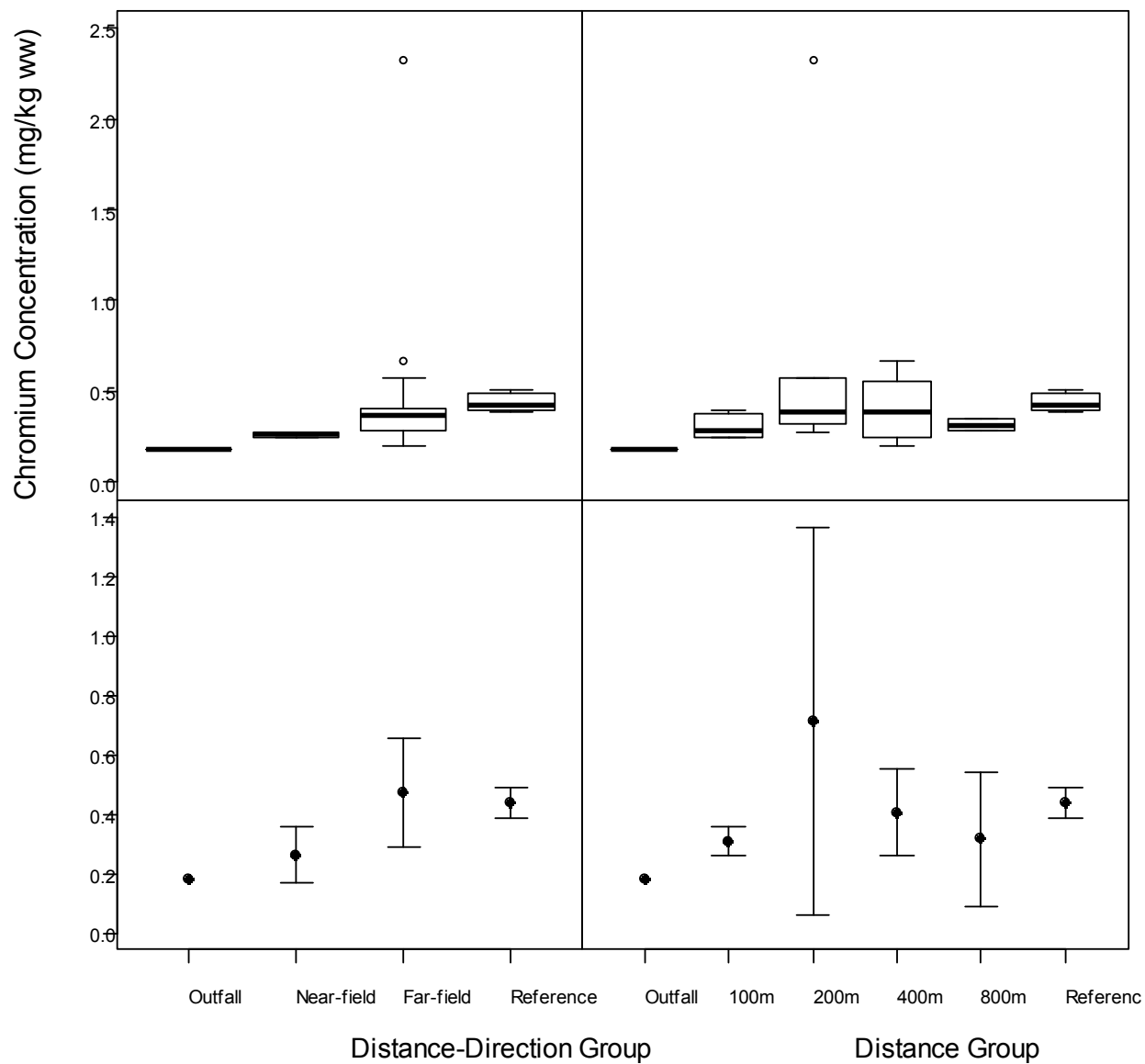


Figure 4.34, continued

j) Chromium

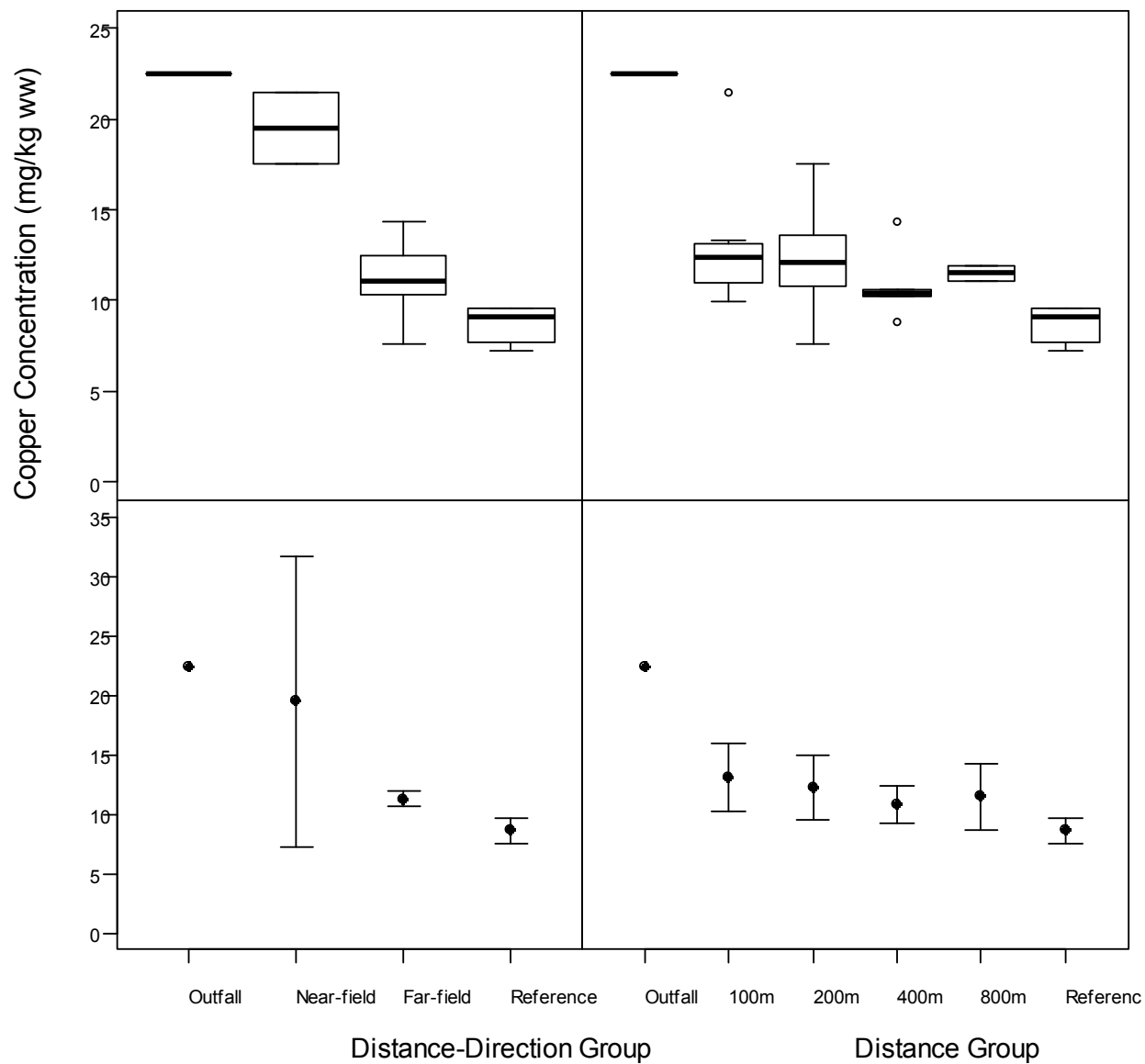


Figure 4.34, continued

k) Copper

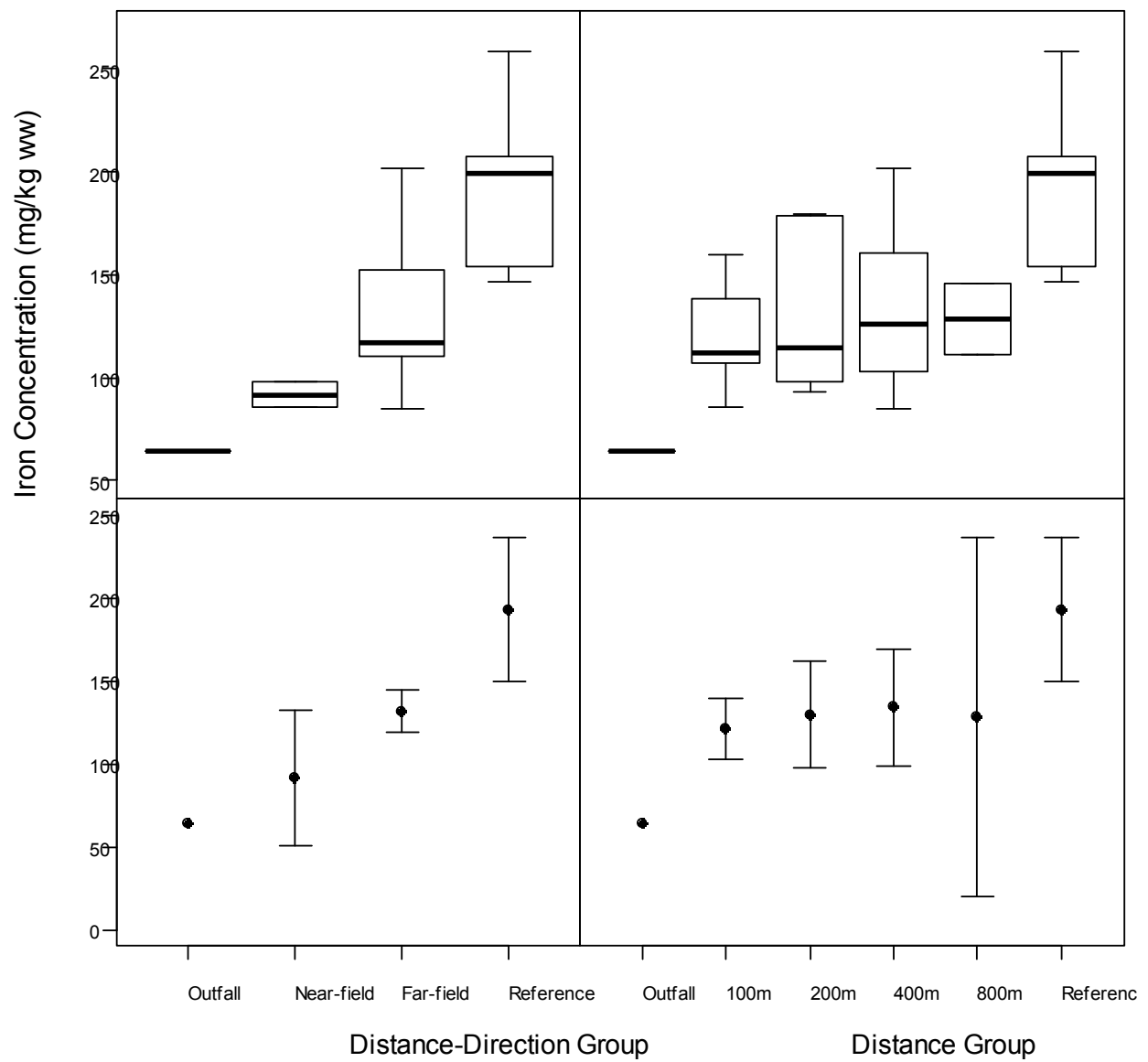


Figure 4.34, continued

I) Iron

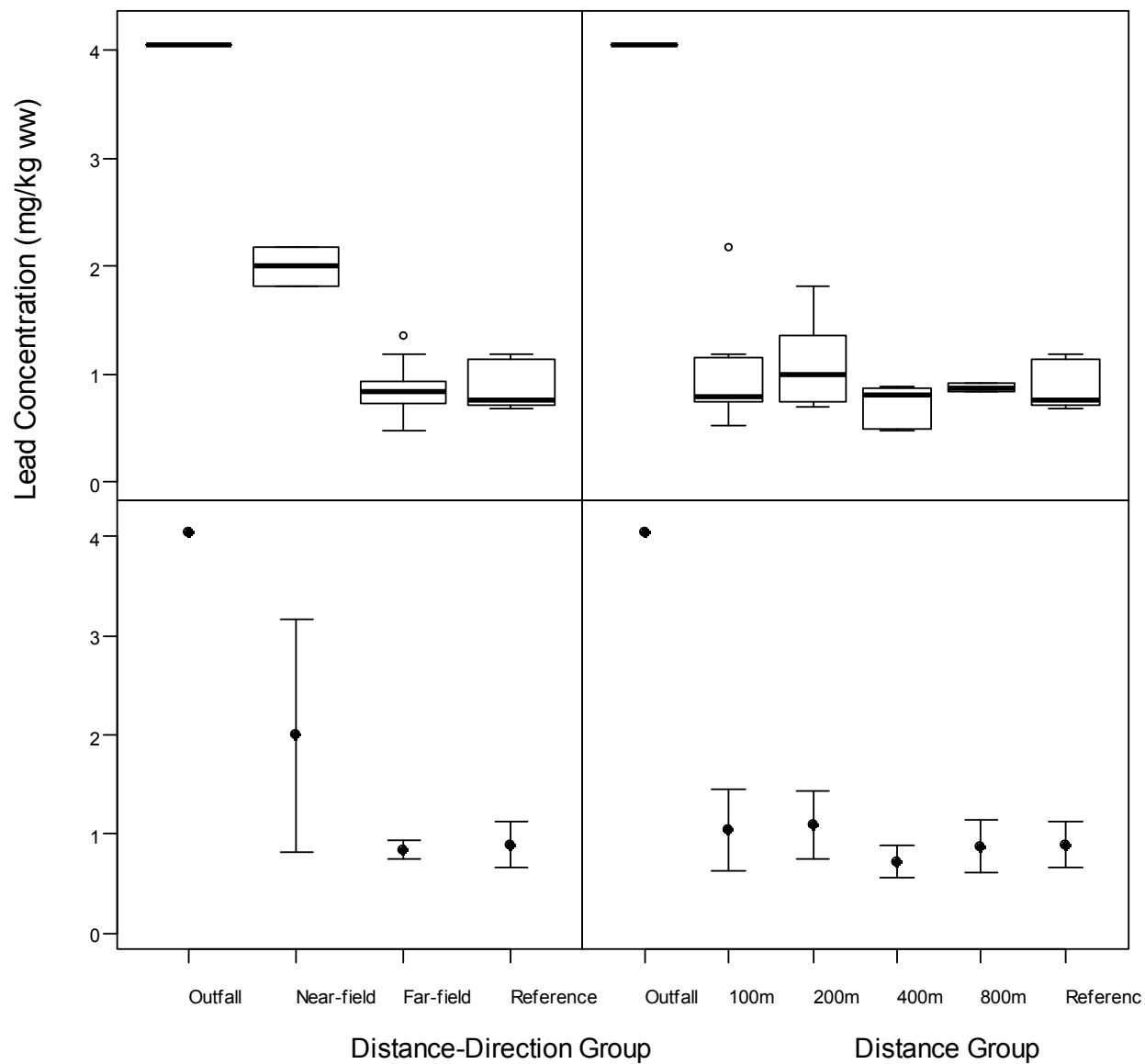


Figure 4.34, continued

m) Lead

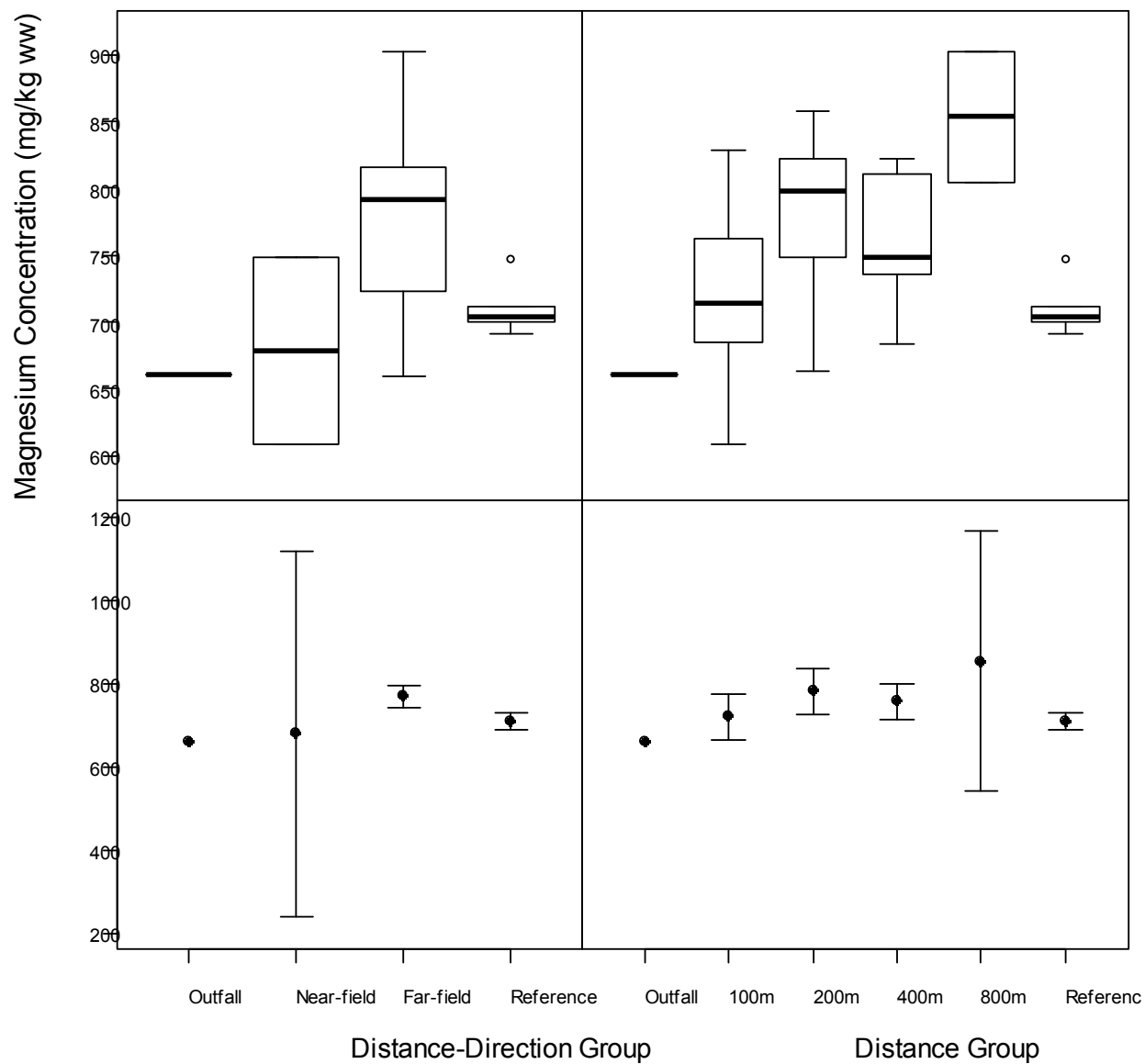


Figure 4.34, continued

n) Magnesium

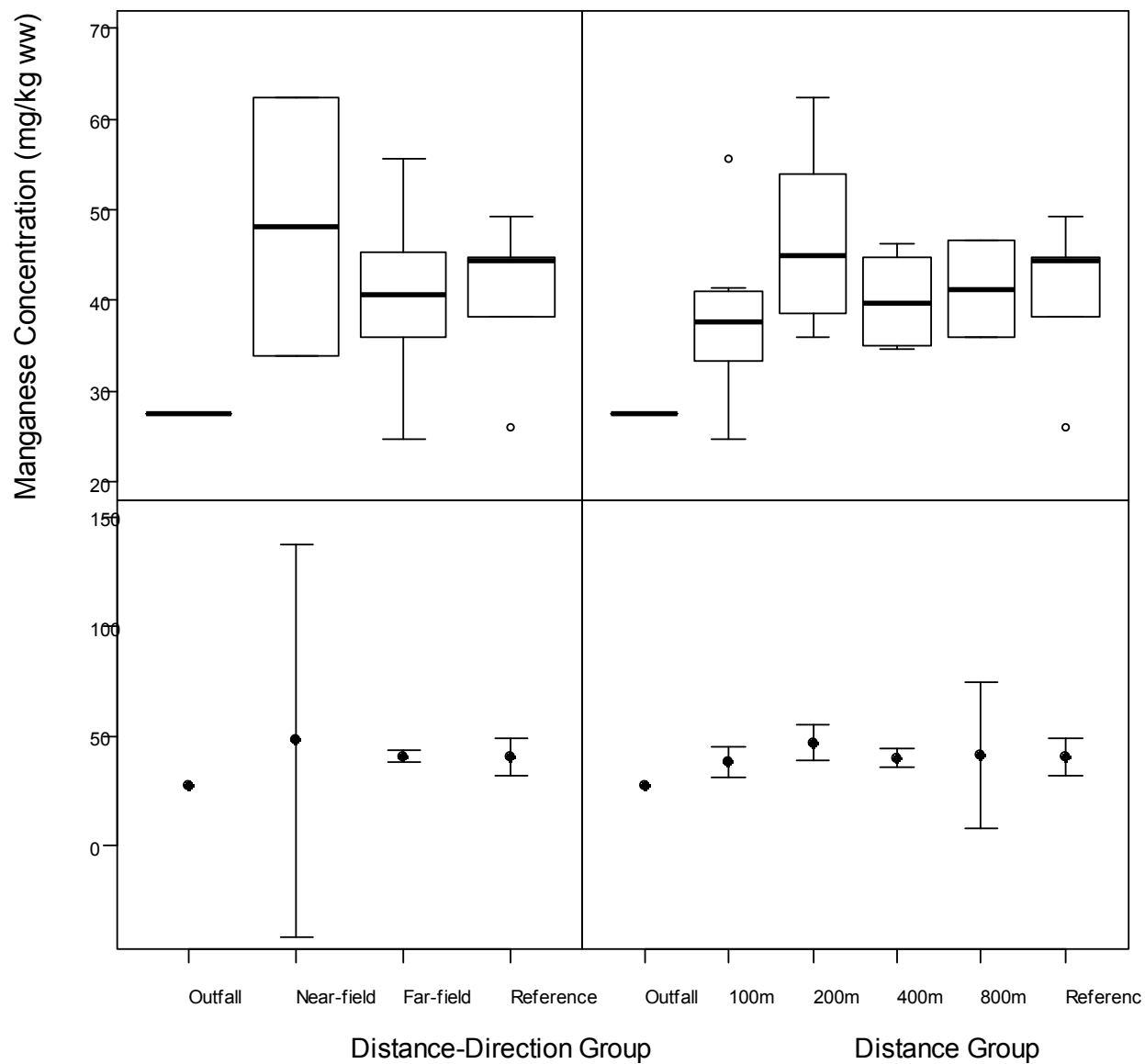


Figure 4.34, continued

o) Manganese

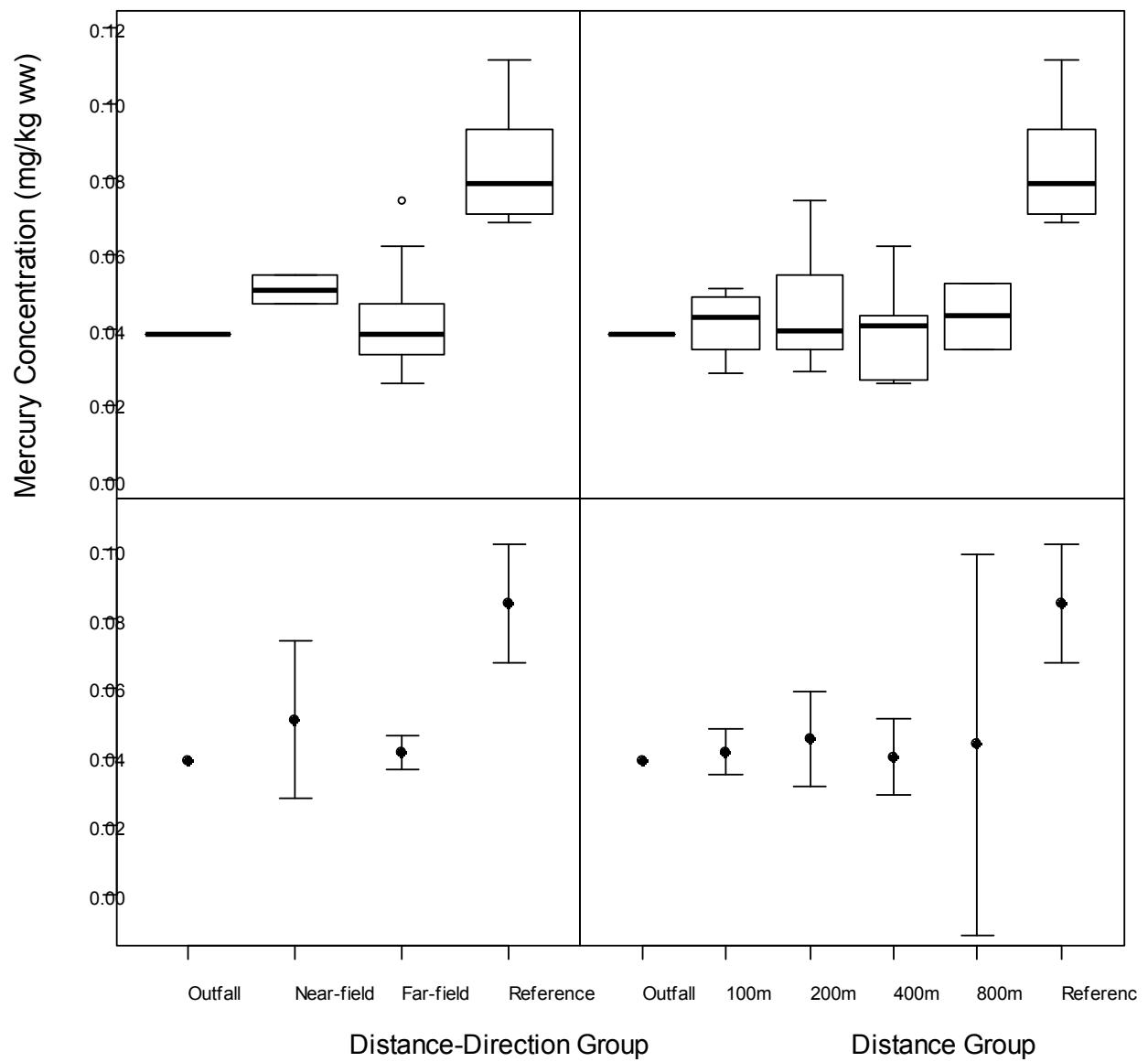


Figure 4.34, continued

p) Mercury

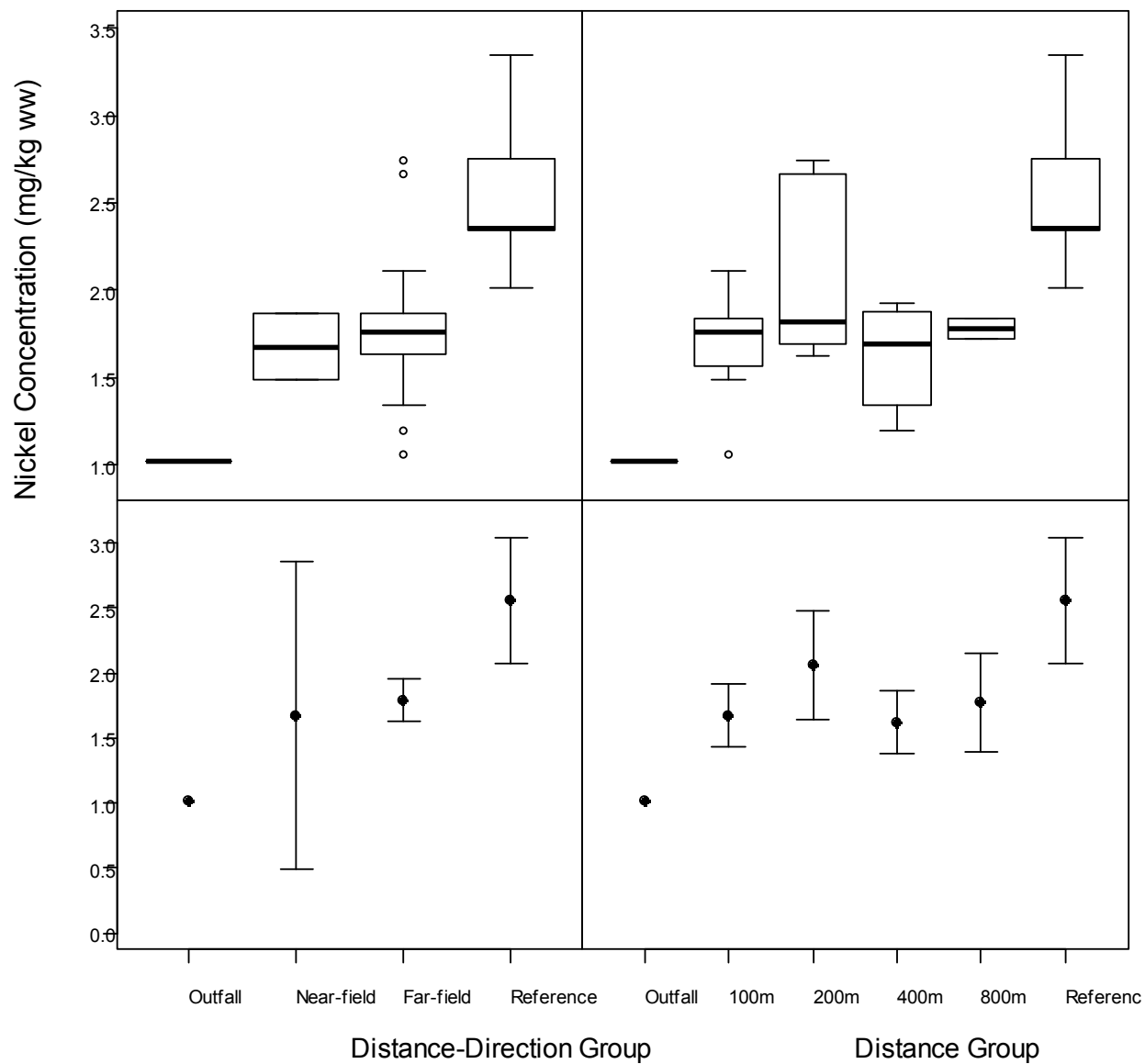


Figure 4.34, continued

q) Nickel

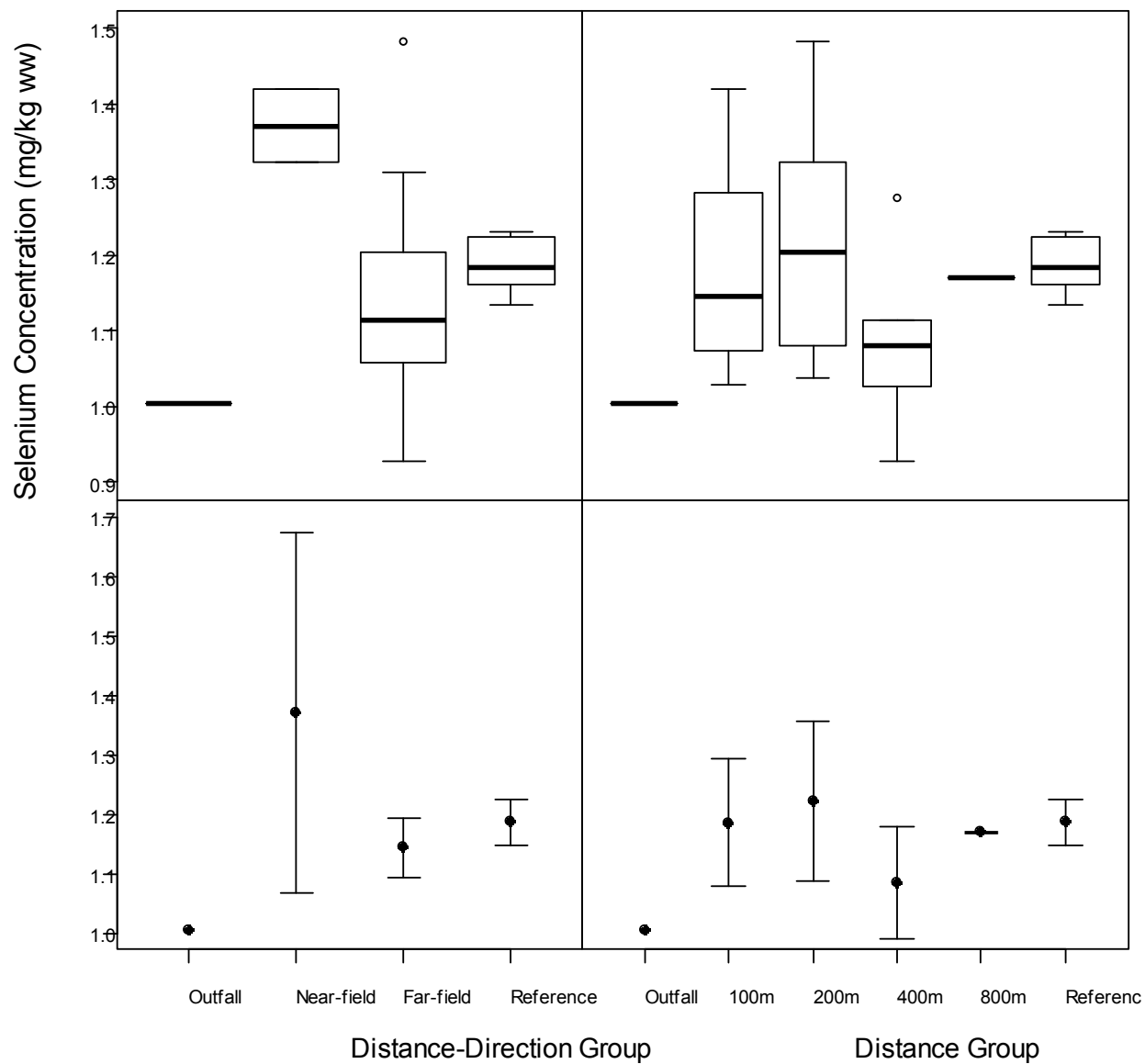


Figure 4.34, continued

r) Selenium

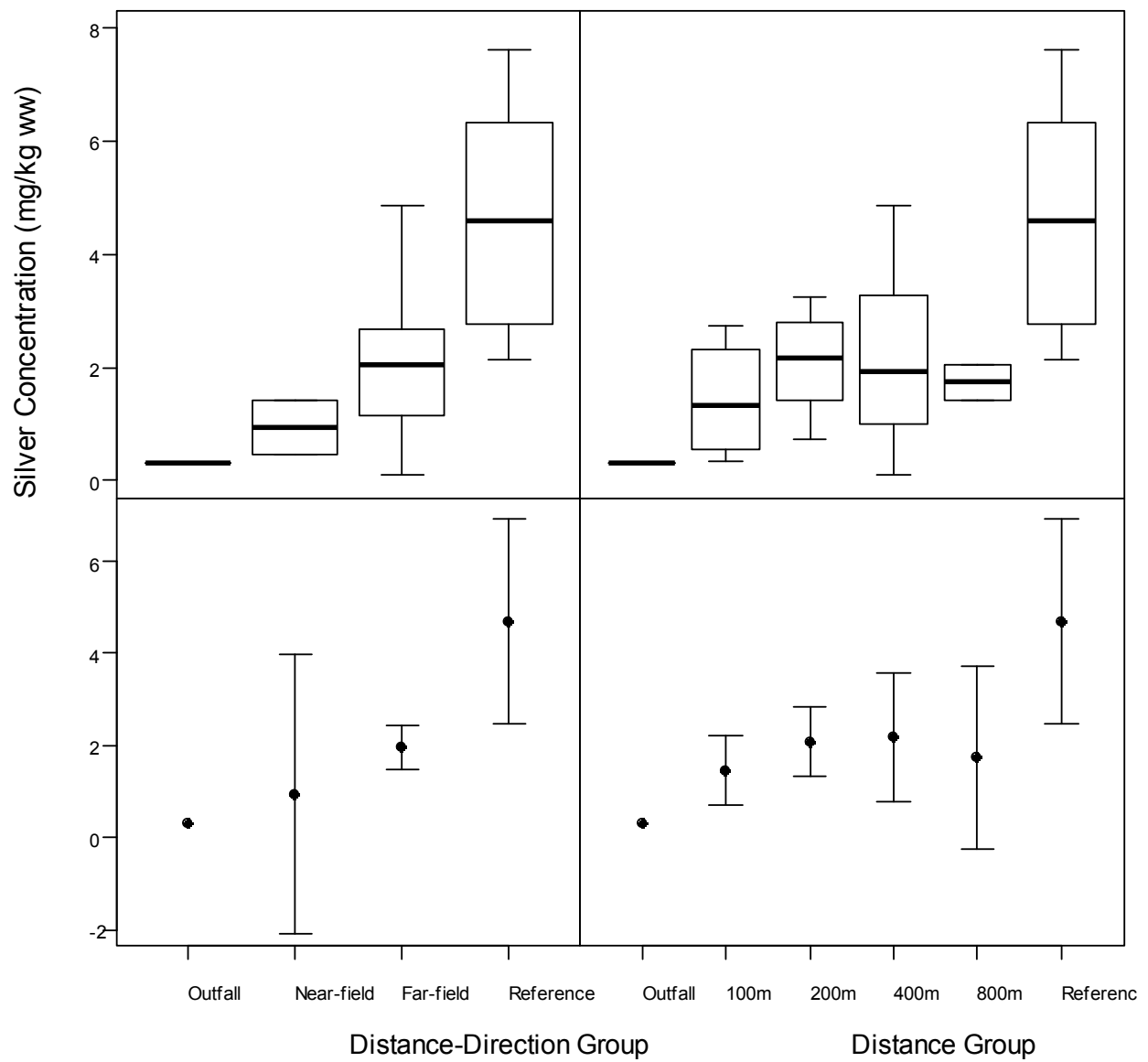


Figure 4.34, continued

s) Silver

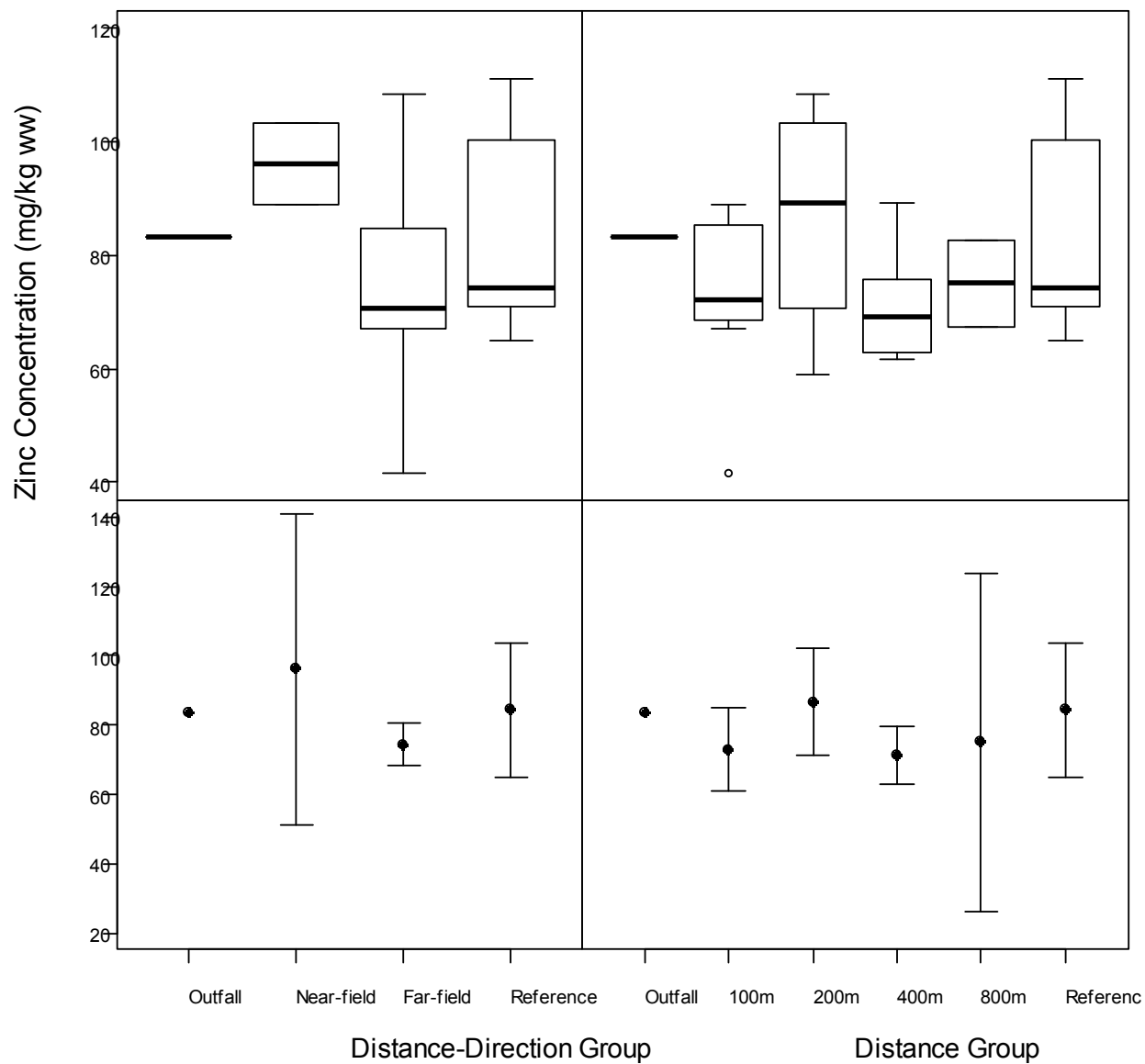


Figure 4.34, continued

t) Zinc

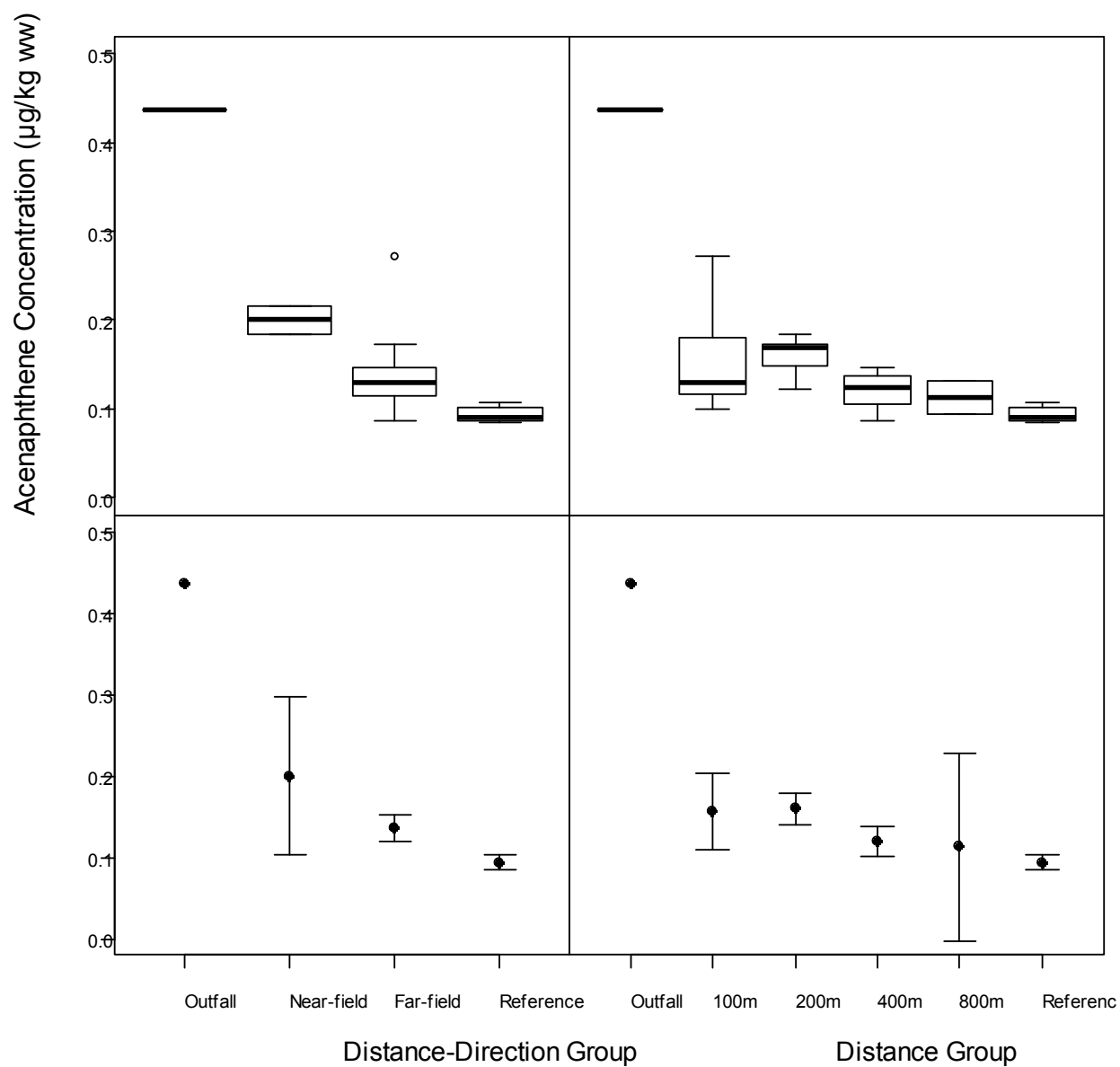


Figure 4.34, continued

u) Acenaphthene

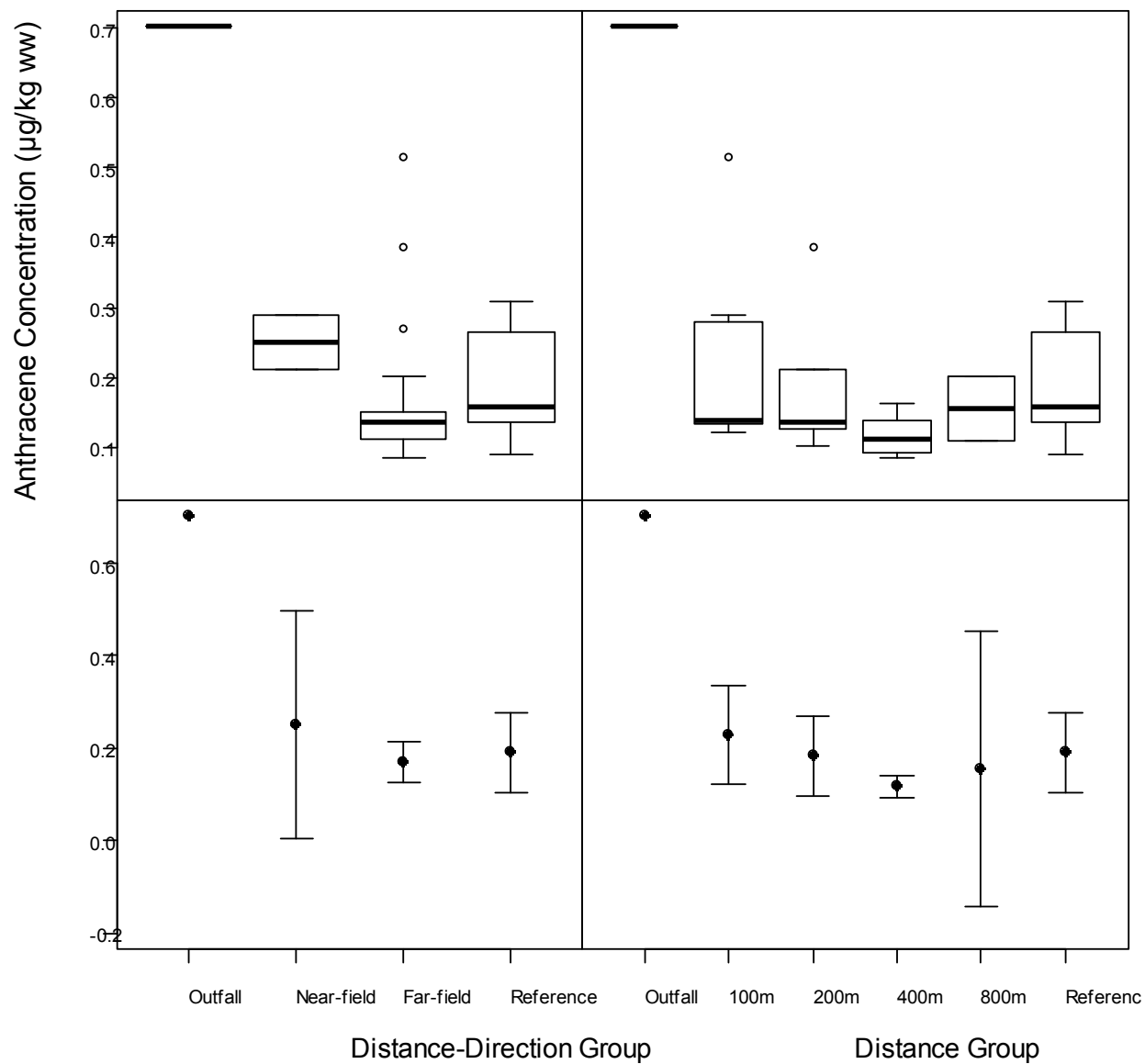


Figure 4.34, continued

v) Anthracene

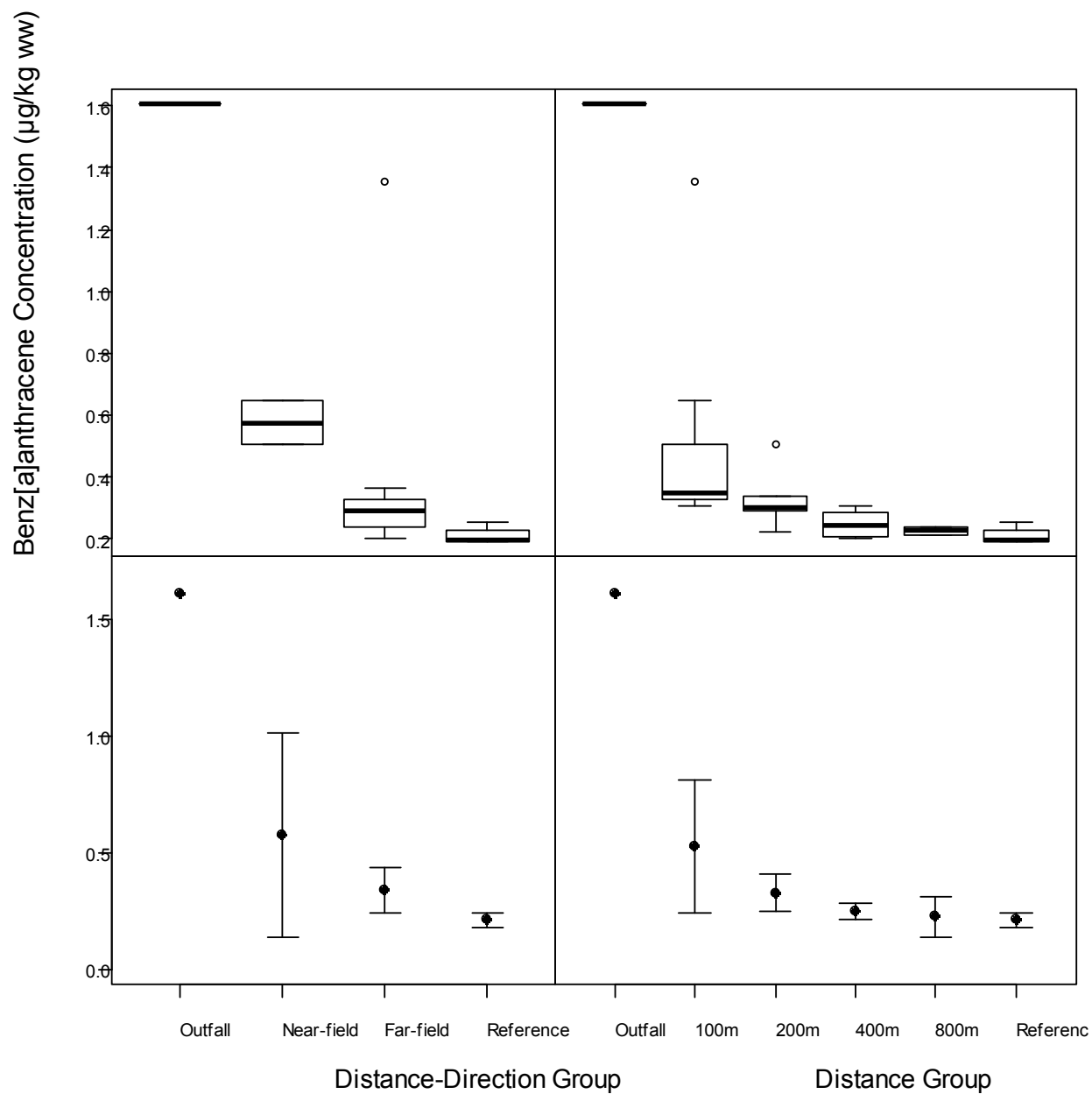


Figure 4.34, continued

w) Benz[a]anthracene

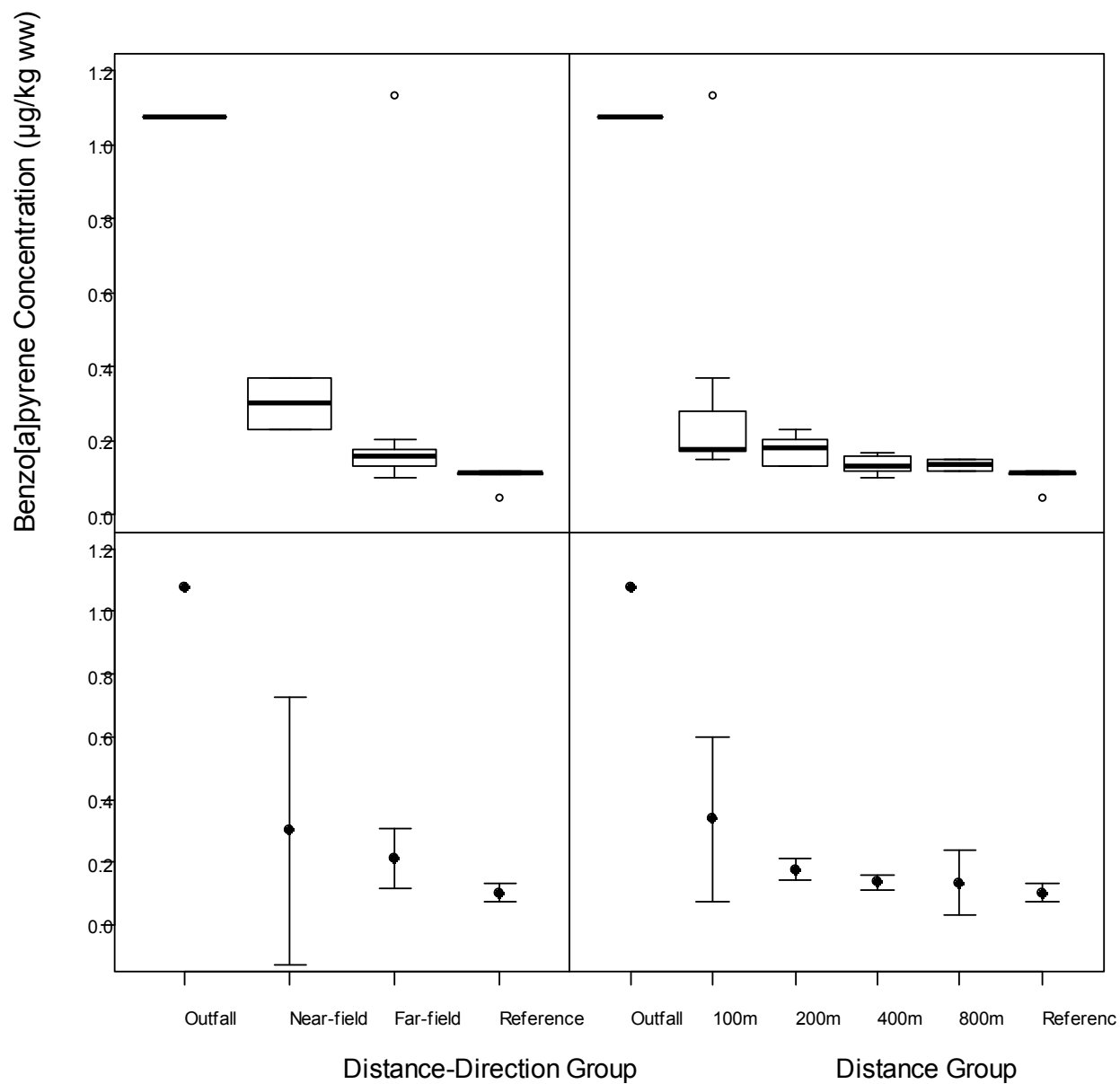


Figure 4.34, continued

x) Benzo[a]pyrene

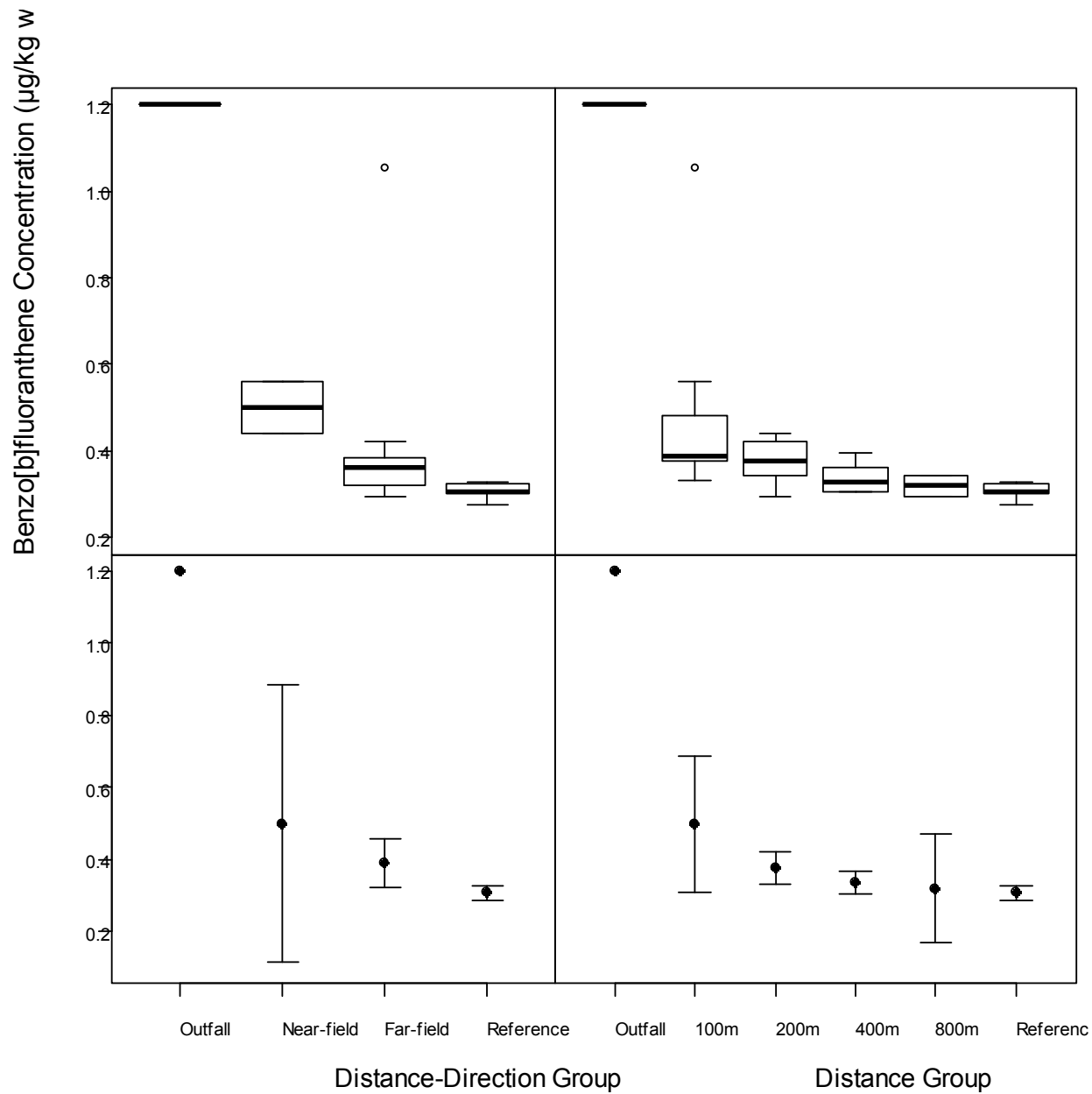


Figure 4.34, continued

y) Benzo[b]fluoranthene

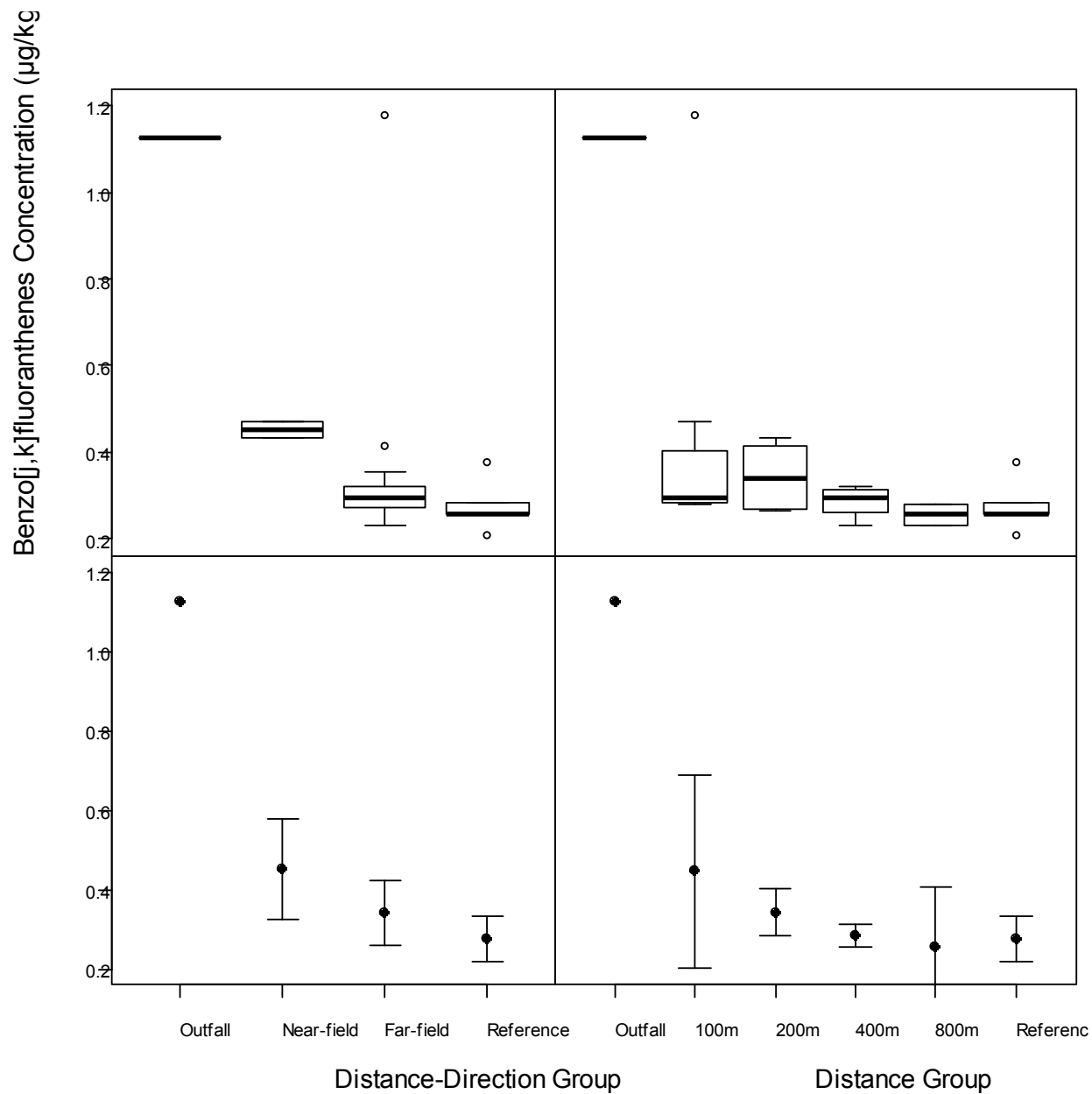


Figure 4.34, continued

z) Benzo[j,k]fluoranthene

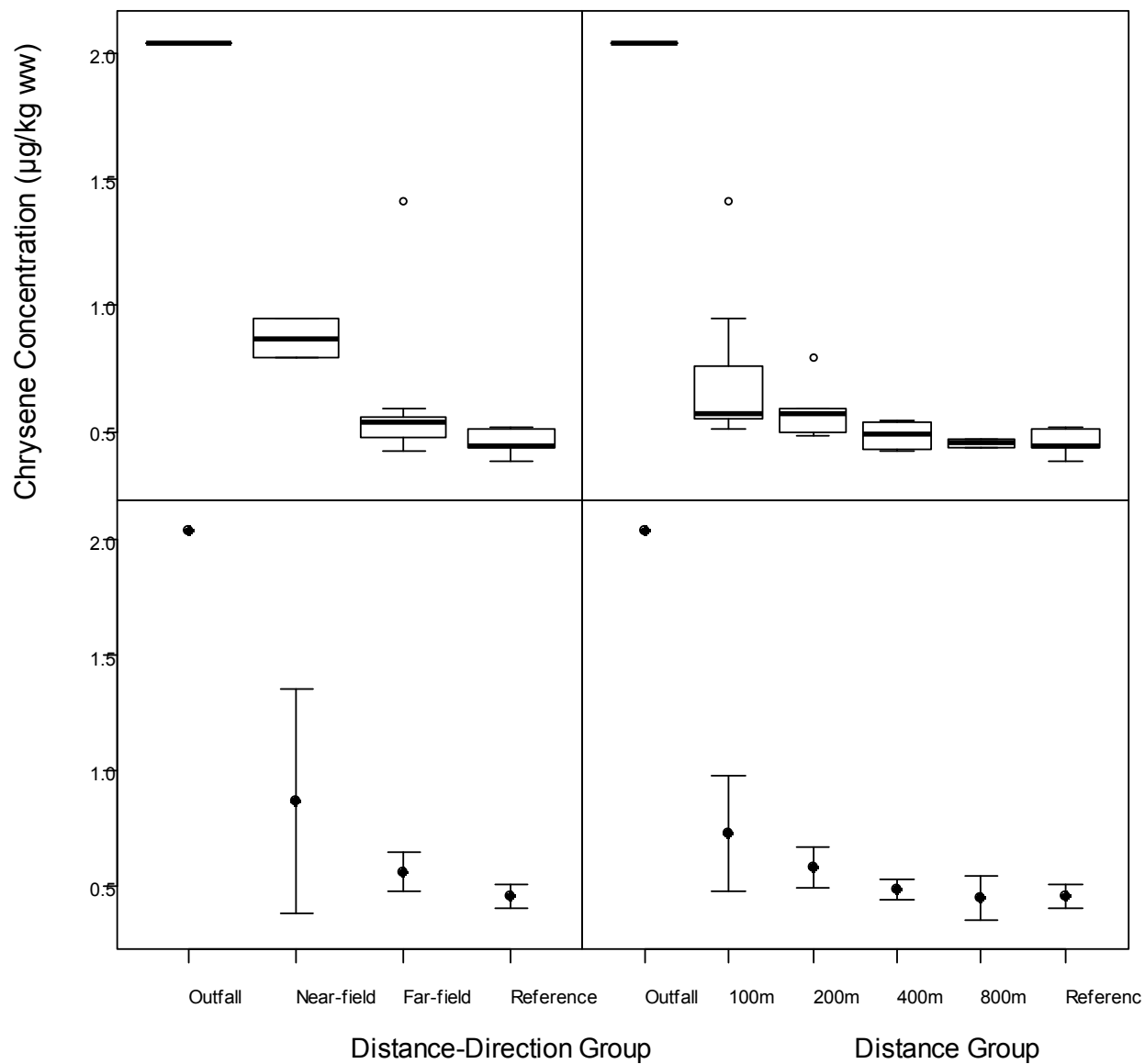


Figure 4.34, continued

aa) Chrysene

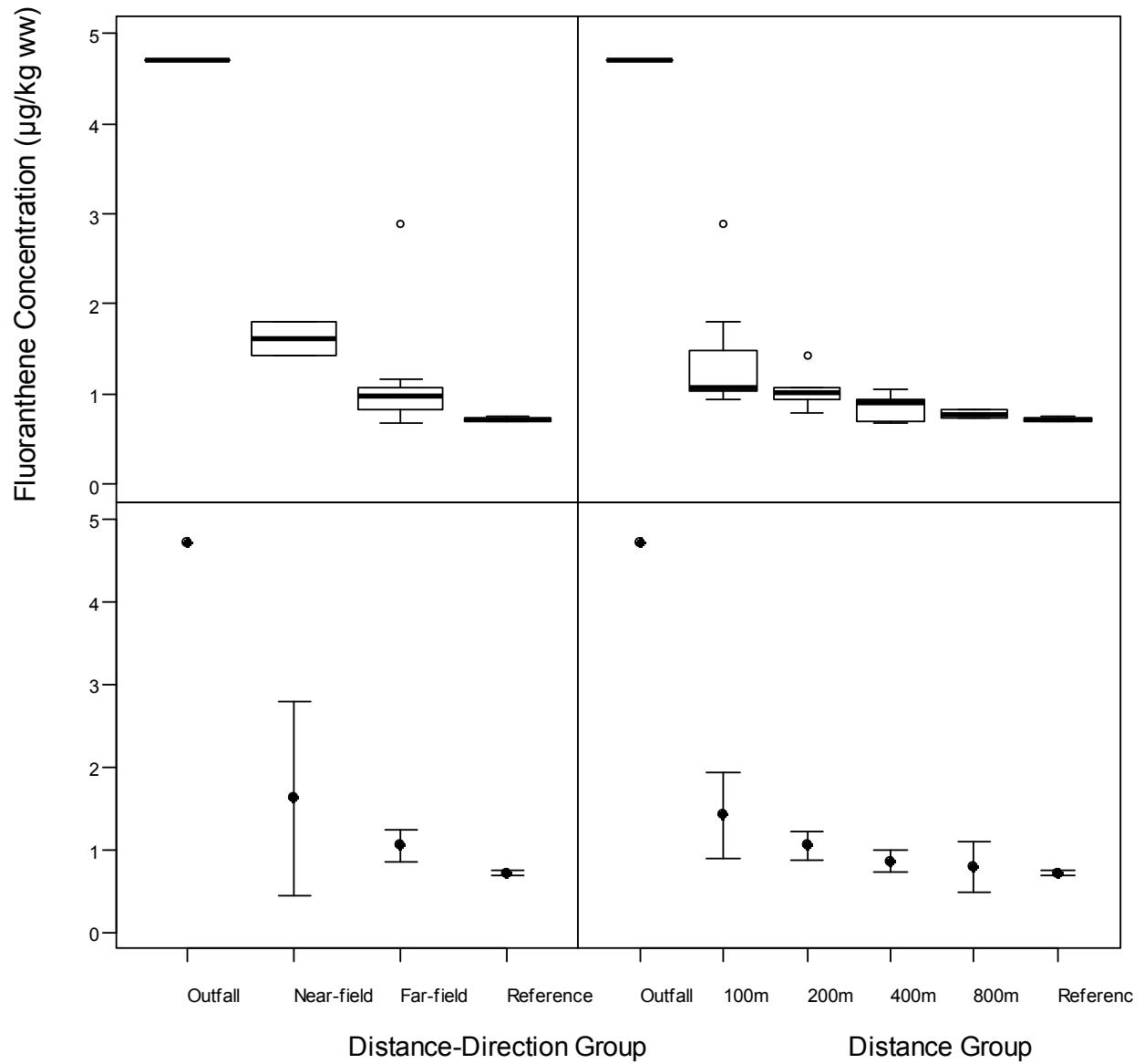


Figure 4.34, continued

bb) Fluoranthene

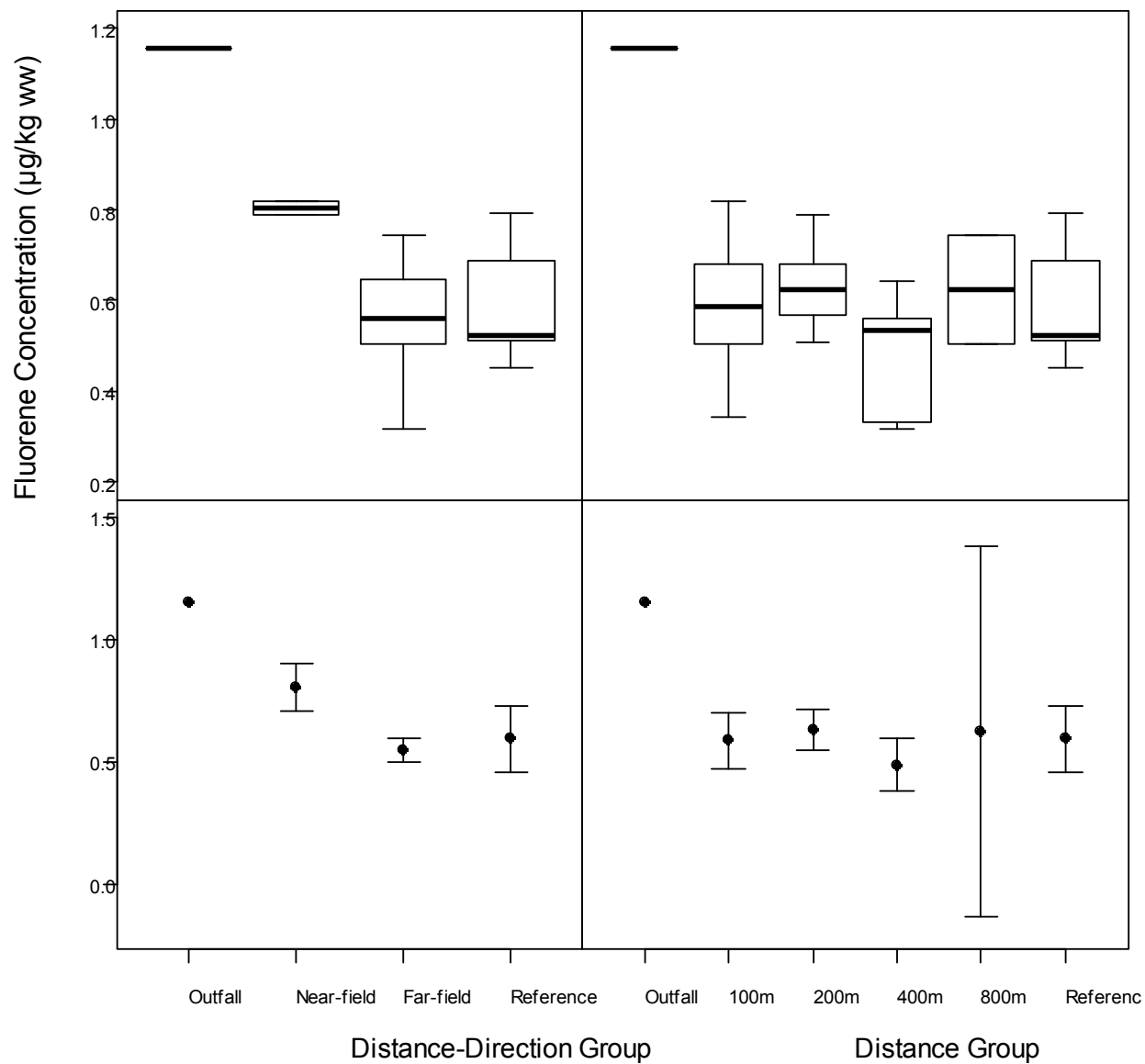


Figure 4.34, continued

cc) Fluorene

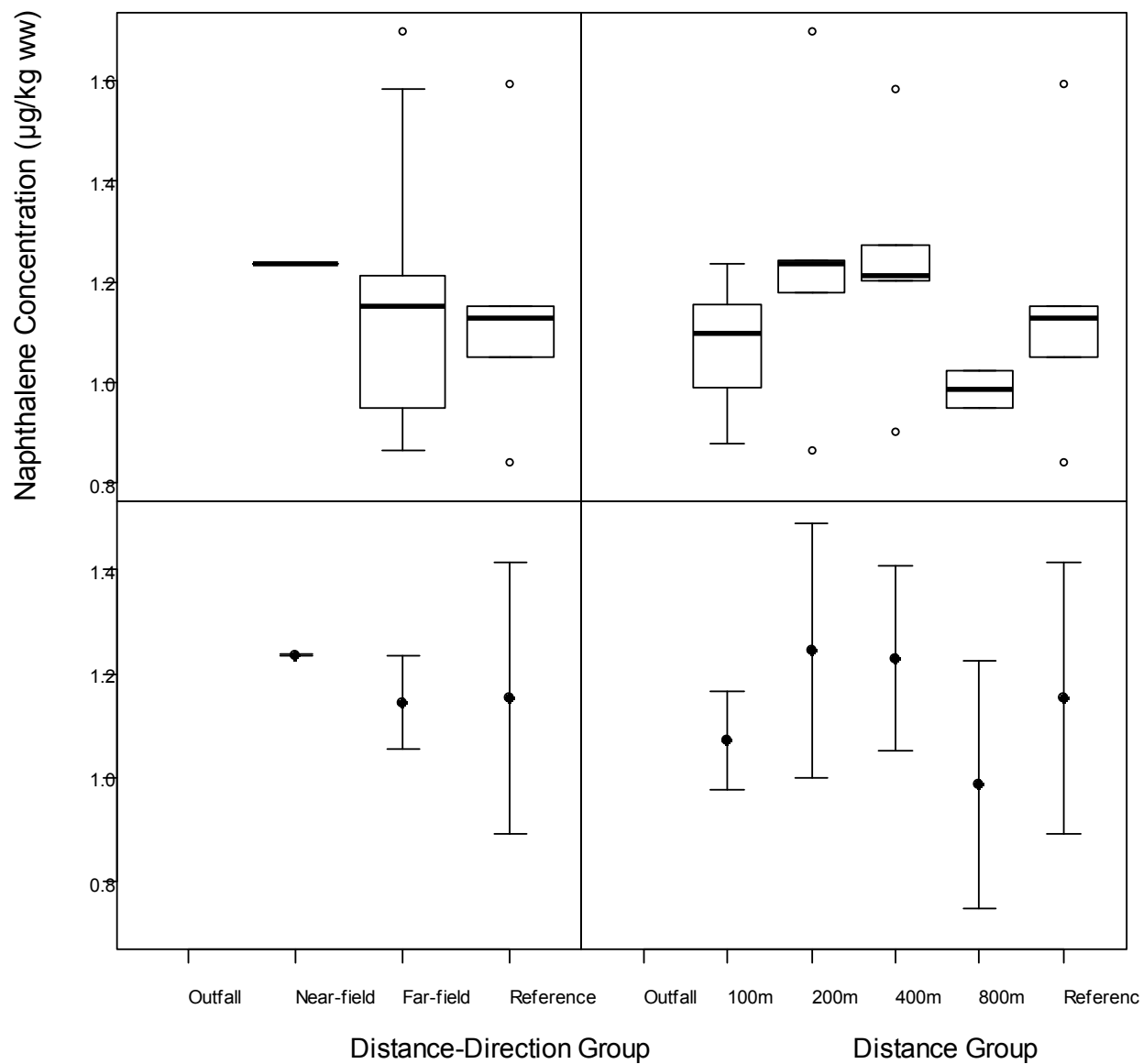


Figure 4.34, continued

dd) Naphthalene

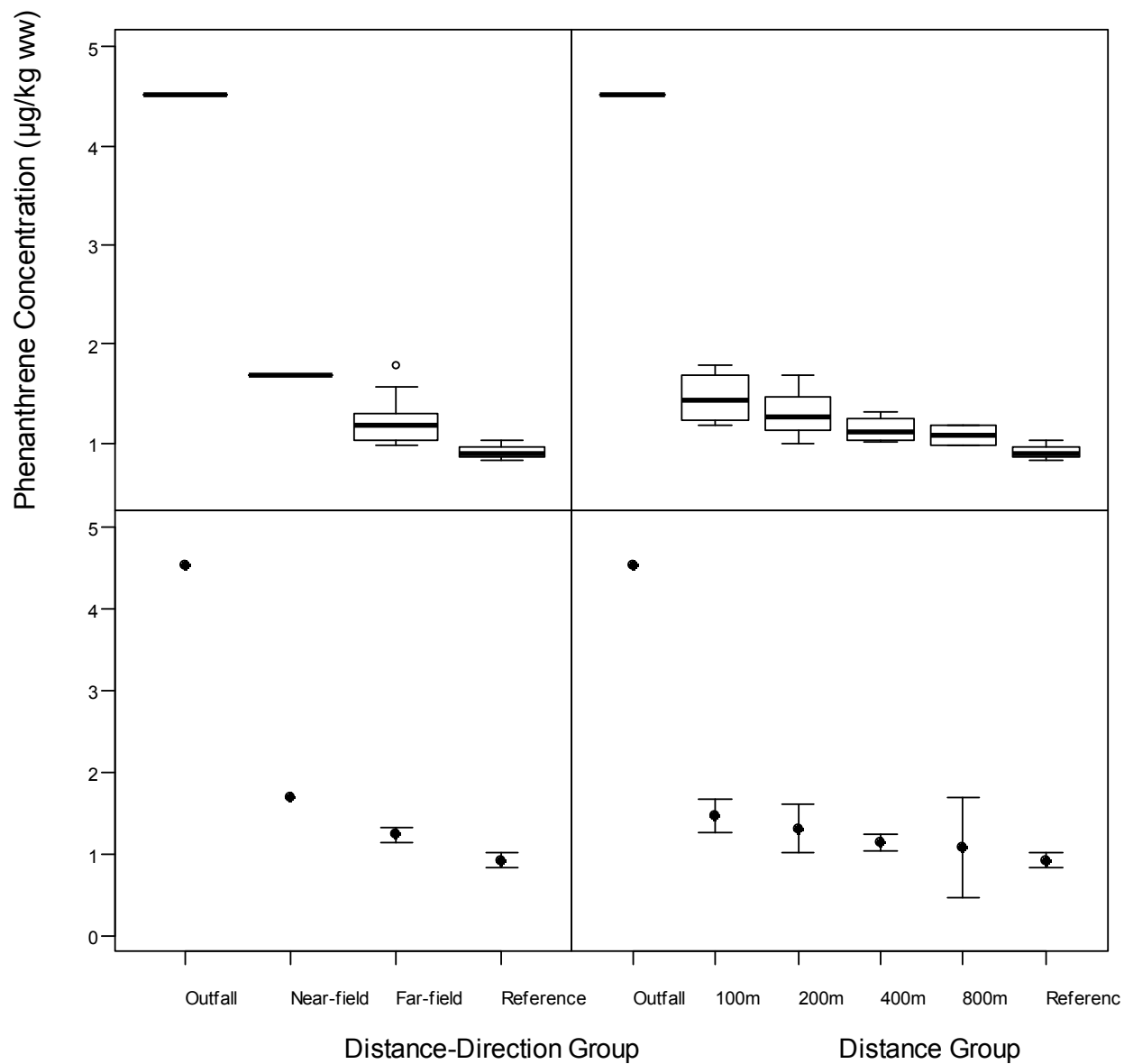


Figure 4.34, continued

ee) Phenanthrene

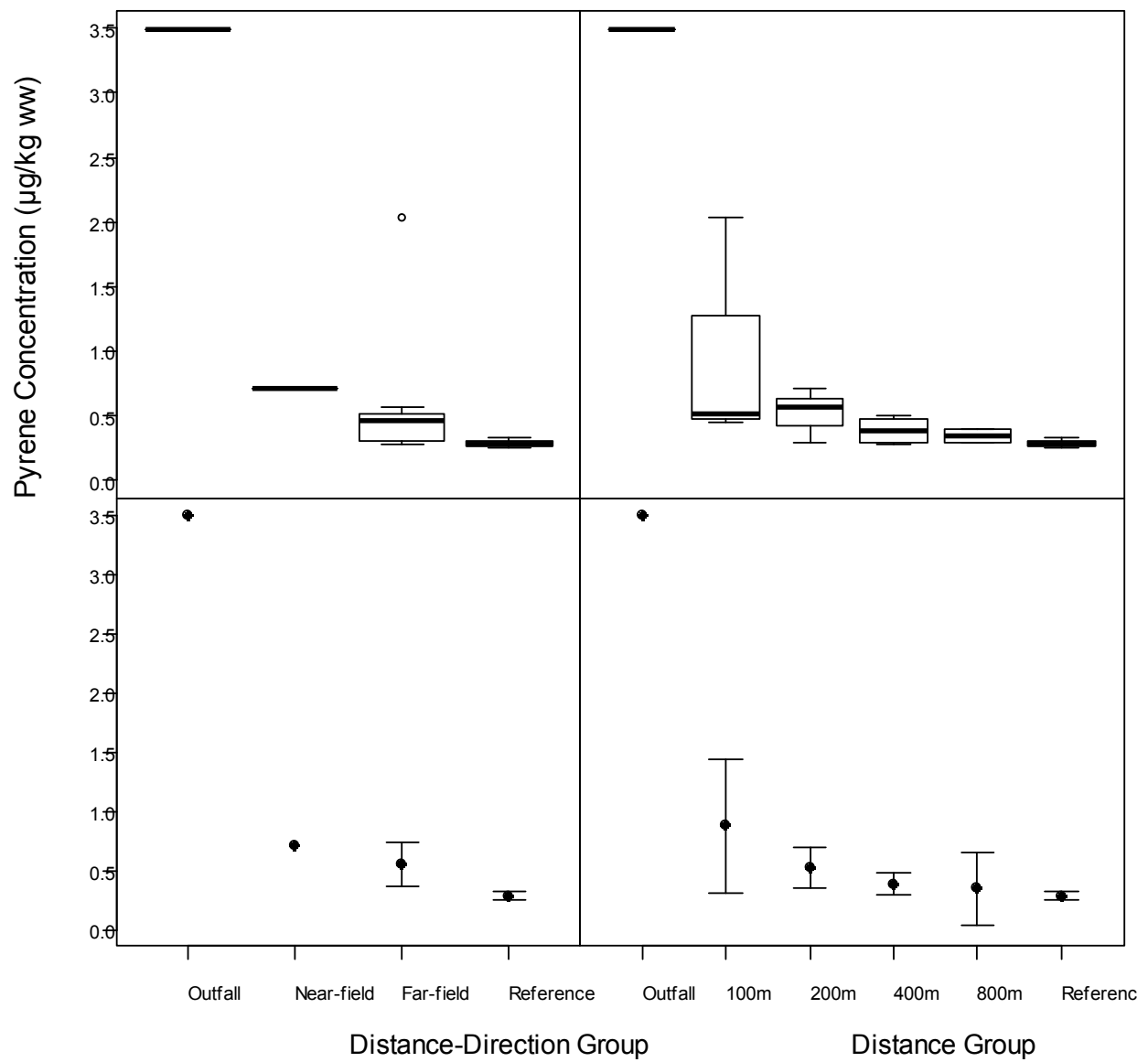


Figure 4.34, continued

ff) Pyrene

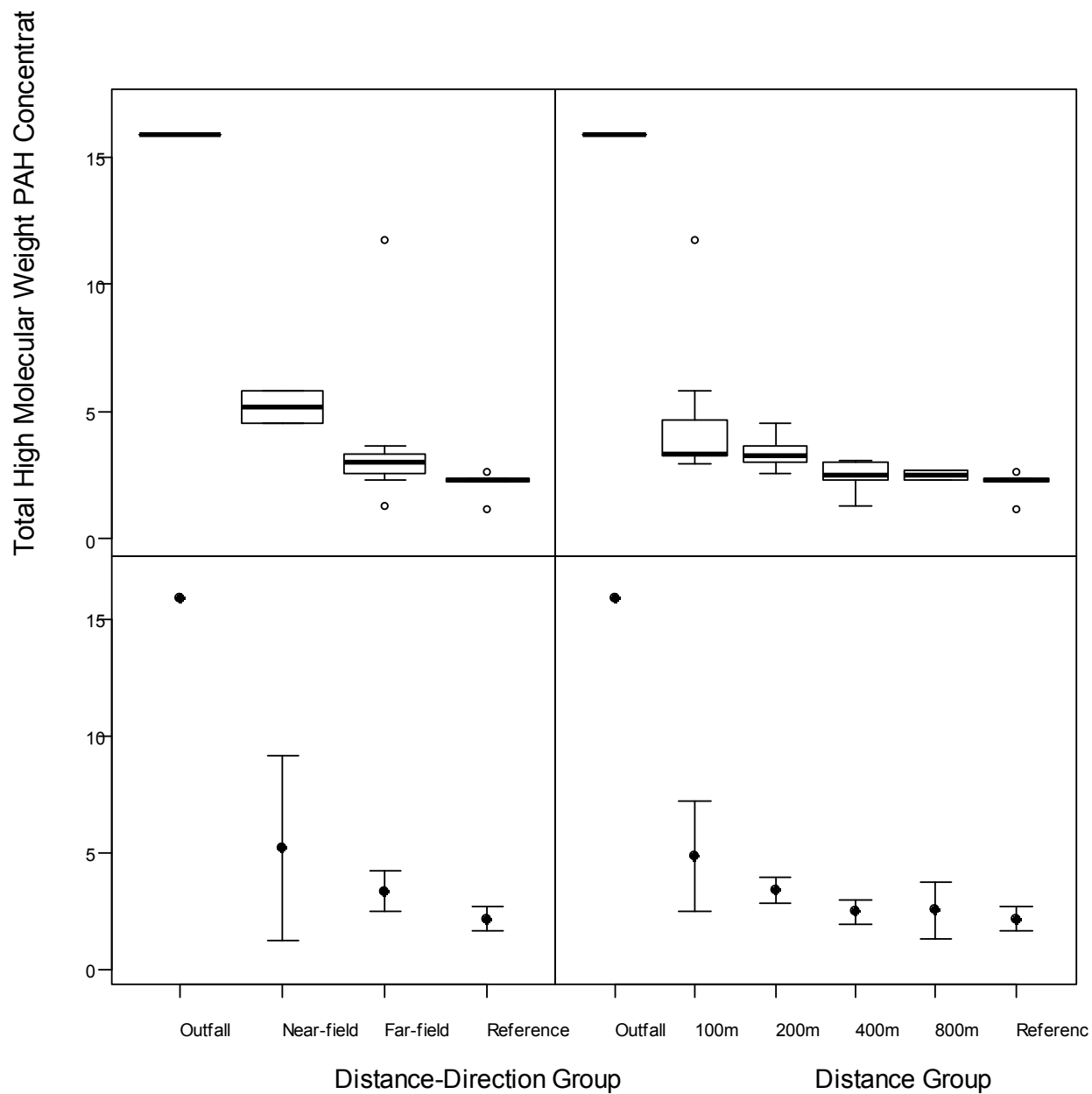


Figure 4.34, continued

gg) Total High Molecular Weight PAHs

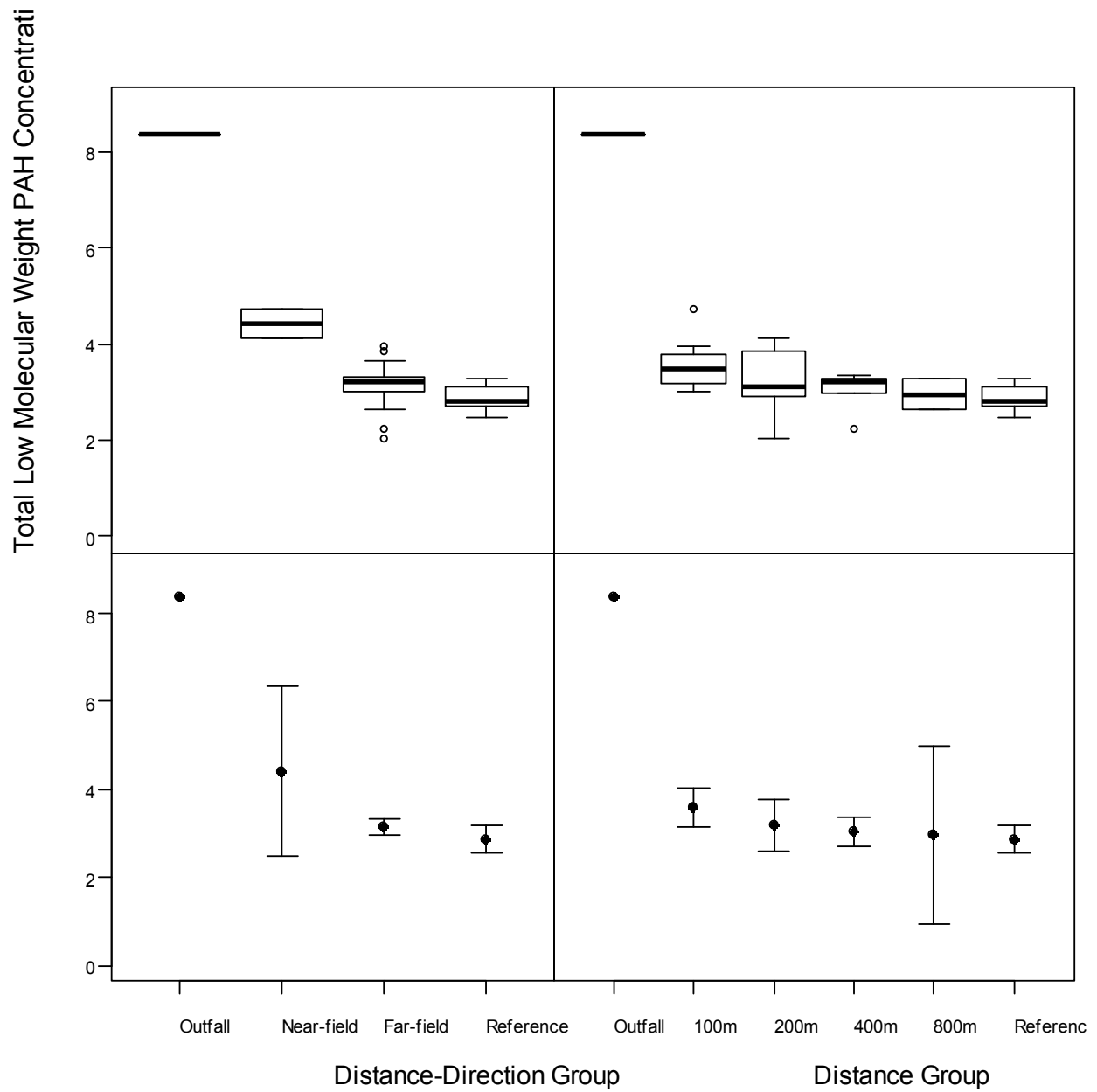


Figure 4.34, continued

hh) Total Low Molecular Weight PAHs

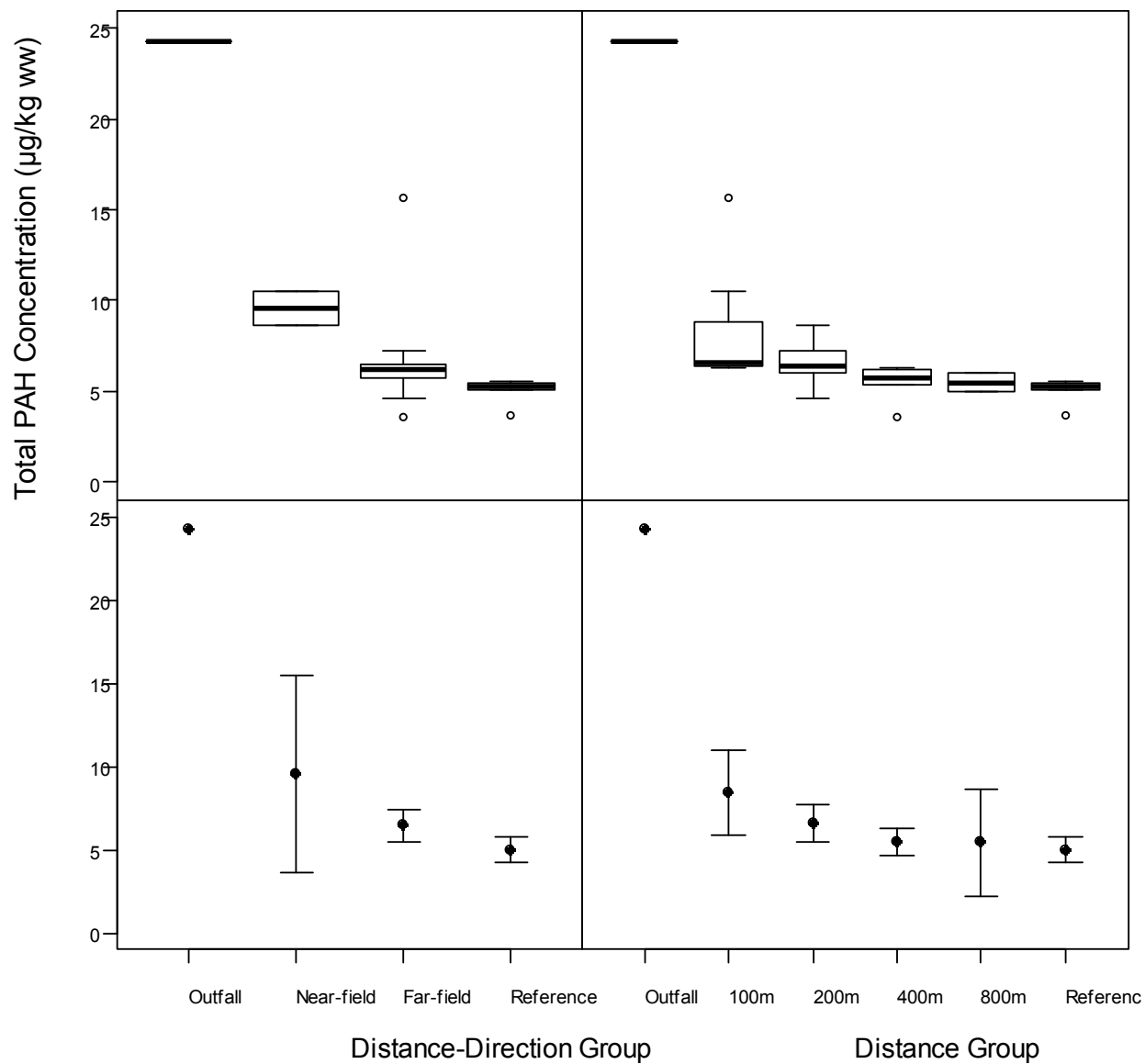


Figure 4.34, continued

ii) Total PAHs

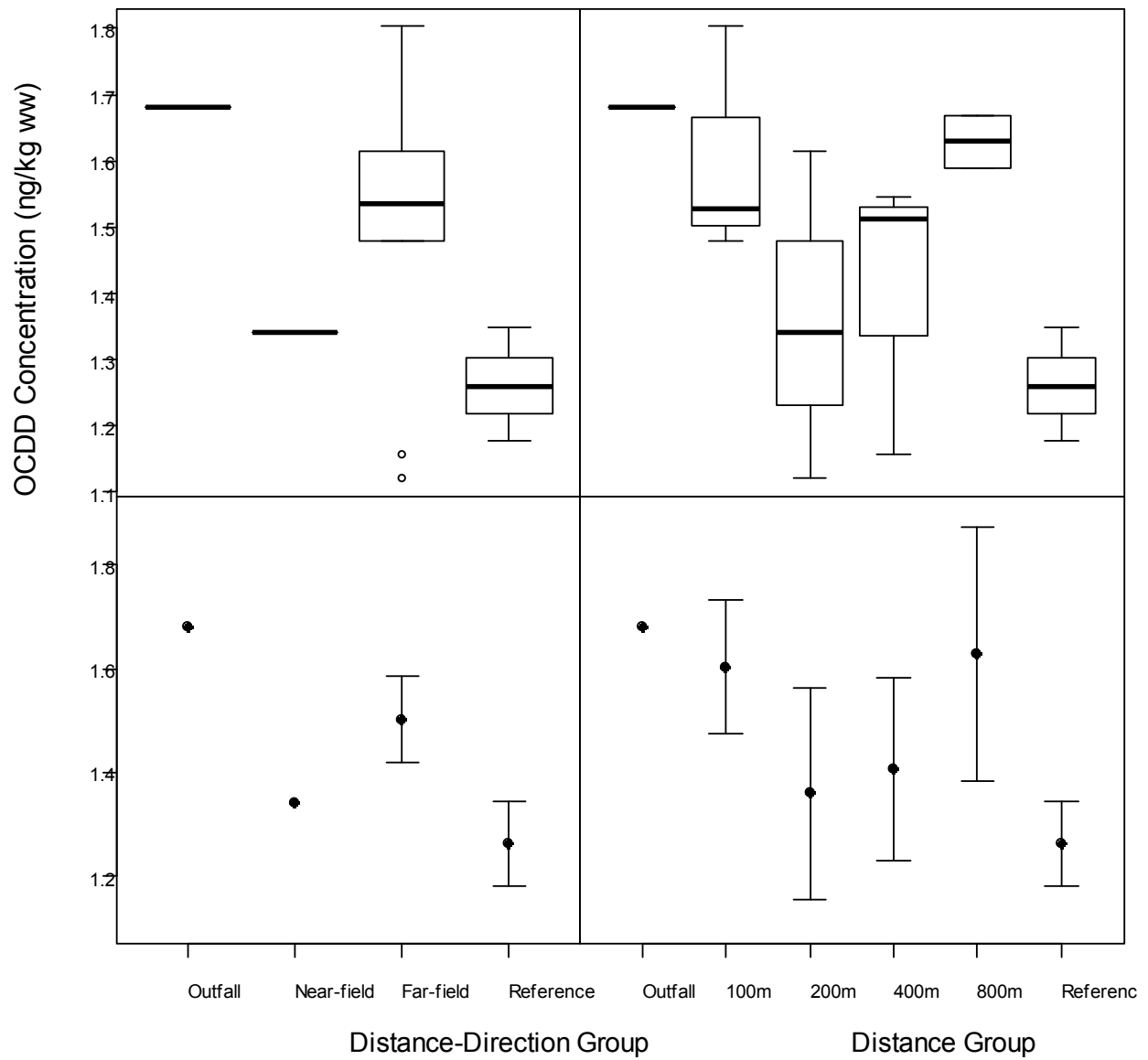


Figure 4.34, concluded

jj) OCDD

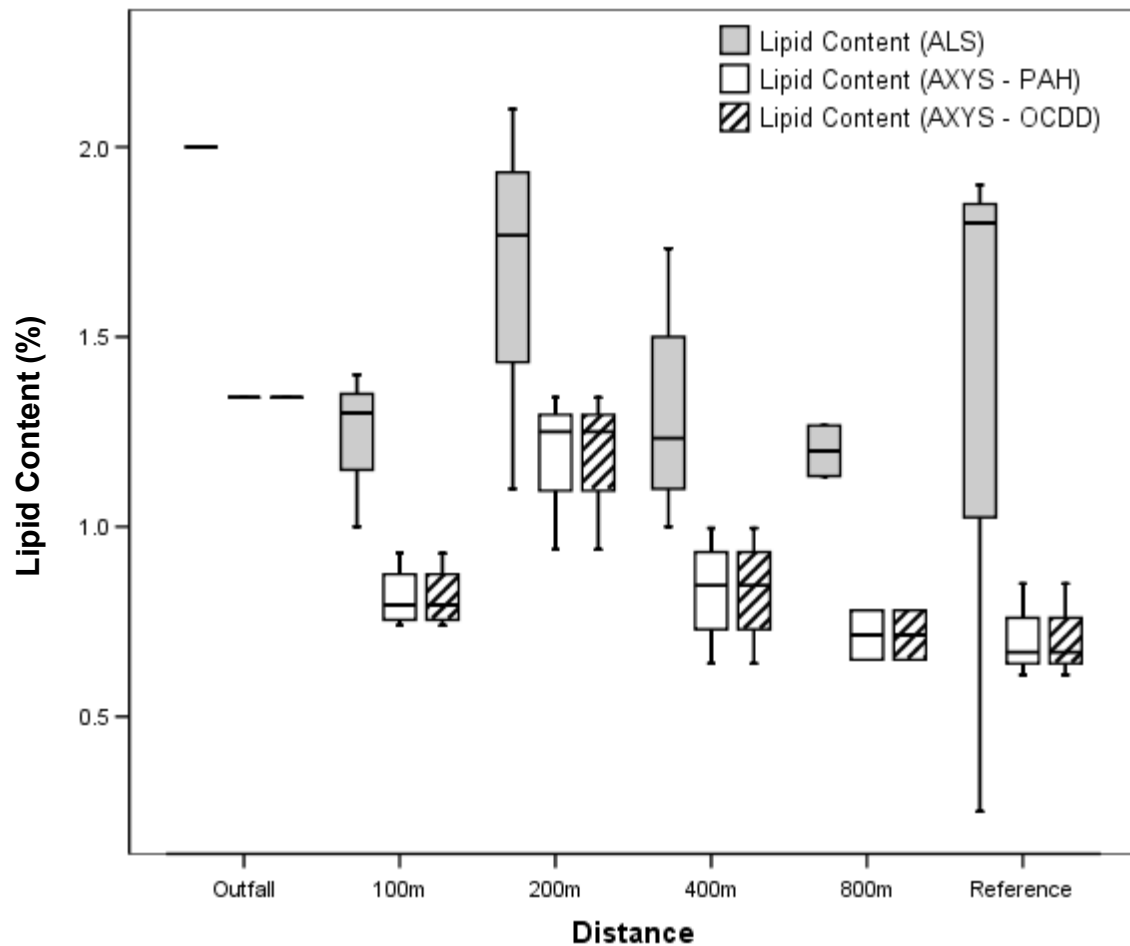


Figure 4.35 Comparison of Lipid Content Data from AXYS and ALS; Lipid content versus Distance-Direction

