APPENDIX AIR10-C

Technical Data Reports Containing Habitat Maps at Local and Regional Scales

TDR MI-1 - Infaunal and Epifaunal Invertebrate Communities TDR

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ROBERTS BANK TERMINAL 2
TECHNICAL DATA REPORT
Infaunal and Epifaunal Invertebrate Communities

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Technical Report / Technical Data Report Disclaimer

The Canadian Environmental Assessment Agency determined the scope of the proposed Roberts Bank Terminal 2 Project (RBT2 or the Project) and the scope of the assessment in the Final Environmental Impact Statement Guidelines (EISG) issued January 7, 2014. The scope of the Project includes the project components and physical activities to be considered in the environmental assessment. The scope of the assessment includes the factors to be considered and the scope of those factors. The Environmental Impact Statement (EIS) has been prepared in accordance with the scope of the Project and the scope of the assessment specified in the EISG. For each component of the natural or human environment considered in the EIS, the geographic scope of the assessment depends on the extent of potential effects.

At the time supporting technical studies were initiated in 2011, with the objective of ensuring adequate information would be available to inform the environmental assessment of the Project, neither the scope of the Project nor the scope of the assessment had been determined.

Therefore, the scope of supporting studies may include physical activities that are not included in the scope of the Project as determined by the Agency. Similarly, the scope of supporting studies may also include spatial areas that are not expected to be affected by the Project.

This out-of-scope information is included in the Technical Report (TR)/Technical Data Report (TDR) for each study, but may not be considered in the assessment of potential effects of the Project unless relevant for understanding the context of those effects or to assessing potential cumulative effects.

EXECUTIVE SUMMARY

The Roberts Bank Terminal 2 Project (RBT2 or Project) is a proposed new three-berth marine terminal at Roberts Bank in Delta, B.C. that could provide 2.4 million TEUs (twenty-foot equivalent unit containers) of additional container capacity annually. The project is part of Port Metro Vancouver's Container Capacity Improvement Program, a long-term strategy to deliver projects to meet anticipated growth in demand for container capacity to 2030.

This technical data report describes the results of the Infaunal and Epifaunal Invertebrate Communities study. Benthic invertebrate communities exhibit considerable spatial and temporal variation in the Fraser River estuary (FRE), where they, along with pelagic phytoplankton and zooplankton, form the foundation of marine food webs. Adequate baseline data on the distribution and diversity of infaunal and epifaunal components of Roberts Bank and the surrounding FRE are needed to inform habitat use of high-trophic level species, such as shorebirds and Pacific salmon that forage on benthic invertebrates.

The purpose of this study was to improve the current state of knowledge on the spatial and temporal patterns of benthic invertebrate community structure at Roberts Bank and surrounding sites in the FRE. Studies included quantifying benthic invertebrate standing-stock biomass and community composition, evaluating patterns of spatio-temporal variability among strata and sampling period, and assessing the relative importance of key environmental variables influencing biomass, abundance, and diversity of infaunal and epifaunal invertebrate taxa.

The study consists of three main components: 1) a review of the existing knowledge on invertebrate communities at Roberts Bank; 2) meiofaunal and macrofaunal intertidal surveys across six strata in the FRE; 3) and a subtidal macroinvertebrate survey at the proposed RBT2 terminal location.

Sediment sampling across six strata (i.e., Sturgeon Bank, Westham Island, Brunswick Point, Inter-causeway Area, Boundary Bay, and Mud Bay) indicated that total biomass, abundance, and diversity were consistently higher at Brunswick Point, the Inter-causeway Area, and Boundary Bay compared to other strata. Across all strata, the meiofaunal community was dominated by nematodes, followed by harpacticoid copepods, while the macrofaunal community was dominated by polychaetes. The subtidal macroinvertebrate community within the proposed terminal and dredge basin footprint is dominated by bivalves, followed by polychaetes.