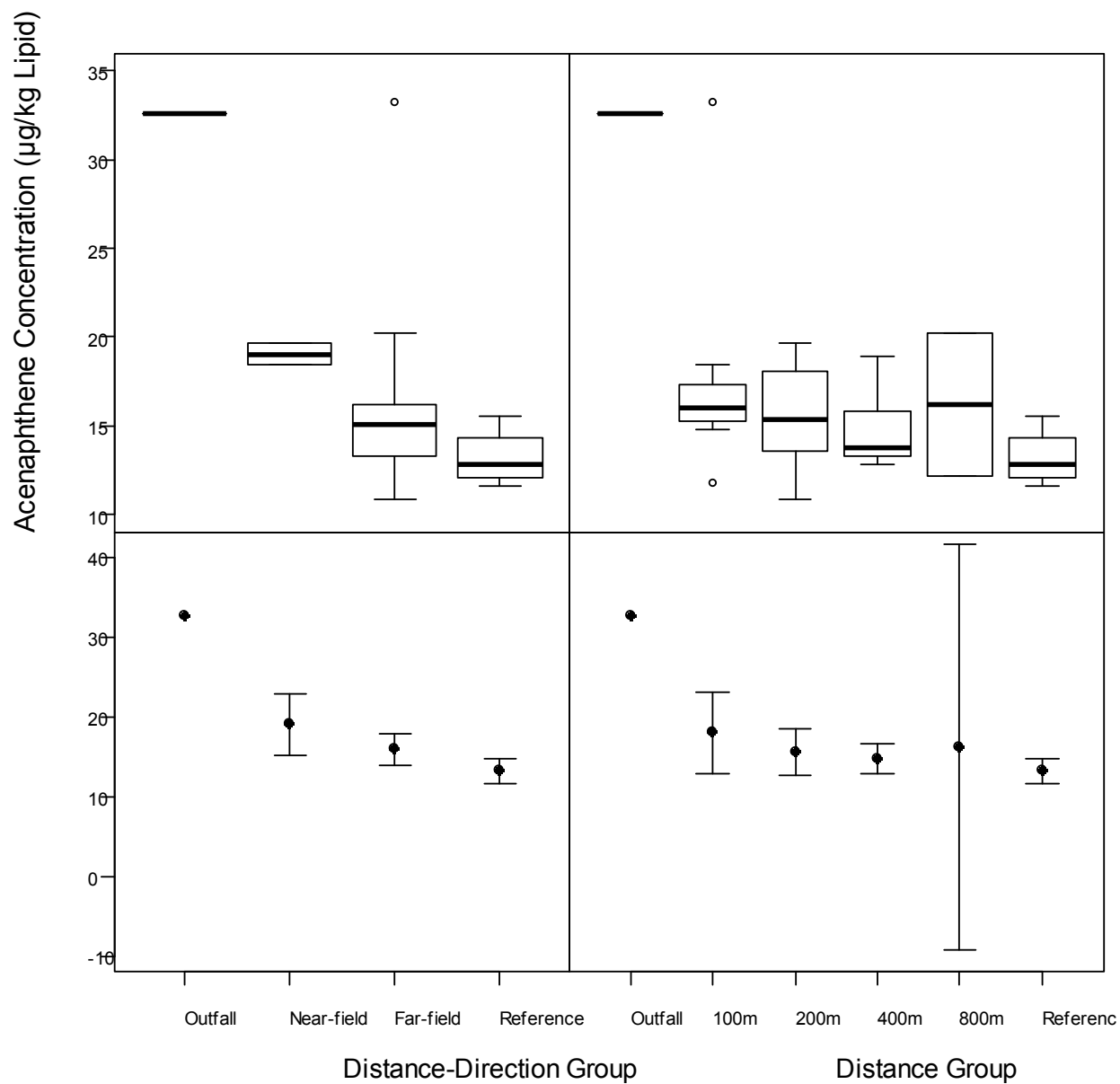


Figure 4.36 Box and Whisper Plots (Top Panel) and Means $\pm$ 95% Confidence Intervals (Bottom Panel) for Lipid-Normalized PAH Concentrations ($\mu\text{g/kg lipid}$) in 2010 Mussel Tissue

a) Acenaphthene

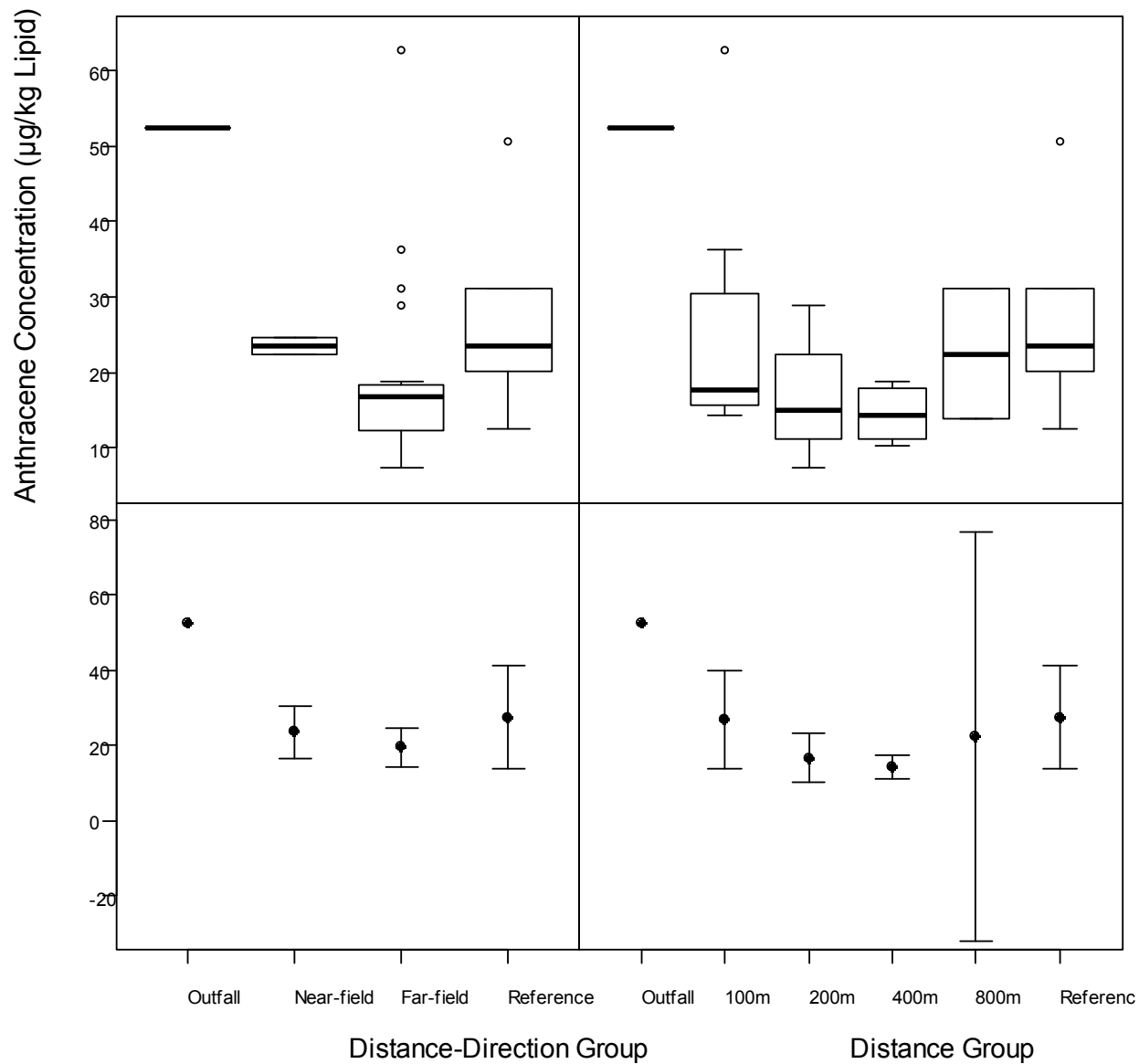


Figure 4.36, continued

b) Anthracene

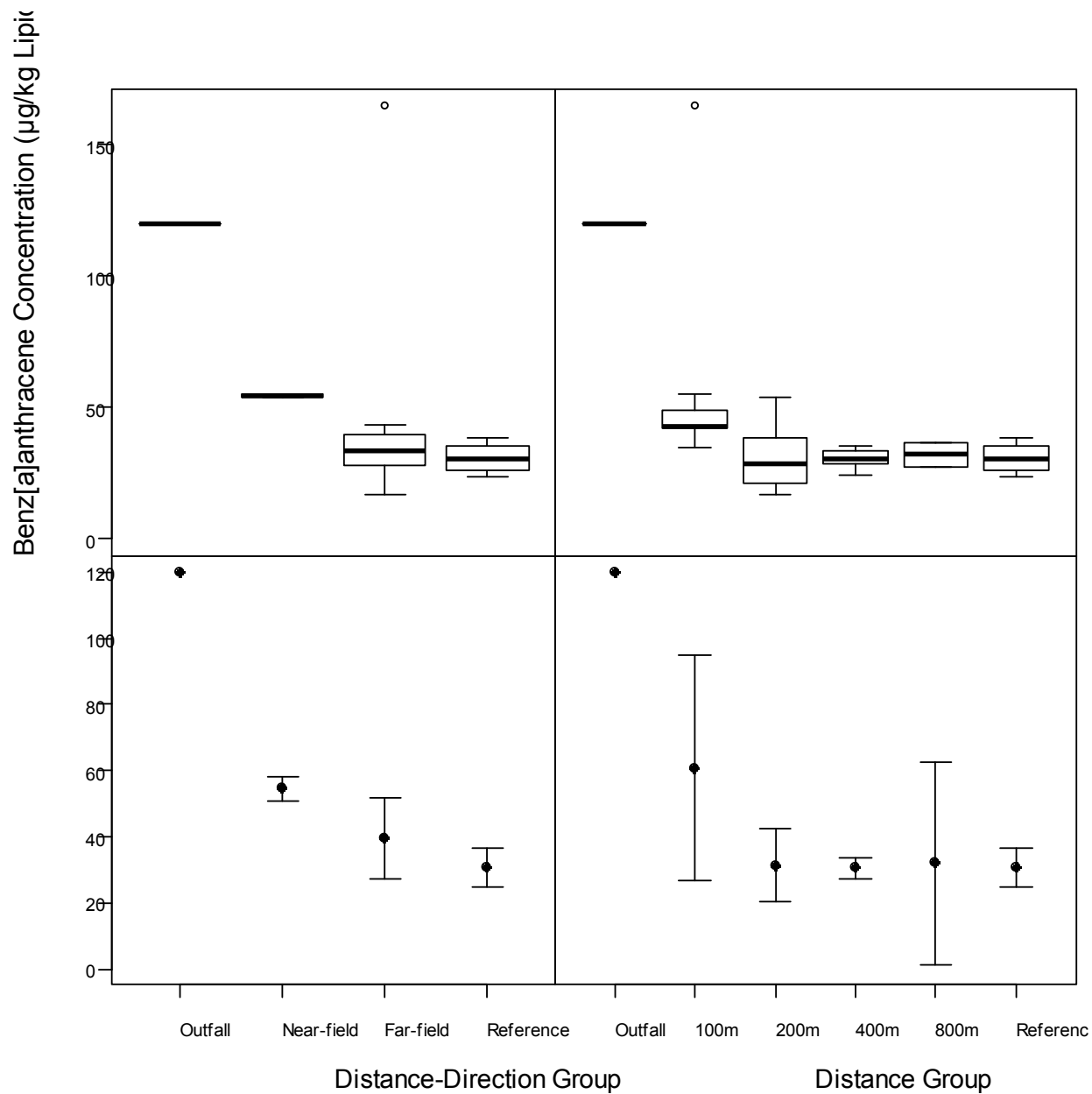


Figure 4.36, continued

c) Benz[a]anthracene

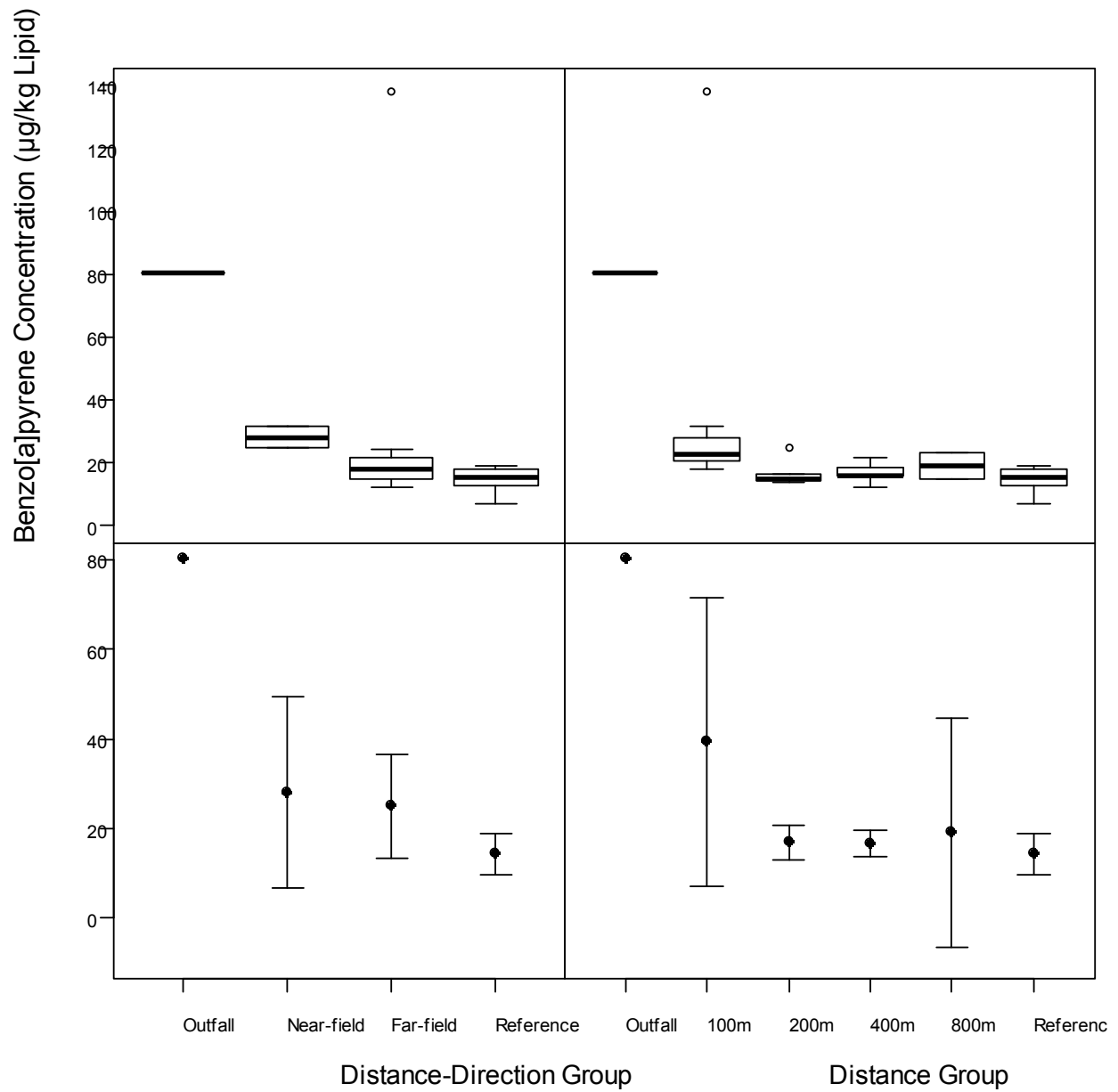


Figure 4.36, continued

d) Benzo[a]pyrene

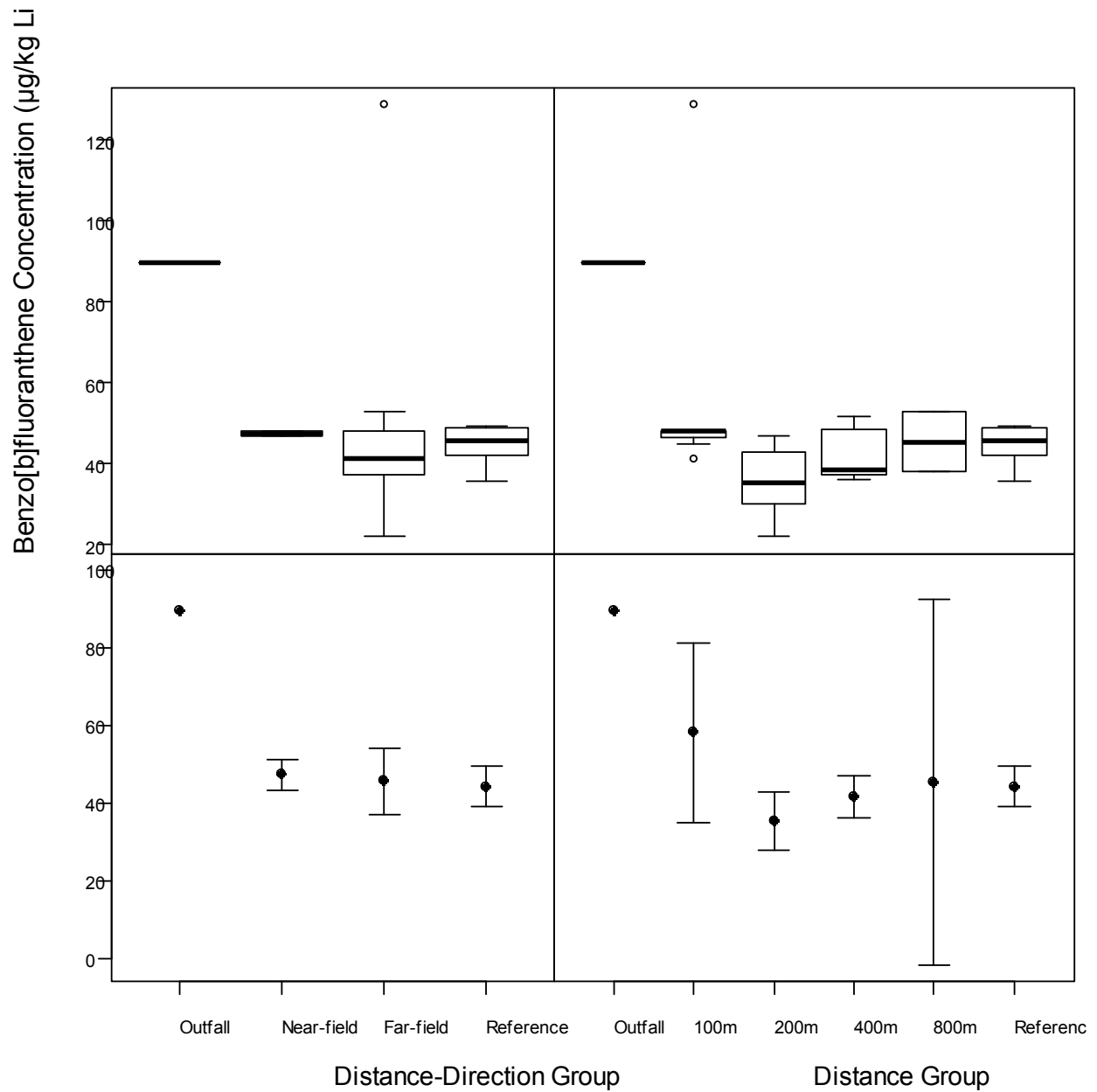


Figure 4.36, continued

e) Benzo[b]fluoranthene

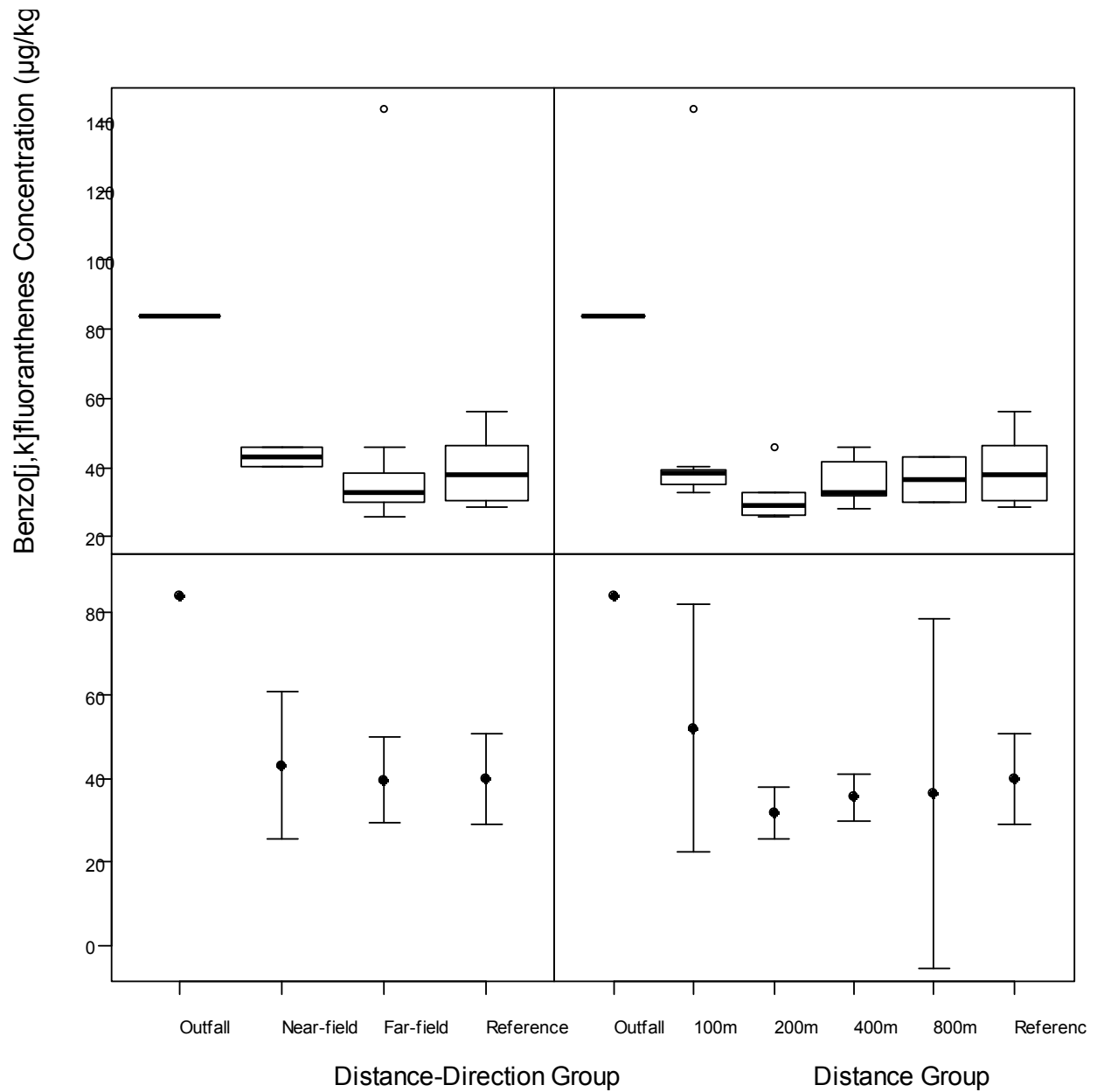


Figure 4.36, continued

f) Benzo[j,k]fluoranthenes

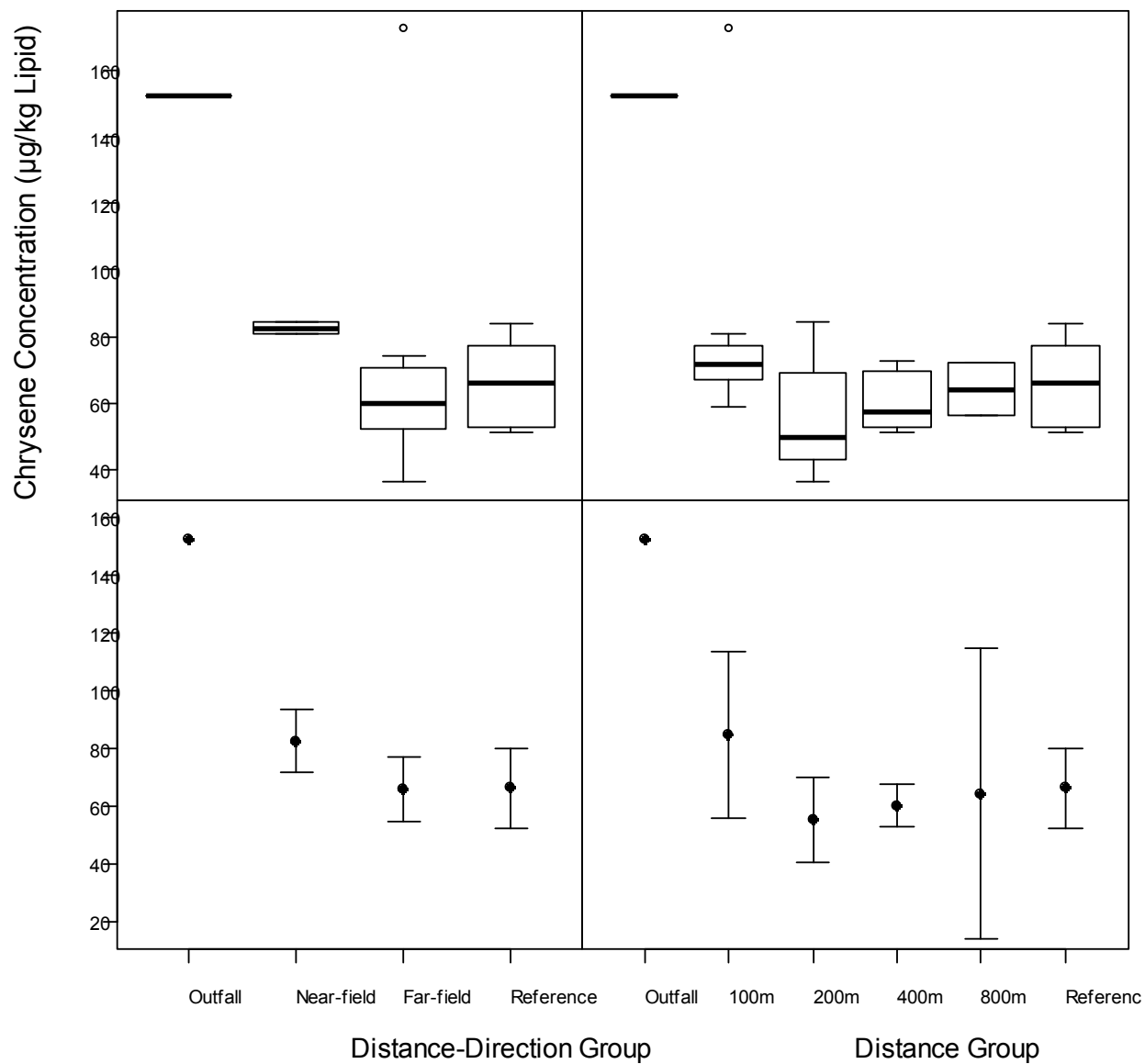


Figure 4.36, continued

g) Chrysene

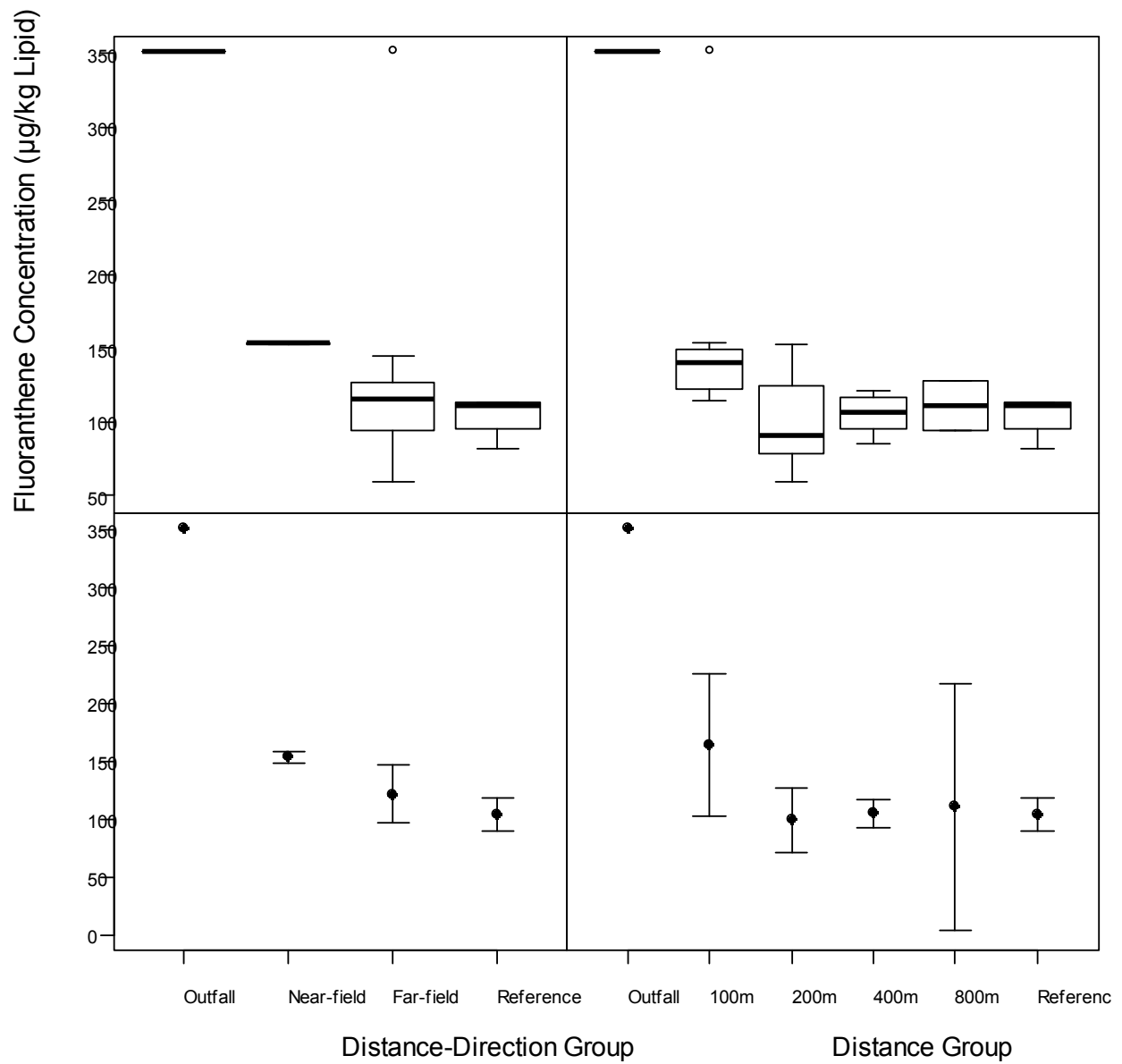


Figure 4.36, continued

h) Fluoranthene

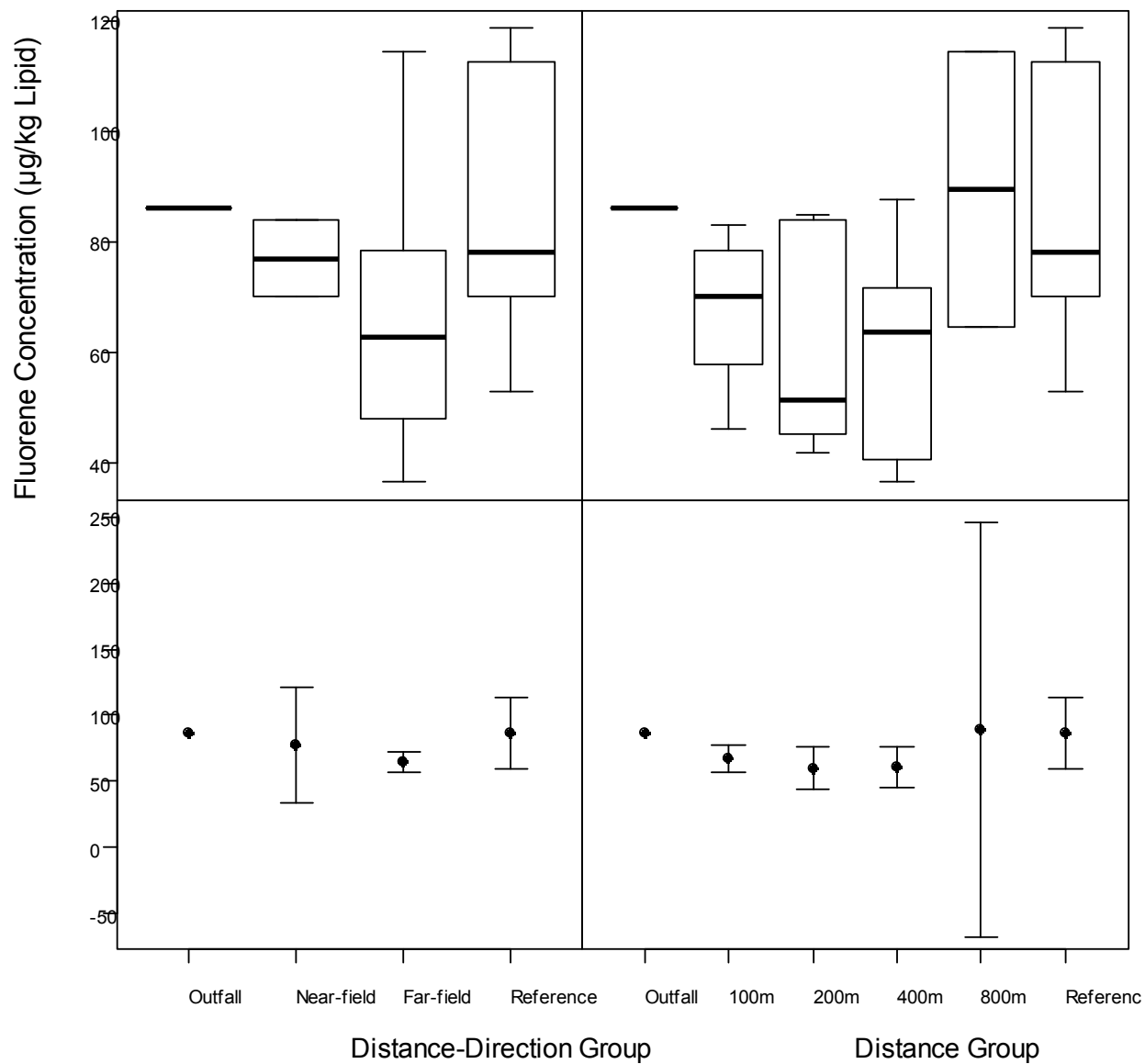


Figure 4.36, continued

i) Fluorene

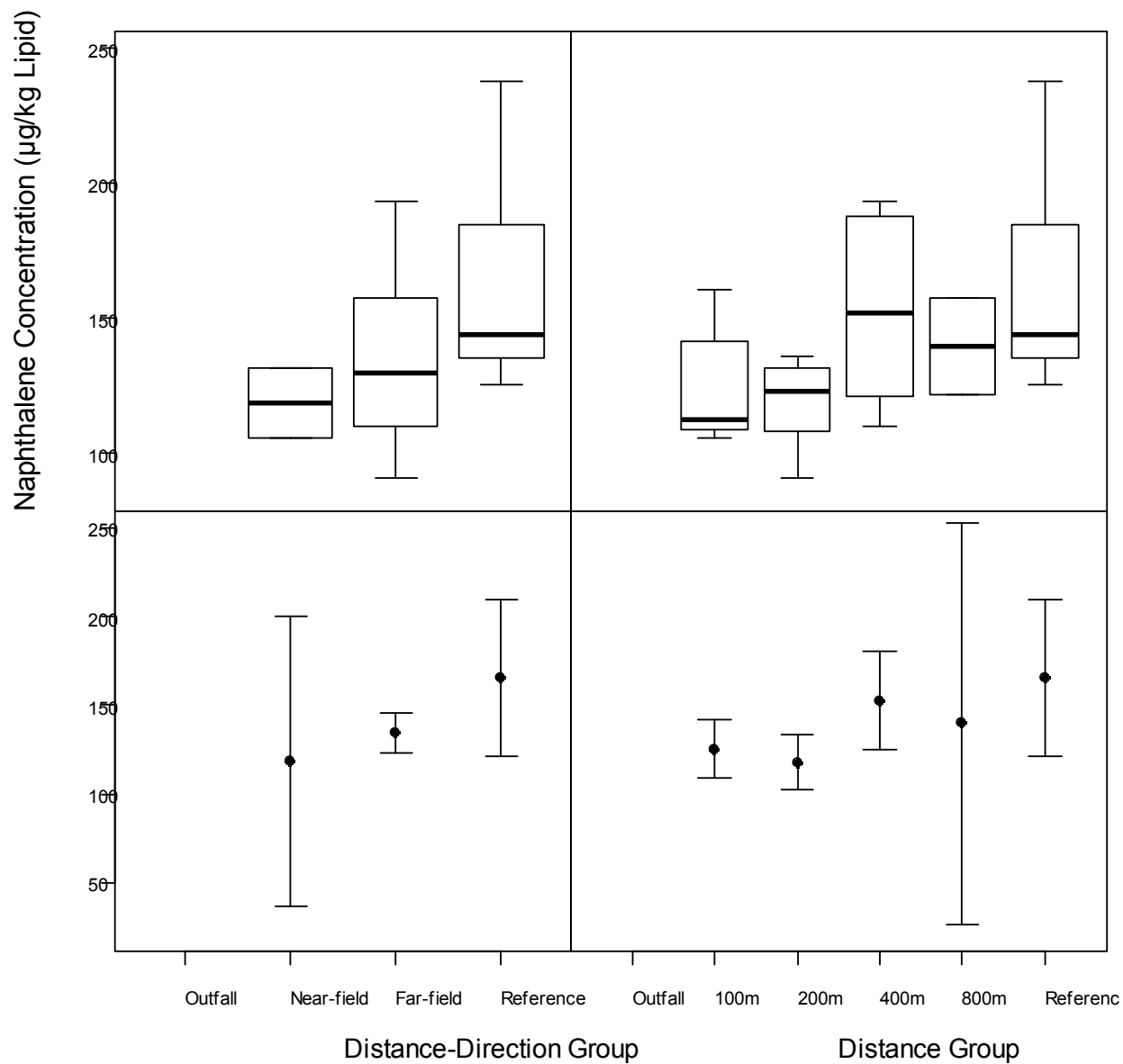


Figure 4.36, continued

j) Naphthalene

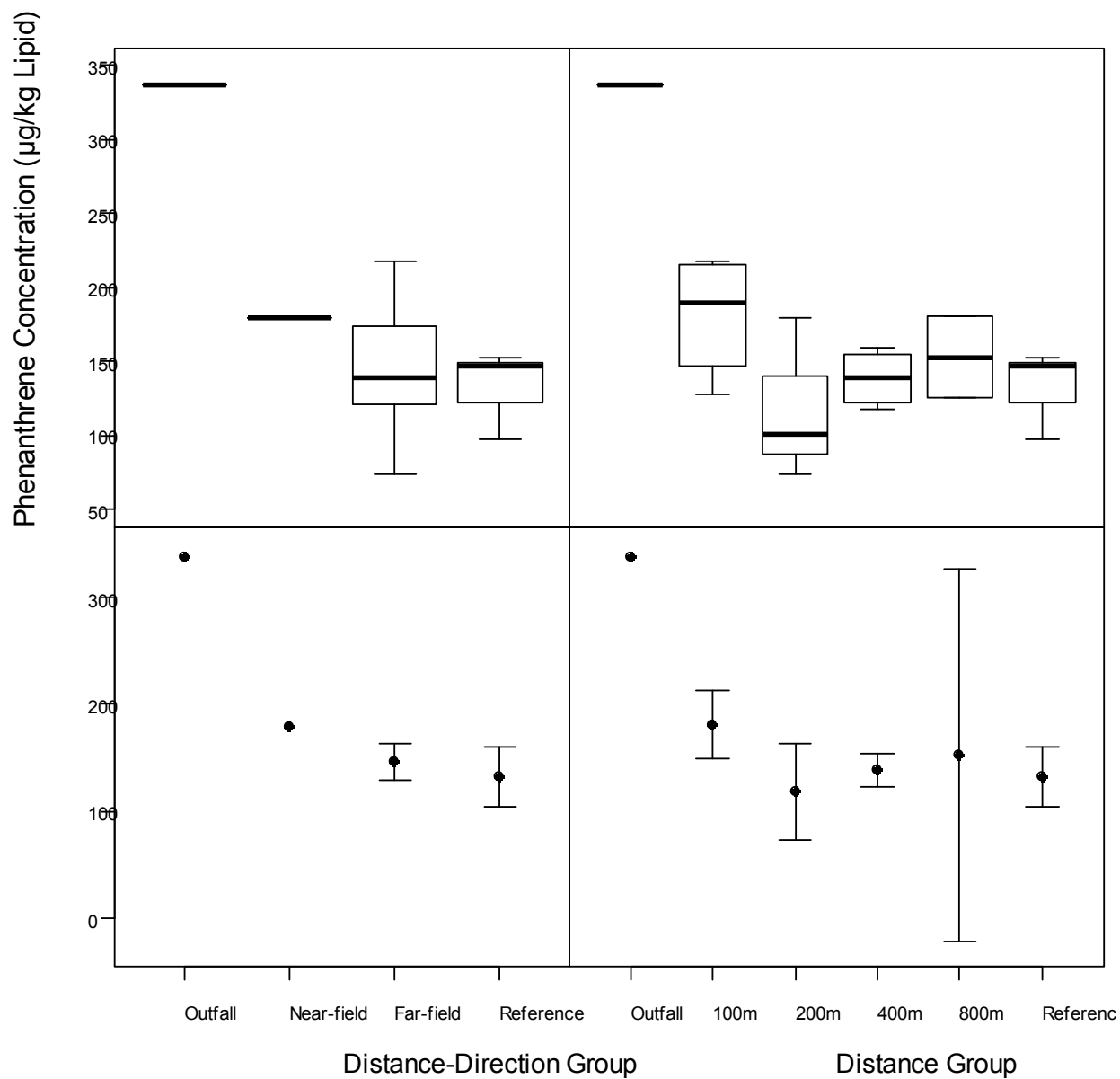


Figure 4.36, continued

k) Phenanthrene

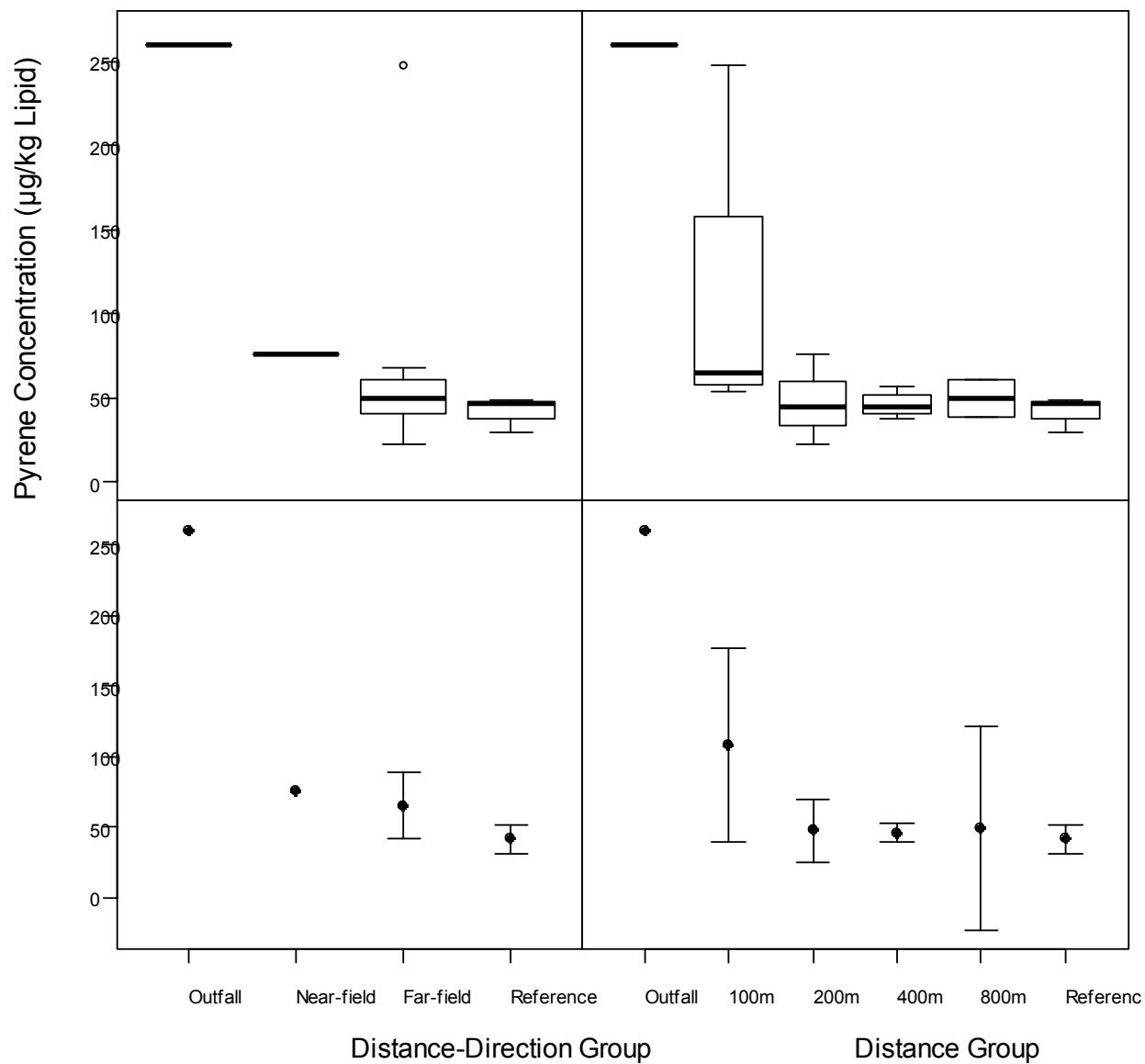


Figure 4.36, continued

I) Pyrene

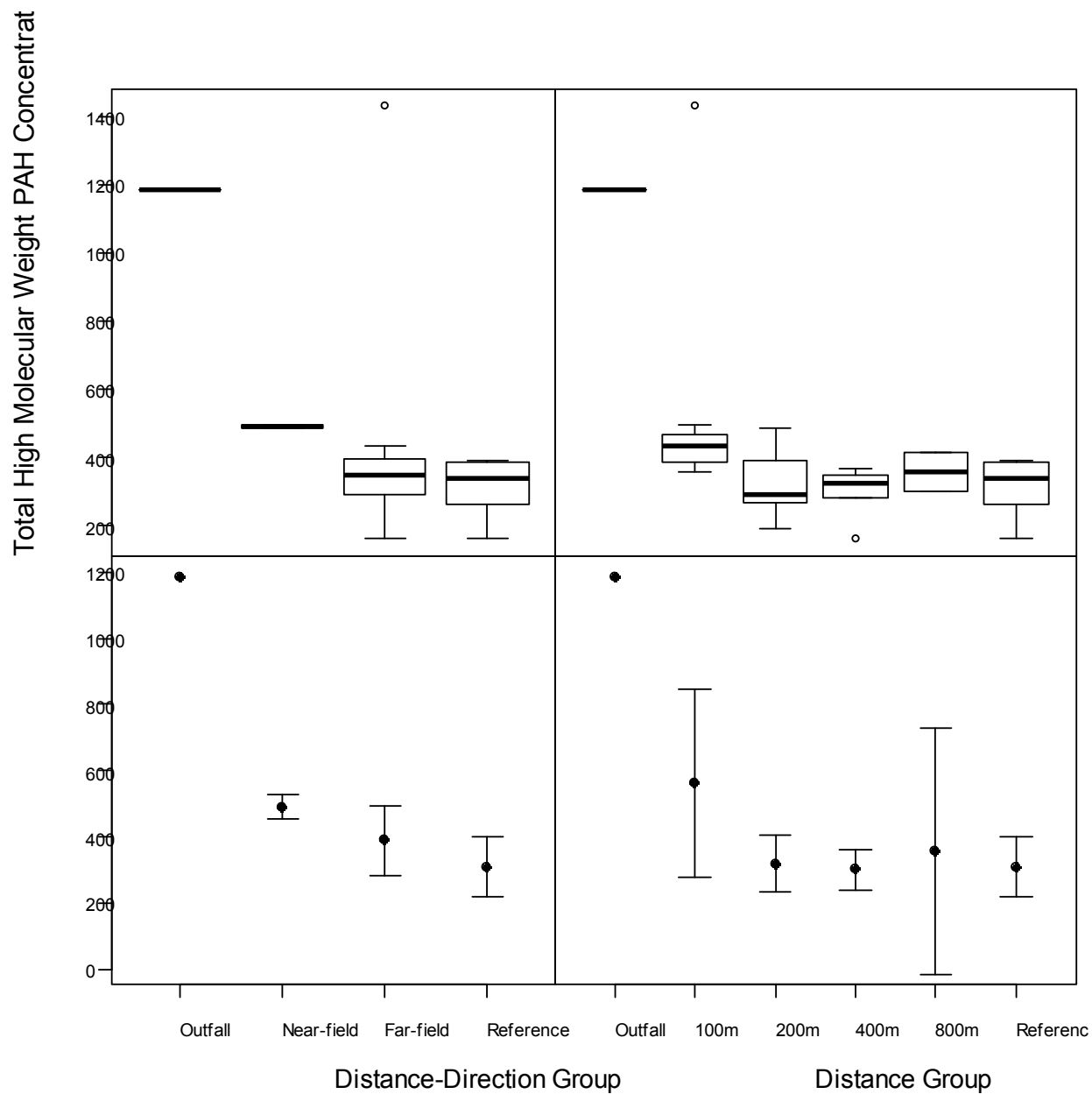


Figure 4.36, continued

m) Total High Molecular Weight PAHs

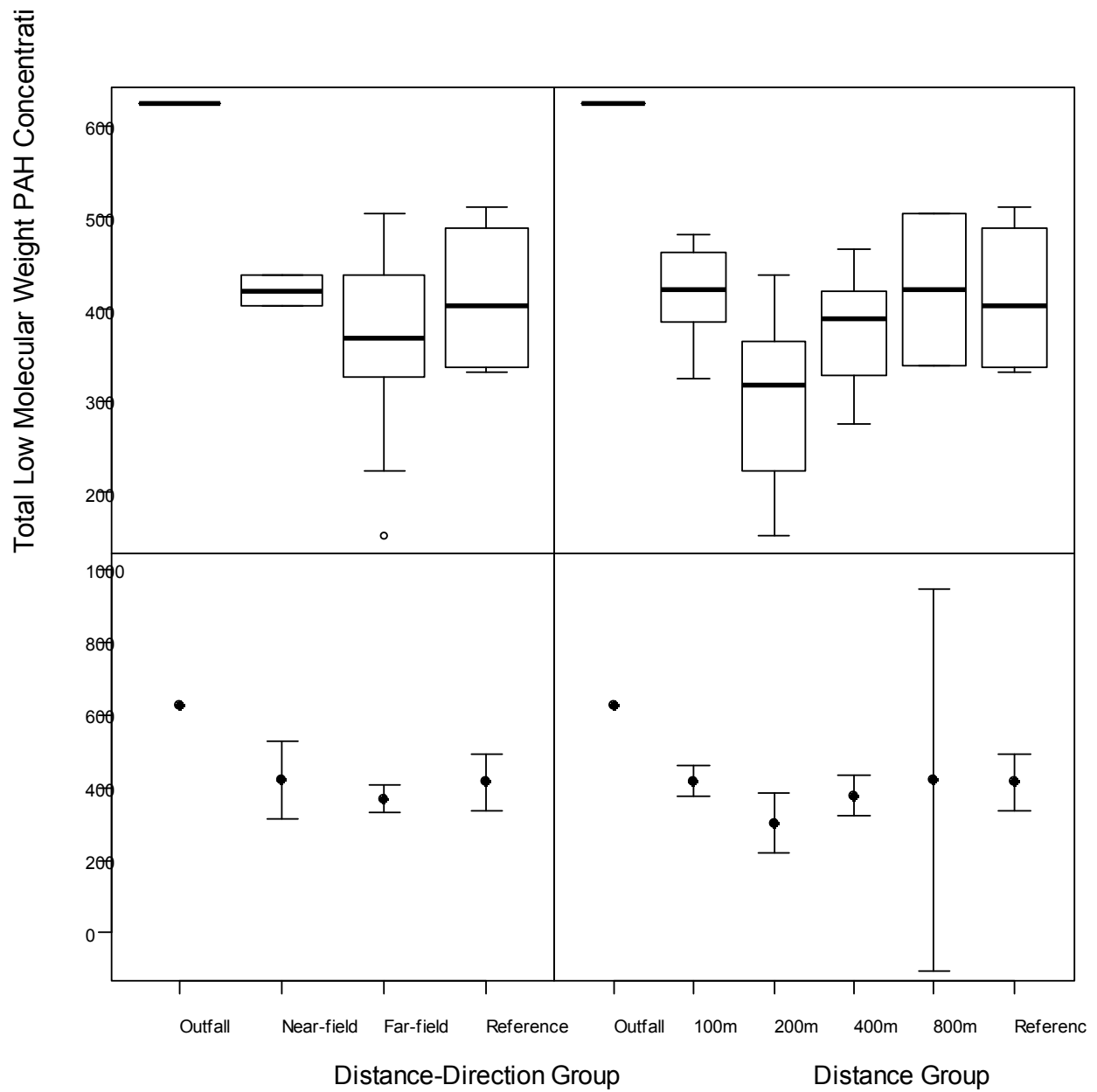


Figure 4.36, continued

n) Total Low Molecular Weight PAHs

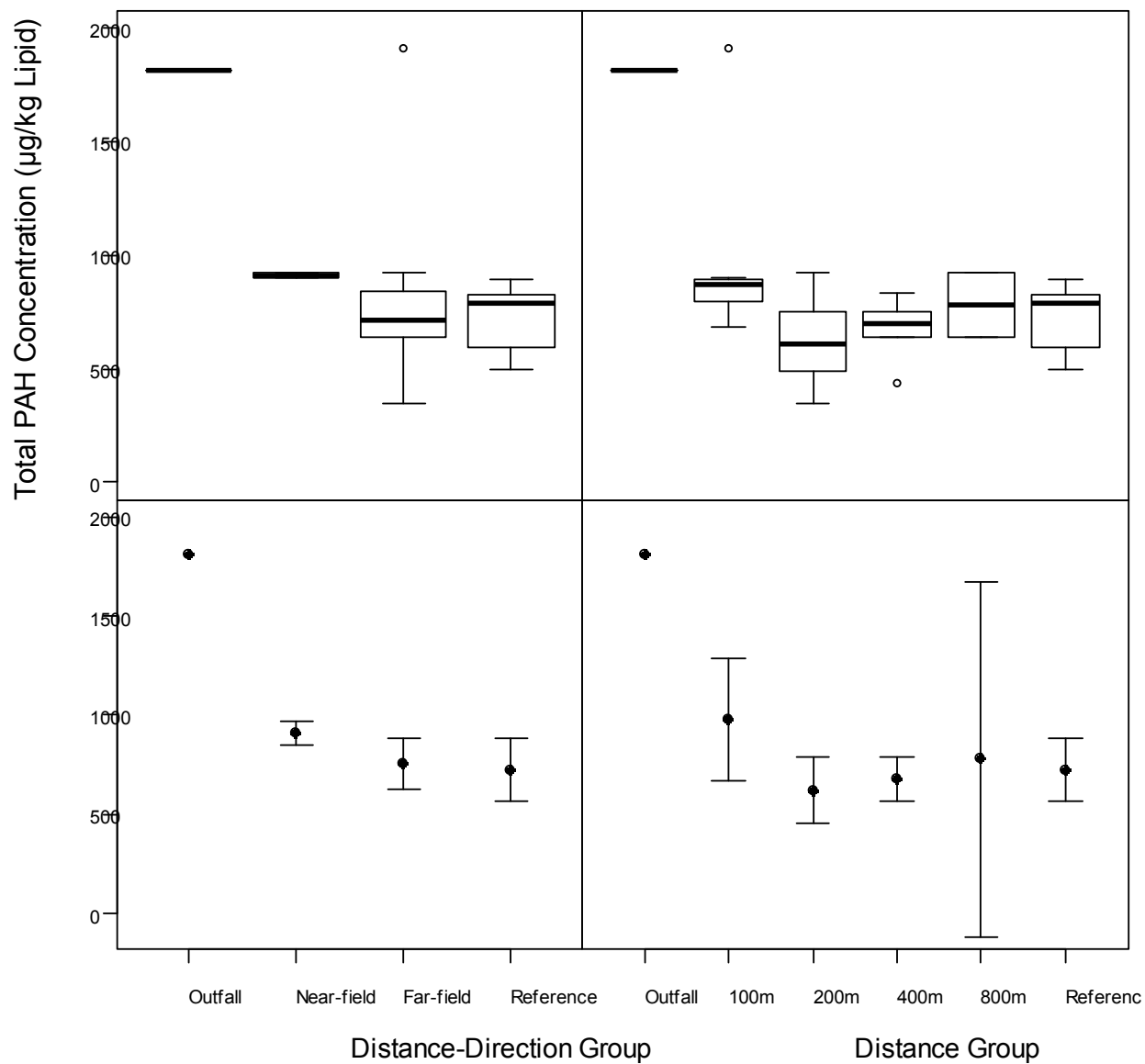


Figure 4.36, continued

o) Total PAHs

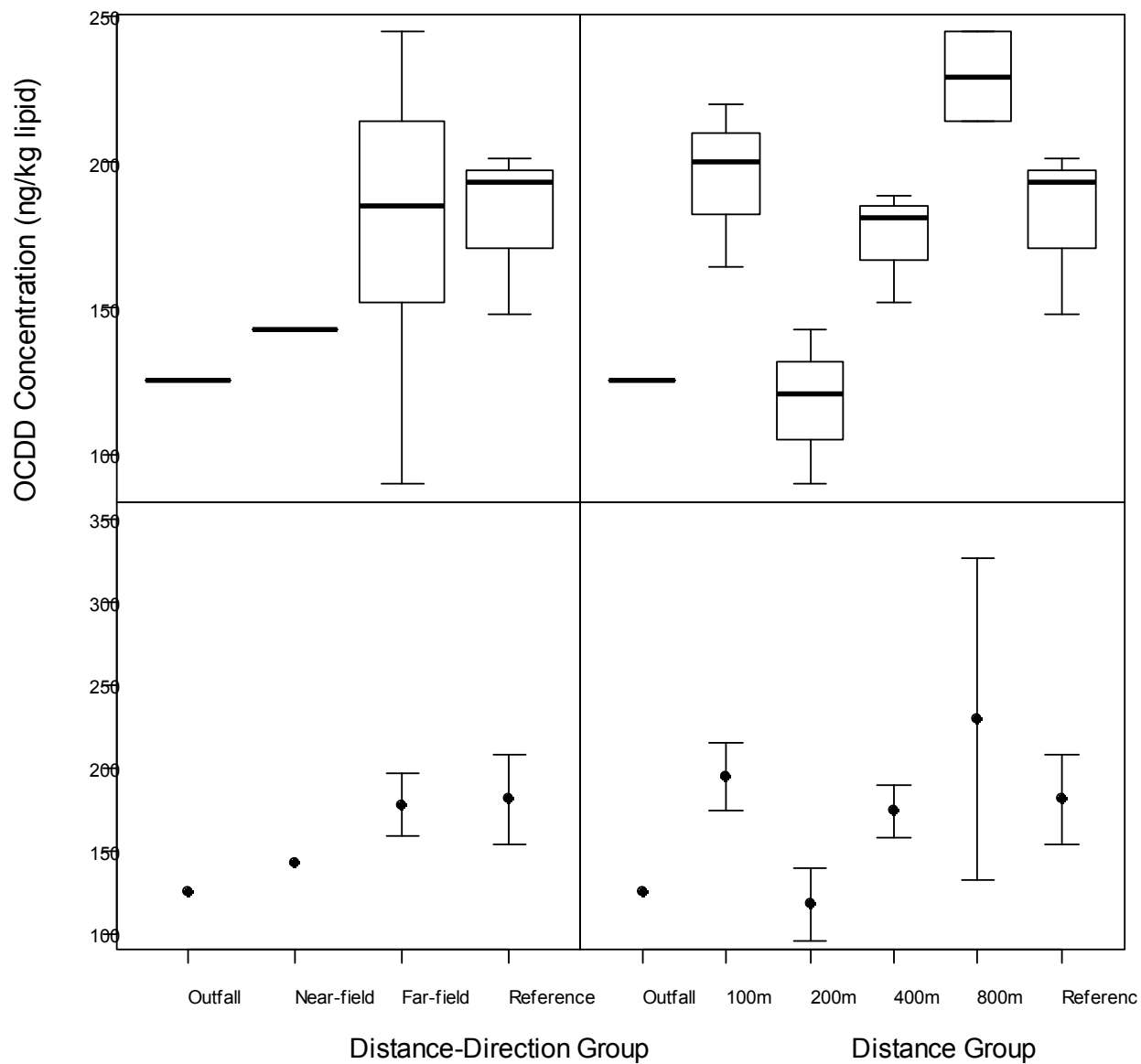


Figure 4.36, continued

p) OCDD

Comparisons to Tissue Guidelines and Food Chain Model

In previous Clover Point mussel study reports (Golder 2007b, 2008b, 2009b, 2010b(Golder, 2010b)) tissue threshold concentrations of copper, zinc and lead were identified following review of a compilation of tissue toxicity data (Jarvinen and Ankley, 1999). To further examine the potential effects of the three metals of primary interest (copper, lead, zinc), studies on tissue toxicity were reviewed to derive literature-based tissue benchmarks for assessing potential harm to organisms higher in the food chain (Golder, 2011b). These benchmarks have a high degree of uncertainty and cannot be used to make definitive statements regarding the potential for harm, but can help provide an overall context for detected substance levels.

For copper, a tissue threshold concentration of 19 mg/kg ww was chosen based on the median tissue concentration that caused effects in the reviewed studies (Golder, 2008c). The maximum measured tissue concentration in CRD horse mussels in 2010 was at Station C0, at 22.5 mg/kg ww (Figure 4.34, Table 4.29). This is slightly higher than both the threshold and the upper range of reported NOECs, but is similar to previous years' results. Station C1E was also slightly above threshold at 21.5 mg/kg ww copper, although it was within the upper range of reported NOECs. All other stations had copper concentrations below threshold (7.3 to 17.6 mg/kg ww).

The tissue threshold concentration for lead was set at 200 mg/kg ww (Golder, 2008c). Tissue concentration of lead in Clover Point horse mussels in 2010 ranged from 0.477 mg/kg ww to 4.05 mg/kg ww (Table 4.29). The highest concentrations were observed at the outfall terminus and near-field stations (C0, C1E, and C2E). All measured tissue concentrations were well below the tissue threshold concentration and were within the range of reported no effects concentrations (Golder, 2011b).

The zinc tissue threshold concentration was set at 148 mg/kg ww (Golder, 2008c). The maximum tissue concentration found in the horse mussel samples in 2010 was 111 mg/kg ww (Figure 4.34, Table 4.29), and was measured in mussels from the reference station CB3. The maximum level of zinc detected at an outfall station was 108 mg/kg ww, at Station C2S. Therefore, all tissue concentrations observed in 2010 were below the tissue threshold concentration. These conclusions were similar to previous sampling years (Golder, 2011b).

In addition to the three metals, toxicity data for PAH exposure was reviewed. Detected tissue concentrations of individual PAHs ranged from 0.046 µg/kg ww (benz(a)pyrene) to 4.71 µg/kg ww (fluoranthene) (Figure 4.34, Table 4.29). The maximum total concentration of PAHs was observed at the outfall terminus (C0; 24.3 µg/kg ww). The tissue PAH levels were well below the threshold concentrations for lethal or sublethal effects in aquatic organisms (3,400 to 50,000 µg/kg ww) (Jarvinen *et al.*, 1999). The maximum concentration observed in 2010 was lower than that observed in 2009, and higher than that of 2008 (Golder, 2011b), with both maximums occurring at Station C0.

Golder (2005b) conducted a screening-level food web bioaccumulation risk assessment; a food chain model (FCM), using historical tissue monitoring data. The exposure terms of the model were re-evaluated using 2010 mussel monitoring data. The mean concentrations of copper, lead, and zinc in the 2010 mussel monitoring data were slightly elevated in comparison to the average mussel tissue concentrations used in the 2005 FCM². Given that the 2010 average mussel tissue concentrations of copper, lead and zinc were only slightly higher than the Golder (2005b) exposure concentrations, it is unlikely to expect significant risks to wildlife receptors in the vicinity of the outfall. If significant increasing trends in these metals are observed over the next few years, the FCM should be re-run using the new exposure concentrations along with updated toxicity values and exposure parameters from the literature, if available (Golder, 2011b).

Notes

¹ Statistical significance (2-tailed): ** = $p < 0.01$; * = $p < 0.05$.

² The FCM in Golder (Golder, 2005b) applied copper, lead, and zinc tissue concentrations of 8.7, 1.1, and 74.8 mg/kg ww, whereas the mean concentrations in 2010 are higher at 11.8, 1.05, and 78.2 mg/kg ww. However, it is likely that the same conclusions would be obtained due to inherent uncertainty with the threshold concentrations and to the conservatism that was built into the model.

Table 4.29 Summary Statistics and Distance Gradients for Mussel Tissue Chemistry Data in 2010 (All Stations)

Parameter	Mean	Median	Standard Deviation	Minimum	Maximum	Correlation (r_s) With Distance-Direction ^{1, 2}	Correlation (r_s) With Distance ^{1, 2}
Conventionals							
Moisture Content (%) - ALS	84.5	84.8	1.02	82.6	86.2	0.270	0.180
Moisture Content (%) - AXYS (PAHs)	84.2	84.3	0.828	82.3	85.7	0.251	0.178
Moisture Content (%) - AXYS (PCDDs)	84.2	84.7	1.16	81.6	85.7	0.342	0.347
Lipid Content (%) - ALS	1.43	1.3	0.483	0.250	2.5	-0.334	-0.260
Lipid Content (%) - AXYS (PAHs)	0.888	0.82	0.222	0.61	1.37	-0.564**	-0.515**
Lipid Content (%) - AXYS (PCDDs)	0.883	0.82	0.231	0.61	1.34	-0.522*	-0.477
Moisture Content (%) - ALS	84.5	84.8	1.02	82.6	86.2	0.270	0.180
Metals (mg/kg ww)							
Aluminum	72.5	70.3	23.3	16.3	131	0.466*	0.421*
Arsenic	2.01	1.98	0.263	1.58	2.61	0.188	0.199
Cadmium	2.78	2.71	0.874	1.08	5.38	0.330	0.478*
Chromium	0.440	0.372	0.394	0.181	2.32	0.516**	0.430*
Copper	11.8	10.8	3.68	7.28	22.5	-0.739**	-0.594**
Iron	138	134	45.1	64.2	259	0.677**	0.510**
Lead	1.05	0.869	0.707	0.477	4.05	-0.365	-0.253
Magnesium	748	736	69.6	609	903	-0.035	0.117
Manganese	40.8	40.7	8.72	24.7	62.3	0.104	0.215
Mercury	0.050	0.043	0.021	0.026	0.112	0.442*	0.445*
Nickel	1.90	1.81	0.533	1.02	3.35	0.597**	0.478*
Selenium	1.16	1.16	0.127	0.928	1.48	0.036	0.075
Silver	2.33	2.05	1.81	0.106	7.63	0.610**	0.495**
Zinc	78.2	74.2	16.2	41.6	111	-0.075	-0.002
PAHs (µg/kg ww)							
Acenaphthene	0.146	0.129	0.075	0.085	0.437	-0.693**	-0.608**
Anthracene	0.199	0.138	0.143	0.085	0.703	-0.179	-0.260
Benz[a]anthracene	0.386	0.291	0.339	0.191	1.61	-0.698**	-0.852**
Benzo[a]pyrene	0.231	0.150	0.269	0.046	1.13	-0.733**	-0.800**
Benzo[b]fluoranthene	0.413	0.347	0.215	0.277	1.20	-0.640**	-0.718**
Benzo[j,k]fluoranthenes	0.367	0.293	0.234	0.209	1.18	-0.513**	-0.530**
Chrysene	0.622	0.523	0.350	0.384	2.04	-0.599**	-0.738**

continued

Table 4.29, continued

Parameter	Mean	Median	Standard Deviation	Minimum	Maximum	Correlation (r_s) With Distance-Direction	Correlation (r_s) With Distance
Fluoranthene	1.19	0.950	0.866	0.680	4.71	-0.682**	-0.802**
Fluorene	0.600	0.568	0.174	0.319	1.15	-0.302	-0.208
Naphthalene	1.15	1.15	0.221	0.840	1.70	-0.195	0.026
Phenanthrene	1.40	1.17	0.849	0.832	4.52	-0.712**	-0.787**
Pyrene	0.687	0.453	0.832	0.251	3.49	-0.666**	-0.744**
Total High Molecular Weight PAHs	3.72	2.99	3.09	1.19	15.9	-0.677**	-0.802**
Total Low Molecular Weight PAHs	3.38	3.20	1.14	2.04	8.37	-0.547**	-0.504**
TOTAL PAHs	7.09	6.12	4.13	3.56	24.3	-0.649**	-0.779**
PAHs ($\mu\text{g/kg lipid}$)							
Acenaphthene	16.4	15.4	5.59	10.9	33.2	-0.534**	-0.431*
Anthracene	22.5	17.7	13.9	7.40	62.8	-0.011	-0.089
Benz[a]anthracene	42.4	34.2	31.5	16.6	165.2	-0.456*	-0.579**
Benzo[a]pyrene	25.4	17.9	27.0	6.82	138	-0.538**	-0.562**
Benzo[b]fluoranthene	47.1	45.0	20.0	21.9	128.8	-0.096	-0.152
Benzo[j,k]fluoranthenes	41.6	34.5	23.5	25.8	143.6	-0.144	-0.133
Chrysene	70.2	66.2	29.5	36.3	172.6	-0.249	-0.230
Fluoranthene	130	115	70.6	59.1	352	-0.479*	-0.535**
Fluorene	70.1	70.1	22.2	36.6	119	0.076	0.152
Naphthalene	140	135	33.7	90.7	237	0.365	0.426*
Phenanthrene	157	150	60.5	73.7	337	-0.417	-0.418
Pyrene	73.1	48.9	69.5	22.1	261	-0.483*	-0.568*
Total High Molecular Weight PAHs	411	358	274	161	1430	-0.431*	-0.520*
Total Low Molecular Weight PAHs	390	403	97.9	152	624	-0.059	-0.044
TOTAL PAHs	800	754	343	344	1910	-0.313	-0.312
PCDDs (ng/kg ww)							
OCDD	1.46	1.51	0.210	1.12	1.80	-0.383	-0.388
PCDDs (ng/kg lipid)							
OCDD	172	181	42.5	89.7	245	0.315	0.319

Notes

¹ See Section 2.2.2 in the report for a description of how the summary statistics were calculated.

² Statistical significance (2-tailed): ** = $p < 0.01$; * = $p < 0.05$.

DETAILED TREND ANALYSIS

Trends in Biological Parameters

Golder (2011b) computed summary statistics for biological parameters by distance and by distance-direction from the outfall. Two sets of statistics were prepared; one for the entire period of record (2000-2010) and one for the most recent three years (2008-2010) (Table 4.30). Data was analyzed using Spearman rank correlations and by analysis of variance (ANOVA). See Golder (2011b) for details of the analyses.

Distance gradients were assessed using Spearman rank correlations between each biological parameter and distance from the outfall (Table 4.31). Correlations were calculated for all stations, including reference, and for all years combined, for recent years only (2008-2010) and for each individual year. Results indicated that both shell length and shell width were significantly negatively correlated with distance from the outfall for all years combined (2000-2010) and in the most recent years (2008-2010) ($p < 0.01$), indicating that mussel lengths and widths tend to decrease with increasing distance from the outfall (Table 4.31).

Both shell length and width have had negative relationships with distance from the outfall for each individual year between 2000 and 2010, with significant correlation coefficients in 9 of the 11 years. When stations were subdivided into the outfall, near-field and far-field distance-direction groups, significant negative correlations were identified for all years combined and in the most recent years between both shell length and width and distance-direction from the outfall. Correlation coefficients were generally weaker than those calculated based on distance alone (Golder, 2011b)(Table 4.31) for both shell length and shell width, although shell width in the most recent years had a slightly stronger negative correlation with distance-direction than with distance alone (Golder, 2011b)

Tissue wet weights and shell weights were significantly negatively correlated to distance from the outfall for all years combined and for recent years (Golder, 2011b)(Table 4.31). Shell weight was strongly negatively correlated with distance in both time periods. The correlation between tissue wet weight and distance from the outfall was weak when all years were combined and moderate when using recent years only, most likely due, in part, to the positive correlation between tissue wet weight and distance observed in the year 2000. All other individual year correlations between tissue wet weight and distance were negative, with significant relationships from 2002 through 2010. Tissue wet weight and shell weight were negatively correlated to distance-direction from the outfall, with slightly stronger correlation coefficients observed in recent years relative to all years combined (Table 4.32). Correlation coefficients were weaker than those observed for distance groups (Golder, 2011b)

Age was significantly negatively correlated with distance from the outfall for both analyses conducted using all years combined and for recent years only (Table 4.31); however the correlation coefficients were weak. In four individual sampling years (2003, 2004, 2008 and 2009), moderate to strong negative correlations were observed between age and distance from the outfall. The relationship between age and distance-direction from the outfall for all years was not significant, while the relationship between age and distance-direction for recent years was significant and negative, although weak (Table 4.32).

Table 4.30 Summary Statistics for Mussel Biological Parameters (2000–2010 and 2008–2010)

A. Shell Length (mm)														
Distance Group	2000-2010 station means							2008-2010 station means						
	n	Mean	Median	SD	Min	Max	%Ref	n	Mean	Median	SD	Min	Max	%Ref
Outfall	11	82.0	83.1	3.3	76.4	87.0	111	3	83.1	83.2	2.2	80.9	85.3	110
100 m stations	83	79.6	79.4	3.7	63.7	86.6	107	21	81.1	81.1	2.8	75.5	85.1	107
200 m stations	66	79.8	79.5	3.5	71.5	88.5	108	18	81.5	82.1	3.8	75.5	88.5	107
400 m stations	66	76.7	76.4	4.1	68.2	85.8	103	18	78.7	79.4	4.5	71.1	85.8	104
800 m stations	22	76.5	76.6	4.1	69.8	86.2	103	6	76.3	74.6	4.6	72.3	85.1	101
Near-field stations	22	78.8	78.7	3.2	70.0	83.2	106	6	82.6	82.7	0.6	81.9	83.2	109
Far-field stations	215	78.5	78.5	4.2	63.7	88.5	106	57	79.8	80.0	4.2	71.1	88.5	105
Reference stations	40	74.2	73.8	3.6	67.4	80.4	100	15	75.8	77.5	3.5	71.6	80.4	100
All Stations	288	78.1	78.2	4.3	63.7	88.5	105	81	79.4	79.6	4.3	71.1	88.5	105
B. Shell Width (mm)														
Distance Group	2000-2010 station means							2008-2010 station means						
	n	Mean	Median	SD	Min	Max	%Ref	n	Mean	Median	SD	Min	Max	%Ref
Outfall	11	37.0	37.2	1.1	35.1	39.1	115	3	37.4	37.4	0.1	37.2	37.5	113
100 m stations	83	37.0	36.8	1.8	30.6	42.2	115	21	37.9	38.4	1.8	34.3	42.2	115
200 m stations	66	36.9	36.9	1.7	33.1	40.3	115	18	37.4	37.7	1.7	34.5	40.3	113
400 m stations	66	35.6	35.5	2.5	26.0	39.7	111	18	36.9	37.1	2.2	33.7	39.7	112
800 m stations	22	35.5	35.3	1.9	32.1	39.7	111	6	36.5	35.7	1.9	34.9	39.7	111
Near-field stations	22	36.2	36.1	1.4	33.2	38.6	113	6	38.0	38.0	0.5	37.4	38.6	115
Far-field stations	215	36.5	36.4	2.2	26.0	42.2	113	57	37.3	37.4	2.0	33.7	42.2	113
Reference stations	40	32.1	32.2	1.5	29.6	35.9	100	15	33.0	32.9	1.5	30.6	35.9	100
All Stations	288	35.9	36.0	2.5	26.0	42.2	112	81	36.5	37.0	2.5	30.6	42.2	111

continued

Table 4.30 continued

C. Tissue Wet Weight (g)														
Distance Group	2000-2010 station means							2008-2010 station means						
	n	Mean	Median	SD	Min	Max	%Ref	n	Mean	Median	SD	Min	Max	%Ref
Outfall	11	11.4	11.5	2.2	6.7	14.5	155	3	12.2	11.2	2.0	11.0	14.5	154
100 m stations	83	10.7	10.6	2.4	4.0	17.5	146	21	12.0	11.3	2.6	8.8	17.5	151
200 m stations	65	10.7	10.5	2.7	5.1	17.8	145	18	12.6	12.2	2.6	7.9	17.8	159
400 m stations	66	9.9	10.3	2.5	4.7	17.2	135	18	10.9	11.1	2.5	7.3	17.2	137
800 m stations	22	9.8	9.7	1.9	6.4	13.4	133	6	10.3	10.4	1.9	7.8	12.6	130
Near-field stations	22	10.3	10.2	2.2	5.9	15.0	140	6	12.1	11.1	2.3	10.1	15.0	152
Far-field stations	214	10.4	10.5	2.5	4.0	17.8	142	57	11.7	11.4	2.6	7.3	17.8	147
Reference stations	40	7.4	7.6	1.3	4.5	9.6	100	15	7.9	7.9	0.8	6.3	9.3	100
All Stations	287	10.0	10.1	2.6	4.0	17.8	136	81	11.0	10.8	2.7	6.3	17.8	139
D. Shell Weight (g)														
Distance Group	2000-2010 station means							2008-2010 station means						
	n	Mean	Median	SD	Min	Max	%Ref	n	Mean	Median	SD	Min	Max	%Ref
Outfall	8	15.2	15.3	1.3	12.6	16.7	160	3	15.0	15.1	0.6	14.3	15.5	145
100 m stations	59	14.1	13.7	1.4	11.3	17.4	148	21	14.4	14.2	1.4	12.2	17.4	140
200 m stations	48	14.4	14.2	1.9	10.8	19.7	152	18	15.1	14.8	2.4	11.3	19.7	146
400 m stations	48	12.5	12.3	1.9	9.2	16.4	132	18	12.9	12.4	2.0	9.8	16.4	125
800 m stations	16	12.2	12.0	1.7	9.5	15.8	129	6	11.9	11.3	1.9	10.3	15.5	116
Near-field stations	16	14.0	13.8	1.1	12.1	15.6	147	6	15.1	15.0	0.3	14.8	15.6	147
Far-field stations	155	13.5	13.4	2.0	9.2	19.7	143	57	13.8	13.6	2.3	9.8	19.7	134
Reference stations	37	9.5	9.3	1.4	7.1	12.5	100	15	10.3	10.3	1.5	8.2	12.5	100
All Stations	216	12.9	13.1	2.4	7.1	19.7	136	81	13.3	13.3	2.5	8.2	19.7	129

continued

Note:

shell weight not measured in 2000, 2001 and 2002

Table 4.30 continued

E. Age														
Distance Group	2000-2010 station means							2008-2010 station means						
	n	Mean	Median	SD	Min	Max	%Ref	n	Mean	Median	SD	Min	Max	%Ref
Outfall	11	8.7	8.6	0.9	7.5	10.7	101	3	8.5	8.4	0.1	8.4	8.6	109
100 m stations	83	8.8	8.6	1.3	6.4	12.3	102	21	8.2	8.1	0.9	6.4	10.6	106
200 m stations	66	8.9	8.7	1.5	5.5	13.7	103	18	8.3	8.2	0.6	7.5	9.4	107
400 m stations	66	8.5	8.2	1.5	5.5	13.8	99	18	7.8	7.9	0.8	6.0	9.3	100
800 m stations	22	8.6	8.1	1.6	6.4	12.4	100	6	7.5	7.4	0.5	6.9	8.3	96
Near-field stations	22	8.7	8.5	1.4	5.7	12.1	101	6	8.7	8.6	0.5	8.0	9.4	111
Far-field stations	215	8.7	8.4	1.4	5.5	13.8	101	57	8.0	8.0	0.8	6.0	10.6	103
Reference stations	40	8.6	8.0	1.7	6.7	13.8	100	15	7.8	7.7	0.7	6.7	9.0	100
All Stations	288	8.7	8.4	1.5	5.5	13.8	101	81	8.0	8.0	0.7	6.0	10.6	103
F. Proportion of Females														
Distance Group	2000-2010 station means							2008-2010 station means						
	n	Mean	Median	SD	Min	Max	%Ref	n	Mean	Median	SD	Min	Max	%Ref
Outfall	11	0.6	0.6	0.1	0.3	0.8	113	3	0.5	0.5	0.2	0.3	0.6	94
100 m stations	83	0.5	0.5	0.2	0.2	0.9	107	21	0.5	0.5	0.1	0.2	0.7	96
200 m stations	65	0.5	0.6	0.2	0.2	0.8	107	17	0.6	0.6	0.1	0.4	0.8	112
400 m stations	66	0.5	0.5	0.2	0.2	0.9	97	18	0.5	0.5	0.1	0.2	0.7	94
800 m stations	22	0.5	0.5	0.1	0.3	0.7	104	6	0.5	0.6	0.1	0.3	0.6	104
Near-field stations	22	0.5	0.5	0.2	0.2	0.8	110	6	0.5	0.5	0.1	0.4	0.6	100
Far-field stations	214	0.5	0.5	0.2	0.2	0.9	103	56	0.5	0.5	0.1	0.2	0.8	101
Reference stations	39	0.5	0.5	0.2	0.1	0.9	100	15	0.5	0.6	0.2	0.1	0.8	100
All Stations	286	0.5	0.5	0.2	0.1	0.9	104	80	0.5	0.5	0.2	0.1	0.8	100

continued

Table 4.30 continued

G. Gonad Index														
Distance Group	2000-2010 station means							2008-2010 station means						
	n	Mean	Median	SD	Min	Max	%Ref	n	Mean	Median	SD	Min	Max	%Ref
Outfall	11	4.2	4.2	0.4	3.3	4.9	107	3	4.2	4.2	0.3	3.9	4.4	107
100 m stations	83	4.2	4.4	0.6	2.5	5.0	108	21	4.2	4.2	0.5	3.3	5.0	106
200 m stations	65	4.1	4.2	0.7	1.9	5.0	104	17	3.9	4.0	0.7	1.9	5.0	101
400 m stations	66	4.2	4.3	0.6	2.6	5.0	105	18	4.2	4.2	0.5	3.4	4.9	107
800 m stations	22	4.1	4.2	0.6	2.5	4.9	104	6	4.2	4.2	0.5	3.6	4.8	108
Near-field stations	22	4.1	4.1	0.5	3.2	4.8	104	6	4.2	4.2	0.4	3.5	4.6	107
Far-field stations	214	4.2	4.3	0.6	1.9	5.0	106	56	4.1	4.2	0.6	1.9	5.0	105
Reference stations	39	3.9	4.0	0.6	2.6	5.0	100	15	3.9	3.9	0.6	2.6	4.8	100
All Stations	286	4.1	4.2	0.6	1.9	5.0	105	80	4.1	4.2	0.5	1.9	5.0	104
H. Reproductive Timing Index														
Distance Group	2000-2010 station means							2008-2010 station means						
	n	Mean	Median	SD	Min	Max	%Ref	n	Mean	Median	SD	Min	Max	%Ref
Outfall	11	4.7	4.7	0.4	4.1	5.6	110	3	4.4	4.4	0.3	4.1	4.7	107
100 m stations	83	4.6	4.8	0.5	3.1	5.4	110	21	4.7	4.6	0.3	4.1	5.3	115
200 m stations	65	4.4	4.6	0.7	2.5	6.0	105	17	4.3	4.3	0.7	2.7	6.0	105
400 m stations	66	4.5	4.6	0.6	2.6	5.5	106	18	4.7	4.8	0.4	3.9	5.3	115
800 m stations	22	4.5	4.6	0.6	3.6	5.6	108	6	4.8	4.8	0.4	4.2	5.5	116
Near-field stations	22	4.5	4.6	0.6	3.3	5.5	108	6	4.6	4.6	0.4	3.9	5.1	112
Far-field stations	214	4.5	4.7	0.6	2.5	6.0	107	56	4.6	4.6	0.5	2.7	6.0	112
Reference stations	39	4.2	4.4	0.6	2.6	5.3	100	15	4.1	4.2	0.6	2.6	4.9	100
All Stations	286	4.5	4.6	0.6	2.5	6.0	106	80	4.5	4.6	0.6	2.6	6.0	110

Table 4.31 Spearman Rank Correlations between Mussel Biological Parameters and Distance

Parameter	2000– 2010	2008– 2010	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Shell Length (mm)	-0.482	-0.507	-0.615	-0.356	-0.183	-0.492	-0.646	-0.619	-0.637	-0.649	-0.579	-0.511	-0.415
Shell Width (mm)	-0.528	-0.534	-0.359	-0.417	-0.350	-0.517	-0.662	-0.660	-0.680	-0.684	-0.630	-0.525	-0.429
Tissue Wet Weight (g)	<u>-0.388</u>	-0.527	0.527	-0.313	-0.442	-0.629	-0.544	-0.646	-0.599	-0.660	-0.722	-0.566	-0.414
Shell Weight (g)	-0.640	-0.635	NM	NM	NM	-0.476	-0.693	-0.680	-0.630	-0.692	-0.758	-0.614	-0.533
Age (annuli)	<u>-0.134</u>	<u>-0.344</u>	0.345	0.123	0.004	-0.477	-0.773	0.030	0.037	-0.309	-0.440	-0.472	-0.299
Gonad Index	<u>-0.138</u>	-0.082	-0.088	-0.165	-0.017	-0.450	-0.153	-0.214	<u>-0.390</u>	-0.443	-0.084	-0.341	0.037
Reproductive Timing Index	<u>-0.212</u>	-0.184	-0.171	-0.170	-0.012	-0.422	-0.104	-0.282	-0.443	-0.426	-0.065	-0.321	-0.215
Proportion of Females	-0.103	0.069	-0.221	-0.159	-0.179	-0.272	0.018	-0.159	-0.211	-0.168	0.122	0.109	-0.013

Note

NM = parameter was not measured this year

Statistically significant correlations ($p < 0.05$) are **bolded**

Bold & underlined = weak ($|r_s| < 0.4$) but statistically significant correlation

X = strong correlation ($|r_s| > 0.6$) **X** = moderate strength correlation ($0.4 < |r_s| < 0.6$)

Table 4.32 Spearman Rank Correlations between Mussel Biological Parameters and Distance-Direction Gradient (i.e. Outfall/Near-field/Far-field/Reference; 2000-2010)

Parameter	2000–2010	2008–2010	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Shell Length (mm)	<u>-0.344</u>	<u>-0.475</u>	-0.174	-0.139	-0.143	-0.298	-0.333	-0.565	-0.507	-0.430	-0.452	-0.421	-0.552
Shell Width (mm)	-0.428	-0.543	-0.102	-0.137	-0.158	-0.316	-0.429	-0.584	-0.579	-0.511	-0.569	-0.501	-0.541
Tissue Wet Weight (g)	<u>-0.370</u>	<u>-0.517</u>	0.098	-0.286	-0.336	-0.497	-0.457	-0.431	-0.557	-0.498	-0.617	-0.573	-0.377
Shell Weight (g)	-0.576	-0.586	NM	NM	NM	-0.368	-0.547	-0.647	-0.647	-0.549	-0.573	-0.517	-0.648
Age (annuli)	-0.088	<u>-0.311</u>	0.398	0.121	0.120	-0.165	-0.424	-0.083	-0.003	-0.100	-0.358	-0.366	-0.367
Gonad Index	-0.090	-0.133	-0.111	0.044	-0.091	-0.267	0.029	0.042	-0.307	-0.305	-0.160	-0.420	-0.065
Reproductive Timing Index	<u>-0.174</u>	<u>-0.244</u>	-0.300	-0.242	-0.391	-0.224	0.031	0.088	-0.318	-0.311	-0.180	-0.372	-0.247
Proportion of Females	-0.081	0.074	-0.035	-0.456	0.062	-0.304	-0.008	-0.299	-0.099	-0.015	0.132	0.088	0.015

Note

NM = parameter was not measured this year

Statistically significant correlations ($p < 0.05$) are **bolded**

Bold & underlined = weak ($|r_s| < 0.4$) but statistically significant correlation

X = strong correlation ($|r_s| > 0.6$) **X** = moderate strength correlation ($0.4 < |r_s| < 0.6$)

Gonad index (GI) and reproductive timing index (RTI) were significantly negatively correlated to distance from the outfall when all years of data were used; however the strength of the relationship was very weak (Table 4.31). The proportion of females was not significantly correlated with distance for any of the time periods analyzed (Golder, 2011b). No significant relationships were identified between GI and distance-direction from the outfall, and only weak negative relationships (Table 4.32) were identified for RTI versus distance (for both time periods). Proportion of females was not significantly correlated with distance-direction for all years, or for recent years; however one significant negative correlation was observed in 2001 (Table 4.32) (Golder, 2011b)

All mussel size and weight parameters exhibited significant differences relative to reference ($p < 0.001$) in ANOVA tests in all years combined and in recent years (Table 4.33). *Post hoc* comparisons revealed, for nearly all size-weight parameters, significant differences between the reference area and most or all of the five distance groups. The only non-significant results for size-weight parameters were observed for shell length at 800m stations versus reference in all years and for 400m and 800m stations versus reference in recent years. Among the remaining biological parameters, RTI exhibited a significant difference among groups for both all years combined and in recent years only. *Post hoc* comparisons revealed significant differences between each of the 100m and 400m versus the reference area for both all years combined and in recent years only.

ANOVA indicated that all size-weight parameters exhibited significant differences ($p < 0.001$) among near-field, far-field and reference groups in all years combined and for recent years only (Table 4.34). *Post hoc* comparisons revealed that for all size-weight parameters, significant differences existed between the reference area and both of the distance-direction groups. Figure 4.33 shows that over the period of record, mussel size and weight parameters were generally higher in all outfall station groups (both distance groups and distance-direction groups) compared to reference. These patterns are qualitatively similar to those observed in the 2010 sampling year. No discernible spatial trends were observed for age or proportion of females. GI and RTI appeared to have slightly decreased mean values in the reference area; however the magnitude of the difference was very small relative to the variability within groups (Golder, 2011b)

Plots of the reference-normalized distance-direction group means over time for the biological parameters are presented in Figure 4.37. Temporal trends are weak for all metrics in recent sampling years when biological metrics are standardized to the reference area mean) (Golder, 2011b). No consistent trends are observed among distance-direction groups, and no individual reproductive metric suggests a long term increasing or decreasing trend over time. In general, temporal trends for mussel biological parameters were stronger when reference stations were excluded. Significant positive correlations (i.e. an increase over time) were identified for mussel shell length, width and tissue wet weight, however the strength of the correlations was weak and only tissue wet weight showed a moderately strong correlation ($r_s = 0.42$, reference excluded). When correlations were calculated for each individual distance group, the strongest positive correlation was identified at C0 for shell length ($r_s = 0.66$). When correlations were calculated for distance-direction groups, strong positive correlations ($r_s > 0.65$) were identified for each of the size and weight metrics in the near-field group. Significant but weak ($r_s < 0.40$) positive correlations were identified for shell length, shell width and tissue wet weight in the far-field group. A significant negative correlation was identified for mussel age in the far-field group, however, the strength of the relationship was weak ($r_s = -0.18$) (Golder, 2011b).

Heterogeneity was not significantly different among stations for any of the biological parameters, as determined by the Van Belle test for homogeneity (Table 4.35). This indicates that temporal trends for these parameters do not differ significantly among individual stations. Results were the same with the inclusion and exclusion of reference stations, indicating that trends at the reference station do not appear to differ significantly from trends at the outfall station (Golder, 2011b)

Trends in Tissue Chemistry

Table 4.36 (Golder, 2011b) summarizes the frequency of detection for all parameters measured in mussel tissues between 2000 and 2010. Fourteen metals in total were retained for the trend assessment. Twelve individual PAH parameters were also retained, although the trend assessment was limited to high

resolution data, collected from 2006-2010. To evaluate the effect of lipid concentrations on trends in mussel PAH concentrations, lipid-normalized PAHs were included in the trend assessment. Summary statistics, including medians, means (or geomeans) and standard deviations (or confidence factors) were calculated for the frequently detected parameters (Table 4.37 and Table 4.38). The summary statistics were calculated for distance groups and distance-direction groups, for two time periods: one for the entire period of record (2000-2010) and one for the most recent three years (2008-2010) (Golder, 2011b).

Eight of the metals (aluminum, arsenic, cadmium, iron, magnesium, mercury, nickel and silver) were significantly ($p < 0.05$) positively correlated with distance from the outfall, indicating that concentrations often increased with distance from station C0 (Table 4.39). However all of these relationships were weak for all years of data combined. For recent years only (2008-2010) four of the eight positively correlated metals (iron, mercury, nickel and silver) showed a significant but weak relationship with distance, although in all cases but silver the correlation was weaker than all years combined. Overall, the high variability of the correlations from year to year is illustrative of the high variability of the concentrations over space and time, and the relative lack of consistently strong or steep spatial trends.

Significant negative relationships were observed for copper and lead in recent years (2008-2010) and when all years were combined. However, these relationships were weak when assessed over multiple years of monitoring data. Overall the correlations indicate a weak pattern of declining copper and lead chemistry with distance from the outfall, with interannual variations in the strength of the relationship.

All individual PAHs with the exception of fluorene were significantly negatively correlated with distance from the outfall, both in recent years (2008-2010) and when all years were combined (2006-2010) (Table 4.39). Nine of the eleven significant correlations showed a stronger relationship when only the recent years data were used. When calculating coefficients by individual year, 2010 had the greatest number of strong significant relationships (eight of the eleven individual PAHs, plus total high molecular weight PAHs).

When PAHs were lipid-normalized, there were fewer significant correlations with distance from the outfall. Three lipid-normalized PAHs (benz(a)anthracene, fluoranthene and pyrene) were significantly negatively correlated with distance from the outfall, both in recent years and when all years were combined (Table 4.39), however the strength of these correlations was weak ($|r_s| < 0.38$). Correlation coefficients calculated for each individual year also yielded fewer significant relationships compared with non lipid-normalized PAHs (Golder, 2011b). These observations are similar to the 2010 data, and similar to that reported in the previous two assessments (Golder 2009b, 2010b). These findings indicate that lipid content differences among distance groups were a factor in explaining the spatial gradients of PAH concentrations across the study area. However the lipid differences do not account for all of the spatial profile in PAH concentrations (Golder, 2011b).

Spatial patterns for metals grouped by distance-direction were similar to those for distance groupings, however more significant and more temporally consistent spatial correlations were observed when all years of data were included (Golder, 2011b)(Table 4.40). Ten of the fourteen metals were significantly positively correlated to distance-direction from the outfall, with three of these metals (iron, nickel and silver) having moderate strength relationships (r_s from 0.46 to 0.53). For recent years, there were fewer metals (five of fourteen) that were significantly positively correlated to distance-direction, with only iron and silver showing moderate strength relationships (Golder, 2011b).

Spatial patterns for PAHs grouped by distance-direction were similar to those for distance groupings; however in general, stronger and more significant spatial correlations were observed. All except two (benzo(a)pyrene and fluorene) of the PAHs were significantly negatively correlated with distance-direction when all years were combined (2006-2010, Table 4.40). When only recent years data were analyzed, all PAHs except fluorene were significantly negatively correlated with distance-direction. When calculated for individual years, 2010 had the greatest number of strong significant relationships (seven of the eleven individual PAHs, plus total high molecular weight PAHs) (Golder, 2011b). When PAHs were lipid-normalized, there were fewer significant correlations with distance-direction compared with non lipid-normalized PAHs (Golder, 2011b).

Table 4.33 Results of Analysis of Variance (ANOVA or Kruskal-Wallis) and Post hoc Statistical Comparisons to Constance Reference for Clover Point Distance Groups (2000–2010)

Parameter	All Years (2000-2010)						Recent Years (2008-2010)					
	ANOVA/ Kruskal- Wallis	Comparison with Reference					ANOVA/ Kruskal- Wallis	Comparison with Reference				
		Outfall	100 m	200 m	400 m	800 m		Outfall	100 m	200 m	400 m	800 m
Shell Length (mm)	< 0.001	< 0.001	< 0.001	< 0.001	0.018	0.319	< 0.001	0.023	< 0.001	0.002	0.108	1.000
Shell Width (mm)	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.023	< 0.001	< 0.001	< 0.001	0.003
Tissue Wet Weight (g)	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.023	< 0.001	< 0.001	0.002	0.031
Shell Weight (g)	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.023	< 0.001	< 0.001	0.003	0.417
Age (annuli)	0.232	NC	NC	NC	NC	NC	0.013	0.257	0.202	0.068	1.000	0.776
Gonad Index	0.125	NC	NC	NC	NC	NC	0.733	NC	NC	NC	NC	NC
Reproductive Timing Index	0.002	0.089	< 0.001	0.164	0.028	0.361	0.004	1.000	0.003	1.000	0.007	0.051
Proportion of Females	0.386	NC	NC	NC	NC	NC	0.611	NC	NC	NC	NC	NC

Note

Significant differences relative to references ($p < 0.05$) are **bolded**.

NC = Not calculated; no comparison made as ANOVA (or non parametric Kruskal-Wallis test if applicable) was not significant.

Table 4.34 Results of Analysis of Variance (ANOVA or Kruskal-Wallis) and Post hoc Statistical Comparisons to Constance Reference for Clover Point Distance-Direction Groups (2000–2010)

Parameter	All Years (2000-2010)				Recent Years (2008-2010)			
	ANOVA/ Kruskal-Wallis	Comparison with Reference			ANOVA/ Kruskal-Wallis	Comparison with Reference		
		Outfall	Near-field	Far-field		Outfall	Near-field	Far-field
Shell Length (mm)	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.023	0.001	0.004
Shell Width (mm)	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.023	0.001	0.000
Tissue Wet Weight (g)	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.023	0.001	0.000
Shell Weight (g)	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.023	0.001	0.000
Age (annuli)	0.451	NC	NC	NC	0.020	0.257	0.038	0.802
Gonad Index	0.072	NC	NC	NC	0.667	NC	NC	NC
Reproductive Timing Index	0.004	0.053	0.064	0.001	0.021	1.000	0.181	0.009
Proportion of Females	0.561	NC	NC	NC	0.931	NC	NC	NC

Note

Significant differences relative to references ($p < 0.05$) are **bolded**.

NC = Not calculated; no comparison made as ANOVA (or non parametric Kruskal-Wallis test if applicable) was not significant.

Table 4.35 Summary of Van Belle Test for Homogeneity of Temporal Trends in Mussel Biological Parameters among Clover Point Stations (2000–2010)

Parameter	Chi-square Homogeneity Test Statistics			
	All Stations	<i>p</i> -value	Reference Excluded	<i>p</i> -value
Shell Length (mm)	24.0	0.632	20.6	0.544
Shell Width (mm)	20.8	0.795	16.2	0.806
Tissue Wet Weight (g)	24.2	0.617	17.9	0.710
Shell Weight (g)	23.6	0.655	19.8	0.598
Age (annuli)	16.4	0.944	13.1	0.931
Gonad Index	9.5	0.999	8.5	0.996
Reproductive Timing Index	22.1	0.734	15.4	0.844
Proportion of Females	19.5	0.849	14.0	0.901

Table 4.36 Frequency of Detection for Tissue Chemistry Parameters (2000–2010)

Parameter	Frequency of Detection	Data Availability ¹	Retained for Trend Assessment
PCDDs			
1,2,3,4,6,7,8-HPCDD	100%	2%	No
1,2,3,4,6,7,8-HPCDF	100%	1%	No
1,2,3,4,7,8,9-HPCDF	0%	6%	No
1,2,3,4,7,8-HXCDD	10%	6%	No
1,2,3,4,7,8-HXCDF	10%	6%	No
1,2,3,6,7,8-HXCDD	24%	5%	No
1,2,3,6,7,8-HXCDF	5%	6%	No
1,2,3,7,8,9-HXCDD	0%	5%	No
1,2,3,7,8,9-HXCDF	0%	6%	No
1,2,3,7,8-PECDD	5%	6%	No
1,2,3,7,8-PECDF	0%	6%	No
2,3,4,6,7,8-HXCDF	10%	6%	No
2,3,4,7,8-PECDF	11%	6%	No
2,3,7,8-TCDD	0%	5%	No
2,3,7,8-TCDF	93%	5%	No
OCDD	100%	5%	No
OCDF	100%	2%	No
TOTAL HEPTA-FURANS	29%	6%	No
TOTAL HEXA-DIOXINS	62%	6%	No
TOTAL PENTA-DIOXINS	5%	6%	No
TOTAL PENTA-FURANS	19%	6%	No
TOTAL TETRA-DIOXINS	14%	6%	No
TOTAL TETRA-FURANS	62%	6%	No
Semi-Volatile Organics			
2-Chloronaphthalene	0%	72%	No
4-Bromophenyl phenyl ether	0%	94%	No
4-Chlorophenyl phenyl ether	0%	94%	No
Bis(2-chloroethoxy)methane	0%	94%	No
Bis(2-chloroethyl)ether	0%	82%	No
Bis(2-chloroisopropyl)ether	0%	91%	No
Chlorinated Hydrocarbons			
1,2,4-Trichlorobenzene	1%	92%	No
1,2-Dichlorobenzene	0%	83%	No
1,3-Dichlorobenzene	0%	64%	No
1,4-Dichlorobenzene	1%	73%	No
Hexachlorobutadiene	0%	90%	No
Hexachloroethane	0%	73%	No
Phenolics			
2,4 & 2,5-Dichlorophenol	0%	94%	No
2,4,6-Trichlorophenol	0%	84%	No
2-Chlorophenol	0%	74%	No

continued

Table 4.36 continued

Parameter	Frequency of Detection	Data Availability ¹	Retained for Trend Assessment
Pentachlorophenol	1%	80%	No
PAHs (<2006)²			
Acenaphthene	1%	83%	No
Acenaphthylene	1%	83%	No
Anthracene	1%	83%	No
Benz[a]anthracene	3%	83%	No
Benzo[a]pyrene	2%	83%	No
Benzo[b]fluoranthene	4%	83%	No
Benzo[g,h,i]perylene	1%	81%	No
Benzo[k]fluoranthene	1%	83%	No
Chrysene	4%	83%	No
Dibenz[a,h]anthracene	1%	83%	No
Fluoranthene	7%	83%	No
Fluorene	1%	83%	No
Indeno[1,2,3-c,d]pyrene	1%	83%	No
Naphthalene	7%	83%	No
Phenanthrene	12%	83%	No
Pyrene	6%	83%	No
PAHs [2006-2010]³			
Acenaphthene	97%	61%	Yes
Acenaphthylene	80%	13%	No
Anthracene	92%	82%	Yes
Benz[a]anthracene	100%	73%	Yes
Benzo[a]pyrene	98%	58%	Yes
Benzo[b]fluoranthene	100%	66%	Yes
Benzo[g,h,i]perylene	50%	7%	No
Benzo[j,k]fluoranthenes	100%	61%	Yes
Chrysene	100%	79%	Yes
Dibenz[a,h]anthracene	3%	79%	No
Fluoranthene	100%	77%	Yes
Fluorene	100%	81%	Yes
Indeno[1,2,3-c,d]pyrene	40%	16%	No
Naphthalene	100%	44%	No
Phenanthrene	100%	61%	Yes
Pyrene	100%	52%	Yes
Total High Molecular Weight PAHs	100%	72%	Yes
Total Low Molecular Weight PAHs	100%	47%	No
TOTAL PAHs	100%	48%	No
Methyl Mercury			
Methyl Mercury	100%	9%	No

continued

Table 4.36 continued

Parameter	Frequency of Detection	Data Availability ¹	Retained for Trend Assessment
Metals			
Aluminum	100%	91%	Yes
Antimony	12%	100%	No
Arsenic	100%	100%	Yes
Barium	100%	9%	No
Beryllium	0%	100%	No
Bismuth	0%	9%	No
Cadmium	100%	100%	Yes
Calcium	100%	7%	No
Chromium	92%	91%	Yes
Cobalt	100%	9%	No
Copper	100%	100%	Yes
Iron	100%	88%	Yes
Lead	100%	100%	Yes
Lithium	100%	9%	No
Magnesium	100%	100%	Yes
Manganese	100%	98%	Yes
Mercury	100%	94%	Yes
Molybdenum	100%	9%	No
Nickel	100%	100%	Yes
Selenium	100%	100%	Yes
Silver	100%	74%	Yes
Strontium	100%	9%	No
Thallium	5%	100%	No
Tin	2%	9%	No
Uranium	100%	7%	No
Vanadium	100%	7%	No
Zinc	100%	100%	Yes

Note

¹ Percentage of samples in which parameter was measured and passed DQO screening.

² Pre-2006, PAHs were measured using low-resolution methods.

³ From 2006-2010, PAHs were measured using high-resolution methods.

Table 4.37 Summary Statistics for Frequently Detected Metals in Mussel Tissue (2000–2010)

A. Aluminum														
Distance Group	2000–2010 Station Means							2008–2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	10	33.2	30.1	1.27	16.3	137.4	42	3	43.5	36.6	1.60	16.3	137.4	55
100m Stations	76	61.7	62.9	1.15	29.9	120.0	78	21	62.6	62.9	1.13	29.9	88.8	79
200m Stations	59	65.5	68.6	1.17	26.4	124.9	83	18	68.3	71.3	1.14	39.4	110.0	86
400m Stations	60	66.6	65.6	1.18	31.1	151.0	84	18	68.6	66.9	1.14	42.3	131.5	86
800m Stations	20	68.2	71.6	1.18	27.7	130.7	86	6	69.3	70.9	1.10	47.1	89.2	87
Near-field Stations	30	42.6	38.6	1.22	16.3	137.4	54	9	46.3	39.4	1.31	16.3	137.4	58
Far-field Stations	195	66.6	67.6	1.16	27.7	151.0	84	57	68.9	67.6	1.11	42.3	131.5	87
Reference Stations	35	79.2	79.1	1.25	38.6	574.1	100	15	79.6	74.4	1.30	42.8	574.1	100
Entire Dataset	260	64.8	66.2	1.20	16.3	574.1	82	81	67.7	67.6	1.19	16.3	574.1	85
B. Arsenic														
Distance Group	2000–2010 Station Means							2008–2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	11	1.61	1.54	0.20	1.36	2.06	77	3	1.83	1.84	0.23	1.59	2.06	85
100m Stations	83	1.74	1.72	0.31	0.90	2.57	83	21	1.97	1.95	0.29	1.57	2.57	91
200m Stations	65	1.84	1.85	0.37	1.02	2.96	88	18	2.07	2.03	0.40	1.45	2.96	96
400m Stations	66	1.71	1.72	0.38	0.98	2.55	82	18	1.95	1.95	0.30	1.56	2.55	90
800m Stations	22	1.79	1.89	0.31	1.09	2.18	86	6	1.92	1.96	0.22	1.60	2.16	89
Near-field Stations	33	1.68	1.59	0.37	0.90	2.61	81	9	2.07	2.06	0.37	1.59	2.61	96
Far-field Stations	214	1.77	1.77	0.34	0.98	2.96	85	57	1.97	1.95	0.31	1.45	2.96	91
Reference Stations	40	2.08	2.13	0.41	1.31	2.98	100	15	2.16	2.22	0.45	1.34	2.98	100
Entire Dataset	287	1.80	1.79	0.37	0.90	2.98	86	81	2.01	1.97	0.35	1.34	2.98	93

continued

Note

units are in milligrams per kilogram wet weight, geomean = geometric mean, CF = confidence factor

Table 4.37 continued

C. Cadmium														
Distance Group	2000-2010 Station Means							2008-2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	11	1.63	1.55	1.21	0.75	3.42	66	3	2.46	2.79	1.19	1.55	3.42	83
100m Stations	83	1.48	1.42	1.16	0.75	3.68	60	21	2.19	2.23	1.15	1.13	3.68	74
200m Stations	65	1.68	1.61	1.17	0.77	4.24	68	18	2.52	2.46	1.16	1.27	4.24	85
400m Stations	66	1.56	1.52	1.17	0.81	3.23	63	18	2.20	2.33	1.15	1.08	3.23	74
800m Stations	22	1.73	1.63	1.11	1.20	2.96	70	6	2.08	2.42	1.18	1.20	2.96	70
Near-field Stations	33	1.42	1.29	1.21	0.75	3.63	57	9	2.35	2.63	1.17	1.35	3.63	79
Far-field Stations	214	1.61	1.53	1.16	0.81	4.24	65	57	2.27	2.38	1.16	1.08	4.24	76
Reference Stations	40	2.47	2.44	1.19	1.08	5.52	100	15	2.97	3.20	1.28	1.08	5.52	100
Entire Dataset	287	1.68	1.60	1.19	0.75	5.52	68	81	2.39	2.50	1.19	1.08	5.52	81
D. Chromium														
Distance Group	2000-2010 Station Means							2008-2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	10	0.23	0.22	1.28	0.08	0.62	68	3	0.22	0.18	1.25	0.15	0.40	69
100m Stations	76	0.26	0.28	1.30	0.05	0.63	78	21	0.26	0.26	1.17	0.09	0.41	82
200m Stations	59	0.29	0.31	1.33	0.05	2.32	86	18	0.34	0.34	1.29	0.15	2.32	105
400m Stations	60	0.26	0.27	1.26	0.06	0.77	78	18	0.29	0.28	1.18	0.18	0.67	90
800m Stations	20	0.27	0.28	1.30	0.06	0.79	82	6	0.31	0.29	1.05	0.28	0.35	95
Near-field Stations	30	0.22	0.25	1.29	0.05	0.62	66	9	0.22	0.25	1.25	0.09	0.40	69
Far-field Stations	195	0.27	0.29	1.29	0.06	2.32	83	57	0.30	0.29	1.20	0.15	2.32	95
Reference Stations	35	0.33	0.36	1.26	0.12	1.10	100	15	0.32	0.32	1.18	0.18	0.61	100
Entire Dataset	260	0.27	0.29	1.29	0.052	2.32	83	81	0.30	0.29	1.20	0.09	2.32	92

continued

Note

units are in milligrams per kilogram wet weight, geomean = geometric mean, CF = confidence factor

Table 4.37 continued

E. Copper														
Distance Group	2000-2010 Station Means							2008-2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	11	14.1	13.1	1.17	8.61	22.9	170	3	18.4	20.8	1.13	13.4	22.5	203
100m Stations	83	8.63	8.12	1.13	5.37	22.0	104	21	10.9	11.6	1.15	6.91	22.0	121
200m Stations	65	8.53	7.82	1.13	5.56	18.3	103	18	10.3	11.1	1.15	6.12	17.6	114
400m Stations	66	8.07	7.51	1.12	4.86	14.4	97	18	9.80	10.3	1.12	6.35	14.4	108
800m Stations	22	8.49	8.11	1.12	5.94	14.1	102	6	10.4	11.0	1.11	7.58	14.1	115
Near-field Stations	33	12.6	11.8	1.16	7.25	22.9	152	9	16.4	17.6	1.15	9.84	22.5	181
Far-field Stations	214	8.14	7.74	1.11	4.86	14.4	98	57	9.93	10.5	1.12	6.12	14.4	110
Reference Stations	40	8.29	7.96	1.11	5.35	14.2	100	15	9.06	9.2514	1.13	5.35	14.2	100
Entire Dataset	287	8.58	7.99	1.13	4.86	22.9	104	81	10.3	10.6	1.15	5.35	22.5	114
F. Iron														
Distance Group	2000-2010 Station Means							2008-2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	9	64.3	56.7	1.28	38.2	270.6	34	2	131.8	167.4	1.56	64.2	270.6	59
100m Stations	75	90.6	91.5	1.18	40.4	202.9	48	20	109.4	117.6	1.15	48.6	163.0	49
200m Stations	59	95.2	94.9	1.21	38.4	361.4	50	18	111.2	126.5	1.19	52.4	179.8	49
400m Stations	60	93.7	96.3	1.20	32.4	201.9	50	18	105.4	112.3	1.19	40.7	201.9	47
800m Stations	20	99.4	111.4	1.19	37.0	179.3	53	6	106.9	121.3	1.15	62.4	145.4	47
Near-field Stations	29	71.0	66.9	1.21	38.2	270.6	38	8	97.9	91.8	1.27	48.6	270.6	43
Far-field Stations	194	95.8	98.9	1.19	32.4	361.4	51	56	110.9	120.3	1.17	40.7	201.9	49
Reference Stations	30	188.8	199.5	1.23	63.6	521.0	100	10	225.2	205.4	1.21	140.8	521.0	100
Entire Dataset	253	100.3	99.8	1.24	32.4	521.0	53	74	120.4	128.8	1.22	40.7	521.0	53

continued

Note

units are in milligrams per kilogram wet weight, geomean = geometric mean, CF = confidence factor

Table 4.37 continued

G. Lead														
Distance Group	2000-2010 Station Means							2008-2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	11	3.25	2.89	1.28	1.25	7.83	391	3	3.68	4.05	1.25	2.12	5.81	445
100m Stations	83	0.92	0.87	1.22	0.44	3.13	111	21	0.98	1.02	1.19	0.49	2.18	118
200m Stations	65	0.94	0.98	1.22	0.36	2.48	113	18	0.97	0.97	1.20	0.36	2.08	117
400m Stations	66	0.77	0.80	1.20	0.34	2.39	93	18	0.78	0.87	1.15	0.48	1.27	94
800m Stations	22	0.86	0.91	1.16	0.38	1.81	104	6	0.72	0.84	1.16	0.38	0.93	87
Near-field Stations	33	1.97	1.88	1.28	0.80	7.83	238	9	2.25	2.08	1.23	1.26	5.81	272
Far-field Stations	214	0.83	0.86	1.19	0.34	2.45	100	57	0.83	0.88	1.16	0.36	1.52	100
Reference Stations	40	0.83	0.93	1.21	0.30	2.21	100	15	0.83	1.01	1.25	0.30	1.47	100
Entire Dataset	287	0.92	0.91	1.25	0.30	7.83	110	81	0.92	0.93	1.24	0.30	5.81	112
H. Magnesium														
Distance Group	2000-2010 Station Means							2008-2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	11	877	838	157	661	1112	95	3	765	795	92	661	838	97
100m Stations	83	873	878	120	609	1139	95	21	817	837	87	609	965	104
200m Stations	65	885	883	106	646	1095	96	18	853	855	75	663	963	108
400m Stations	66	901	900	110	543	1140	98	18	849	858	88	683	1023	108
800m Stations	22	923	903	94	765	1149	100	6	860	887	61	765	917	109
Near-field Stations	33	861	846	130	609	1112	94	9	780	813	91	609	884	99
Far-field Stations	214	893	893	111	543	1149	97	57	846	856	79	661	1023	107
Reference Stations	40	920	910	152	644	1161	100	15	788	790	93	644	964	100
Entire Dataset	287	893	893	120	543	1161	97	81	828	838	86	609	1023	105

continued

Note

units are in milligrams per kilogram wet weight, geomean = geometric mean, CF = confidence factor

Table 4.37 continued

I. Manganese														
Distance Group	2000-2010 Station Means							2008-2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	10	33.1	36.7	1.21	14.5	57.7	70	2	37.2	38.9	1.20	27.6	50.2	77
100m Stations	82	36.0	35.5	1.17	17.5	84.1	77	20	37.8	39.7	1.13	23.7	62.4	78
200m Stations	65	37.9	39.9	1.18	13.0	69.3	81	18	36.3	36.9	1.19	13.1	62.3	75
400m Stations	66	33.7	34.1	1.17	14.4	72.5	72	18	38.0	39.7	1.13	21.3	55.3	78
800m Stations	22	33.7	35.8	1.17	17.7	80.4	72	6	34.4	31.6	1.26	17.7	80.4	71
Near-field Stations	32	37.5	39.5	1.19	14.5	70.9	80	8	45.1	47.1	1.15	27.6	62.4	93
Far-field Stations	213	35.2	35.5	1.17	13.0	84.1	75	56	36.1	37.6	1.16	13.1	80.4	74
Reference Stations	35	47.0	49.3	1.15	25.5	80.7	100	10	48.5	51.6	1.13	26.1	68.0	100
Entire Dataset	280	36.8	37.7	1.18	13.0	84.1	78	74	38.5	39.7	1.16	13.1	80.4	79
J. Mercury														
Distance Group	2000-2010 Station Means							2008-2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	10	0.034	0.035	1.16	0.019	0.058	46	2	0.042	0.042	1.06	0.039	0.046	43
100m Stations	81	0.036	0.034	1.17	0.017	0.095	49	20	0.035	0.038	1.15	0.019	0.060	36
200m Stations	63	0.037	0.036	1.18	0.020	0.099	51	18	0.035	0.035	1.16	0.020	0.074	36
400m Stations	62	0.036	0.036	1.21	0.014	0.116	49	18	0.033	0.035	1.19	0.014	0.062	33
800m Stations	20	0.039	0.038	1.21	0.016	0.106	53	6	0.031	0.036	1.21	0.016	0.052	31
Near-field Stations	31	0.035	0.034	1.19	0.017	0.099	47	8	0.039	0.042	1.14	0.022	0.054	40
Far-field Stations	205	0.037	0.036	1.18	0.014	0.116	50	56	0.034	0.036	1.17	0.014	0.074	34
Reference Stations	35	0.074	0.078	1.22	0.013	0.161	100	10	0.098	0.093	1.12	0.068	0.145	100
Entire Dataset	271	0.040	0.038	1.22	0.013	0.161	54	74	0.039	0.038	1.24	0.014	0.145	40

continued

Note

units are in milligrams per kilogram wet weight, geomean = geometric mean, CF = confidence factor

Table 4.37 continued

K. Nickel														
Distance Group	2000-2010 Station Means							2008-2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	11	0.95	1.02	1.17	0.49	1.51	41	3	1.03	1.02	1.18	0.71	1.51	49
100m Stations	83	1.48	1.47	1.15	0.63	3.11	64	21	1.55	1.64	1.13	0.87	2.52	74
200m Stations	65	1.55	1.58	1.14	0.81	3.11	67	18	1.64	1.79	1.14	0.97	2.75	78
400m Stations	66	1.52	1.52	1.17	0.74	3.16	66	18	1.65	1.69	1.13	1.03	2.40	78
800m Stations	22	1.63	1.69	1.13	0.95	2.68	70	6	1.62	1.64	1.14	1.07	2.66	77
Near-field Stations	33	1.09	1.13	1.15	0.49	1.86	47	9	1.25	1.47	1.16	0.71	1.86	59
Far-field Stations	214	1.56	1.59	1.14	0.74	3.16	67	57	1.64	1.75	1.13	0.97	2.75	78
Reference Stations	40	2.32	2.63	1.19	0.78	4.67	100	15	2.11	2.35	1.26	0.78	3.48	100
Entire Dataset	287	1.59	1.58	1.18	0.49	4.67	68	81	1.67	1.75	1.17	0.71	3.48	79
L. Selenium														
Distance Group	2000-2010 Station Means							2008-2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	11	0.76	0.68	1.14	0.54	1.52	77	3	1.06	1.00	1.16	0.78	1.52	86
100m Stations	83	0.85	0.85	1.14	0.47	1.83	87	21	1.17	1.15	1.14	0.78	1.83	95
200m Stations	65	0.84	0.83	1.14	0.46	2.00	86	18	1.11	1.11	1.13	0.61	2.00	90
400m Stations	66	0.82	0.77	1.14	0.51	2.22	84	18	1.13	1.05	1.14	0.76	2.22	91
800m Stations	22	0.84	0.81	1.15	0.40	1.61	86	6	1.16	1.18	1.12	0.85	1.61	94
Near-field Stations	33	0.84	0.79	1.17	0.51	2.00	86	9	1.23	1.32	1.16	0.78	2.00	99
Far-field Stations	214	0.84	0.81	1.14	0.40	2.22	85	57	1.12	1.09	1.13	0.61	2.22	91
Reference Stations	40	0.98	0.90	1.14	0.64	2.26	100	15	1.24	1.18	1.18	0.70	2.26	100
Entire Dataset	287	0.86	0.83	1.14	0.40	2.26	87	81	1.15	1.13	1.14	0.61	2.26	93

continued

Note

units are in milligrams per kilogram wet weight, geomean = geometric mean, CF = confidence factor

Table 4.37 continued

M. Silver														
Distance Group	2000-2010 Station Means							2008-2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	8	0.32	0.28	1.37	0.11	1.09	6	3	0.19	0.20	1.24	0.11	0.30	4
100m Stations	61	1.49	1.54	1.34	0.29	5.97	30	21	1.23	1.42	1.37	0.29	4.17	28
200m Stations	48	1.53	1.67	1.39	0.35	6.60	31	18	1.30	1.45	1.39	0.35	4.46	30
400m Stations	52	1.42	1.64	1.47	0.11	6.95	29	18	1.04	1.68	1.56	0.11	4.87	24
800m Stations	18	1.29	1.57	1.58	0.21	10.3	26	6	0.56	0.50	1.57	0.21	2.05	13
Near-field Stations	25	0.58	0.48	1.45	0.11	5.02	12	9	0.40	0.35	1.41	0.11	1.42	9
Far-field Stations	162	1.56	1.69	1.40	0.11	10.3	31	57	1.18	1.63	1.46	0.11	4.87	27
Reference Stations	25	4.96	5.51	1.48	0.23	22.0	100	15	4.35	5.51	1.62	0.23	22.0	100
Entire Dataset	212	1.59	1.69	1.51	0.11	22.0	32	81	1.33	1.64	1.62	0.11	22.0	31
N. Zinc														
Distance Group	2000-2010 Station Means							2008-2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	11	74.3	74.9	1.16	45.6	136.1	93	3	80.6	83.4	1.11	62.9	99.8	105
100m Stations	83	69.1	67.7	1.15	34.6	143.5	87	21	71.9	72.1	1.11	41.6	116.4	94
200m Stations	65	71.3	74.0	1.15	27.4	141.1	89	18	72.7	70.6	1.13	42.7	108.5	95
400m Stations	66	64.2	62.2	1.16	24.6	127.0	81	18	70.0	69.0	1.10	50.7	97.2	91
800m Stations	22	69.4	72.4	1.15	33.6	131.4	87	6	71.3	64.4	1.16	48.5	131.4	93
Near-field Stations	33	77.4	83.4	1.16	40.5	136.1	97	9	89.1	88.9	1.09	62.9	116.4	116
Far-field Stations	214	67.3	68.7	1.15	24.6	143.5	84	57	69.5	69.0	1.11	41.6	131.4	91
Reference Stations	40	79.7	85.9	1.18	33.8	147.8	100	15	76.7	87.2	1.20	33.8	143.2	100
Entire Dataset	287	70.0	71.6	1.16	24.6	147.8	88	81	72.8	71.9	1.14	33.8	143.2	95

Note

units are in milligrams per kilogram wet weight, geomean = geometric mean, CF = confidence factor

Table 4.38 Summary Statistics for Frequently Detected PAH Parameters in Mussel Tissue (2006–2010)

A. Acenaphthene														
Distance Group	2006-2010 Station Means							2008-2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	3	0.00049	0.00046	1.07	0.00043	0.00058	433	3	0.00049	0.00046	1.07	0.00043	0.00058	433
100m Stations	24	0.00015	0.00014	1.20	0.00008	0.00037	131	21	0.00014	0.00013	1.20	0.00008	0.00037	128
200m Stations	13	0.00014	0.00016	1.19	0.00006	0.00022	120	9	0.00012	0.00012	1.20	0.00006	0.00018	105
400m Stations	13	0.00011	0.00011	1.11	0.00007	0.00017	101	9	0.00011	0.00011	1.10	0.00007	0.00015	97
800m Stations	3	0.00012	0.00013	1.12	0.00009	0.00016	111	2	0.00011	0.00011	1.11	0.00009	0.00013	99
Near-field Stations	9	0.00030	0.00026	1.19	0.00018	0.00058	264	7	0.00032	0.00027	1.20	0.00018	0.00058	283
Far-field Stations	47	0.00013	0.00013	1.16	0.00006	0.00037	111	37	0.00012	0.00012	1.16	0.00006	0.00037	107
Reference Stations	12	0.00011	0.00011	1.08	0.00008	0.00015	100	12	0.00011	0.00011	1.08	0.00008	0.00015	100
Entire Dataset	68	0.00014	0.00013	1.21	0.00006	0.00058	122	56	0.00013	0.00012	1.22	0.00006	0.00058	119
B. Anthracene														
Distance Group	2006-2010 Station Means							2008-2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	3	0.00077	0.00069	1.26	0.00048	0.00136	572	2	0.00097	0.00103	1.23	0.00069	0.00136	694
100m Stations	24	0.00018	0.00016	1.19	0.00012	0.00051	133	17	0.00019	0.00015	1.21	0.00012	0.00051	132
200m Stations	24	0.00014	0.00013	1.17	0.00008	0.00039	102	18	0.00014	0.00013	1.18	0.00008	0.00039	98
400m Stations	24	0.00013	0.00013	1.11	0.00008	0.00019	96	18	0.00012	0.00013	1.10	0.00008	0.00018	88
800m Stations	7	0.00014	0.00012	1.11	0.00010	0.00020	101	5	0.00013	0.00012	1.13	0.00010	0.00020	94
Near-field Stations	10	0.00035	0.00027	1.32	0.00019	0.00136	264	7	0.00039	0.00028	1.36	0.00019	0.00136	276
Far-field Stations	72	0.00014	0.00013	1.14	0.00008	0.00051	103	53	0.00014	0.00013	1.16	0.00008	0.00051	97
Reference Stations	14	0.00013	0.00014	1.21	0.00005	0.00031	100	9	0.00014	0.00014	1.27	0.00005	0.00031	100
Entire Dataset	96	0.00015	0.00014	1.23	0.00005	0.00136	113	69	0.00015	0.00014	1.25	0.00005	0.00136	109

continued

Note

units are in milligrams per kilogram wet weight, geomean = geometric mean, CF = confidence factor

Table 4.38 continued

C. Benz[a]anthracene														
Distance Group	2006-2010 Station Means							2008-2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	3	0.00170	0.00161	1.20	0.00115	0.00268	900	3	0.00170	0.00161	1.20	0.00115	0.00268	900
100m Stations	25	0.00037	0.00032	1.24	0.00019	0.00135	193	21	0.00035	0.00030	1.24	0.00019	0.00135	185
200m Stations	18	0.00031	0.00030	1.15	0.00017	0.00055	161	13	0.00029	0.00029	1.16	0.00017	0.00055	151
400m Stations	17	0.00028	0.00027	1.13	0.00019	0.00053	148	12	0.00026	0.00027	1.10	0.00019	0.00039	136
800m Stations	6	0.00027	0.00027	1.07	0.00021	0.00032	141	4	0.00025	0.00025	1.05	0.00021	0.00028	130
Near-field Stations	10	0.00087	0.00076	1.26	0.00051	0.00268	461	8	0.00093	0.00078	1.29	0.00051	0.00268	488
Far-field Stations	59	0.00029	0.00029	1.14	0.00017	0.00135	153	45	0.00028	0.00027	1.15	0.00017	0.00135	146
Reference Stations	14	0.00019	0.00019	1.08	0.00014	0.00026	100	14	0.00019	0.00019	1.08	0.00014	0.00026	100
Entire Dataset	83	0.00031	0.00028	1.26	0.00014	0.00268	163	67	0.00029	0.00026	1.27	0.00014	0.00268	156
D. Benzo[a]pyrene														
Distance Group	2006-2010 Station Means							2008-2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	4	0.00091	0.00097	1.28	0.00043	0.00170	426	2	0.00136	0.00140	1.15	0.00109	0.00170	766
100m Stations	22	0.00037	0.00022	2.06	0.00015	0.43364	172	13	0.00025	0.00019	1.30	0.00015	0.00113	138
200m Stations	15	0.00021	0.00020	1.15	0.00013	0.00035	98	8	0.00017	0.00017	1.09	0.00013	0.00023	95
400m Stations	13	0.00018	0.00016	1.21	0.00010	0.00049	86	7	0.00014	0.00015	1.09	0.00010	0.00017	78
800m Stations	6	0.00016	0.00016	1.11	0.00012	0.00024	77	2	0.00013	0.00013	1.08	0.00012	0.00015	75
Near-field Stations	9	0.00058	0.00057	1.31	0.00023	0.00170	270	5	0.00063	0.00060	1.42	0.00023	0.00170	352
Far-field Stations	51	0.00023	0.00019	1.65	0.00010	0.43364	110	27	0.00017	0.00016	1.20	0.00010	0.00113	97
Reference Stations	18	0.00021	0.00026	1.30	0.00005	0.00058	100	10	0.00018	0.00017	1.39	0.00005	0.00058	100
Entire Dataset	78	0.00025	0.00021	1.57	0.00005	0.43364	119	42	0.00020	0.00017	1.35	0.00005	0.00170	114

continued

Note

units are in milligrams per kilogram wet weight, geomean = geometric mean, CF = confidence factor

Table 4.38 continued

E. Benzo[b]fluoranthene														
Distance Group	2006-2010 Station Means							2008-2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	3	0.00122	0.00121	1.14	0.00090	0.00165	396	3	0.00122	0.00121	1.14	0.00090	0.00165	396
100m Stations	24	0.00046	0.00040	1.15	0.00033	0.00106	149	20	0.00043	0.00039	1.14	0.00033	0.00106	141
200m Stations	22	0.00041	0.00038	1.13	0.00027	0.00079	135	16	0.00037	0.00037	1.08	0.00027	0.00053	119
400m Stations	19	0.00039	0.00037	1.11	0.00031	0.00060	127	14	0.00036	0.00034	1.08	0.00031	0.00051	116
800m Stations	6	0.00037	0.00036	1.08	0.00030	0.00049	120	4	0.00034	0.00034	1.05	0.00030	0.00038	110
Near-field Stations	10	0.00076	0.00071	1.19	0.00044	0.00165	245	8	0.00076	0.00069	1.22	0.00044	0.00165	247
Far-field Stations	64	0.00040	0.00038	1.12	0.00027	0.00106	130	49	0.00037	0.00036	1.09	0.00027	0.00106	120
Reference Stations	15	0.00031	0.00031	1.06	0.00024	0.00043	100	15	0.00031	0.00031	1.06	0.00024	0.00043	100
Entire Dataset	89	0.00041	0.00037	1.16	0.00024	0.00165	134	72	0.00039	0.00036	1.16	0.00024	0.00165	125
F. Benzo[j,k]fluoranthenes														
Distance Group	2006-2010 Station Means							2008-2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	3	0.00123	0.00113	1.17	0.00091	0.00182	487	3	0.00123	0.00113	1.17	0.00091	0.00182	487
100m Stations	24	0.00037	0.00033	1.18	0.00024	0.00118	147	20	0.00036	0.00031	1.19	0.00024	0.00118	142
200m Stations	19	0.00034	0.00033	1.10	0.00026	0.00049	136	15	0.00032	0.00032	1.09	0.00026	0.00046	129
400m Stations	17	0.00031	0.00031	1.07	0.00023	0.00041	124	14	0.00031	0.00031	1.06	0.00023	0.00040	122
800m Stations	5	0.00029	0.00028	1.08	0.00023	0.00038	116	4	0.00027	0.00028	1.05	0.00023	0.00030	108
Near-field Stations	10	0.00069	0.00062	1.23	0.00043	0.00182	272	8	0.00072	0.00065	1.25	0.00043	0.00182	285
Far-field Stations	58	0.00032	0.00031	1.11	0.00023	0.00118	128	48	0.00031	0.00030	1.11	0.00023	0.00118	124
Reference Stations	15	0.00025	0.00026	1.08	0.00020	0.00038	100	15	0.00025	0.00026	1.08	0.00020	0.00038	100
Entire Dataset	83	0.00034	0.00031	1.18	0.00020	0.00182	134	71	0.00033	0.00029	1.19	0.00020	0.00182	130

continued

Note

units are in milligrams per kilogram wet weight, geomean = geometric mean, CF = confidence factor

Table 4.38 continued

G. Chrysene														
Distance Group	2006-2010 Station Means							2008-2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	3	0.00222	0.00202	1.15	0.00169	0.00320	491	3	0.00222	0.00202	1.15	0.00169	0.00320	491
100m Stations	25	0.00067	0.00057	1.17	0.00044	0.00142	147	21	0.00063	0.00055	1.16	0.00044	0.00142	140
200m Stations	22	0.00060	0.00058	1.14	0.00035	0.00123	133	16	0.00053	0.00054	1.10	0.00035	0.00079	117
400m Stations	20	0.00056	0.00054	1.10	0.00042	0.00096	123	14	0.00051	0.00050	1.07	0.00042	0.00071	113
800m Stations	6	0.00054	0.00049	1.10	0.00044	0.00074	119	4	0.00047	0.00046	1.03	0.00044	0.00051	103
Near-field Stations	10	0.00132	0.00123	1.21	0.00077	0.00320	291	8	0.00132	0.00119	1.24	0.00077	0.00320	291
Far-field Stations	66	0.00057	0.00055	1.11	0.00035	0.00142	126	50	0.00053	0.00052	1.10	0.00035	0.00142	117
Reference Stations	15	0.00045	0.00044	1.07	0.00035	0.00057	100	15	0.00045	0.00044	1.07	0.00035	0.00057	100
Entire Dataset	91	0.00060	0.00055	1.18	0.00035	0.00320	133	73	0.00056	0.00052	1.18	0.00035	0.00320	125
H. Fluoranthene														
Distance Group	2006-2010 Station Means							2008-2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	3	0.00470	0.00467	1.19	0.00318	0.00698	691	3	0.00470	0.00467	1.19	0.00318	0.00698	691
100m Stations	24	0.00122	0.00108	1.20	0.00065	0.00322	179	21	0.00120	0.00109	1.20	0.00065	0.00322	177
200m Stations	22	0.00102	0.00103	1.13	0.00051	0.00171	150	16	0.00095	0.00098	1.12	0.00051	0.00150	140
400m Stations	19	0.00092	0.00095	1.10	0.00065	0.00141	135	13	0.00089	0.00090	1.09	0.00068	0.00120	130
800m Stations	6	0.00092	0.00091	1.07	0.00073	0.00115	135	4	0.00084	0.00086	1.05	0.00073	0.00093	124
Near-field Stations	10	0.00252	0.00217	1.26	0.00143	0.00698	370	8	0.00266	0.00255	1.28	0.00143	0.00698	390
Far-field Stations	64	0.00098	0.00099	1.12	0.00051	0.00289	144	49	0.00095	0.00095	1.12	0.00051	0.00289	140
Reference Stations	14	0.00068	0.00070	1.07	0.00047	0.00086	100	14	0.00068	0.00070	1.07	0.00047	0.00086	100
Entire Dataset	88	0.00103	0.00097	1.21	0.00047	0.00698	151	71	0.00100	0.00093	1.23	0.00047	0.00698	147

continued

Note

units are in milligrams per kilogram wet weight, geomean = geometric mean, CF = confidence factor

Table 4.38 continued

I. Fluorene														
Distance Group	2006-2010 Station Means							2008-2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	3	0.00101	0.00113	1.15	0.00071	0.00130	171	3	0.00101	0.00113	1.15	0.00071	0.00130	171
100m Stations	24	0.00053	0.00054	1.14	0.00020	0.00083	90	20	0.00053	0.00054	1.15	0.00020	0.00083	90
200m Stations	21	0.00051	0.00057	1.14	0.00022	0.00079	87	16	0.00052	0.00057	1.15	0.00022	0.00079	88
400m Stations	22	0.00042	0.00042	1.14	0.00023	0.00074	71	16	0.00041	0.00043	1.15	0.00023	0.00064	70
800m Stations	8	0.00043	0.00044	1.17	0.00026	0.00074	73	6	0.00043	0.00044	1.19	0.00026	0.00074	73
Near-field Stations	11	0.00072	0.00071	1.15	0.00045	0.00130	121	9	0.00078	0.00079	1.14	0.00050	0.00130	132
Far-field Stations	67	0.00047	0.00049	1.14	0.00020	0.00074	79	52	0.00046	0.00051	1.15	0.00020	0.00074	78
Reference Stations	15	0.00059	0.00058	1.09	0.00045	0.00086	100	15	0.00059	0.00058	1.09	0.00045	0.00086	100
Entire Dataset	93	0.00051	0.00052	1.16	0.00020	0.00130	86	76	0.00052	0.00054	1.16	0.00020	0.00130	87
J. Phenanthrene														
Distance Group	2006-2010 Station Means							2008-2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	2	0.00559	0.00573	1.14	0.00449	0.00697	638	2	0.00559	0.00573	1.14	0.00449	0.00697	638
100m Stations	18	0.00137	0.00119	1.17	0.00092	0.00322	156	14	0.00139	0.00119	1.18	0.00100	0.00322	158
200m Stations	19	0.00110	0.00104	1.12	0.00074	0.00181	125	13	0.00105	0.00099	1.13	0.00074	0.00181	120
400m Stations	18	0.00109	0.00103	1.08	0.00079	0.00160	125	12	0.00108	0.00103	1.09	0.00079	0.00160	123
800m Stations	6	0.00110	0.00105	1.06	0.00098	0.00140	125	4	0.00104	0.00100	1.04	0.00098	0.00117	118
Near-field Stations	7	0.00267	0.00189	1.28	0.00166	0.00697	304	5	0.00315	0.00322	1.30	0.00168	0.00697	359
Far-field Stations	56	0.00111	0.00105	1.10	0.00074	0.00288	127	40	0.00111	0.00104	1.11	0.00074	0.00288	126
Reference Stations	8	0.00088	0.00085	1.08	0.00072	0.00123	100	8	0.00088	0.00085	1.08	0.00072	0.00123	100
Entire Dataset	71	0.00118	0.00105	1.18	0.00072	0.00697	135	53	0.00118	0.00104	1.21	0.00072	0.00697	134

continued

Note

units are in milligrams per kilogram wet weight, geomean = geometric mean, CF = confidence factor

Table 4.38 continued

K. Pyrene														
Distance Group	2006-2010 Station Means							2008-2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	3	0.00312	0.00346	1.34	0.00151	0.00581	1051	2	0.00448	0.00464	1.17	0.00346	0.00581	1489
100m Stations	18	0.00097	0.00054	2.16	0.00036	0.85396	328	14	0.00062	0.00052	1.27	0.00036	0.00204	207
200m Stations	17	0.00048	0.00044	1.18	0.00029	0.00092	162	13	0.00043	0.00038	1.16	0.00029	0.00085	144
400m Stations	16	0.00040	0.00040	1.10	0.00027	0.00056	134	12	0.00039	0.00039	1.10	0.00027	0.00056	130
800m Stations	5	0.00041	0.00045	1.09	0.00030	0.00049	140	4	0.00040	0.00042	1.09	0.00030	0.00047	132
Near-field Stations	8	0.00165	0.00157	1.37	0.00071	0.00581	557	5	0.00190	0.00204	1.48	0.00071	0.00581	630
Far-field Stations	51	0.00053	0.00045	1.62	0.00027	0.85396	177	40	0.00044	0.00044	1.17	0.00027	0.00203	147
Reference Stations	11	0.00030	0.00028	1.08	0.00024	0.00040	100	8	0.00030	0.00031	1.09	0.00024	0.00040	100
Entire Dataset	70	0.00055	0.00044	1.59	0.00024	0.85396	185	53	0.00048	0.00041	1.31	0.00024	0.00581	159
L. Total High Molecular Weight PAHs														
Distance Group	2006-2010 Station Means							2008-2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	2	0.01986	0.02037	1.15	0.01581	0.02494	844	2	0.01986	0.02037	1.15	0.01581	0.02494	844
100m Stations	21	0.00390	0.00342	1.21	0.00245	0.01173	166	17	0.00380	0.00333	1.21	0.00245	0.01173	162
200m Stations	22	0.00319	0.00310	1.13	0.00187	0.00559	136	16	0.00293	0.00295	1.12	0.00187	0.00465	124
400m Stations	20	0.00272	0.00264	1.13	0.00132	0.00535	116	14	0.00260	0.00262	1.11	0.00132	0.00360	110
800m Stations	6	0.00294	0.00277	1.09	0.00233	0.00403	125	4	0.00263	0.00273	1.04	0.00233	0.00278	112
Near-field Stations	8	0.00819	0.00683	1.30	0.00455	0.02494	348	6	0.00878	0.00764	1.36	0.00455	0.02494	373
Far-field Stations	63	0.00302	0.00299	1.14	0.00132	0.01173	129	47	0.00290	0.00291	1.14	0.00132	0.01173	123
Reference Stations	10	0.00235	0.00248	1.12	0.00119	0.00327	100	10	0.00235	0.00248	1.12	0.00119	0.00327	100
Entire Dataset	81	0.00324	0.00299	1.22	0.00119	0.02494	138	63	0.00312	0.00279	1.24	0.00119	0.02494	133

continued

Note

units are in milligrams per kilogram wet weight, geomean = geometric mean, CF = confidence factor

Table 4.38 continued

M. Lipid-Normalized Acenaphthene														
Distance Group	2006-2010 Station Means							2008-2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	4	0.0255	0.0266	1.21	0.0154	0.0407	206	3	0.0302	0.0324	1.16	0.0208	0.0407	241
100m Stations	27	0.0126	0.0107	1.47	0.0044	0.5937	102	21	0.0122	0.0129	1.20	0.0064	0.0332	97
200m Stations	16	0.0097	0.0095	1.19	0.0059	0.0197	78	9	0.0111	0.0115	1.21	0.0059	0.0197	89
400m Stations	17	0.0090	0.0098	1.23	0.0033	0.0190	73	9	0.0117	0.0133	1.18	0.0057	0.0190	94
800m Stations	4	0.0124	0.0114	1.17	0.0089	0.0202	100	2	0.0157	0.0162	1.17	0.0122	0.0202	125
Near-field Stations	11	0.0176	0.0186	1.22	0.0090	0.0407	142	7	0.0225	0.0197	1.16	0.0150	0.0407	180
Far-field Stations	57	0.0105	0.0098	1.35	0.0033	0.5937	84	37	0.0115	0.0122	1.19	0.0057	0.0332	92
Reference Stations	15	0.0124	0.0126	1.10	0.0081	0.0195	100	12	0.0125	0.0127	1.08	0.0098	0.0171	100
Entire Dataset	83	0.0116	0.0109	1.32	0.0033	0.5937	93	56	0.0127	0.0130	1.20	0.0057	0.0407	102
N. Lipid-Normalized Anthracene														
Distance Group	2006-2010 Station Means							2008-2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	4	0.0420	0.0391	1.33	0.0236	0.0958	309	2	0.0704	0.0738	1.21	0.0518	0.0958	398
100m Stations	26	0.0180	0.0137	1.75	0.0046	3.48	132	17	0.0169	0.0142	1.25	0.0082	0.0628	96
200m Stations	27	0.0097	0.0095	1.28	0.0032	0.0289	71	18	0.0119	0.0112	1.21	0.0061	0.0289	67
400m Stations	28	0.0099	0.0102	1.19	0.0045	0.0187	73	18	0.0113	0.0109	1.15	0.0060	0.0187	64
800m Stations	9	0.0094	0.0088	1.26	0.0053	0.0311	69	5	0.0125	0.0096	1.27	0.0085	0.0311	71
Near-field Stations	12	0.0207	0.0236	1.42	0.0061	0.0958	153	7	0.0295	0.0243	1.38	0.0091	0.0958	167
Far-field Stations	82	0.0114	0.0100	1.45	0.0032	3.48	84	53	0.0125	0.0116	1.21	0.0060	0.0628	71
Reference Stations	17	0.0136	0.0126	1.28	0.0052	0.0506	100	9	0.0177	0.0166	1.32	0.0052	0.0506	100
Entire Dataset	111	0.0125	0.0108	1.44	0.0032	3.48	92	69	0.0143	0.0136	1.28	0.0052	0.0958	81

continued

Note

units are in milligrams per kilogram wet weight, geomean = geometric mean, CF = confidence factor

Table 4.38 continued

O. Lipid-Normalized Benz[a]anthracene														
Distance Group	2006-2010 Station Means							2008-2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	4	0.0864	0.0860	1.34	0.0474	0.1890	427	3	0.1055	0.1202	1.33	0.0517	0.1890	509
100m Stations	28	0.0343	0.0250	1.88	0.0122	29.9	169	21	0.0296	0.0285	1.31	0.0126	0.1652	143
200m Stations	21	0.0222	0.0213	1.20	0.0110	0.0539	110	13	0.0253	0.0233	1.20	0.0144	0.0539	122
400m Stations	21	0.0223	0.0222	1.15	0.0127	0.0353	110	12	0.0265	0.0285	1.12	0.0151	0.0353	128
800m Stations	8	0.0217	0.0219	1.15	0.0149	0.0369	107	4	0.0287	0.0269	1.08	0.0256	0.0369	139
Near-field Stations	12	0.0532	0.0505	1.28	0.0226	0.1890	263	8	0.0674	0.0546	1.26	0.0364	0.1890	326
Far-field Stations	70	0.0245	0.0215	1.52	0.0110	29.9	121	45	0.0258	0.0257	1.21	0.0126	0.1652	124
Reference Stations	17	0.0202	0.0205	1.17	0.0120	0.0382	100	14	0.0207	0.0214	1.17	0.0120	0.0382	100
Entire Dataset	99	0.0261	0.0228	1.47	0.0110	29.9	129	67	0.0276	0.0265	1.27	0.0120	0.1890	133
P. Lipid-Normalized Benzo[a]pyrene														
Distance Group	2006-2010 Station Means							2008-2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	4	0.0575	0.0613	1.33	0.0272	0.1198	258	2	0.0987	0.1005	1.13	0.0813	0.1198	446
100m Stations	22	0.0262	0.0204	2.05	0.0087	25.2	118	13	0.0224	0.0209	1.36	0.0089	0.1380	101
200m Stations	15	0.0131	0.0138	1.16	0.0075	0.0248	59	8	0.0140	0.0141	1.14	0.0090	0.0248	63
400m Stations	13	0.0149	0.0142	1.17	0.0089	0.0344	67	7	0.0148	0.0157	1.14	0.0089	0.0218	67
800m Stations	6	0.0126	0.0123	1.19	0.0071	0.0231	57	2	0.0187	0.0191	1.14	0.0151	0.0231	84
Near-field Stations	9	0.0384	0.0315	1.30	0.0204	0.1198	172	5	0.0509	0.0449	1.33	0.0248	0.1198	230
Far-field Stations	51	0.0169	0.0138	1.65	0.0071	25.2	76	27	0.0166	0.0157	1.25	0.0089	0.1380	75
Reference Stations	18	0.0223	0.0233	1.25	0.0068	0.0599	100	10	0.0221	0.0218	1.31	0.0068	0.0599	100
Entire Dataset	78	0.0198	0.0166	1.55	0.0068	25.2	89	42	0.0203	0.0183	1.33	0.0068	0.1380	92

continued

Note

units are in milligrams per kilogram wet weight, geomean = geometric mean, CF = confidence factor

Table 4.38 continued

Q. Lipid-Normalized Benzo[b]fluoranthene														
Distance Group	2006-2010 Station Means							2008-2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	3	0.0754	0.0907	1.27	0.0408	0.1159	221	3	0.0754	0.0907	1.27	0.0408	0.1159	221
100m Stations	24	0.0341	0.0318	1.20	0.0197	0.1288	100	20	0.0364	0.0329	1.20	0.0231	0.1288	107
200m Stations	22	0.0307	0.0307	1.12	0.0198	0.0473	90	16	0.0333	0.0321	1.12	0.0219	0.0473	97
400m Stations	19	0.0332	0.0326	1.12	0.0202	0.0516	97	14	0.0363	0.0367	1.10	0.0220	0.0516	106
800m Stations	6	0.0332	0.0354	1.15	0.0226	0.0528	97	4	0.0397	0.0378	1.09	0.0329	0.0528	116
Near-field Stations	10	0.0489	0.0470	1.22	0.0268	0.1159	143	8	0.0554	0.0479	1.20	0.0340	0.1159	162
Far-field Stations	64	0.0319	0.0316	1.15	0.0197	0.1288	93	49	0.0348	0.0329	1.14	0.0219	0.1288	102
Reference Stations	15	0.0342	0.0347	1.11	0.0233	0.0491	100	15	0.0342	0.0347	1.11	0.0233	0.0491	100
Entire Dataset	89	0.0339	0.0320	1.16	0.0197	0.1288	99	72	0.0365	0.0348	1.16	0.0219	0.1288	107
R. Lipid-Normalized Benzo[j,k]fluoranthenes														
Distance Group	2006-2010 Station Means							2008-2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	3	0.0762	0.0843	1.29	0.0409	0.1284	272	3	0.0762	0.0843	1.29	0.0409	0.1284	272
100m Stations	24	0.0277	0.0270	1.24	0.0148	0.1436	99	20	0.0302	0.0286	1.24	0.0163	0.1436	108
200m Stations	19	0.0265	0.0265	1.15	0.0160	0.0460	95	15	0.0297	0.0291	1.12	0.0182	0.0460	106
400m Stations	17	0.0281	0.0302	1.15	0.0136	0.0458	100	14	0.0314	0.0317	1.10	0.0185	0.0458	112
800m Stations	5	0.0287	0.0288	1.14	0.0185	0.0431	102	4	0.0320	0.0293	1.09	0.0285	0.0431	114
Near-field Stations	10	0.0446	0.0410	1.27	0.0195	0.1284	159	8	0.0524	0.0436	1.23	0.0300	0.1284	187
Far-field Stations	58	0.0267	0.0279	1.18	0.0136	0.1436	95	48	0.0295	0.0291	1.16	0.0163	0.1436	105
Reference Stations	15	0.0280	0.0286	1.16	0.0172	0.0562	100	15	0.0280	0.0286	1.16	0.0172	0.0562	100
Entire Dataset	83	0.0286	0.0286	1.20	0.0136	0.1436	102	71	0.0312	0.0300	1.19	0.0163	0.1436	111

continued

Note

units are in milligrams per kilogram wet weight, geomean = geometric mean, CF = confidence factor

Table 4.38 continued

S. Lipid-Normalized Chrysene														
Distance Group	2006-2010 Station Means							2008-2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	4	0.1180	0.1136	1.26	0.0747	0.2253	236	3	0.1374	0.1509	1.27	0.0763	0.2253	273
100m Stations	28	0.0617	0.0485	1.75	0.0249	30.5	123	21	0.0535	0.0505	1.20	0.0295	0.1726	107
200m Stations	25	0.0444	0.0432	1.14	0.0246	0.0843	89	16	0.0484	0.0455	1.13	0.0308	0.0843	96
400m Stations	24	0.0453	0.0477	1.12	0.0276	0.0726	90	14	0.0522	0.0517	1.09	0.0323	0.0726	104
800m Stations	8	0.0447	0.0416	1.12	0.0343	0.0722	89	4	0.0548	0.0538	1.10	0.0433	0.0722	109
Near-field Stations	12	0.0812	0.0755	1.21	0.0501	0.2253	162	8	0.0959	0.0825	1.21	0.0635	0.2253	191
Far-field Stations	77	0.0482	0.0434	1.42	0.0246	30.5	96	50	0.0497	0.0499	1.14	0.0295	0.1726	99
Reference Stations	18	0.0500	0.0477	1.13	0.0335	0.0837	100	15	0.0502	0.0512	1.12	0.0335	0.0837	100
Entire Dataset	107	0.0515	0.0466	1.37	0.0246	30.5	103	73	0.0535	0.0513	1.17	0.0295	0.2253	107
T. Lipid-Normalized Fluoranthene														
Distance Group	2006-2010 Station Means							2008-2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	4	0.2374	0.2462	1.33	0.1290	0.4918	331	3	0.2909	0.3488	1.32	0.1435	0.4918	391
100m Stations	27	0.1153	0.0977	1.80	0.0379	59.4	161	21	0.1017	0.1056	1.25	0.0437	0.3520	137
200m Stations	25	0.0737	0.0778	1.17	0.0361	0.1524	103	16	0.0867	0.0855	1.15	0.0513	0.1524	117
400m Stations	23	0.0724	0.0724	1.15	0.0355	0.1208	101	13	0.0893	0.0953	1.11	0.0531	0.1208	120
800m Stations	8	0.0753	0.0777	1.15	0.0498	0.1277	105	4	0.0984	0.0914	1.08	0.0881	0.1277	132
Near-field Stations	12	0.1526	0.1392	1.28	0.0697	0.4918	212	8	0.1937	0.1533	1.26	0.1056	0.4918	260
Far-field Stations	75	0.0818	0.0762	1.46	0.0355	59.4	114	49	0.0893	0.0921	1.17	0.0437	0.3520	120
Reference Stations	17	0.0718	0.0797	1.16	0.0394	0.1132	100	14	0.0744	0.0802	1.15	0.0439	0.1132	100
Entire Dataset	104	0.0860	0.0811	1.41	0.0355	59.4	120	71	0.0940	0.0921	1.22	0.0437	0.4918	126

continued

Note

units are in milligrams per kilogram wet weight, geomean = geometric mean, CF = confidence factor

Table 4.38 continued

U. Lipid-Normalized Fluorene														
Distance Group	2006-2010 Station Means							2008-2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	4	0.0590	0.0668	1.24	0.0318	0.0915	93	3	0.0626	0.0843	1.29	0.0318	0.0915	95
100m Stations	27	0.0462	0.0464	1.37	0.0138	0.4215	73	20	0.0448	0.0478	1.22	0.0138	0.0830	68
200m Stations	24	0.0355	0.0345	1.27	0.0159	0.1065	56	16	0.0439	0.0465	1.25	0.0183	0.1065	67
400m Stations	26	0.0331	0.0356	1.24	0.0148	0.0875	52	16	0.0375	0.0404	1.27	0.0148	0.0875	57
800m Stations	10	0.0370	0.0338	1.32	0.0159	0.1142	59	6	0.0416	0.0461	1.37	0.0180	0.1142	63
Near-field Stations	13	0.0445	0.0493	1.28	0.0183	0.0915	70	9	0.0544	0.0616	1.24	0.0238	0.0915	83
Far-field Stations	78	0.0378	0.0366	1.31	0.0138	0.4215	60	52	0.0412	0.0414	1.26	0.0138	0.1142	63
Reference Stations	18	0.0632	0.0629	1.18	0.0357	0.1186	100	15	0.0657	0.0638	1.17	0.0357	0.1186	100
Entire Dataset	109	0.0419	0.0405	1.30	0.0138	0.4215	66	76	0.0467	0.0501	1.25	0.0138	0.1186	71
V. Lipid-Normalized Phenanthrene														
Distance Group	2006-2010 Station Means							2008-2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	3	0.2815	0.3352	1.33	0.1357	0.4906	290	2	0.4055	0.4129	1.12	0.3352	0.4906	384
100m Stations	21	0.1423	0.1007	1.69	0.0364	7.80	147	14	0.1227	0.1228	1.20	0.0611	0.2404	116
200m Stations	21	0.0816	0.0737	1.22	0.0355	0.1790	84	13	0.0946	0.0935	1.17	0.0519	0.1790	90
400m Stations	20	0.0848	0.0882	1.18	0.0401	0.1589	87	12	0.1066	0.1095	1.13	0.0533	0.1589	101
800m Stations	7	0.0964	0.0943	1.18	0.0520	0.1803	99	4	0.1213	0.1134	1.13	0.0943	0.1803	115
Near-field Stations	9	0.1628	0.1629	1.33	0.0678	0.4906	168	5	0.2584	0.2404	1.22	0.1629	0.4906	245
Far-field Stations	63	0.0974	0.0919	1.41	0.0355	7.80	100	40	0.1044	0.1011	1.16	0.0519	0.2180	99
Reference Stations	11	0.0971	0.0918	1.16	0.0512	0.1523	100	8	0.1055	0.0948	1.12	0.0808	0.1523	100
Entire Dataset	83	0.1029	0.0935	1.39	0.0355	7.80	106	53	0.1139	0.1047	1.20	0.0519	0.4906	108

continued

Note

units are in milligrams per kilogram wet weight, geomean = geometric mean, CF = confidence factor

Table 4.38 continued

W. Lipid-Normalized Pyrene														
Distance Group	2006-2010 Station Means							2008-2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	3	0.2154	0.2581	1.38	0.0946	0.4094	642	2	0.3250	0.3337	1.15	0.2581	0.4094	897
100m Stations	18	0.0758	0.0498	2.11	0.0199	49.6	226	14	0.0552	0.0498	1.30	0.0262	0.2480	152
200m Stations	17	0.0364	0.0344	1.21	0.0149	0.0759	109	13	0.0390	0.0344	1.20	0.0220	0.0759	108
400m Stations	16	0.0348	0.0351	1.14	0.0221	0.0572	104	12	0.0386	0.0404	1.12	0.0221	0.0572	107
800m Stations	5	0.0430	0.0446	1.11	0.0313	0.0612	128	4	0.0465	0.0447	1.09	0.0383	0.0612	128
Near-field Stations	8	0.1151	0.0852	1.37	0.0539	0.4094	343	5	0.1560	0.1523	1.38	0.0757	0.4094	431
Far-field Stations	51	0.0438	0.0379	1.61	0.0149	49.6	131	40	0.0418	0.0434	1.19	0.0220	0.2480	115
Reference Stations	11	0.0335	0.0367	1.15	0.0191	0.0489	100	8	0.0362	0.0371	1.10	0.0271	0.0489	100
Entire Dataset	70	0.0469	0.0408	1.56	0.0149	49.6	140	53	0.0463	0.0439	1.29	0.0220	0.4094	128
X. Lipid-Normalized Total High Molecular Weight PAHs														
Distance Group	2006-2010 Station Means							2008-2010 Station Means						
	N	Geomean	Median	CF	Min	Max	%Ref	N	Geomean	Median	CF	Min	Max	%Ref
Outfall	3	0.9764	1.18	1.36	0.4492	1.76	353	2	1.44	1.47	1.13	1.18	1.76	491
100m Stations	24	0.3911	0.2832	1.91	0.1380	263	141	17	0.3484	0.3056	1.24	0.1901	1.43	119
200m Stations	25	0.2346	0.2294	1.16	0.1308	0.4845	85	16	0.2672	0.2569	1.14	0.1691	0.4845	91
400m Stations	24	0.2234	0.2350	1.15	0.1199	0.3681	81	14	0.2652	0.2715	1.11	0.1610	0.3681	91
800m Stations	8	0.2423	0.2359	1.14	0.1708	0.4158	88	4	0.3083	0.2868	1.09	0.2646	0.4158	105
Near-field Stations	10	0.5218	0.4669	1.31	0.2283	1.76	189	6	0.7264	0.6017	1.28	0.4181	1.76	248
Far-field Stations	74	0.2601	0.2388	1.48	0.1199	263	94	47	0.2809	0.2682	1.16	0.1610	1.43	96
Reference Stations	13	0.2765	0.2886	1.15	0.1559	0.3895	100	10	0.2929	0.2920	1.12	0.1627	0.3890	100
Entire Dataset	97	0.2817	0.2540	1.44	0.1199	263	102	63	0.3095	0.2886	1.22	0.1610	1.76	106

Note

units are in milligrams per kilogram wet weight, geomean = geometric mean, CF = confidence factor

Table 4.39 Spearman Rank Correlations between Tissue Chemistry and Distance from the Outfall (2000–2010)

Parameter	All Years	2008-2010	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Metals													
Aluminum	<u>0.225</u>	0.167	-0.234	0.567	0.517	0.667	0.159	0.252	NM	0.603	0.100	0.052	0.421
Arsenic	<u>0.218</u>	0.117	-0.394	0.535	0.649	0.187	0.310	0.226	0.476	0.527	-0.070	0.363	0.182
Cadmium	<u>0.290</u>	0.159	-0.018	0.341	0.626	0.432	0.432	0.337	0.555	0.555	-0.134	0.333	0.478
Chromium	0.083	0.157	-0.165	0.265	-0.133	0.351	-0.214	0.358	NM	0.591	0.234	-0.125	0.428
Copper	<u>-0.127</u>	<u>-0.247</u>	-0.690	0.166	0.241	0.111	-0.150	-0.628	-0.003	-0.225	-0.240	-0.092	-0.594
Iron	<u>0.330</u>	<u>0.260</u>	-0.115	0.482	0.706	0.532	0.286	0.436	NM	0.695	-0.038	0.129	0.526
Lead	<u>-0.193</u>	<u>-0.257</u>	-0.764	0.009	0.311	0.004	-0.196	-0.469	-0.126	-0.105	-0.451	-0.215	-0.253
Magnesium	<u>0.136</u>	-0.017	-0.106	0.486	0.496	0.259	0.222	0.135	0.438	0.429	-0.090	0.091	0.117
Manganese	0.099	0.157	-0.651	0.120	0.643	0.304	0.027	-0.127	0.363	0.336	-0.263	0.297	0.226
Mercury	<u>0.307</u>	<u>0.268</u>	-0.157	0.342	0.579	0.536	<u>0.393</u>	0.337	0.374	0.805	-0.310	0.331	0.445
Nickel	<u>0.332</u>	<u>0.293</u>	-0.276	0.397	0.629	0.451	0.425	0.251	0.611	0.646	0.042	0.569	0.478
Selenium	0.104	0.056	-0.384	0.290	0.819	0.280	0.014	0.219	0.575	-0.090	0.075	0.326	0.072
Silver	<u>0.310</u>	<u>0.338</u>	0.240	0.643	0.218	0.515	<u>0.384</u>	NM	NM	0.132	0.069	0.365	0.543
Zinc	0.060	0.034	-0.741	0.139	0.656	0.382	-0.064	-0.335	0.233	0.348	-0.283	0.236	0.001
PAHs													
Acenaphthene	<u>-0.378</u>	-0.406	NM	NM	NM	NM	NM	NM	-0.432	-0.457	-0.591	-0.164	-0.608
Anthracene	<u>-0.372</u>	<u>-0.299</u>	NM	NM	NM	NM	NM	NM	-0.475	-0.424	-0.147	-0.461	-0.260
Benz[a]anthracene	-0.613	-0.661	NM	NM	NM	NM	NM	NM	-0.827	-0.306	-0.737	-0.573	-0.852
Benzo[a]pyrene	<u>-0.264</u>	-0.427	NM	NM	NM	NM	NM	NM	-0.419	-0.159	-0.315	-0.298	-0.800
Benzo[b]fluoranthene	-0.536	-0.605	NM	NM	NM	NM	NM	NM	NM	-0.476	-0.730	-0.407	-0.718
Benzo[j,k]fluoranthenes	-0.510	-0.521	NM	NM	NM	NM	NM	NM	NM	-0.369	-0.717	-0.434	-0.530
Chrysene	-0.481	-0.535	NM	NM	NM	NM	NM	NM	-0.796	-0.321	-0.608	-0.338	-0.738
Fluoranthene	-0.621	-0.680	NM	NM	NM	NM	NM	NM	-0.721	-0.231	-0.718	-0.665	-0.802
Fluorene	-0.168	-0.134	NM	NM	NM	NM	NM	NM	-0.489	-0.369	-0.299	0.053	-0.208
Phenanthrene	-0.520	-0.530	NM	NM	NM	NM	NM	NM	-0.772	-0.030	-0.615	-0.524	-0.787
Pyrene	-0.679	-0.636	NM	NM	NM	NM	NM	NM	-0.885	-0.866	-0.419	-0.576	-0.744
Total HMW PAHs	-0.541	-0.575	NM	NM	NM	NM	NM	NM	-0.866	-0.313	-0.419	-0.364	-0.802

continued

Table 4.39 continued

Parameter	All Years	2008-2010	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
PAHs [Lipid-normalized]													
Acenaphthene	-0.077	-0.149	NM	NM	NM	NM	NM	NM	-0.062	0.095	-0.171	-0.026	-0.431
Anthracene	-0.163	-0.153	NM	NM	NM	NM	NM	NM	-0.393	0.244	-0.131	-0.276	-0.089
Benz[a]anthracene	<u>-0.267</u>	<u>-0.300</u>	NM	NM	NM	NM	NM	NM	-0.414	-0.005	-0.458	-0.304	-0.579
Benzo[a]pyrene	-0.037	-0.119	NM	NM	NM	NM	NM	NM	-0.013	0.137	0.038	-0.075	-0.562
Benzo[b]fluoranthene	-0.024	-0.069	NM	NM	NM	NM	NM	NM	NM	0.018	-0.057	-0.024	-0.152
Benzo[j,k]fluoranthenes	-0.018	-0.096	NM	NM	NM	NM	NM	NM	NM	0.095	-0.118	-0.031	-0.133
Chrysene	-0.094	-0.101	NM	NM	NM	NM	NM	NM	-0.192	0.060	-0.031	-0.019	-0.230
Fluoranthene	<u>-0.271</u>	<u>-0.336</u>	NM	NM	NM	NM	NM	NM	-0.292	0.112	-0.391	-0.518	-0.535
Fluorene	0.102	0.152	NM	NM	NM	NM	NM	NM	-0.153	0.066	0.164	0.272	0.146
Phenanthrene	-0.158	-0.160	NM	NM	NM	NM	NM	NM	-0.584	0.289	-0.241	-0.303	-0.418
Pyrene	<u>-0.376</u>	<u>-0.336</u>	NM	NM	NM	NM	NM	NM	-0.665	-0.866	-0.294	-0.464	-0.568
Total HMW PAHs	-0.149	-0.153	NM	NM	NM	NM	NM	NM	-0.316	0.142	-0.116	0.039	-0.520

Note

NM = parameter was not measured this year

Statistically significant correlations ($p < 0.05$) are **bolded****Bold & underlined** = weak ($|r_s| < 0.4$) but statistically significant correlation.**X**= strong correlation ($|r_s| > 0.6$)**X**= moderate strength correlation ($0.4 < |r_s| < 0.6$)

Table 4.40 Spearman Rank Correlations between Tissue Chemistry and Distance-Direction from the Outfall (i.e. Near-field/Far-field-Reference) (2000–2010)

Parameter	All Years	2008-2010	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Metals													
Aluminum	<u>0.315</u>	<u>0.238</u>	0.437	0.468	0.617	0.587	0.532	0.521	NM	0.509	0.192	0.224	0.466
Arsenic	<u>0.284</u>	0.098	0.203	0.346	0.401	0.523	0.613	0.526	0.660	0.522	-0.120	0.417	0.170
Cadmium	<u>0.350</u>	0.192	0.278	0.033	0.478	0.651	0.603	0.533	0.640	0.717	-0.113	0.585	0.330
Chromium	<u>0.182</u>	0.192	0.344	0.272	0.183	0.502	0.283	0.632	NM	0.490	0.266	-0.087	0.506
Copper	<u>-0.258</u>	<u>-0.368</u>	-0.385	-0.375	-0.307	-0.075	-0.291	-0.568	-0.126	-0.502	-0.447	-0.328	-0.739
Iron	0.459	0.457	0.555	0.478	0.617	0.566	0.675	0.697	NM	0.684	0.318	0.369	0.677
Lead	<u>-0.311</u>	<u>-0.303</u>	-0.534	-0.373	-0.169	-0.235	-0.301	-0.414	-0.297	-0.240	-0.502	-0.155	-0.365
Magnesium	0.107	-0.064	-0.178	-0.033	0.460	0.149	0.395	0.162	0.609	0.466	0.002	-0.101	-0.035
Manganese	0.146	0.104	-0.274	0.099	0.395	0.384	0.106	0.187	0.549	0.435	-0.434	0.161	0.113
Mercury	0.374	0.388	0.201	0.132	0.370	0.512	0.567	0.611	0.410	0.851	-0.173	0.535	0.442
Nickel	0.466	0.377	0.344	0.445	0.619	0.630	0.703	0.649	0.778	0.734	0.097	0.761	0.597
Selenium	0.152	0.040	0.294	0.216	0.401	0.406	0.259	0.607	0.640	-0.129	-0.016	0.292	0.027
Silver	0.529	0.584	0.371	0.363	0.592	0.705	0.741	NM	NM	0.548	0.482	0.744	0.627
Zinc	0.044	-0.039	-0.395	-0.099	0.436	0.416	0.080	0.008	0.319	0.395	-0.371	0.118	-0.066
PAHs													
Acenaphthene	-0.499	-0.438	NM	NM	NM	NM	NM	NM	-0.588	-0.648	-0.307	-0.119	-0.693
Anthracene	-0.310	-0.262	NM	NM	NM	NM	NM	NM	-0.105	-0.593	-0.357	-0.477	-0.179
Benz[a]anthracene	-0.733	-0.733	NM	NM	NM	NM	NM	NM	-0.771	-0.574	-0.820	-0.779	-0.698
Benzo[a]pyrene	-0.202	-0.326	NM	NM	NM	NM	NM	NM	-0.261	-0.047	NM	-0.387	-0.733
Benzo[b]fluoranthene	-0.634	-0.633	NM	NM	NM	NM	NM	NM	NM	-0.522	-0.733	-0.600	-0.640
Benzo[j,k]fluoranthenes	-0.663	-0.643	NM	NM	NM	NM	NM	NM	NM	-0.583	-0.820	-0.679	-0.513
Chrysene	-0.593	-0.562	NM	NM	NM	NM	NM	NM	-0.672	-0.545	-0.628	-0.484	-0.599
Fluoranthene	-0.709	-0.707	NM	NM	NM	NM	NM	NM	-0.771	-0.559	-0.771	-0.712	-0.682
Fluorene	-0.082	-0.092	NM	NM	NM	NM	NM	NM	-0.284	-0.075	-0.045	0.045	-0.302
Phenanthrene	-0.606	-0.583	NM	NM	NM	NM	NM	NM	-0.595	-0.545	NM	-0.639	-0.712
Pyrene	-0.681	-0.637	NM	NM	NM	NM	NM	NM	-0.764	-0.866	NM	-0.675	-0.666
Total HMW PAHs	-0.588	-0.541	NM	NM	NM	NM	NM	NM	-0.771	-0.545	NM	-0.456	-0.677

continued

Table 4.40 continued

Parameter	All Years	2008-2010	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
PAHs (Lipid-normalized)													
Acenaphthene	-0.115	<u>-0.315</u>	NM	NM	NM	NM	NM	NM	-0.120	-0.518	-0.133	-0.059	-0.534
Anthracene	-0.068	-0.074	NM	NM	NM	NM	NM	NM	-0.021	0.081	-0.102	-0.317	-0.011
Benz[a]anthracene	<u>-0.386</u>	<u>-0.497</u>	NM	NM	NM	NM	NM	NM	-0.419	-0.533	-0.645	-0.590	-0.456
Benzo[a]pyrene	-0.012	-0.120	NM	NM	NM	NM	NM	NM	0.068	0.198	NM	-0.157	-0.538
Benzo[b]fluoranthene	-0.151	<u>-0.267</u>	NM	NM	NM	NM	NM	NM	NM	-0.410	-0.181	-0.377	-0.113
Benzo[j,k]fluoranthenes	-0.185	<u>-0.315</u>	NM	NM	NM	NM	NM	NM	NM	-0.583	-0.355	-0.360	-0.144
Chrysene	<u>-0.197</u>	<u>-0.297</u>	NM	NM	NM	NM	NM	NM	-0.120	-0.545	-0.192	-0.265	-0.249
Fluoranthene	<u>-0.319</u>	<u>-0.473</u>	NM	NM	NM	NM	NM	NM	-0.345	-0.522	-0.576	-0.584	-0.479
Fluorene	<u>0.224</u>	0.183	NM	NM	NM	NM	NM	NM	0.187	0.075	0.420	0.294	0.067
Phenanthrene	-0.156	<u>-0.337</u>	NM	NM	NM	NM	NM	NM	-0.288	-0.341	NM	-0.538	-0.417
Pyrene	-0.431	-0.431	NM	NM	NM	NM	NM	NM	-0.547	-0.866	NM	-0.575	-0.483
Total HMW PAHs	-0.168	-0.245	NM	NM	NM	NM	NM	NM	-0.320	-0.477	NM	-0.146	-0.431

Note

NM = parameter was not measured this year

Statistically significant correlations ($p < 0.05$) are **bolded****Bold & underlined** = weak ($|r_s| < 0.4$) but statistically significant correlation.**X**= strong correlation ($|r_s| > 0.6$)**X**= moderate strength correlation ($0.4 < |r_s| < 0.6$)

Most (12 out of 14) of the metals exhibited significant differences (for most distance groups relative to reference) in the analysis of variance (all years, Table 4.41). *Post hoc* multiple comparisons revealed that for arsenic, cadmium, iron, mercury, nickel and silver, significant differences were observed between the reference area and all of the five distance groups. Average concentrations at the reference area were significantly higher than average tissue concentrations at the outfall stations (Figure 4.38). Selenium concentrations were also significantly higher at the reference stations than at C0 and at the 400m stations. Conversely, concentrations of copper and lead were significantly higher at C0 than at the reference stations (Golder, 2011b).

All of the PAHs exhibited significant differences relative to reference in at least one distance group when all years of data were analyzed (Table 4.41). There were fewer significant differences relative to reference for PAHs once they were lipid-normalized.

The analysis of variance for the three distance-direction groups identified significant differences between groups for all metals with the exception of magnesium (all years, Table 4.42). Mussels collected in the near-field had significantly lower tissue metal concentrations than mussels collected in the reference area for nine of the fourteen metals (aluminum, arsenic, cadmium, chromium, iron, manganese, mercury, nickel and silver) (Table 4.42 and Figure 4.38). All of these metals, with the exception of aluminum and chromium, were also significantly lower at far field stations compared to the reference area. Concentrations of copper and lead in mussels collected from the near-field stations were significantly higher than those at the reference area, whereas tissue concentrations at far-field stations were not significantly different from reference conditions (Golder, 2011b).

ANOVA results identified significantly higher concentrations of all PAHs (with the exception of fluorene) in the near-field group relative to reference (Table 4.42 and Figure 4.39). Significantly higher concentrations of PAHs in the far-field group relative to reference were also identified for seven of the individual PAHs as well as total high molecular weight PAHs. There were fewer significant differences relative to reference for PAHs once they were lipid-normalized (Golder, 2011b).

Lipid normalization was carried out because organic contaminants tend to concentrate in lipid, and lipid-normalized data is often used to reduce within-sample variability in species where lipid content is variable. Focus in this report is on wet weight concentrations, because these can be compared to effects threshold data from the literature and regulatory tissue guidelines. Statistical analyses and temporal assessments were also performed using the wet weight converted concentrations, to remain consistent with previous years.

Plots of the distance-direction group mean metals concentrations over time are presented in Figure 4.40. Concentrations of metals in mussel tissues did not exhibit consistent trends among metals or among distance-direction groups. Interestingly, the temporal trends in mussels collected from the reference stations are at least as, if not more, variable than the concentrations from the outfall monitoring stations. Cadmium and selenium concentrations appear to be increasing over time at all stations, as the measurements made in 2009 and 2010 are the highest measured over the period of record. Copper concentrations also appear to be exhibiting a gradual increase over time; concentrations in 2010 were similar to those measured in 2000. Magnesium concentrations appear to decrease consistently between 2007 and 2010, similar to what was observed between 2002 and 2004. Further monitoring is required to confirm whether these apparent trends are real or spurious (Golder, 2011b).

Plots of the distance-direction group mean PAH concentrations over time are presented in Figure 4.41. Although PAH concentrations at the outfall station and in the near-field group appear to be consistently higher than in other distance-direction groups, no consistent temporal trends are evident. Most PAH compounds exhibit a flat concentration profile from 2006-2010, with variability obscuring any temporal trends. Several of the PAHs indicate a spike in concentrations in 2009 at the outfall station; concentrations of PAHs decreased in 2010 but remain greater than in the previous sampling years (2006-2008) (Golder, 2011b).

Heterogeneity was not significantly different among stations for any of the substances (Table 4.43). This indicates that temporal trends for these parameters do not differ significantly among individual stations.

Results were the same with the inclusion and exclusion of reference stations, indicating that trends at the reference area do not appear to differ significantly from trends at the outfall stations (Golder, 2011b).