Analysis of variance revealed variation in infaunal biomass, as well as total and taxon-specific abundance and density across, strata, and sampling periods. Stratum (or location) was an important component of observed variability for all biotic parameters considered in this analysis, with the exception of meiofaunal and macrofaunal cumacean abundance. Variance components among sampling period revealed statistically significant seasonal differences in meiofaunal total biomass and abundance, and macrofaunal diversity that are likely determined by taxon-specific recruitment patterns or temporal fluctuations in abiotic factors.

Linear regression analyses yielded little statistical evidence regarding the role of environmental variables in explaining observed variability in meiofaunal and macrofaunal biotic parameters. While multivariate analyses had much higher predictive power, optimized models revealed that spatio-temporal changes in biotic parameters are most likely dictated by multiple abiotic variables. Analyses revealed that salinity, total organic carbon, sediment grain size and distance from shore (intertidal elevation), co-varied with meiofaunal and macrofaunal biotic parameters.

Meiofauna and macrofauna abundance were consistently positively correlated with salinity, although linear models explained only a small part of the observed variation. In multivariate analyses, positive relationships existed between biotic variables and salinity for many meiofaunal and macrofaunal invertebrate community members, and at Brunswick Point specifically, salinity and total organic carbon were most commonly positively associated with meiofaunal and macrofaunal biotic parameters. Linear regression models also revealed positive correlations between meiofaunal diversity and total organic carbon and salinity.

Sediment grain size, expressed as percent sand, was negatively correlated with all meiofaunal and macrofaunal parameters considered in linear models. Similarly, multivariate optimized models showed that sediment grain size and distance from shore were negatively correlated with many biotic variables, suggesting that high infaunal abundance and diversity may be associated with upper intertidal environments at Roberts Bank known to support high levels of primary productivity (WorleyParsons 2015). The inconsistent relationships between abundance of various taxa (especially macrofaunal nematodes and ostracods) and sediment grain size likely reflects between-species variations in habitat preferences (Ysebaert and Herman 2002) that could not be captured by higher taxonomic classifications considered in this study.

While the hierarchy of abiotic variables influencing the distribution of infaunal and epifaunal taxa and overall invertebrate community biomass, abundance, and diversity is complex and not easily decoupled, results of this study contribute to baseline information on environmental factors and processes influencing infaunal and epifaunal components of the Roberts Bank ecosystem, and may serve as a reference for large-scale changes to meiofaunal and macrofaunal communities relating to future development in the area.

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1.0 INTRODUCTION

1.1 PROJECT BACKGROUND

The Roberts Bank Terminal 2 Project (RBT2 or Project) is a proposed new three-berth marine terminal at Roberts Bank in Delta, B.C. that could provide 2.4 million TEUs (twenty-foot equivalent unit containers) of additional container capacity annually. The project is part of Port Metro Vancouver's Container Capacity Improvement Program, a long-term strategy to deliver projects to meet anticipated growth in demand for container capacity to 2030.

Port Metro Vancouver retained Hemmera to undertake environmental studies to inform a future effects assessment for the Project. This technical data report describes the results of the study of intertidal, soft-bottom benthic invertebrates. Several other technical data reports provided complimentary information:

- Subtidal Benthic Productivity Survey for Disposal At Sea Site Characterisation Technical Data Report: provides information on infaunal macroinvertebrates and bottom-associated epifauna in the candidate disposal at sea (DAS) area and intermediate transfer pit (ITP);
- Shellfish Harvesting Potential and Contaminant-Related Consumption Risks at Roberts Bank, Fraser River Delta Technical Data Report: provides information on edible intertidal bivalves;
- Marine Invertebrates – Juvenile Dungeness Crabs Technical Data Report;
- Marine Invertebrates, Crab Productivity Study Technical Data Report; and
- Delta Port Third Berth Adaptive Management Strategy (AMS): annual sampling has occurred since 2007 to monitor the infaunal benthic invertebrate community within the Roberts Bank Inter-causeway ecosystem.