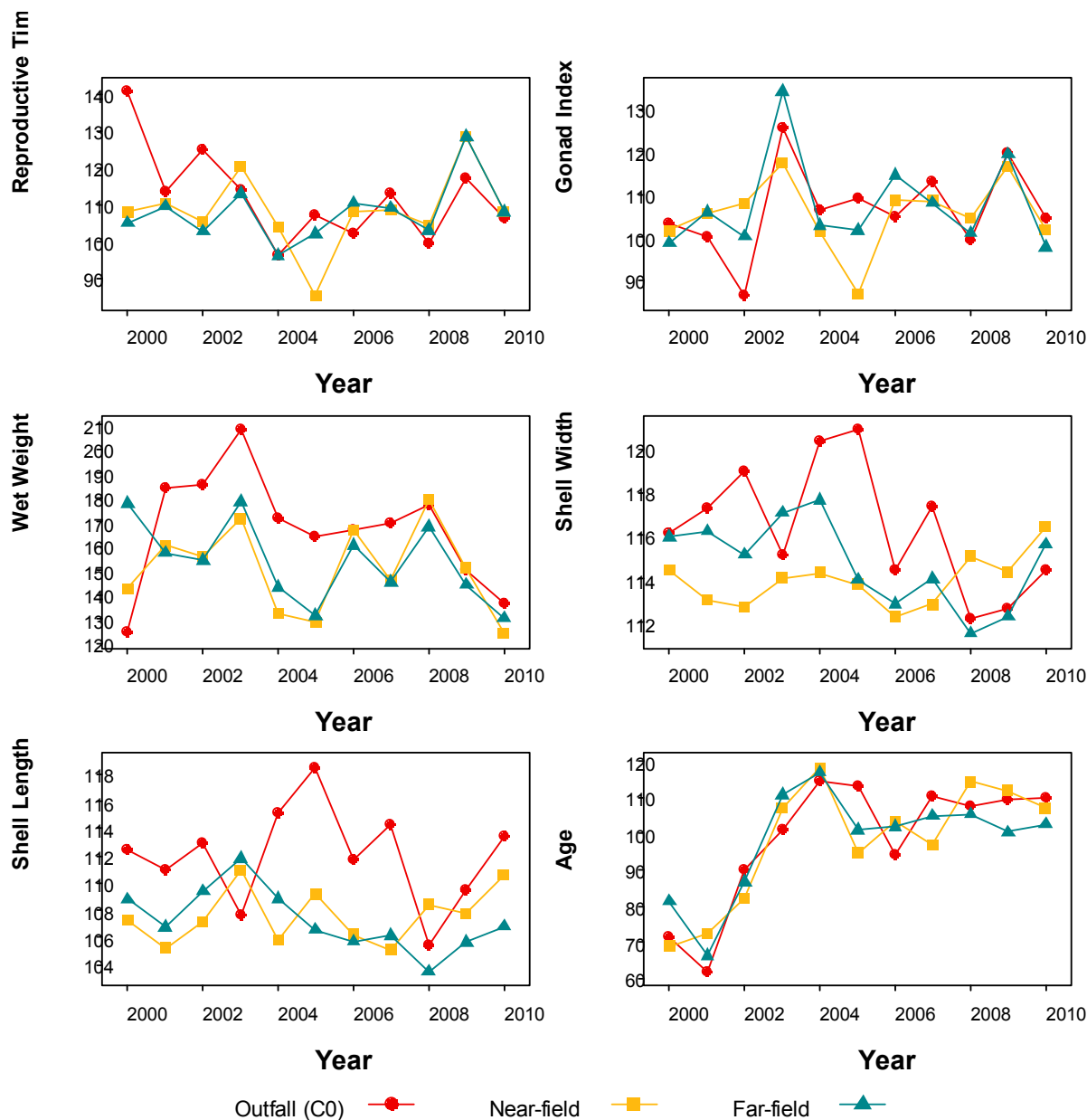


Figure 4.37 Plots of Reference-Normalized Biological Metrics Over Time for Mussels Collected at Clover Point Stations (2000 to 2010)

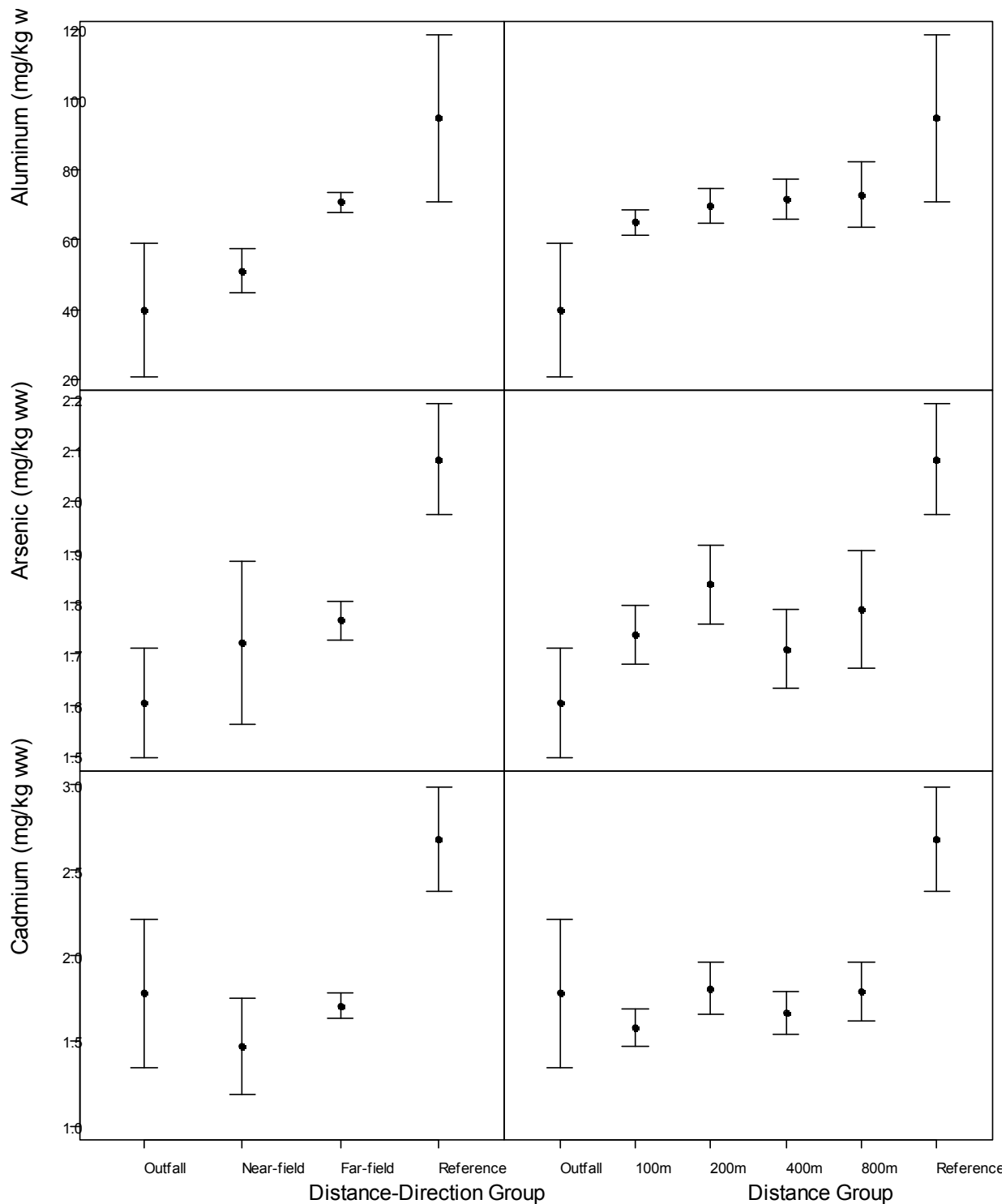


Figure 4.38 Means ± 95% Confidence Intervals for Mussel Tissue Metals (2000-2010)

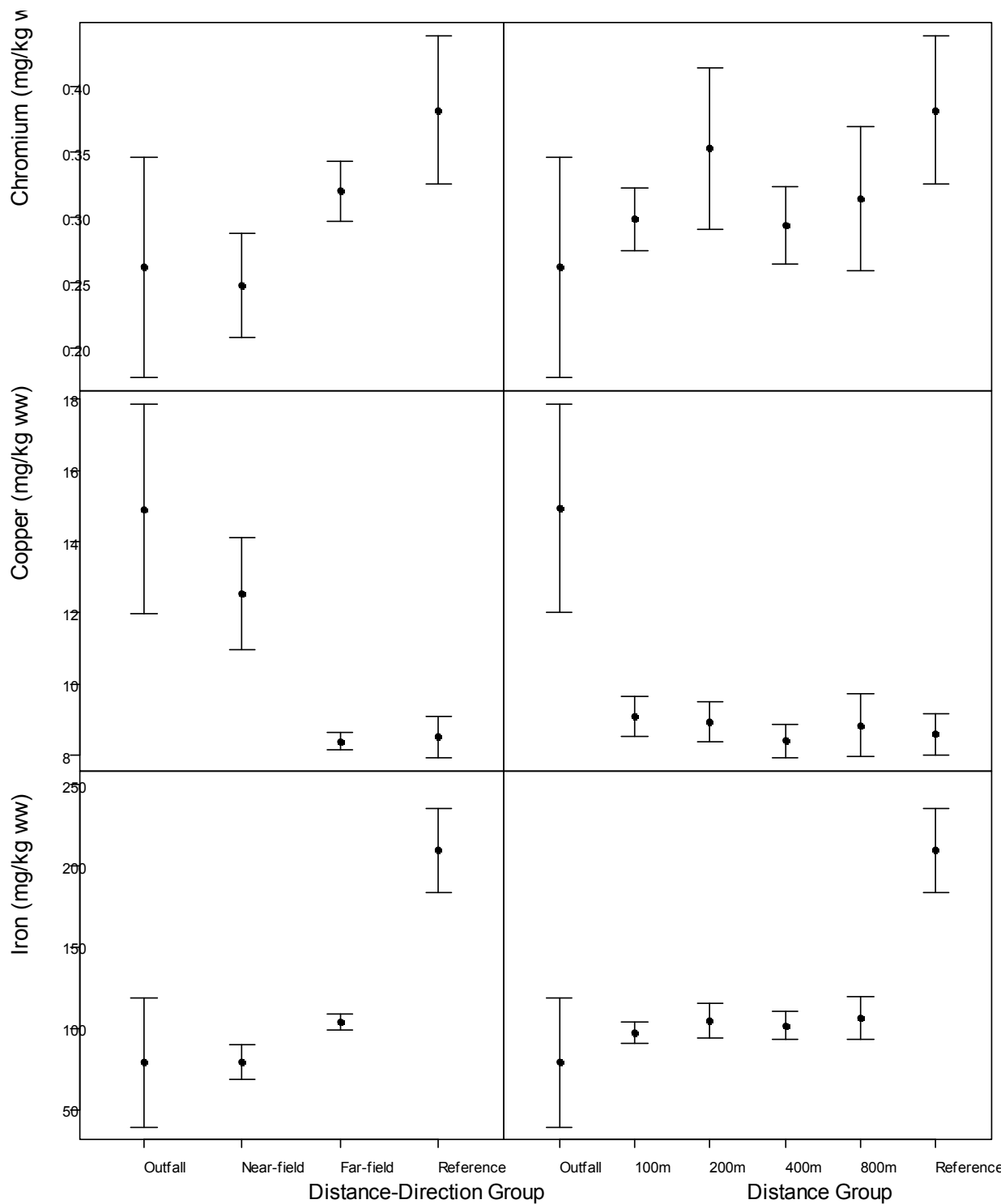


Figure 4.38, continued

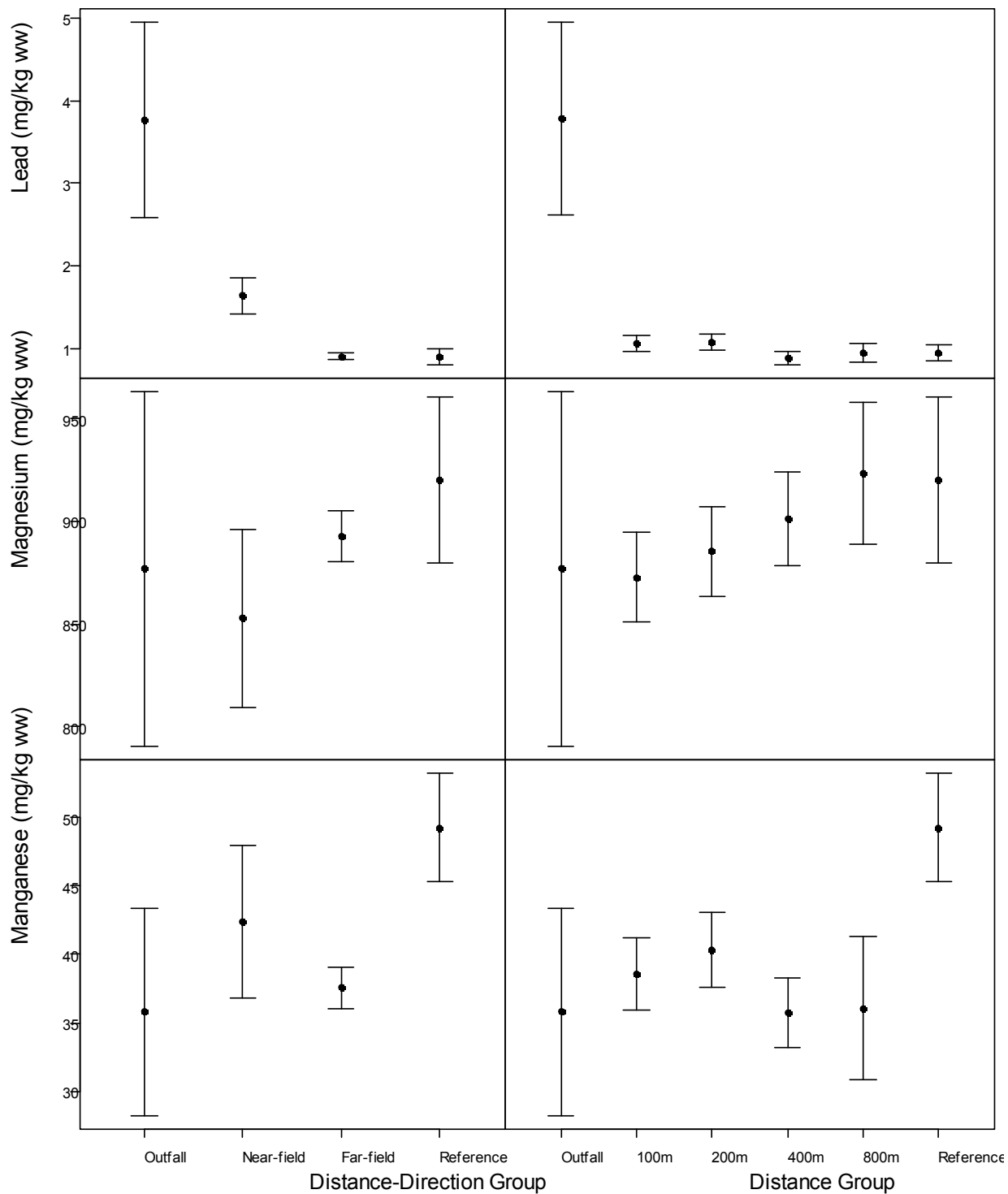


Figure 4.38, continued

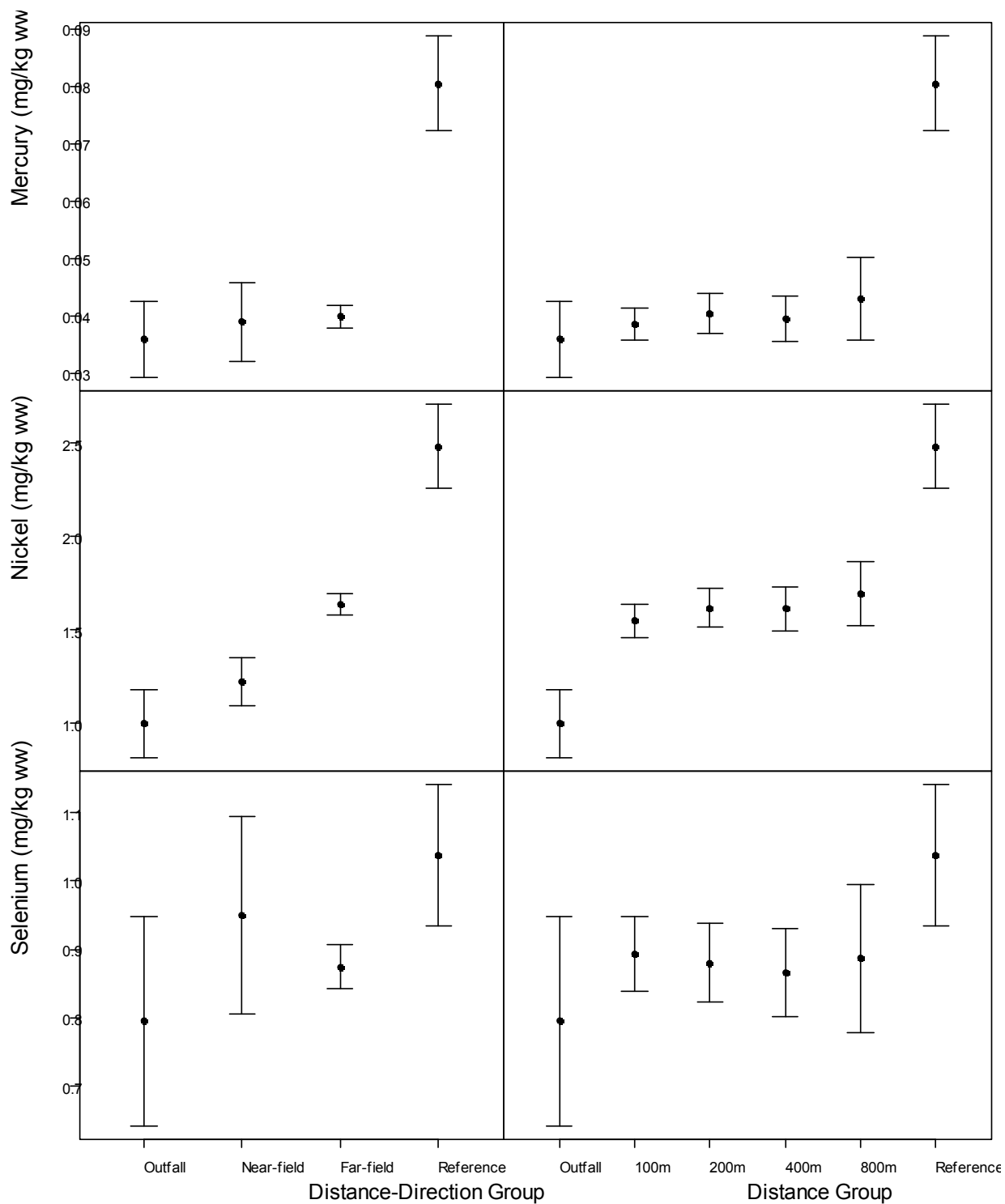


Figure 4.38, continued

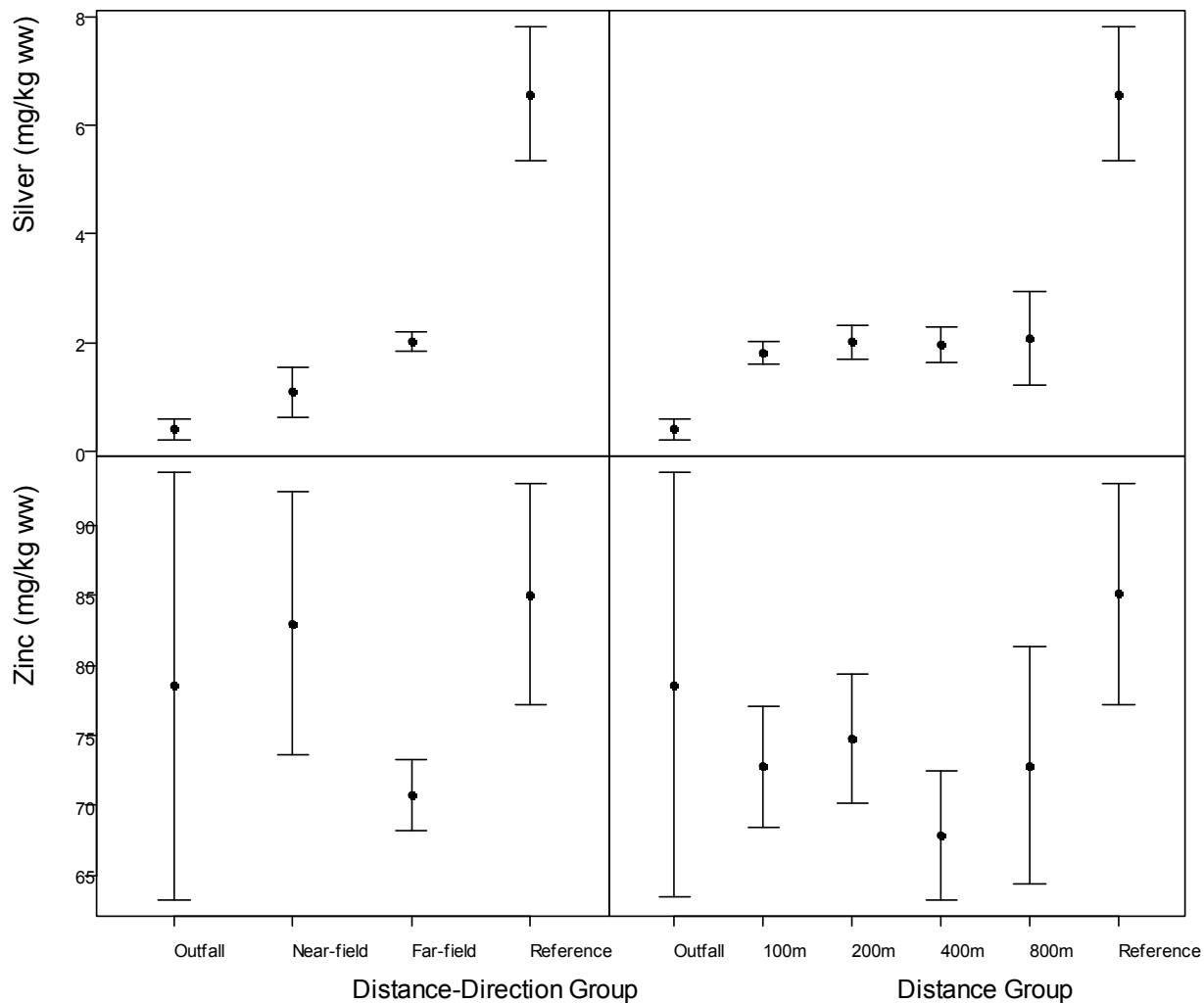


Figure 4.38, concluded

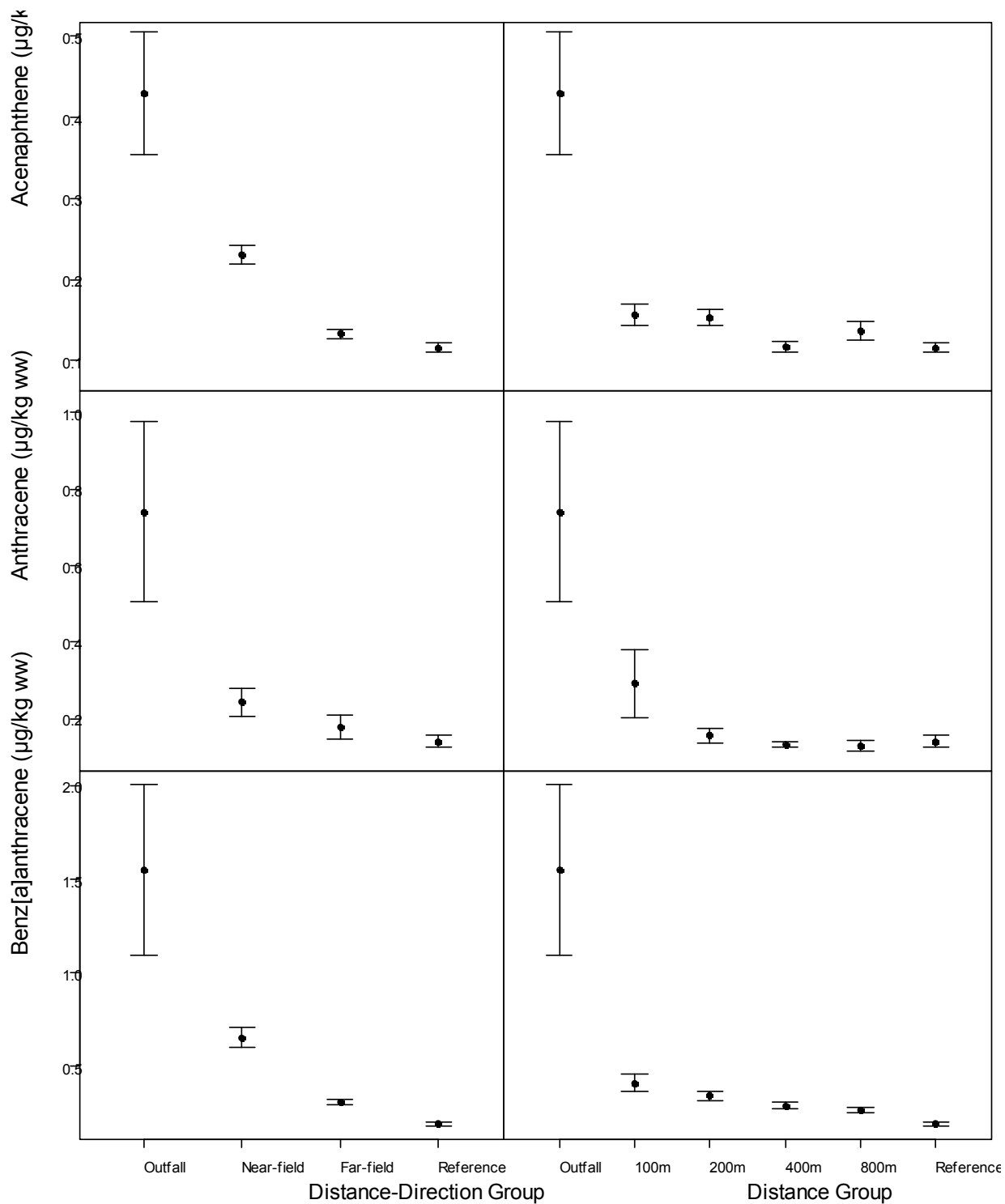


Figure 4.39 Means ± 95% Confidence Intervals for Mussel Tissue PAHs (2006-2010)

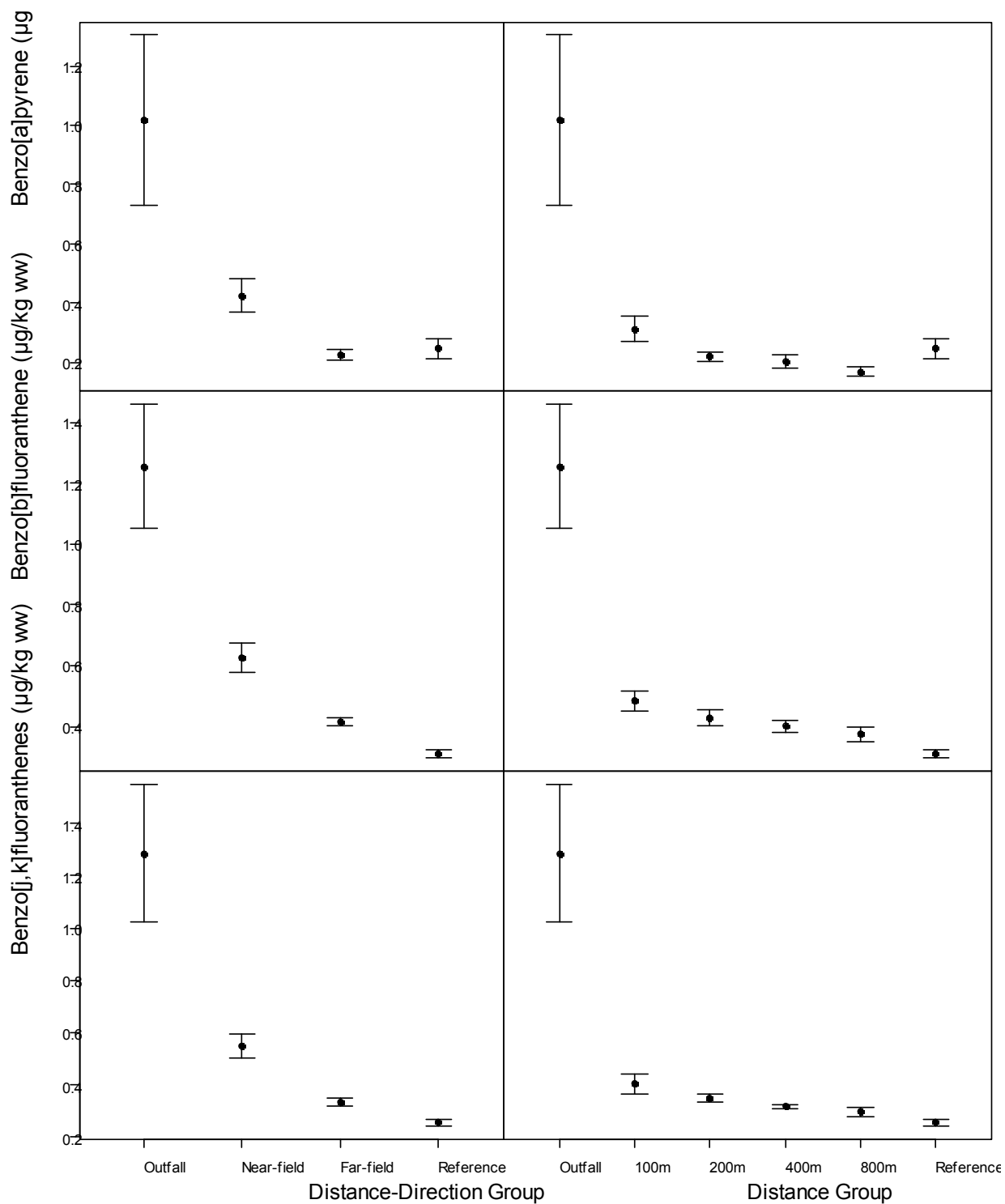


Figure 4.39, continued

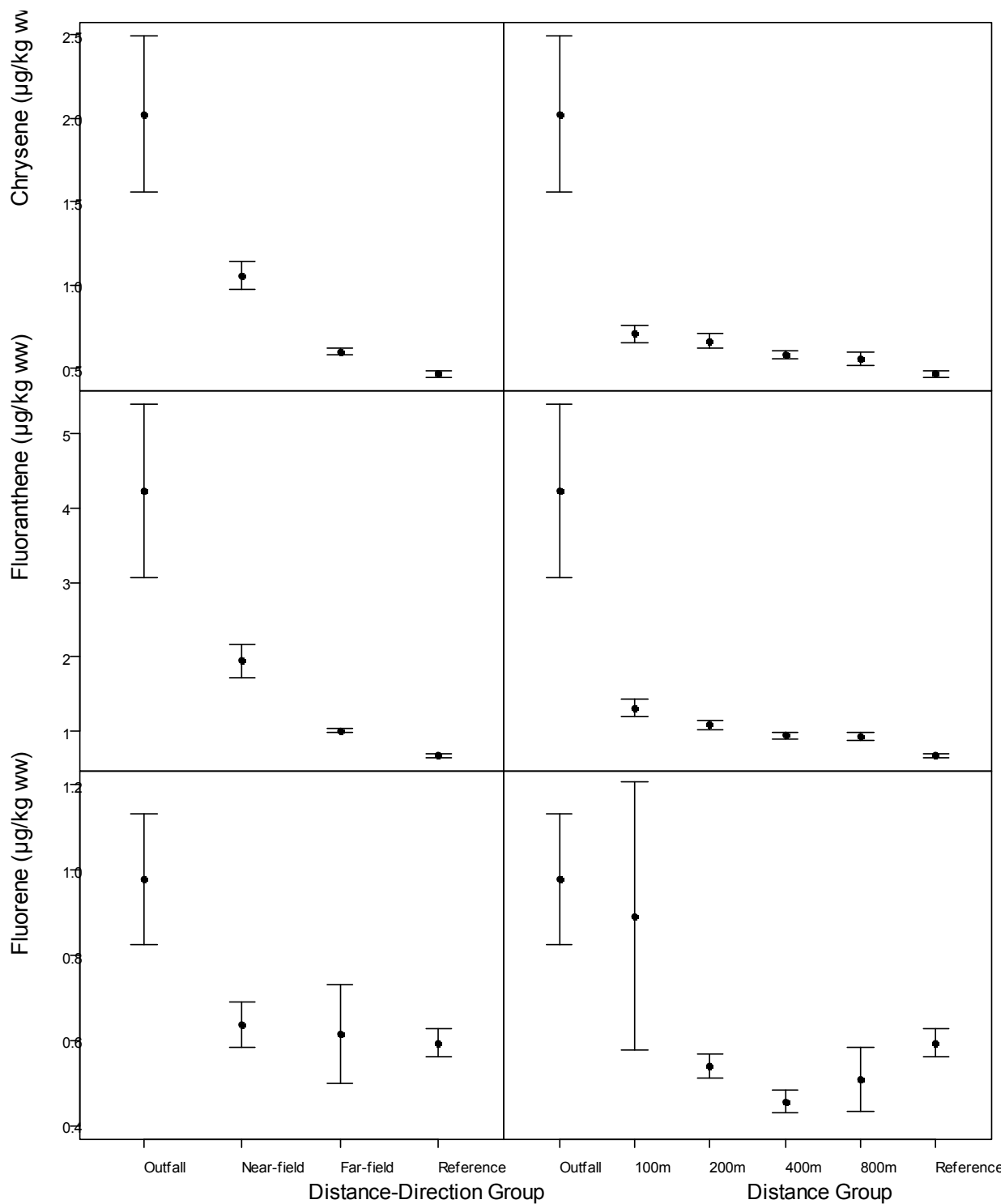


Figure 4.39, continued

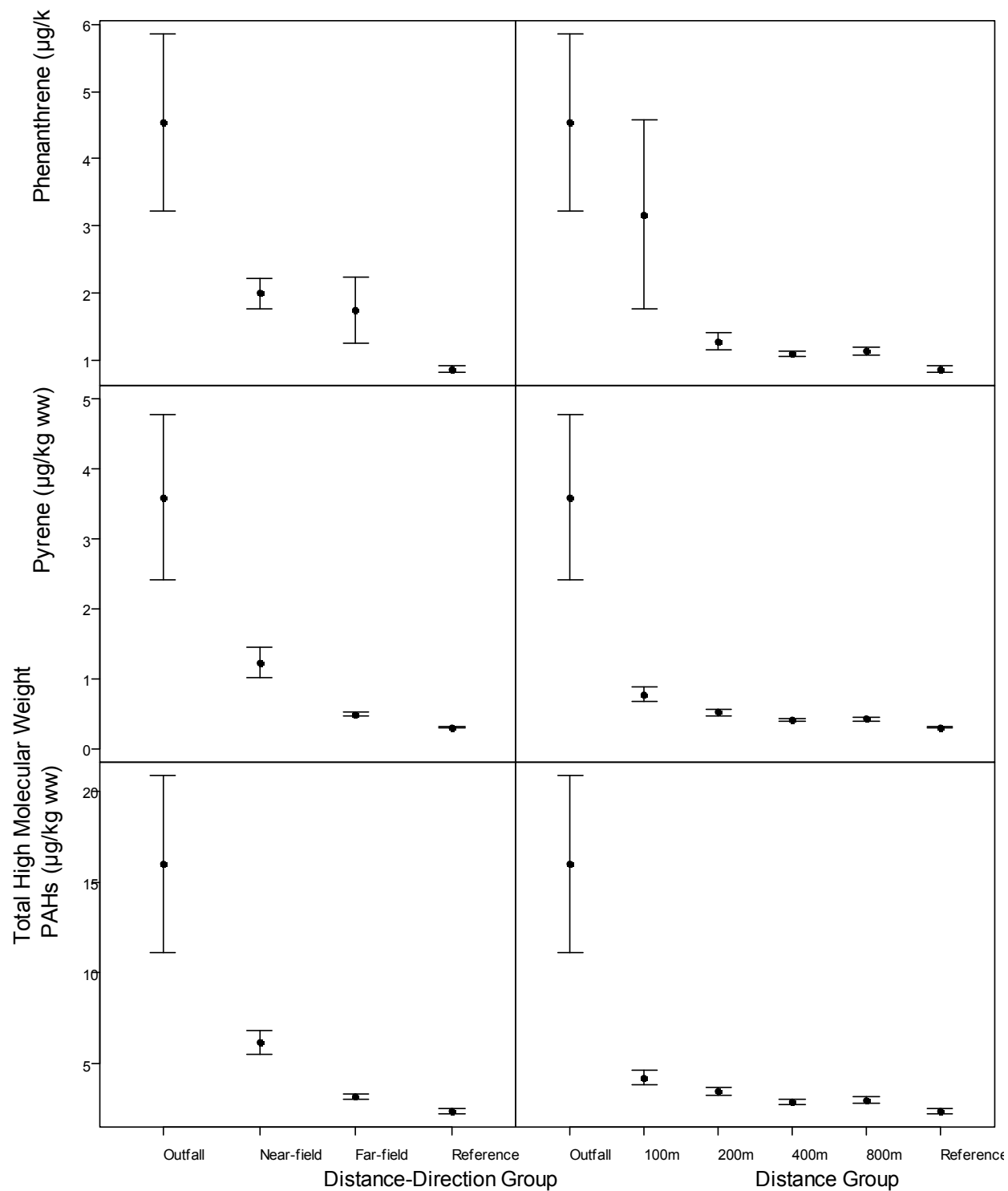
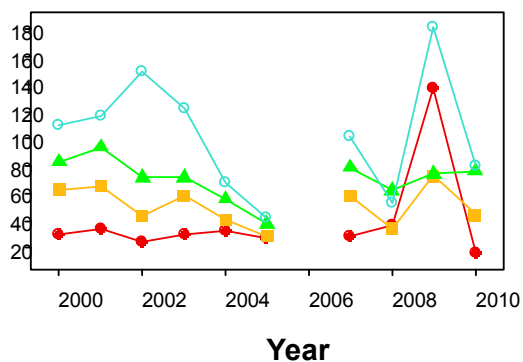
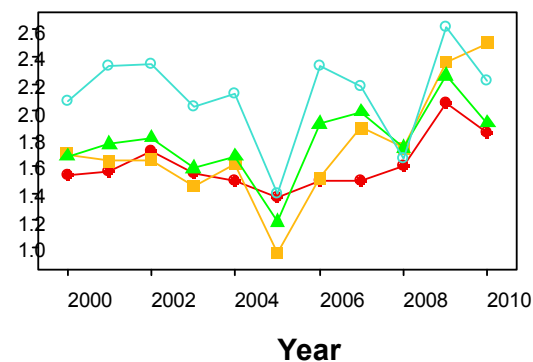


Figure 4.39, concluded

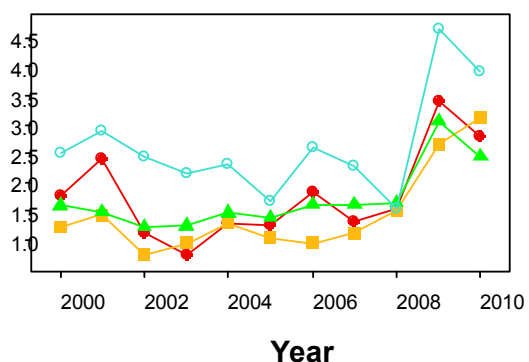
Aluminum (mg/kg ww)



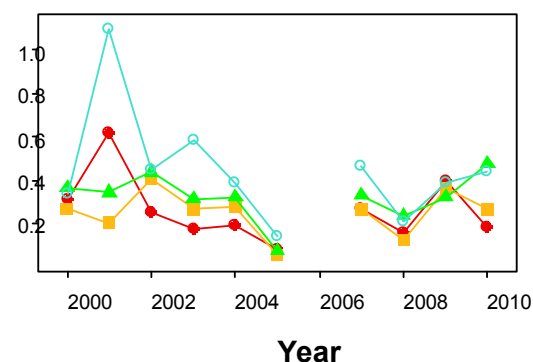
Arsenic (mg/kg ww)



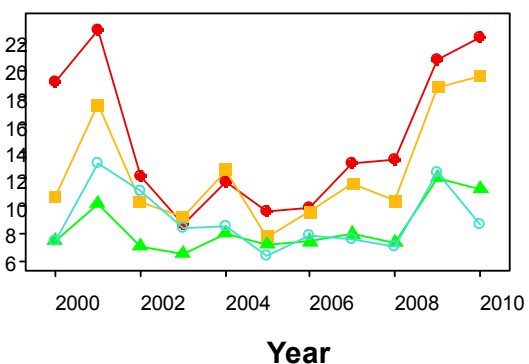
Cadmium (mg/kg ww)



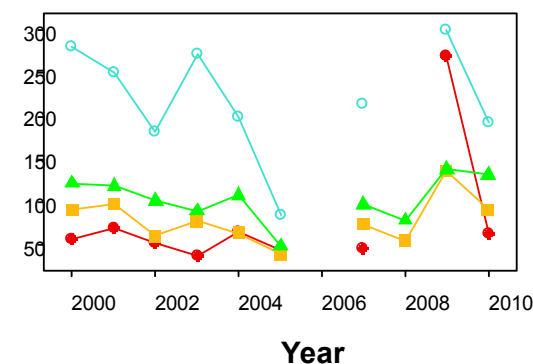
Chromium (mg/kg ww)



Copper (mg/kg ww)



Iron (mg/kg ww)



Outfall (C0) Near-field Far-field Reference

Figure 4.40 Plots of Tissue Metal Concentrations (mg/kg wet weight) over Time for Mussels Collected at Clover Point Stations (2000-2010)

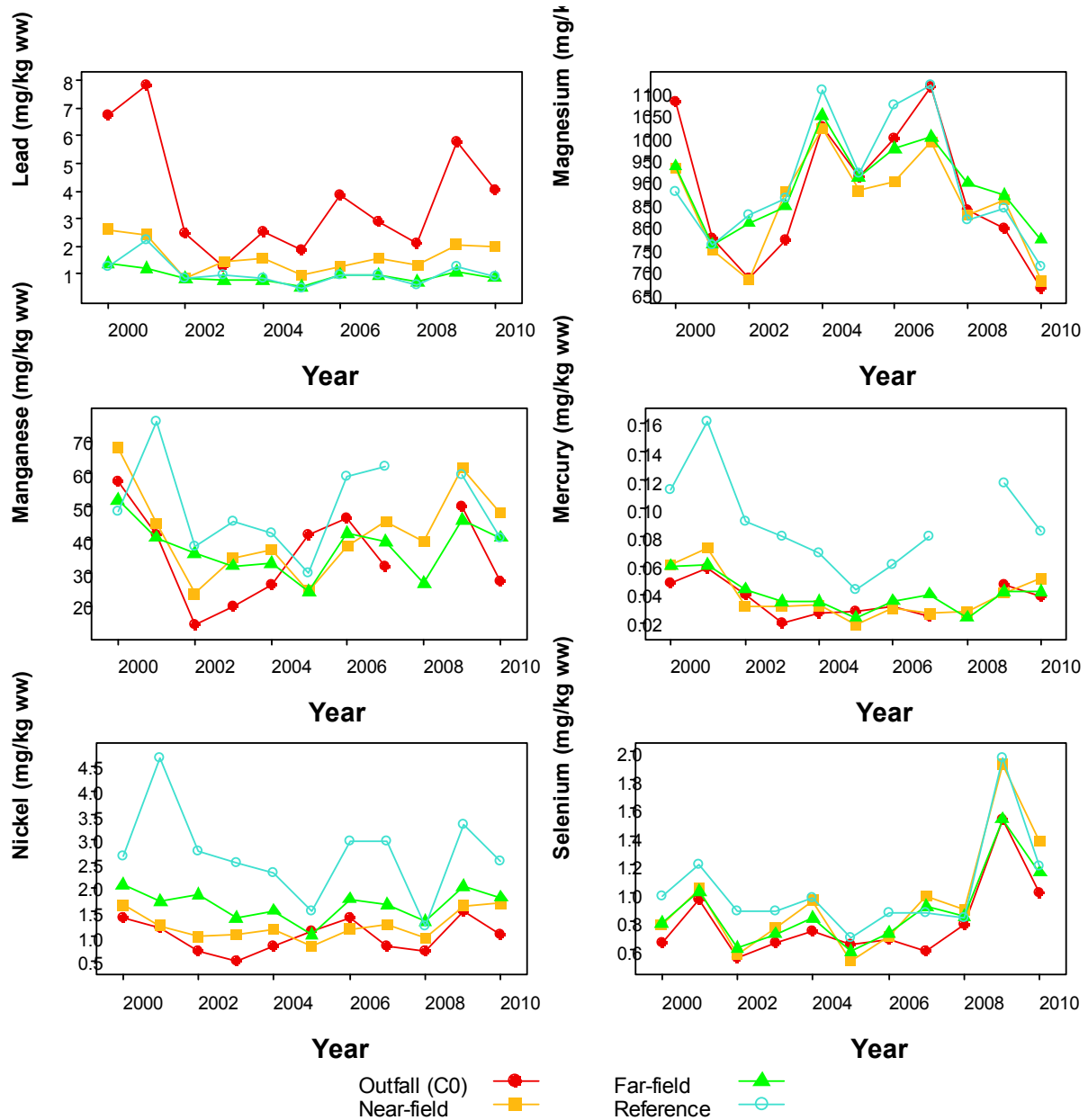


Figure 4.40, continued

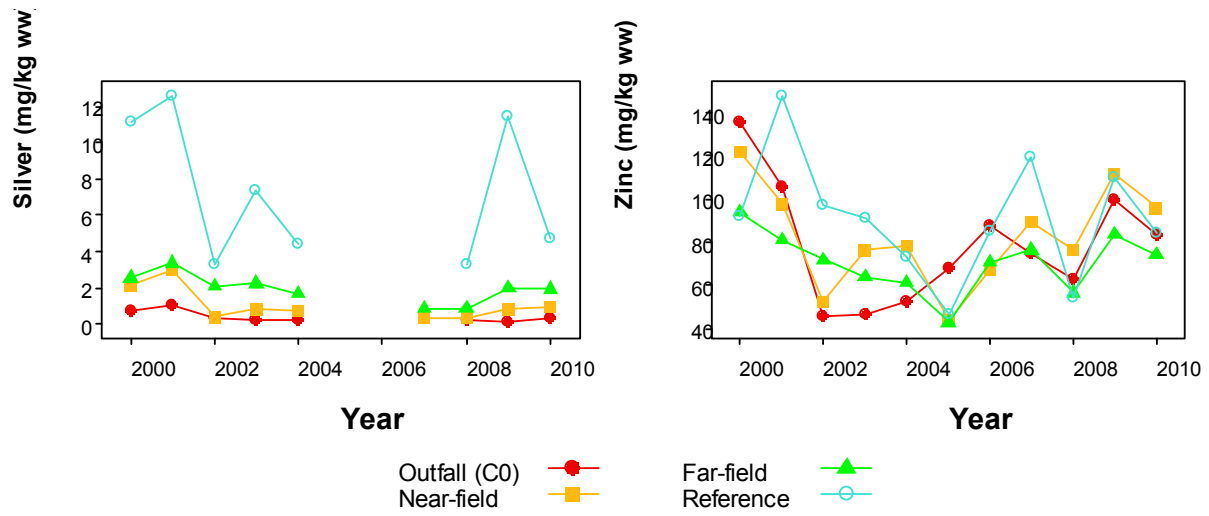


Figure 4.40, concluded

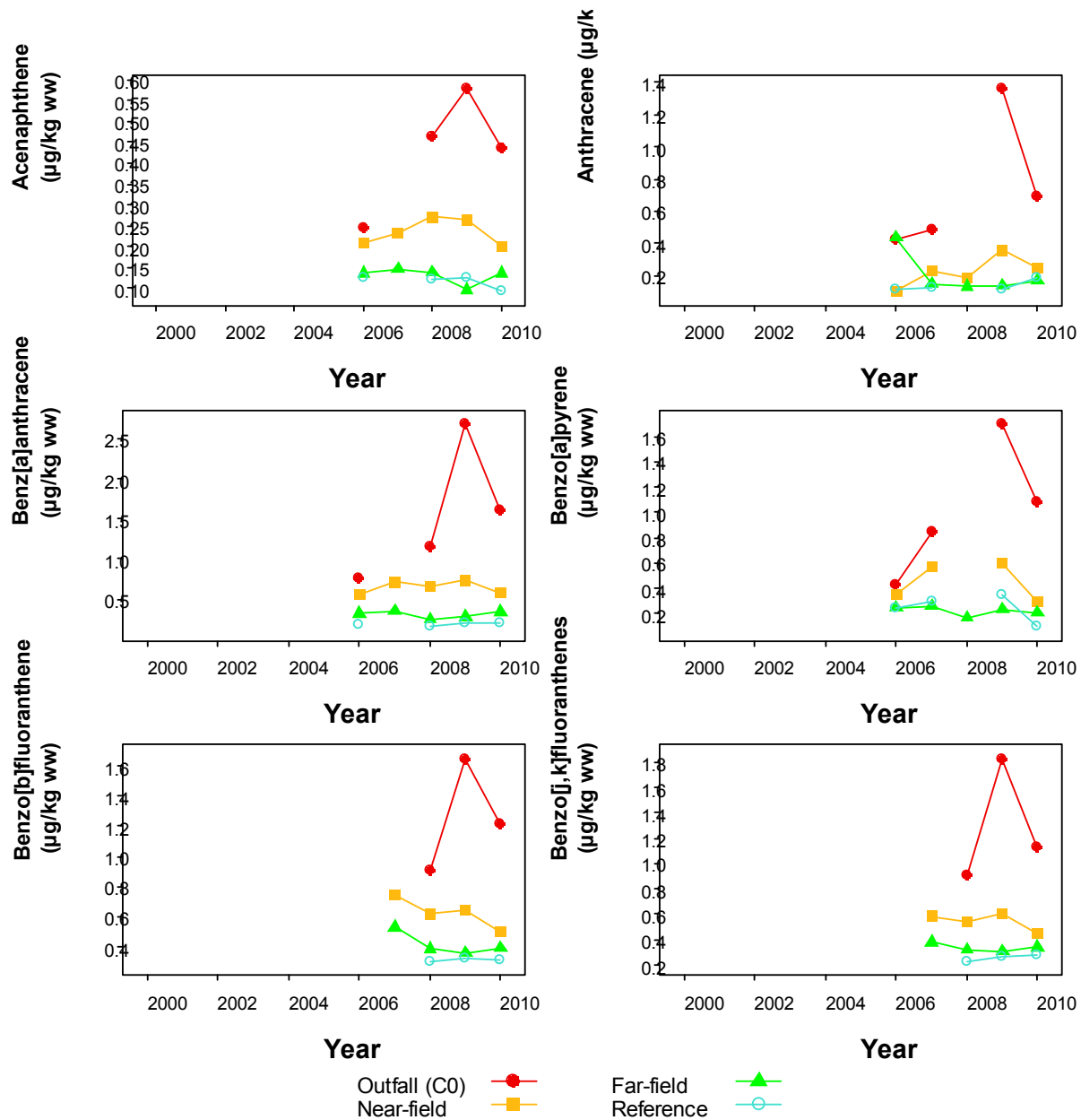


Figure 4.41 Plots of Tissue PAH Concentrations over Time for Mussels Collected at Clover Point Stations (2006 to 2010)

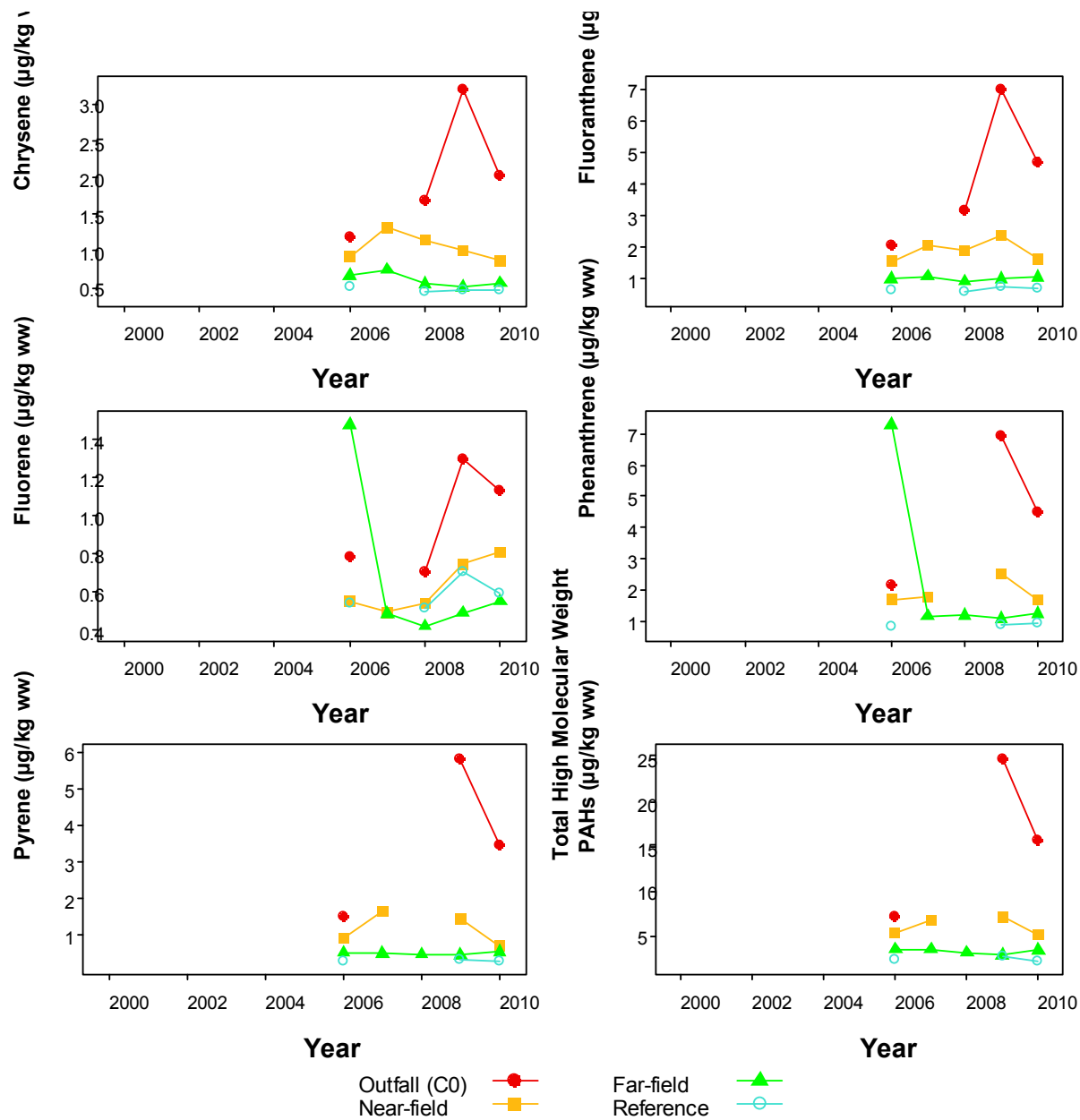


Figure 4.41, concluded

Table 4.41 Results of the Analysis of Variance (ANOVA or Kruskal-Wallis) and Post hoc Multiple Comparisons of Tissue Chemistry at Clover Point Distance Groups (2000–2010)

Parameter	2000-2010 ¹						2008-2010					
	ANOV A / KW	Outfall	100m	200m	400m	800m	ANOV A / KW	Outfall	100m	200m	400m	800 m
Metals												
Aluminum	<0.001	<0.001	0.044	0.467	0.494	1.00	0.720	NS	NS	NS	NS	NS
Arsenic	<0.001	0.007	<0.001	0.004	<0.001	0.014	0.489	NS	NS	NS	NS	NS
Cadmium	<0.001	0.048	<0.001	<0.001	<0.001	0.002	0.184	NS	NS	NS	NS	NS
Chromium	0.135	NS	NS	NS	NS	NS	0.495	NS	NS	NS	NS	NS
Copper	0.001	<0.001	1.00	1.00	1.00	1.00	0.095	NS	NS	NS	NS	NS
Iron	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	0.002	1.00	<0.001	0.002	<0.001	0.008
Lead	<0.001	<0.001	0.597	0.486	0.896	0.998	<0.001	<0.001	0.670	0.741	0.995	0.94
Magnesium	0.346	NS	NS	NS	NS	NS	0.138	NS	NS	NS	NS	NS
Manganese	<0.001	0.102	0.003	0.034	<0.001	0.006	0.247	NS	NS	NS	NS	NS
Mercury	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.158	<0.001	<0.001	<0.001	0.006
Nickel	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.052	NS	NS	NS	NS	NS
Selenium	0.023	0.048	0.111	0.092	0.005	0.375	0.922	NS	NS	NS	NS	NS
Silver	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.054	<0.001	0.003	0.002	0.012
Zinc	0.048	0.956	0.104	0.318	0.006	0.376	0.946	NS	NS	NS	NS	NS
PAHs												
Acenaphthene	0.001	0.013	0.152	0.064	1.00	0.808	0.024	<0.001	0.194	0.998	1.00	1.00
Anthracene	<0.001	0.012	0.027	1.00	1.00	1.00	0.008	0.169	1.00	1.00	1.00	1.00
Benz[a]anthracene	<0.001	0.012	<0.001	<0.001	<0.001	0.001	<0.001	0.041	<0.001	0.003	0.006	0.073
Benzo[a]pyrene	0.004	0.014	1.00	1.00	1.00	0.626	0.022	0.158	1.00	1.00	1.00	1.00
Benzo[b]fluoranthene	<0.001	0.038	<0.001	0.002	0.013	0.120	<0.001	0.038	<0.001	0.025	0.145	0.668
Benzo[j,k]fluoranthenes	<0.001	0.038	<0.001	0.002	0.004	0.444	<0.001	0.038	0.002	0.010	0.013	1.00
Chrysene	<0.001	0.011	<0.001	0.002	0.019	0.334	<0.001	0.038	0.004	0.121	0.303	1.00
Fluoranthene	<0.001	0.012	<0.001	<0.001	<0.001	0.002	<0.001	0.041	<0.001	0.001	0.024	0.073
Fluorene	<0.001	0.042	1.00	1.00	0.013	0.822	0.003	<0.001	0.854	0.709	0.011	0.210
Phenanthrene	<0.001	0.051	<0.001	0.014	0.017	0.038	0.002	0.184	0.008	0.411	0.103	0.632
Pyrene	<0.001	0.051	<0.001	0.003	0.011	0.074	<0.001	0.184	0.001	0.056	0.084	0.309
Total HMW PAHs	<0.001	0.044	<0.001	0.006	0.209	0.024	<0.001	0.158	0.002	0.199	1.00	0.599

continued

Table 4.41 continued

Parameter	2000-2010 ¹						2008-2010					
	ANOVA / KW	Outfall	100m	200m	400m	800m	ANOVA / KW	Outfall	100m	200m	400m	800m
PAHs (Lipid-normalized)												
Acenaphthene	0.019	0.035	1.00	0.289	0.308	1.00	0.104	NS	NS	NS	NS	NS
Anthracene	0.003	0.036	1.00	0.403	0.459	0.501	0.009	0.169	1.00	0.285	0.118	1.00
Benz[a]anthracene	0.022	0.012	0.482	1.00	1.00	1.00	0.029	0.041	0.3451	1.00	0.320	0.446
Benzo[a]pyrene	0.001	0.086	1.00	0.015	0.065	0.098	0.047	0.158	1.00	0.310	0.592	1.00
Benzo[b]fluoranthene	0.191	NS	NS	NS	NS	NS	0.185	NS	NS	NS	NS	NS
Benzo[j,k]fluoranthenes	0.175	NS	NS	NS	NS	NS	0.150	NS	NS	NS	NS	NS
Chrysene	0.043	0.053	1.00	1.00	1.00	1.00	0.124	NS	NS	NS	NS	NS
Fluoranthene	0.013	0.012	0.494	1.00	1.00	1.00	0.020	0.041	0.200	0.988	0.727	0.355
Fluorene	0.004	1.00	0.262	0.007	0.002	0.079	0.049	1.00	0.115	0.114	0.012	0.237
Phenanthrene	0.072	NS	NS	NS	NS	NS	0.110	NS	NS	NS	NS	NS
Pyrene	0.005	0.051	0.097	1.00	1.00	0.963	0.037	0.184	0.280	1.00	1.00	0.632
Total HMW PAHs	0.015	0.044	1.00	0.639	0.225	1.00	0.095	NS	NS	NS	NS	NS

Note:Significant differences ($p < 0.05$) are **bolded**.

NS = analysis of variance not significant, multiple comparisons not conducted.

¹ Only data from 2006 through 2010 were available for high resolution PAH analysis.

Table 4.42 Results of the Analysis of Variance (ANOVA or Kruskal-Wallis) and Post hoc Multiple Comparisons of Tissue Chemistry among Distance-Direction Groups (2000–2010)

Parameter	2000-2010 ¹			2008-2010		
	ANOVA/KW	Near-field vs Reference	Far-field vs Reference	ANOVA/KW	Near-field vs Reference	Far-field vs Reference
Metals						
Aluminum	<0.001	<0.001	0.127	0.041	0.051	1.00
Arsenic	<0.001	<0.001	<0.001	0.140	NS	NS
Cadmium	<0.001	<0.001	<0.001	0.069	NS	NS
Chromium	0.013	0.012	0.171	0.171	NS	NS
Copper	<0.001	<0.001	1.00	<0.001	0.001	0.529
Iron	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lead	<0.001	<0.001	0.999	<0.001	<0.001	1.000
Magnesium	0.188	NS	NS	0.018	1.00	0.047
Manganese	<0.001	0.021	<0.001	0.015	0.848	0.020
Mercury	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	<0.001	<0.001	<0.001	0.003	0.031	0.026
Selenium	0.008	0.081	0.004	0.592	NS	NS
Silver	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	0.002	0.890	0.006	0.042	0.347	0.380
PAHs						
Acenaphthene	<0.001	<0.001	0.251	<0.001	<0.001	0.971
Anthracene	<0.001	0.001	1.00	<0.001	0.019	0.814
Benz[a]anthracene	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Benzo[a]pyrene	<0.001	0.002	0.427	0.006	0.029	1.00
Benzo[b]fluoranthene	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Benzo[j,k]fluoranthenes	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chrysene	<0.001	<0.001	<0.001	<0.001	<0.001	0.015
Fluoranthene	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Fluorene	<0.001	0.131	0.074	<0.001	0.051	0.032
Phenanthrene	<0.001	<0.001	<0.001	<0.001	0.007	0.015
Pyrene	<0.001	<0.001	<0.001	<0.001	0.007	0.002
Total HMW PAHs	<0.001	<0.001	<0.001	<0.001	0.002	0.027
PAHs (Lipid-normalized)						
Acenaphthene	0.001	0.071	0.100	<0.001	0.001	1.00
Anthracene	0.012	0.185	0.213	0.002	0.202	0.063
Benz[a]anthracene	<0.001	<0.001	0.882	<0.001	<0.001	0.181
Benzo[a]pyrene	<0.001	0.070	0.003	0.002	0.100	0.175
Benzo[b]fluoranthene	0.007	0.092	0.697	0.005	0.016	1.00
Benzo[j,k]fluoranthenes	0.011	0.070	1.00	0.002	0.007	1.00
Chrysene	<0.001	0.005	0.277	<0.001	0.002	1.00
Fluoranthene	<0.001	<0.001	1.00	<0.001	<0.001	0.154
Fluorene	0.001	0.156	<0.001	0.006	0.9121	0.004
Phenanthrene	0.042	0.125	1.00	0.003	0.007	1.00
Pyrene	<0.001	<0.001	0.723	0.001	0.007	0.586
Total HMW PAHs	<0.001	0.011	0.164	<0.001	0.002	0.669

Note:

Significant differences ($p < 0.05$) are **bolded**.

NS = analysis of variance not significant, multiple comparisons not conducted.

¹ Only data from 2006 through 2010 were available for high resolution PAH analysis.

Table 4.43 Summary of van Belle Test for Homogeneity of Temporal Trends in Mussel Tissue Chemistry Among Clover Point Stations (2000–2010)

Parameter	Chi-square Homogeneity Test Statistics			
	All Stations	P-value	Reference Excluded	P-value
Metals				
Aluminum	16.45	0.94	12.55	0.94
Arsenic	15.29	0.97	14.05	0.90
Cadmium	14.88	0.97	13.29	0.92
Chromium	17.60	0.92	10.48	0.98
Copper	17.85	0.91	13.46	0.92
Iron	10.89	1.00	9.59	0.99
Lead	16.25	0.95	9.17	0.99
Magnesium	17.85	0.91	8.53	1.00
Manganese	23.13	0.68	20.48	0.55
Mercury	26.89	0.47	7.74	1.00
Nickel	18.00	0.90	16.29	0.80
Selenium	12.26	0.99	11.58	0.97
Silver	30.37	0.30	26.65	0.22
Zinc	22.73	0.70	20.61	0.54
PAHs				
Acenaphthene	17.58	0.86	16.17	0.71
Anthracene	34.65	0.12	28.29	0.13
Benz[a]anthracene	23.53	0.60	13.46	0.89
Benzo[a]pyrene	14.30	0.94	13.38	0.82
Benzo[b]fluoranthene	24.97	0.52	20.93	0.46
Benzo[j,k]fluoranthenes	27.46	0.39	21.22	0.45
Chrysene	25.72	0.48	15.66	0.79
Fluoranthene	28.55	0.33	21.10	0.45
Fluorene	25.80	0.47	21.43	0.43
Phenanthrene	19.68	0.72	16.51	0.74
Pyrene	22.49	0.37	20.96	0.28
Total HMW PAHs	14.64	0.96	9.54	0.98
PAHs (Lipid-normalized)				
Acenaphthene	10.43	1.00	7.62	0.99
Anthracene	11.03	1.00	10.16	0.98
Benz[a]anthracene	11.10	1.00	8.36	0.99
Benzo[a]pyrene	22.71	0.54	15.55	0.69
Benzo[b]fluoranthene	6.87	1.00	6.53	1.00
Benzo[j,k]fluoranthenes	7.07	1.00	6.47	1.00
Chrysene	11.09	1.00	8.48	0.99
Fluoranthene	5.02	1.00	4.33	1.00
Fluorene	12.90	0.98	9.06	0.99
Phenanthrene	9.52	1.00	9.09	0.99
Pyrene	11.35	0.96	10.98	0.90
Total HMW PAHs	13.62	0.98	5.79	1.00

Note

¹ Only data from 2006 through 2010 were available for high resolution PAH analysis.

OVERALL ASSESSMENT

Results of the 2010 mussel monitoring component were qualitatively similar to previous years. The specific similarities were as follows:

- Shell length, shell width, shell weight and tissue weight were generally enhanced in the vicinity of the outfall relative to the reference stations.
- There was no evidence of significant effects of the Clover Point outfall on age or reproductive status (gonad index, reproductive timing index or sex ratio).
- Concentrations of lead and zinc in mussel tissue were below tissue effects thresholds derived from the literature. Copper concentration was slightly elevated above the tissue effects threshold in two samples (stations C0 and C1E), however the exceedences were minor, and the risks are considered low.
- Concentrations of metals other than copper and lead were either unrelated to distance from the outfall, or increased with distance from the outfall, possibly due to growth dilution but also due to higher metals concentrations occurring at reference stations.
- Concentrations of most organic substances (e.g. base-neutral extractables and chlorinated phenolics) were either below analytical detection limits or were rarely detected. Analyses of PAHs revealed negative correlations with distance from the outfall, but did not reveal any tissue levels of environmental concern based on screening to literature-based effects thresholds.

Historically, minor differences in the patterns around the outfall have been observed among sampling years (i.e., strength of distance gradients) (Paine et al., 2004). However, the findings of the 2010 WMEP were very similar to the findings from the past six years (2004 to 2009), resulting from a continued degree of standardization of sampling techniques and analytical methods.

Overall, the 2010 monitoring data do not provide any indication of harm to the resident mussel communities, or to higher trophic level organisms as a result of eating the mussels and bioaccumulation/biomagnification of substances. Furthermore, the temporal trends of mussel tissue chemistry do not suggest that harm is likely to occur in the near future, based on the current discharge regime (Golder, 2011b).

5.0 ADDITIONAL INVESTIGATIONS

Additional investigations are important elements of the WMEP and are conducted to address issues that pertain to the WMEP, clarify aspects of the program and provide concurrent data for the assessment of environmental effects. The SETAC review of the program agreed that one-time investigations are appropriate to fill in information gaps as needed (SETAC, 2006). Studies undertaken as part of the additional investigations component of the WMEP are usually recommended and reviewed by the MMAG. The group periodically reviews the list of additional investigations based on WMEP results, current scientific issues and the need to supplement the existing knowledge on environmental effects of the Macaulay and Clover points wastewater discharges.

In 2005, the MMAG initiated a comprehensive review of the list of additional investigations. This review was completed in 2006. Table 5.1 presents the studies that were recommended based on a risk assessment framework: contaminant source, pathways (i.e., ways in which contaminants can reach receptors), and receptors (e.g., fish, invertebrates, and human health, etc.). For each of these categories, studies were ranked as high, medium or low priority.

Subsequently, in 2006, the CRD received a letter from the Minister of Environment requesting that an amendment to the Core Area LWMP, detailing a schedule for the provision of wastewater treatment, be provided by June 30, 2007. The additional investigations presented in Table 5.1 were evaluated by the MMAG before this decision to move to advanced treatment was made. As such, all additional investigations that had already been implemented by the receipt date of this letter were continued, but new additional investigations were put on hold because their priority may change when new treatment is put in place. The additional investigation list will be reassessed once plans for further treatment in the core area have been confirmed, likely in 2012. The MMAG will assist with the additional investigation review as necessary.

Investigations that deal with new emerging scientific issues are best undertaken under collaborative research programs. For example, the potential for environmental effects of pharmaceuticals and personal care products (PPCP) has recently been highlighted in the scientific community and was identified as a high priority by the MMAG (Table 5.1). There was also a requirement, under the Core Area LWMP approval letter of 26 March 2003, to undertake some collaborative studies on pharmaceuticals and personal care products (PPCPs). These substances are believed to be present in very low concentrations in wastewater discharges. However, routine laboratory analytical techniques for quantifying these substances have only relatively recently been developed and there are presently relatively few commercial laboratories in Canada that can reliably analyze for these compounds. There are also no standard methods currently available to assess their potential environmental effects. These substances are best studied under a research program where collaborative resources from academia and government can be used to answer environmental questions.

Other emerging scientific issues include the presence of endocrine disrupting compounds (EDCs) in wastewater discharges. Environmental effects of low-level EDCs are not very well known. This topic is also well suited for a collaborative approach. Results from additional investigations dealing with PPCPs and EDCs from 2005 to 2010 will be incorporated in the overall assessment of effects on the marine environment when they are available.

As mentioned previously, studies that were currently underway in 2006 have since been completed or are continuing, but new investigations have not been initiated since then. The studies that are on-going or were completed in 2010 are identified in Table 5.1 and discussed in the following sections.

Table 5.1 Macaulay and Clover Points Additional Investigations Prioritization (2006)

Category	Investigation	Description and Characteristics	2006 Rating	Status/ Anticipated Initiation Date	Anticipated Completion Date
Contaminant Source	1. Study to address the presence of endocrine disrupting compounds and pharmaceuticals and personal care products in wastewater and the potential effects on the receiving environment.	The first part of an overall phased-approach to study these substances will be to measure the concentrations of a group of substances in wastewater. This is an area of emerging concern related to human health and potential environmental effects (from the chemical, biological and toxicological aspects).	High	Initiated in 2004	Completed in 2011.
	2. Assessment of contaminants associated with oil and grease.	Determination of contaminants associated with oil and grease originating from the outfalls. Relates to the potential human health and environmental effects issues (e.g., windsurfers, seagulls, etc.). The first phase of this investigation will be to undertake a literature review.	Medium	No dates (study will be re-evaluated when WMEP is reviewed)	
	3. Identification of pathogens in wastewater and the presence of these in surface waters around the outfalls.	Analysis of wastewater for different types of pathogens that have the potential to affect human health and determine if these pathogens are present in the receiving environment around the outfalls (related to die-offs, etc. in marine waters).	Low	No dates (study will be re-evaluated when WMEP is reviewed)	
	4. Bacteria source identification.	Determine the different sources of fecal coliform to differentiate between various mammals such as cows, dogs and humans.	Low	No dates (study will be re-evaluated when WMEP is reviewed)	

continued

Table 5.1 continued

Category	Investigation	Description and Characteristics	2006 Rating	Status/ Anticipated Initiation Date	Anticipated Completion Date
Pathways	5. Sediment transport/deposition/re-suspension.	The first step in this investigation would include a determination of the different particle size fractions in wastewater (this could be conducted through a literature review and/or through laboratory experiments). The second phase would include the determination of the settling of particles from the discharge onto sediments. Results from these analyses would be used in the overall assessment of sediment particle deposition and the subsequent movement of sediments around the outfalls.	High	Initiated in 2005 (study is on hold – will be re-evaluated when WMEP is reviewed)	
	6. Conduct a sediment core sampling program.	Determination of sedimentation and mixing rates and the fluxes of contaminants near the outfalls and at reference sites. A mass balance approach could be used where rates of contaminant accumulation in sediments are compared with the rate of contaminant discharge from the outfalls in an attempt to determine the proportion of each contaminant captured by and stored in the sediments. A sediment trap study could be added to study contaminant transport in the near bottom nepheloid layer.	Medium	Initiated in 2006 and ongoing in conjunction with IOS	Additional results expected in 2011.

continued

Table 5.1 continued

Category	Description	Description and Characteristics	2006 Rating	Status/ Anticipated Initiation Date	Anticipated Completion Date
Receptors and Potential Effects	7. Effects of EDCs and PPCPs on the receiving environment.	As part of a phased-approach to study effects of EDCs, laboratory exposures, bioassay and/or caged studies (or an organism found around the outfall) could be conducted to assess the potential effects of these substances on the receiving environment around the outfalls.	High	Collaborative study with UVic on toxicogenomic effects on mussels initiated in 2007	Future direction of this project is under review.
	8. Assessment of chemical concentrations in tissue of different trophic level organisms (including higher trophic levels).	Measurement of contaminants in crab, finfish or other organisms near the outfalls would provide a basis for a food-ingestion human health risk assessment. This information could also be used to model bioconcentration and biomagnification of contaminants to higher trophic levels near the outfalls.	High	No dates (study will be re-evaluated when WMEP is reviewed)	
	9. Identification of biological resources.	Identification of the harvestable organisms around the outfalls.	Low	No dates (study will be re-evaluated when WMEP is reviewed)	
	10. Clover Point mussel population biology.	Conduct some additional studies on the mussel population around the Clover Point outfall (e.g., reproductive cycle, health, etc.). Additional data relates to the current monitoring and to potential studies on emerging chemicals.	Low	No dates (study will be re-evaluated when WMEP is reviewed)	
	11. Levels of pathogens in biota (epibenthic, etc.).	Assess the presence and concentration of pathogens in biota near the outfalls.	Low	No dates (study will be re-evaluated when WMEP is reviewed)	
	12. Assess potential risks associated with pathogens/antibacterial resistance.	A literature review, risk assessment or a pilot study could be conducted to study antibiotic bacteria and the relevance as a potential emerging concern to human health, wildlife and domestic animals.	Low	No dates (study will be re-evaluated when WMEP is reviewed)	
	13. Investigate the structure of algal plankton communities.	Assess the potential effects of the wastewater discharges on algal communities (planktonic and benthic).	Low	No dates (study will be re-evaluated when WMEP is reviewed)	

5.1 Investigations Completed or Underway in 2010

Additional investigations completed or underway in 2010 included the following:

- supplementing the high resolution chemical and PPCP analyses from previous years
- continuation of the collaborative study on the presence of PPCPs in wastewater and potential environmental effects on biological communities with UVic (Royal Roads University [RRU] was brought in as a collaborative partner in 2010)
- continuation of the collaborative project on potential toxicogenomic effects of emerging chemicals in municipal wastewater with Environment Canada
- continuation of analysis of sediment core samples in collaboration with Fisheries and Oceans Canada and UVic, including the addition of complementary benthic invertebrate samples
- completion of a detailed PAH fingerprinting analysis in sediment and wastewater samples
- continuation of a collaborative project on potential mussel biomarker effects of municipal wastewater with Environment Canada

5.1.1 Macaulay and Clover Points Additional Investigations: High-Resolution Chemical Analyses

As part of the additional investigations identified by MMAG (Table 5.1), and to fulfill requirements under the LWMP approval, high-resolution analyses for several substances in wastewater, sediment and mussel tissue samples from the Macaulay and Clover points outfalls were conducted from 2003 to 2007. Substances analysed at high resolution included those that are potentially environmentally persistent, toxic, and/or bioaccumulative, such as PCBs, PBDEs, nonylphenols, chlorobenzenes, organochlorine pesticides and phthalates. Results of this additional investigation were presented in two previous annual reports (CRD, 2005; CRD, 2008). The wastewater samples were collected and analysed in collaboration with Environment Canada as part of the Georgia Basin Action Plan initiative. Environment Canada is still reviewing and writing up the CRD results in comparison to those from other jurisdictions. Once available, these results will be summarized in a future annual report.

In 2010, high-resolution analyses were conducted on sediment samples for PCBs, PAHs, nonylphenols, OC pesticides, and PBDEs, and on tissue samples for PAHs and PCDDs. In addition, methylmercury and tributyltin in Clover and Macaulay Point wastewaters were analyzed.

METHYLMERCURY

Methylmercury (MeHg) was first added to the WMEP in 2009 and was analyzed in wastewater, tissue and sediment. At that time, concentrations in all matrices were below environmental quality guidelines. As such, it was decided that MeHg would only be analysed in wastewater in 2010 so that wastewater concentrations could be better characterized over time.

MeHg is of concern because it is a potent neurotoxin and because it accounts for >95% of the total mercury (Hg) found in fish tissues (Chen *et al.*, 2008). Methylmercury is of special concern not only because of its toxicity, but also because of its tendency to biomagnify in upper trophic levels of aquatic food webs (CCME, 2003b). MeHg passes easily through the digestive wall and bioconcentrates in tissues, whereas inorganic Hg is more likely to be excreted (CCME, 2003b). Diet is the most important route of uptake of MeHg for organisms higher in the food chain, like piscivorous fish, aquatic birds, piscivorous mammals and marine mammals (CCME, 2003b; Clarkson *et al.*, 2006; Wiener *et al.*, 2008). MeHg may comprise only 5–15% of the total mercury burden in sediments and water (Beckvar *et al.* 1996) while aquatic animals can contain a very high proportion of MeHg in muscle tissue (90–100% to total Hg) (Beckvar *et al.*, 1996; CCME, 2003b).

Canadian water quality guidelines (WQG) for inorganic mercury and methylmercury for the protection of aquatic (freshwater) life were developed based on the CCME protocol (CCME, 1991). No marine water quality guideline has been developed for Hg. In addition, the protocol does not address exposure through food or bioaccumulation to higher trophic levels, meaning aquatic life that are exposed to MeHg primarily through food may not be adequately protected. The aquatic interim guideline is 4 ng/L (Table 5.2) but this

WQG may not prevent the accumulation of MeHg in aquatic life, and therefore, the tissue residue guideline (33 µg MeHg/kg ww) for the protection of wildlife that consume aquatic life may be exceeded (CCME, 2003b). From conservative assumptions, concentrations of MeHg below 0.007 ng Hg/L may be required to protect all wildlife species in Canada while concentrations above 0.2 ng Hg/L may pose a risk to wildlife species. MeHg concentrations in water between these limits may be hazardous to some wildlife depending on their feeding habits (e.g. preferred prey items) (CCME, 2003b).

The BC Water Quality Guidelines (Ministry of Environment, 2001) were updated to be consistent with the CCME tissue residue guideline to protect wildlife from MeHg in their diet (CCME, 2003b). Guidelines to protect aquatic life in freshwater, estuarine and marine environments were also set and state that the average concentration of total mercury in water as measured over a 30-day period should not exceed 20.0 ng/L when MeHg constitutes less than or equal to 0.5% of the total mercury concentration (Table 5.2). When the proportion of MeHg increases, then the total allowable mercury guideline is also adjusted (i.e. 1.0% MeHg→10.0 ng/L, 2.5% MeHg→ 4.0 ng/L, 5.0% MeHg→ 2.0 ng/L) (Ministry of Environment, 2001).

The US Environmental Protection Agency (US EPA) National Recommended Water Quality Criteria has methylmercury criteria for the protection of human health only (0.3 mg/kg in fish tissue (US EPA, 2009)) (Table 1).

Canadian interim sediment quality guidelines (ISQGs) and probable effects levels (PELs) for Hg can be used to evaluate the degree to which adverse biological effects are likely to occur in aquatic biota as a result of exposure to Hg in sediments (CCME, 1999a). Few studies have measured concentrations of methylmercury in Canadian sediments; however, the fraction of MeHg in sediments is generally only 0.01–10% of the total Hg. The marine/estuarine ISQG (0.13 mg/kg dw) and PEL (0.70 mg/kg dw) (Table 5.2) refer to total concentrations of Hg in surficial sediments (top 5 cm) (CCME, 1999a).

In the USA, there is no sediment criteria for either methylmercury or total mercury, and NOAA (National Oceanic and Atmospheric Administration) recommends a site-specific approach that focuses on determining the availability of Hg and the potential for toxic effects (Beckvar et al., 1996). Two of the more frequently used approaches are the National Status and Trends Effects Range approach and the Apparent Effects Threshold (AET) concentrations (used by Washington State Department of Environment). The Effects Range-Low (ERL) and Effects Range-Median (ERM) concentrations are the lower and median concentrations associated with toxic effects. The ERL and ERM concentrations for total Hg in marine and estuarine sediments are 0.15 and 0.71 mg/kg respectively, while the AET concentrations for Hg range between 0.41 and 2.1 mg/kg (Beckvar et al., 1996) (Table 5.2).

In 2010, all MeHg results were non-detect in wastewater (Table 5.2), similar to the 2009 results. However, MeHg monitoring in wastewater will be shifted to the routine WMEP in 2011 to allow for monitoring of trends over time, because there is potential for environmental toxicity should concentrations increase, and because only negligible costs are associated with the analyses.

Table 5.2 Methylmercury Criteria and CRD Methylmercury Preliminary Results

Methylmercury Criteria			CRD Preliminary Methylmercury Results		Methylmercury Concentrations Relative to Total Mercury (% of total)
			2009	2010	
Aquatic	CCME interim	4 ng/L	all <0.4 ng/mL (below detection limit)	Non detect in Clover and Macaulay Point wastewaters	0%
	BC WQG	20.0 ng/L if MeHg ≤0.5% total Hg			
Tissue	CCME tissue residue	33 µg MeHg/kg ww	range from 1.8 µg/kg ww to 11.1 µg/kg ww	n/a	3.8% to 23%
	BC WQG tissue	33 µg MeHg/kg ww			
	US EPA human health	0.3 mg/kg in fish tissue	range from 0.0018 mg/kg ww to 0.01111 mg/kg ww		
Sediment	CCME ISQG (total Hg in surficial sediments)	0.13 mg/kg dw	range from 0.000150 to 0.00192 mg/kg dry weight	n/a	0.03% to 3.7%
	CCME PEL (total Hg in surficial sediments)	0.70 mg/kg dw			
	ERL (total Hg)	0.15 mg/kg			
	ERM (total Hg)	0.71 mg/kg			
	AET	0.41–2.1 mg/kg			

TRIBUTYLtin

Tributyltin (TBT) was first added to the WMEP in 2009 when it was analyzed in wastewater. At that time, a number of results exceeded environmental quality guidelines. As such, it was decided that TBT would be analysed again in wastewater in 2010 so that wastewater concentrations could be better characterized over time.

TBT is of concern because it is a toxic chemical used for various industrial purposes such as slime control in paper mills, disinfection of circulating industrial cooling waters, antifouling agents, and the preservation of wood (antizar-Ladislao, 2008a; CCME, 1999b; US EPA, 2003). Due to its widespread use as an antifouling agent in boat paints, TBT is a common contaminant of marine and freshwater ecosystems, frequently exceeding acute and chronic toxicity levels (antizar-Ladislao, 2008b).

The potential for aquatic biota to bioconcentrate organotin compounds from the environment depends on the specific number and types of organic moieties attached to the tin atom (NRCC, 1985). Once released from an antifouling coating, TBT is rapidly absorbed by organic materials such as bacteria and algae or adsorbed onto suspended particles in the water. Subsequently it is readily incorporated into the tissues of filter-feeding zooplankton, grazing invertebrates, and eventually, higher organisms such as fish, water birds, and mammals where it accumulates (antizar-Ladislao, 2008c).

The interim Canadian water quality guidelines (WQG) for organotins for the protection of aquatic life were developed based on the CCME protocol (CCME, 1991). The interim water quality guideline for tributyltin for the protection of freshwater life is 0.008 µg/L (CCME, 1992) (Table 5.3). It was derived by multiplying the 33-d LOEL for growth of 0.08 µg/L for juvenile fathead minnows by a safety factor of 0.1 (CCME, 1991). The interim water quality guideline for tributyltin for the protection of marine life is 0.001 µg/L (CCME, 1992). It was derived by multiplying the 14-d LOEL of 0.01 µg/L for the clam *M. mercenaria* by a safety factor of 0.1 (CCME, 1991).

BC Working Water Quality Guidelines are consistent with the CCME guidelines (CCME, 1999b) for TBT, at 0.008 µg/L for the protection of freshwater aquatic life, and 0.001 µg/L for marine aquatic life (Table 5.3) (Ministry of Environment, 2006).

In the USA, the National Oceanic and Atmospheric Administration (NOAA) established surface water maximums of 0.46 µg/L of TBT for acute toxic effects and 0.072 µg/L TBT for chronic toxic effects for freshwater (Table 5.3). Marine surface water TBT maximums are 0.042 µg/L for acute toxic effects and 0.0074 µg/L (Table 5.3) for chronic toxic effects (Buchman, 20008).

The United States Environmental Protection Agency (US EPA) derived Ambient Aquatic Life Water Quality Criteria for TBT (Table 5.3). The criterion to protect freshwater aquatic life from chronic toxic effects is 0.072 /L. This criterion is implemented as a four-day average, not to be exceeded more than once every three years on the average. The criterion to protect freshwater aquatic life from acute toxic effects is 0.46 /L. This criterion is implemented as a one-hour average, not to be exceeded more than once every three years on the average. The criterion to protect saltwater aquatic life from chronic toxic effects is 0.0074 µ/L. This criterion is implemented as a four-day average, not to be exceeded more than once every three years on the average. The criterion to protect saltwater aquatic life from acute toxic effects is 0.42 µ/L (Table 5.3). This criterion is implemented as a one-hour average, not to be exceeded more than once every three years on the average (US EPA, 2003).

Table 5.3 Tributyltin Criteria and CRD Tributyltin Preliminary Results

Tributyltin Criteria			CRD Preliminary Results	
			2009	2010
Aquatic	US EPA ambient aquatic life—freshwater	0.072 µg/L chronic toxic effects; 0.46 µg/L acute toxic effects	range from <0.001 µg/L (below detection limit) to 0.004 µg/L	0.00522 µg/L average concentration at Macaulay Point wastewaters; 0.00189 µg/L average concentration at Clover Point wastewaters
	US EPA ambient aquatic life—marine	0.0074 µg/L chronic toxic effects; 0.42 µg/L acute toxic effects		
	CCME interim	0.008 µg/L freshwater; 0.001 µg/L marine		
	BC WQG	0.008 µg/L freshwater; 0.001 µg/L marine		
	NOAA ambient aquatic life—freshwater	0.072 µg/L chronic toxic effects; 0.46 µg/L acute toxic effects		
	NOAA ambient aquatic life—marine	0.0074 µg/L chronic toxic effects; 0.42 µg/L acute toxic effects		

In 2010, average TBT concentrations at both outfalls continued to exceed CCME and BC marine WQG (Table 5.2), similar to 2009 results. As such, TBT monitoring in wastewater will be shifted to the routine WMEP in 2011 to allow for continued monitoring of WQG exceedences over time.

5.1.2 Collaborative Study on PPCPs in Wastewater and Potential Effects on Biological Communities in the Marine Environment

A collaborative research project between the CRD WMEP and the University of Victoria was initiated in 2004. This type of investigation was included in the requirements under Condition 1 of the LWMP approval. The goal of the original study was to assess the fate of PPCPs in the marine environment around the Macaulay and Clover points outfalls. However, some of the anticipated funding did not materialize, and therefore, the scope of the project was changed in 2006 to accommodate the available funding.

The revised project was divided into two components:

1. The assessment of PPCPs in wastewater and the potential environmental and ecological relevance of the results, as well as the determination of potential correlations with prescription rates and demographic data; and
2. The analysis of potential toxicogenomic effects on mussels.

Additional PPCP characterization samples were collected in November 2009.

5.1.2.1 Assessment of PPCPs in Wastewater at Clover and Macaulay Outfalls and Two Upstream Pump Stations

The Macaulay and Clover point outfalls and two pump stations (one upstream of each outfall) were tested for 125 different PPCPs by AXYS Analytical (Sidney, BC) in samples from five concurrent days (November 2 to 6, 2009). Results from these analyses were presented in last year's annual report (CRD, 2010). Further assessment of these results was continued in 2010/11 in collaboration with the UVic. The results were also assessed from a different perspective in collaboration with Royal Roads University (RRU) and the Regional Source Control Program (RSCP).

The UVic assessment (Lowe, 2011) determined that a total of 92 of the analytes were detected in at least one sample from the four locations, with only 64 analytes being detected in more than half the samples. Where comparisons could be made, the results were similar to concentrations observed in the CRD samples collected from 2004 to 2006 (see Section 5.1.2.2). There were no indications of differences in overall concentration profiles for the four sites. However, differences in concentrations between sampling days were identified, likely due to variations in wastewater flow volumes following a rain event.

Concentrations were compared to those of conventional wastewater parameters typically used to characterize bulk loading characteristics of wastewater and determine treatment plant capacity requirements (i.e., carbonaceous biochemical oxygen demand, chemical oxygen demand, total suspended solids and volatile suspended solids). Relatively few target analyte concentrations were correlated with those of the conventional wastewater parameters. This suggests that designing and optimizing treatment plants to efficiently reduce conventional parameter loadings may not lead to as efficient reductions in the concentrations of all PPCPs assessed in this study. However, the PPCP results were based on analyses of the filtered aqueous fraction of the wastewater samples, whereas the conventional parameter results were based on whole unfiltered effluent samples. As such, there was no direct link between the two sets of results.

A preliminary relative loading assessment confirmed that the target analyte concentrations were generally proportional to the population equivalents of a wastewater system catchment area. Population equivalents represent the base census population of an area plus "population equivalents" based on the amount of industrial, commercial and institutional land use in the area. Minor proportional deviations were observed and they could have been a result of disproportional hospital loading inputs into one of the pump station catchment areas, as well as dilution due to wastewater system inflow and infiltration in the other pump station catchment area. Further details can be found in Lowe (2011).

The RSCP sponsored the RRU student report (inSolution, 2011). The RRU students predicted partitioning and degradation of PPCPs following secondary treatment, as planned for the core area, and

included a ranking matrix to determine which of the 125 PPCPs pose the greatest environmental risk from a biosolids land application perspective. The ranking matrix included assessments of PPCP sludge partitioning behavior, anaerobic biodegradation probability, soil half-life, soil leaching behavior, aquatic toxicity, and wastewater concentrations. A PPCP top 10 priority list (Table 5.4) was generated from the ranking assessment, with six of the ten substances being antibiotic in nature. Two non-medicinal antibiotic bacteriostats, triclosan and triclocarban, were also identified as the top priority PPCPs, along with acetaminophen (analgesic), amitriptyline (anti-anxiety), gemfibrozil (anti-lipid), and glyburide (diabetic) (inSolution 2011). This report concluded that, even with secondary treatment, there is likely no easy way to reduce the loadings of all PPCPs found in municipal wastewaters.

The November 2009 results continue to be assessed with respect to their potential for marine environmental toxicity, as well as in relation to concentrations and loadings observed in other jurisdictions; results will be included in an upcoming annual report when available.

Table 5.4 Top Ten Priority PPCPs as Determined by Scoring Matrix (inSolution 2011)

Substance Name	Type	Group
Triclocarban	Antibiotic	Bacteriostats
Triclosan	Antibiotic	Bacteriostats
Acetaminophen	Analgesic	Analgesic
Clarithromycin	Antibiotic	Macrolides
4-Epitetracycline [ETC]	Other	Chlorotetracycline degradate
Amitriptyline	Nervous system	Anti-anxiety
Azithromycin	Antibiotic	Macrolides
Erythromycin	Antibiotic	Macrolides
Gemfibrozil	Blood	Anti-lipid
Glyburide	Alimentary	Diabetic

5.1.2.2 Assessment of PPCPs in Wastewater and Determination of Potential Correlation with Prescription Rates and Demographic Data

Wastewater samples from Macaulay and Clover points were collected monthly from 2004 to 2006. Samples were analysed using an analytical method developed in conjunction with the University of Victoria (Verenitch et al., 2006) for a select group of acidic pharmaceuticals including salicylic acid (acetylsalicylic acid metabolite), ibuprofen, gemfibrozil, fenoprofen, naproxen, ketoprofen, and diclofenac.

Wastewater concentrations and environmental loadings were compared to demographic and prescription rate data from the CRD outfall catchment areas to determine whether they could be used together as predictors of future PPCP concentrations. Prescription data that overlaps all sample collection dates was received from the BC College of Pharmacists and 2001 census data for the CRD outfall catchment areas were provided directly by Statistics Canada. Query fields for census data analysis included population age distribution, population size, and gender distribution.

The environmental relevance of the observed pharmaceutical concentrations relative to concentrations or effects data presented in the literature was also assessed. The CRD C3 hydrodynamic model (Hodgins, 2006; Lorax, 2006) was used to extrapolate observed wastewater concentrations to the receiving environment. Minimum initial dilution values and effluent flow rates were used to predict environmental loadings and concentrations.

Concentrations and environmental loadings of the seven pharmaceuticals were within the ranges observed by other jurisdictions, both in comparison to jurisdictions with wastewaters treated to the same level as well as those receiving more advanced treatment. Seasonal patterns were also observed, primarily driven by wastewater flow volume increases following heavy rain events. Based on comparison to literature derived toxicological effects thresholds, there did not appear to be any potential for acute effects of these pharmaceuticals in the environment around the outfalls. There did appear to be some

potential for chronic effects on organisms based on the environmental concentrations predicted for ibuprofen. However, sub-lethal and chronic effects endpoints are relatively limited in availability in the literature, as are literature thresholds derived from organism exposure to PPCP mixtures. Additional adverse chronic effects of these substances may be discovered in the future.

Pharmaceutical prescription rates and wastewater system catchment area population demographics were investigated to determine whether they were good predictors of the observed wastewater pharmaceutical concentrations and loadings. Although wastewater concentrations and loadings were proportional to both prescription rates and population size, the regression relationships were statistically weak or insignificant. As such, prescription rates and population size could not be used to accurately predict pharmaceutical wastewater concentrations and loadings on their own. Wastewater flow volumes, derived population equivalents (see section 5.1.2.1 for a description of population equivalents) and analytical method variability were also important factors to consider. No relationships were observed between wastewater PPCP concentrations and loadings and either population age or gender breakdown.

Further details about the UVic collaborative PPCP assessment can be found in Lowe (2011). This project is now complete.

5.1.2.3 Analysis of Potential Toxicogenomic Effects on Mussels

The use of toxicogenomic endpoints to assess potential effects of contaminants such as PPCPs on organisms is showing great promise (CRD, 2008; Golder, 2008a; Veldhoen *et al.*, 2004; Veldhoen *et al.*, 2006; Veldhoen *et al.*, 2009; Zhang *et al.*, 2006). A particularly powerful technique for gene expression monitoring is real-time quantitative polymerase chain reaction (QPCR) analysis, which currently is regarded as the most accurate assessment method available (Tom *et al.*, 2005). This highly sensitive method allows for the relatively rapid analysis of a large number of samples for changes in the expression of key genes involved in important cellular pathways.

Phase one of the toxicogenomic project included the isolation of gene sequences from the Clover Point horse mussels (*Modiolus modiolus*) that present possible gene expression biomarkers for this species. Phase two of the project involved the design of gene-specific primers for QPCR and optimizing reaction conditions on a limited set of mussel samples collected from Clover Point stations CB4 and C1SE. The levels of each mRNA transcript were evaluated in adductor muscle, gonad, and hepatopancreas tissues. Results (Veldhoen *et al.*, 2009) indicated that there were significant changes in mRNA abundance in C1SE mussels relative to those mussels from CB4 for some of the genes. Results of this assessment were previously presented in CRD (2010).

Phase three (Veldhoen *et al.*, 2011) of this study was initiated in 2009 to verify the phase 2 results by repeating the experiments using archived mussels collected from a greater number of stations. This work was a more extensive investigation of the benthic environment surrounding the Clover Point outfall compared to a previous study (Veldhoen *et al.*, 2009). In this analysis, researchers examined several biological and chemical indicators of *M. modiolus* health across 15 sampling sites organized into five geospatial groupings (Veldhoen *et al.*, 2011): Group 1 (C1N, C2N), Group 2 (C0), Group 3 (C1SE, C1S, C2S), Group 4 (C2E, C4E, C8E, C4SE), and Group 5 (C1SW, C4SW, C2W, C4W, C8W). Comparisons of tissue chemical contaminant concentrations with biological endpoints in animals located at the Clover Point outfall were explored to assess if any relationship existed between pollutant exposure and changes in *M. modiolus* biology.

mRNA abundance profiling showed elevated levels in all four transcripts in the southerly Group 3. Groups 4 and 5 also had some elevated levels. The data therefore suggest that potential biological effects extend further from the outfall than is apparent from gross mussel size metrics and the chemical concentrations detected within the *Modiolus* tissues (Veldhoen *et al.*, 2011). All PAHs, chlorinated hydrocarbons, and base-neutral extractable concentrations are below levels identified for lethal and sublethal threshold effects in aquatic organisms.

Conclusions of Veldhoen *et al.* (2011) include that PAHs appear to have a minimal relationship to the transcript pattern whereas correlations were observed between some of the metals and mRNA transcripts

and a strong negative correlation was observed with bis(2-ethylhexyl) phthalate (BEHP) and three mRNAs. The importance of this relationship is currently unclear, but it highlights the need for evaluating other emerging chemicals such as personal care products and pharmaceuticals. It is currently unknown if these relationships are causal, but their findings suggest that altered mRNA abundance patterns within the mussel transcriptome are a result of bioactive anthropogenic agents originating from the outfall. The chemicals responsible for the effects are currently not known, but the expression pattern suggests dispersion around the outfall of substances that may accumulate in the south/south-easterly direction (Veldhoen *et al.*, 2011)

The future direction of this project is currently being reviewed; no additional analyses are currently being done.

5.1.3 Collaborative Program on Potential Toxicogenomic Effects of Emerging Chemicals in Municipal Wastewaters

A collaborative study between the CRD's WMEP and Environment Canada's Pacific Environmental Science Centre (PESC) was initiated in 2004 to determine the potential toxicogenomic effects of wastewater on marine fish. This type of investigation was included as part of the requirements under Condition 1 of the LWMP approval. As part of this study, effluent samples from the Macaulay and Clover points outfalls were collected on a regular basis from 2004 to 2006 and a marine fish species were exposed to different environmentally relevant concentrations (i.e., concentrations that marine fish would be exposed to in the receiving environment). The overall objective of the study was to determine if these exposures caused changes in gene expression using a gene chip array and other toxicogenomic tools.

The research used microarrays and QPCR to evaluate the effects of the sewage on liver gene expression in exposed juvenile Chinook salmon (*Oncorhynchus tshawytscha*). The study highlighted the effects of xenoestrogens on gene expression. Xenoestrogens can alter the expression of genes associated with adult fish reproductive processes, particularly those relating to egg production (female-specific): vitellogenin and the vitelline envelope proteins. Examination of genetic males and females indicated very few significant differences in the expression of female-specific genes between the sexes, indicating that gene expression alterations caused by sewage were unrelated to genetic sex in the underyearling fish. Gene expression patterns were examined for trends across time and sewage concentrations. Trends found included U-shaped and linear dose response curves. All concentrations of sewage examined caused gene expression alterations, including the very low environmentally relevant concentrations: 0.05%, 0.1% and 0.7%. Further details about this study can be found in Osachoff (2008). The environmental relevance of these results is still being assessed, and will be reported on at a later date.

In addition to the above exposure tests, all effluent samples were analysed for a suite of emerging compounds, including PPCPs and natural and synthetic hormones. Effluent chemistry results, and the potential ecological implications of these results, were previously presented in the 2007 WMEP annual report (CRD, 2008).

5.1.4 Sediment Core Analyses

Sediment chemistry data collected as part of the WMEP have shown some variations from year to year. Variations in the measured surface concentration of a contaminant may not only reflect variations in the source; the local rates of sedimentation and mixing also affect the observed surface concentration. As such, collecting only surface sediment can potentially be misleading. A sediment core study was recommended as part of the additional investigations prioritized by the MMAG (Table 5.1). Sediment cores record past contamination history, and rates of sediment accumulation and mixing can be interpreted from them.

A sediment core study was undertaken in collaboration with Fisheries and Oceans Canada, Institute of Ocean Sciences (IOS) and three sediment cores were collected in 2006. Results of this assessment were presented in the 2007 WMEP annual report (CRD, 2008).

Additional sediment cores and benthic invertebrate tissue samples were collected in 2010 for further analyses of individual PBDE and PCB congeners. All results were assessed as part of an expanded collaborative study that includes the DFO, UVic and Metro Vancouver, to examine the dispersal of particles from submarine municipal outfalls. PBDEs are relatively new chemicals that remain concentrated near wastewater outfalls, which are their main route of entry into the environment (Song *et al.*, 2006). PBDEs therefore provide an excellent proxy to track the transport and fate of all particle-active contaminants discharged with wastewater. ²¹⁰Pb dating of sediment cores was used to calculate sedimentation rates and surface mixed layers. Benthic invertebrates living in sediment bioturbate the surface layers, mixing older material upwards and newer material down (Meysman *et al.*, 2006). Near Macaulay Point, the surface mixed layer is approximately 7 cm, consistent with other studies in the area (Johannessen *et al.*, 2005). Sedimentation rate and SML were used to model PBDE deposition and calculate the proportion of PBDEs discharged with wastewater that is captured near the outfall pipe.

Most PBDEs discharged into receiving waters from the Macaulay Point outfall are dispersed far beyond the near-field of deposition because of high speed currents. Less than 1% are deposited in sediments within an 800m radius of the outfall pipe (Dinn *et al.*, 2011). Beyond 800m, concentrations of PBDEs in sediment are similar to reference sites and cannot be attributed to the outfall source. Once deposited in sediment, PBDEs and other chemicals associated with particles remain relatively undiluted because there are no significant external sources of sediment (i.e. from major rivers) to bury them (Hill *et al.*, 2008). Despite higher than expected PBDE concentrations in sediment, bioaccumulation rates are low, especially at the end of the outfall pipe (M0). This is because bioaccumulation of PBDEs by benthic invertebrates depends on total organic carbon (TOC) content in sediment. PBDEs bind tightly to organic carbon, and higher concentrations of organic carbon lead to less uptake of the associated contaminants. TOC concentrations in sediment near the Macaulay Point outfall are high, and this inhibits the uptake of PBDEs by benthic invertebrates.

5.1.5 PAH Fingerprinting Analyses

High variability in PAH analyses has been an issue with Macaulay Point sediment samples for a number of years. One suspected source of the variability was coal contamination from a nearby sunken collier. A study initiated in 2007, with detailed results presented in CRD (CRD, 2008) and Yunker (2008), determined that the parent PAHs predominantly found in CRD samples originated mostly from combustion sources, and not the coal. These parent PAHs most likely make their way into the marine environment via atmospheric deposition, stormwater discharges (i.e., shoreline discharges) and the Macaulay and Clover outfalls.

Additional assessments of the alkyl PAHs—a minor component of the total PAH sediment profiles—were undertaken in 2009/2010 to better quantify the contribution of the alkyl substituted PAHs from the coal to the sediments. A comprehensive suite of resolved and UCM (unresolved complex mixture) alkanes, tricyclic terpane, hopane and sterane biomarkers, and parent and alkyl polycyclic aromatic hydrocarbons (PAHs) in samples of coal, wastewater and sediments were analyzed (Yunker *et al.*, 2011). Composition patterns, principal components analysis (PCA) models, and PAH and biomarker ratios confirm that coal from the SS San Pedro collier does not make a dominant contribution to any sediment sample. Overall, results suggest that PAHs have predominant sources in wood combustion, coal and possibly coke, with a likelihood of much lower bioavailability than would be expected from wastewater dominated by oils and soot from vehicle combustion (Yunker *et al.*, 2011)

This study is now complete.

5.1.6 Mussel Biomarker Assessment

Mussels were collected from Clover Point in September 2007 for the toxicogenomic method validation (Section 5.1.2.3) (CRD, 2008). Gill and gonad biopsy samples were collected from the same mussels and sent to the Aquatic Ecosystem Protection Research group of Environment Canada in Montréal. It was anticipated that these biopsy samples would be analyzed for biomarker endpoints similar to those described in Gagné *et al.* (2002) and Gagné *et al.* (2008) and that the results would be directly

comparable to the UVic toxicogenomic results (Section 5.1.2.3). These analyses have been put on hold until further review of the UVic toxicogenomic results has taken place.

5.2 Investigations Planned for 2011

No new additional investigations or studies are planned for 2011. Studies that will be continuing include:

- supplementing the high resolution chemical and PPCP analyses from previous years
- the two collaborative projects on potential toxicogenomic effects of emerging chemicals in municipal wastewater with Environment Canada and the University of Victoria
- the collaborative project on analysis of sediment core and benthic invertebrate tissue samples with Fisheries and Oceans Canada, the University of Victoria and Metro Vancouver
- the collaborative project on potential mussel biomarker effects of municipal wastewater with Environment Canada

Additional details on these investigations and results will be presented in future WMEP annual reports as they become available.

6.0 CONCLUSIONS

The different monitoring components of the WMEP and the additional elements of the WMEP (i.e., the additional investigations) are effective tools to assess the effects of the Macaulay and Clover points discharges on the marine receiving environment. The 2010 WMEP results showed effects on the receiving environment that were limited spatially and, for the most part, have been relatively stable over time. The 2010 results were consistent with previous studies and identified areas of effect generally within 200 m of the Macaulay Point outfall and 100 m of the Clover Point outfall.

6.1 Wastewater

Wastewater compliance monitoring results indicate that the quality of the effluents from Macaulay and Clover points outfalls in 2010 was similar to results from recent years. Concentrations of all conventional parameters were generally within the expected range for fine-screened wastewater, and the estimated receiving environment concentrations (based on the predicted minimum initial dilution) did not exceed applicable BC and CCME WQG. Wastewater priority substance monitoring results were also similar to previous years and those substances with applicable WQGs showed receiving environment concentrations (based on the predicted minimum initial dilution) below guidelines, with most below guidelines in effluent even before discharge to the marine environment. Since measured parameters did not exceed WQG, this implies that there is a low potential for these parameters originating in the plume to directly affect organisms in the environment around the outfalls. However, there are many newer substances that do not have WQGs yet, that the CRD may or may not measure. The influence of these chemicals on the benthic community is unknown. The CRD attempts to assess risk of chemicals that do not have guidelines with additional investigations.

6.2 Surface Water

Surface water fecal coliform sampling results show that the potential for human exposure to fecal coliforms in the marine environment from the wastewaters is low. All station geometric means were below the threshold value of 200 CFU/100 mL at both outfalls. Fecal coliform concentrations greater than 200 CFU/100 mL were observed primarily in October at Macaulay Point and primarily in December at Clover Point, both within and outside the IDZ. The observation of higher fecal coliform values during winter months was consistent with hydrodynamic modeling predictions, with Clover Point experiencing slightly higher counts than Macaulay Point. The seasonality of high coliform counts can be attributed to higher effluent flows in winter coupled with the oceanography of this particular area (i.e., relative lack of water-column stratification due to wind and relatively cool surface waters). Summer plume surfacing events are also predicted at both outfalls, associated with the morning flush in the wastewater system, weak water column stratification and slack tide. Events are predicted to be less frequent in summer than in winter. During summer, the core of the plume is predicted to be trapped at depth, but the diluted edge of the plume is predicted to surface occasionally. Overall, the fecal coliform results indicate that the surface water effects of the outfalls were limited, with the core of the plumes being predominantly trapped at depth for most of the year and only substantially diluted effluent occasionally reaching the surface.

In 2010, the CRD increased sampling frequency to five samples in 30 days for one summer month, as per MMAG and SETAC recommendations. This was intended to determine if fecal coliform levels exceed BC MoE WQG for recreational primary contact as they were defined, during the time of year when the most recreational activity is expected around the outfalls. Geometric mean results were far below the BC MoE WQG, confirming that the potential for human exposure to harmful levels of effluent derived fecal coliforms was very unlikely. Beginning in 2011, the CRD will analyze surface water samples for enterococci as well as fecal coliforms, because enterococci are now considered by Health Canada to be a more appropriate indicator of recreational health.

6.3 Sediment Chemistry

Sediment chemistry concentrations in 2010 were similar to previous years. At Clover Point, copper, mercury, acenaphthene, and bis(2-ethylhexyl)phthalate exceeded SQGs at the outfall terminus station

M0. A number of SQG exceedences were also observed at Macaulay Point, with the vast majority within the IDZ and all within 200 m of the outfall. Macaulay Point SQG exceedences outside the IDZ were observed at M2N, M2E, and M2SE. There was a similar number of SQG exceedences in 2010 relative to 2009, both in the number of different substances exceeding SQGs and the number of stations at which SQGs were exceeded.

Overall, the results indicate that the potential for biological effects from sediment contamination is predominantly limited to within 200 m to the southeast of Macaulay and within the IDZ at Clover, although at Macaulay, effects may be present for some distance between the 200 m grid and the 400 m grid.

6.4 Benthic Invertebrate Communities

The 2010 multi-year trend assessment had a different conclusion from previous benthic community assessments; namely, that true changes are occurring in the biological assemblages adjacent to the Macaulay Point outfall. Although 2010 benthic community assessment suggests that broad spatial trends and summary metrics were similar to recent years, more detailed analysis of the 1994 to 2010 data identified a number of significant changes in recent years relative to earlier in the 2000's. Benthic community stations at the outfall terminus are now indicative of a "highly degraded" benthic community. The near-field stations are now ranked as a "moderately degraded" benthic community, while the mid-field stations showed a small negative response. Beyond the mid-field, impacts were considered to be net-neutral or positive.

The most significant changes identified were that, near the outfall, there is now a lower total organism abundance, a modified benthic community with fewer types of species and lower numbers of individuals, reduced biological diversity that now extends beyond the IDZ (and in some cases beyond the near-field stations), a decreased abundance of sensitive species, and an increase in abundance of pollution-tolerant species. Although several species did appear to benefit from modest increases in organics at the mid-field distances from the outfall, there were fewer species that exhibited strong positive responses to outfall-related exposures than in previous years.

While the taxa richness at the outfall terminus in recent years has approximately doubled since the 1994 monitoring study, the assessment for the outfall terminus station changed in 2009 and 2010 relative to 2008 and previous years, when a conclusion of a "moderately degraded" benthic community was reached. Patterns of total organic carbon and substrate composition can partially explain benthic community variation around the outfalls, but these variables alone cannot fully explain the patterns observed in 2010 and other recent years.

The CRD will continue to monitor the Macaulay Point benthic community conditions around the outfall to assess whether the declines in benthic community health that have been observed in recent years are spurious or are ongoing negative trends.

6.5 Mussel Communities

The detailed assessment of the 2000 to 2010 mussel dataset determined that mussel tissue chemistry has been relatively consistent over the period of study and, as a result, significant ecological harm is unlikely to occur in the near future, based on the current discharge regime.

Overall, the 2010 Clover Point horse mussel monitoring data did not provide any indication of adverse effects to the mussel community, or any potential to affect higher trophic level organisms as a result of bioaccumulation/biomagnification of contaminants. The biological assessments indicated that the predominant effect of the outfall on the mussels was a positive response to organic carbon concentrations, specifically, growth enhancement closer to the outfall relative to the reference stations. The outfall did not appear to have any effects on the age and reproductive status of the mussel community.

Copper and lead decreased with distance from the outfall, while other metals were either unrelated to distance or increased with distance from the outfall (i.e., aluminum, iron, mercury and nickel). Mussel

tissue lead and zinc concentrations were lower than relevant tissue effects threshold levels for the protection of wildlife and consumers of mussels. Copper levels were slightly elevated relative to tissue effects threshold levels, but the potential risks to organisms higher up the food chain were considered low. Concentrations of most organic substances were either below routine analytical detection limits or were rarely detected. High-resolution concentrations of most PAHs decreased with distance from the outfall along with lipid concentrations. All 2010 high resolution PAH concentrations were substantially lower than lethal- or sublethal-effects threshold concentrations.

6.6 Additional Investigations

The additional investigations completed in 2010 provided information that complemented the routine WMEP findings and added to the knowledge about emerging substances in municipal wastewaters and their potential effects on aquatic life.

High resolution analyses were supplemented in 2010 with the analyses of methylmercury and tributyltin in wastewaters. Results of the analyses indicate that methylmercury concentrations were all well below relevant WQGs. Tributyltin levels did exceed some Canadian interim and BC WQGs. Both methylmercury and tributyltin analyses in wastewater will be shifted to the routine WMEP to allow for long-term monitoring of concentrations, environmental loadings and potential for environmental toxicity are not increasing over time.

Investigations on the potential effects of emerging substances, such as pharmaceuticals and personal care products (PPCP), are ongoing. Additional samples were collected in 2009 to characterize PPCPs in Macaulay and Clover point wastewaters and results were similar to those in CRD samples collected from 2004 to 2006 and those observed in other jurisdictions, as expected. For the November 2009 results, no differences in overall concentration profiles for the four sampling sites were identified. However, differences in concentrations between sampling days were identified, likely due to variations in wastewater flow volumes following a rain event. Concentrations were compared to those of conventional wastewater parameters typically used to characterize bulk loading characteristics of wastewater and determine treatment plant capacity requirements. Relatively few target analyte concentrations were correlated with those of the conventional wastewater parameters, suggesting that designing and optimizing treatment plants to efficiently reduce conventional parameter loadings may not lead to as efficient reductions in the concentrations of all PPCPs assessed in this study. A preliminary relative loading assessment confirmed that the target analyte concentrations were generally proportional to the population equivalents of a wastewater system catchment area. Minor proportional deviations were observed and could have been a result of disproportional hospital loading inputs into one of the pump station catchment areas, as well as dilution due to wastewater system inflow and infiltration in the other pump station catchment area.

The 2009 data was also used to predict partitioning and degradation behaviour of PPCPs following secondary treatment, as is planned for the core area. The assessment included a ranking matrix to determine which of the 125 PPCPs pose the greatest environmental risk from a biosolids land application perspective. Six of the top ten substances were antibiotic in nature, two were non-medicinal antibiotic bacteriostats, and one of each of the following types of medications were identified: analgesic, anti-anxiety, anti-lipid and diabetic. Results suggest that, even with secondary treatment, there is likely no easy way to reduce the loadings of all PPCPs found in municipal wastewaters.

Concentrations and environmental loadings of the seven pharmaceuticals assessed from 2004 to 2006 were within the ranges observed by other jurisdictions, both in comparison to jurisdictions with wastewaters treated to the same level as well as those receiving more advanced treatment. Seasonal patterns were also observed, primarily driven by wastewater flow volume increases following heavy rain events. There did not appear to be any potential for acute effects of these pharmaceuticals in the environment around the outfalls, but there did appear to be some potential for chronic effects on organisms based on the environmental concentrations predicted for ibuprofen. However, sub-lethal and chronic effects endpoints are relatively limited in availability in the literature, as are literature thresholds derived from organism exposure to PPCP mixtures. Additional adverse chronic effects of these substances may be discovered in the future. Wastewater concentrations and loadings were proportional

to both prescription rates and population size, but the relationships were statistically weak or insignificant. As such, prescription rates and population size could not be used to accurately predict pharmaceutical wastewater concentrations and loadings on their own. Wastewater flow volumes, derived population equivalents and analytical method variability were also important factors to consider. No relationships were observed between wastewater PPCP concentrations and loadings and either population age or gender breakdown.

Results of phase 3 of the UVic mussel toxicogenomic study suggest that potential biological effects extend further from the outfall than is apparent from gross mussel size metrics and the chemical concentrations detected within the *Modiolus* tissues. The concentrations of PAHs appear to have a minimal relationship to the mRNA transcript pattern whereas correlations were observed between some of the metals and mRNA transcripts and a strong negative correlation was observed with bis(2-ethylhexyl) phthalate and three mRNAs. The importance of this relationship is currently unclear, but it highlights the need for evaluating other emerging chemicals such as personal care products and pharmaceuticals. It is currently unknown if these relationships are causal, but their findings suggest that altered mRNA abundance patterns within the mussel transcriptome are a result of bioactive anthropogenic agents originating from the outfall. The chemicals responsible for the effects are currently not known, but the expression pattern suggests dispersion around the outfall of substances that may accumulate in the south/south-easterly direction. The future direction of this project is currently under review. In addition, biomarker assessments in collaboration with Environment Canada have been put on hold until the future direction of the UVic project has been reviewed.

The environmental relevance of the results from the Environment Canada toxicogenomic microarray study are still being reviewed. However, results indicate that even salmon exposed to low environmentally relevant wastewater concentrations are susceptible to altered vitellogenin and vitelline envelope protein expression profiles, regardless of the genetic sex of the underyearling fish. Wastewater derived xenoestrogens are the likely cause of the altered gene expression profiles, but further research is necessary to confirm this.

The 2006 sediment core study in collaboration with Fisheries and Oceans Canada will be supplemented by additional sediment core and benthic invertebrate samples that were collected in 2010. PBDE and PCB profiles will be assessed in these samples, and comparisons will be made to similar samples collected from around the Iona outfall in Vancouver. All results will be assessed as part of an expanded collaborative study that includes the DFO, UVic and Metro Vancouver. Results will be included in a future annual report.

The PAH fingerprinting assessment was completed in 2010. Results confirmed the finding of the previous analysis that determined that the parent PAHs predominantly found in CRD samples originated mostly from combustion sources, and not coal from the nearby collier. These parent PAHs most likely make their way into the marine environment via atmospheric deposition, stormwater discharges (i.e., shoreline discharges) and the Macaulay and Clover outfalls. The PAHs that are found in sediments around the CRD outfalls have predominant sources in wood combustion, coal and possibly coke, with a likelihood of much lower bioavailability than would be expected from wastewater dominated by oils and soot from vehicle combustion.

6.7 Wastewater and Marine Environment Program Sampling Design Changes

Based on the results of the recent CRD and BC Ministry of Environment review of the WMEP, substantial changes to the WMEP will be implemented in 2011 to address comments and concerns raised by previous program reviewers (e.g. the SETAC review in 2006 and the ongoing MMMAG reviews). In short, the WMEP will shift from an annual monitoring program to one based on a five-year cycle. The addition of new monitoring endpoints, as described in previous sections of this report, will be balanced by a reduction in sampling frequency and the number of stations. This will be the last year in which an “annual” report will be generated. In future years, there will be annual “update” reports, with an overall final report summarizing the results at the end of the entire five-year cycle.

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APPENDIX A

Substances, Stations Sampled and Frequency for Wastewater, Sediment and Mussel Tissue Sampling in 2010

- Appendix A1 Substance List and Sampling Frequency for 2010 WMEP Components**
- Appendix A2 Stations Included in 2010 Seafloor Component—Macaulay Point**
- Appendix A3 Stations Included in 2010 Seafloor Component—Clover Point**
- Appendix A4 Guidance Manual for Assessment of WMEP Data**

Appendix A1 Substance List and Sampling Frequency for 2010 WMEP Components

Substance	RSCP Regulate (✓), Monitor (x)	Potential Sources	Priority Substances				
			Wastewater		Sediment		Mussel Tissue
			(full list)	(modified list)	(full list)	(modified list)	
			Quarterly	Monthly	Annually	Annually	Annually
CONVENTIONALS							
alkalinity			✓	✓			
biochemical oxygen demand,	x		✓	✓			
carbonaceous biochemical oxygen demand,			✓	✓			
chemical oxygen demand	✓		✓	✓			
chloride	✓		✓	✓			
conductivity	✓		✓	✓			
cyanide-SAD	x		✓	✓			
cyanide-WAD	x		✓	✓			
cyanide, total	✓				✓	✓	
fecal coliforms			✓	✓			
hardness, dissolved			✓	✓			
hardness, total			✓	✓			
lipids							✓
moisture					✓	✓	✓
nitrogen, ammonia		naturally present in seawater	✓	✓			
nitrogen, nitrate			✓	✓			
nitrogen, nitrite			✓	✓			
nitrogen, total Kjeldahl			✓	✓			
oil and grease, mineral	✓	automotive repair, vehicle wash, printing	✓	✓			
oil and grease, total	✓	food services	✓	✓			
organic carbon, total			✓	✓	✓	✓	
particle size					✓	✓	
pH	✓		✓	✓	✓	✓	
sulphate	✓		✓	✓			
sulphide	✓		✓	✓			
sulphide, acid volatile					✓	✓	
suspended solids, total	✓	carpet cleaning, fermentation, recreation facility	✓	✓			

Appendix A1, continued

Appendix A-1, continued

Substance	RSCP Regulate (✓), Monitor (x)	Potential Sources	Priority Substances				
			Wastewater		Sediment		Mussel Tissue
			(full list)	(modified list)	(full list)	(modified list)	Annually
			Quarterly	Monthly	Annually	Annually	
METALS							
Total Metals							
aluminum	x		✓	✓	✓	✓	✓
antimony	x		✓	✓	✓	✓	✓
arsenic	✓		✓	✓	✓	✓	✓
barium	✓		✓	✓	✓	✓	✓
beryllium	x		✓	✓	✓	✓	✓
bismuth	x						✓
cadmium	✓		✓	✓	✓	✓	✓
calcium	x		✓	✓	✓	✓	✓
chromium	✓		✓	✓	✓	✓	✓
chromium VI	x		✓	✓			
cobalt	✓		✓	✓	✓	✓	✓
copper	✓	ageing plumbing, dental practices, automotive repair, vehicle wash	✓	✓	✓	✓	✓
iron	✓		✓	✓	✓	✓	✓
lead	✓	ageing plumbing, automotive repair, vehicle wash	✓	✓	✓	✓	✓
lithium	x				✓	✓	✓
magnesium	x		✓	✓	✓	✓	✓
manganese	✓		✓	✓	✓	✓	✓
mercury	✓	dental practices	✓	✓	✓	✓	✓
molybdenum	✓	corrosion inhibitors	✓	✓	✓	✓	✓
nickel	✓	automotive repair, vehicle wash	✓	✓	✓	✓	✓
phosphorus	x		✓	✓	✓	✓	
potassium	x		✓	✓	✓	✓	
selenium	✓		✓	✓	✓	✓	✓
silver	✓	photographic imaging, dental practices	✓	✓	✓	✓	✓
sodium					✓	✓	
strontium					✓	✓	✓
thallium	x		✓	✓	✓	✓	✓
tin	x		✓	✓	✓	✓	✓

Appendix A1, continued

Substance	RSCP Regulate (✓), Monitor (x)	Potential Sources	Priority Substances				
			Wastewater		Sediment		Mussel Tissue
			(full list)	(modified list)	(full list)	(modified list)	Annually
			Quarterly	Monthly	Annually	Annually	
titanium	x				✓	✓	✓
uranium	x						✓
vanadium	x				✓	✓	✓
zinc	✓	dental practices, automotive repair, vehicle wash	✓	✓	✓	✓	✓
Dissolved Metals							
aluminum			✓	✓			
antimony			✓	✓			
arsenic		1	✓	✓			
barium			✓	✓			
beryllium			✓	✓			
cadmium		1	✓	✓			
calcium			✓	✓			
chromium		1	✓	✓			
cobalt		1	✓	✓			
copper		1	✓	✓			
iron		1	✓	✓			
lead		1	✓	✓			
magnesium		1	✓	✓			
manganese		1	✓	✓			
mercury		1	✓	✓			
molybdenum		1	✓	✓			
nickel		1	✓	✓			
phosphorus			✓	✓			
potassium			✓	✓			
selenium		1	✓	✓			
silver		1	✓	✓			
thallium			✓	✓			
tin			✓	✓			
zinc		1	✓	✓			
Extractable Metals							
cadmium		1			✓	✓	

Appendix A1, continued

Substance	RSCP Regulate (✓), Monitor (x)	Potential Sources	Priority Substances				
			Wastewater		Sediment		Mussel Tissue
			(full list)	(modified list)	(full list)	(modified list)	Annually
			Quarterly	Monthly	Annually	Annually	
copper		1			✓	✓	
lead		1			✓	✓	
mercury		1			✓	✓	
nickel		1			✓	✓	
zinc		1			✓	✓	
ALDEHYDES							
acrolein		combustion, pesticide	✓	✓	✓		
PHENOLIC COMPOUNDS							
total phenols	✓		✓	✓	✓	✓	
CHLORINATED PHENOLICS							
2,4,6-trichlorophenol	✓	pesticides, herbicides, wood preservatives, disinfectant	✓	✓	✓	✓	✓
2,4/2,5-dichlorophenol	✓	pesticides, herbicides, wood preservatives, disinfectant	✓	✓	✓	✓	✓
2,3-dichlorophenol	✓	pesticides, herbicides, wood preservatives, disinfectant			✓	✓	
2-chlorophenol	✓	pesticides, herbicides, wood preservatives, disinfectant	✓	✓	✓	✓	✓
4-chloro-3-methylphenol	✓	pesticides, herbicides, wood preservatives, disinfectant	✓	✓			
pentachlorophenol	✓	pesticides, herbicides, wood preservatives, disinfectant	✓	✓	✓	✓	✓
NON CHLORINATED PHENOLICS							
2,4-dimethylphenol	✓	wood preservatives, pesticides	✓	✓			
2,4-dinitrophenol	✓	wood preservatives, pesticides	✓	✓	✓	✓	
2-methyl-4,6-dinitrophenol	✓	wood preservatives, pesticides	✓	✓	✓	✓	
2-nitrophenol	✓	wood preservatives, pesticides	✓	✓	✓	✓	
4-nitrophenol	✓	wood preservatives, pesticides	✓	✓	✓	✓	
phenol	✓	disinfectant, vehicle emissions	✓	✓	✓	✓	
Organochlorine Pesticides							
2,4-DDD	x	insecticide	✓				
2,4-DDE	x	insecticide	✓				

Appendix A1, continued

Substance	RSCP Regulate (✓), Monitor (x)	Potential Sources	Priority Substances				
			Wastewater		Sediment		Mussel Tissue
			(full list)	(modified list)	(full list)	(modified list)	Annually
			Quarterly	Monthly	Annually	Annually	
2,4-DDT	x	insecticide	✓		✓*	✓*	
4,4-DDD	x	insecticide	✓		✓*	✓*	
4,4-DDE	x	insecticide	✓		✓*	✓*	
4,4-DDT	x	insecticide	✓		✓*	✓*	
aldrin	x	insecticide	✓		✓*	✓*	
alpha chlordane	x	insecticide	✓		✓*	✓*	
alpha-endosulfan	x	insecticide	✓		✓*	✓*	
alpha-BHC	x	insecticide	✓		✓*	✓*	
beta-endosulfan	x	insecticide	✓		✓*	✓*	
beta-BHC	x	insecticide	✓		✓*	✓*	
chlordane	x	insecticide	✓		✓*	✓*	
delta-BHC	x	insecticide	✓		✓*	✓*	
dieldrin	x	insecticide	✓		✓*	✓*	
endosulfan sulfate	x	insecticide	✓		✓*	✓*	
endrin	x	insecticide	✓		✓*	✓*	
endrin aldehyde	x	insecticide	✓		✓*	✓*	
gamma chlordane	x	insecticide	✓		✓*	✓*	
heptachlor	x	insecticide	✓		✓*	✓*	
heptachlor epoxide	x	insecticide	✓		✓*	✓*	
gamma BHC	x	insecticide	✓		✓*	✓*	
methoxychlor	x	insecticide	✓		✓*	✓*	
mirex	x	insecticide	✓		✓*	✓*	
octachlorostyrene	x	insecticide	✓		✓*	✓*	
toxaphene	x	insecticide	✓		✓*	✓*	
Polychlorinated biphenyls							
PCB Aroclor 1016	x	dielectric fluid	✓		✓*	✓*	
PCB Aroclor 1221	x	dielectric fluid	✓		✓*	✓*	
PCB Aroclor 1232	x	dielectric fluid	✓		✓*	✓*	
PCB Aroclor 1242	x	dielectric fluid	✓		✓*	✓*	
PCB Aroclor 1248	x	dielectric fluid	✓		✓*	✓*	
PCB Aroclor 1254	x	dielectric fluid	✓		✓*	✓*	
PCB Aroclor 1260	x	dielectric fluid	✓		✓*	✓*	

Appendix A1, continued

Substance	RSCP Regulate (✓), Monitor (x)	Potential Sources	Priority Substances				
			Wastewater		Sediment		Mussel Tissue
			(full list)	(modified list)	(full list)	(modified list)	Annually
			Quarterly	Monthly	Annually	Annually	
total PCBs	x	dielectric fluid	✓		✓*	✓*	
PCB-1					✓*	✓*	
PCB-3					✓*	✓*	
PCB-4/10					✓*	✓*	
PCB-5/8					✓*	✓*	
PCB-15					✓*	✓*	
PCB-18					✓*	✓*	
PCB-19					✓*	✓*	
PCB-23/34					✓*	✓*	
PCB-28					✓*	✓*	
PCB-31					✓*	✓*	
PCB-37					✓*	✓*	
PCB-40					✓*	✓*	
PCB-44					✓*	✓*	
PCB-43/49					✓*	✓*	
PCB-52/73					✓*	✓*	
PCB-54					✓*	✓*	
PCB-56/60					✓*	✓*	
PCB-66/80					✓*	✓*	
PCB-77					✓*	✓*	
PCB-81					✓*	✓*	
PCB-87/115/116					✓*	✓*	
PCB-89/90/101					✓*	✓*	
PCB-93/95					✓*	✓*	
PCB-99					✓*	✓*	
PCB-104					✓*	✓*	
PCB-105/127					✓*	✓*	
PCB-106/118					✓*	✓*	
PCB-110					✓*	✓*	
PCB-114					✓*	✓*	
PCB-123					✓*	✓*	
PCB-126					✓*	✓*	

Appendix A1, continued

Substance	RSCP Regulate (✓), Monitor (x)	Potential Sources	Priority Substances				
			Wastewater		Sediment		Mussel Tissue
			(full list)	(modified list)	(full list)	(modified list)	Annually
			Quarterly	Monthly	Annually	Annually	
PCB-138/163/164					√*	√*	
PCB 139/149					√*	√*	
PCB-151					√*	√*	
PCB-153					√*	√*	
PCB-155					√*	√*	
PCB-156					√*	√*	
PCB-157					√*	√*	
PCB-167					√*	√*	
PCB-169					√*	√*	
PCB-170/190					√*	√*	
PCB-180					√*	√*	
PCB-182/187					√*	√*	
PCB-183					√*	√*	
PCB-188					√*	√*	
PCB-189					√*	√*	
PCB-194					√*	√*	
PCB-196/203					√*	√*	
PCB-202					√*	√*	
PCB-205					√*	√*	
PCB-206					√*	√*	
PCB-208					√*	√*	
PCB-209					√*	√*	
Aroclor 1016					√*	√*	
Aroclor 1221					√*	√*	
Aroclor 1232					√*	√*	
Aroclor 1242					√*	√*	
Aroclor 1248					√*	√*	
Aroclor 1254 (estimated)					√*	√*	
Aroclor 1260					√*	√*	
POLYCYCLIC AROMATIC HYDROCARBONS							
2-chloronaphthalene	✓	coal, combustion	✓	✓	√*	√*	
2-methylnaphthalene	✓	coal, combustion	✓	✓	√*	√*	√*

Appendix A1, continued

Substance	RSCP Regulate (✓), Monitor (x)	Potential Sources	Priority Substances				
			Wastewater		Sediment		Mussel Tissue
			(full list)	(modified list)	(full list)	(modified list)	Annually
			Quarterly	Monthly	Annually	Annually	
acenaphthene	✓	coal, combustion	✓	✓	✓*	✓*	✓*
acenaphthylene	✓	coal, combustion	✓	✓	✓*	✓*	✓*
anthracene	✓	coal, combustion	✓	✓	✓*	✓*	✓*
benzo(a)anthracene	✓	coal, combustion	✓	✓	✓*	✓*	✓*
benzo(a)pyrene	✓	coal, combustion	✓	✓	✓*	✓*	✓*
benzo(b)fluoranthene	✓	coal, combustion	✓	✓	✓*	✓*	✓*
benzo(g,h,i)perylene	✓	coal, combustion	✓	✓	✓*	✓*	✓*
benzo(k)fluoranthene	✓	coal, combustion	✓	✓	✓*	✓*	✓*
chrysene	✓	coal, combustion	✓	✓	✓*	✓*	✓*
dibenzo(a,h)anthracene	✓	coal, combustion	✓	✓	✓*	✓*	✓*
fluoranthene	✓	coal, combustion	✓	✓	✓*	✓*	✓*
fluorene	✓	coal, combustion	✓	✓	✓*	✓*	✓*
indeno(1,2,3-c,d)pyrene	✓	coal, combustion	✓	✓	✓*	✓*	✓*
naphthalene	✓	coal, combustion	✓	✓	✓*	✓*	✓*
phenanthrene	✓	coal, combustion	✓	✓	✓*	✓*	✓*
pyrene	✓	coal, combustion	✓	✓	✓*	✓*	✓*
total high molecular weight - PAHs	✓	coal, combustion	✓	✓			✓*
total low molecular weight - PAHs	✓	coal, combustion	✓	✓			✓*
total PAHs	✓	coal, combustion	✓	✓			✓*
SEMI-VOLATILE ORGANICS							
Phthalates							
bis(2-ethylhexyl)phthalate	x	plastics	✓	✓	✓	✓	✓
butylbenzyl phthalate	x	plastics	✓	✓	✓	✓	✓
diethyl phthalate	x	plastics	✓	✓	✓	✓	✓
dimethyl phthalate	x	plastics	✓	✓	✓	✓	✓
di-n-butyl phthalate	x	plastics	✓	✓	✓	✓	✓
di-n-octyl phthalate	x	plastics	✓	✓	✓	✓	✓
MISCELLANEOUS SEMI-VOLATILE ORGANICS							
1,2,3,4-tetrachlorobenzene	✓						
1,2,3,5/1,2,4,5-tetrachlorobenzene	✓						

Appendix A1, continued

Substance	RSCP Regulate (√), Monitor (x)	Potential Sources	Priority Substances				
			Wastewater		Sediment		Mussel Tissue
			(full list)	(modified list)	(full list)	(modified list)	Annually
			Quarterly	Monthly	Annually	Annually	
1,2,3-trichlorobenzene	√	chemical manufacturing, termite control					
1,2,4-trichlorobenzene	√	dyes, wood preservative, herbicides	√		√	√	√
1,2-diphenylhydrazine	√	dyes, medications	√	√			
1,3,5-trichlorobenzene	√						
2,4-dinitrotoluene	√	plastics, foams	√	√	√	√	
2,6-dinitrotoluene	√	plastics, foams	√	√	√	√	
3,3-dichlorobenzidine	√	dyes	√	√			
4-bromophenyl phenyl ether	√	flame retardant	√		√	√	√
4-chlorophenyl phenyl ether	√		√		√	√	√
benzidine	√	dyes	√	√			
bis(2-chloroethoxy)methane	√		√		√	√	√
bis(2-chloroethyl)ether	√		√		√		√
bis(2-chloroisopropyl)ether	√		√		√		√
hexachlorobenzene	√	POP (former use in pesticides)	√		√	√	
hexachlorobutadiene	√	rubber compounds, solvent	√		√	√	√
hexachlorocyclopentadiene	√	pesticides, flame retardants	√				
hexachloroethane	√	fungicides, insecticides, plastics	√		√	√	√
isophorone	√	solvent	√	√	√	√	
nitrobenzene	√	pesticides, drugs	√	√	√	√	
N-nitrosodimethylamine	√	toiletries, cosmetics, cleansers	√	√			
N-nitrosodi-n-propylamine	√	herbicides	√	√			
N-nitrosodiphenylamine	√		√	√			
VOLATILE ORGANICS							
Monocyclic Aromatic Hydrocarbons							
benzene	√	printing	√	√	√		
chlorobenzene	x	solvent, degreaser	√	√	√		
1,2-dichlorobenzene	x	herbicides	√	√	√	√	√
1,3-dichlorobenzene	x	herbicides, insecticides, medications, dyes	√	√	√	√	√
1,4-dichlorobenzene	x	urinal deodorants, mothballs	√	√	√	√	√
ethylbenzene	√	printing	√	√	√		
m & p xylenes	√	gasoline	√	√	√		

Appendix A1, continued

Substance	RSCP Regulate (✓), Monitor (x)	Potential Sources	Priority Substances				
			Wastewater		Sediment		Mussel Tissue
			(full list)	(modified list)	(full list)	(modified list)	Annually
			Quarterly	Monthly	Annually	Annually	
o-xylene	✓		✓	✓	✓		
styrene	x		✓	✓	✓		
toluene	✓	printing	✓	✓	✓		
xylene	✓	printing	✓	✓			
Aliphatic							
acrylonitrile	✓	plastics, rubber, acrylic	✓	✓			
methyl tertiary butyl ether	✓	gasoline additive	✓	✓	✓		
Chlorinated Aliphatic							
1,1,1,2-tetrachloroethane	✓		✓	✓	✓		
1,1,1-trichloroethane	✓	solvent, degreaser	✓	✓	✓		
1,1,2,2-tetrachloroethane	✓	chemical intermediate	✓	✓	✓		
1,1,2-trichloroethane	✓	solvent, chemical intermediate	✓	✓	✓		
1,1-dichloroethane	✓	degreaser	✓	✓	✓		
1,1-dichloroethene	✓	plastics, flame retardant	✓	✓	✓		
1,2-dichloroethane	✓	vinyl chloride, solvent	✓	✓	✓		
1,2-dichloropropane	✓	chemical intermediate	✓	✓	✓		
2-chloroethyl vinyl ether	✓				✓		
bromomethane	✓	insecticide, raticide, fungicide	✓	✓	✓		
chloroethane	✓	medications, dyes	✓	✓	✓		
chloroethene	✓		✓	✓	✓		
chloromethane	✓	combustion, natural sources	✓	✓	✓		
cis-1,2-dichloroethene	✓		✓	✓	✓		
cis-1,3-dichloropropene	✓		✓	✓	✓		
dibromoethane	✓		✓	✓			
dibromomethane	✓		✓	✓	✓		
dichloromethane	✓	paint stripping solvents	✓	✓	✓		
tetrabromomethane	✓		✓	✓	✓		
tetrachloroethene	✓	dry cleaning	✓	✓	✓		
tetrachloromethane	✓		✓	✓	✓		
trans-1,2-dichloroethene	✓		✓	✓	✓		
trans-1,3-dichloropropene	✓		✓	✓	✓		
trichloroethene	✓		✓	✓	✓		

Appendix A1, continued

Substance	RSCP Regulate (✓), Monitor (x)	Potential Sources	Priority Substances				
			Wastewater		Sediment		Mussel Tissue
			(full list)	(modified list)	(full list)	(modified list)	Annually
			Quarterly	Monthly	Annually	Annually	
trichlorofluoromethane	✓		✓	✓	✓		
Trihalomethanes							
bromodichloromethane	✓		✓	✓	✓		
chlorodibromomethane	✓		✓	✓	✓		
tribromomethane	✓		✓	✓	✓		
trichloromethane	✓		✓	✓	✓		
Ketones							
dimethyl ketone	✓	perfumes, paints	✓	✓			
methyl ethyl ketone	✓	perfumes, paints	✓	✓			
methyl isobutyl ketone	✓	perfumes, paints	✓	✓			
TERPENES							
alpha-terpineol			✓	✓			
NONYLPHENOLS							
4-nonylphenols			✓		✓		
4-nonylphenol monoethoxylates			✓		✓		
4-nonylphenol diethoxylates			✓		✓		
POLYCHLORINATED DIBENZODIOXINS (PCDDs)							
2,3,7,8-TCDD					✓*		✓*
1,2,3,7,8-PECDD					✓*		✓*
1,2,3,4,7,8-HXCDD					✓*		✓*
1,2,3,6,7,8-HXCDD					✓*		✓*
1,2,3,7,8,9-HXCDD					✓*		✓*
1,2,3,4,6,7,8-HPCDD					✓*		✓*
OCDD					✓*		✓*
dibenzo-p-dioxin					✓*		✓*
POLYBROMINATED DIPHENYL ETHERS (PBDEs)							
BR2-DPE-7			✓*		✓*		
BR2-DPE-8/11			✓*		✓*		

Appendix A1, continued

Substance	RSCP Regulate (✓), Monitor (x)	Potential Sources	Priority Substances				
			Wastewater		Sediment		Mussel Tissue
			(full list)	(modified list)	(full list)	(modified list)	Annually
			Quarterly	Monthly	Annually	Annually	
BR2-DPE-10			√*		√*		
BR2-DPE-12/13			√*		√*		
BR2-DPE-15			√*		√*		
BR3-DPE-17/25			√*		√*		
BR3-DPE-28/33			√*		√*		
BR3-DPE-30			√*		√*		
BR3-DPE-32			√*		√*		
BR3-DPE-35			√*		√*		
BR3-DPE-37			√*		√*		
BR4-DPE-47			√*		√*		
BR4-DPE-49			√*		√*		
BR4-DPE-51			√*		√*		
BR4-DPE-66			√*		√*		
BR4-DPE-71			√*		√*		
BR4-DPE-75			√*		√*		
BR4-DPE-77			√*		√*		
BR4-DPE-79			√*		√*		
BR5-DPE-85			√*		√*		
BR5-DPE-99			√*		√*		
BR5-DPE-100			√*		√*		
BR5-DPE-105			√*		√*		
BR5-DPE-116			√*		√*		
BR5-DPE-119/120			√*		√*		
BR5-DPE-126			√*		√*		
BR6-DPE-128			√*		√*		
BR6-DPE-138/166			√*		√*		
BR6-DPE-140			√*		√*		
BR6-DPE-153			√*		√*		
BR6-DPE-154			√*		√*		
BR6-DPE-155			√*		√*		
BR7-DPE-181			√*		√*		
BR7-DPE-183			√*		√*		

Appendix A1, continued

Substance	RSCP Regulate (✓), Monitor (x)	Potential Sources	Priority Substances				
			Wastewater		Sediment		Mussel Tissue
			(full list)	(modified list)	(full list)	(modified list)	Annually
			Quarterly	Monthly	Annually	Annually	
BR7-DPE-190			√*		√*		
BR8-DPE-203			√*		√*		
BR9-DPE-206			√*		√*		
BR9-DPE-207			√*		√*		
BR9-DPE-208			√*		√*		
BR10-DPE-209			√*		√*		
pentabromoethylbenzene (PBEB)			√*		√*		
hexabromobenzene (HBB)			√*		√*		
1,2-Bis(2,4,6- tribromophenoxy)ethane (BTBPE)			√*		√*		
decabromodiphenylethane (DBDPE)			√*		√*		

Notes

1. Dissolved and extractable metals are already included within total metals.
√* Analyses were conducted at a higher resolution (i.e., at AXYS analytical)

Appendix A2 Stations Included in 2010 Seafloor Component—Macaulay Point

Station	Sediment		Benthic Community
	Priority Substances (full list)	Priority Substances (modified list)	Community Indices
M0	√		√
M1E		√	√
M1N		√	√
M1NE		√	√
M1NW		√	√
M1S		√	√
M1SE		√	√
M1SW		√	√
M1W		√	√
M2E		√	√
M2N		√	√
M2NE		√	√
M2NW		√	√
M2S		√	√
M2SE		√	√
M2SW		√	√
M2W		√	√
M4E		√	√
M4SE		√	√
M4SW		√	√
M4W		√	√
M8E		√	√
M8W		√	√
Parry Bay 1	√		√
Parry Bay 2		√	√
Parry Bay 3		√	√
Parry Bay 4		√	√
Parry Bay 5		√	√

Appendix A3 Stations Included in 2009 Seafloor Component—Clover Point

Station	Sediment	Mussel Community	
	Priority Substances (full list)	Priority Substances	Physiology (i.e., weight, size, age, reproductive index)
C0	√	√	√
C1E		√	√
C1N*			
C1NE		√	√
C1NW		√	√
C1S		√	√
C1SE		√	√
C1SW		√	√
C1W		√	√
C2E		√	√
C2N		√	√
C2NE		√	√
C2NW		√	√
C2S		√	√
C2W		√	√
C4E		√	√
C4NE		√	√
C4NW		√	√
C4SE		√	√
C4SW		√	√
C4W		√	√
C8E		√	√
C8W		√	√
Constance Bank 1	√	√	√
Constance Bank 2		√	√
Constance Bank 3		√	√
Constance Bank 4		√	√
Constance Bank 5		√	√

*C1N was not collected because of sampling difficulties

Appendix A4

Guidance Manual for Assessment and Analysis of WMEP Data

**From Golder Associates 09-1421-0017, July 14, 2009 DRAFT
Wastewater and Marine Environment Programs
Updated Guidance Manual for Assessment and Analysis of WMEP Data**

APPENDIX B

Macaulay and Clover Points Outfalls: Mean Daily Flow, Frequency of Detection of Substances, and Wastewater Mean Concentrations and Loadings

- Appendix B1 Macaulay Point Effluent Flow**
- Appendix B2 Clover Point Effluent Flow**
- Appendix B3 Compliance Monitoring Results for Biochemical Oxygen Demand and Total Suspended Solids**
- Appendix B4 Macaulay and Clover Wastewater Chemistry Quality Assurance and Quality Control Results**
- Appendix B5 Frequency of Detection of Substances in Macaulay and Clover Points Wastewaters**
- Appendix B6 Mean Concentrations and Loadings of Substances Analyzed in Macaulay Point Wastewater**
- Appendix B7 Mean Concentrations and Loadings of Substances Analyzed in Clover Point Wastewater**

Appendix B1 Macaulay Point Effluent Flow¹

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	50,360	46,600	43,580	48,300	41,780	44,800	38,320	38,980	41,500	41,140	41,540	60280
2	56,360	45,300	43,240	46,380	42,700	41,080	38,720	34,880	39,040	41,140	55,180	49280
3	60,220	45,060	43,000	48,720	44,060	42,980	37,060	37,240	40,180	39,980	45,840	47400
4	56,880	44,060	42,720	54,600	53,940	41,320	36,520	37,540	38,100	40,880	43,780	45440
5	101,160	44,020	42,000	50,020	43,980	40,780	37,900	37,860	36,760	40,200	42,380	49000
6	87,000	43,300	42,280	47,700	42,860	42,280	40,360	37,300	36,380	39,120	44,000	45120
7	65,080	43,000	41,960	45,080	43,160	44,060	37,940	38,420	41,500	38,320	42,900	43860
8	58,920	44,420	42,600	44,960	41,360	42,100	38,100	40,300	43,480	39,940	46,840	43260
9	63,000	43,940	42,580	47,580	43,400	41,540	38,380	37,920	41,460	38,340	43,000	74680
10	60,680	42,820	41,380	46,100	41,900	42,180	37,720	38,780	39,380	42,440	40,960	91960
11	57,720	43,220	41,120	43,860	44,160	41,120	36,800	37,960	38,000	43,200	41,620	70600
12	71,300	43,320	44,520	45,020	41,220	42,560	37,780	39,620	39,560	48,080	40,220	82900
13	63,080	43,020	50,480	45,020	40,680	39,980	40,040	37,840	43,680	40,820	40,880	166180
14	60,540	43,760	46,060	42,080	41,840	41,000	37,540	38,520	41,380	39,280	41,060	93600
15	73,080	45,360	44,120	41,840	40,180	41,660	37,740	36,520	38,940	38,580	45,080	110780
16	94,040	43,880	47,040	41,700	41,480	40,940	37,460	36,740	39,080	39,940	43,660	84400
17	70,040	44,460	45,540	42,520	41,120	39,780	38,660	38,120	40,000	38,620	42,360	68720
18	62,440	43,440	43,780	44,480	40,760	39,900	38,820	38,820	42,020	40,740	45,640	61240
19	57,280	43,100	43,300	45,000	41,500	39,940	37,560	37,860	44,520	39,000	42,880	56780
20	53,920	42,900	42,040	44,400	41,000	38,920	38,680	37,620	45,760	37,840	43,920	54520
21	52,100	42,280	42,140	48,940	40,640	39,320	38,640	37,580	42,140	39,300	45,260	58020
22	50,560	43,440	42,980	45,820	41,240	41,780	37,800	36,960	41,980	37,560	45,220	51800
23	49,740	42,840	42,060	44,540	38,200	39,400	37,820	38,400	39,620	38,020	43,180	49100
24	48,220	41,740	40,900	46,180	37,520	38,720	37,700	39,460	39,580	40,420	41,360	49360
25	48,220	44,540	40,900	44,240	41,540	39,440	38,340	37,640	40,340	43,400	42,540	48660
26	47,340	44,260	42,980	43,680	39,900	40,480	37,680	37,360	40,500	59,260	42,980	44600
27	46,060	43,580	43,240	47,640	42,780	38,600	38,320	37,440	54,420	47,520	48,100	45860
28	45,460	44,920	43,240	45,760	41,580	39,100	38,040	37,880	43,120	43,420	46,300	48180
29	45,060		43,420	46,260	43,460	40,280	37,660	38,660	40,100	40,540	45,940	43860
30	44,100		59,200	45,060	40,540	38,240	37,780	37,820	40,360	41,800	46,100	45240
31	47,900		54,680		43,440		38,920	38,240		41,140		45480
TOTAL Flow (m³/day)	1,847,860	1,226,580	1,369,080	1,373,480	1,303,920	1,224,280	1,180,800	1,176,280	1,232,880	1,279,980	1,320,720	1,930,160
Average	59,608	43,806	44,164	45,783	42,062	40,809	38,090	37,945	41,096	41,290	44,024	62,263
Maximum	101,160	46,600	59,200	54,600	53,940	44,800	40,360	40,300	54,420	59,260	55,180	166,180
Minimum	44,100	41,740	40,900	41,700	37,520	38,240	36,520	34,880	36,380	37,560	40,220	43,260
n	31	28	31	30	31	30	31	31	30	31	30	31
											Annual Average	45,112

¹ Flows are in m³/day.
PV = Permit violation, Permit maximum daily: 200,000 m³/day; Permit maximum mean: 50,000 m³/day.

Appendix B2 Clover Point Effluent Flow¹

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	61,350	53,985	40,461	56,160	46,014	55,243	42,918	37,948	53,121	46,630	43,630	60,765
2	73,201	58,037	47,262	53,561	45,751	47,174	43,390	36,622	44,694	45,510	65,532	49,086
3	70,540	52,027	48,871	58,563	54,089	48,837	43,030	37,971	43,294	44,731	49,843	48,496
4	69,053	52,649	48,240	62,411	60,061	46,753	41,674	42,167	43,737	45,158	47,373	47,393
5	118,260	51,838	48,063	53,614	48,311	47,262	42,616	42,803	41,817	44,867	45,330	44,972
6	118,633	51,788	47,520	53,012	46,636	45,499	43,593	43,225	41,477	43,993	49,578	45,817
7	76,541	49,058	46,699	51,812	46,520	51,920	43,261	43,067	50,660	44,242	46,712	45,317
8	67,822	56,919	48,067	51,263	45,652	48,054	42,818	48,226	46,648	43,670	48,008	45,360
9	92,889	48,537	47,996	53,133	44,764	46,963	43,481	43,085	43,002	45,195	45,460	76,870
10	81,708	49,093	46,682	53,737	44,923	51,485	42,900	44,562	43,010	48,438	43,207	101,152
11	71,575	50,493	46,698	50,068	37,720	47,283	41,570	43,358	40,574	50,786	42,903	74,757
12	88,129	49,998	54,579	49,111	42,116	46,267	41,692	43,389	39,254	44,917	44,032	88,456
13	75,776	50,839	69,619	49,088	27,239	45,346	43,091	43,382	47,249	39,333	44,221	166,292
14	65,701	47,774	52,878	48,620	44,967	45,810	43,191	42,546	43,598	43,355	44,720	110,839
15	83,566	54,218	52,236	44,410	44,526	47,440	43,371	40,053	41,741	43,298	48,575	126,373
16	107,375	49,335	55,638	47,558	44,276	45,650	43,657	41,025	44,413	42,793	51,689	97,951
17	82,035	55,146	52,326	47,674	44,183	45,651	43,043	43,371	45,157	41,813	46,840	78,693
18	72,905	48,523	51,015	48,075	43,837	45,653	40,876	41,956	45,682	41,723	50,850	69,477
19	67,692	47,328	50,536	46,903	42,810	44,902	40,880	41,700	49,887	42,515	46,081	63,327
20	63,576	49,087	49,410	46,888	44,926	44,170	42,975	42,329	55,118	42,196	48,976	57,902
21	61,293	51,677	48,489	58,597	45,689	43,864	42,289	42,666	47,860	41,991	50,216	52,034
22	60,729	43,954	52,464	48,483	44,425	45,288	42,237	41,265	46,194	42,255	46,619	53,689
23	58,278	47,231	49,334	48,203	42,412	45,226	42,932	41,294	44,812	41,243	44,954	51,377
24	54,146	46,748	48,925	50,745	41,765	45,165	43,100	42,816	47,688	39,923	44,827	50,987
25	55,656	49,381	48,336	50,202	43,733	43,816	41,241	42,439	47,157	47,824	44,088	47,022
26	56,308	51,022	55,385	48,285	43,884	43,798	41,470	41,843	45,426	70,637	53,686	44,424
27	54,355	47,396	53,494	48,820	51,630	42,845	40,435	42,219	74,639	51,002	54,872	45,888
28	50,366	32,195	49,066	47,593	45,616	43,027	39,968	41,964	51,805	46,519	48,769	50,340
29	51,418		49,599	46,475	57,459	44,136	39,562	40,770	48,547	45,362	47,244	45,017
30	52,446		79,629	46,371	46,827	43,777	40,988	41,266	47,141	45,121	48,039	46,587
31	62,604		63,411		47,162		40,183	42,350		45,036		44,582
TOTAL Flow (m³/day)	2,225,926	1,396,276	1,602,928	1,519,435	1,409,923	1,388,304	1,308,432	1,303,677	1,405,402	1,402,076	1,436,874	2,031,242
Average	71,804	49,867	51,707	50,648	45,481	46,277	42,207	42,054	46,847	45,228	47,896	65,524
Maximum	118,633	58,037	79,629	62,411	60,061	55,243	43,657	48,226	74,639	70,637	65,532	166,292
Minimum	50,366	32,195	40,461	44,410	27,239	42,845	39,562	36,622	39,254	39,333	42,903	44,424
n	31	28	31	30	31	30	31	31	30	31	30	31
Annual Average												50,495

Notes: ¹ Flows are in m³/day, Permit maximum daily: 300,000 m³/day; Permit maximum mean: 72,000 m³/day.

Appendix B3 Compliance Monitoring Results for Biochemical Oxygen Demand and Total Suspended Solids

Month	Macaulay	Clover	Macaulay	Clover
	Biochemical Oxygen demand (mg/L)		Total Suspended Solids (mg/L)	
January	178	149	223	134
February	221	192	226	224
March	240	201	250	192
April	235	215	221	174
May	260	208	228	170
June	201	192	206	184
July	239	213	254	178
August	265	245	207	212
September	226	224	286	242
October	256	189	72	276
November	200	242	186	222
December	266	242	252	298
Average	232	209	218	209
Maximum	266	245	286	298

Appendix B4 Macaulay and Clover Points Wastewater Chemistry Quality Assurance and Quality Control Results
(Refer to Appendix A4 for details on the CRD Quality Assurance and Quality Control Assessment Procedure.)

Parameters	Jan		Feb		March		April		May		June		July		Aug		Sept		Oct		Nov		Dec	
	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND
Conventionals																								
TOC											R	R	J-	UN									R	U
Oil & grease, mineral							R	R					J-	UN	J-	UN			R	R	R	R	J-	UN
Oil & grease, total							R	R	R	U			R	R					R	R			R	R
SAD cyanide sulfide											R	U											J-	UN
Total Metals																								
antimony							J-	UN															R	R
arsenic													J	UN										
barium																							R	R
calcium																							J-	UN
chromium																							J-	UN
cobalt																			J+	UN				
copper													J+	UN									R	R
lead																							R	R
manganese																							R	R
mercury	J-	UN							J	UN	J-	UN							R	U				
molybdenum							J-	UN															R	R
nickel																							R	R
silver			J-	UN			J-	UN			J-	UN												
tin	J-	UN	J-	UN			J-	UN															R	R
zinc													J+	U									R	R
Dissolved Metals																								
aluminum															R	R								
antimony																							J-	UN
barium																							R	R
copper																							R	R
iron															R	R								
manganese																							R	R
mercury	J-	UN																						
molybdenum																							R	R
nickel																							R	R

Appendix B4, continued

Parameters	Jan		Feb		March		April		May		June		July		Aug		Sept		Oct		Nov		Dec	
	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND
selenium	R	R																					R	U
silicon																								
silver	J-	UN	J-	UN			R	R																
tin																							R	R
zinc			J-	UN																			R	R
Speciated Metals																								
chromium VI			R	R			J-	UN			J-	UN											J+	U
Organotins																								
Tributyltin	J-	UN					J-	UN											R	R				
Dibutyltin	J-	UN					J-	UN					J-	UN					J-	UN				
Monobutyltin	J-	UN					J-	UN					R	R					J-	UN				
Tributyltin chloride	J-	UN																						
Dibutyltin dichloride	J-	UN																						
Monobutyltin trichloride	J-	UN																						
Phenolic Compounds																								
total phenols																							R	R
Chlorinated Phenolics																								
2-nitrophenol	J-	UN	J-	UN	J-	UN									J-	UN	J-	UN						
pentachlorophenol									J+	U														
4-chloro-3-methylphenol																								
Non Chlorinated Phenolics																								
4-nitrophenol	J-	UN	J-	UN	J-	UN	J-	UN	J-	UN	J-	UN	J-	UN	J-	UN	J-	UN			J-	UN		
2,4-dinitrophenol																							J-	UN
phenol									R	U											R	R	J-	UN
2-methyl-4,6-dinitrophenol	J-	UN	J-	UN	J-	UN					J-	UN			J-	UN	J-	UN			J-	UN		
Organochlorine Pesticides																								
2,4-DDD	R	R											R	R										
4,4-DDD													J+	UN										
Chlordane	R	R					R	R					R	R										
endrin													J+	U										
endrin aldehyde													J-	UN										
heptachlor epoxide													J+	U										

Appendix B4, continued

Parameters	Jan		Feb		March		April		May		June		July		Aug		Sept		Oct		Nov		Dec	
	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND
Polycyclic Aromatic Hydrocarbons																								
2-methylnaphthalene															R	UN					J-	UN	J+	U
acenaphthene	R	U	R	U																	J-	UN		
acenaphthylene																					R	R	J+	U
anthracene											J	UN									J-	UN	J+	U
benzo(a)pyrene											R	R					J	UN			R	R	J+	U
benzo(a)anthracene											R	R									R	R	J+	U
benzo(g,h,i)perylene							R	R									J	UN			R	R	R	U
benzo(k)fluoranthene																					J-	UN	J+	U
chrysene											R	R									J-	UN	J+	U
dibenzo(a,h)anthracene																					J-	UN	R	U
fluoranthene											R	R									J-	UN	J+	U
fluorene															R	U					R	R		
indeno(1,2,3-c,d)pyrene							R	R													J-	UN	J+	U
naphthalene															R	U					J-	UN		
phenanthrene																					J-	UN		
pyrene	R	U	R	U							R	R									J-	UN	J+	U
Total HMW-PAH's							J	UN			R	R					R	R			J	UN		
Total LMW-PAH's																					J	UN		
total PAHs											R	R									J	UN		
Semi-Volatile Organics																								
Phthalates																								
dimethyl phthalate	J-	UN									R	R			R	R					R	R	R	U
diethyl phthalate					J-	UN			R	U	R	R							R	U	R	R	R	U
di-n-butyl phthalate									R	U											R	U	J-	UN
di-n-octyl phthalate							R	U																
bis(2-ethylhexyl)phthalate	R	R			R	U			R	U														
butylbenzyl phthalate											J-	UN			J-	UN					R	R	R	U
Misc Semivolatile Organics																								
2,4-dinitrotoluene																					J-	UN	R	U
2,6-dinitrotoluene	R	R																					J+	U
3,3-dichlorobenzidine			R	R	R	R	J-	UN	R	R	R	R	J-	UN	R	R	R	R	J-	UN	R	R	R	U
benzidine	J-	UN					J-	UN					J-	UN					J-	UN				
hexachlorobutadiene	J-	UN					J-	UN					J-	UN										

Appendix B4, continued

Parameters	Jan		Feb		March		April		May		June		July		Aug		Sept		Oct		Nov		Dec	
	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND
hexachlorocyclopentadiene	R	R					J-	UN					J-	UN										
hexachloroethane	J-	UN					J-	UN					J-	UN										
nitrobenzene					J+	U															R	U		
N-nitrosodimethylamine	J-	UN	J-	UN	J-	UN	J-	UN	J-	UN	J-	UN	J-	UN	J-	UN	J-	UN			J-	UN		
N-nitrosodi-n-propylamine					J-	UN			J+	U					J+	U					R	U		
Chlorinated Aliphatic																								
tetrabromomethane																							R	U
trans-1,3-dichloropropene	J-	UN																					J+	U

Notes

R flag: Severe DQO failure; rejected data

J flag: Value is an estimate

J+ flag: Value is an estimate with potential high bias

J- flag: Value is an estimate with potential low bias

UN flag: Value was not detected, possible false negative

U: Value was not detected (no DQO failure)

D: detected results

ND: not detected results

Appendix B5 Frequency of Detection of Substances in Macaulay and Clover Points Wastewaters

Parameter Description	Units	Clover		Macaulay	
		n	% Freq	n	% Freq
Conventionals					
alkalinity - total - pH 4.5	mg/L	12	100	12	100
biochemical oxygen demand	mg/L O2	12	100	12	100
carbonaceous biochemical oxygen demand	mg/L O2	12	100	12	100
chemical oxygen demand	mg/L O2	12	100	12	100
chloride	mg/L	12	100	12	100
conductivity	µS/cm	12	100	12	100
cyanide, SAD	mg/L	12	100	12	100
cyanide, WAD	mg/L	12	100	12	100
fecal coliform	CFU/100 mL	12	100	12	100
hardness (as CaCO3)	mg/L	11	100	11	100
N - NH3	mg/L N	12	100	12	100
N - NO2	mg/L N	12	75	12	67
N - NO3	mg/L N	12	58	12	67
N - TKN	mg/L N	10	100	9	100
oil & grease, mineral	mg/L	11	92	12	83
oil & grease, total	mg/L	7	100	7	100
organic carbon, total	mg/L	10	100	10	100
P - PO4	mg/L	9	100	9	100
P - PO4	mg/L	9	100	9	100
pH	pH	12	100	12	100
sulfide	mg/L	11	100	11	100
suspended solids, total	mg/L	12	100	12	100
temperature	°C	10	100	10	100
Metals - Total					
aluminum	mg/L	12	100	12	100
antimony	mg/L	11	100	11	100
arsenic	mg/L	12	100	12	100
barium	mg/L	11	100	11	100
beryllium	mg/L	12	58	12	25
cadmium	mg/L	12	100	12	100
calcium	mg/L	12	100	12	100
chromium	mg/L	12	100	12	100
chromium VI	mg/L	11	42	11	33
cobalt	mg/L	12	100	12	100
copper	mg/L	11	100	11	100
iron	mg/L	12	100	12	100
lead	mg/L	11	100	11	100

Appendix B5 continued

Parameter Description	Units	Clover		Macaulay	
		n	% Freq	n	% Freq
magnesium	mg/L	12	100	12	100
manganese	mg/L	11	100	11	100
mercury	mg/L	11	67	11	50
molybdenum	mg/L	11	100	11	100
nickel	mg/L	11	100	11	100
phosphorus	mg/L	3	100	3	100
potassium	mg/L	12	100	12	100
selenium	mg/L	12	100	12	100
silver	mg/L	12	100	12	100
sulphate	mg/L	12	100	12	100
thallium	mg/L	12	100	12	100
tin	mg/L	11	100	11	100
zinc	mg/L	11	100	11	100
Metals - Dissolved					
aluminum	mg/L	11	100	11	100
antimony	mg/L	12	100	12	100
arsenic	mg/L	12	100	12	100
barium	mg/L	11	100	11	100
beryllium	mg/L	12	17	12	0
cadmium	mg/L	12	100	12	100
calcium	mg/L	12	100	12	100
chromium	mg/L	12	100	12	100
cobalt	mg/L	12	100	12	100
copper	mg/L	11	100	11	100
iron	mg/L	11	100	11	100
lead	mg/L	12	100	12	100
magnesium	mg/L	11	100	11	100
manganese	mg/L	12	100	12	100
mercury	mg/L	12	67	12	67
molybdenum	mg/L	11	100	11	100
nickel	mg/L	11	100	11	100
phosphorus	mg/L	3	100	3	100
potassium	mg/L	12	100	12	100
selenium	mg/L	12	100	11	100
silver	mg/L	9	100	10	100
sulphate	mg/L	11	100	11	100
thallium	mg/L	12	50	12	0
tin	mg/L	11	100	11	100
zinc	mg/L	11	100	11	100

Appendix B5 continued

Parameter Description	Units	Clover		Macaulay	
		n	% Freq	n	% Freq
Metals - Other					
dibutyltin	mg/L	4	75	4	100
dibutyltin dichloride	mg/L	1	0	1	100
monobutyltin	mg/L	3	25	3	25
monobutyltin trichloride	mg/L	1	0	1	0
tributyltin	mg/L	3	75	3	100
tributyltin chloride	mg/L	2	50	2	100
methyl mercury	ng/mL	3	0	3	0
Aldehydes					
acrolein	mg/L	12	8	12	0
Phenolic Compounds					
total phenols	mg/L	11	100	11	100
Chlorinated Phenolics					
2,4 + 2,5 Dichlorophenol	mg/L	12	17	12	0
2,4,6-trichlorophenol	mg/L	12	17	12	0
2-chlorophenol	mg/L	12	17	12	0
4-chloro-3-methylphenol	mg/L	12	17	12	0
pentachlorophenol	mg/L	12	17	12	0
Non-chlorinated Phenolics					
2,4-dimethylphenol	mg/L	12	17	12	0
2,4-dinitrophenol	mg/L	12	17	12	0
2-methyl-4,6-dinitrophenol	mg/L	12	17	12	0
2-nitrophenol	mg/L	12	17	12	0
4-nitrophenol	mg/L	12	17	12	0
phenol	mg/L	10	100	10	100
Organochlorine Pesticides					
2,4-DDD	mg/L	3	50	4	0
2,4-DDE	mg/L	3	0	4	0
2,4-DDT	mg/L	4	0	2	0
4,4-DDD	mg/L	4	0	4	0
4,4-DDE	mg/L	4	0	4	0
4,4-DDT	mg/L	4	0	4	0
aldrin	mg/L	4	0	4	0
alpha chlordane	mg/L	4	0	4	0
alpha-endosulfan	mg/L	2	0	2	0
alpha-HCH	mg/L	2	0	2	0
beta-endosulfan	mg/L	4	0	4	0
beta-HCH	mg/L	2	0	2	0
chlordane	mg/L	1	0	1	0
delta-HCH	mg/L	2	0	2	0

Appendix B5 continued

Parameter Description	Units	Clover		Macaulay	
		n	% Freq	n	% Freq
dieldrin	mg/L	4	0	4	0
endosulfan sulfate	mg/L	4	0	4	0
endrin	mg/L	4	0	4	0
endrin aldehyde	mg/L	4	0	4	0
gamma chlordane	mg/L	4	0	4	0
heptachlor	mg/L	4	0	4	0
heptachlor epoxide	mg/L	4	0	4	0
gamma HCH	mg/L	4	0	4	0
methoxychlor	mg/L	4	0	4	0
mirex	mg/L	4	0	4	0
octachlorostyrene	mg/L	4	0	4	0
total endosulfan	mg/L	1	0	1	0
toxaphene	mg/L	4	0	4	0
Polychlorinated biphenyls					
PCB Aroclor 1016	mg/L	4	0	4	0
PCB Aroclor 1221	mg/L	4	0	4	0
PCB Aroclor 1232	mg/L	4	0	4	0
PCB Aroclor 1242	mg/L	4	0	4	25
PCB Aroclor 1248	mg/L	4	0	4	0
PCB Aroclor 1254	mg/L	4	0	4	0
PCB Aroclor 1260	mg/L	4	0	4	0
Total Pentachloro Biphenyls	mg/L	4	0	4	25
Polycyclic Aromatic Hydrocarbons					
2-chloronaphthalene	mg/L	12	17	12	0
2-methylnaphthalene	mg/L	11	100	11	100
acenaphthene	mg/L	10	100	10	83
acenaphthylene	mg/L	11	42	11	42
anthracene	mg/L	12	25	12	17
benzo(a)anthracene	mg/L	10	50	10	42
benzo(a)pyrene	mg/L	12	25	11	17
benzo(b)fluoranthene + benzo(j)fluoranthene	mg/L	10	42	11	25
benzo(g,h,i)perylene	mg/L	10	25	10	17
benzo(k)fluoranthene	mg/L	12	42	12	0
chrysene	mg/L	11	67	11	75
dibenzo(a,h)anthracene	mg/L	12	17	12	0
fluoranthene	mg/L	11	67	11	67
fluorene	mg/L	12	75	12	67
indeno(1,2,3-c,d)pyrene	mg/L	11	25	11	17
naphthalene	mg/L	11	75	11	67

Appendix B5 continued

Parameter Description	Units	Clover		Macaulay	
		n	% Freq	n	% Freq
phenanthrene	mg/L	12	75	12	75
pyrene	mg/L	10	50	11	33
total HMW-PAH's	mg/L	10	67	10	67
total LMW-PAH's	mg/L	12	83	12	75
total PAHs	mg/L	11	100	11	83
Semivolatile Organics					
bis(2-ethylhexyl)phthalate	mg/L	9	100	9	100
butylbenzyl phthalate	mg/L	11	17	11	0
diethyl phthalate	mg/L	7	100	7	92
dimethyl phthalate	mg/L	9	17	9	0
di-n-butyl phthalate	mg/L	11	17	11	8
di-n-octyl phthalate	mg/L	12	17	12	0
Misc Semivolatile Organics					
1,2,4-trichlorobenzene	mg/L	4	25	4	0
1,2-diphenylhydrazine	mg/L	12	17	12	8
2,4-dinitrotoluene	mg/L	12	17	12	0
2,6-dinitrotoluene	mg/L	11	17	11	0
3,3-dichlorobenzidine	mg/L	5	17	5	0
4-bromophenyl phenyl ether	mg/L	4	25	4	0
4-chlorophenyl phenyl ether	mg/L	4	25	4	0
benzidine	mg/L	4	25	4	0
bis(2-chloroethoxy)methane	mg/L	4	25	4	0
bis(2-chloroethyl)ether	mg/L	4	25	4	0
bis(2-chloroisopropyl)ether	mg/L	4	25	4	0
hexachlorobenzene	mg/L	4	0	4	0
hexachlorobutadiene	mg/L	4	0	4	0
hexachlorocyclopentadiene	mg/L	3	0	3	0
hexachloroethane	mg/L	4	0	4	0
isophorone	mg/L	12	25	12	0
nitrobenzene	mg/L	11	17	12	0
N-nitrosodimethylamine	mg/L	12	17	12	0
N-nitrosodi-n-propylamine	mg/L	11	17	12	0
N-nitrosodiphenylamine	mg/L	12	17	12	0
Volatile Organic Compounds					
Monocyclic Aromatic Hydrocarbons					
1,2-dichlorobenzene	mg/L	12	8	12	0
1,3-dichlorobenzene	mg/L	12	8	12	0
1,4-dichlorobenzene	mg/L	12	8	12	8
benzene	mg/L	12	8	12	0
chlorobenzene	mg/L	12	8	12	0

Appendix B5 continued

Parameter Description	Units	Clover		Macaulay	
		n	% Freq	n	% Freq
ethylbenzene	mg/L	12	8	12	8
m & p xylenes	mg/L	12	8	12	8
o-xylene	mg/L	12	8	12	8
styrene	mg/L	12	8	12	0
toluene	mg/L	12	92	12	100
xylenes	mg/L	12	8	12	8
aliphatic					
acrylonitrile	mg/L	12	8	12	0
methyl tertiary butyl ether	mg/L	12	8	12	0
Chlorinated Aliphatic					
1,1,1,2-tetrachloroethane	mg/L	12	8	12	0
1,1,1-trichloroethane	mg/L	12	8	12	0
1,1,2,2-tetrachloroethane	mg/L	12	8	12	0
1,1,2-trichloroethane	mg/L	12	8	12	0
1,1-dichloroethane	mg/L	12	8	12	0
1,1-dichloroethene	mg/L	12	8	12	0
1,2-dichloroethane	mg/L	12	8	12	0
1,2-dichloropropane	mg/L	12	8	12	0
bromomethane	mg/L	12	8	12	0
chloroethane	mg/L	12	8	12	0
chloroethene	mg/L	12	8	12	0
chloromethane	mg/L	12	8	12	0
cis-1,2-dichloroethene	mg/L	12	8	12	0
cis-1,3-dichloropropene	mg/L	12	8	12	0
dibromoethane	mg/L	12	8	12	0
dibromomethane	mg/L	12	8	12	0
dichloromethane	mg/L	12	17	12	0
tetrabromomethane	mg/L	12	8	12	0
tetrachloroethene	mg/L	12	8	12	0
tetrachloromethane	mg/L	12	8	12	0
trans-1,2-dichloroethene	mg/L	12	8	12	0
trans-1,3-dichloropropene	mg/L	12	8	12	0
trichloroethene	mg/L	12	8	12	0
trichlorofluoromethane	mg/L	12	8	12	0
Trihalomethanes					
bromodichloromethane	mg/L	12	8	12	0
chlorodibromomethane	mg/L	12	8	12	0
tribromomethane	mg/L	12	8	12	0
trichloromethane	mg/L	12	100	12	100

Appendix B5 continued

Parameter Description	Units	Clover		Macaulay	
		n	% Freq	n	% Freq
Ketones					
4-methyl-2-pentanone	mg/L	12	8	12	0
dimethyl ketone	mg/L	12	100	12	100
endrin ketone	mg/L	4	0	4	0
methyl ethyl ketone	mg/L	12	8	12	8
Terpenes					
alpha-terpineol	mg/L	12	100	12	100

Appendix B6 Mean Concentrations and Loadings of Substances Analyzed in Macaulay Point Wastewater

Substance	Unit	2010 Mean Concentration			Annual Load (kg)
		Freq %	Average	±St Dev	
Conventionals					
alkalinity - total - pH 4.5	mg/L	100	186.1	22.19	n/a
biochemical oxygen demand	mg/L O ₂	100	232.5	28.35	n/a
carbonaceous biochemical oxygen demand	mg/L O ₂	100	185.4	26.32	n/a
chemical oxygen demand	mg/L O ₂	100	481.2	73.57	n/a
chloride	mg/L	100	100.4	53.51	1,604,960
conductivity	µS/cm	100	800.6	217.5	n/a
cyanide, SAD	mg/L	100	0.003208	0.000555	51
cyanide, WAD	mg/L	100	0.001386	0.000336	22
fecal coliform	CFU/100 mL	100	5744000	1500000	n/a
hardness (as CaCO ₃)	mg/L	100	71.7	23.71	n/a
N - NH ₃	mg/L N	100	34.14	5.69	545,882
N - NO ₂	mg/L N	67	0.02044	0.02081	327
N - NO ₃	mg/L N	67	0.08331	0.08028	1,332
N - TKN	mg/L N	100	52.71	6.118	842,774
oil & grease, mineral	mg/L	83	5.81	3.77	92,816
oil & grease, total	mg/L	100	22.71	6.05	363,143
organic carbon, total	mg/L	100	57.2	9.277	914,481
P - PO ₄	mg/L	100	5.02	1.953	80,263
P - PO ₄	mg/L	100	5.769	1.772	92,224
pH	pH	100	7.345	0.267	n/a
sulfide	mg/L	100	0.1621	0.05536	2,592
suspended solids, total	mg/L	100	234.5	29.08	3,749,052
temperature	°C	100	16.89	2.37	n/a
Metals - Total					
aluminum	mg/L	100	0.4609	0.1306	7,368
antimony	mg/L	100	0.0002891	0.0001376	5
arsenic	mg/L	100	0.0005403	0.0001599	9
barium	mg/L	100	0.0223	0.003432	357
beryllium	mg/L	25	---	---	---
cadmium	mg/L	100	0.0003077	0.0001482	5
calcium	mg/L	100	18.62	4.527	297,633
chromium	mg/L	100	0.001872	0.000644	30
chromium VI	mg/L	33	---	---	---
cobalt	mg/L	100	0.0009814	0.0004984	16
copper	mg/L	100	0.1249	0.02448	1,997
iron	mg/L	100	0.5385	0.1032	8,610
lead	mg/L	100	0.004455	0.001119	71
magnesium	mg/L	100	8.681	3.664	138,784
manganese	mg/L	100	0.06128	0.01946	980
mercury	mg/L	50	0.0000233	0.0000267	0
molybdenum	mg/L	100	0.002254	0.002634	36
nickel	mg/L	100	0.004943	0.001901	79
phosphorus	mg/L	100	5.79	0.9967	92,567
potassium	mg/L	100	14.89	2.699	238,128

Appendix B6 continued

Substance	Unit	2010 Mean Concentration			Annual Load (kg)
		Freq %	Average	±StDev	
selenium	mg/L	100	0.0003525	0.0001313	6
silver	mg/L	100	0.0002399	0.0003284	4
sulphate	mg/L	100	23.58	11.45	376,992
thallium	mg/L	100	0.00000561	0.00000095	0
tin	mg/L	100	0.001448	0.001059	23
zinc	mg/L	100	0.09684	0.0136	1,548
Metals - Dissolved					
aluminum	mg/L	100	0.03821	0.004088	611
antimony	mg/L	100	0.0002069	0.0000668	3
arsenic	mg/L	100	0.0003594	0.0001017	6
barium	mg/L	100	0.008082	0.002196	129
beryllium	mg/L	0	---	---	---
cadmium	mg/L	100	0.00007564	0.0000511	1
calcium	mg/L	100	16.33	4.434	261,039
chromium	mg/L	100	0.0011	0.000632	18
cobalt	mg/L	100	0.0007273	0.0003862	12
copper	mg/L	100	0.06481	0.01344	1,036
iron	mg/L	100	0.2719	0.03694	4,347
lead	mg/L	100	0.001048	0.0001997	17
magnesium	mg/L	100	7.717	3.213	123,370
manganese	mg/L	100	0.04717	0.0163	754
mercury	mg/L	67	0.0000125	0.0000038	0
molybdenum	mg/L	100	0.001732	0.001702	28
nickel	mg/L	100	0.003521	0.001683	56
phosphorus	mg/L	100	3.891	0.6708	62,209
potassium	mg/L	100	14.89	2.636	237,991
selenium	mg/L	100	0.0002227	0.0000396	4
silver	mg/L	100	0.0001116	0.00002782	2
sulphate	mg/L	100	20	8.344	319,700
thallium	mg/L	0	---	---	---
tin	mg/L	100	0.000783	0.0001079	13
zinc	mg/L	100	0.02231	0.006181	357
Metals - Other					
dibutyltin	mg/L	100	0.00000542	0.00000796	0
dibutyltin dichloride	mg/L	100	0.000002	0	0
monobutyltin	mg/L	25	---	---	---
monobutyltin trichloride	mg/L	0	---	---	---
tributyltin	mg/L	100	0.00000522	0.00000386	0
tributyltin chloride	mg/L	100	0.00000483	0.00000118	0
methyl mercury	ng/mL	0	---	---	---
Aldehydes					
acrolein	mg/L	0	---	---	---
Phenolic Compounds					
total phenols	mg/L	100	0.04464	0.00963	714
Chlorinated Phenolics					
2,4 + 2,5 Dichlorophenol	mg/L	0	---	---	---
2,4,6-trichlorophenol	mg/L	0	---	---	---
2-chlorophenol	mg/L	0	---	---	---
4-chloro-3-methylphenol	mg/L	0	---	---	---

Appendix B6 continued

Substance	Unit	2010 Mean Concentration			Annual Load (kg)
		Freq %	Average	±StDev	
pentachlorophenol	mg/L	0	---	---	---
Non-chlorinated Phenolics					
2,4-dimethylphenol	mg/L	0	---	---	---
2,4-dinitrophenol	mg/L	0	---	---	---
2-methyl-4,6-dinitrophenol	mg/L	0	---	---	---
2-nitrophenol	mg/L	0	---	---	---
4-nitrophenol	mg/L	0	---	---	---
phenol	mg/L	100	0.02627	0.01451	420
Organochlorine Pesticides					
2,4-DDD	mg/L	0	---	---	---
2,4-DDE	mg/L	0	---	---	---
2,4-DDT	mg/L	0	---	---	---
4,4-DDD	mg/L	0	---	---	---
4,4-DDE	mg/L	0	---	---	---
4,4-DDT	mg/L	0	---	---	---
aldrin	mg/L	0	---	---	---
alpha chlordane	mg/L	0	---	---	---
alpha-endosulfan	mg/L	0	---	---	---
alpha-HCH	mg/L	0	---	---	---
beta-endosulfan	mg/L	0	---	---	---
beta-HCH	mg/L	0	---	---	---
chlordane	mg/L	0	---	---	---
delta-HCH	mg/L	0	---	---	---
dieldrin	mg/L	0	---	---	---
endosulfan sulfate	mg/L	0	---	---	---
endrin	mg/L	0	---	---	---
endrin aldehyde	mg/L	0	---	---	---
gamma chlordane	mg/L	0	---	---	---
heptachlor	mg/L	0	---	---	---
heptachlor epoxide	mg/L	0	---	---	---
gamma HCH	mg/L	0	---	---	---
methoxychlor	mg/L	0	---	---	---
mirex	mg/L	0	---	---	---
octachlorostyrene	mg/L	0	---	---	---
total endosulfan	mg/L	0	---	---	---
toxaphene	mg/L	0	---	---	---
Polychlorinated biphenyls					
PCB Aroclor 1016	mg/L	0	---	---	---
PCB Aroclor 1221	mg/L	0	---	---	---
PCB Aroclor 1232	mg/L	0	---	---	---
PCB Aroclor 1242	mg/L	25	---	---	---
PCB Aroclor 1248	mg/L	0	---	---	---
PCB Aroclor 1254	mg/L	0	---	---	---
PCB Aroclor 1260	mg/L	0	---	---	---
Total Pentachloro Biphenyls	mg/L	25	---	---	---
Polycyclic Aromatic Hydrocarbons					
2-chloronaphthalene	mg/L	0	---	---	---
2-methylnaphthalene	mg/L	100	0.0001045	0.000046	2

Appendix B6 continued

Substance	Unit	2010 Mean Concentration			Annual Load (kg)
		Freq %	Average	±StDev	
acenaphthene	mg/L	83	0.000124	0.0000397	2
acenaphthylene	mg/L	42	---	---	---
anthracene	mg/L	17	---	---	---
benzo(a)anthracene	mg/L	42	---	---	---
benzo(a)pyrene	mg/L	17	---	---	---
benzo(b)fluoranthene + benzo(j)fluoranthene	mg/L	25	---	---	---
benzo(g,h,i)perylene	mg/L	17	---	---	---
benzo(k)fluoranthene	mg/L	0	---	---	---
chrysene	mg/L	75	0.0000664	0.0000541	1
dibenzo(a,h)anthracene	mg/L	0	---	---	---
fluoranthene	mg/L	67	0.0001397	0.0000816	2
fluorene	mg/L	67	0.0002947	0.0003365	5
indeno(1,2,3-c,d)pyrene	mg/L	17	---	---	---
naphthalene	mg/L	67	0.0002855	0.0002039	5
phenanthrene	mg/L	75	0.0002081	0.0000432	3
pyrene	mg/L	33	---	---	---
total HMW-PAH's	mg/L	67	0.0002617	0.0001841	4
total LMW-PAH's	mg/L	75	0.0008847	0.0004972	14
total PAHs	mg/L	83	0.001078	0.0006583	17
Semivolatile Organics					
bis(2-ethylhexyl)phthalate	mg/L	100	0.01644	0.01054	263
butylbenzyl phthalate	mg/L	0	---	---	---
diethyl phthalate	mg/L	92	0.001667	0.001459	27
dimethyl phthalate	mg/L	0	---	---	---
di-n-butyl phthalate	mg/L	8	---	---	---
di-n-octyl phthalate	mg/L	0	---	---	---
Misc Semivolatile Organics					
1,2,4-trichlorobenzene	mg/L	0	---	---	---
1,2-diphenylhydrazine	mg/L	8	---	---	---
2,4-dinitrotoluene	mg/L	0	---	---	---
2,6-dinitrotoluene	mg/L	0	---	---	---
3,3-dichlorobenzidine	mg/L	0	---	---	---
4-bromophenyl phenyl ether	mg/L	0	---	---	---
4-chlorophenyl phenyl ether	mg/L	0	---	---	---
benzidine	mg/L	0	---	---	---
bis(2-chloroethoxy)methane	mg/L	0	---	---	---
bis(2-chloroethyl)ether	mg/L	0	---	---	---
bis(2-chloroisopropyl)ether	mg/L	0	---	---	---
hexachlorobenzene	mg/L	0	---	---	---
hexachlorobutadiene	mg/L	0	---	---	---
hexachlorocyclopentadiene	mg/L	0	---	---	---
hexachloroethane	mg/L	0	---	---	---
isophorone	mg/L	0	---	---	---
nitrobenzene	mg/L	0	---	---	---
N-nitrosodimethylamine	mg/L	0	---	---	---
N-nitrosodi-n-propylamine	mg/L	0	---	---	---
N-nitrosodiphenylamine	mg/L	0	---	---	---

Appendix B6 continued

Substance	Unit	2010 Mean Concentration			Annual Load (kg)
		Freq %	Average	±StDev	
Volatile Organic Compounds					
Monocyclic Aromatic Hydrocarbons					
1,2-dichlorobenzene	mg/L	0	---	---	---
1,3-dichlorobenzene	mg/L	0	---	---	---
1,4-dichlorobenzene	mg/L	8	---	---	---
benzene	mg/L	0	---	---	---
chlorobenzene	mg/L	0	---	---	---
ethylbenzene	mg/L	8	---	---	---
m & p xylenes	mg/L	8	---	---	---
o-xylene	mg/L	8	---	---	---
styrene	mg/L	0	---	---	---
toluene	mg/L	100	0.002917	0.004305	47
xylenes	mg/L	8	---	---	---
aliphatic					
acrylonitrile	mg/L	0	---	---	---
methyl tertiary butyl ether	mg/L	0	---	---	---
Chlorinated Aliphatic					
1,1,1,2-tetrachloroethane					
1,1,1-trichloroethane	mg/L	0	---	---	---
1,1,2,2-tetrachloroethane	mg/L	0	---	---	---
1,1,2-trichloroethane	mg/L	0	---	---	---
1,1-dichloroethane	mg/L	0	---	---	---
1,1-dichloroethene	mg/L	0	---	---	---
1,2-dichloroethane	mg/L	0	---	---	---
1,2-dichloropropane	mg/L	0	---	---	---
bromomethane	mg/L	0	---	---	---
chloroethane	mg/L	0	---	---	---
chloroethene	mg/L	0	---	---	---
chloromethane	mg/L	0	---	---	---
cis-1,2-dichloroethene	mg/L	0	---	---	---
cis-1,3-dichloropropene	mg/L	0	---	---	---
dibromoethane	mg/L	0	---	---	---
dibromomethane	mg/L	0	---	---	---
dichloromethane	mg/L	0	---	---	---
tetrabromomethane	mg/L	0	---	---	---
tetrachloroethene	mg/L	0	---	---	---
tetrachloromethane	mg/L	0	---	---	---
trans-1,2-dichloroethene	mg/L	0	---	---	---
trans-1,3-dichloropropene	mg/L	0	---	---	---
trichloroethene	mg/L	0	---	---	---
trichlorofluoromethane	mg/L	0	---	---	---
Trihalomethanes					
bromodichloromethane	mg/L	0	---	---	---
chlorodibromomethane	mg/L	0	---	---	---
tribromomethane	mg/L	0	---	---	---
trichloromethane	mg/L	100	0.00361	0.00098	58
Ketones					
4-methyl-2-pentanone	mg/L	0	---	---	---
dimethyl ketone	mg/L	100	0.0773	0.0692	1,236

Appendix B6 continued

Substance	Unit	2010 Mean Concentration			Annual Load (kg)
		Freq %	Average	±StDev	
endrin ketone	mg/L	0	---	---	---
methyl ethyl ketone	mg/L	8	---	---	---
Terpenes					
alpha-terpineol	mg/L	100	0.02008	0.00417	321

Note

– concentrations and loadings were not calculated for substances detected ≤50% of the time.

n/a Loadings were not calculated for conventional substances not suited to the calculation (e.g., BOD and conductivity).

Appendix B7 Mean Concentrations and Loadings of Substances Analyzed in Clover Point Wastewater

Substance	Unit	2010 Mean Concentration			Annual Load (kg)
		Freq %	Average	±StDev	
Conventionals					
alkalinity - total - pH 4.5	mg/L	100	149.5	11.83	n/a
biochemical oxygen demand	mg/L O2	100	209.5	27.67	n/a
carbonaceous biochemical oxygen demand	mg/L O2	100	172.4	26.92	n/a
chemical oxygen demand	mg/L O2	100	406.6	57.43	n/a
chloride	mg/L	100	44.97	4.88	801,775
conductivity	µS/cm	100	515.9	32.44	n/a
cyanide, SAD	mg/L	100	0.002928	0.000506	52
cyanide, WAD	mg/L	100	0.001306	0.000397	23
fecal coliform	CFU/100 mL	100	5308000	2104000	n/a
hardness (as CaCO3)	mg/L	100	59.61	11.24	n/a
N - NH3	mg/L N	100	24.79	4.36	441,984
N - NO2	mg/L N	75	0.05478	0.05268	977
N - NO3	mg/L N	58	0.1095	0.07374	1,952
N - TKN	mg/L N	100	36.94	6.045	658,607
oil & grease, mineral	mg/L	92	5.27	2.27	93,959
oil & grease, total	mg/L	100	21.76	3.72	387,961
organic carbon, total	mg/L	100	52.34	10.58	933,176
P - PO4	mg/L	100	3.772	0.6567	67,251
P - PO4	mg/L	100	4.532	0.7218	80,802
pH	pH	100	7.206	0.293	n/a
sulfide	mg/L	100	0.1568	0.06023	2,796
suspended solids, total	mg/L	100	209.1	46.9	3,728,067
temperature	°C	100	18.09	2.144	n/a
Metals - Total					
aluminum	mg/L	100	0.4054	0.05446	7,228
antimony	mg/L	100	0.0003309	0.0002913	6
arsenic	mg/L	100	0.0005494	0.0001315	10
barium	mg/L	100	0.02054	0.003143	366
beryllium	mg/L	58	0.0000128	0.0000092	0.2
cadmium	mg/L	100	0.0002013	0.00005405	4
calcium	mg/L	100	16.67	2.953	297,211
chromium	mg/L	100	0.001269	0.000528	23
chromium VI	mg/L	42	---	---	---
cobalt	mg/L	100	0.0003998	0.0001192	7
copper	mg/L	100	0.1244	0.01513	2,218
iron	mg/L	100	0.5778	0.1138	10,302
lead	mg/L	100	0.005031	0.001089	90
magnesium	mg/L	100	5.876	1.511	104,764
manganese	mg/L	100	0.04506	0.009221	803
mercury	mg/L	67	0.000018	0.0000157	0
molybdenum	mg/L	100	0.001846	0.001122	33
nickel	mg/L	100	0.003483	0.001595	62
phosphorus	mg/L	100	4.381	0.8583	78,109

Appendix B7 continued

Substance	Unit	2010 Mean Concentration			Annual Load (kg)
		Freq %	Average	±StDev	
potassium	mg/L	100	10.86	2.312	193,624
selenium	mg/L	100	0.0003181	0.000086	6
silver	mg/L	100	0.0001831	0.0001267	3
sulphate	mg/L	100	15.62	3.304	278,491
thallium	mg/L	100	0.000006	0.00000091	0
tin	mg/L	100	0.001102	0.0007201	20
zinc	mg/L	100	0.08486	0.01373	1,513
Metals - Dissolved					
aluminum	mg/L	100	0.037	0.004713	660
antimony	mg/L	100	0.0001875	0.0000537	3
arsenic	mg/L	100	0.0003742	0.0000855	7
barium	mg/L	100	0.007438	0.001562	133
beryllium	mg/L	17	---	---	---
cadmium	mg/L	100	0.00003247	0.00002218	1
calcium	mg/L	100	14.76	2.6	263,158
chromium	mg/L	100	0.000478	0.000201	9
cobalt	mg/L	100	0.0002182	0.00006983	4
copper	mg/L	100	0.06318	0.01145	1,126
iron	mg/L	100	0.2744	0.05132	4,892
lead	mg/L	100	0.001102	0.000193	20
magnesium	mg/L	100	5.529	1.22	98,577
manganese	mg/L	100	0.03245	0.00678	579
mercury	mg/L	67	0.0000131	0.0000046	0
molybdenum	mg/L	100	0.001763	0.0009983	31
nickel	mg/L	100	0.001896	0.000452	34
phosphorus	mg/L	100	2.989	0.5564	53,291
potassium	mg/L	100	10.74	1.831	191,485
selenium	mg/L	100	0.0002178	0.000025	4
silver	mg/L	100	0.0001356	0.00005003	2
sulphate	mg/L	100	15.42	4.885	274,925
thallium	mg/L	50	0.00000219	0.00000033	---
tin	mg/L	100	0.0006364	0.0000913	11
zinc	mg/L	100	0.02301	0.007406	410
Metals - Other					
dibutyltin	mg/L	75	0.00000267	0.00000271	0
dibutyltin dichloride	mg/L	0	---	---	---
monobutyltin	mg/L	25	---	---	---
monobutyltin trichloride	mg/L	0	---	---	---
tributyltin	mg/L	75	0.00000189	0.00000069	0
tributyltin chloride	mg/L	50	0.0000035	0.00000259	---
methyl mercury	ng/mL	0	---	---	---
Aldehydes					
acrolein	mg/L	8	---	---	---
Phenolic Compounds					
total phenols	mg/L	100	0.03203	0.00848	571
Chlorinated Phenolics					
2,4 + 2,5 Dichlorophenol	mg/L	17	---	---	---
2,4,6-trichlorophenol	mg/L	17	---	---	---
2-chlorophenol	mg/L	17	---	---	---

Appendix B7 continued

Substance	Unit	2010 Mean Concentration			Annual Load (kg)
		Freq %	Average	±StDev	
4-chloro-3-methylphenol	mg/L	17	---	---	---
pentachlorophenol	mg/L	17	---	---	---
Non-chlorinated Phenolics					
2,4-dimethylphenol	mg/L	17	---	---	---
2,4-dinitrophenol	mg/L	17	---	---	---
2-methyl-4,6-dinitrophenol	mg/L	17	---	---	---
2-nitrophenol	mg/L	17	---	---	---
4-nitrophenol	mg/L	17	---	---	---
phenol	mg/L	100	0.02123	0.02226	379
Organochlorine Pesticides					
2,4-DDD	mg/L	50	0.00003011	0.00001983	---
2,4-DDE	mg/L	0	---	---	---
2,4-DDT	mg/L	0	---	---	---
4,4-DDD	mg/L	0	---	---	---
4,4-DDE	mg/L	0	---	---	---
4,4-DDT	mg/L	0	---	---	---
aldrin	mg/L	0	---	---	---
alpha chlordane	mg/L	0	---	---	---
alpha-endosulfan	mg/L	0	---	---	---
alpha-HCH	mg/L	0	---	---	---
beta-endosulfan	mg/L	0	---	---	---
beta-HCH	mg/L	0	---	---	---
chlordane	mg/L	0	---	---	---
delta-HCH	mg/L	0	---	---	---
dieldrin	mg/L	0	---	---	---
endosulfan sulfate	mg/L	0	---	---	---
endrin	mg/L	0	---	---	---
endrin aldehyde	mg/L	0	---	---	---
gamma chlordane	mg/L	0	---	---	---
heptachlor	mg/L	0	---	---	---
heptachlor epoxide	mg/L	0	---	---	---
gamma HCH	mg/L	0	---	---	---
methoxychlor	mg/L	0	---	---	---
mirex	mg/L	0	---	---	---
octachlorostyrene	mg/L	0	---	---	---
total endosulfan	mg/L	0	---	---	---
toxaphene	mg/L	0	---	---	---
Polychlorinated biphenyls					
PCB Aroclor 1016	mg/L	0	---	---	---
PCB Aroclor 1221	mg/L	0	---	---	---
PCB Aroclor 1232	mg/L	0	---	---	---
PCB Aroclor 1242	mg/L	0	---	---	---
PCB Aroclor 1248	mg/L	0	---	---	---
PCB Aroclor 1254	mg/L	0	---	---	---
PCB Aroclor 1260	mg/L	0	---	---	---
Total Pentachloro	mg/L	0	---	---	---

Appendix B7 continued

Substance	Unit	2010 Mean Concentration			Annual Load (kg)
		Freq %	Average	±StDev	
Biphenyls					
Polycyclic Aromatic Hydrocarbons					
2-chloronaphthalene	mg/L	17	---	---	---
2-methylnaphthalene	mg/L	100	0.0000973	0.0000651	2
acenaphthene	mg/L	100	0.0000997	0.0000433	2
acenaphthylene	mg/L	42	---	---	---
anthracene	mg/L	25	---	---	---
benzo(a)anthracene	mg/L	50	0.000053	0.0000304	---
benzo(a)pyrene	mg/L	25	---	---	---
benzo(b)fluoranthene + benzo(j)fluoranthene	mg/L	42	---	---	---
benzo(g,h,i)perylene	mg/L	25	---	---	---
benzo(k)fluoranthene	mg/L	42	---	---	---
chrysene	mg/L	67	0.0000618	0.0000608	1
dibenzo(a,h)anthracene	mg/L	17	---	---	---
fluoranthene	mg/L	67	0.0001288	0.0000534	2
fluorene	mg/L	75	0.0002469	0.0003519	4
indeno(1,2,3-c,d)pyrene	mg/L	25	---	---	---
naphthalene	mg/L	75	0.0001815	0.0000806	3
phenanthrene	mg/L	75	0.0001922	0.0000473	3
pyrene	mg/L	50	0.00012	0.0000504	---
total HMW-PAH's	mg/L	67	0.000336	0.0003441	6
total LMW-PAH's	mg/L	83	0.0009594	0.001259	17
total PAHs	mg/L	100	0.00131	0.001328	23
Semivolatile Organics					
bis(2-ethylhexyl)phthalate	mg/L	100	0.01207	0.00177	215
butylbenzyl phthalate	mg/L	17	---	---	---
diethyl phthalate	mg/L	100	0.001392	0.001295	25
dimethyl phthalate	mg/L	17	---	---	---
di-n-butyl phthalate	mg/L	17	---	---	---
di-n-octyl phthalate	mg/L	17	---	---	---
Misc Semivolatile Organics					
1,2,4-trichlorobenzene	mg/L	25	---	---	---
1,2-diphenylhydrazine	mg/L	17	---	---	---
2,4-dinitrotoluene	mg/L	17	---	---	---
2,6-dinitrotoluene	mg/L	17	---	---	---
3,3-dichlorobenzidine	mg/L	17	---	---	---
4-bromophenyl phenyl ether	mg/L	25	---	---	---
4-chlorophenyl phenyl ether	mg/L	25	---	---	---
benzidine	mg/L	25	---	---	---
bis(2-chloroethoxy)methane	mg/L	25	---	---	---
bis(2-chloroethyl)ether	mg/L	25	---	---	---
bis(2-chloroisopropyl)ether	mg/L	25	---	---	---
hexachlorobenzene	mg/L	0	---	---	---

Appendix B7 continued

Substance	Unit	2010 Mean Concentration			Annual Load (kg)
		Freq %	Average	±StDev	
hexachlorobutadiene	mg/L	0	---	---	---
hexachlorocyclopentadiene	mg/L	0	---	---	---
hexachloroethane	mg/L	0	---	---	---
isophorone	mg/L	25	---	---	---
nitrobenzene	mg/L	17	---	---	---
N-nitrosodimethylamine	mg/L	17	---	---	---
N-nitrosodi-n-propylamine	mg/L	17	---	---	---
N-nitrosodiphenylamine	mg/L	17	---	---	---
Volatile Organic Compounds					
Monocyclic Aromatic Hydrocarbons					
1,2-dichlorobenzene	mg/L	8	---	---	---
1,3-dichlorobenzene	mg/L	8	---	---	---
1,4-dichlorobenzene	mg/L	8	---	---	---
benzene	mg/L	8	---	---	---
chlorobenzene	mg/L	8	---	---	---
ethylbenzene	mg/L	8	---	---	---
m & p xylenes	mg/L	8	---	---	---
o-xylene	mg/L	8	---	---	---
styrene	mg/L	8	---	---	---
toluene	mg/L	92	0.001389	0.00064	25
xylenes	mg/L	8	---	---	---
aliphatic					
acrylonitrile	mg/L	8	---	---	---
methyl tertiary butyl ether	mg/L	8	---	---	---
Chlorinated Aliphatic					
1,1,1,2-tetrachloroethane	mg/L	8	---	---	---
1,1,1-trichloroethane	mg/L	8	---	---	---
1,1,2,2-tetrachloroethane	mg/L	8	---	---	---
1,1,2-trichloroethane	mg/L	8	---	---	---
1,1-dichloroethane	mg/L	8	---	---	---
1,1-dichloroethene	mg/L	8	---	---	---
1,2-dichloroethane	mg/L	8	---	---	---
1,2-dichloropropane	mg/L	8	---	---	---
bromomethane	mg/L	8	---	---	---
chloroethane	mg/L	8	---	---	---
chloroethene	mg/L	8	---	---	---
chloromethane	mg/L	8	---	---	---
cis-1,2-dichloroethene	mg/L	8	---	---	---
cis-1,3-dichloropropene	mg/L	8	---	---	---
dibromoethane	mg/L	8	---	---	---
dibromomethane	mg/L	8	---	---	---
dichloromethane	mg/L	17	---	---	---
tetrabromomethane	mg/L	8	---	---	---
tetrachloroethene	mg/L	8	---	---	---
tetrachloromethane	mg/L	8	---	---	---
trans-1,2-dichloroethene	mg/L	8	---	---	---
trans-1,3-dichloropropene	mg/L	8	---	---	---

Appendix B7 continued

Substance	Unit	2010 Mean Concentration			Annual Load (kg)
		Freq %	Average	±StDev	
trichloroethene	mg/L	8	---	---	---
trichlorofluoromethane	mg/L	8	---	---	---
Trihalomethanes					
bromodichloromethane	mg/L	8	---	---	---
chlorodibromomethane	mg/L	8	---	---	---
tribromomethane	mg/L	8	---	---	---
trichloromethane	mg/L	100	0.00369	0.00097	66
Ketones					
4-methyl-2-pentanone	mg/L	8	---	---	---
dimethyl ketone	mg/L	100	0.0624	0.0301	1,113
endrin ketone	mg/L	0	---	---	---
methyl ethyl ketone	mg/L	8	---	---	---
Terpenes					
alpha-terpineol	mg/L	100	0.01775	0.00508	316

Note

– concentrations and loadings were not calculated for substances detected ≤50% of the time.

n/a Loadings were not calculated for conventional substances not suited to the calculation (e.g., BOD and conductivity).

APPENDIX C

2010 Surface Water Monitoring

- Appendix C1 Macaulay Point Surface Fecal Coliform Results**
- Appendix C2 Clover Point Surface Fecal Coliform Results**
- Appendix C3 Macaulay Point Surface Fecal Coliform 5 Sampling Events in 30 Days Results**
- Appendix C4 Clover Point Surface Fecal Coliform 5 Sampling Events in 30 Days Results**
- Appendix C5 Clover Point Surface Dissolved Oxygen Results**
- Appendix C6 Clover Point Surface Dissolved Oxygen Results**

Appendix C1 Macaulay Point Surface Fecal Coliform Results, 2010

Results are in CFU/100mL (Shaded results are > 200 CFU/100 mL)

Station ¹	13-Jan	01-Feb	08-Mar	14-Apr	14-May	15-Jun	14-Jul	04-Aug	14-Sep	13-Oct	25-Nov	08-Dec	Geometric Mean ²
Mac-D1	30	48	21	1	2	1	4	1	1	150	28	60	6
Mac-01	23	77	34	1	2	3	7	1	1	530	44	44	9
Mac-02	22	220	38	2	2	6	7	1	4	970	52	35	15
Mac-03	40	87	30	1	1	3	8	1	36	200	53	46	12
Mac-04	28	50	27	4	1	2	1	1	1	190	54	98	7
Mac-05	30	55	38	3	1	1	12	1	1	1500	44	44	9
Mac-06	21	250	51	1	1	7	17	1	1	2100	44	56	12
Mac-07	36	240	21	3	5	8	33	1	1	1300	37	35	16
Mac-08	34	84	37	2	7	4	13	1	13	290	38	28	15
Mac-09	36	48	22	3	1	7	2	1	1	93	44	89	8
Mac-10	30	80	26	1	1	1	2	1	1	10	83	45	5
Mac-11	24	59	30	1	1	4	3	1	1	340	44	89	8
Mac-12	20	56	38	1	1	4	2	1	1	2200	32	76	8
Mac-13	27	200	37	2	3	4	23	1	1	1800	33	49	14
Mac-14	22	30	20	2	3	2	4	1	1	14	29	35	6
Mac-15	31	91	20	4	1	10	7	1	1	860	28	28	10
Mac-16	41	100	29	1	3	7	9	1	1	11	34	21	7
Mac-17	26	45	24	2	1	3	5	1	1	4	42	91	6
Mac-18	26	34	11	1	1	3	3	1	1	4	25	78	4
Mac-19	32	43	22	1	1	1	4	1	4	140	37	51	7
Mac-20	20	27	22	1	3	6	1	1	11	2500	38	66	11
Mac-21	24	140	50	1	5	1	1	1	2	1100	33	21	8
Mac-22	46	74	1	57	9	5	6	2	6	10	27	28	11
Mac-23	38	21	1	71	2	8	4	1	12	10	29	28	8
Mac-24	40	49	3	44	4	4	5	1	4	17	41	34	10
Mac-25	47	71	21	3	3	10	11	1	9	90	22	31	13
Mac-26	53	200	27	60	2	8	34	1	570	39	25	41	26
Mac-27	69	60	14	6	1	14	14	1	1	5	21	40	8
Mac-28	69	56	15	4	1	2	5	1	1	9	31	57	6
Mac-29	73	32	17	1	1	4	2	1	1	8	36	44	5
Mac-30	47	43	13	8	4	3	2	1	3	8	45	48	8
Mac-31	44	61	8	1	4	1	1	1	2	5	14	22	4
Mac-32	22	52	17	1	4	1	4	1	2	14	58	13	6
Mac-33	31	59	250	1	4	1	2	2	1	1600	54	64	11
Mac-34	14	39	26	1	1	5	2	1	2	2300	23	66	8
Mac-35	16	48	26	2	4	1	3	1	1	4	25	14	5
Mac-36	17	38	8	2	5	4	1	1	5	7	29	24	6
Mac-37	29	32	2	2	4	1	2	1	2	15	27	18	5

Note

¹ Mac = Macaulay Point surface water station identifier (refer to Figure 3.1 for locations).

² when values was <1, 0.5 was substituted for calculation of geometric mean

³ Station denotes a visible plume surfacing event

Appendix C2 Clover Point Surface Fecal Coliform Results, 2010

Results are in CFU/100mL (Shaded results are > 200 CFU/100 mL)

Station ¹	14-Jan	01-Feb	11-Mar	13-Apr	15-May	16-Jun	13-Jul	05-Aug	13-Sep	12-Oct	24-Nov	06-Dec	Geometric mean ²
Clo-D1	29	22	29	29	---	24	< 1	< 1	20	3	16	270	14
Clo-01	55	8	24	14	3	14	6	< 1	21	10	20	510	14
Clo-02	38	20	8	18	8	8	5	< 1	22	6	24	260	13
Clo-03	41	11	20	6	6	21	14	< 1	15	6	27	460	15
Clo-04	49	12	18	4	4	7	9	< 1	14	5	19	380	11
Clo-05	38	18	3	11	8	14	6	< 1	28	6	19	340	12
Clo-06	49	9	6	18	4	26	6	< 1	37	11	15	230	13
Clo-07	37	11	17	27	3	22	13	< 1	27	5	23	350	15
Clo-08	55	15	42	8	3	14	15	< 1	20	5	30	360	15
Clo-09	45	15	52	14	3	13	3	< 1	25	10	35	390	16
Clo-10	48	15	5	21	8	4	9	< 1	23	5	21	94	11
Clo-11	53	16	7	6	4	13	2	< 1	20	17	20	210	11
Clo-12	47	14	6	11	9	13	5	< 1	34	14	25	210	13
Clo-13	48	37	2	6	4	24	5	< 1	41	12	24	270	
Clo-14	43	200	20	27	6	4	18	< 1	14	16	21	240	18
Clo-15	41	98	20	12	14	3	15	< 1	40	4	29	100	15
Clo-16	45	48	38	7	5	14	37	< 1	110	4	34	370	21
Clo-17	47	16	23	< 1	7	4	14	< 1	57	6	24	900	14
Clo-18	72	19	21	6	6	5	4	< 1	21	14	36	35	11
Clo-19	48	19	37	4	5	4	< 1	< 1	25	20	26	100	10
Clo-20	46	20	12	11	8	12	4	< 1	32	40	48	92	16
Clo-21	56	24	11	17	7	26	< 1	< 1	20	10	71	310	15
Clo-22	30	14	18	24	2	21	2	4	26	12	24	85	14
Clo-23	31	41	20	30	10	6	9	2	32	9	46	31	16
Clo-24	30	36	22	19	22	< 1	9	< 1	50	5	36	75	14
Clo-25	34	64	32	14	6	13	7	< 1	200	4	32	350	19
Clo-26	100	55	110	10	8	3	7	< 1	150	5	37	550	22
Clo-27	47	24	30	< 1	4	32	9	< 1	170	29	32	960	19
Clo-28	27	20	29	< 1	< 1	39	6	< 1	410	30	35	420	16
Clo-29	19	20	21	< 1	< 1	14	8	< 1	120	33	37	27	10
Clo-30	27	20	29	11	8	22	6	< 1	31	2300	32	26	22
Clo-31	40	7	19	10	10	< 1	4	< 1	36	28	6	21	8
Clo-32	34	11	24	10	11	3	3	< 1	31	10	8	26	9
Clo-33	44	12	3	12	16	2	< 1	< 1	17	14	8	33	7
Clo-34	65	18	5	7	19	5	< 1	< 1	18	13	35	110	10
Clo-35	50	12	14	3	7	8	< 1	< 1	32	12	34	100	10
Clo-36	39	27	10	18	26	14	3	< 1	18	51	66	72	18
Clo-37	37	15	18	31	25	14	5	2	57	15	54	30	18

Note

¹ Clo = Clover Point surface water station identifier (refer to Figure 3.1 for locations).

² when values was <1, 0.5 was substituted for calculation of geometric mean

Appendix C3 Macaulay Point Surface Fecal Coliform 5 Sampling Events in 30 Days Results, 2010
Results are in CFU/100mL

Stations	15-Jun	23-Jun	29-Jun	05-Jul	14-Jul	Geometric mean
Mac-D1	1	2	1	7	4	2
Mac-01	3	4	2	5	7	4
Mac-02	6	1	1	3	7	3
Mac-03	3	1	3	3	8	3
Mac-04	2	2	1	3	1	2
Mac-05	1	3	3	4	12	3
Mac-06	7	2	1	4	17	4
Mac-07	8	2	2	7	33	6
Mac-08	4	1	2	5	13	3
Mac-09	7	5	1	3	2	3
Mac-10	1	6	2	5	2	3
Mac-11	4	2	2	4	3	3
Mac-12	4	2	1	7	2	3
Mac-13	4	4	3	3	23	5
Mac-14	2	2	3	3	4	3
Mac-15	10	1	1	3	7	3
Mac-16	7	8	1	2	9	4
Mac-17	3	5	3	4	5	4
Mac-18	3	4	1	4	3	3
Mac-19	1	4	1	4	4	2
Mac-20	6	2	1	3	1	2
Mac-21	1	1	3	6	1	2
Mac-22	5	2	14	6	6	6
Mac-23	8	1	1	6	4	3
Mac-24	4	1	1	6	5	3
Mac-25	10	4	3	4	11	6
Mac-26	8	9	2	3	34	7
Mac-27	14	1	1	2	14	3
Mac-28	2	1	2	4	5	2
Mac-29	4	1	1	1	2	2
Mac-30	3	4	1	6	2	3
Mac-31	1	1	1	2	1	1
Mac-32	1	3	2	4	4	2
Mac-33	1	5	2	4	2	2
Mac-34	5	3	6	3	2	4
Mac-35	1	1	10	9	3	3
Mac-36	4	1	2	7	1	2
Mac-37	1	1	11	6	2	3

Appendix C4 Clover Point Surface Fecal Coliform 5 Sampling Events in 30 Days Results, 2010
Results are in CFU/100mL

Station	16-Jun	22-Jun	28-Jun	6-Jul	13-Jul	Geometric Mean
Clo-01	14	30	7	1	6	7
Clo-02	8	35	6	1	5	6
Clo-03	21	1	16	1	14	5
Clo-04	7	5	12	1	9	5
Clo-05	14	39	13	1	6	8
Clo-06	26	25	12	1	6	9
Clo-07	22	14	6	4	13	10
Clo-08	14	6	7	1	15	6
Clo-09	13	2	4	1	3	3
Clo-10	4	4	1	1	9	3
Clo-11	13	15	7	1	2	5
Clo-12	13	30	13	1	5	8
Clo-13	24	35	8	2	5	9
Clo-14	4	36	11	11	18	13
Clo-15	3	1	3	2	15	3
Clo-16	14	4	2	1	37	5
Clo-17	4	4	3	2	14	4
Clo-18	5	7	2	4	4	4
Clo-19	4	2	4	2	1	2
Clo-20	12	34	12	1	4	7
Clo-21	26	33	1	10	1	6
Clo-22	21	16	13	4	2	8
Clo-23	6	17	8	9	9	9
Clo-24	1	100	5	11	9	9
Clo-25	13	31	7	4	7	10
Clo-26	3	4	2	1	7	3
Clo-27	32	1	1	1	9	3
Clo-28	39	1	1	1	6	3
Clo-29	14	1	1	2	8	3
Clo-30	22	3	11	3	6	7
Clo-31	1	3	4	3	4	3
Clo-32	3	1	3	5	3	3
Clo-33	2	3	4	1	1	2
Clo-34	5	9	4	4	1	4
Clo-35	8	25	3	11	1	6
Clo-36	14	45	7	11	3	11
Clo-37	14	15	10	4	5	8

Appendix C5 Macaulay Point Surface Dissolved Oxygen Results, 2010

Results are in mg/L DO

MACAULAY POINT 2010 DISSOLVED OXYGEN DAILY DATA															
Station	2010 Jan 13	2010 Feb 03	2010 Mar 08	2010 Apr 14	2010 May 14	2010 Jun 15	2010 Jun 23	2010 Jun 29	2010 Jul 05	2010 Jul 14	2010 Aug 04	2010 Sep 14	2010 Oct 13	2010 Nov 25	2010 Dec 08
Mac-BK	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Mac-00	---	---	---	---	---	---	---	---	---	---	---	5.97	---	---	---
Mac-D0	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Mac-D1	---	8.29	8.46	---	8.23	7.01	6.91	7.03	7.76	6.83	---	6.16	6.38	---	7.89
Mac-01	---	8.36	8.39	8.93	8.11	6.99	6.91	7.1	7.74	6.77	---	6.35	6.02	---	7.91
Mac-02	---	8.34	8.52	8.93	8.15	7.12	7.04	7.19	7.91	6.93	---	6.44	6.29	---	8.07
Mac-03	---	8.37	8.42	8.94	8.1	7.08	7.12	7.05	7.76	7.01	---	6.23	6.27	---	7.94
Mac-04	---	8.39	8.56	8.91	8.14	7.12	7.12	7.18	7.8	6.98	---	6.19	6.24	---	7.92
Mac-05	---	8.26	8.56	8.92	8.15	7.05	7.02	7.14	7.77	6.87	---	6.22	6.12	---	7.99
Mac-06	---	8.34	8.41	8.98	8.06	7.1	7.04	7.14	7.79	6.93	---	6.3	6.24	---	7.91
Mac-07	---	8.33	8.54	8.98	7.95	7.12	7.1	7.12	7.78	6.82	---	6.11	6.24	---	8.
Mac-08	---	8.4	8.5	8.96	8.09	7.12	7.06	7.08	7.83	6.94	---	6.3	6.35	---	7.97
Mac-09	---	8.33	8.56	8.92	8.11	7.01	7.03	7.12	7.91	6.83	---	6.3	6.07	---	8.02
Mac-10	---	8.31	8.5	8.94	7.94	7.08	6.97	7.05	7.94	6.95	---	6.47	6.39	---	7.97

Appendix C5, continued

MACAULAY POINT 2010 DISSOLVED OXYGEN DAILY DATA															
Station	2010 Jan 13	2010 Feb 03	2010 Mar 08	2010 Apr 14	2010 May 14	2010 Jun 15	2010 Jun 23	2010 Jun 29	2010 Jul 05	2010 Jul 14	2010 Aug 04	2010 Sep 14	2010 Oct 13	2010 Nov 25	2010 Dec 08
Mac-11	---	8.32	8.42	8.94	8.13	7.06	6.91	7.21	7.86	7.02	---	6.43	6.21	---	7.98
Mac-12	---	8.37	8.51	8.97	8.14	6.98	6.84	7.11	7.83	6.95	---	6.2	6.23	---	7.97
Mac-13	---	8.36	8.5	8.95	8.07	7.08	6.87	7.12	7.8	6.96	---	6.13	6.33	---	8.06
Mac-14	---	8.2	8.5	8.9	8.81	7.02	6.86	7.15	7.89	7.09	---	6.36	6.2	---	7.9
Mac-15	---	8.23	8.4	8.91	8.41	7.1	7.01	7.09	7.81	7.03	---	6.22	6.31	---	8.04
Mac-16	---	8.31	8.36	8.91	8.08	6.99	6.88	6.92	8.04	6.9	---	6.27	6.32	---	8.1
Mac-17	---	8.35	8.4	8.95	8.06	7.01	6.89	6.93	7.82	6.84	---	6.17	6.32	---	7.9
Mac-18	---	8.34	8.45	8.89	8.21	7.04	6.81	7.12	7.85	6.83	---	6.25	6.19	---	7.92
Mac-19	---	8.26	8.41	8.91	8.13	7.06	6.79	7.15	7.78	6.93	---	6.09	6.3	---	7.88
Mac-20	---	8.33	8.5	8.91	8.15	7.01	6.71	7.21	---	6.94	---	6.14	6.16	---	7.93
Mac-21	---	8.33	8.5	8.94	8.05	7.03	6.92	7.12	7.87	7.37	---	5.97	6.32	---	7.96
Mac-22	---	8.28	8.55	8.72	8.61	7.1	6.97	7.27	7.77	7.21	---	6.18	6.3	---	8.
Mac-23	---	8.36	8.55	8.75	9.23	7.05	6.97	7.18	7.81	7.26	---	6.22	6.33	---	8.07
Mac-24	---	8.31	8.5	8.8	9.06	9.08	7.05	7.16	7.79	7.28	---	6.17	6.26	---	8.07
Mac-25	---	8.3	8.5	8.85	8.7	7.61	6.96	6.99	7.87	6.95	---	6.18	6.32	---	7.81

Appendix C5, continued

MACAULAY POINT 2010 DISSOLVED OXYGEN DAILY DATA															
Station	2010 Jan 13	2010 Feb 03	2010 Mar 08	2010 Apr 14	2010 May 14	2010 Jun 15	2010 Jun 23	2010 Jun 29	2010 Jul 05	2010 Jul 14	2010 Aug 04	2010 Sep 14	2010 Oct 13	2010 Nov 25	2010 Dec 08
Mac-26	---	8.3	8.4	8.9	8.46	6.98	6.97	7.	7.94	6.92	---	6.01	6.31	---	8.17
Mac-27	---	8.39	8.4	8.93	8.05	6.95	7.08	7.08	7.85	6.95	---	6.31	6.18	---	8.
Mac-28	---	8.33	8.45	8.94	7.82	6.88	7.06	7.11	7.87	6.87	---	6.14	6.	---	7.99
Mac-29	---	8.29	8.52	8.93	---	7.09	6.97	7.1	7.92	6.91	---	6.26	6.22	---	7.93
Mac-30	---	8.22	8.45	8.88	---	7.01	6.73	7.05	7.7	7.21	---	6.29	6.1	---	7.86
Mac-31	---	8.31	8.45	8.94	---	7.11	6.79	7.18	7.77	---	---	6.16	6.42	---	7.75
Mac-32	---	8.3	8.4	9.	---	7.07	6.82	7.3	7.8	---	---	5.92	6.27	---	7.92
Mac-33	---	8.4	8.4	8.88	---	7.09	6.73	7.09	7.88	7.13	---	5.91	6.23	---	7.78
Mac-34	---	8.29	8.55	8.92	8.13	6.98	6.82	7.14	7.83	6.97	---	6.21	6.03	---	7.91
Mac-35	---	8.3	8.48	8.93	9.17	7.11	6.94	7.09	7.74	7.32	---	6.3	6.3	---	8.06
Mac-36	---	8.31	8.55	8.95	8.55	7.09	6.89	7.19	7.75	7.61	---	5.89	6.43	---	8.1
Mac-37	---	8.29	8.5	9.02	8.35	7.14	6.97	7.14	7.81	7.48	---	6.	6.41	---	8.04

Appendix C6 Clover Point Surface Dissolved Oxygen Results, 2010

Results are in mg/L DO

CLOVER POINT 2010 DISSOLVED OXYGEN DAILY DATA.															
Station	2010 Jan 12	2010 Feb 01	2010 Mar 11	2010 Apr 13	2010 May 13	2010 Jun 16	2010 Jun 22	2010 Jun 28	2010 Jul 06	2010 Jul 13	2010 Aug 03	2010 Sep 13	2010 Oct 12	2010 Nov 23	2010 Dec 06
Clo-BK	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Clo-00	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Clo-D0	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Clo-D1	---	8.21	8.71	8.8	---	6.83	---	6.42	7.94	6.37	---	6.23	6.44	---	7.91
Clo-01	---	8.23	8.74	8.79	8.42	6.97	7.	6.36	7.95	6.49	---	6.07	6.32	---	7.9
Clo-02	---	8.11	8.66	8.79	8.22	6.97	7.37	6.5	7.93	6.62	---	6.21	6.33	---	7.94
Clo-03	---	8.29	8.69	8.88	8.41	6.96	7.28	6.3	7.9	6.56	---	6.08	6.4	---	7.87
Clo-04	---	8.24	8.7	8.85	8.32	6.97	7.12	6.37	8.01	6.3	---	6.05	6.31	---	7.94
Clo-05	---	8.25	8.68	8.88	8.18	7.06	7.04	6.49	7.98	6.42	---	5.93	6.29	---	7.92
Clo-06	---	8.33	8.7	8.81	8.33	6.92	7.15	6.47	7.72	6.57	---	6.09	6.41	---	7.85
Clo-07	---	8.2	8.76	8.84	8.52	6.95	7.15	6.43	7.8	6.62	---	6.18	6.35	---	7.97
Clo-08	---	8.29	8.67	8.84	8.48	6.99	7.22	6.41	7.89	6.41	---	6.14	6.4	---	7.84
Clo-09	---	8.41	8.58	8.81	8.31	7.01	7.05	6.4	8.03	6.59	---	5.99	6.38	---	7.76
Clo-10	---	8.3	8.61	8.78	8.16	7.09	7.09	6.48	7.98	6.35	---	6.2	6.38	---	7.81

Appendix C6, continued

CLOVER POINT 2010 DISSOLVED OXYGEN DAILY DATA.															
Station	2010 Jan 12	2010 Feb 01	2010 Mar 11	2010 Apr 13	2010 May 13	2010 Jun 16	2010 Jun 22	2010 Jun 28	2010 Jul 06	2010 Jul 13	2010 Aug 03	2010 Sep 13	2010 Oct 12	2010 Nov 23	2010 Dec 06
Clo-11	---	8.35	8.68	8.83	8.2	7.01	7.05	6.42	7.93	6.38	---	5.85	6.43	---	7.86
Clo-12	---	8.38	8.63	8.86	8.37	7.01	7.19	6.43	7.88	6.5	---	6.19	6.29	---	7.91
Clo-13	---	8.12	8.63	8.91	8.48	6.93	7.11	6.53	7.87	6.63	---	5.92	6.3	---	7.82
Clo-14	---	8.19	8.85	8.76	8.48	6.96	7.14	6.42	7.85	6.56	---	6.07	6.19	---	7.77
Clo-15	---	8.15	8.76	8.81	8.34	6.92	7.08	6.43	7.91	6.42	---	6.28	6.36	---	7.82
Clo-16	---	8.24	8.6	8.81	8.21	6.98	7.05	6.5	8.03	6.52	---	6.22	6.4	---	7.88
Clo-17	---	8.29	8.66	8.83	8.14	6.9	6.98	6.39	7.93	6.09	---	6.11	6.45	---	7.84
Clo-18	---	8.32	8.6	8.86	8.38	7.02	7.21	6.35	7.75	6.43	---	6.05	6.28	---	7.75
Clo-19	---	8.27	8.65	8.86	8.45	7.12	7.01	6.41	7.88	6.47	---	5.99	6.51	---	7.82
Clo-20	---	8.5	8.67	8.84	8.44	6.99	7.06	6.43	7.87	6.64	---	5.84	6.11	---	7.92
Clo-21	---	8.23	8.68	8.84	8.31	7.11	7.02	6.44	7.71	6.7	---	5.88	6.26	---	7.92
Clo-22	---	8.39	8.83	8.83	8.69	7.02	7.38	6.69	8.33	7.09	---	6.18	6.42	---	7.8
Clo-23	---	8.31	8.71	8.88	8.17	6.9	7.41	6.37	7.79	6.79	---	6.23	6.25	---	7.83
Clo-24	---	8.39	8.63	8.86	8.2	7.04	7.2	6.44	7.86	6.6	---	6.07	6.36	---	7.85
Clo-25	---	8.34	8.62	8.83	8.21	6.89	7.12	6.4	7.98	6.46	---	6.2	6.18	---	7.7

Appendix C6, continued

CLOVER POINT 2010 DISSOLVED OXYGEN DAILY DATA.															
Station	2010 Jan 12	2010 Feb 01	2010 Mar 11	2010 Apr 13	2010 May 13	2010 Jun 16	2010 Jun 22	2010 Jun 28	2010 Jul 06	2010 Jul 13	2010 Aug 03	2010 Sep 13	2010 Oct 12	2010 Nov 23	2010 Dec 06
Clo-26	---	8.34	8.61	8.82	8.16	7.03	6.9	6.43	7.97	6.62	---	6.2	6.23	---	7.87
Clo-27	---	8.29	8.62	8.77	8.05	6.87	7.28	6.44	8.02	6.44	---	6.22	6.33	---	7.9
Clo-28	---	8.07	8.62	8.77	8.38	6.9	7.22	6.47	7.67	6.47	---	6.06	6.19	---	7.81
Clo-29	---	8.29	8.65	8.9	8.3	6.92	7.3	6.44	7.77	6.29	---	6.13	6.03	---	7.99
Clo-30	---	8.1	8.61	8.75	7.86	6.96	7.16	6.43	7.8	6.36	---	5.82	6.24	---	7.82
Clo-31	---	8.13	8.65	8.79	7.76	7.07	7.13	6.45	7.8	---	---	5.8	6.2	---	7.83
Clo-32	---	8.2	8.64	8.86	7.89	7.14	6.94	6.54	7.87	6.34	---	5.97	6.38	---	7.89
Clo-33	---	8.17	8.7	8.83	7.79	7.09	7.05	6.51	7.94	6.63	---	6.06	6.28	---	7.76
Clo-34	---	8.56	8.64	8.86	7.85	7.19	7.27	6.54	7.72	6.61	---	6.08	6.28	---	7.84
Clo-35	---	8.36	8.63	8.9	8.43	6.99	7.08	6.57	7.83	6.87	---	5.94	6.21	---	7.84
Clo-36	---	8.37	8.68	8.81	8.16	6.98	7.02	6.62	7.85	6.81	---	6.03	6.32	---	7.83
Clo-37	---	8.14	9.04	8.9	8.11	7.27	7.32	6.79	8.17	7.29	---	6.22	6.19	---	7.7

APPENDIX D

Sediment Chemistry Monitoring

**Appendix D1 Sediment Chemistry Quality Assurance and Quality Control
Methods and Results**

Appendix D2 Macaulay and Clover Points Sediment Chemistry Results

Appendix D1 Sediment Chemistry Quality Assurance and Quality Control Methods and Results

METHODS

Field quality assurance and quality control (QA/QC) methods are detailed in CRD (2009f). In short, field procedures followed the Puget Sound Ambient Monitoring program (PSAMP, 2002) protocols and guidelines. These regionally developed protocols standardize marine sampling techniques and help to reduce variability between sampling events.

Rigorous QA/QC procedures were employed for mussel chemistry analyses. Approximately ten percent of the samples were identified for field and laboratory QA/QC, which consisted of the following procedures:

- analysis of a field triplicate (i.e., three replicate samples were collected in the field for an individual station)
- analysis of a laboratory triplicate (i.e., a sample was split by the laboratory into triplicate samples for analysis)
- analysis of one standard reference material (SRM); or, when reference materials were not available, analysis of a spiked sample (i.e., not a spiked blank)
- analysis of reference or surrogate standards spiked into each sample

All data reported to the CRD was uncorrected for blank or deuterated recoveries. Replicate (both field and laboratory triplicates) analyses were reported as the relative standard deviation (RSD) if the results were greater than or equal to 5x the detection limit, or standard deviation if the results were less than 5x the detection limit. RSD was calculated as follows:

$$\text{RSD} = \frac{\text{standard deviation concentration of replicate samples}}{\text{mean concentration of replicate samples}} \times 100\%$$

All 2010 results were screened using the revised CRD QA/QC Assessment Procedure (Golder, 2007d; CRD, 2009f). This procedure is based on data quality objectives (DQOs) that were originally developed with the MMAG in the early 1990s, following established laboratory analytical standards, but were re-evaluated and updated with new DQOs in 2007 (Golder, 2007d). The reassessment of the procedure was undertaken after a higher than usual number of QA/QC requirement failures was observed for the 2005 sediment and mussel tissue chemistry results.

Applying the revised DQOs involved procedures that evaluated the data for precision (based on variability in laboratory or field replicates), bias (based on recoveries of spikes, surrogate standards or certified reference materials), and representativeness (based on blank sample contamination) using specific criteria for each analytical group. The extremity of precision, bias or representativeness failures were determined, and data with moderate failures were flagged, while data with severe failures were rejected. All data that exhibited failures were questioned and a determination of the causes was undertaken. Rejected results are not presented in this report and are not used for further analyses (e.g., statistical analyses). Appendix A4 presents a detailed summary of the revised CRD QA/QC Assessment Procedures, and a description of the data flags (Golder, 2007d).

Sediment chemistry analyses of total metals, PAHs, chlorinated hydrocarbons, halogenated and non-halogenated volatiles, base-neutral extractables, and phthalate esters were conducted by ALS in five batches. Table D1-1 lists the sites analyzed in each batch. Each batch had associated blank and matrix spike samples that were used to assess DQOs for representativeness and bias on a batch-wide basis. All batches had laboratory replicates and field replicates that were used to assess precision.

RESULTS

Table D1-2 contains a summary of the results of the application of the revised QA/QC Assessment Procedure to modified and full priority substance batches; CRD (2009f) contains more detailed information about how the data flags were determined. The substances that did not meet the DQOs in 2009 are identified by "QA" in table D2 and were rejected for use in statistical analysis. All remaining sediment analysis results passed both laboratory and DQOs (i.e., analyte spikes, method blanks, laboratory triplicates, field triplicates and standard reference materials) (CRD, 2009f).

Appendix D1-1 Summary of Batch Information for 2010 Sediment Data

Sediment Data			
Station	ALS – Sample Type	Station	Axys – Sample Type
Batch 1		PCB 1A (WG34092)	
M0	SS	M100E	SS (Top 10cm)
PB	FR1	PB1	FR1 (Top 10cm)
PB	FR2	PB1	FR2 (Top 10cm)
PB	FR3	PCB 1B (WG34160)	
PB (Top 10cm)	FR1	PB1	FR3 (Top 10cm)
PB (Top 10cm)	FR2	PAH 1A (WG34093)	
PB (Top 10cm)	FR3	M2E	SS (Top 10cm)
C0	SS	M8E	SS (Top 10cm)
CB	SS	PB1	FR1 (Top 10cm)
CB	LR1	PB1	FR2 (Top 10cm)
CB	LR2	PB1	FR3 (Top 10cm)
Batch 2		PAH 1B (WG34732)	
M100E	SS, LR1, LR2, Recheck	M1E	SS (Top 10cm)
M100N	FR1, Recheck	NP 1A (WG34179)	
M100N	FR2, Recheck	M1E	SS (Top 10cm)
M100N	FR3, Recheck	NP 1B (WG34780)	
M100NE	SS, Recheck	PB1	FR1 (Top 10cm)
M100NW	SS	PB1	FR2 (Top 10cm)
M100S	SS, Recheck	PB1	FR3 (Top 10cm)
M100SE	SS, Recheck	OC Pest E1 (WG34895)	
Batch 3		M1E	SS (Top 10cm)
M100SW	SS, LR1, LR2, Recheck	M2E	SS (Top 10cm)
M100W	FR1, Recheck	M8E	SS (Top 10cm)
M100W	FR2, Recheck	PB1	FR1 (Top 10cm)
M100W	FR3, Recheck	PB1	FR2 (Top 10cm)
M200E	SS	PB1	FR3 (Top 10cm)
M200N	SS	OC Pest E2 1A (WG34090)	
M200NE	SS	M1E	SS (Top 10cm)
M200NW	SS, Recheck	M2E	SS (Top 10cm)
PB5	SS	M8E	SS (Top 10cm)
Batch 4		PB1	FR1 (Top 10cm)
M400E	SS, LR1, LR2, Recheck	PB1	FR2 (Top 10cm)
M200SE	FR1, Recheck	OC Pest E2 1B (WG34895)	
M200SE	FR2, Recheck	PB1	FR3 (Top 10cm)
M200SE	FR3, Recheck	PBDE (WG34091)	
M200E (Top 10cm)	SS, Recheck	M1E	SS (Top 10cm)
M200E (Top 10cm)	SS, Recheck	M2E	SS (Top 10cm)
M200SW	SS	M8E	SS (Top 10cm)
M200W	SS	PB1	FR1 (Top 10cm)
M200S	SS	PB1	FR2 (Top 10cm)
M400SE	SS, Recheck	PB1	FR3 (Top 10cm)
Batch 5			
PB2	SS, LR1, LR2, Recheck		
M400W	FR1		
M400W	FR2		
M400W	FR3		
M800E	SS, Recheck		
M800W	SS		
M400SW	SS		
M100E (Top 10cm)	SS		
PB3	SS		
PB4	SS		

Appendix D1-2 Summary of DQO Failures and Data Qualifiers for the 2010 Sediment Data

[illegible]

Appendix D1-2, continued

[illegible]

Appendix D1-2, continued

[illegible]

Appendix D1-2, continued

[illegible]

Note

R flag: Severe DQO failure; rejected data

J+ flag: Value is an estimate with potential high bias

UN flag: Value was not detected, possible false negative

Shaded: These substances were not measured in batches 2 to 5

J flag: Value is an estimate

J- flag: Value is an estimate with potential low bias

U flag: Value was not detected (no DQO failure)

Appendix D1-3 Summary of DQO Failures and Data Qualifiers for the 2010 High-Resolution PCB Sediment Data

Parameters	BATCH WIDE FLAGS			
	PCB Batch 1A (WG34092)		PCB Batch 1B (WG34160)	
	Detects	Non-Detects	Detects	Non-Detects
PCB 1	•	•	•	•
PCB 2	•	•	•	•
PCB 3	J+	U	J+	U
PCB 4	•	•	•	•
PCB 5	•	•	•	•
PCB 6	•	•	•	•
PCB 7	•	•	•	•
PCB 8	•	•	•	•
PCB 9	•	•	•	•
PCB 10	•	•	•	•
PCB 11	•	•	R	U
PCB 12/13	•	•	•	•
PCB 14	•	•	•	•
PCB 15	•	•	•	•
PCB 16	•	•	•	•
PCB 17	•	•	•	•
PCB 18/30	•	•	•	•
PCB 19	J+	U	•	•
PCB 20/28	•	•	•	•
PCB 21/23	•	•	•	•
PCB 22	•	•	•	•
PCB 23	•	•	•	•
PCB 24	•	•	•	•
PCB 25	•	•	•	•
PCB 26/29	•	•	•	•
PCB 27	•	•	•	•
PCB 31	•	•	•	•
PCB 32	•	•	•	•
PCB 34	•	•	•	•
PCB 35	•	•	•	•
PCB 36	•	•	•	•
PCB 37	•	•	•	•
PCB 38	•	•	•	•
PCB 39	•	•	•	•
PCB 40/41/71	•	•	•	•
PCB 42	•	•	•	•
PCB 43	•	•	•	•
PCB 44/47/65	•	•	•	•
PCB 45/51	•	•	•	•
PCB 46	•	•	•	•
PCB 48	•	•	•	•
PCB 49/69	•	•	•	•
PCB 50/53	•	•	•	•
PCB 52	•	•	•	•

Appendix D1-3 continued

Parameters	BATCH WIDE FLAGS			
	PCB Batch 1A (WG34092)		PCB Batch 1B (WG34160)	
	Detects	Non-Detects	Detects	Non-Detects
PCB 54	•	•	•	•
PCB 55	•	•	•	•
PCB 56	•	•	•	•
PCB 57	•	•	•	•
PCB 58	•	•	•	•
PCB 59/62/75	•	•	•	•
PCB 60	•	•	•	•
PCB 61/70/74/76	•	•	•	•
PCB 63	•	•	•	•
PCB 64	•	•	•	•
PCB 66	•	•	•	•
PCB 67	•	•	•	•
PCB 68	•	•	•	•
PCB 72	•	•	•	•
PCB 73	•	•	•	•
PCB 77	•	•	•	•
PCB 78	•	•	•	•
PCB 79	•	•	•	•
PCB 80	•	•	•	•
PCB 81	•	•	•	•
PCB 82	•	•	•	•
PCB 83	•	•	•	•
PCB 84	•	•	•	•
PCB 85/116/117	•	•	•	•
PCB 86/87/97/108/119/125	•	•	•	•
PCB 88/91	•	•	•	•
PCB 89	•	•	•	•
PCB 90/101/113	•	•	•	•
PCB 92	•	•	•	•
PCB 93/95/98/100/102	•	•	•	•
PCB 94	•	•	•	•
PCB 96	•	•	•	•
PCB 103	•	•	•	•
PCB 104	•	•	•	•
PCB 105	•	•	•	•
PCB 106	•	•	•	•
PCB 107/124	•	•	•	•
PCB 109	•	•	•	•
PCB 110/115	•	•	•	•
PCB 111	•	•	•	•
PCB 112	•	•	•	•
PCB 114	•	•	•	•
PCB 118	•	•	•	•
PCB 120	•	•	•	•
PCB 121	•	•	•	•
PCB 122	•	•	•	•
PCB 123	•	•	•	•
PCB 126	•	•	•	•

Appendix D1-3 continued

Parameters	BATCH WIDE FLAGS			
	PCB Batch 1A (WG34092)		PCB Batch 1B (WG34160)	
	Detects	Non-Detects	Detects	Non-Detects
PCB 127	•	•	•	•
PCB 128/166	•	•	•	•
PCB 129/138/160/163	•	•	•	•
PCB 130	•	•	•	•
PCB 131	•	•	•	•
PCB 132	•	•	•	•
PCB 133	•	•	•	•
PCB 134/143	•	•	•	•
PCB 135/151/154	•	•	•	•
PCB 136	•	•	•	•
PCB 137	•	•	•	•
PCB 139/140	•	•	•	•
PCB 141	•	•	•	•
PCB 142	•	•	•	•
PCB 144	•	•	•	•
PCB 145	•	•	•	•
PCB 146	•	•	•	•
PCB 147/149	•	•	•	•
PCB 148	•	•	•	•
PCB 150	•	•	•	•
PCB 152	•	•	•	•
PCB 153/168	•	•	•	•
PCB 155	•	•	•	•
PCB 156/157	•	•	•	•
PCB 158	•	•	•	•
PCB 159	•	•	•	•
PCB 161	•	•	•	•
PCB 162	•	•	•	•
PCB 164	•	•	•	•
PCB 165	•	•	•	•
PCB 167	•	•	•	•
PCB 169	•	•	•	•
PCB 170	•	•	•	•
PCB 171/173	•	•	•	•
PCB 172	•	•	•	•
PCB 174	•	•	•	•
PCB 175	•	•	•	•
PCB 176	•	•	•	•
PCB 177	•	•	•	•
PCB 178	•	•	•	•
PCB 179	•	•	•	•
PCB 180/193	•	•	•	•
PCB 181	•	•	•	•
PCB 182	•	•	•	•
PCB 183/185	•	•	•	•
PCB 184	•	•	•	•
PCB 186	•	•	•	•
PCB 187	•	•	•	•

Appendix D1-3 continued

Parameters	BATCH WIDE FLAGS			
	PCB Batch 1A (WG34092)		PCB Batch 1B (WG34160)	
	Detects	Non-Detects	Detects	Non-Detects
PCB 188	•	•	•	•
PCB 189	•	•	•	•
PCB 190	•	•	•	•
PCB 191	•	•	•	•
PCB 192	•	•	•	•
PCB 194	•	•	•	•
PCB 195	•	•	•	•
PCB 196	•	•	•	•
PCB 197/200	•	•	•	•
PCB 198/199	•	•	•	•
PCB 201	•	•	•	•
PCB 202	•	•	•	•
PCB 203	•	•	•	•
PCB 204	•	•	•	•
PCB 205	•	•	•	•
PCB 206	•	•	•	•
PCB 207	•	•	•	•
PCB 208	•	•	•	•
PCB 209	•	•	•	•
% Moisture	•	•	•	•
Decachloro Biphenyl	•	•	•	•
TEQ (ND = 0)	J	UN	J	UN
TEQ (ND = 1/2 DL)	R	UN	R	UN
Total Dichloro Biphenyls	•	•	•	•
Total Heptachloro Biphenyls	•	•	•	•
Total Hexachloro Biphenyls	•	•	•	•
Total Monochloro Biphenyls	•	•	•	•
Total Nonachloro Biphenyls	•	•	•	•
Total Octachloro Biphenyls	•	•	•	•
TOTAL PCBs	•	•	•	•
Total Pentachloro Biphenyls	•	•	•	•
Total Tetrachloro Biphenyls	•	•	•	•
Total Trichloro Biphenyls	•	•	•	•

Notes

- Symbol indicates that all DQOs met for analyte and batch.
- R flag: Severe DQO failure; rejected data
- J flag: Value is an estimate
- J+ flag: Value is estimate with potential bias
- J- flag: Value is an estimate with potential low bias
- UN flag: Value not detected, possible false negative
- U: Value was not detected (no DQO failure)

Appendix D1-4 Summary of DQO Failures and Data Qualifiers for the 2010 High-Resolution PAH Sediment Data

Parameters	BATCH WIDE FLAGS			
	PAH Batch 1A (WG34093)		PAH Batch 1B (WG34732)	
	Detects	Non-Detects	Detects	Non-Detects
1-Methylphenanthrene	•	•	•	•
2,3,5-Trimethylnaphthalene	•	•	•	•
2,6-Dimethylnaphthalene	•	•	•	•
2-Methylnaphthalene	•	•	•	•
Acenaphthene	•	•	•	•
Acenaphthylene	•	•	•	•
Anthracene	•	•	•	•
Benz[a]anthracene	•	•	•	•
Benzo[a]pyrene	•	•	•	•
Benzo[b]fluoranthene	•	•	•	•
Benzo[e]pyrene	J	UN	•	•
Benzo[ghi]perylene	•	•	•	•
Benzo[j,k]fluoranthenes	•	•	•	•
Chrysene	•	•	•	•
Dibenz[a,h]anthracene	•	•	•	•
Dibenzothiophene	•	•	•	•
Fluoranthene	•	•	•	•
Fluorene	•	•	•	•
Indeno[1,2,3-cd]pyrene	•	•	•	•
Naphthalene	•	•	•	•
Perylene	•	•	•	•
Phenanthrene	•	•	•	•
Pyrene	•	•	•	•

Notes

• Symbol indicates that all DQOs met for analyte and batch.

R flag: Severe DQO failure; rejected data

J flag: Value is an estimate

J+ flag: Value is estimate with potential bias

J- flag: Value is an estimate with potential low bias

UN flag: Value not detected, possible false negative

U: Value was not detected (no DQO failure)

Appendix D1-5 Summary of DQO Failures and Data Qualifiers for the 2010 High-Resolution Nonylphenol Sediment Data

Parameters	BATCH WIDE FLAGS			
	NP Batch 1A (WG34179)		NP Batch 1B (WG34780)	
	Detects	Non-Detects	Detects	Non-Detects
% Moisture	•	•	•	•
4-Nonylphenol diethoxylates	•	•	•	•
4-Nonylphenol monoethoxylates	•	•	•	•
4-Nonylphenols	•	•	•	•
Octylphenol	•	•	•	•

Notes

- Symbol indicates that all DQOs met for analyte and batch.
- R flag: Severe DQO failure; rejected data
- J flag: Value is an estimate
- J+ flag: Value is estimate with potential bias
- J- flag: Value is an estimate with potential low bias
- UN flag: Value not detected, possible false negative
- U: Value was not detected (no DQO failure)

Appendix D1-6 Summary of DQO Failures and Data Qualifiers for the 2010 High-Resolution OC Pesticide Sediment Data

Parameters	BATCH WIDE FLAGS			
	OC Pest Batch 1 (WG34895)		OC Pest Batch 2 (WG34090)	
	Detects	Non-Detects	Detects	Non-Detects
% Moisture	•	•	•	•
1,2,3,4-Tetrachlorobenzene	•	•		
1,2,3-Trichlorobenzene	J+	U		
1,2,4,5-/1,2,3,5-Tetrachlorobenzene	R	U		
1,2,4-Trichlorobenzene	J+	U		
1,2-Dichlorobenzene	J+	U		
1,3,5-Trichlorobenzene	R	U		
1,3-Dichlorobenzene	R	R		
1,4-Dichlorobenzene	J+	U		
2,4'-DDD	•	•		
2,4'-DDE	•	•		
2,4'-DDT	•	•		
4,4'-DDD	•	•		
4,4'-DDE	•	•		
4,4'-DDT	•	•		
Aldrin	•	•		
Chlordane, alpha (cis)	•	•		
Chlordane, gamma (trans)	J+	U		
Chlordane, oxy-	•	•		
HCH, alpha	J+	U		
HCH, beta	•	•		
HCH, gamma	•	•		
Heptachlor	•	•		
Hexachlorobenzene	•	•		
Hexachlorobutadiene	•	•		
Mirex	R	R		
Nonachlor, cis-	J+	U		
Nonachlor, trans-	J+	U		
Pentachlorobenzene	J+	U		
alpha-Endosulphan	•	•	J+	U
beta-Endosulphan	•	•	•	•
Dieldrin	•	•	J+	U
Endosulphan Sulphate	•	•	•	•
Endrin	•	•	•	•
Endrin Aldehyde	•	•	•	•
Endrin Ketone	R	U	J+	U
HCH, delta	•	•	•	•
Heptachlor Epoxide	•	•	•	•
Methoxychlor	•	•	•	•

Notes

Shading = parameter was not analyzed in this batch
• Symbol indicates that all DQOs met for analyte and batch.
R flag: Severe DQO failure; rejected data
J flag: Value is an estimate
J+ flag: Value is estimate with potential bias
J- flag: Value is an estimate with potential low bias
UN flag: Value not detected, possible false negative
U: Value was not detected (no DQO failure)

Appendix D1-7 Summary of DQO Failures and Data Qualifiers for the 2010 High-Resolution PBDE Sediment Data

Parameters	BATCH WIDE FLAGS	
	PBDE Batch 1 (WG34091)	
	Detects	Non-Detects
PBDE 7	•	•
PBDE 8/11	•	•
PBDE 10	•	•
PBDE 12/13	•	•
PBDE 15	•	•
PBDE 17/25	•	•
PBDE 28/33	•	•
PBDE 30	•	•
PBDE 32	•	•
PBDE 35	•	•
PBDE 37	J+	U
PBDE 47	J+	U
PBDE 49	•	•
PBDE 51	•	•
PBDE 66	•	•
PBDE 71	J	UN
PBDE 75	J+	U
PBDE 77	•	•
PBDE 79	•	•
PBDE 85	•	•
PBDE 99	J+	U
PBDE 100	J+	U
PBDE 105	•	•
PBDE 116	•	•
PBDE 119/120	•	•
PBDE 126	•	•
PBDE 128	•	•
PBDE 138/166	•	•
PBDE 140	•	•
PBDE 153	•	•
PBDE 154	J+	U
PBDE 155	•	•
PBDE 181	•	•
PBDE 183	•	•
PBDE 190	•	•
PBDE 203	J+	U
PBDE 206	J+	U
PBDE 207	•	•
PBDE 208	•	•
PBDE 209	•	•
% Moisture	•	•

Notes • Symbol indicates that all DQOs met for analyte and batch.

R flag: Severe DQO failure; rejected data

J flag: Value is an estimate

J+ flag: Value is estimate with potential bias

J- flag: Value is an estimate with potential low bias

UN flag: Value not detected, possible false negative

U: Value was not detected (no DQO failure)

Appendix D2 Macaulay and Clover Points Sediment Chemistry Results 2010

(All results expressed on a dry weight basis.)

Station	Physical Tests: Moisture						
	ALS	Axys-PAHs	Axys-PCBs	Axys-PBDEs	Axys-NPs	Axys-Pest E1	Axys-Pest E2
Units	%	%	%	%	%	%	%
MDL	0.1						
BC SEDQC _{TCS} ¹							
CCME PEL ²							
WSDOE 2LAET ³							
C0	18.4						
CB1	22.1±1.8						
M0	31.7						
M100N	37.7±1.2						
M100NE	36±0						
M100E	39.6±0.63						
M100E–Top 10cm	36.6	33.9	34.4	34.4	35.8	32.4	35.8
M100SE	43±0						
M100S	38.4±0						
M100SW	41.4±0.83						
M100W	38.5±0.1						
M100NW	36.1						
M200N	34.5						
M200NE	37.4						
M200E	39.6						
M200E–Top 10cm	36.7±0	35.4	-	37.3	-	36.2	37.6
M200SE	38.1±2.37						
M200S	35.8						
M200SW	36						
M200W	37.6						
M200NW	39.5±0						
M400E	34.3±1.66						
M400SE	33.3±0						
M400SW	35.9						
M400W	34.5±0.66						
M800E	37.2±0						
M800E–Top 10cm	33.7±4.03	35.8	-	38.8	-	35.8	37.7
M800W	34.3						
PB1	31.7±1.56						
PB1–Top 10 cm	30.9±1.42	31.5±1.14	30.8±0.17	31.2±0.85	30.7±0.95	29±0.7	29.9±0.74
PB2	28.9±0.21						
PB3	32.5						
PB4	31.6						
PB5	38.9						

Station	Physical Tests		Particle Size			
	pH (ALS)	Total Organic Carbon	% Gravel (>2.0mm)	% Sand (2.0mm–0.063mm)	% Silt (0.063mm–4µm)	% Clay (<4µm)
Units	pH	%	%	%	%	%
MDL	0.1	0.1	1	1	1	1
BC SEDQC_{TCS}¹						
CCME PEL²						
WSDOE 2LAET³						
C0	8.25	1.01	18	75.1	6.08	0.76
CB1	8.24±0.06	0.85±0.23	21.9±5.08	60.2±4.14	14.5±1.04	3.38±0.04
M0	7.99	2.5	19	60.4	18	2.64
M100N	8±0.06	2.48±1.69	3.3±0.73	51.7±1.52	37.7±1.21	7.38±0.43
M100NE	8.11	1.08	0.77	58.3	35.4	5.54
M100E	7.89±0.05	3.66±0.33	3.23±0	61±1.42	30.4±1.07	5.39±1.57
M100E–Top 10 cm	8.07	2.74	2.43	55.1	34.6	7.88
M100SE	8.03	3	10.3	55.6	26.8	7.36
M100S	8.13	2.95	6.19	56.8	31.1	5.91
M100SW	8±0.11	3.76±0.25	1.7±0	58.5±3.8	35.4±4.08	4.43±0.65
M100W	8.02±0.02	2.83±1.22	0.9±1.43	57±3.79	39.3±2.54	2.96±1.63
M100NW	8.05	0.85	0.7	61.8	32.2	5.28
M200N	8.1	1.49	4.4	51.4	37	7.2
M200NE	8.19	3.8	1.32	51.3	42.7	4.72
M200E	8.12	2.09	<0.10	60	35.8	4.15
M200E–Top 10cm	7.85	4.05	3.9	60.8	27	8.29
M200SE	7.78±0.03	3.38±0.7	4.36±0.86	60.8±2.34	29±3.63	5.92±2.44
M200S	7.85	1.66	<0.10	51.8	43.7	4.54
M200SW	7.91	1.14	<0.10	59.4	36.9	3.79
M200W	7.88	9.42	<0.10	58.1	37.1	4.83
M200NW	8.12	0.79	<0.10	60.7	33.2	6.04
M400E	7.98±0.1	2.2±0.14	4.3±1.17	54.2±0.65	36.8±0.91	4.59±0.92
M400SE	8.01	1.27	0.17	65.3	29.9	4.61
M400SW	8.06	0.74	<0.10	54.9	36.1	8.96
M400W	8±0.1	0.89±0.1	0.77±0.3	57.4±1.72	37.8±0.85	4.3±1.1
M800E	8.1	1.77	3.38	52.6	37.6	6.47
M800E–Top 10cm	7.92	1.91	0.81	55.5	33.4	10.3
M800W	7.9	0.66	<0.10	57	38.8	4.28
PB1	8±0.02	0.53±0.02	<0.10	68.5±1.01	27±1.12	4.46±0.52
PB1–Top 10 cm	8.14±0.1	0.53±0.04	0.43±0.56	71.4±1.71	23.5±0.95	4.68±0.59
PB2	8.09±0.02	0.54±0.04	<0.10	71.5±1.07	26±1.45	2.55±0.48
PB3	7.98	0.69	<0.10	56.8	34.6	8.57
PB4	7.94	0.71	<0.10	60.1	36	3.88
PB5	8.07	0.85	<0.10	43.6	48.4	8.02

Appendix D2, continued (All results expressed on a dry weight basis.)

Station	Cyanides	Extractable Metals			
	Total Cyanide	Cd Cadmium	Cu Copper	Pb Lead	Hg Mercury
Units	mg/kg	µmol/g	µmol/g	µmol/g	µmol/g
MDL	3	0.005	0.01	0.02	0.00005
BC SEDQC _{TCS} ¹					
CCME PEL ²					
WSDOE 2LAET ³					
C0	<3.0	<0.0050	0.043	0.066	QA
CB1	<3.0	<0.0050	0.01±0	<0.020	QA
M0	<3.0	0.0061	0.361	0.13	QA
M100N	<3.0	<0.0050	0.4±0.38	0.2±0.13	QA
M100NE	<3.0	<0.0050	0.054	0.021	QA
M100E	<3.0	<0.0050	0.09±0.02	0.06±0.01	QA
M100E–Top 10cm	<3.0	-	-	-	-
M100SE	<3.0	0.0077	0.025	0.789	QA
M100S	<3.0	<0.0050	0.064	0.031	QA
M100SW	<3.0	<0.0050	QA	QA	QA
M100W	<3.0	<0.0050	QA	QA	QA
M100NW	<3.0	<0.0050	0.053	0.032	QA
M200N	<3.0	<0.0050	QA	QA	QA
M200NE	<3.0	<0.0050	QA	QA	QA
M200E	<3.0	<0.0050	QA	QA	QA
M200E–Top 10cm	<3.0	-	-	-	-
M200SE	<3.0	0±0	0.12±0.03	QA	<0.000050
M200S	<3.0	<0.0050	0.06	QA	<0.000050
M200SW	<3.0	<0.0050	0.055	QA	<0.000050
M200W	<3.0	<0.0050	0.057	QA	<0.000050
M200NW	<3.0	<0.0050	QA	QA	QA
M400E	<3.0	<0.0050	0.1±0.01	QA	<0.000050
M400SE	<3.0	<0.0050	1.15±1.54	QA	<0.000050
M400SW	<3.0	<0.0050	0.059	0.021	QA
M400W	<3.0	<0.0050	0.06±0	0±0.01	QA
M800E	<3.0	<0.0050	0.058	0.027	QA
M800E–Top 10cm	<3.0	-	-	-	-
M800W	<3.0	<0.0050	0.051	<0.020	QA
PB1	<3.0	<0.0050	0.03±0	<0.020	QA
PB1–Top 10cm	<3.0	-	-	-	QA
PB2	<3.0	<0.0050	0.03±0	<0.020	QA
PB3	<3.0	<0.0050	0.047	<0.020	QA
PB4	<3.0	<0.0050	0.043	<0.020	QA
PB5	<3.0	<0.0050	QA	QA	QA

Appendix D2, continued (All results expressed on a dry weight basis.)

Station	Extractable Metals		Total Metals			
	Ni Nickel	Zn Zinc	Al Aluminum	Sb Antimony	As Arsenic	Be Beryllium
Units	µmol/g	µmol/g	mg/kg	mg/kg	mg/kg	mg/kg
MDL	0.05	0.005	50	0.05	0.05	0.5
BC SEDQC _{TCS} ¹					50	
CCME PEL ²					41.6	
WSDOE 2LAET ³				200	93	
C0	<0.050	3.93	17200	3.18	3.16	<0.50
CB1	<0.050	0.07±0.01	10970±2079	0.21±0	3.51±0.46	<0.50
M0	<0.050	0.685	22100	1.45	8.84	<0.50
M100N	0.14±0.15	1.54±1.67	19467±289	0.66±0.38	6.7±0.56	<0.50
M100NE	<0.050	0.224	18000	0.339	5	<0.50
M100E	<0.050	0.42±0.01	17867±2113	0.74±0.03	10.3±0.76	<0.50
M100E–Top 10cm	-	-	17200	0.892	9.48	<0.50
M100SE	<0.050	1.15	18400	1.03	13	<0.50
M100S	<0.050	0.334	23300	0.575	6.9	0.52
M100SW	0.06±0	QA	18200±2406	1.71±0.4	15.1±1.01	0.36±0.18
M100W	<0.050	QA	18133±1582	1.38±1.52	7.53±0.67	<0.50
M100NW	<0.050	0.229	19500	0.289	5.8	<0.50
M200N	0.113	QA	19100	0.646	5.5	<0.50
M200NE	<0.050	QA	18400	1.27	8.2	<0.50
M200E	<0.050	QA	17600	0.448	5.6	<0.50
M200E–Top 10cm	-	-	18000	QA	9.54±0.2	<0.50
M200SE	<0.050	0.42±0.1	16633±1739	QA	8.87±0.5	<0.50
M200S	<0.050	0.204	17100	QA	7.2	<0.50
M200SW	<0.050	0.242	23100	QA	6.6	<0.50
M200W	<0.050	0.276	16400	QA	7.3	<0.50
M200NW	<0.050	QA	19700	0.342	5.1	<0.50
M400E	<0.050	0.3±0.01	19400±4029	QA	6.63±0.36	0.34±0.16
M400SE	<0.050	0.263	22600	QA	9.06	0.51
M400SW	<0.050	0.258	19800	0.273	5.62	<0.50
M400W	<0.050	0.24±0.01	20033±924	0.25±0.02	4.73±0.22	<0.50
M800E	<0.050	0.22	13600	0.324	7±1.07	<0.50
M800E–Top 10cm	-	-	21500	QA	6	<0.50
M800W	<0.050	0.235	21500	0.22	5.37	<0.50
PB1	<0.050	0.19±0.01	18333±1250	0.22±0.01	5.2±0.31	<0.50
PB1–Top 10cm	-	-	16433±1955	0.19±0.16	4.74±0.54	<0.50
PB2	<0.050	0.16±0	15700±2179	0.19±0.01	6.24±0.26	<0.50
PB3	<0.050	0.216	19100	0.202	5.53	<0.50
PB4	<0.050	0.23	20800	0.218	5.1	<0.50
PB5	<0.050	QA	19000	0.22	5.4	<0.50

Appendix D2, continued (All results expressed on a dry weight basis.)

Station	Total Metals (continued)					
	Cd Cadmium	Cr Chromium	Cu Copper	Fe Iron	Pb Lead	Mg Magnesium
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
MDL	0.02	2	1	50	0.2	50
BC SEDQC _{TCS} ¹	5	190	130		130	
CCME PEL ²	4.2	160	108		112	
WSDOE 2LAET ³	6.7	270	390		530	
C0	0.474	50.7	155	24200	72.1	8760
CB1	0.09±0.01	17.5±4.11	11±3	15600±2955	3.96±0.4	5610±1081
M0	0.595	67.5	224	26600	35.3	9690
M100N	0.21±0.03	29.7±1.1	30.3±9.83	26900±700	35.3±8.08	8540±125
M100NE	0.219	28.4	19.6	23900	11.8	8320
M100E	1.31±0.36	27.9±3.11	50.3±15.63	22867±2113	28.6±3.61	7977±762
M100E–Top 10 cm	0.709	28.5	45.3	20400	36	6590
M100SE	0.986	32.3	238	29400	111	8600
M100S	0.269	34.3	50.4	28400	50	9770
M100SW	1.01±0.23	36.6±3.23	109.3±14.5	30400±1947	QA	8103±787
M100W	0.41±0.03	41.1±2.35	67.7±12.19	27933±3612	QA	7863±289
M100NW	0.186	29.5	19.6	25300	10.2	8630
M200N	0.241	28.4	25.2	27100	QA	8280
M200NE	0.28	29.6	55.3	26600	QA	7950
M200E	0.336	27.9	32.4	23900	QA	7790
M200E–Top 10cm	0.422	32.6	43.4	29300	54.6	8200
M200SE	0.56±0.12	26.9±2.04	59.9±27.1	22433±1762	24.6±3.39	7090±451
M200S	0.155	26	14.5	21900	11	7090
M200SW	0.218	34.8	19.7	29100	9.35	9300
M200W	0.215	25.2	17	21200	8.43	6770
M200NW	0.194	29.5	19.3	25200	QA	8320
M400E	0.24±0.02	30.5±6.05	73.5±12.6	27133±5116	27.6±5.5	8080±1501
M400SE	0.258	33.6	36.4	29800	19.4	8620
M400SW	0.105	28	13.6	23300	5.93	7380
M400W	0.13±0.01	28.3±1.29	15.5±0.99	23400±1039	5.91±0.48	7450±286
M800E	0.094	20.8	12.9	18600	QA	5430
M800E–Top 10cm	0.222	34	21.6	29100	27.5	9090
M800W	0.103	30.3	14.1	25500	5.98	7970
PB1	0.11±0.01	29.9±1.58	12.4±0.35	27133±874	5.32±0.36	8000±339
PB1–Top 10cm	0.11±0	27.6±3.21	11.4±1.65	24500±2905	5.27±0.14	7303±921
PB2	0.09±0.01	25.8±3.24	9.8±1.13	21300±2600	4.25±0.8	6607±849
PB3	0.075	27.9	13	24000	5.2	7330
PB4	0.106	30.4	13.7	26500	5.5	8010
PB5	0.119	29.1	16.1	26100	QA	8530

Appendix D2, continued (All results expressed on a dry weight basis.)

Station	Total Metals (continued)					
	Mn Manganese	Hg Mercury	Ni Nickel	P Phosphorus	K Potassium	Ag Silver
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
MDL	1.0	0.005	2.0	50	200	0.02
BC SEDQC _{TCS} ¹		0.84				
CCME PEL ²		0.7				
WSDOE 2LAET ³		0.59				6.1
C0	311	9.5	29.6	1270	1160	3.59
CB1	197±32.5	0.02±0	14.4±1.84	405±63.2	1563±291	0.05±0.01
M0	278	1.66	23.8	2010	2330	1.48
M100N	223±7.5	QA	19.1±3.24	724±37.5	2867±46	0.13±0.02
M100NE	204	QA	16.8	698	2660	0.127
M100E	192±19.6	QA	17.7±1.84	877±91.9	2697±197	0.75±0.18
M100E–Top 10 cm	170	1.12	14.5	719	2630	0.641
M100SE	233	QA	22.2	1060	2820	0.815
M100S	243	QA	20.4	936	3320	0.821
M100SW	225±22.7	0.86±0.2	26.6±4.03	917±43.5	2797±273	0.62±0.19
M100W	209±13.45	0.32±0.22	21.8±5.13	774±66.3	2800±137	0.41±0.2
M100NW	214	QA	17.3	662	2870	0.296
M200N	231	0.056	21	663	2770	0.1
M200NE	226	0.061	23.7	663	2890	0.113
M200E	203	0.296	18.5	681	2940	0.095
M200E–Top 10cm	221	0.114	22.1	785	2310	QA
M200SE	189±24	0.56±0.33	18.5±2.92	656±39.4	2350±193	QA
M200S	178	0.0728	19.8	522	2500	QA
M200SW	238	0.0522	19.4	671	3380	QA
M200W	172	0.118	18.7	507	2380	QA
M200NW	217	0.0512	18.2	611	3280	0.08
M400E	217±40.3	0.07±0.03	21.1±1.88	736±202	2683±592	QA
M400SE	241	0.151	20.1	753	3140	QA
M400SW	196	0.0396	13.4	551	2880	0.074
M400W	198±6.8	0.05±0.01	14±0.91	544±13.4	3063±112	0.1±0.05
M800E	153	0.247	11.4	472	2160	0.067
M800E–Top 10cm	236	0.0525	22.7	707	3070	QA
M800W	214	0.039	13.7	598	3210	0.057
PB1	232±11.8	0.03±0	17.77±1.01	575±14.8	2613±210	0.06±0.01
PB1 –Top 10cm	205±23	0.03±0	17.6±1.22	478±57.6	2413±287	0.06±0
PB2	195±24.5	0.03±0	13.7±1.43	486±56.9	2397±275	0.04±0.01
PB3	210	0.0358	13.9	596	2760	0.052
PB4	222	0.0396	16	607	3010	0.054
PB5	228	0.0421	18.7	629	3070	0.064

Appendix D2, continued (All results expressed on a dry weight basis.)

Station	Total Metals (continued)		Speciated Metals	Inorganic Substances
	Tl Thallium	Zn Zinc	Hexavalent Chromium	Acid Volatile Sulphide
Units	mg/kg	mg/kg	mg/kg	umol/g
MDL	0.5	1.0	0.1	0.2
BC SEDQC _{TCS} ¹		330		
CCME PEL ²		271		
WSDOE 2LAET ³		960		
C0	<0.50	137	<0.10	9.85
CB1	<0.50	25.8±4.45	<0.10	<0.20
M0	<0.50	137	<0.10	10.3
M100N	<0.50	164±121	<0.10	5.15±3.23
M100NE	<0.50	59.3	<0.10	0.75
M100E	<0.50	84.5±5.84	<0.10	15±1.25
M100E–Top 10 cm	<0.50	72.1	<0.10	-
M100SE	<0.50	337	<0.10	44.8
M100S	<0.50	70.7	<0.10	3.22
M100SW	<0.50	158±20.9	<0.10	25.8±4.02
M100W	<0.50	80.7±16.8	<0.10	12.17±3.63
M100NW	<0.50	56.6	<0.10	1.55
M200N	<0.50	79	<0.10	9.73
M200NE	<0.50	102	<0.10	7.82
M200E	<0.50	65.7	<0.10	40.9
M200E–Top 10cm	<0.50	130	<0.10	-
M200SE	<0.50	77.2±13.31	<0.10	15.3±5.58
M200S	<0.50	46.6	<0.10	0.89
M200SW	<0.50	63.2	<0.10	2.71
M200W	<0.50	46.7	<0.10	3.24
M200NW	<0.50	58	<0.10	4.13
M400E	<0.50	87±27.49	<0.10	1.59±0.3
M400SE	<0.50	69.9	<0.10	9.32
M400SW	<0.50	48.4	<0.10	0.89
M400W	<0.50	50.6±2.22	<0.10	1.51±1.15
M800E	<0.50	39.8	<0.10	1.06
M800E–Top 10cm	<0.50	65.5	<0.10	-
M800W	<0.50	51.2	<0.10	<0.20
PB1	<0.50	47.7±1.13	<0.10	<0.21
PB1–Top 10cm	<0.50	43.8±5.32	<0.10	-
PB2	<0.50	38.9±4.14	<0.10	<0.20
PB3	<0.50	47.2	<0.10	<0.20
PB4	<0.50	51	<0.10	<0.20
PB5	<0.50	56.3	<0.10	<0.21

Appendix D2, continued (All results expressed on a dry weight basis.)

Station	Volatile Organic Compounds					
	Bromo-dichloro-methane	Bromoform	Bromo-methane	Carbon Tetra-chloride	Chloro-benzene	Dibromo-chloro-methane
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
MDL	0.01	0.01	0.05	0.01	0.01	0.01
BC SEDQC _{TCS} ¹						
CCME PEL ²						
WSDOE 2LAET ³						
C0	<0.010	<0.010	<0.050	<0.010	<0.010	<0.010
CB1	<0.010	<0.010	<0.050	<0.010	<0.010	<0.010
M0	<0.010	<0.010	<0.050	<0.010	<0.010	<0.010
PB1	<0.010	<0.010	<0.050	<0.010	<0.010	<0.010
PB1–Top 10cm	<0.010	<0.010	<0.050	<0.010	<0.010	<0.010
Station	Chloro-ethane	2-Chloroethyl vinyl ether	Chloroform	Chloro-methane	Dibromo-methane	1,1-Dichloro-ethane
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
MDL	0.01	0.1	0.005	0.005	0.02	0.01
BC SEDQC _{TCS} ¹						
CCME PEL ²						
WSDOE 2LAET ³						
C0	<0.020	<0.10	<0.0050	<0.050	<0.020	<0.010
CB1	<0.010	<0.10	<0.0050	<0.010	<0.020	<0.010
M0	<0.010	<0.10	<0.0050	<0.010	<0.020	<0.010
PB1	<0.010	<0.10	<0.0050	<0.010	<0.020	<0.010
PB1–Top 10cm	<0.010	<0.10	<0.0050	<0.010	<0.020	<0.010
Station	1,2-Dichloro-ethane	1,1-Dichloro-ethylene	cis-1,2-Dichloro-ethylene	trans-1,2-Dichloro-ethylene	Dichloro-methane	1,2-Dichloro-propane
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
MDL	0.01	0.01	0.01	0.01	0.05	0.01
BC SEDQC _{TCS} ¹						
CCME PEL ²						
WSDOE 2LAET ³						
C0	<0.010	<0.010	<0.010	<0.010	<0.050	<0.010
CB1	<0.010	<0.010	<0.010	<0.010	<0.050	<0.010
M0	<0.010	<0.010	<0.010	<0.010	<0.050	<0.010
PB1	<0.010	<0.010	<0.010	<0.010	<0.050	<0.010
PB1–Top 10cm	<0.010	<0.010	<0.010	<0.010	<0.050	<0.010

Appendix D2, continued (All results expressed on a dry weight basis.)

Station	Volatile Organic Compounds (continued)					
	cis-1,3-Dichloro-propylene	trans-1,3-Dichloro-propylene	Ethylbenzene	Methyl t-butyl ether (MTBE)	Styrene	Tetrabromo-methane
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
MDL	0.01	0.01	0.005	0.005	0.005	1.25
BC SEDQC _{TCS} ¹						
CCME PEL ²						
WSDOE 2LAET ³			0.033			
C0	<0.010	<0.010	<0.0050	<0.0050	<0.0050	-
CB1	<0.010	<0.010	<0.0050	<0.0050	<0.0050	-
M0	<0.010	<0.010	<0.0050	<0.0050	<0.0050	-
PB1	<0.010	<0.010	<0.0050	<0.0050	<0.0050	-
PB1–Top 10cm	<0.010	<0.010	<0.0050	<0.0050	<0.0050	-
Station	1,1,1,2-Tetrachloro-ethane	1,1,2,2-Tetrachloro-ethane	Tetrachloro-ethylene	Toluene	1,1,1-Trichloro-ethane	1,1,2-Trichloro-ethane
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
MDL	0.01	0.05	0.01	0.005	0.01	0.01
BC SEDQC _{TCS} ¹						
CCME PEL ²						
WSDOE 2LAET ³			0.14			
C0	<0.010	<0.050	<0.010	0.0189	<0.010	<0.010
CB1	<0.010	<0.050	<0.010	<0.0050	<0.010	<0.010
M0	<0.010	<0.050	<0.010	0.0212	<0.010	<0.010
PB1	<0.010	<0.050	<0.010	<0.0050	<0.010	<0.010
PB1–Top 10cm	<0.010	<0.050	<0.010	<0.0050	<0.010	<0.010
Station	Trichloro-ethylene	Trichloro-fluoromethane	Vinyl Chloride	ortho-Xylene	meta- & para-Xylene	Benzene
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
MDL	0.01	0.01	0.01	0.005	0.005	0.005
BC SEDQC _{TCS} ¹						
CCME PEL ²						
WSDOE 2LAET ³					0.1	
C0	<0.010	<0.010	<0.010	<0.0050	<0.0050	<0.0050
CB1	<0.010	<0.010	<0.010	<0.0050	<0.0050	<0.0050
M0	<0.010	<0.010	<0.010	<0.0050	<0.0050	<0.0050
PB1	<0.010	<0.010	<0.010	<0.0050	<0.0050	<0.0050
PB1–Top 10cm	<0.010	<0.010	<0.010	<0.0050	<0.0050	<0.0050

Appendix D2, continued (All results expressed on a dry weight basis.)

Station	Water Soluble Volatiles	Polycyclic Aromatic Hydrocarbons			
	Acrolein	Acenaphthene	Acenaphthylene	Anthracene	Benz(a)anthracene
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
MDL	1.25	0.005	0.005	0.005	0.01
BC SEDQC _{TCS} ¹		0.11	0.15	0.29	0.83
CCME PEL ²		0.08890	0.128	0.245	0.693
WSDOE 2LAET ³		0.50000	1.3	0.96	1.6
C0	<0.050	0.384	0.0181	0.0893	0.139
CB1	<0.050	<0.0050	<0.0050	<0.0040	<0.010
M0	<0.050	0.0386	0.011	0.149	0.685
M100N		QA	0.02±0.02	QA	QA
M100NE		QA	0.0092	QA	QA
M100E		QA	0.01±0	QA	QA
M100E–Top 10cm		0.106	0.0201	0.216	0.485
M100SE		QA	<0.025	QA	QA
M100S		QA	<0.0050	QA	QA
M100SW		0.05±0.02	0.02±0.01	0.13±0.06	0.35±0.1
M100W		0.01±0	0.02±0.02	0.05±0.02	0.1±0.07
M100NW		QA	<0.0050	QA	QA
M200N		0.0113	0.0094	0.0246	0.068
M200NE		<0.010	0.0078	0.0191	0.06
M200E		0.13	<0.0050	0.368	1.26
M200E–Top 10cm		0.211	0.01±0	0.3±0.32	1.41±1.71
M200SE		0.07±0.05	0.02±0.01	0.17±0.1	0.38±0.22
M200S		<0.0050	<0.0050	<0.0040	<0.010
M200SW		<0.0050	0.0116	0.0104	0.035
M200W		0.0069	<0.0050	0.0114	0.026
M200NW		<0.0050	<0.0050	0.0044	<0.010
M400E		0.01±0	0.01±0	0.01±0.01	0.04±0
M400SE		<0.0050	<0.0050	0.0044	<0.010
M400SW		<0.0050	<0.0050	0.0051	0.013
M400W		0.004±0	0.01±0	0.02±0.01	0.04±0.05
M800E		<0.0050	<0.0050	0.0074	<0.010
M800E–Top 10cm		<0.015	0.06±0.02	0.0391	0.224
M800W		<0.0050	<0.0050	<0.0040	<0.010
PB1	<0.050	<0.0050	<0.0050	<0.0040	<0.010
PB1–Top 10cm	<0.050	<0.0050	<0.0050	<0.0040	<0.010
PB2		<0.0050	<0.0050	<0.0040	<0.010
PB3		<0.0050	0.0051	0.0065	0.018
PB4		<0.0050	<0.0050	<0.0040	<0.010
PB5		<0.0050	<0.0050	<0.0040	<0.010

Appendix D2, continued (All results expressed on a dry weight basis.)

Station	Polycyclic Aromatic Hydrocarbons (continued)				
	Benzo(a)-pyrene	Benzo(b)-fluoranthene	Benzo(g,h,i)-perylene	Benzo(k)-fluoranthene	Chrysene
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
MDL	0.01	0.01	0.01	0.01	0.01
BC SEDQC _{TCS} ¹	0.92				1
CCME PEL ²	0.763				0.846
WSDOE 2LAET ³	1.6		0.72		2.8
C0	<0.15	0.288	0.116	<0.090	0.206
CB1	<0.010	<0.010	<0.010	<0.010	<0.010
M0	0.733	0.819	0.235	0.345	0.612
M100N	0.18±0.12	0.18±0.18	0.09±0.06	0.07±0.07	QA
M100NE	QA	QA	0.097	QA	QA
M100E	0.52±0.35	0.75±0.51	0.24±0.17	0.21±0.19	QA
M100E–Top 10cm	0.415	0.482	0.194	0.199	0.465
M100SE	QA	QA	QA	QA	QA
M100S	0.055	0.061	0.016	0.023	QA
M100SW	0.67±0.21	0.68±0.21	0.37±0.14	0.27±0.08	0.32±0.08
M100W	0.11±0.05	0.09±0.06	0.04±0.03	0.04±0.04	0.09±0.06
M100NW	0.046	0.059	0.022	0.022	QA
M200N	0.082	0.093	0.048	0.036	0.062
M200NE	0.063	0.079	0.034	0.029	0.056
M200E	1.47	1.42	0.758	0.515	1.13
M200E–Top 10cm	1.57±1.87	1.78±2.15	0.89±1.12	0.6±0.71	1.3±1.55
M200SE	0.41±0.24	0.51±0.23	0.17±0.11	0.20±0.11	0.34±0.19
M200S	<0.010	0.01	<0.010	<0.010	<0.010
M200SW	0.03	0.035	0.011	0.015	0.039
M200W	0.033	0.04	0.014	0.016	0.029
M200NW	<0.010	<0.010	<0.010	<0.010	<0.010
M400E	0.04±0	0.05±0	0.02±0	0.02±0	0.05±0
M400SE	<0.020	0.014	<0.010	<0.010	0.013
M400SW	<0.020	0.015	<0.010	<0.010	0.017
M400W	0.04±0.05	0.05±0.06	0.02±0.02	0.02±0.02	0.05±0.05
M800E	<0.020	0.015	<0.010	<0.010	0.014
M800E–Top 10cm	0.198	0.205	0.059	0.09	0.216
M800W	<0.020	0.011	<0.010	<0.010	<0.010
PB1	<0.010	<0.010	<0.010	<0.010	<0.010
PB1–Top 10cm	<0.010	<0.010	<0.010	<0.010	<0.010
PB2	<0.010	<0.010	<0.010	<0.010	<0.010
PB3	0.022	0.023	0.014	<0.010	0.022
PB4	<0.010	0.011	<0.010	<0.010	0.014
PB5	<0.010	<0.010	<0.010	<0.010	0.013

Appendix D2, continued (All results expressed on a dry weight basis.)

Station	Polycyclic Aromatic Hydrocarbons (continued)				
	Dibenz(a,h)-anthracene	Fluoranthene	Fluorene	Indeno(1,2,3-c,d)pyrene	2-Methyl-naphthalene
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
MDL	0.005	0.01	0.01	0.01	0.01
BC SEDQC _{TCS} ¹	0.16	1.8	0.17		0.24
CCME PEL ²	0.135	1.494	0.144		0.201
WSDOE 2LAET ³	0.23	2.5	0.54	0.69	0.67
C0	<0.070	0.264	0.128	<0.11	0.048
CB1	<0.0050	<0.010	<0.010	<0.010	0.01±0
M0	0.0862	1.36	0.038	0.341	0.024
M100N	0.02±0.02	QA	0.04±0.02	0.1±0.07	0.05±0.01
M100NE	0.0304	QA	0.04	0.117	0.041
M100E	0.07±0.05	QA	0.04±0.02	0.29±0.21	0.05±0
M100E–Top 10cm	0.0492	0.914	0.081	0.216	0.046
M100SE	QA	QA	0.686	QA	0.077
M100S	<0.0050	QA	0.012	0.019	0.041
M100SW	0.08±0.03	0.68±0.33	0.05±0.02	0.39±0.12	0.09±0.04
M100W	0.01±0.01	0.18±0.09	0.04±0.03	0.05±0.04	0.06±0.01
M100NW	0.0062	QA	0.016	0.025	0.048
M200N	0.0098	0.152	0.021	0.048	0.051
M200NE	0.0071	0.098	0.016	0.034	0.061
M200E	0.157	3.03	0.088	0.904	0.048
M200E–Top 10cm	0.2±0.24	2.74±3.33	0.1±0.06	1±1.26	0.11±0.02
M200SE	0.07±0.06	0.70±0.39	0.07±0.03	0.22±0.13	0.06±0.01
M200S	<0.0050	0.013	0.01	<0.010	0.042
M200SW	<0.0050	0.06	0.012	0.015	0.045
M200W	<0.0050	0.058	0.013	0.014	0.044
M200NW	<0.0050	0.015	0.011	<0.010	0.042
M400E	<0.0060	0.06±0.01	0.02±0	0.03±0	0.05±0.01
M400SE	<0.0050	0.017	<0.010	<0.010	0.033
M400SW	<0.0050	0.027	<0.010	<0.010	0.039
M400W	0.01±0.01	0.08±0.09	0.01±0	0.02±0.03	0.05±0.01
M800E	<0.0050	0.026	0.011	<0.010	0.04
M800E–Top 10cm	0.0223	0.218	0.023	0.084	0.144
M800W	<0.0050	0.019	<0.010	<0.010	0.039
PB1	<0.0050	<0.010	<0.010	<0.010	0.03±0
PB1–Top 10cm	<0.0050	<0.010	<0.010	<0.010	0.03±0.01
PB2	<0.0050	<0.010	<0.010	<0.010	0.03±0
PB3	<0.0050	0.025	0.011	0.012	0.046
PB4	<0.0050	0.025	0.01	<0.010	0.039
PB5	<0.0050	0.012	0.011	<0.010	0.046

Appendix D2, continued (All results expressed on a dry weight basis.)

Station	Polycyclic Aromatic Hydrocarbons (cont'd)			Chlorinated Hydrocarbons	
	Naphthalene	Phenanthrene	Pyrene	1,2-Dichloro- benzene	1,3-Dichloro- benzene
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
MDL	0.01	0.01	0.01	0.01	0.01
BC SEDQC_{TCS}¹	0.47	0.65	1.7		
CCME PEL²	0.391	0.544	1.398		
WSDOE 2LAET³	2.1	1.5	3.3	0.05	
C0	0.065	0.455	0.247	<0.050	<0.050
CB1	<0.010	0.01±0	<0.010	<0.010	<0.010
M0	0.034	0.364	1.07	<0.050	<0.050
M100N	0.05±0.01	0.26±0.16	QA	<0.010	<0.010
M100NE	0.03	0.342	QA	<0.010	<0.010
M100E	0.07±0.02	0.36±0.22	QA	<0.010	<0.010
M100E–Top 10cm	0.049	0.737	0.811	0.027	<0.010
M100SE	0.084	8.7	QA	<0.010	<0.010
M100S	0.057	0.06	QA	<0.010	<0.010
M100SW	0.11±0.02	0.42±0.25	0.73±0.15	<0.010	<0.010
M100W	0.05±0.02	0.18±0.1	0.16±0.1	<0.010	<0.010
M100NW	0.03	0.111	QA	<0.010	<0.010
M200N	0.053	0.086	0.129	<0.010	<0.010
M200NE	0.033	0.094	0.095	<0.010	<0.010
M200E	0.051	1.22	2.69	<0.010	<0.010
M200E–Top 10cm	0.11±0.03	0.95±0.89	2.46±2.91	<0.010	<0.010
M200SE	0.09±0.06	0.58±0.28	0.59±0.34	<0.020	<0.020
M200S	0.027	0.045	0.013	<0.010	<0.010
M200SW	0.036	0.06	0.05	<0.010	<0.010
M200W	0.024	0.069	0.048	<0.010	<0.010
M200NW	0.022	0.047	0.015	<0.010	<0.010
M400E	0.05±0	0.07±0.03	0.06±0	<0.010	<0.010
M400SE	0.034	0.04	0.018	<0.010	<0.010
M400SW	0.02	0.049	0.03	<0.010	<0.010
M400W	0.03±0.01	0.07±0.02	0.07±0.07	<0.010	<0.010
M800E	0.027	0.053	0.03	<0.010	<0.010
M800E–Top 10cm	0.113	0.09	0.234	<0.010	<0.010
M800W	0.018	0.045	0.019	<0.010	<0.010
PB1	0.02±0	0.03±0	<0.010	<0.010	<0.010
PB1–Top 10cm	0.01±0	0.03±0	<0.010	<0.010	<0.010
PB2	0.01±0	0.03±0	<0.010	<0.010	<0.010
PB3	0.021	0.051	0.027	<0.010	<0.010
PB4	0.019	0.057	0.023	<0.010	<0.010
PB5	0.02	0.049	0.012	<0.010	<0.010

Appendix D2, continued (All results expressed on a dry weight basis.)

Station	Chlorinated Hydrocarbons (continued)				
	1,4-Dichloro- benzene	Hexachloro- benzene	Hexachloro- butadiene	Hexachloro- ethane	1,2,4- Trichloro- benzene
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
MDL	0.01	0.01	0.01	0.01	0.01
BC SEDQC _{TCS} ¹					
CCME PEL ²					
WSDOE 2LAET ³	0.11	0.07	0.12		0.051
C0	0.08	<0.050	<0.050	<0.050	<0.050
CB1	<0.010	<0.010	<0.010	<0.010	<0.010
M0	0.216	<0.050	<0.050	<0.050	<0.050
M100N	<0.010	<0.010	<0.010	<0.010	<0.010
M100NE	0.016	<0.010	<0.010	<0.010	<0.010
M100E	0.11±0.05	<0.010	<0.010	<0.010	0.01±0
M100E–Top 10cm	0.101	<0.010	<0.010	<0.010	<0.010
M100SE	0.098	<0.010	<0.010	<0.010	<0.010
M100S	0.065	<0.010	<0.010	<0.010	<0.010
M100SW	0.21±0.04	<0.010	<0.010	<0.010	<0.010
M100W	0.06±0.01	<0.010	<0.010	<0.010	<0.010
M100NW	<0.010	<0.010	<0.010	<0.010	<0.010
M200N	<0.010	<0.010	<0.010	<0.010	<0.010
M200NE	0.047	<0.010	<0.010	<0.010	<0.010
M200E	0.017	<0.010	<0.010	<0.010	<0.010
M200E–Top 10cm	0.058	<0.010	<0.010	<0.010	0.173
M200SE	0.11±0.01	<0.020	<0.020	<0.020	<0.020
M200S	<0.010	<0.010	<0.010	<0.010	<0.010
M200SW	<0.010	<0.010	<0.010	<0.010	<0.010
M200W	0.016	<0.010	<0.010	<0.010	<0.010
M200NW	<0.010	<0.010	<0.010	<0.010	<0.010
M400E	0.01±0.01	<0.010	<0.010	<0.010	<0.010
M400SE	0.015	<0.010	<0.010	<0.010	<0.010
M400SW	<0.010	<0.010	<0.010	<0.010	<0.010
M400W	<0.010	<0.010	<0.010	<0.010	<0.010
M800E	<0.010	<0.010	<0.010	<0.010	<0.010
M800E–Top 10cm	<0.010	<0.010	<0.010	<0.010	<0.010
M800W	<0.010	<0.010	<0.010	<0.010	<0.010
PB1	<0.010	<0.010	<0.010	<0.010	<0.010
PB1–Top 10cm	<0.010	<0.010	<0.010	<0.010	<0.010
PB2	<0.010	<0.010	<0.010	<0.010	<0.010
PB3	<0.010	<0.010	<0.010	<0.010	<0.010
PB4	<0.010	<0.010	<0.010	<0.010	<0.010
PB5	<0.010	<0.010	<0.010	<0.010	<0.010

Appendix D2, continued (All results expressed on a dry weight basis.)

Station	Phthalate Esters					
	Bis(2-ethylhexyl) phthalate	Benzyl butyl phthalate	Diethyl phthalate	Dimethyl phthalate	Di-n-butyl phthalate	Di-n-octyl phthalate
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
MDL	0.1	0.1	1.0	1.0	0.1	0.1
BC SEDQC_{TCS}¹						
CCME PEL²						
WSDOE 2LAET³	1.9	0.9	0.2	0.16	1.4	6.2
C0	8.9	0.57	<5.0	<5.0	<0.50	<0.50
CB1	<0.10	<0.10	<1.0	<1.0	<0.10	<0.10
M0	<0.50	<0.50	<5.0	<5.0	<0.50	<0.50
M100N	<0.10	<0.10	<1.0	<1.0	<0.10	<0.10
M100NE	0.16	<0.10	<1.0	<1.0	<0.10	<0.10
M100E	1.66±0.35	<0.10	<1.0	<1.0	<0.10	<0.10
M100E–Top 10cm	0.39	<0.10	<1.0	<1.0	<0.10	<0.10
M100SE	0.19	<0.10	<1.0	<1.0	<0.10	<0.10
M100S	<0.10	<0.10	<1.0	<1.0	<0.10	<0.10
M100SW	0.96±0.52	<0.10	<1.0	<1.0	<0.10	<0.10
M100W	0.3±0.13	<0.10	<1.0	<1.0	<0.10	<0.10
M100NW	<0.10	<0.10	<1.0	<1.0	0.11	<0.10
M200N	<0.10	<0.10	<1.0	<1.0	<0.10	<0.10
M200NE	0.1	<0.10	<1.0	<1.0	<0.10	<0.10
M200E	<0.20	<0.10	<1.0	<1.0	<0.10	<0.10
M200E–Top 10cm	<0.10	<0.10	<1.0	<1.0	<0.10	<0.10
M200SE	0.63±0.4	<0.20	<1.0	<1.0	<0.30	<0.20
M200S	<0.10	<0.10	<1.0	<1.0	<0.10	<0.10
M200SW	0.12	<0.10	<1.0	<1.0	<0.10	<0.10
M200W	<0.10	<0.10	<1.0	<1.0	<0.10	<0.10
M200NW	QA	<0.10	<1.0	<1.0	<0.10	<0.10
M400E	0.22±0.17	<0.10	<1.0	<1.0	<0.10	<0.10
M400SE	0.16	<0.10	<1.0	<1.0	<0.10	<0.10
M400SW	<0.10	<0.10	<1.0	<1.0	<0.10	<0.10
M400W	<0.10	<0.10	<1.0	<1.0	<0.10	<0.10
M800E	<0.10	<0.10	<1.0	<1.0	<0.10	<0.10
M800E–Top 10cm	<0.10	<0.10	<1.0	<1.0	<0.10	<0.10
M800W	0.26	<0.10	<1.0	<1.0	<0.10	<0.10
PB1	<0.10	<0.10	<1.0	<1.0	<0.10	<0.10
PB1–Top 10cm	<0.10	<0.10	<1.0	<1.0	<0.10	<0.10
PB2	<0.10	<0.10	<1.0	<1.0	<0.10	<0.10
PB3	<0.10	<0.10	<1.0	<1.0	<0.10	<0.10
PB4	<0.10	<0.10	<1.0	<1.0	<0.10	<0.10
PB5	<0.10	<0.10	<1.0	<1.0	<0.10	<0.10

Appendix D2, continued (All results expressed on a dry weight basis.)

Station	Base Neutral Extractables				
	4-Bromo-phenyl phenyl ether	Bis(2-chloro-ethoxy)-methane	Bis(2-chloro-ethyl)-ether	Bis(2-chloro-isopropyl)-ether	4-Chloro-phenyl phenyl ether
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
MDL	0.02	0.02	0.02	0.02	0.02
BC SEDQC _{TCS} ¹					
CCME PEL ²					
WSDOE 2LAET ³					
C0	<0.10	<0.10	<1.0	<0.10	<0.10
CB1	<0.020	<0.020	<0.90	<0.020	<0.020
M0	<0.10	<0.10	<1.4	<0.10	<0.10
PB1	<0.020	<0.020	<0.90	<0.020	<0.020
PB1–Top 10cm	<0.020	<0.020	<0.90	<0.020	<0.020
Station	2,4-Dinitrotoluene (2,4-DNT)	2,6-Dinitrotoluene (2,6-DNT)	Isophorone	Nitrobenzene (NB)	N-Nitrosodi-n-propylamine
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
MDL	0.02	0.02	0.02	0.02	0.02
BC SEDQC _{TCS} ¹					
CCME PEL ²					
WSDOE 2LAET ³					
C0	<0.10	<0.10	<0.10	<0.10	<0.11
CB1	<0.020	<0.020	<0.020	<0.020	<0.020
M0	<0.10	<0.10	<0.10	<0.10	<0.10
PB1	<0.020	<0.020	<0.020	<0.020	<0.020
PB1–Top 10cm)	<0.020	<0.020	<0.020	<0.020	<0.020

Appendix D2, continued (All results expressed on a dry weight basis.)

Station	Base-Neutral Extractables (continued)	Non-Chlorinated Phenolics				
	2-Chloronaphthalene	2,4-Dinitrophenol	2-Methyl 4,6-Dinitrophenol	4-Nitrophenol	2-Nitrophenol	Phenol
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
MDL	0.02	0.025	0.025	0.025	0.025	0.02
BC SEDQC _{TCS} ¹						
CCME PEL ²						
WSDOE 2LAET ³						1.2
C0	<0.10	<0.20	<0.20	<0.20	<0.20	0.025
CB1	<0.020	<0.090	<0.050	<0.050	<0.050	<0.020
M0	<0.10	<0.20	<0.20	<0.20	<0.20	0.021
M100N	<0.020	QA	<0.50	<0.15	<0.05	<0.030
M100NE	<0.020	QA	<0.25	<0.25	<0.25	<0.10
M100E	0.02±0.02	QA	<5.0	<5.0	<0.05	<0.030
M100E–Top 10cm	<0.020	QA	<1.0	<1.0	<1.0	0.32
M100SE	<0.020	QA	<2.5	<0.25	<0.25	<0.10
M100S	<0.020	QA	<0.50	<0.05	<0.05	<0.050
M100SW	<0.020	QA	<1.3	<1.3	<1.3	<0.040
M100W	<0.020	QA	<1.0	<0.25	<0.25	<0.030
M100NW	<0.020	QA	<0.25	<0.25	<0.25	<0.10
M200N	<0.020	QA	<0.25	<0.25	<0.25	<0.020
M200NE	<0.020	QA	<1.0	<0.25	<0.25	<0.020
M200E	<0.020	QA	<1.0	<0.25	<0.25	<0.020
M200E–Top 10cm	<0.020	<5.0	<5.0	<5.0	<5.0	1.84±0.17
M200SE	<0.020	<0.50	<0.050	<0.050	<0.050	<0.22
M200S	<0.020	<0.50	<0.10	<0.050	<0.050	0.023
M200SW	<0.020	<1.0	<1.0	<0.050	<0.050	0.022
M200W	<0.020	<0.50	<0.10	<0.050	<0.050	0.022
M200NW	<0.020	QA	<0.25	<0.25	<0.25	<0.020
M400E	<0.020	<0.50	<0.050	<0.050	<0.050	0.08±0.01
M400SE	<0.020	<1.0	<0.10	<0.10	<0.050	0.133
M400SW	<0.020	QA	<0.50	<0.50	<0.50	<0.020
M400W	<0.020	QA	<0.50	<0.50	<0.50	0.02±0.01
M800E	<0.020	QA	<1.0	<1.0	<1.0	<0.020
M800E–Top 10cm	<0.020	<0.50	<0.050	<0.050	<0.050	0.473
M800W	<0.020	QA	<0.50	<0.50	<0.50	0.024
PB1	<0.020	<0.050	<0.050	<0.050	<0.050	0.01±0.01
PB1–Top 10cm	<0.020	<0.50	<0.050	<0.050	<0.050	0.03±0
PB2	<0.020	QA	<0.50	<0.50	<0.50	<0.020
PB3	<0.020	QA	<0.50	<0.50	<0.50	0.02
PB4	<0.020	QA	<0.50	<0.50	<0.50	<0.020
PB5	<0.020	QA	<0.25	<0.25	<0.25	<0.020

Appendix D2, continued (All results expressed on a dry weight basis.)

Station	Chlorinated Phenolics				Total Phenols
	2-Chloro-phenol	2,4 & 2,5-Dichloro-phenol	Pentachloro-phenol	2,4,6-Trichloro-phenol	Phenols (4AAP)
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
MDL	0.02	0.02	0.02	0.02	0.05
BC SEDQC _{TCS} ¹				0.69	
CCME PEL ²					
WSDOE 2LAET ³	1.2			0.69	
C0	<0.070	<0.020	<0.020	<0.020	0.18
CB1	<0.020	<0.020	<0.020	<0.020	0.41±0.04
M0	<0.020	<0.020	<0.020	<0.020	8.71
M100N	<0.020	<0.020	<0.020	<0.020	0.81±0.07
M100NE	<0.020	<0.020	<0.020	<0.020	1.77
M100E	<0.020	<0.020	<0.020	<0.020	2.81±0.38
M100E–Top 10cm	<0.020	<0.020	<0.020	<0.020	1.25
M100SE	<0.030	<0.020	<0.020	<0.020	1.55
M100S	<0.020	<0.020	<0.020	<0.020	1.73
M100SW	<0.030	<0.020	<0.020	<0.020	1.1±0.3
M100W	<0.020	<0.020	<0.020	<0.020	3.11±1.18
M100NW	<0.020	<0.020	<0.020	<0.020	0.29
M200N	<0.020	<0.020	<0.020	<0.020	2.08
M200NE	<0.030	<0.020	<0.020	<0.020	0.84
M200E	<0.020	<0.020	<0.020	<0.020	2.43
M200E–Top 10cm	<0.020	<0.020	<0.020	<0.020	QA
M200SE	<0.080	<0.020	<0.020	<0.020	QA
M200S	<0.020	<0.020	<0.020	<0.020	QA
M200SW	<0.020	<0.020	<0.020	<0.020	QA
M200W	<0.020	<0.020	<0.020	<0.020	QA
M200NW	<0.020	<0.020	<0.020	<0.020	1.66
M400E	<0.020	<0.020	<0.020	<0.020	QA
M400SE	<0.020	<0.020	<0.020	<0.020	QA
M400SW	<0.020	<0.020	<0.020	<0.020	0.87
M400W	<0.020	<0.020	<0.020	<0.020	0.64±0.18
M800E	<0.020	<0.020	<0.020	<0.020	0.32
M800E–Top 10cm	<0.030	<0.020	<0.020	<0.020	QA
M800W	<0.020	<0.020	<0.020	<0.020	0.61
PB1	<0.020	<0.020	<0.020	<0.020	0.31±0.16
PB1–Top 10cm	<0.020	<0.020	<0.020	<0.020	0.47±0.23
PB2	<0.020	<0.020	<0.020	<0.020	0.37±0.12
PB3	<0.020	<0.020	<0.020	<0.020	0.42
PB4	<0.020	<0.020	<0.020	<0.020	0.32
PB5	<0.020	<0.020	<0.020	<0.020	0.54

Appendix D2, continued (All results expressed on a dry weight basis.)

Station	High Resolution PAHs					
	1-Methylphenanthrene	2,3,5-Trimethylphenanthrene	2,6-Dimethylphenanthrene	2-Methylphenanthrene	1-Methylphenanthrene	Acenaphthene
Units	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
M1E–Top 10cm	73.4	128	64.7	93.6	50.6	21.7
M2E–Top 10cm	113	82.4	48.1	78.9	83.1	35.9
M8E–Top 10cm	34	124	73.3	118	9.41	24.3
PB1–Top 10cm	14±0.64	32.2±3.01	33.4±1.89	41.3±4.13	1.62	0.55±0.07
Station	Acenaphthylene	Anthracene	Benz[a]-anthracene	Benzo[a]pyrene	Benzo[b]-fluoranthene	Benzo[e]-pyrene
Units	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
M1E–Top 10cm	149	382	439	355	280	250
M2E–Top 10cm	249	798	963	768	NDR	517
M8E–Top 10cm	26.8	NDR	124	121	86.6	78.1
PB1–Top 10cm	2.01±0.16	3.9±0.08	2.83±0.16	4.96±0.25	2.76±0.21	3.46±0.28
Station	Benzo[ghi]perylene	Benzo[j,k]fluoranthene	Chrysene	Dibenz[a,h]-anthracene	Dibenzothiophene	Fluoranthene
Units	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
M1E–Top 10cm	362	418	64	34.5	848	49.2
M2E–Top 10cm	669	877	146	43.1	1690	36.7
M8E–Top 10cm	107	131	17	NDR	221	12.8
PB1–Top 10cm	1.76±0.34	8.31±0.28	0.52±0.09	NDR	8.53±0.31	5.13±0.64
Station	Fluorene	Indeno[1,2,3-cd]pyrene	Naphthalene	Perylene	Phenanthrene	Pyrene
Units	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
M1E–Top 10cm	49.2	266	260	131	486	776
M2E–Top 10cm	36.7	596	207	256	450	1670
M8E–Top 10cm	12.8	84.5	154	57.7	95.5	278
PB1–Top 10cm	5.13±0.64	2.44±0.16	21.3±4.47	18.8±1.63	32.4±1.16	10.2±0.4
Station	Total High Molecular Weight PAHs	Total Low Molecular Weight PAHs	TOTAL PAHs			
Units	ng/g	ng/g	ng/g			
M1E–Top 10cm	4570	1020	5590			
M2E–Top 10cm	8950	1060	10000			
M8E–Top 10cm	1310	323	1630			
PB1–Top 10cm	67.3±1.54	61.9±3.71	129.3±2.31			

Appendix D2, continued (All results expressed on a dry weight basis.)

Station	High Resolution PCBs					
	PCB 1	PCB 2	PCB 3	PCB 4	PCB 5	PCB 6
Units	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
M1E–Top 10cm	17.5	12.8	17.6	18	1.15	11
M2E–Top 10cm	-	-	-	-	-	-
M8E–Top 10cm	-	-	-	-	-	-
PB1–Top 10cm	1.52±0.43	1.04±0.3	0.86±0.4	2.11±0.47	0.09±0.02	0.98±0.28
Station	PCB 7	PCB 8	PCB 9	PCB 10	PCB 11	PCB 12/13
Units	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
M1E–Top 10cm	2.94	53.2	2.99	NDR	25.9	8.07
M2E–Top 10cm	-	-	-	-	-	-
M8E–Top 10cm	-	-	-	-	-	-
PB1–Top 10cm	0.27±0.07	5.83±1.45	0.23±0.05	0.08±0.02	8.5±1.73	0.93±0.27
Station	PCB 14	PCB 15	PCB 16	PCB 17	PCB 18/30	PCB 19
Units	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
M1E–Top 10cm	<0.475	38.3	29.5	38.1	80.2	13.9
M2E–Top 10cm	-	-	-	-	-	-
M8E–Top 10cm	-	-	-	-	-	-
PB1–Top 10cm	<0.124	5.4±1.26	2.11±0.63	2.28±0.6	4.7±1.52	0.47±0.16
Station	PCB 20/28	PCB 21/23	PCB 22	PCB 23	PCB 24	PCB 25
Units	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
M1E–Top 10cm	145	72.9	41.2	0.233	0.729	10.4
M2E–Top 10cm	-	-	-	-	-	-
M8E–Top 10cm	-	-	-	-	-	-
PB1–Top 10cm	15±4.28	5.91±1.77	4.38±1.32	<0.0405	<0.0405	1.03±0.33
Station	PCB 26/29	PCB 27	PCB 31	PCB 32	PCB 34	PCB 35
Units	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
M1E–Top 10cm	18.7	12.8	105	20.3	0.795	4.42
M2E–Top 10cm	-	-	-	-	-	-
M8E–Top 10cm	-	-	-	-	-	-
PB1–Top 10cm	2.07±0.71	0.43±0.13	10.3±3.14	1.69±0.61	0.057	0.57±0.14
Station	PCB 36	PCB 37	PCB 38	PCB 39	PCB 40/41/71	PCB 42
Units	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
M1E–Top 10cm	1.05	30.5	0.711	1.29	110	43.8
M2E–Top 10cm	-	-	-	-	-	-
M8E–Top 10cm	-	-	-	-	-	-
PB1–Top 10cm	0.35±0.18	4.54±1.24	0.08	0.065	6.44±2	3.06±0.94
Station	PCB 43	PCB 44/47/65	PCB 45/51	PCB 46	PCB 48	PCB 49/69
Units	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
M1E–Top 10cm	4.98	253	24.2	13	35.9	166
M2E–Top 10cm	-	-	-	-	-	-
M8E–Top 10cm	-	-	-	-	-	-
PB1–Top 10cm	0.39±0.03	11.1±3.37	1.16±0.4	0.35±0.09	1.96±0.65	7.04±2.25

Appendix D2, continued (All results expressed on a dry weight basis.)

Station	High Resolution PCBs continued					
	PCB 50/53	PCB 52	PCB 54	PCB 55	PCB 56	PCB 57
Units	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
M1E–Top 10cm	47.9	519	2.47	1.96	74.1	0.605
M2E–Top 10cm	-	-	-	-	-	-
M8E–Top 10cm	-	-	-	-	-	-
PB1–Top 10cm	1.17±0.45	12.1±3.84	<0.0405	0.19±0.01	7.14±2.22	0.07±0.03
Station	PCB 58	PCB 59/62/75	PCB 60	PCB 61/70/74/76	PCB 63	PCB 64
Units	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
M1E–Top 10cm	0.564	13.3	36.6	546	7.48	85.3
M2E–Top 10cm	-	-	-	-	-	-
M8E–Top 10cm	-	-	-	-	-	-
PB1–Top 10cm	<0.0486	1.01±0.31	4.27±1.29	26.3±7.28	0.61±0.17	4.72±1.53
Station	PCB 66	PCB 67	PCB 68	PCB 72	PCB 73	PCB 77
Units	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
M1E–Top 10cm	185	3.62	2.08	3.09	<0.0368	15.3
M2E–Top 10cm	-	-	-	-	-	-
M8E–Top 10cm	-	-	-	-	-	-
PB1–Top 10cm	14.8±4.11	0.45±0.16	0.12±0.02	0.15±0.06	<0.0405	2.1±0.53
Station	PCB 78	PCB 79	PCB 80	PCB 81	PCB 82	PCB 83
Units	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
M1E–Top 10cm	<0.4	6.47	<0.363	NDR	76	455
M2E–Top 10cm	-	-	-	-	-	-
M8E–Top 10cm	-	-	-	-	-	-
PB1–Top 10cm	<0.0469	0.2±0.09	<0.0425	NDR	2.25±0.53	10.9±2.37
Station	PCB 84	PCB 85/116/117	PCB 86/87/97/108/119/125	PCB 88/91	PCB 89	PCB 90/101/113
Units	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
M1E–Top 10cm	177	122	520	88	5.16	795
M2E–Top 10cm	-	-	-	-	-	-
M8E–Top 10cm	-	-	-	-	-	-
PB1–Top 10cm	3.5±0.8	3.76±0.84	11.4±2.47	1.89±0.45	0.19±0.06	15.9±4
Station	PCB 92	PCB 93/95/98/100/102	PCB 94	PCB 96	PCB 103	PCB 104
Units	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
M1E–Top 10cm	121	574	2.49	3.94	4.3	<0.0718
M2E–Top 10cm	-	-	-	-	-	-
M8E–Top 10cm	-	-	-	-	-	-
PB1–Top 10cm	2.83±0.8	10.6±2.61	<0.0764	NDR	0.17±0.05	<0.0405

Appendix D2, continued (All results expressed on a dry weight basis.)

Station	High Resolution PCBs continued					
	PCB 105	PCB 106	PCB 107/124	PCB 109	PCB 110/115	PCB 111
Units	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
M1E–Top 10cm	289	<1.7	24.3	43.7	853	<0.492
M2E–Top 10cm	-	-	-	-	-	-
M8E–Top 10cm	-	-	-	-	-	-
PB1–Top 10cm	8.64±2.58	<0.0828	0.72±0.2	1.53±0.45	17.9±3.56	<0.055
Station	PCB 112	PCB 114	PCB 118	PCB 120	PCB 121	PCB 122
Units	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
M1E–Top 10cm	<0.496	13.4	670	1.35	<0.519	7.41
M2E–Top 10cm	-	-	-	-	-	-
M8E–Top 10cm	-	-	-	-	-	-
PB1–Top 10cm	<0.0536	0.43±0.16	18±5.08	0.119	<0.0553	0.24±0.02
Station	PCB 123	PCB 126	PCB 127	PCB 128/166	PCB 129/138/160/163	PCB 130
Units	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
M1E–Top 10cm	9.27	1.83	<1.64	110	685	40.1
M2E–Top 10cm	-	-	-	-	-	-
M8E–Top 10cm	-	-	-	-	-	-
PB1–Top 10cm	0.37±0.13	0.162	<0.0875	3.27±0.81	20.8±5.8	1.58±0.26
Station	PCB 131	PCB 132	PCB 133	PCB 134/143	PCB 135/151/154	PCB 136
Units	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
M1E–Top 10cm	8.58	202	7.45	31	210	86.3
M2E–Top 10cm	-	-	-	-	-	-
M8E–Top 10cm	-	-	-	-	-	-
PB1–Top 10cm	0.159	5.1±1.78	0.346	0.8±0.27	5.43±1.62	1.63±0.42
Station	PCB 137	PCB 139/140	PCB 141	PCB 142	PCB 144	PCB 145
Units	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
M1E–Top 10cm	38.2	12.1	103	<0.297	33.2	<0.103
M2E–Top 10cm	-	-	-	-	-	-
M8E–Top 10cm	-	-	-	-	-	-
PB1–Top 10cm	0.76±0.18	0.29±0.06	2.34±0.7	<0.0732	0.71±0.2	<0.0405
Station	PCB 146	PCB 147/149	PCB 148	PCB 150	PCB 152	PCB 153/168
Units	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
M1E–Top 10cm	70.3	428	1.25	0.923	0.572	512
M2E–Top 10cm	-	-	-	-	-	-
M8E–Top 10cm	-	-	-	-	-	-
PB1–Top 10cm	3.34±1.47	12.2±3.96	0.16±0.12	NDR	<0.0405	17.5±5.61

Appendix D2, continued (All results expressed on a dry weight basis.)

Station	High Resolution PCBs continued					
	PCB 155	PCB 156/157	PCB 158	PCB 159	PCB 161	PCB 162
Units	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
M1E–Top 10cm	0.159	101	72.3	4.16	<0.223	NDR
M2E–Top 10cm	-	-	-	-	-	-
M8E–Top 10cm	-	-	-	-	-	-
PB1–Top 10cm	<0.0405	2.25±0.7	1.57±0.48	0.19±0.05	<0.0549	<0.0582
Station	PCB 164	PCB 165	PCB 167	PCB 169	PCB 170	PCB 171/173
Units	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
M1E–Top 10cm	40.6	<0.251	31	<0.887	190	51.8
M2E–Top 10cm	-	-	-	-	-	-
M8E–Top 10cm	-	-	-	-	-	-
PB1–Top 10cm	1.01±0.35	<0.0617	1.05±0.13	<0.0554	4.64±0.84	1.57±0.28
Station	PCB 172	PCB 174	PCB 175	PCB 176	PCB 177	PCB 178
Units	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
M1E–Top 10cm	27.7	156	6.93	18.9	88.1	29.1
M2E–Top 10cm	-	-	-	-	-	-
M8E–Top 10cm	-	-	-	-	-	-
PB1–Top 10cm	0.95±0.1	4.08±0.78	0.21±0.04	0.56±0.12	3.44±0.84	1.26±0.28
Station	PCB 179	PCB 180/193	PCB 181	PCB 182	PCB 183/185	PCB 184
Units	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
M1E–Top 10cm	60.2	393	1.94	1.06	115	0.286
M2E–Top 10cm	-	-	-	-	-	-
M8E–Top 10cm	-	-	-	-	-	-
PB1–Top 10cm	1.94±0.29	9.46±1.89	<0.108	<0.0997	3.35±0.6	<0.0756
Station	PCB 186	PCB 187	PCB 188	PCB 189	PCB 190	PCB 191
Units	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
M1E–Top 10cm	<0.246	179	0.262	7.07	35.2	7.37
M2E–Top 10cm	-	-	-	-	-	-
M8E–Top 10cm	-	-	-	-	-	-
PB1–Top 10cm	<0.0822	7.75±2.11	<0.0573	0.14±0.1	0.78±0.18	0.15±0.03
Station	PCB 192	PCB 194	PCB 195	PCB 196	PCB 197/200	PCB 198/199
Units	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
M1E–Top 10cm	<0.284	163	46	48.6	15	105
M2E–Top 10cm	-	-	-	-	-	-
M8E–Top 10cm	-	-	-	-	-	-
PB1–Top 10cm	<0.095	2.19±0.52	0.91±0.26	1.28±0.34	0.44±0.08	3.25±0.75

Appendix D2, continued (All results expressed on a dry weight basis.)

Station	High Resolution PCBs continued					
	PCB 201	PCB 202	PCB 203	PCB 204	PCB 205	PCB 206
Units	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
M1E–Top 10cm	10.6	17.7	71.9	<0.694	9.01	107
M2E–Top 10cm	-	-	-	-	-	-
M8E–Top 10cm	-	-	-	-	-	-
PB1–Top 10cm	0.41±0.24	0.9±0.41	1.88±0.37	<0.281	0.12±0.08	2±0.71
Station	PCB 207	PCB 208	PCB 209	Decachloro Biphenyl	TEQ (ND=0)	TEQ (ND=1/2 DL)
Units	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
M1E–Top 10cm	8.72	18.5	47	47	0.34	8.72
M2E–Top 10cm	-	-	-	-	-	-
M8E–Top 10cm	-	-	-	-	-	-
PB1–Top 10cm	0.25±0.14	0.69±0.22	1.66±0.39	1.66±0.39	0.01±0.01	0.25±0.14
Station	Total Dichloro Biphenyls	Total Heptachloro Biphenyls	Total Hexachloro Biphenyls	Total Monochloro Biphenyls	Total Nonachloro Biphenyls	Total Octachloro Biphenyls
Units	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
M1E–Top 10cm	QA	162	1370	2830	47.9	134
M2E–Top 10cm	-	-	-	-	-	-
M8E–Top 10cm	-	-	-	-	-	-
PB1–Top 10cm	QA	25.5±6.5	40.2±8.13	80.6±24.4	3.42±1.13	2.9±1.04
Station	TOTAL PCBs	Total Pentachloro Biphenyls	Total Tetrachloro Biphenyls	Total Trichloro Biphenyls		
Units	pg/g	pg/g	pg/g	pg/g		
M1E–Top 10cm	12800	4860	2200	628		
M2E–Top 10cm	-	-	-	-		
M8E–Top 10cm	-	-	-	-		
PB1–Top 10cm	438±118	111±27.1	107±31.2	55.6±16.4		
Station	High Resolution PBDEs					
	PBDE 7	PBDE 8/11	PBDE 10	PBDE 12/13	PBDE 15	PBDE 17/25
Units	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
M1E–Top 10cm	29.7	14.4	<0.309	NDR	4.35	79.3
M2E–Top 10cm	17.3	9.68	<0.107	0.635	3.41	47.7
M8E–Top 10cm	6.7	5.72	<0.078	0.44	2.72	15.7
PB1–Top 10cm	1.03±0.16	0.72±0.07	<0.138	0.07±0.03	0.46±0.03	3.21±0.29
Station	PBDE 28/33	PBDE 30	PBDE 32	PBDE 35	PBDE 37	PBDE 47
Units	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
M1E–Top 10cm	18.9	<0.168	NDR	NDR	NDR	637
M2E–Top 10cm	17.6	<0.293	NDR	<0.221	0.311	283
M8E–Top 10cm	7.32	<0.066	NDR	NDR	NDR	77.7
PB1–Top 10cm	1.45±0.19	<0.147	<0.101	<0.0822	<0.0789	15.2±0.87

Appendix D2, continued (All results expressed on a dry weight basis.)

Station	High Resolution PBDEs continued					
	PBDE 49	PBDE 51	PBDE 66	PBDE 71	PBDE 75	PBDE 77
Units	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
M1E–Top 10cm	91.5	NDR	18.6	9.18	NDR	NDR
M2E–Top 10cm	45.8	5.88	8.3	5.73	NDR	NDR
M8E–Top 10cm	12.6	NDR	2.86	1.2	0.22	0.06
PB1–Top 10cm	2.39±0.13	0.42	0.58	NDR	NDR	<0.0739
Station	PBDE 79	PBDE 85	PBDE 99	PBDE 100	PBDE 105	PBDE 116
Units	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
M1E–Top 10cm	<0.0868	23.6	470	114	<3.22	<5.25
M2E–Top 10cm	<0.0195	5.7	169	42.1	<2.79	<3.32
M8E–Top 10cm	NDR	NDR	51.1	14.2	<0.952	<1.38
PB1–Top 10cm	<0.0737	NDR	8.85±0.85	2.78±0.21	<0.246	<0.4
Station	PBDE 119/120	PBDE 126	PBDE 128	PBDE 138/166	PBDE 140	PBDE 153
Units	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
M1E–Top 10cm	NDR	<1.62	<2.29	5.2	1.73	37.5
M2E–Top 10cm	<1.97	<1.44	<1.96	2.31	NDR	14.2
M8E–Top 10cm	<0.742	<0.432	<7.55	<1.11	<0.664	6.1
PB1–Top 10cm	<0.166	<0.121	<0.311	<1.35	<0.729	NDR
Station	PBDE 154	PBDE 155	PBDE 181	PBDE 183	PBDE 190	PBDE 203
Units	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
M1E–Top 10cm	34.1	NDR	<1.67	NDR	NDR	NDR
M2E–Top 10cm	15	1.6	<4.62	9.82	<8.23	50.4
M8E–Top 10cm	5.38	1.08	<2.05	NDR	<3.52	7.76
PB1–Top 10cm	1.24±0.13	NDR	<0.815	NDR	<1.43	1
Station	PBDE 206	PBDE 207	PBDE 208	PBDE 209		
Units	pg/g	pg/g	pg/g	pg/g		
M1E–Top 10cm	NDR	171	NDR	1490		
M2E–Top 10cm	297	435	271	3060		
M8E–Top 10cm	75.8	NDR	58.1	945		
PB1–Top 10cm	7.32	NDR	NDR	57.1±1.2		
Station	High Resolution Nonylphenols					
	4-Nonylphenol diethoxylates		4-Nonylphenol monoethoxylates		4-Nonylphenols	Octylphenol
Units	ng/g		ng/g		ng/g	ng/g
M1E–Top 10 cm	<17.6		141		251	NDR
M2E–Top 10cm	-		-		-	-
M8E–Top 10cm	-		-		-	-
PB1–Top 10cm	<1.5		<0.627		<1.54	NDR

Appendix D2, continued (All results expressed on a dry weight basis.)

Station	High Resolution Pesticides (E1)					
	1,2,3,4-Tetrachloro benzene	1,2,3-Trichlorobenzene	1,2,4,5-/1,2,3,5-Tetrachloro benzene	1,2,4-Trichlorobenzene	1,2-Dichlorobenzene	1,3,5-Trichlorobenzene
Units	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
M1E–Top 10cm	0.083	0.195	QA	1.16	3.71	QA
M2E–Top 10cm	0.092	2.58	QA	6.85	2.74	QA
M8E–Top 10cm	0.085	0.156	QA	0.852	0.811	QA
PB1–Top 10cm	0.05±0.01	0.07±0.02	QA	0.56±0.16	0.12±0.04	QA
Station	1,3-Dichlorobenzene	1,4-Dichlorobenzene	2,4'-DDD	2,4'-DDE	2,4'-DDT	4,4'-DDD
Units	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
M1E–Top 10cm	QA	776	0.291	0.022	0.113	0.659
M2E–Top 10cm	QA	178	0.845	0.025	0.084	2.09
M8E–Top 10cm	QA	21.5	0.117	0.011	0.012	0.304
PB1–Top 10cm	QA	1.78±0.39	0.01±0	0.01±0	<0.0059	0.04±0
Station	4,4'-DDE	4,4'-DDT	Aldrin	Chlordane, alpha (cis)	Chlordane, gamma (trans)	Chlordane, oxy-
Units	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
M1E–Top 10cm	0.354	0.278	NDR	0.276	0.275	NDR
M2E–Top 10cm	0.43	0.363	NDR	0.055	0.059	NDR
M8E–Top 10cm	0.16	0.055	0.004	NDR	0.011	<0.0036
PB1–Top 10cm	0.07±0	<0.0065	<0.0013	0.003	NDR	<0.0035
Station	HCH, alpha	HCH, beta	HCH, gamma	Heptachlor	Hexachlorobenzene	Hexachlorobutadiene
Units	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
M1E–Top 10cm	0.34	0.156	0.115	0.003	0.089	NDR
M2E–Top 10cm	0.207	0.111	0.041	<0.0019	NDR	NDR
M8E–Top 10cm	0.067	0.05	NDR	0.003	0.07	NDR
PB1–Top 10cm	0.02±0	0.02±0	0.003±0	<0.0024	0.04±0	0.005
Station	Mirex	Nonachlor, cis-	Nonachlor, trans-	Pentachlorobenzene		
Units	ng/g	ng/g	ng/g	ng/g		
M1E–Top 10cm	QA	0.044	0.098	0.052		
M2E–Top 10cm	QA	0.016	0.03	0.039		
M8E–Top 10cm	QA	<0.0047	NDR	0.04		
PB1–Top 10cm	QA	<0.0027	0.003	0.03±0		

Appendix D2, continued (All results expressed on a dry weight basis.)

Station	High Resolution Pesticides (E2)					
	alpha-Endosulphan	beta-Endosulphan	Dieldrin	Endosulphan Sulphate	Endrin	Endrin Aldehyde
Units	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
M1E–Top 10cm	0.049	NDR	0.53	NDR	<0.0079	<0.0133
M2E–Top 10cm	NDR	NDR	0.096	<0.0327	<0.0082	<0.0104
M8E–Top 10cm	NDR	<0.0513	0.02	<0.0436	<0.0119	<0.0199
PB1–Top 10cm	<0.02	<0.0333	<0.0057	<0.0283	<0.0081	<0.0145
Station	Endrin Ketone	HCH, delta	Heptachlor Epoxide	Methoxychlor		
Units	ng/g	ng/g	ng/g	ng/g		
M1E–Top 10cm	<0.0046	0.143	0.011	NDR		
M2E–Top 10cm	<0.004	0.086	0.008	NDR		
M8E–Top 10cm	<0.0081	0.013	<0.0048	NDR		
PB1–Top 10cm	<0.0056	<0.0043	<0.0037	<0.0113		

Notes

“QA” denotes that value has failed the data quality objective (DQO) screening, and has been rejected for use in statistical analyses. For stations with multiple results (i.e. lab replicates or field replicates), average and standard deviation are presented.

- 1 BC Contaminated Sites Regulation Typical Contaminated Site Criteria (BCMWLAP, 2003)
- 2 Canadian Council of Ministers of the Environment Probable Effects Level (PEL) (CCME, 2002)
- 3 Washington State Department of Ecology, 2nd lowest AET (WSDOE, 1991)

Grey highlighting indicates that concentration exceeds at least one of the sediment criteria

APPENDIX E

Mussel and Benthic Community Monitoring

- Appendix E1 Clover Point Mussel Tissue Chemistry Quality Assurance and Quality Control Methods and Results**
- Appendix E2 Clover Point Mussel Tissue Chemistry Results**
- Appendix E3 Macaulay Point Benthic Community Spatial Distributions by Distance and Distance-Direction Group**

Appendix E1 Clover Point Mussel Tissue Chemistry Quality Assurance and Quality Control Methods and Results

METHODS

Field quality assurance and quality control (QA/QC) methods are detailed in CRD (2009d). In short, field procedures followed the Puget Sound Ambient Monitoring program (PSAMP, 2002) protocols and guidelines. These regionally developed protocols standardize marine sampling techniques and help to reduce variability between sampling events.

Rigorous QA/QC procedures were employed for mussel chemistry analyses. Approximately ten percent of the samples were identified for field and laboratory QA/QC, which consisted of the following procedures:

- analysis of a field triplicate (i.e., three replicate samples were collected in the field for an individual station)
- analysis of a laboratory triplicate (i.e., a sample was split by the laboratory into triplicate samples for analysis)
- analysis of one standard reference material (SRM); or, when reference materials were not available, analysis of a spiked sample (i.e., not a spiked blank)
- analysis of reference or surrogate standards spiked into each sample

All data reported to the CRD was uncorrected for blank or deuterated recoveries. Replicate (both field and laboratory triplicates) analyses were reported as the relative standard deviation (RSD) if the results were greater than or equal to 5x the detection limit, or standard deviation if the results were less than 5x the detection limit. RSD was calculated as follows:

$$\text{RSD} = \frac{\text{standard deviation concentration of replicate samples}}{\text{mean concentration of replicate samples}} \times 100\%$$

All 2010 results were screened using the revised CRD QA/QC Assessment Procedure (Golder, 2007d; CRD, 2009d). This procedure is based on data quality objectives (DQOs) that were originally developed with the MMAG in the early 1990s, following established laboratory analytical standards, but were re-evaluated and updated with new DQOs in 2007 (Golder, 2007d). The reassessment of the procedure was undertaken after a higher than usual number of QA/QC requirement failures was observed for the 2005 sediment and mussel tissue chemistry results.

Applying the revised DQOs involved procedures that evaluated the data for precision (based on variability in lab or field replicates), bias (based on recoveries of spikes, surrogate standards or certified reference materials), and representativeness (based on blank sample contamination) using specific criteria for each analytical group. The extremity of precision, bias or representativeness failures were determined, and data with moderate failures were flagged, while data with severe failures were rejected. All data that exhibited failures were questioned and a determination of the causes was undertaken. Rejected results are not presented in this report and are not used for further analyses (e.g., statistical analyses). Appendix A4 presents a detailed summary of the revised CRD QA/QC Assessment Procedures, and a description of the data flags (Golder, 2007d).

Mussel tissue analyses of total metals, chlorinated hydrocarbons, base-neutral extractables, chlorinated phenolics and phthalate esters were conducted by ALS in four batches. Table E1-1 lists the sites and substances analyzed in each batch. Each batch had associated blank and matrix spike samples that were used to assess DQOs for representativeness and bias on a batch-wide basis. All batches had laboratory and field replicates that were used to assess precision. Precision was assessed on a batch-wide basis.

Mussel tissue analyses of PAHs and phthalates were conducted by AXYS in three batches. Table E1-1 lists the samples analyzed in each batch. Each batch had associated blank and matrix spike samples that were used to assess DQOs for representativeness and bias on a batch-wide basis. All batches had laboratory and field replicates that were used to assess precision.

RESULTS

Table E1-2 presents a summary of the DQO failures observed for each of the three DQO types for the ALS and AXYS data. The substances that did not meet the DQOs in 2010 are identified by "QA" in table E2 and were rejected for use in statistical analysis. All remaining mussel analysis results passed both laboratory and DQOs (i.e., analyte spikes, method blanks, laboratory triplicates, field triplicates and standard reference materials) (CRD, 2009d).

Table E1-1 Summary of Batch Information for 2010 Mussel Data

Mussel Tissue (ALS data)			Mussel Tissue (AXYS data)		
Station	Sample Type	CRD Sample Name	Station	Sample Type	CRD Sample Name
Batch 1			PAH Batch 1A (WG34777)		
C100S	SS, LR1, LR2		C0	SS	
C400W	FR1, Recheck		C0	SS (Duplicate)	
C400W	FR2, Recheck		C0	SS (Duplicate)	
C400W	FR3, Recheck		PAH Batch 1B (WG34105)		
C100E	SS, Recheck		C200E	SS	
CB2	SS		C400W	FR1	
CB3	SS, Recheck		C400W	FR2	
CB4	SS, Recheck		C400W	FR3	
CB5	SS, Recheck		C200S	SS	
C0	SS		C100SW	SS	
Batch 2			C100NE	SS	
CB	SS, LR1, LR2		C100NW	SS	
C400SW	FR1, Recheck		C100SE	SS	
C400SW	FR2, Recheck		CB	SS	
C400SW	FR3, Recheck		C400SE	SS	
C100NW	SS		CB2	SS	
C100SE	SS		CB3	SS	
C100SW	SS		C400E	SS	
C200N	SS, Recheck		C800E	FR1	
Batch 3			C800W	SS	
C200W	SS, LR1, LR2, Recheck		C200W	SS	
C100W	FR1, Recheck		C400SW	FR1	
C100W	FR2, Recheck		PAH Batch 2 (WG34156)		
C100W	FR3, Recheck		C100E	SS	
C100NE	SS		C100E	SS (Duplicate)	
C200NW	SS		C100S	SS	
C200NE	SS		C100W	FR1	
C200S	SS, Recheck		C100W	FR2	
Batch 4			C100W	FR3	
C800W	SS, LR1, LR2, Recheck		C200NE	SS	
C400NE	SS		C200NW	SS	
C400SE	SS		C400NE	SS	
C800E	FR1, Recheck		C400NW	SS	
C800E	FR2, Recheck		CB4	SS	
C800E	FR3, Recheck		CB5	SS	
C400E	SS				
C400NW	SS		Continues on next page/...		
C200E	SS, Recheck				

Table E1-1 continued

Mussel Tissue (ALS data)			Mussel Tissue (AXYS data)		
Station	Sample Type	CRD Sample Name	Station	Sample Type	CRD Sample Name
			PCDD Batch 1 (WG34122)		
			C0	SS	
			C200NE	SS	
			C100NE	SS	
			C100NW	SS	
			C100SE	SS	
			C100SW	SS	
			C200E	SS	
			C200S	SS	
			C200W	SS	
			C400E	SS	
			C400SE	SS	
			C400SW	FR1	
			C400W	FR1	
			C400W	FR2	
			C400W	FR3	
			C800E	FR1	
			C800W	SS	
			CB2	SS	
			CB3	SS	

Table E1-2 Summary of DQO Failures and Data Qualifiers for the 2010 Mussel Data, Batch Wide Flags

Parameter	BATCH WIDE FLAGS							
	Batch 1		Batch 2		Batch 3		Batch 4	
	Detects	Non-detects	Detects	Non-Detects	Detects	Non-Detects	Detects	Non-Detects
Physical Tests								
% Moisture	.	.	.	.	.	.	.	.
Metals								
Aluminum (Al)-Total	.	.	.	.	.	.	J	UN
Antimony (Sb)-Total	.	.	.	.	.	.	.	.
Arsenic (As)-Total	.	.	.	.	.	.	.	.
Beryllium (Be)-Total	.	.	.	.	.	.	.	.
Cadmium (Cd)-Total	.	.	J	UN	.	.	J	UN
Chromium (Cr)-Total	.	.	.	.	.	.	.	.
Copper (Cu)-Total	.	.	J	UN	.	.	.	.
Iron (Fe)-Total	.	.	.	.	.	.	.	.
Lead (Pb)-Total	.	.	J	UN	.	.	.	.
Magnesium (Mg)-Total	.	.	.	.	.	.	.	.
Manganese (Mn)-Total	.	.	.	.	.	.	.	.
Mercury (Hg)-Total	.	.	.	.	.	.	J	UN
Nickel (Ni)-Total	.	.	.	.	.	.	J-	UN
Selenium (Se)-Total	.	.	.	.	.	.	.	.
Silver (Ag)-Total	J	UN	J	UN	J	UN	J	UN
Thallium (Tl)-Total	.	.	.	.	.	.	.	.
Zinc (Zn)-Total	.	.	.	.	.	.	.	.
Aggregate Organics								
Lipid Content	.	.	.	.	.	.	.	.
Chlorinated Hydrocarbons								
1,2-Dichlorobenzene	.	.	.	.	.	.	.	.
1,3-Dichlorobenzene	.	.	.	.	.	.	.	.
1,4-Dichlorobenzene	.	.	.	.	.	.	.	.
Hexachlorobutadiene	.	.	.	.	.	.	.	.
Hexachloroethane	.	.	.	.	.	.	R	R
1,2,4-Trichlorobenzene	.	.	.	.	.	.	.	.
Phthalate Esters								
Bis(2-ethylhexyl) phthalate	.	.	.	.	.	.	.	.
Benzyl butyl phthalate	.	.	.	.	.	.	.	.
Diethyl phthalate	.	.	.	.	.	.	.	.
Dimethyl phthalate	.	.	.	.	.	.	.	.
Di-n-butyl phthalate	.	.	.	.	.	.	.	.
Di-n-octyl phthalate	.	.	.	.	.	.	.	.

Table E1-2 continued

Parameter	BATCH WIDE FLAGS continued							
	Batch 1		Batch 2		Batch 3		Batch 4	
	Detects	Non-detects	Detects	Non-Detects	Detects	Non-Detects	Detects	Non-Detects
Semi-Volatile Organics								
4-Bromophenyl phenyl ether	.	.	.	.	.	.	.	.
Bis(2-chloroethoxy)methane	.	.	.	.	.	.	.	.
Bis(2-chloroethyl)ether	R	U	R	U	R	U	R	U
Bis(2-chloroisopropyl)ether	.	.	.	.	.	.	.	.
2-Chloronaphthalene	.	.	.	.	.	.	.	.
4-Chlorophenyl phenyl ether	.	.	.	.	.	.	.	.
Phenolics								
2-Chlorophenol	.	.	.	.	J-	UN	.	.
2,4 & 2,5-Dichlorophenol	.	.	.	.	J-	UN	.	.
Pentachlorophenol	.	.	.	.	.	.	.	.
2,4,6-Trichlorophenol	.	.	.	.	J-	UN	.	.
PCDDs (AXYS)								
% Lipid	.	.						
% Moisture	.	.						
1,2,3,4,6,7,8-HPCDD	.	.						
1,2,3,4,6,7,8-HPCDF	.	.						
1,2,3,4,7,8,9-HPCDF	.	.						
1,2,3,4,7,8-HXCDD	.	.						
1,2,3,4,7,8-HXCDF	.	.						
1,2,3,6,7,8-HXCDD	.	.						
1,2,3,6,7,8-HXCDF	.	.						
1,2,3,7,8,9-HXCDD	.	.						
1,2,3,7,8,9-HXCDF	.	.						
1,2,3,7,8-PECDD	.	.						
1,2,3,7,8-PECDF	.	.						
2,3,4,6,7,8-HXCDF	.	.						
2,3,4,7,8-PECDF	J+	U						
2,3,7,8-TCDD	.	.						
2,3,7,8-TCDF	.	.						
OCDD	.	.						
OCDF	J+	UN						
TEQ (ND = 0)	R	R						
TEQ (ND = 1/2 DL)	R	R						
Total Hepta-Dioxins	R	R						
Total Hepta-Furans	.	.						
Total Hexa-Dioxins	.	.						
Total Hexa-Furans	R	UN						
Total Penta-Dioxins	J	UN						
Total Penta-Furans	.	.						
Total Tetra-Dioxins	.	.						
Total Tetra-Furans	.	.						

Table E1-2 continued

Parameter	BATCH WIDE FLAGS							
	PAH Batch 1A		PAH Batch 1B		PAH Batch 2			
	Detects	Non-detects	Detects	Non-Detects	Detects	Non-Detects		
PAHs (AxyS)								
% Lipid	•	•	•	•	•	•		
% Moisture	•	•	•	•	•	•		
Acenaphthene	•	•	J+	U	J+	U		
Acenaphthylene	•	•	•	•	•	•		
Anthracene	•	•	J+	U	J+	U		
Benz[a]anthracene	•	•	•	•	•	•		
Benzo[a]pyrene	•	•	•	•	•	•		
Benzo[b]fluoranthene	•	•	•	•	•	•		
Benzo[ghi]perylene	•	•	•	•	•	•		
Benzo[j,k]fluoranthenes	•	•	•	•	•	•		
Chrysene	•	•	•	•	•	•		
Dibenz[a,h]anthracene	•	•	•	•	•	•		
Fluoranthene	•	•	•	•	J+	U		
Fluorene	•	•	J+	U	J+	U		
Indeno[1,2,3-cd]pyrene	•	•	•	•	•	•		
Naphthalene	R	U	J+	U	J+	U		
Phenanthrene	•	•	J+	U	R	U		
Pyrene	•	•	J+	U	R	U		
Total High Molecular Weight PAHs	•	•	•	•	J+	U		
Total Low Molecular Weight PAHs	J+	U	•	•	J+	U		
TOTAL PAHs	•	•	•	•	J+	U		

Notes:

- Symbol indicates that all DQOs met for analyte and batch.

R flag: Severe DQO failure; rejected data

J flag: Value is an estimate

J+ flag: Value is estimate with potential bias

J- flag: Value is an estimate with potential low bias

UN flag: Value not detected, possible false negative

U: Value was not detected (no DQO failure)

Table E1-3 Summary of DQO Failures and Data Qualifiers for the 2010 Mussel ALS Data

Parameter	SAMPLE SPECIFIC FLAGS																																																			
	Batch 1														Batch 2								Batch 3								Batch 4																					
	C400W FR1	C400W FR1 RECHECK	C400W FR2	C400FR2 RECHECK	C400W FR3	C400W FR3 RECHECK	C100E SS	C100E SS RECHECK	CB3 SS	CB3 SS RECHECK	CB4 SS	CB4 SS RECHECK	CB5 SS	CB5 SS RECHECK	C400SW FR1	C400SW FR1 RECHECK	C400SW FR2	C400SE FR2 RECHECK	C400SW FR3	C400SW FR3 RECHECK	C200N SS	C200N SS RECHECK	C200W SS	C200W LR1	C200W LR2	C200W SS RECHECK	C100W FR1	C100W FR1 RECHECK	C100W FR2	C100W FR2 RECHECK	C100W FR3	C100W FR3 RECHECK	C200S SS	C200S SS RECHECK	C800W SS	C800W LR1	C800W LR2	C800W SS RECHECK	C800E FR1	C800E FR1 RECHECK	C800E FR2	C800E FR2 RECHECK	C800E FR3	C800E FR3 RECHECK	C200E SS	C200E SS RECHECK						
Metals																																																				
Aluminum (Al)–Total																																									J		J		J							
Arsenic (As)–Total																																																				
Cadmium (Cd)–Total																																																				
Chromium (Cr)–Total																														R		R		J		J																
Copper (Cu)–Total																																																				
Lead (Pb)–Total																																																				
Manganese (Mn)–Total				R		R																																														
Mercury (Hg)–Total																																												J		J		J				
Silver (Ag)–Total	J		J		R		R												J		J		J		J			J		J						R								J		J						
Aggregate Organics																																																				
Lipid Content										R			R		J		J																																			

Notes
Sample specific failure apply to sample only.
R flag: Severe DQO failure; rejected data
J flag: Value is an estimate
J+ flag: Value is an estimate with potential high bias
J- flag: Value is an estimate with potential low bias
UN flag: Value was not detected, possible false negative
U: Value was not detected (no DQO failure)

Appendix E2 Clover Point Mussel Tissue Chemistry Results 2010

All results expressed on a dry weight basis.

Station	Physical Tests						Total Metals											
	Lipid Content (ALS)	Lipid Content (AXYS-PAH)	Lipid Content (AXYS-PCDD)	Moisture (ALS)	Moisture (AXYS-PAH)	Moisture (AXYS-PCDD)	Al Alumium	Sb Antimony	As Arsenic	Be Beryllium	Cd Cadmium	Cr Chromium	Cu Copper	Fe Iron	Pb Lead	Mg Magnesium	Mn Manganese	Hg Mercury
Units	%	%		%		%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
MDL	0.5	---		0.1		---	10	0.05	0.05	0.3	0.03	0.5	0.05	1	0.1	3	0.05	0.005
C0	2	1.34	1.34	84.3	84.8	84.5±1.66	104	<0.050	11.7	<0.30	17.8	1.15	143	409	25.8	4210	176	0.246
C1E	2.5	1.17	n/a	82.7±0	82.3±0.29	n/a	217	<0.050	13.8±1.13	<0.30	15.2	1.44	124	493	12.6	3520	196	0.272
C1NE	1	0.93	0.93	83.7	84.2	83.3	545	<0.050	12.5	<0.30	16.6	2.21	81.5	981	4.38	5080	341	0.198
C1NW	1.3	0.74	0.74	85.7	85.7	84.8	526	<0.10	11.7	<0.60	13	1.7	86.4	991	3.61	4990	173	0.2
C1S	2.03±0.15	0.85	n/a	83.5±0	83.7	n/a	361±7.23	<0.10	13.2±0.15	<0.60	13.3±0.21	2.37±0.05	79.2±2.38	666±30.6	4.79±0.13	3997±30.6	251±2.08	0.31±0.02
C1SE	1.4	0.77	0.77	85.3	84.6	83	383	<0.10	13	<0.60	18.5	1.7	67.5	708	7.73	4990	223	0.344
C1SW	1.3	0.82	0.82	85.5	83.6	83.9	524	<0.10	12.6	<0.60	15.4	2.7	68.8	927	5.33	4890	260	0.299
C1W	1.67±0.12	0.81±0.05	n/a	85±1.68	84.5±0.46	n/a	420±46.8	<0.050	12±0.4	<0.30	14.3±0.8	1.88±0.47	79.5±5.45	747±53.5	7.9±0.91	5293±661	272±27.2	0.25±0.01
C2E	2.1	0.94	0.94	82.6±0	83.5	81.6	294	<0.050	15±2.26	<0.30	20.9±3.89	1.6	101	565	10.4	4300	358	0.312
C2N	1.6	1.37	n/a	83±0	82.5	n/a	464	<0.10	12.2	<0.60	14.2	13.7±1.2	44.9	1050	5.58	3900	259	0.227
C2NE	0.9	0.96	n/a	84.2	83.5	n/a	504	<0.050	13.1	<0.30	14.4	3.65	73.3	741	4.4	5200	228	0.22
C2NW	0.9	0.8	n/a	84.5	83.7	n/a	604	<0.10	12.8	<0.60	14.8	2.4	81.2	1160	4.76	5160	348	0.185
C2S	1.1	1.34	1.34	84.4±0	83.3	83.3	440	<0.10	15.9	<0.60	24.9±0.42	2.6	87.2	714	8.69	5500	293	0.475
C2W	1.77±0.31	1.25	1.25	85±0.14	84.7	85.5	372±17.6	<0.10	12±0	<0.60	17.2±0.2	2.13±0.49	71.9±0.89	619±31.6	6.85±0.07	5310±45.8	257±2.08	0.27±0.01
C4E	1.2	0.87	0.87	83.2	83.4	82.7	261	<0.050	10.7	<0.30	6.42	1.49	85.6	507	2.84	4530	206	0.153
C4NE	1.2	0.77	n/a	84.1	84.3	n/a	827	<0.10	12.2	<0.60	17.8	4.2	65.1	1270	5.48	5170	282	0.241
C4NW	1.9	0.82	n/a	85.9	85.1	n/a	439	<0.10	11.2	<0.60	14.5	1.4	74	733	3.45	5750	328	0.189
C4SE	1	0.64	0.64	85.5	84.4	85.7	773	<0.10	11.4	<0.60	16.4	3.8	61	794	5.08	4710	260	0.427
C4SW	1.27±0.15	0.82	0.82	86.2±1.39	85.2	84.7	579±101	<0.10	12.2±1.77	<0.60	20.1±4.48	2.63±0.74	74.2±15.8	1164±190	6.3±1.6	5333±526	254±41.1	0.31±0.03
C4W	1.73±0.12	1.00±0.12	1.00±0.12	85.1±1.1	84.5±0.82	84.7±1.32	471±70.3	<0.10	13.2±0.53	<0.60	18.3±1.16	2.73±0.31	71.2±8.62	922±109	5.98±0.48	4923±537	280±2.83	0.29±0.02
C8E	1.27±0.06	0.65	0.65	84.5±0.91	84.1	85	577±130	<0.10	12.9±1.3	<0.60	18.1±3.64	2.27±0.11	77.2±14.15	940±62.55	5.39±0.72	5200±429	301±55.8	0.34±0.09
C8W	1.13±0.15	0.78	0.78	85.5±0	84.6	84.7	451±56.03	<0.10	13±0.7	<0.60	17.5±1.11	1.93±0.58	76.3±3.23	766±51	6.34±0.46	6227±401	248±16.5	0.24±0.01
CB1	1.9	0.85	0.85	85.4±0	84.3	83.1	580±39.3	<0.10	14.3±0.32	<0.60	21.9±0.45	3.33±0.11	49.8±0.55	1420±120	5.18±0.23	5113±75.1	307±6.93	0.47±0.01
CB2	1.8	0.61	0.61	84.8	85.7	85.5	606	<0.10	14.2	<0.60	19.5	2.8	63.2	1310	4.52	4550	251	0.517
CB3	<0.5	0.73	n/a	83.1	83.8	n/a	573	<0.10	13.9	<0.60	29.1	3	56.7	1530	6.69	4210	292	0.551
CB4	1	0.67	n/a	85.1	84.3	n/a	434	<0.10	14.9	<0.60	21.3	2.6	51.4	982	4.81	4700	175	0.473
CB5	0.9	0.94		85.3		84.4	430	<0.10	15.2	<0.60	35.6±2.97	2.6	60.5	1020	7.8	4660	294	0.74

Appendix E2, continued. All results expressed on a dry weight basis.

Station	Total Metals <i>continued</i>						Base Neutral Extractables						Chlorinated Hydrocarbons					
	Ni Nickel	Se Selenium	Ag Silver	Tl Thallium	Zn Zinc	Methyl- mercury	4- Bromo- phenyl phenyl ether	Bis(2- chloroethoxy)- methane	Bis(2- chloroethyl) ether	Bis(2- chloro- isopropyl)- ether	2-Chloro- naphthalene	4- Chlorophenyl phenyl ether	1,2- Dichloro- benzene	1,3- Dichloro- benzene	1,4- Dichloro- benzene	Hexachloro- butadiene	Hexachloro- ethane	1,2,4- Trichloro- benzene
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
MDL	0.5	1	0.03	0.03	0.5	0.005	0.1	0.1	2	0.1	0.1	0.1	0.01	0.01	0.01	0.01	0.01	0.01
C0	6.5	6.4	1.91	<0.030	531		<0.70	<0.70	<9.0	<0.70	<0.70	<0.70	<0.070	<0.070	<0.070	<0.070	<0.50	<0.070
C1E	8.6	8.2	2.66	<0.030	514		<0.70	<0.70	<12	<0.70	<0.70	<0.70	<0.070	<0.070	<0.070	<0.070	<0.50	<0.070
C1NE	11.1	7.7	2.07	0.034	536		<0.70	<0.70	<7.0	<0.70	<0.70	<0.70	<0.070	<0.070	<0.070	<0.070	<0.50	<0.070
C1NW	7.4	7.2	4.26	<0.060	291		<0.70	<0.70	<11	<0.70	<0.70	<0.70	<0.070	<0.070	<0.070	<0.070	<0.50	<0.070
C1S	12.8±0.15	7.93±0.21	12.4±1.59	<0.060	505±4.36		<1.0	<1.0	<13	<1.0	<1.0	<1.0	<0.10	<0.10	<0.10	<0.10	<0.50	<0.10
C1SE	12	7.4	18.7	<0.060	456		<0.70	<0.70	<12	<0.70	<0.70	<0.70	<0.070	<0.070	<0.070	<0.070	<0.50	<0.070
C1SW	12.8	7.9	17.9	<0.060	497		<0.70	<0.70	<12	<0.70	<0.70	<0.70	<0.070	<0.070	<0.070	<0.070	<0.50	<0.070
C1W	10.9±0.75	7.07±0.57	8.8±0.51	<0.030	467±57.2		<0.70	<0.70	<8.5	<0.70	<0.70	<0.70	<0.070	<0.070	<0.070	<0.070	<0.50	<0.070
C2E	10.7	7.6	8.16	<0.030	593		<0.70	<0.70	<6.5	<0.70	<0.70	<0.70	<0.070	<0.070	<0.070	<0.070	<0.50	<0.070
C2N	15.7	6.1	16.5	<0.060	541		<0.60	<0.60	<9.0	<0.60	<0.60	<0.60	<0.060	<0.060	<0.060	<0.060	<0.50	<0.060
C2NE	10.3	7.6	4.55	<0.030	374		<0.70	<0.70	<8.0	<0.70	<0.70	<0.70	<0.070	<0.070	<0.070	<0.070	<0.50	<0.070
C2NW	11.5	7.8	13.3	<0.060	557		<0.70	<0.70	<7.5	<0.70	<0.70	<0.70	<0.070	<0.070	<0.070	<0.070	<0.50	<0.070
C2S	17.6	9.5	20.7	<0.060	694		<0.70	<0.70	<8.5	<0.70	<0.70	<0.70	<0.070	<0.070	<0.070	<0.070	<0.50	<0.070
C2W	11.3±0.1	7.2±0.1	15.2±6.59	<0.060	472±5.51		<0.70	<0.70	<9.0	<0.70	<0.70	<0.70	<0.070	<0.070	<0.070	<0.070	<0.50	<0.070
C4E	7.13	7.6	0.63	<0.030	367		<0.70	<0.70	<8.5	<0.70	<0.70	<0.70	<0.070	<0.070	<0.070	<0.070	<0.50	<0.070
C4NE	12.1	7	11.2	<0.060	561		<0.70	<0.70	<8.5	<0.70	<0.70	<0.70	<0.070	<0.070	<0.070	<0.070	<0.50	<0.070
C4NW	9.5	7.5	7.1	<0.060	445		<0.70	<0.70	<9.0	<0.70	<0.70	<0.70	<0.070	<0.070	<0.070	<0.070	<0.50	<0.070
C4SE	11.3	6.4	33.6	<0.060	522		<0.70	<0.90	<12	<0.70	<0.70	<0.70	<0.070	<0.070	<0.070	<0.070	<0.50	<0.070
C4SW	12.7±1.8	7.43±1.4	14.8±6.05	<0.060	500±55.9		<0.70	<0.70	<12	<0.70	<0.70	<0.70	<0.070	<0.070	<0.070	<0.070	<0.50	<0.070
C4W	12.6±0.65	7.4±0.3	21.9±15.1	<0.060	462±86.5		<0.70	<0.70	<8.0	<0.70	<0.70	<0.70	<0.070	<0.070	<0.070	<0.070	<0.50	<0.070
C8E	11.9±1.5	7.57±0.32	13.3±9.77	<0.060	535±28.7		<0.70	<0.70	<8.0	<0.70	<0.70	<0.70	<0.070	<0.070	<0.070	<0.070	<0.50	<0.070
C8W	11.8±0.76	8.07±0.64	9.79±5.63	<0.060	464±23.2		<0.70	<0.70	<8.0	<0.70	<0.70	<0.70	<0.070	<0.070	<0.070	<0.070	<0.50	<0.070
CB1	16.1±0.26	7.77±0.15	14.6±4.98	<0.060	487±19.7		<2.0	<2.0	<27	<2.0	<2.0	<2.0	<0.20	<0.20	<0.20	<0.20	<0.50	<0.20
CB2	15.4	8.1	30.2	<0.060	488		<0.90	<0.90	<11	<0.90	<0.90	<0.90	<0.090	<0.090	<0.090	<0.090	<0.50	<0.090
CB3	19.8	7	37.5	<0.060	658		<0.70	<0.70	<8.0	<0.70	<0.70	<0.70	<0.070	<0.070	<0.070	<0.070	<0.50	<0.070
CB4	13.5	7.8	18.5	<0.060	436		<0.70	<0.70	<9.0	<0.70	<0.70	<0.70	<0.070	<0.070	<0.070	<0.070	<0.50	<0.070
CB5	18.2	8.1	50.5	<0.060	664		<0.70	<0.70	<8.0	<0.70	<0.70	<0.70	<0.070	<0.070	<0.070	<0.070	<0.50	<0.070

Appendix E2, continued. All results expressed on a dry weight basis.

Station	Chlorinated Phenolics				Phthalate Esters						HIGH Resolution PAHs					
	2-Chloro-phenol	2,4 & 2,5-Dichloro-phenol	Pentachloro-phenol	2,4,6-Trichloro-phenol	Bis(2-ethylhexyl) phthalate	Benzyl butyl phthalate	Diethyl phthalate	Dimethyl phthalate	Di-n-butyl phthalate	Di-n-octyl phthalate	Acenaphthene	Acenaphthylene	Anthracene	Benz[a]-anthracene	Benzo[a]-pyrene	Benzo[b]-fluoranthene
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
MDL	0.1	0.1	0.1	0.1	0.1	0.1	1	1	0.1	0.1	---	---	---	---	---	---
C0	<0.10	<0.10	<0.10	<0.10	<1.3	<0.70	<7.0	<7.0	<0.70	<0.70	2.87±0.05	NDR	4.62±0.2	10.6±0.32	7.08±0.63	7.9±0.34
C1E	<0.10	<0.10	<0.10	<0.10	<1.1	<1.4	<7.0	<7.0	<0.70	<0.70	1.22±0.07	NDR	1.63±0.19	3.64±0.28	2.08±0.15	3.16±0.26
C1NE	<0.10	<0.10	<0.10	<0.10	<1.5	<5.7	<1.0	<1.0	<0.90	<0.40	0.928	NDR	0.837	2.04	1.05	2.42
C1NW	<0.10	<0.10	<0.10	<0.10	<1.4	<4.2	<1.0	<1.0	<0.30	<0.20	0.838	NDR	1.88	2.13	1.04	2.33
C1S	<0.10	<0.10	<0.10	<0.10	<1.0	<1.0	<10	<10	<1.0	<1.0	0.615	NDR	0.74	2.23	1.09	2.48
C1SE	<0.10	<0.10	<0.10	<0.10	<0.70	<2.0	<1.0	<1.0	<0.20	<0.20	0.74	NDR	0.884	2.15	1.14	2.4
C1SW	<0.10	<0.10	<0.10	<0.10	<1.4	<1.0	<1.0	<1.0	<0.30	<0.60	1.66	NDR	3.14	8.26	6.9	6.44
C1W	<0.10	<0.10	<0.10	<0.10	<2.4	<5.4	<1.0	<1.0	<0.80	<0.60	0.83±0.08	NDR	0.89±0.14	2.26±0.14	1.26±0.19	2.5±0.14
C2E	<0.10	<0.10	<0.10	<0.10	<0.80	<0.70	<1.0	<1.0	<0.20	<0.10	1.12	NDR	1.28	3.07	1.41	2.66
C2N	<0.10	<0.10	<0.10	<0.10	<0.90	<1.1	<1.5	<1.0	<0.20	<0.20	0.851	NDR	0.579	1.67	1.17	2.42
C2NE	<0.10	<0.10	<0.10	<0.10	<1.7	<5.5	<1.0	<1.0	<0.80	<0.20	1.05	NDR	0.759	1.76	0.804	2.31
C2NW	<0.10	<0.10	<0.10	<0.10	<1.1	<5.2	<1.0	<1.0	<0.70	<0.20	0.754	NDR	0.827	1.89	0.814	2.11
C2S	<0.10	<0.10	<0.10	<0.10	2.32	<4.7	<1.0	<1.0	0.46	0.47	NDR	NDR	2.32	1.33	NDR	1.76
C2W	<0.10	<0.10	0.08±0.05	<0.10	<3.0	<7.4	<1.0	<1.0	<1.2	<1.6	1.11	NDR	0.908	2.21	1.18	2.46
C4E	<0.10	<0.10	<0.10	<0.10	<1.1	<0.70	<1.0	<1.0	<0.30	<0.10	0.829	NDR	0.978	1.85	NDR	2.09
C4NE	<0.10	<0.10	<0.10	<0.10	<0.50	<4.0	<1.0	<1.0	<0.20	<0.10	0.93	NDR	0.88	1.65	1.07	2.53
C4NW	<0.10	<0.10	<0.10	<0.10	<0.60	<2.0	<1.0	<1.0	<0.20	<0.20	0.704	NDR	0.568	1.56	0.879	2.05
C4SE	<0.10	<0.10	<0.10	<0.10	<1.4	<1.4	<1.0	<1.0	<0.30	<0.10	0.559	NDR	0.698	1.34	0.764	1.99
C4SW	0.08±0.05	<0.10	<0.10	<0.10	<4.0	<5.1	<1.0	<1.0	<0.30	<0.20	0.772	NDR	0.617	1.35	0.668	2.07
C4W	<0.10	<0.10	<0.10	<0.10	<0.90	<0.70	<7.0	<7.0	<0.70	<0.70	0.86±0.09	NDR	0.75±0.03	1.84±0.33	1.01±0.19	2.33±0.1
C8E	<0.10	<0.10	<0.10	<0.10	<0.60	<1.7	<1.0	<1.0	<0.30	<0.10	0.827	NDR	1.27	1.51	0.946	2.16
C8W	<0.10	<0.10	<0.10	<0.10	<2.5	<6.0	<1.0	<1.0	<0.40	<0.20	0.616	NDR	0.702	1.38	0.764	1.92
CB1	-	-	-	-	<1.6	<1.6	<1.0	<1.0	<0.60	<0.10	NDR	NDR	0.884	1.25	<0.597	2.15
CB2	<0.10	<0.10	<0.10	<0.10	<0.90	<0.90	<9.0	<9.0	<0.90	<0.90	0.68	NDR	1.68	1.27	0.689	1.93
CB3	<0.10	<0.10	<0.10	<0.10	<0.70	<0.70	<7.0	<7.0	<0.70	<0.70	0.664	NDR	2.16	1.37	0.808	1.94
CB4	<0.10	<0.10	<0.10	<0.10	<0.70	<0.70	<7.0	<7.0	<0.70	<0.70	0.524	NDR	0.56	NDR	0.695	1.9
CB5	<0.10	<0.10	<0.10	<0.10	<0.70	<0.70	<7.0	<7.0	<0.70	<0.70	0.558	NDR	0.999	1.63	0.765	2.08

Appendix E2 continued. All results expressed on a dry weight basis.

Station	HIGH Resolution PAHs <i>continued</i>												
	Benzo[ghi]- perylene	Benzo[j,k]- fluoranthenes	Chrysene	Dibenz[a,h]- anthracene	Fluoran-thene	Fluorene	Indeno[1,2,3- cd]pyrene	Naph- thalene	Phenan- threne	Pyrene	Total High Molecular Weight PAHs	Total Low Molecular Weight PAHs	TOTAL PAHs
Units	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
MDL	---	---	---	---	---	---	---	---	---	---	---	---	---
C0	NDR	7.4±0.13	13.4±0.5	0.63±0.02	31±0.81	7.59±0.57	3.62±0.4	QA	29.7±0.87	23±0.9	104±1.15	55±0.72	160±2.31
C1E	NDR	2.66±0.22	5.33±0.18	<0.159	10.2±0.3	4.63±0.15	NDR	6.97±1.16	QA	QA	32.7±2.31	26.6±1.15	59.4±2.61
C1NE	NDR	2.13	3.46	<0.55	6.76	3.27	NDR	6.61	7.5	3.19	21.1	19.1	40.2
C1NW	NDR	2	3.57	<0.631	6.54	2.4	NDR	8.3	11	3.17	20.8	24.4	45.2
C1S	NDR	1.72	3.39	<0.131	6.15	4.33	NDR	5.73	QA	QA	19.5	19.2	38.7
C1SE	NDR	1.91	3.7	<0.309	7	3.82	NDR	7.31	8.35	3.4	21.7	21.1	42.8
C1SW	NDR	7.18	8.63	NDR	17.6	3	4.07	5.35	10.9	12.4	71.5	24.1	95.5
C1W	NDR	1.8±0.14	3.72±0.3	<0.155	7.55±0.51	4.2±0.35	0.789	7.08±2.13	QA	QA	22.6±0.92	23.5±2.66	46±3.41
C2E	NDR	2.62	4.8	<0.474	8.68	4.78	NDR	7.49	10.2	4.31	27.6	24.9	52.4
C2N	NDR	2.37	3.38	NDR	6.18	3.29	0.786	7.1	QA	QA	21	17.5	38.5
C2NE	NDR	1.62	3.03	<0.123	5.7	3.07	NDR	7.15	QA	QA	18.1	19	37.1
C2NW	NDR	1.62	3.39	NDR	6.12	4.17	NDR	5.31	QA	QA	19.1	17.9	37
C2S	NDR	2.12	2.91	<0.467	4.74	4.01	0.713	NDR	5.91	1.77	15.3	12.2	27.6
C2W	NDR	2.11	3.83	<0.308	6.88	3.71	NDR	11.1	8.23	3.67	22.3	25.1	47.4
C4E	NDR	1.77	3.15	<0.401	6.33	1.92	NDR	7.66	7.87	3	18.2	19.3	37.4
C4NE	NDR	2.05	3.41	NDR	5.74	3.52	NDR	7.72	QA	QA	16.5	20.6	37
C4NW	NDR	1.54	2.83	<0.135	NDR	2.24	NDR	6.05	QA	QA	8.86	15.1	23.9
C4SE	NDR	1.88	2.98	<0.282	4.36	3.59	NDR	7.7	6.52	1.76	15.1	19.1	34.1
C4SW	NDR	1.76	2.91	<0.535	4.73	3.48	NDR	10.7	7.09	2.1	15.6	22.7	38.2
C4W	NDR	2.03±0.49	3.5±0.34	<0.633	6.13±0.57	4.14±0.25	NDR	7.8±1.16	7.56±0.24	2.98±0.45	19.8±2.3	21.1±1.15	40.9±1.7
C8E	NDR	1.76	2.95	<0.226	5.22	4.67	NDR	6.44	7.37	2.5	17	20.6	37.6
C8W	NDR	1.51	2.85	<0.343	4.76	3.27	NDR	6.16	6.35	1.94	15.1	17.1	32.2
CB1	NDR	1.67	2.9	<0.485	4.8	3.42	NDR	10.4	6.67	2.14	14.9	21.4	36.3
CB2	NDR	1.65	2.77	<0.261	4.4	2.87	NDR	7.33	5.3	1.6	14.3	17.9	32.2
CB3	NDR	1.97	3.57	<0.381	4.83	4.8	NDR	7.88	6.26	1.99	16.5	21.8	38.2
CB4	NDR	1.29	2.37	<0.164	NDR	3.16	NDR	6.49	QA	QA	7.33	15.2	22.5
CB5	NDR	2.4	3.3	<0.189	4.79	5.06	NDR	5.35	QA	QA	16.6	17.2	33.8

Appendix E2, continued. All results expressed on a dry weight basis.

Station	High Resolution Polychlorinated Dibenzodioxins (PCDDs)														
	1,2,3,4,6,7,8- HPCDD	1,2,3,4,6,7,8- HPCDF	1,2,3,4,7,8,9- HPCDF	1,2,3,4,7,8- HXCDD	1,2,3,4,7,8- HXCDF	1,2,3,6,7,8- HXCDD	1,2,3,6,7,8- HXCDF	1,2,3,7,8,9- HXCDD	1,2,3,7,8,9- HXCDF	1,2,3,7,8- PECDD	1,2,3,7,8- PECDF	2,3,4,6,7,8- HXCDF	2,3,4,7,8- PECDF	2,3,7,8- TCDD	2,3,7,8- TCDF
Units	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
MDL	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
C0	1.86±0.37	NDR	<0.341	0.26±0.16	0.51±0.61	0.43±0.46	<0.27	<0.329	<0.27	0.45±0.51	<0.27	0.49±0.59	<0.27	<0.27	0.779
C1E	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
C1NE	NDR	NDR	<0.273	<0.424	<0.273	NDR	<0.273	<0.429	<0.273	<0.273	<0.273	<0.273	<0.273	<0.273	0.441
C1NW	NDR	NDR	<0.312	<0.59	<0.312	<0.597	<0.312	<0.594	<0.312	<0.316	<0.312	<0.312	<0.312	<0.312	NDR
C1S	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
C1SE	1.99	NDR	<0.426	<0.281	<0.281	<0.281	<0.281	NDR	<0.281	<0.281	<0.281	0.312	<0.281	NDR	0.361
C1SW	NDR	NDR	<0.29	<0.29	<0.29	NDR	<0.29	<0.29	<0.29	<0.29	<0.29	<0.29	<0.29	<0.29	NDR
C1W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
C2E	NDR	0.87	<0.255	<0.255	<0.255	<0.255	<0.255	<0.255	<0.255	<0.284	<0.255	<0.255	<0.255	<0.255	0.372
C2N	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
C2NE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
C2NW	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
C2S	1.98	NDR	<0.292	0.294	<0.282	0.378	<0.282	NDR	<0.282	<0.282	<0.282	<0.282	<0.282	<0.282	0.388
C2W	2.66	NDR	<0.341	<0.341	<0.341	0.463	<0.341	<0.341	<0.341	<0.341	<0.341	<0.341	<0.341	<0.341	0.409
C4E	2.04	NDR	<0.282	<0.614	<0.282	<0.637	<0.282	<0.626	<0.282	<0.282	<0.282	<0.282	<0.282	<0.282	0.543
C4NE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
C4NW	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
C4SE	NDR	NDR	<0.349	<0.349	<0.349	<0.349	<0.349	<0.349	<0.349	<0.349	<0.349	<0.349	<0.349	NDR	NDR
C4SW	NDR	NDR	<0.391	<0.561	0.38	<0.584	<0.321	<0.573	<0.321	<0.321	<0.321	<0.321	<0.321	<0.321	0.338
C4W	1.85	NDR	<0.353	<0.353	<0.353	NDR	<0.353	<0.353	<0.353	<0.353	<0.353	<0.353	0.25±0.13	<0.353	0.55±0.12
C8E	NDR	NDR	<0.323	<0.323	<0.323	<0.323	0.326	<0.323	<0.323	<0.323	NDR	<0.323	<0.323	<0.323	0.389
C8W	NDR	1.15	<0.302	<0.386	<0.302	<0.385	<0.302	<0.385	<0.302	<0.302	<0.302	<0.302	<0.302	<0.302	0.423
CB1	1.87	0.704	<0.331	<0.444	<0.331	<0.462	<0.331	<0.453	<0.331	<0.331	<0.331	<0.331	<0.331	NDR	NDR
CB2	NDR	NDR	NDR	<0.276	NDR	0.473	<0.276	NDR	NDR	NDR	<0.276	NDR	0.325	<0.276	0.518
CB3	NDR	NDR	<0.33	<0.385	<0.33	NDR	<0.33	<0.391	<0.33	<0.33	<0.33	<0.33	<0.33	<0.33	<0.322
CB4	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CB5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

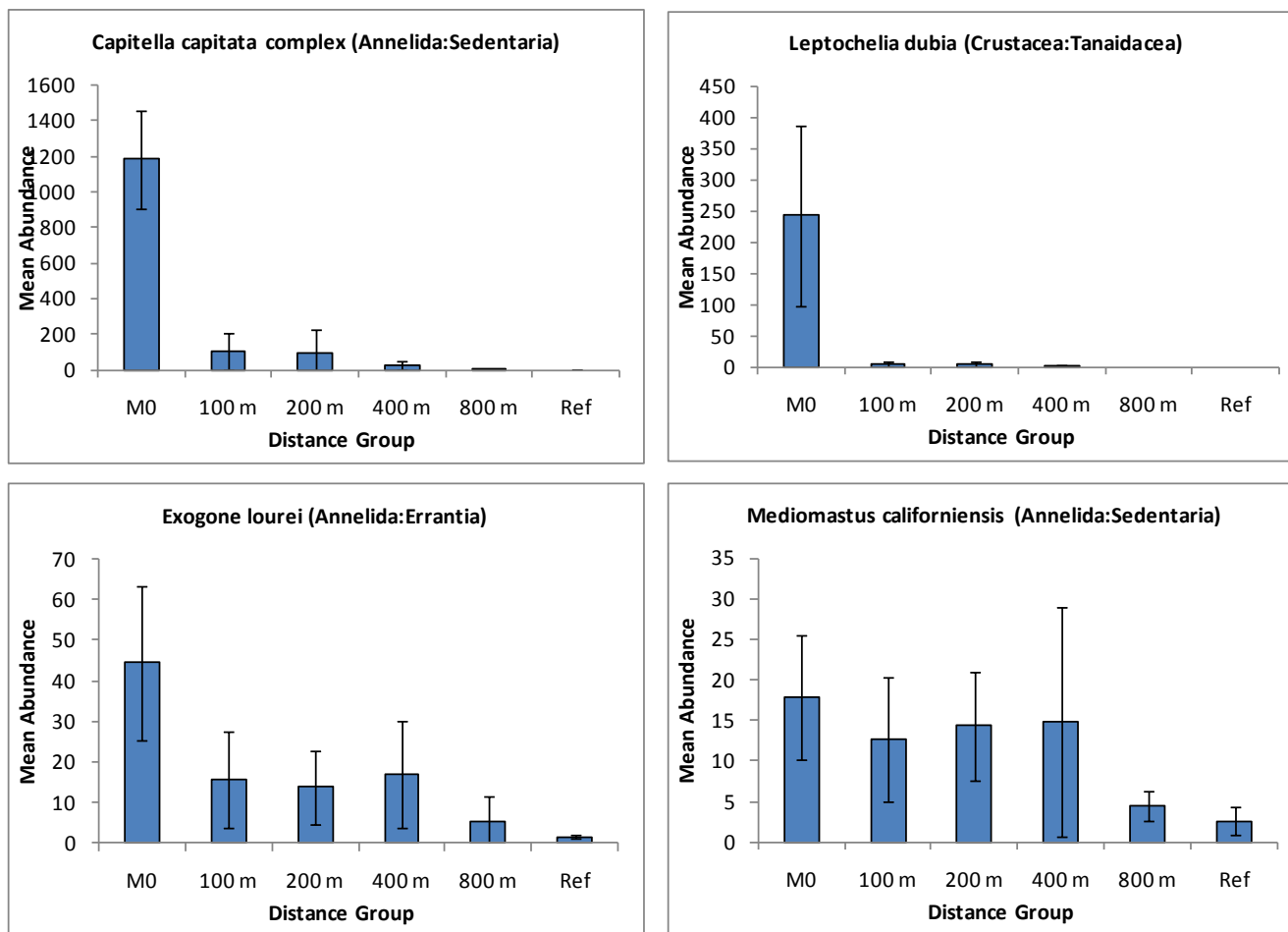
Appendix E2, continued. All results expressed on a dry weight basis.

Station	HIGH Resolution PCDDs <i>continued</i>											
	OCDD	OCDF	TEQ (ND = 0)	TEQ (ND = 1/2 DL)	TOTAL Hepta-Dioxins	TOTAL Hepta-Furans	TOTAL Hexa-Dioxins	TOTAL Hexa-Furans	TOTAL Penta-Dioxins	TOTAL Penta-Furans	TOTAL Tetra-Dioxins	TOTAL Tetra-Furans
Units	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g	pg/g
MDL	---	---	---	---	---	---	---	---	---	---	---	---
C0	10.9±1.97	NDR	QA	QA	QA	0.3±0.27	0.98±0.39	QA	0.65±0.86	0.51±0.62	<0.314	1.3±0.43
C1E	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
C1NE	9.15	0.945	QA	QA	QA	<0.273	<0.435	QA	<0.273	<0.273	<0.273	<0.287
C1NW	9.73	0.979	QA	QA	QA	<0.312	<0.597	QA	<0.316	<0.312	<0.312	0.394
C1S	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
C1SE	NDR	NDR	QA	QA	QA	<0.426	0.719	QA	<0.281	<0.281	<0.281	0.807
C1SW	11.2	1.23	QA	QA	QA	<0.29	<0.29	QA	<0.29	<0.29	0.484	<0.29
C1W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
C2E	7.29	1.09	QA	QA	QA	1.24	<0.255	QA	<0.284	<0.255	<0.255	<0.255
C2N	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
C2NE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
C2NW	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
C2S	9.67	NDR	QA	QA	QA	<0.292	1.46	QA	<0.282	<0.282	0.414	0.282
C2W	7.73	NDR	QA	QA	QA	<0.341	2.36	QA	<0.341	<0.341	<0.341	0.345
C4E	NDR	0.881	QA	QA	QA	<0.282	<0.637	QA	<0.282	<0.282	<0.282	<0.282
C4NE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
C4NW	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
C4SE	8.1	NDR	QA	QA	QA	<0.349	1.4	QA	<0.349	0.538	<0.349	<0.349
C4SW	10.1	NDR	QA	QA	QA	0.839	1.11	QA	<0.321	<0.321	<0.321	0.413
C4W	9.87±2.02	1.67	QA	QA	QA	<0.353	1.15±0.32	QA	<0.353	0.346	<0.353	0.88±0.5
C8E	10.6	NDR	QA	QA	QA	<0.323	<0.323	QA	<0.323	<0.323	<0.323	1.11
C8W	10.9	NDR	QA	QA	QA	1.15	<0.386	QA	<0.302	<0.302	<0.302	<0.362
CB1	9.05	0.61	QA	QA	QA	1.27	<0.462	QA	<0.331	<0.331	<0.331	<0.331
CB2	7.45	NDR	QA	QA	QA	<0.276	1.67	QA	<0.276	0.325	0.893	1.4
CB3	8.13	NDR	QA	QA	QA	0.503	0.799	QA	<0.33	<0.33	<0.33	<0.33
CB4	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CB5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Notes:
For stations with multiple results (i.e., lab replicates or field replicates), average and standard deviation are presented.
"QA" denotes that value has failed the data quality objective (DQO) screening, and has been rejected for use in statistical analyses.
"NDR" denotes that laboratory quantification criteria were not met and that the result is not considered reliable due to qualitative and quantitative uncertainty. These values were omitted from statistical analyses.
MDLs are sample specific for high-resolution analyses (AXYS) and were not provided in the table.

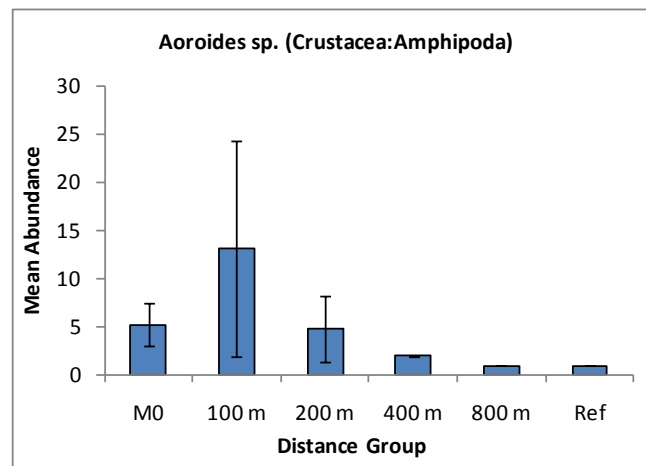
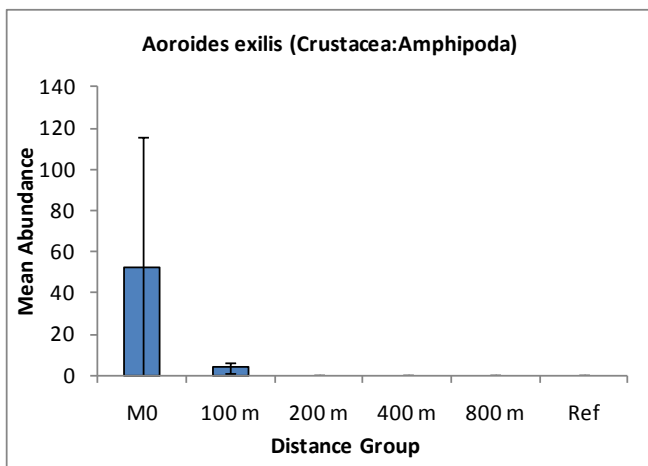
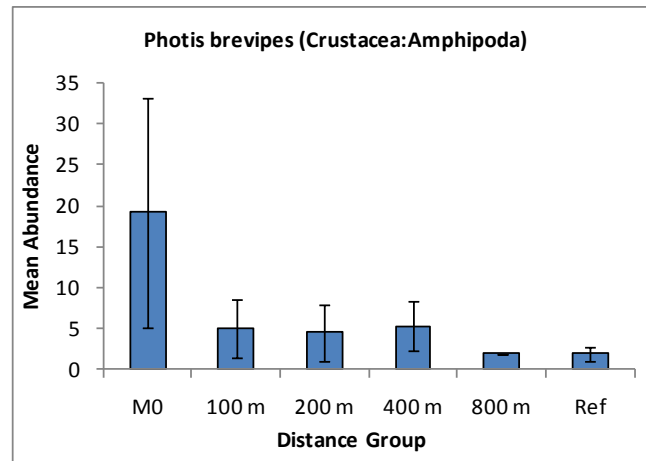
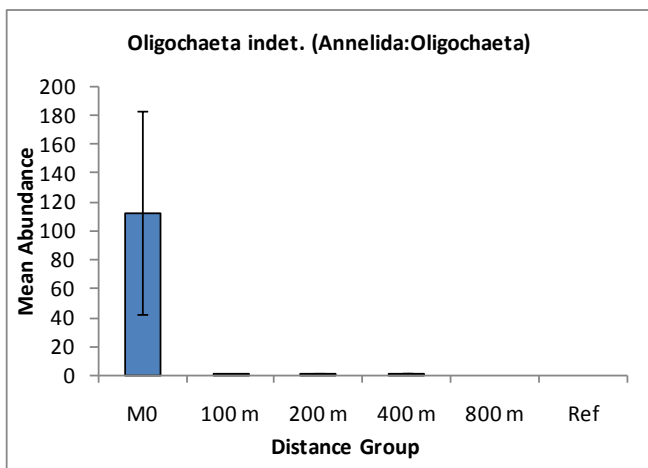
Appendix E3 Macaulay Point Benthic Community Spatial Distributions Patterns by Distance and Distance-Direction Group 2010

1. Distance Groups



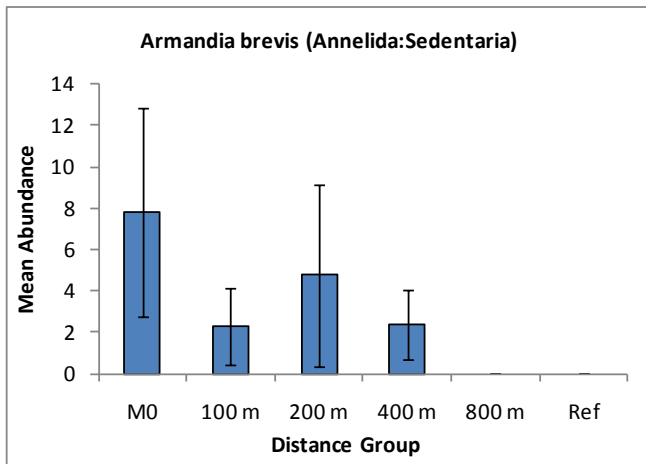
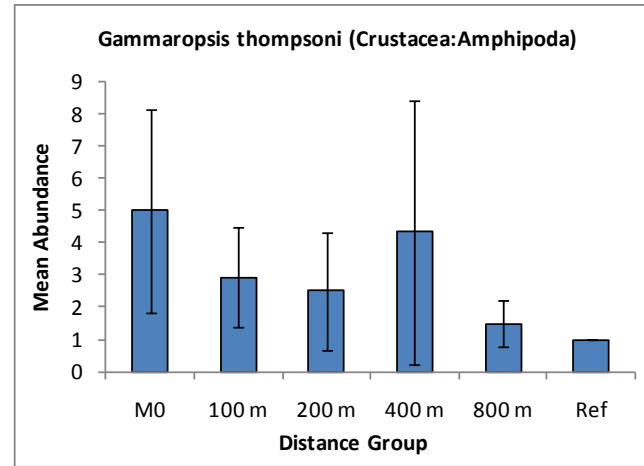
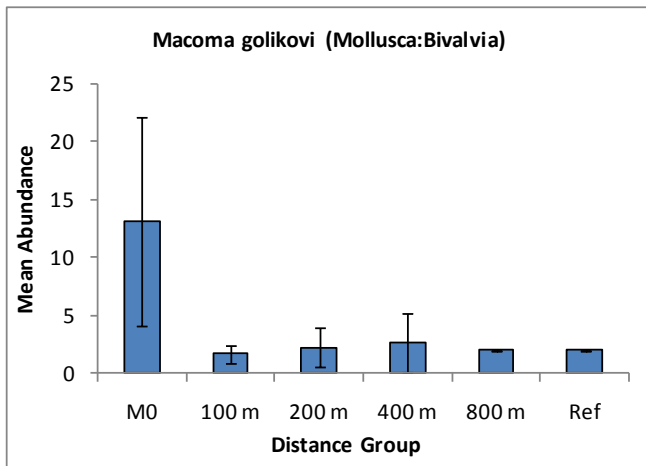
Pattern A (Most Abundant Near Outfall and Declining with Distance)

continued



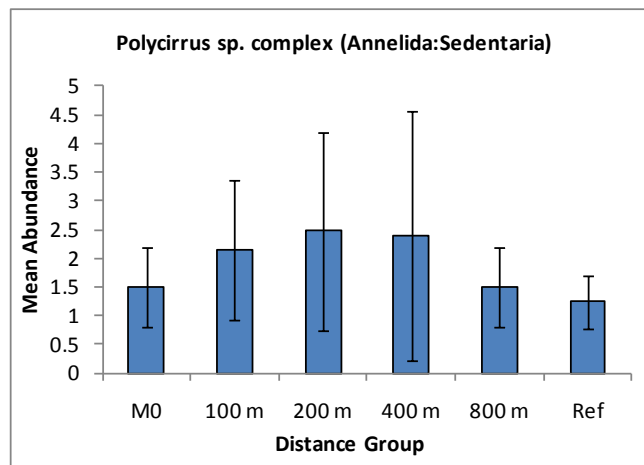
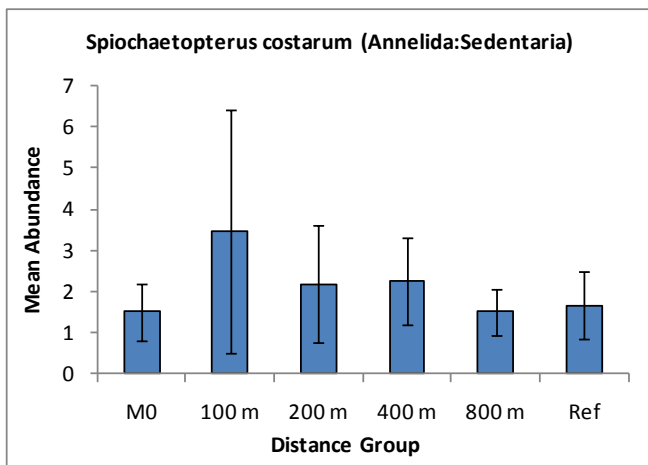
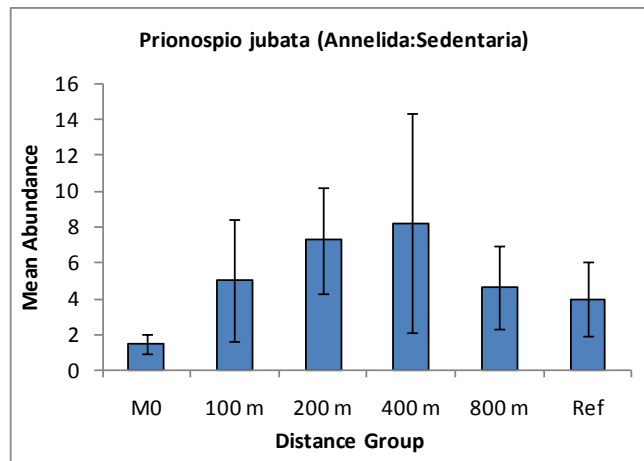
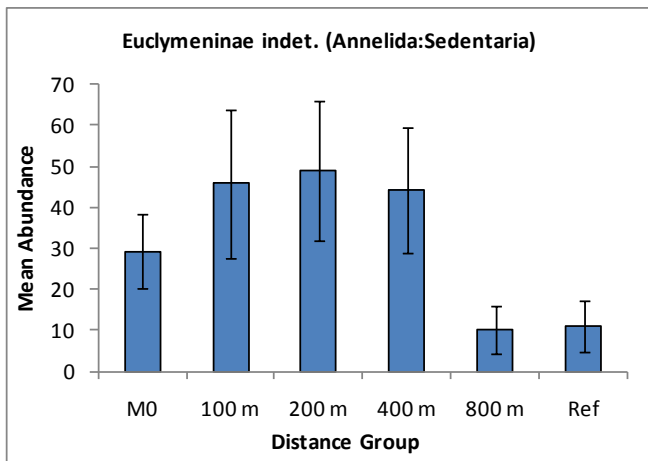
Distance Groups, Pattern A (continued)

continued



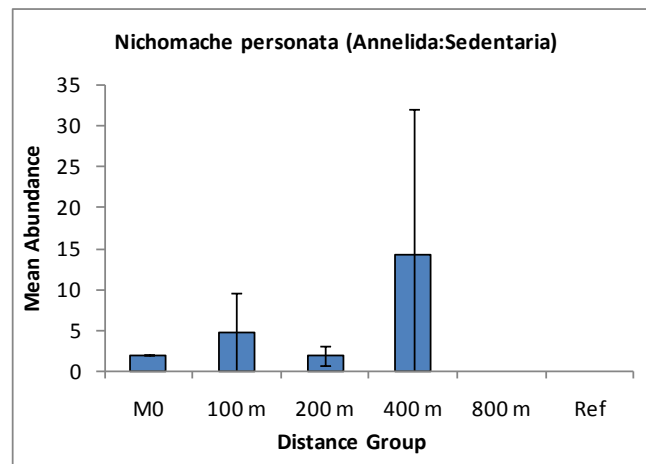
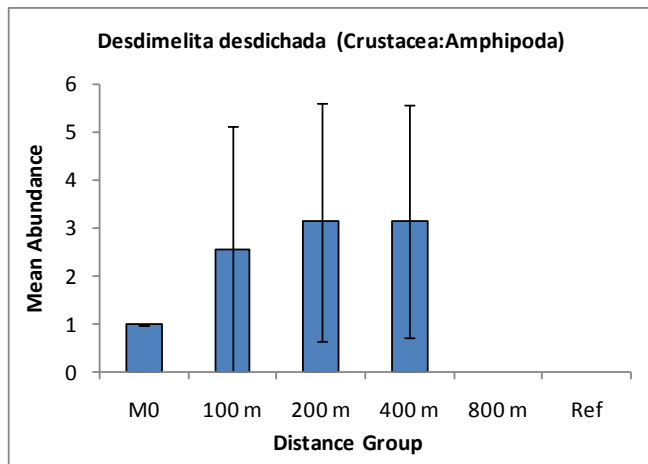
Distance Groups, Pattern A (continued)

continued



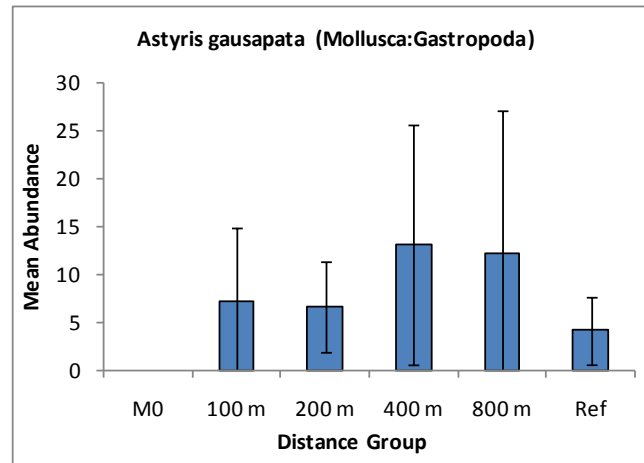
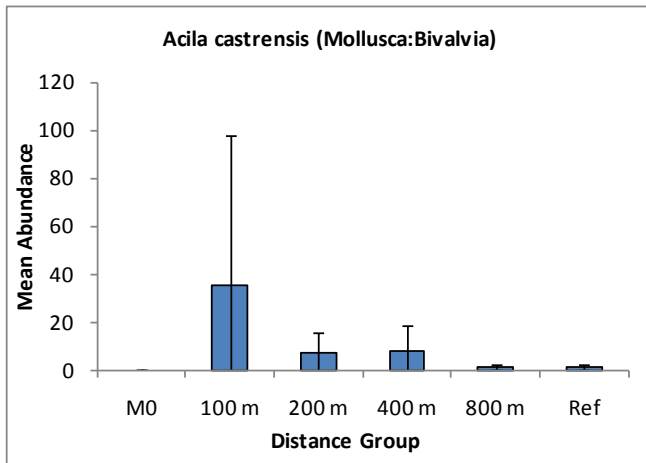
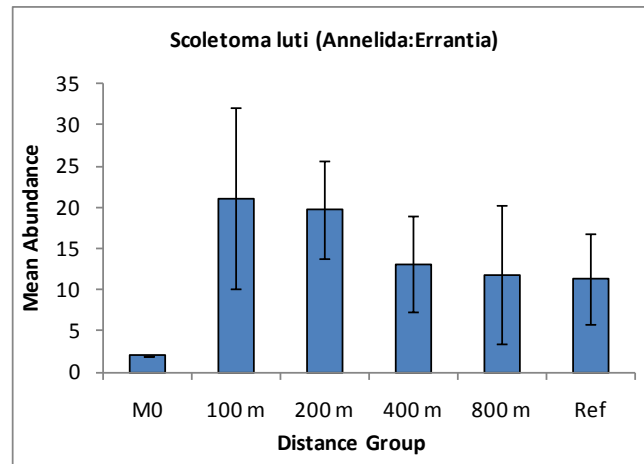
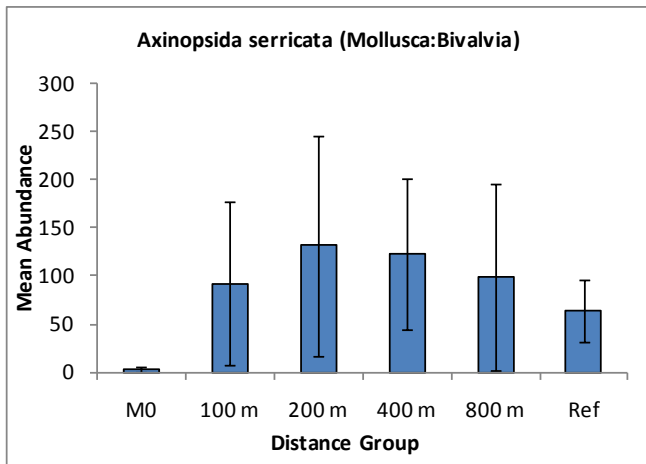
Distance Groups, Pattern B1 (Low Abundance at Outfall; Most Abundant at Intermediate Distance from Outfall)

continued



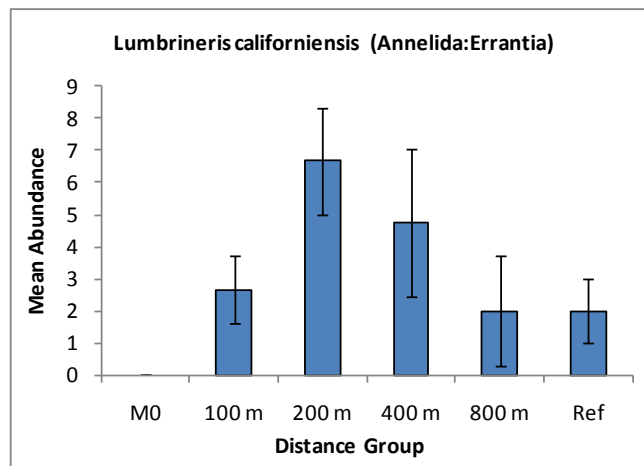
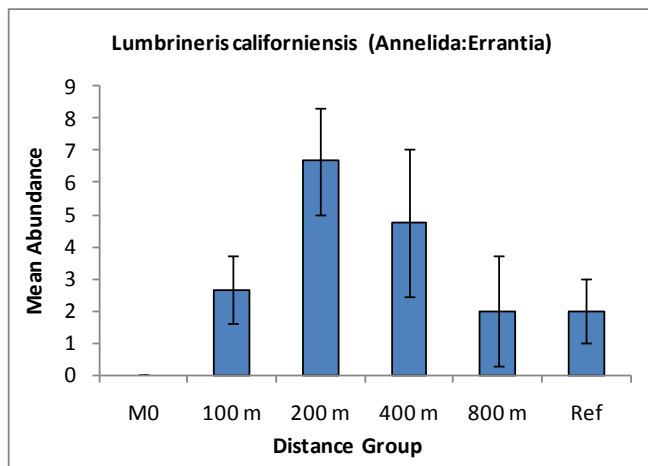
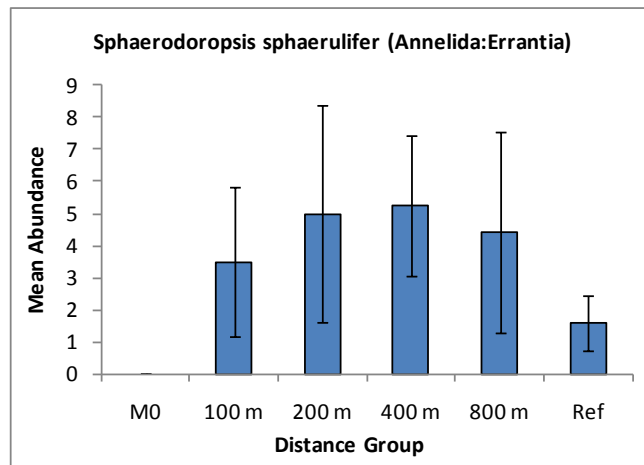
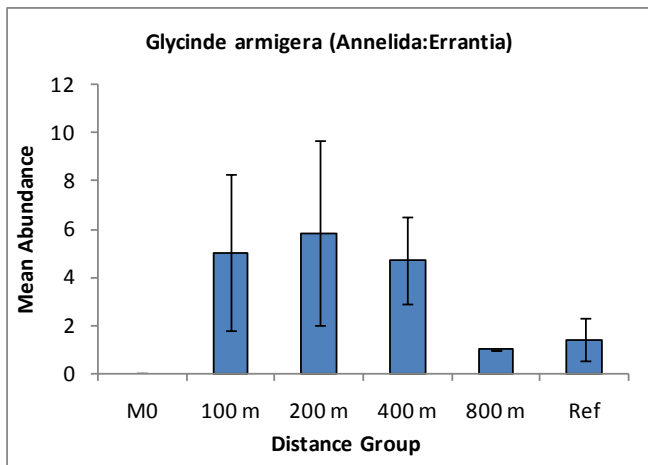
Distance Groups Pattern B1 (continued)

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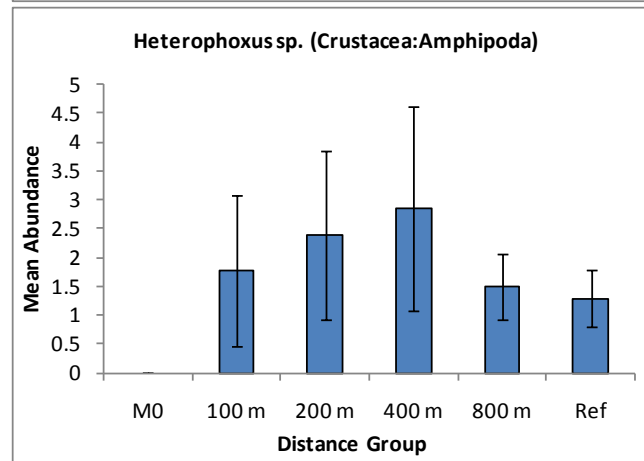
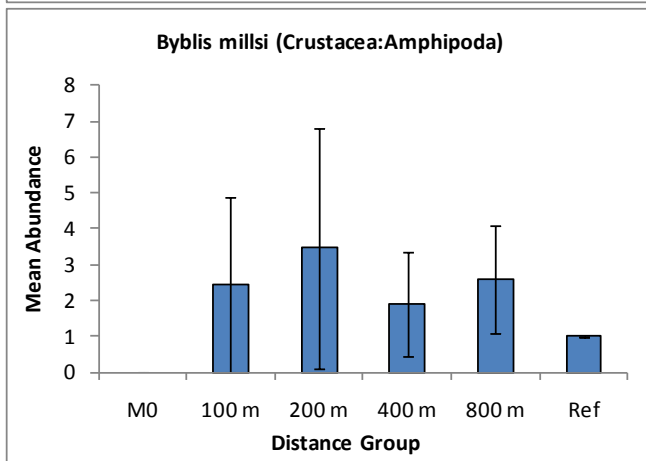
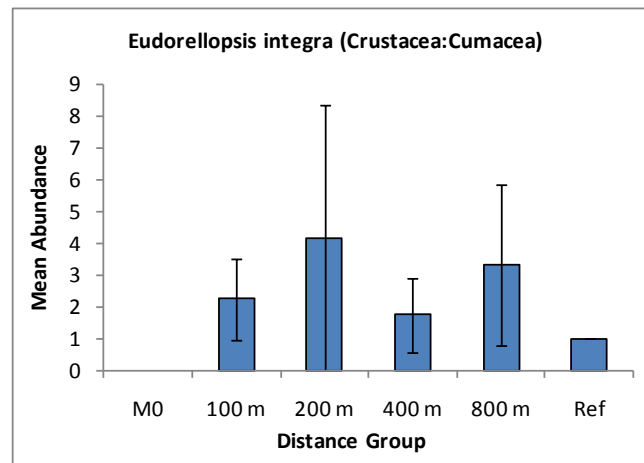
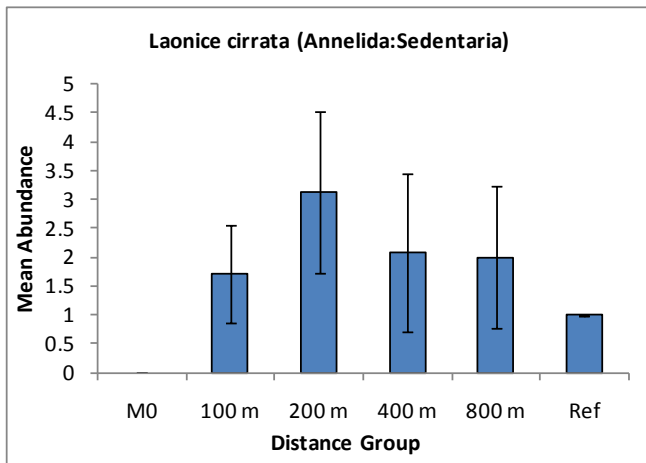
Distance Groups, Pattern B2 (Very Low Abundance at Outfall; Most Abundant at Intermediate Distance from Outfall)

continued



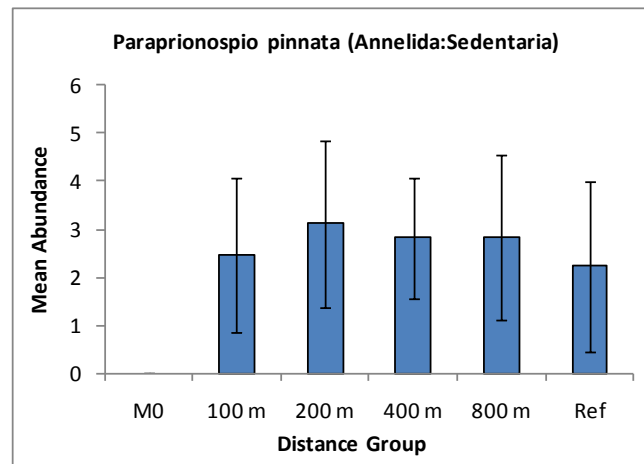
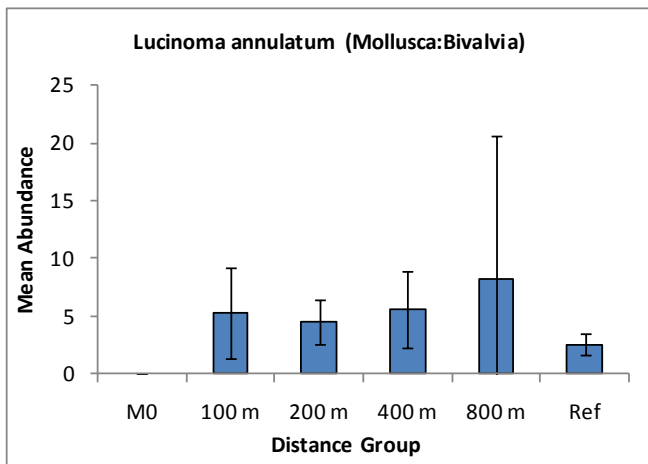
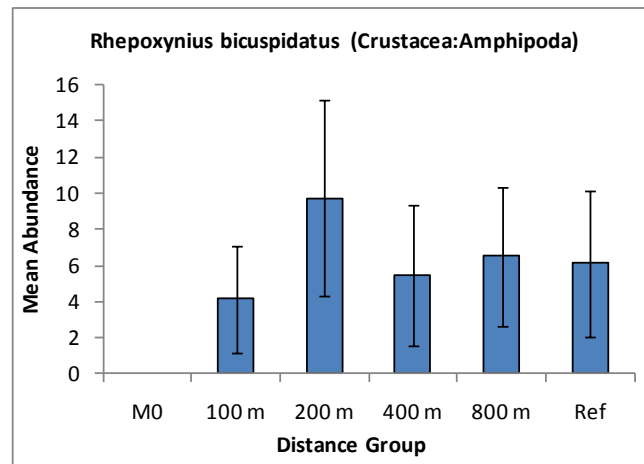
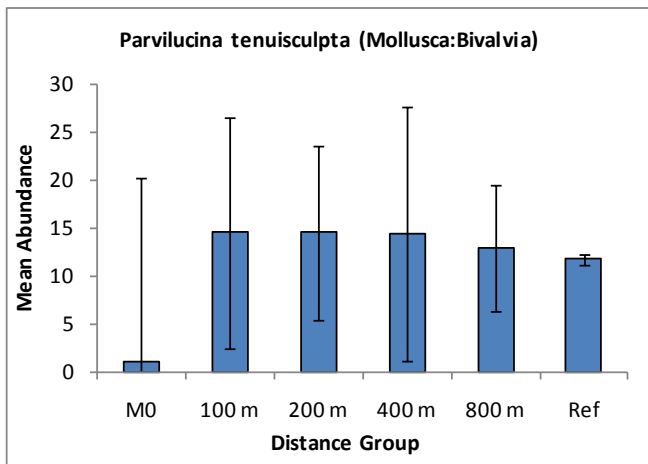
Distance Groups, Pattern B2 (continued)

continued



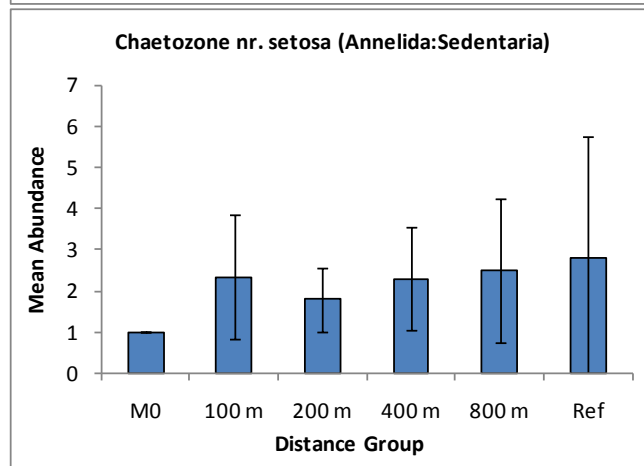
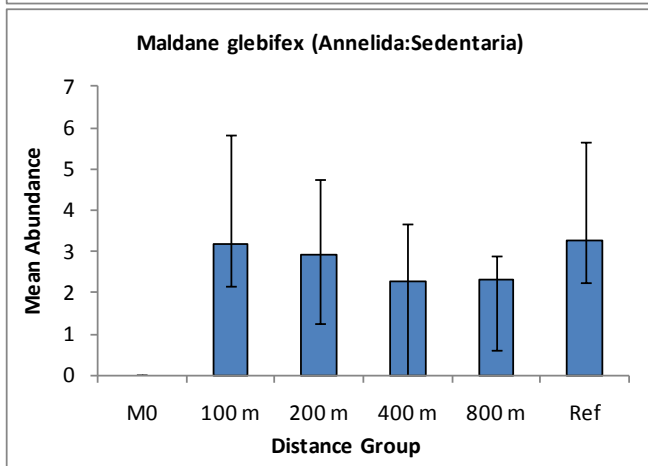
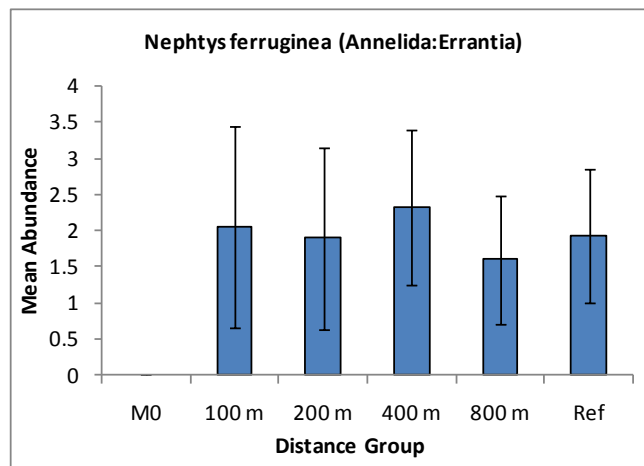
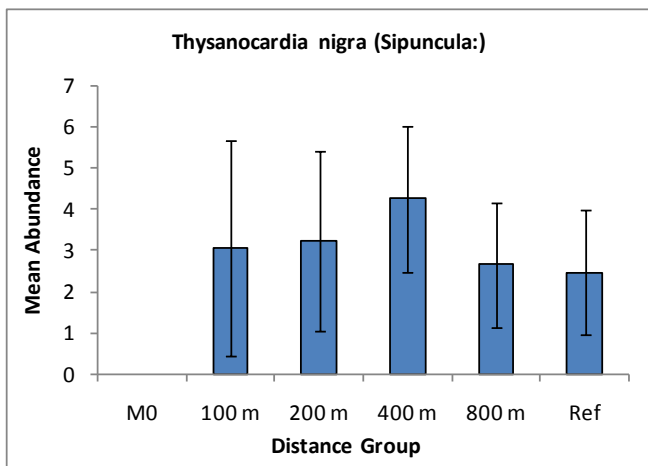
Distance Groups, Pattern B2 (continued)

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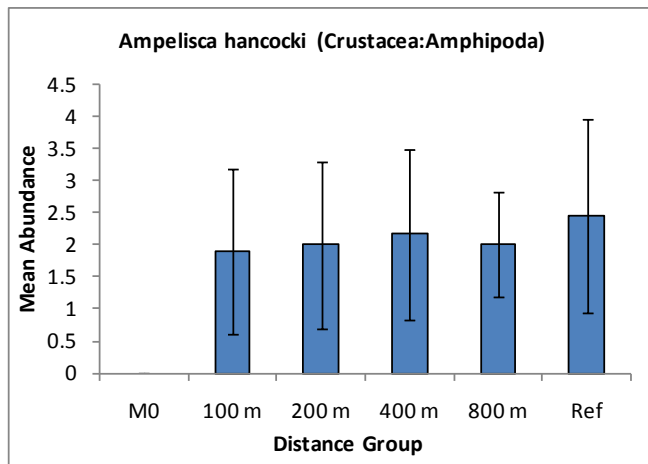
Distance Groups, Pattern C (Low Abundance Near Outfall; Similar Abundance Among Other Groups)

continued



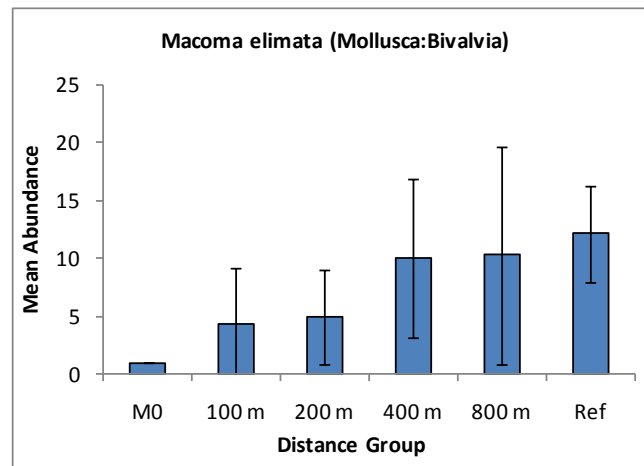
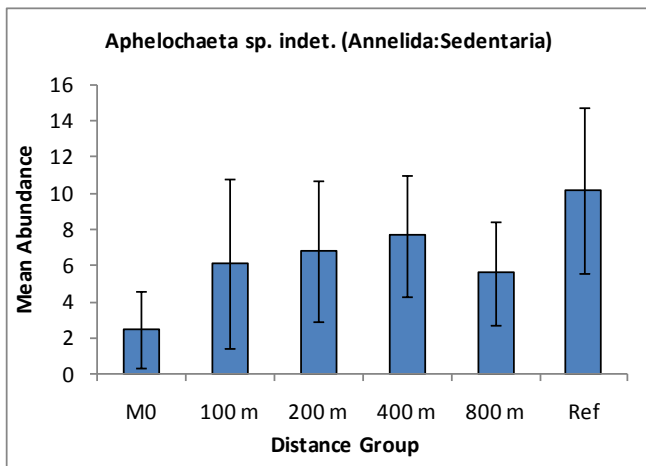
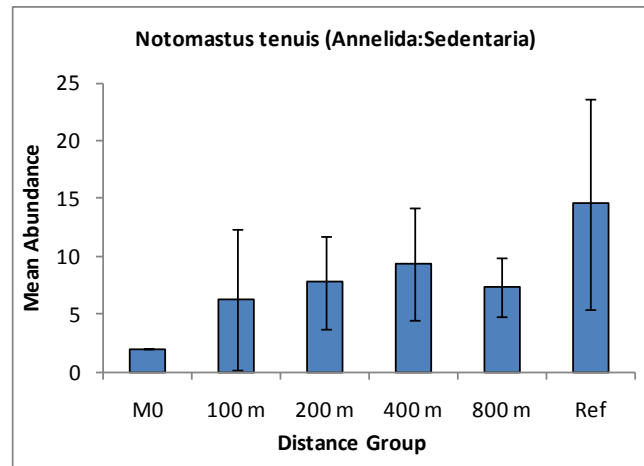
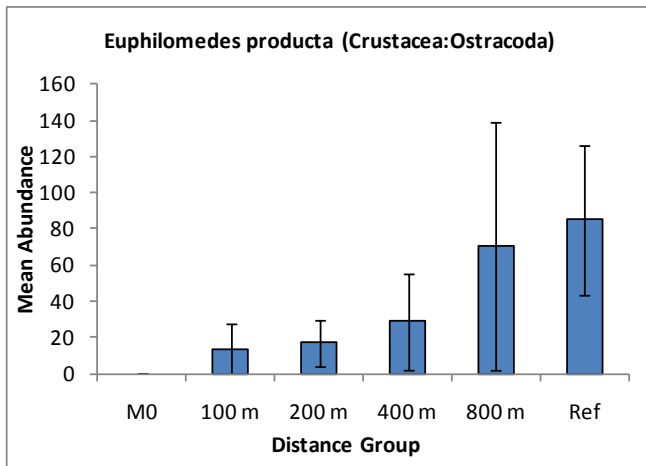
Distance Groups, Pattern C (continued)

continued



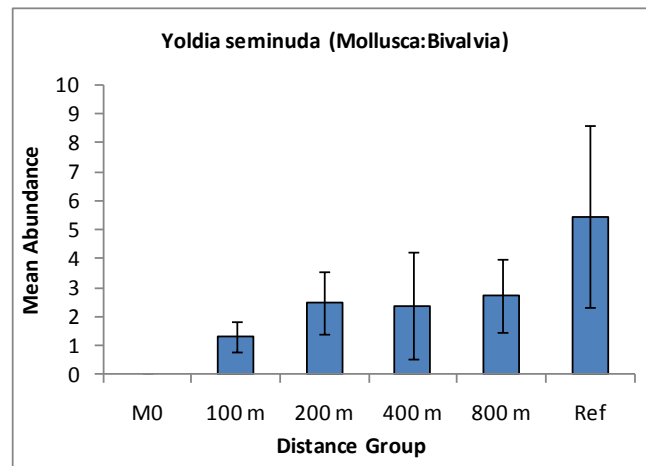
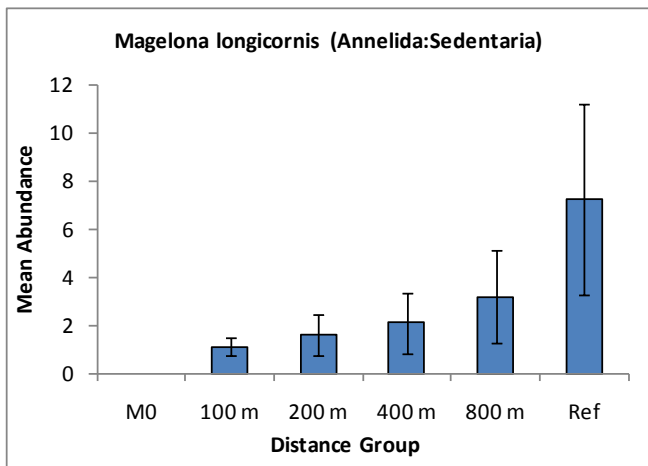
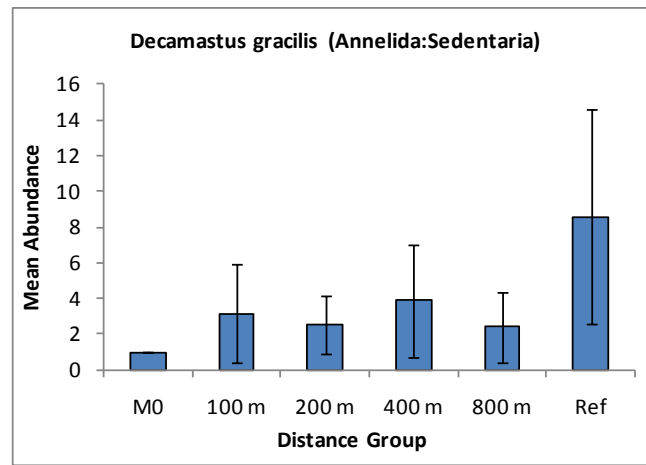
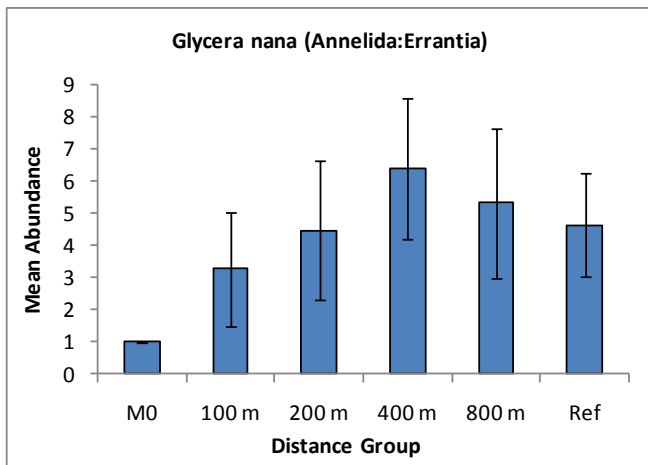
Distance Groups, Pattern C (continued)

continued



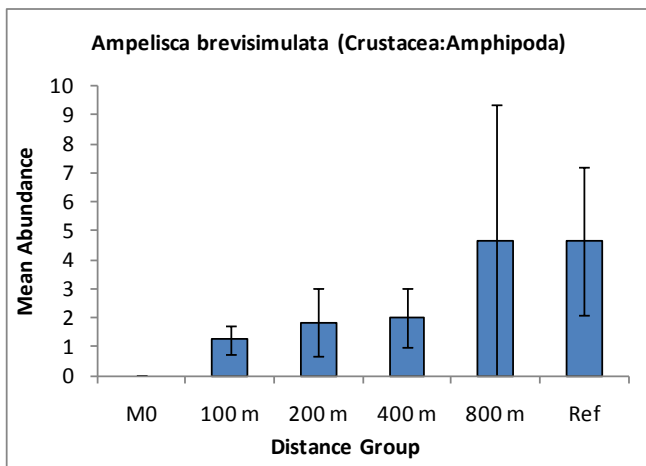
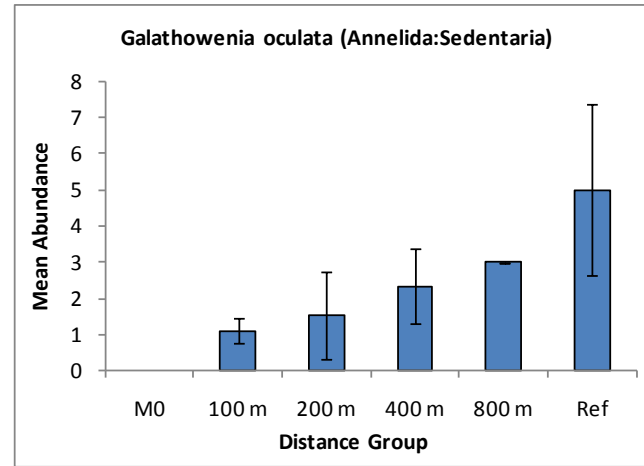
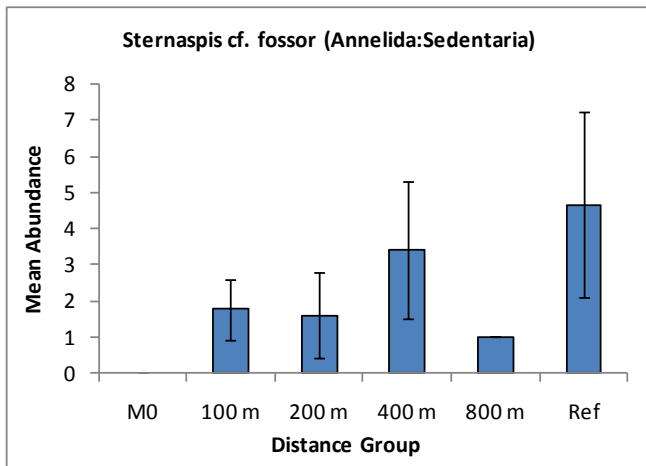
Distance Groups, Pattern D (Generally Increasing with Distance from Outfall)

continued



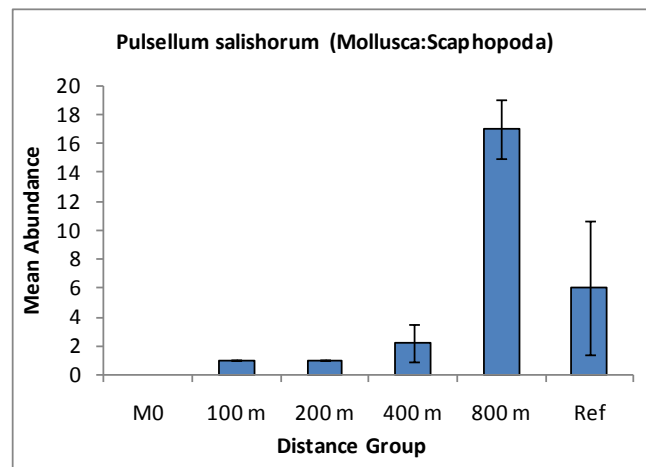
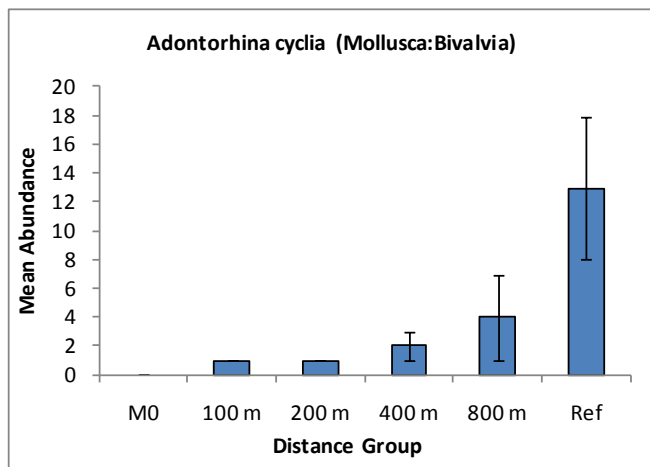
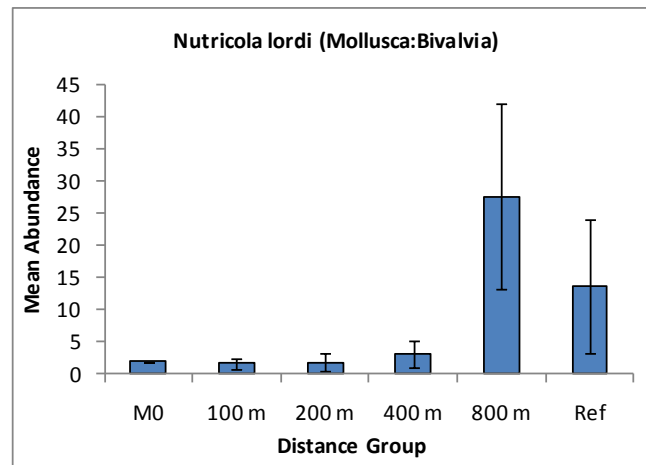
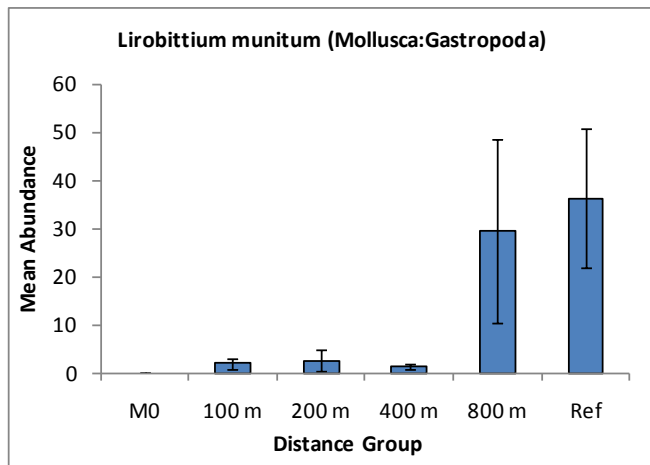
Distance Groups, Pattern D (continued)

continued



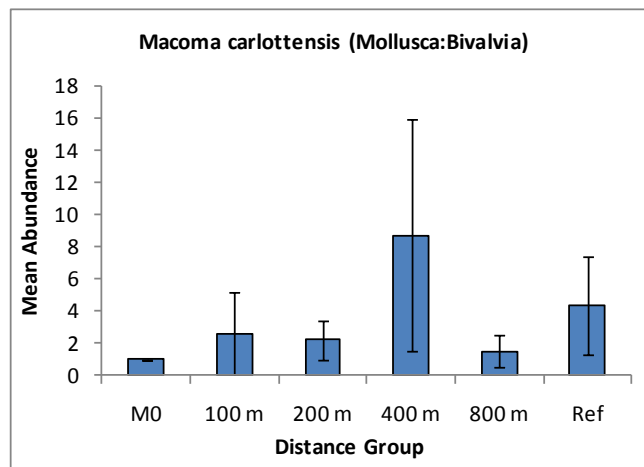
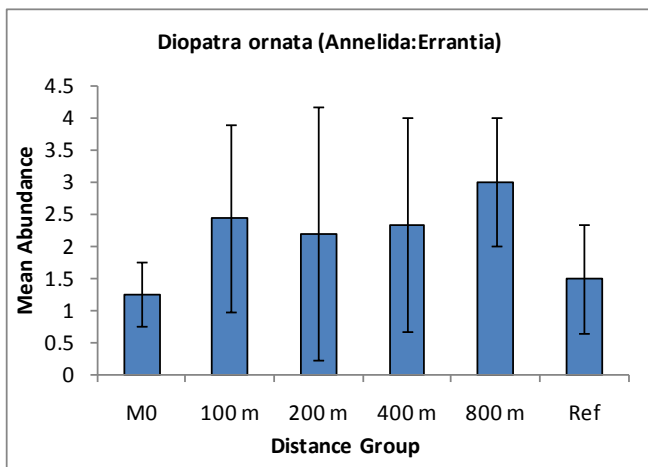
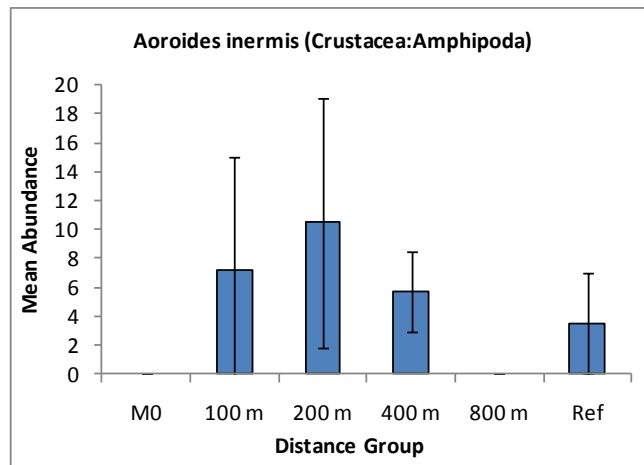
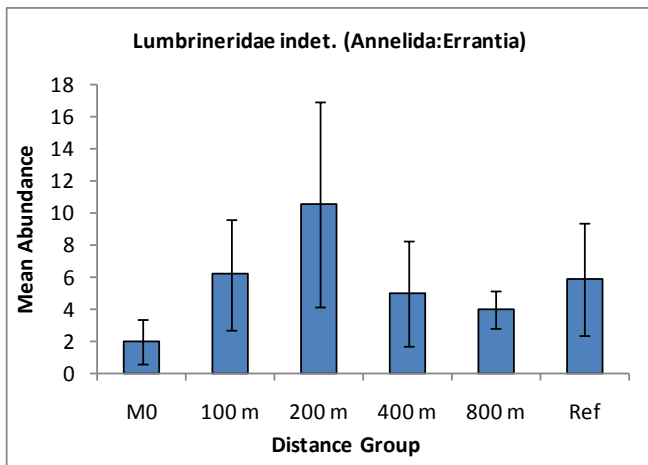
Distance Groups, Pattern D (continued)

continued



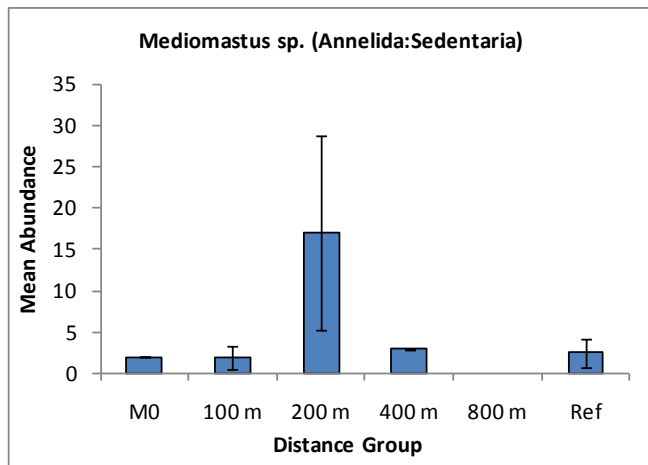
Distance Groups, Pattern E (Pronounced Increase with Distance from Outfall)

continued



Distance Groups, Pattern F (No Discernible Spatial Trend)

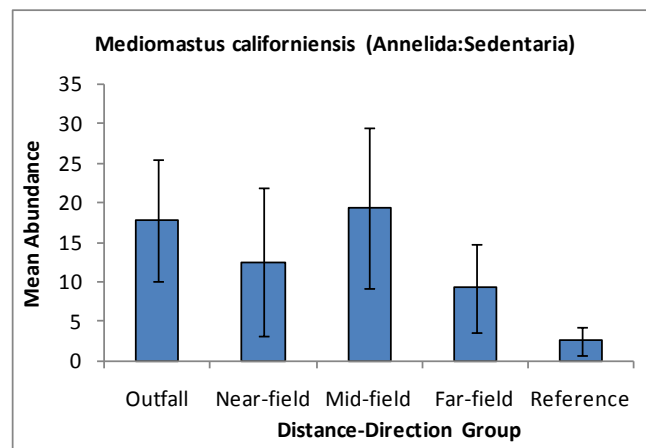
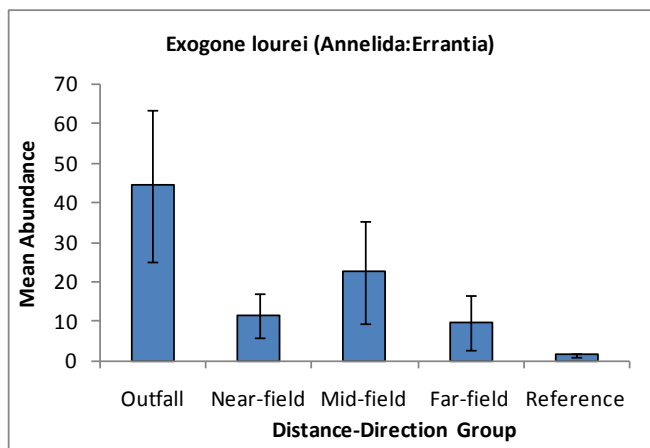
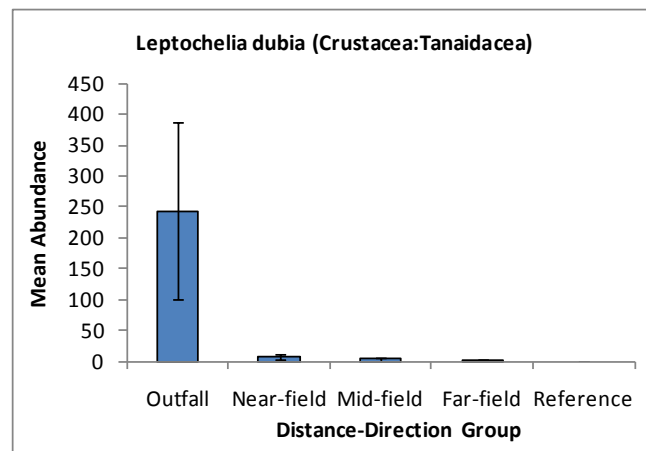
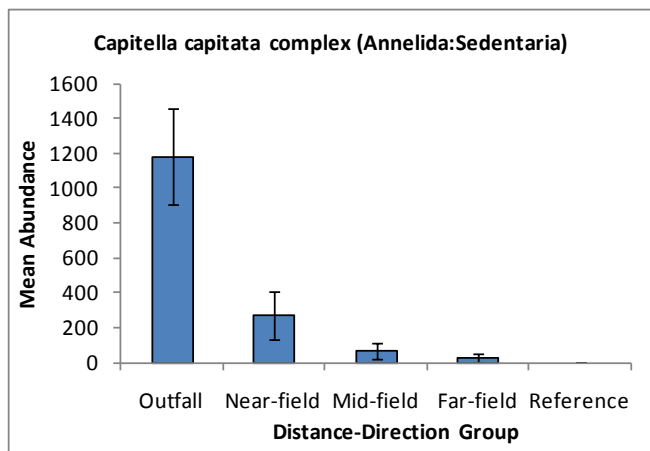
continued



Distance Groups, Pattern F (continued)

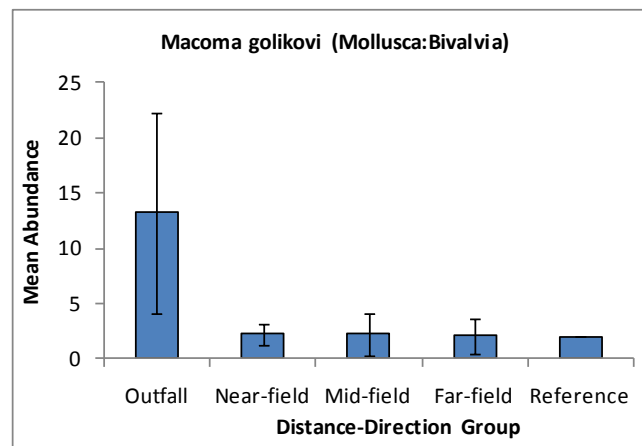
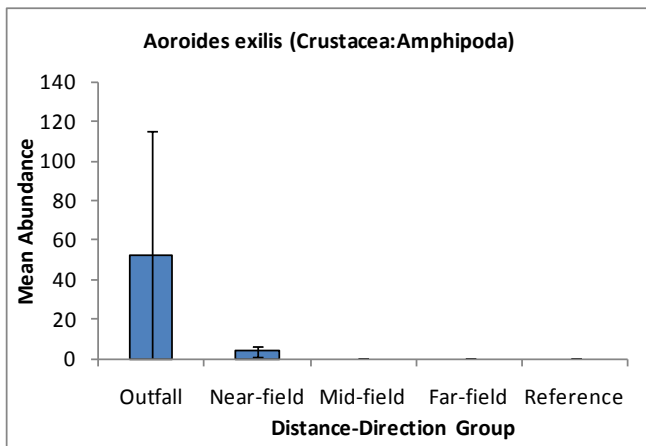
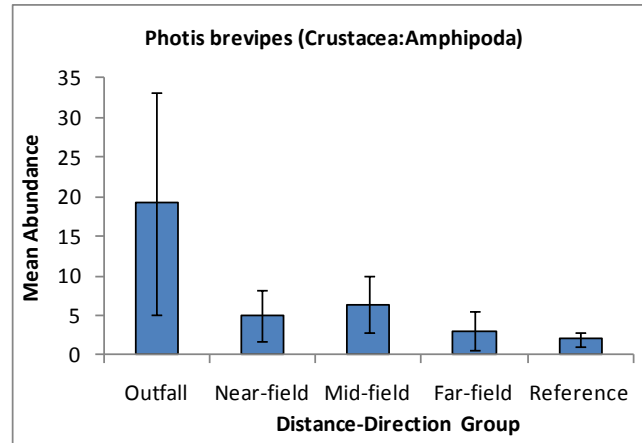
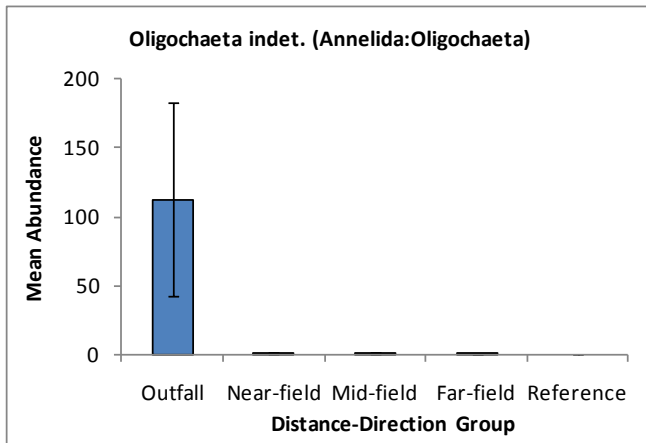
continued

2. Distance-Direction Groups



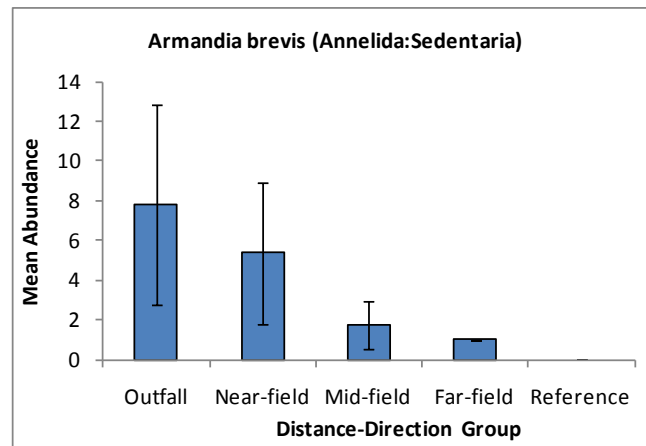
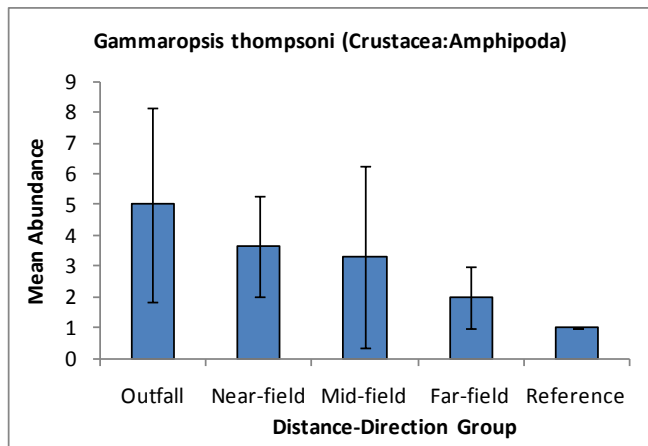
Pattern A (Most Abundant Near Outfall and Declining with Distance)

continued



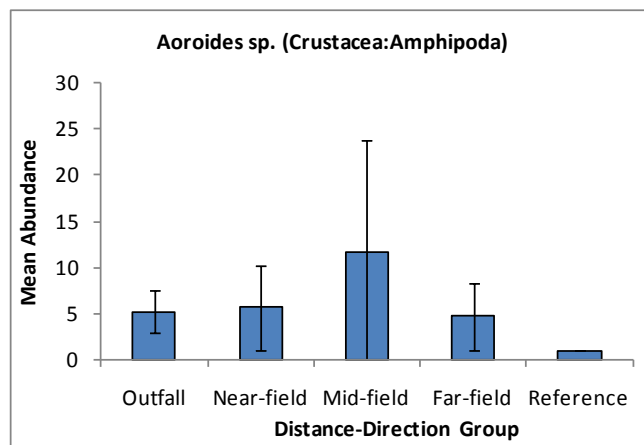
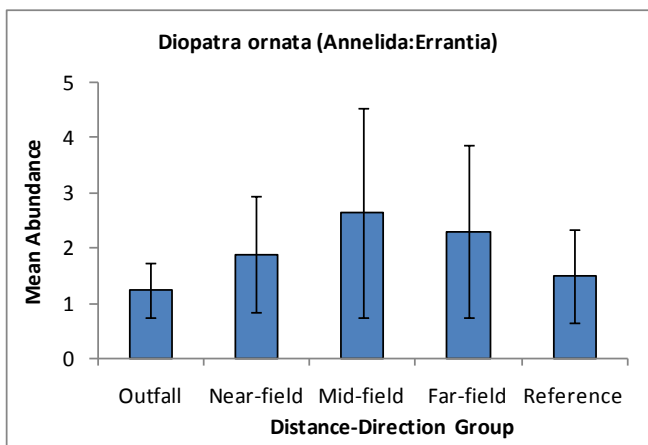
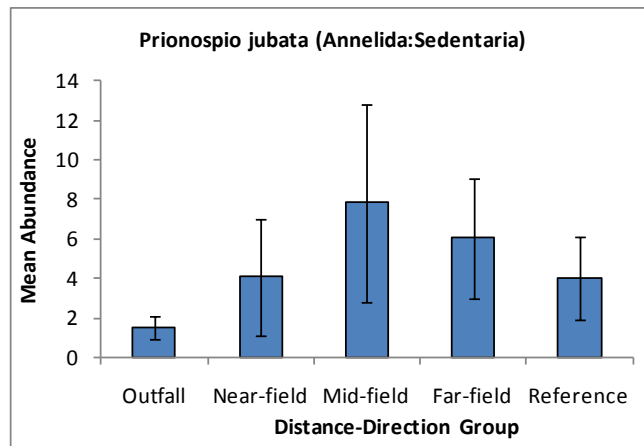
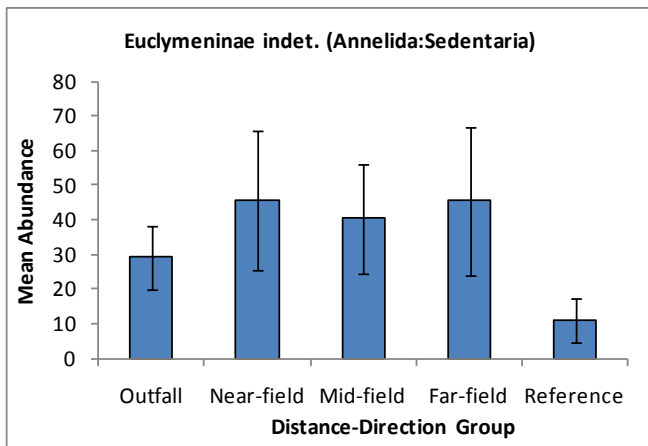
Distance-Direction Groups, Pattern A (continued)

continued



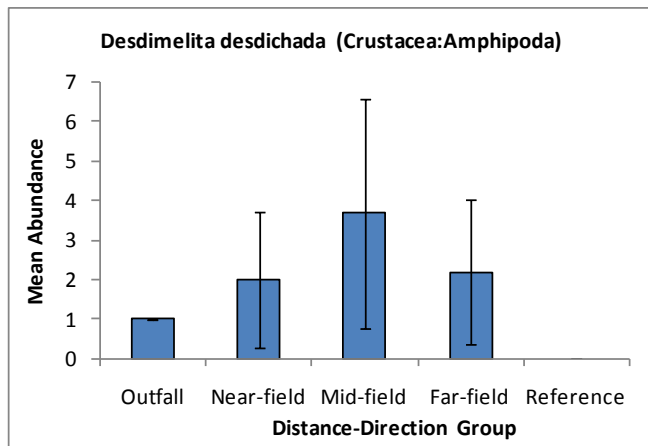
Distance-Direction Groups, Pattern A (continued)

continued



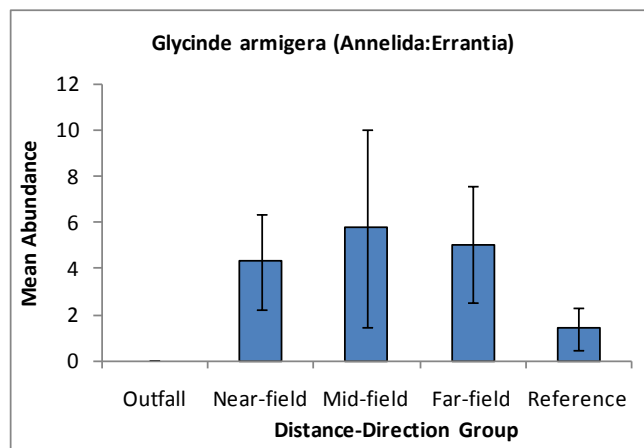
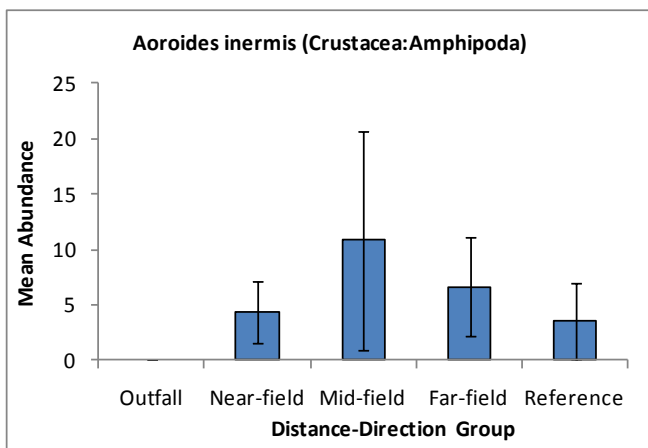
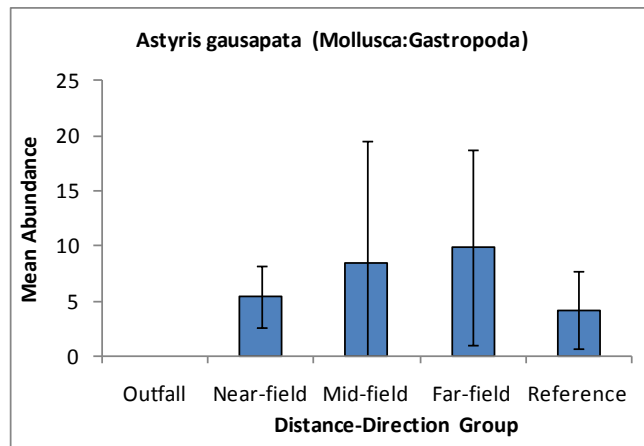
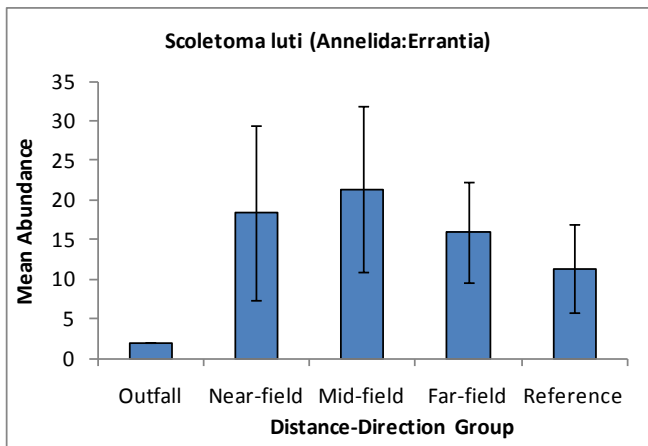
Distance-Direction Groups, Pattern B1 (Low Abundance at Outfall; Most Abundant at Intermediate Distance from Outfall)

continued



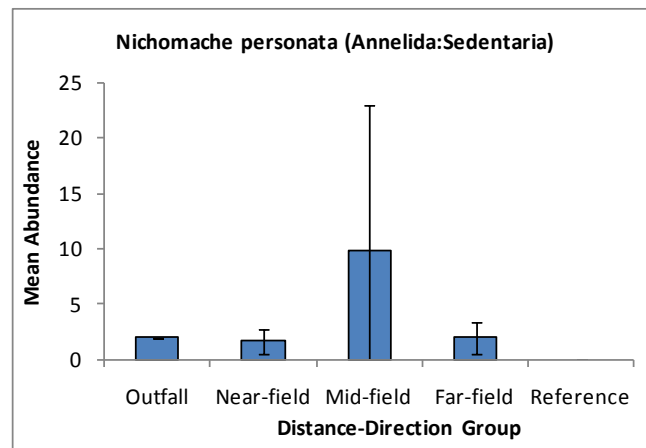
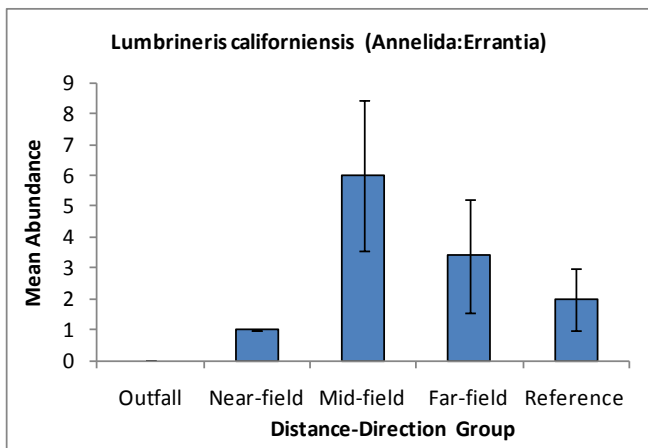
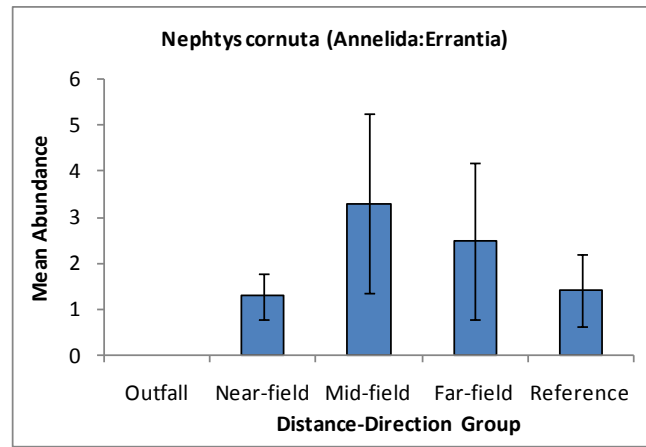
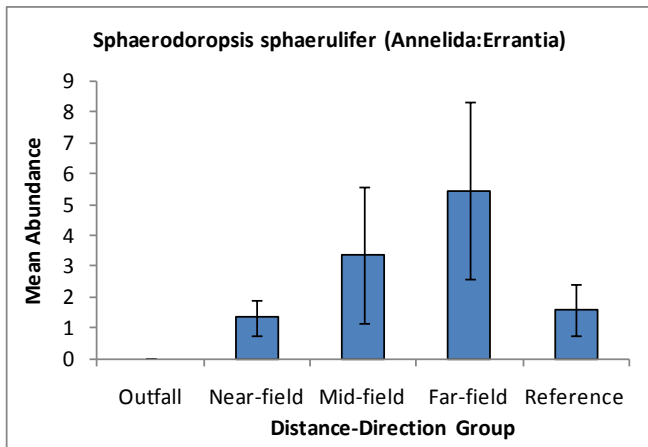
Distance-Direction Groups, Pattern B1 (continued)

continued



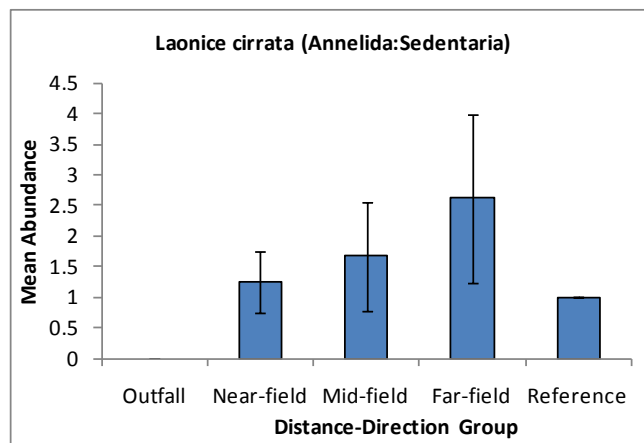
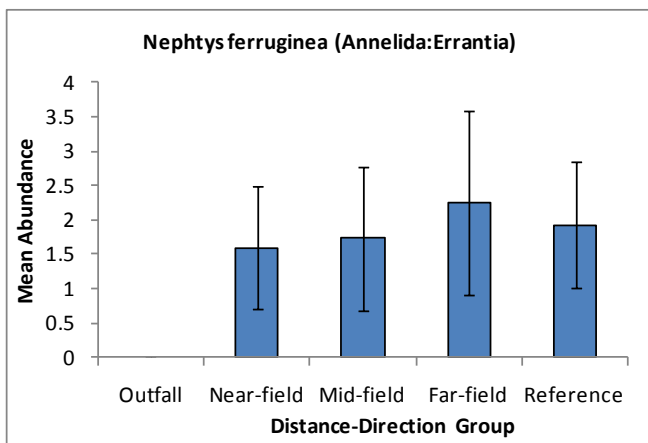
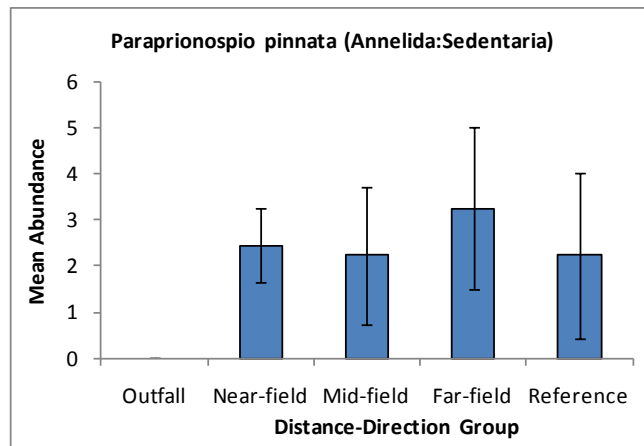
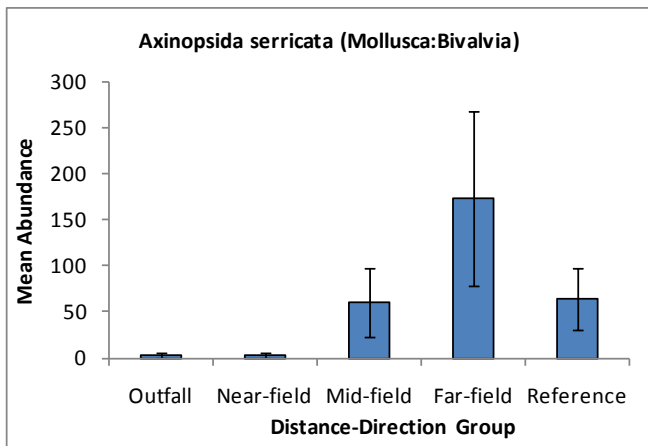
Distance-Direction Groups, Pattern B2 (Very Low Abundance at Outfall; Most Abundant at Intermediate Distance from Outfall)

continued



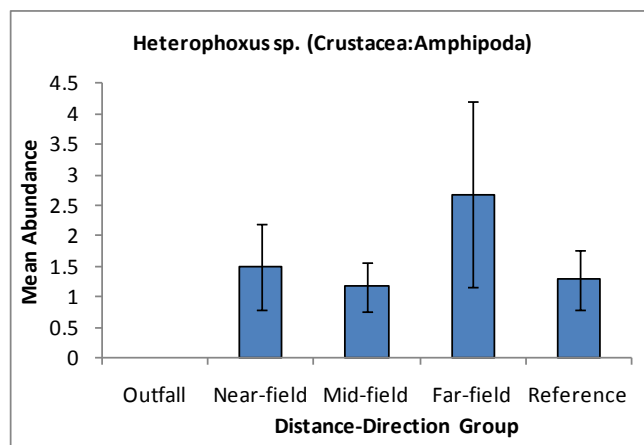
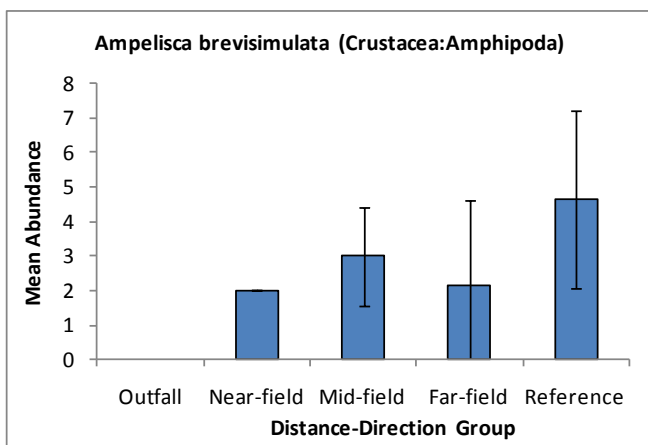
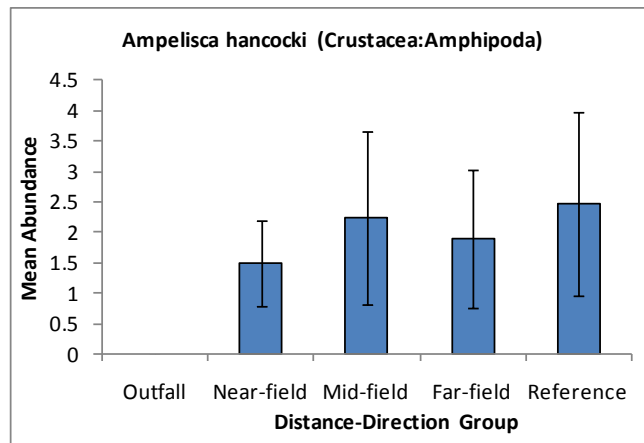
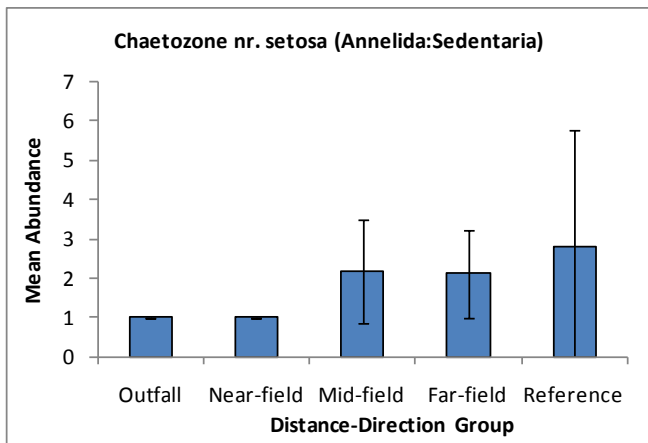
Pattern B2 (continued)

continued



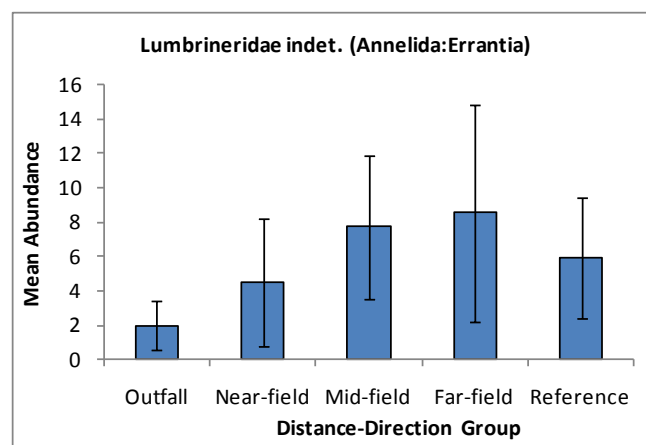
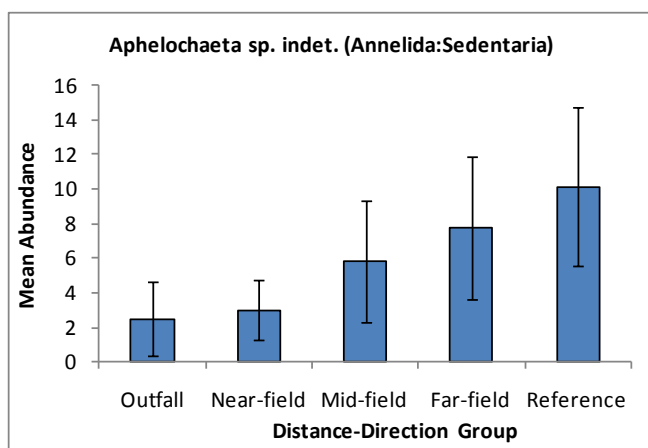
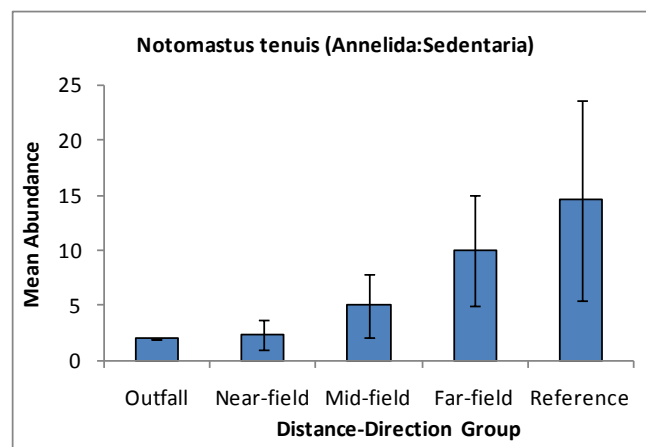
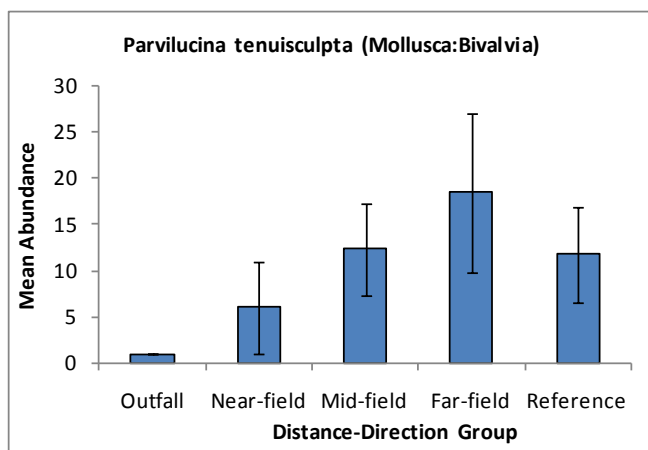
Distance-Direction Groups, Pattern C (Low Abundance at Outfall; Similar Abundances across Other Distance Groups)

continued



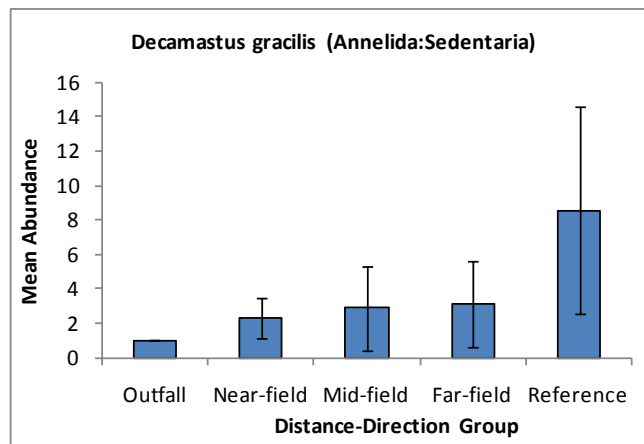
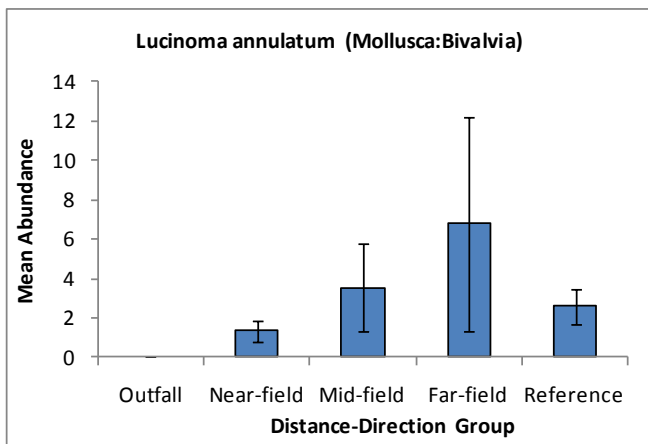
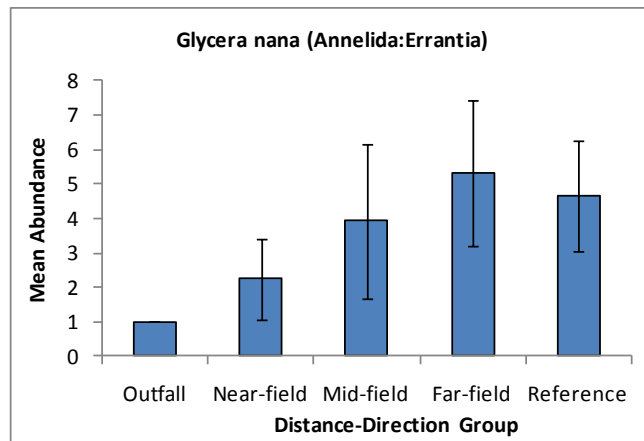
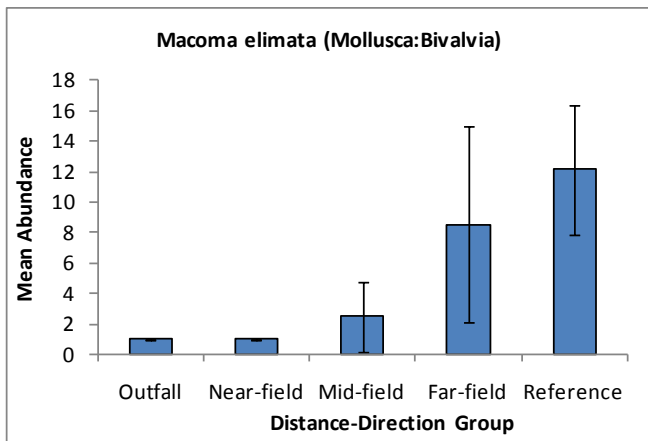
Distance-Direction Groups, Pattern C (continued)

continued



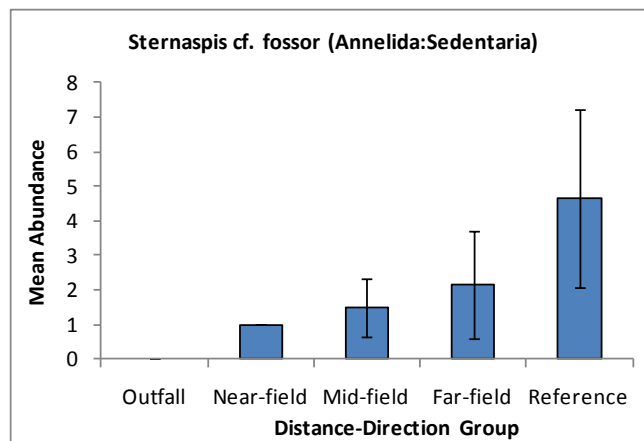
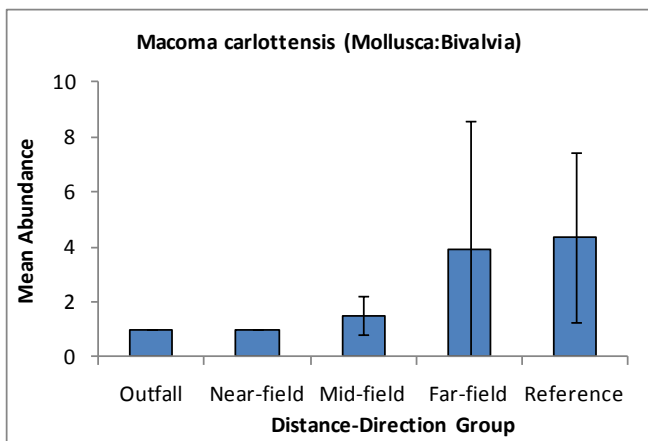
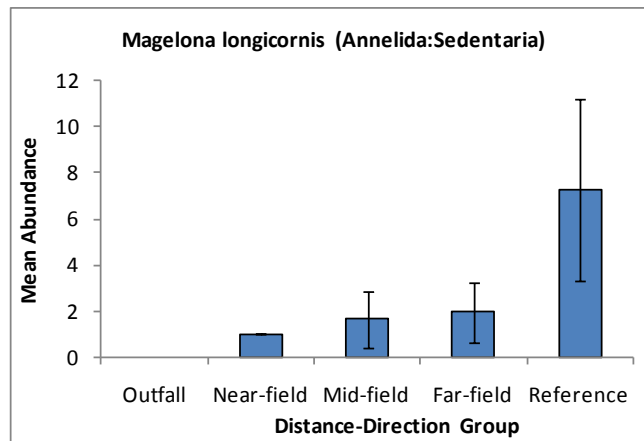
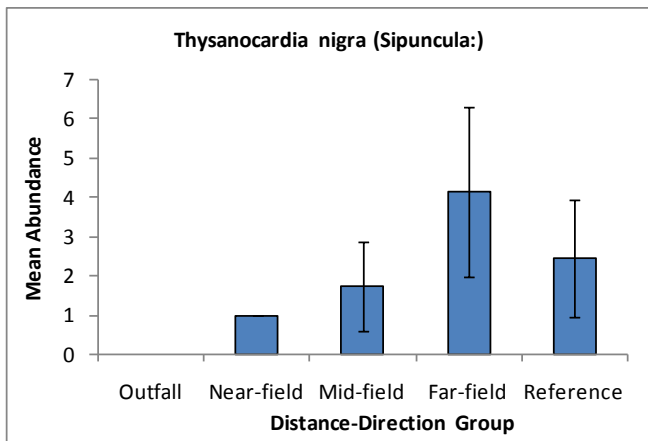
Distance-Direction Groups, Pattern D (Generally Increasing with Distance from Outfall)

continued



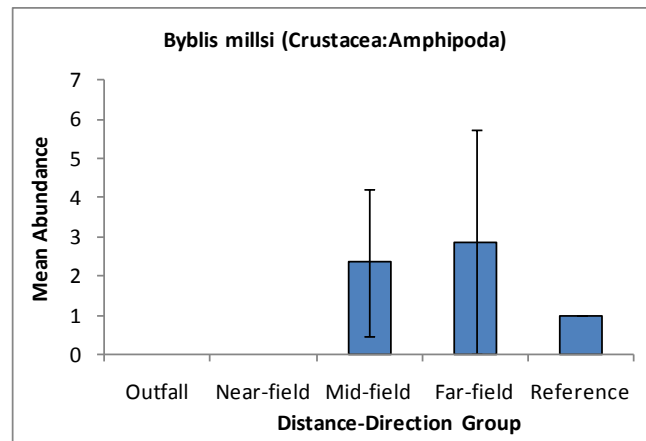
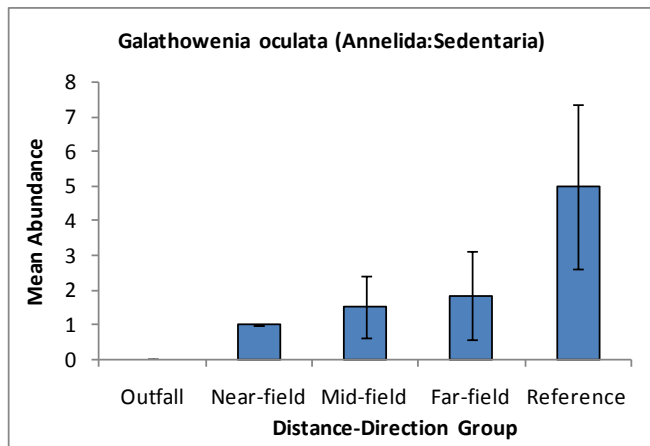
Distance-Direction Groups, Pattern D (continued)

continued



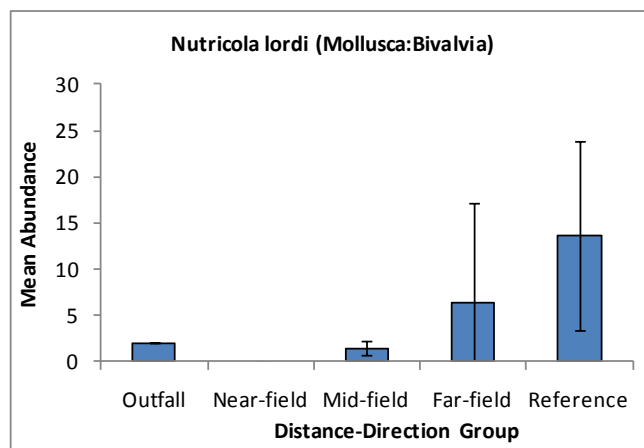
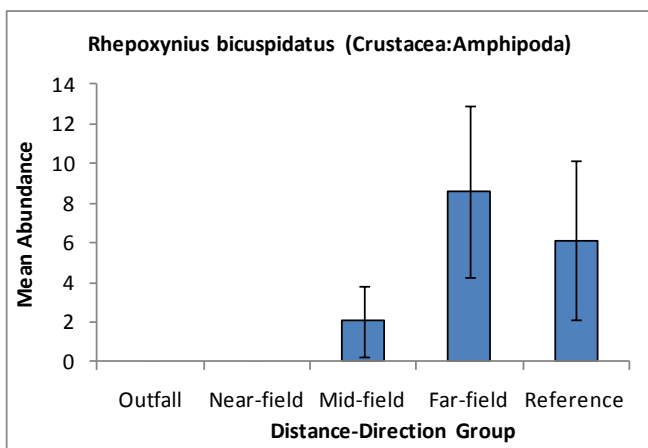
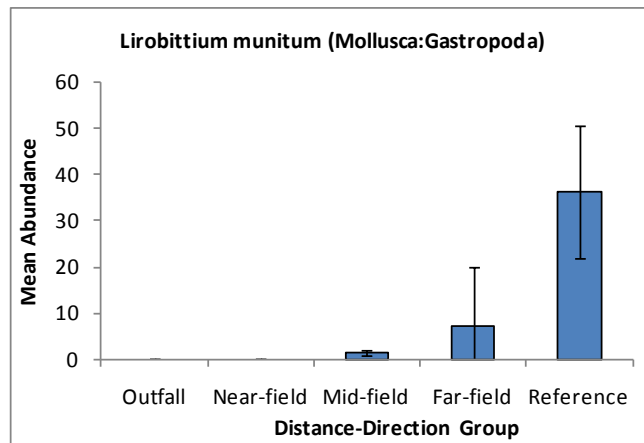
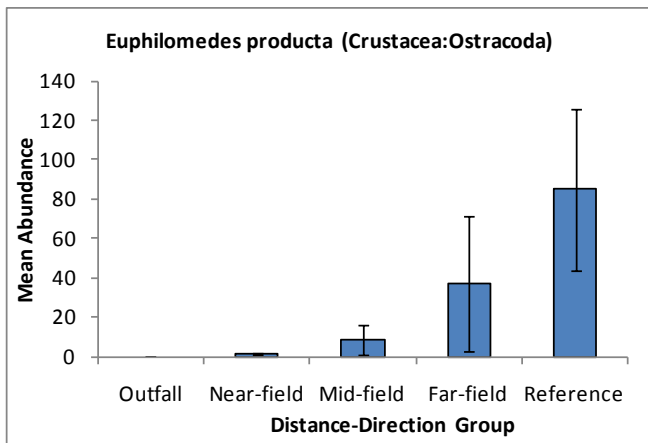
Distance-Direction Groups, Pattern D (continued)

continued



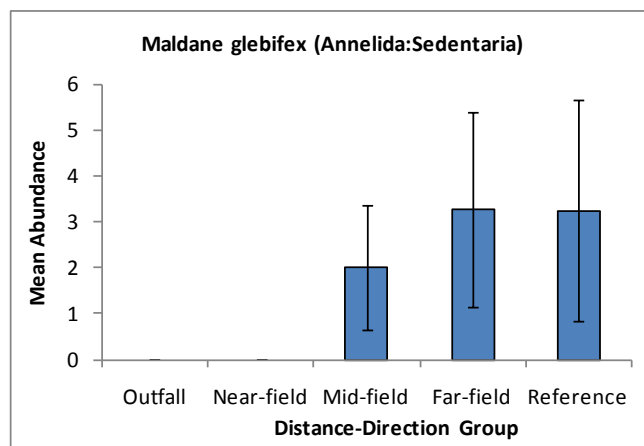
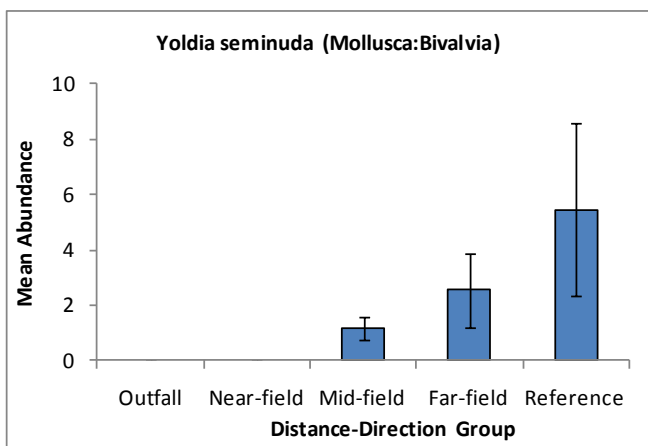
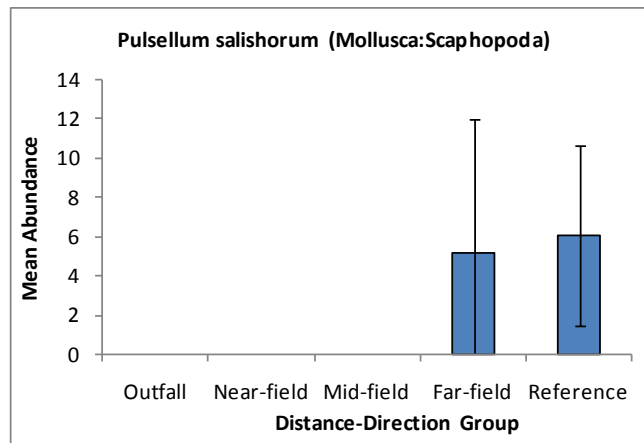
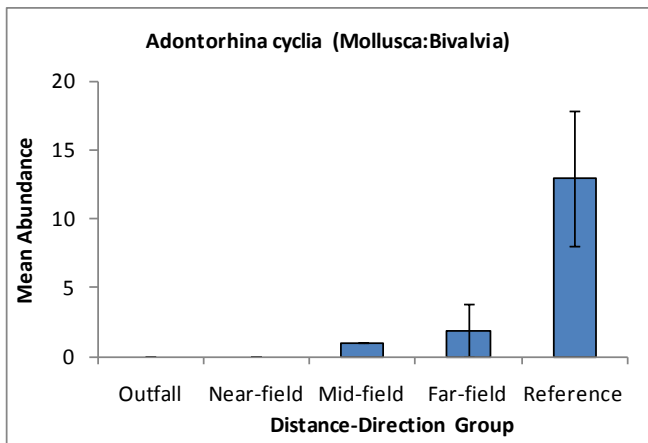
Distance-Direction Groups, Pattern D (continued)

continued



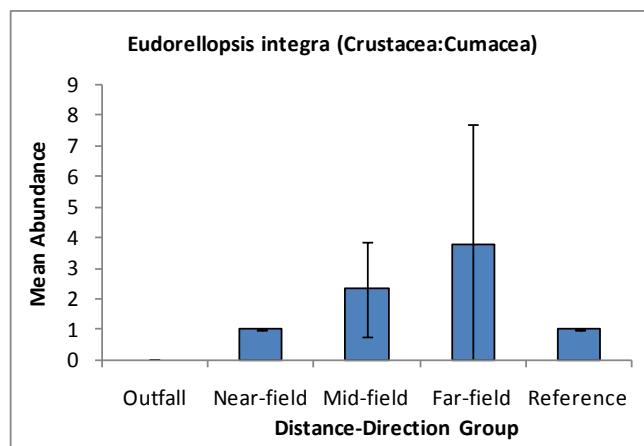
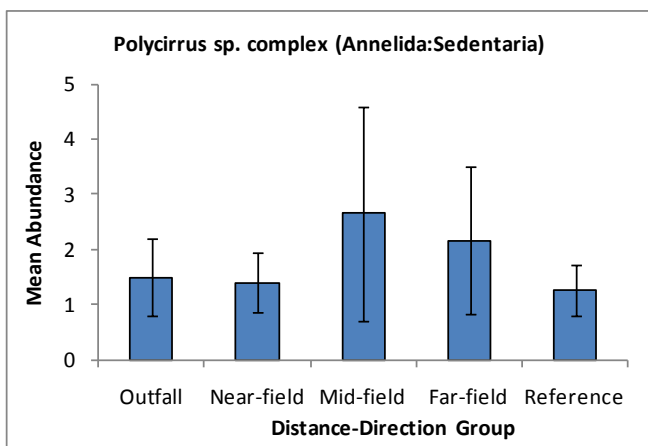
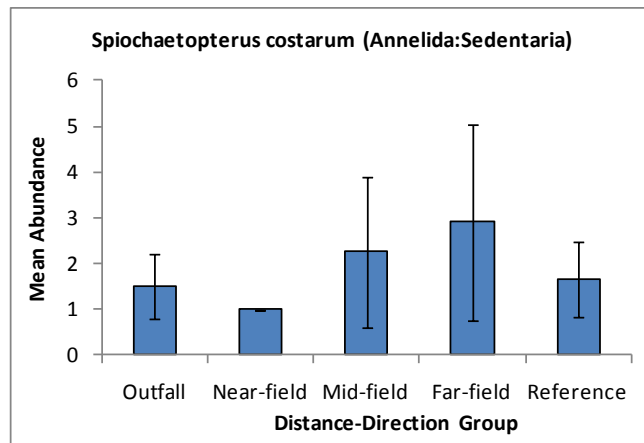
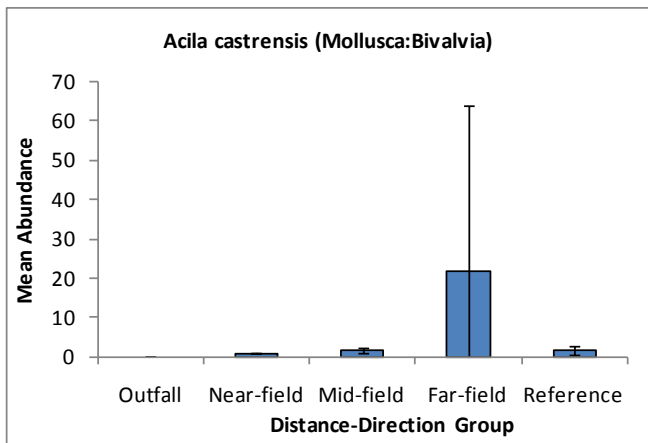
Distance-Direction Groups, Pattern E (Pronounced Increase at Distance from Outfall)

continued



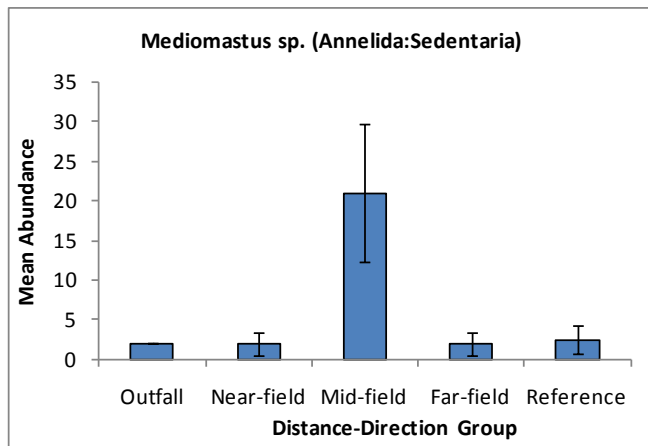
Distance-Direction Groups, Pattern E (continued)

continued



Distance-Direction Groups, Pattern F (No Discernible Spatial Trend)

continued



Distance-Direction Groups, Pattern F (conclusion)