Further information from these studies is not presented in this report; literature reviews on existing data, methods, and results can be found in the respective documents.

1.2 INFAUNAL AND EPIFAUNAL INVERTEBRATES OVERVIEW

A review of the existing knowledge was completed for intertidal soft-substrate benthic invertebrate communities in the vicinity of Roberts Bank to identify key data gaps and areas of uncertainty. This technical data report describes the study findings for key components identified from this gap analysis. Study components, major objectives, and a brief overview are provided in **Table 1-1**.

Table 1-1 Infaunal and Epifaunal Invertebrates Study Components and Major Objectives

Component	Major Objective	Brief Overview
Intertidal community composition and standing stock biomass of meiofauna and macrofauna	• Describe Fraser River estuary (FRE) infaunal and epifaunal invertebrate communities in terms of taxonomic composition, densities, biomass, and diversity • Evaluate patterns of spatial and temporal variability	Sediment samples were collected from the intertidal tideflats in the FRE during 2012 and 2013. Samples were analyzed for benthic invertebrate biomass, taxonomic composition, and abundance.
Abiotic drivers of invertebrate biomass and abundance	• Describe relationships between invertebrate taxa and their biophysical environment	Data collection was integrated for three biological studies: biofilm, infaunal, and epifaunal invertebrates, and sediment chemistry. Data were compiled across disciplines to provide an extensive dataset of multiple environmental variables collected at Roberts Bank, and co-located data points were queried for analyses.
Subtidal community composition and standing stock biomass of macrofauna	• Characterise the biomass and diversity of benthic infaunal macroinvertebrates at the proposed terminal location	Van Veen sediment grab samples were collected from 12 sites in the proposed RBT2 footprint and dredge basin. Sediment grab samples were sieved (>1.0 mm) and macroinvertebrate samples were sorted and enumerated to assess for biomass and taxonomy.

Infaunal and epifaunal invertebrate communities across the Fraser River estuary (FRE) are the subject of published studies that span more than three decades (Levings and Coustalin 1975; Chapman and Brinkhurst 1981; McEwan and Gordon 1985; Sewell 1996; Sutherland et al. 2000, 2013; Sewell and Elner 2001). Many of these studies are dated, however, and/or were based on low sample sizes. Furthermore, previous studies do not provide a coherent picture of the extent of spatial and temporal variation of the benthic invertebrate communities at Roberts Bank, and across the FRE. Since benthic invertebrates form the foundation of marine food webs, data are needed to understand patterns in habitat use of animals that forage on infaunal and epifaunal invertebrates, such as shorebirds and Pacific salmon.

2.0 REVIEW OF EXISTING LITERATURE AND DATA

The term ‘infaunal and epifaunal invertebrates’ is broad and includes many taxonomic groups. Here, the term is used to describe organisms that reside on (epifauna) or within (infauna) the bottom substrate. These invertebrates are typically divided into two body size classes: meiofauna (63 to 500 µm in length along the longest axis) and macrofauna (>500µm in length)[1] and these operational definitions are used throughout this report. Many phyla are exclusive to the meiofauna size class where they develop directly into adults, while macrofauna often have planktonic stages classified as meiofauna before reaching a macrofaunal adult size.

2.1 LIFE HISTORY & BEHAVIOUR

Infaunal and epifaunal invertebrates have a wide variety of larval forms and life history strategies (Vance 1973), though some general reproductive characteristics exist for meiofauna and macrofauna (Warwick 1984). For meiofauna, one reproductive event generally occurs while many macrofaunal species can reproduce multiple times in their lifetime. The life cycle of meiofauna is typically less than one year with growth continuing until adult size is reached, while the macrofauna life cycle is often one year or longer.

Reproductive strategies of infaunal and epifaunal invertebrates are diverse. Most are broadcast spawners, dispersing their gametes (sperm and eggs) freely into the water column where fertilization occurs (Crimaldi and Zimmer 2014), generally cued by lunar cycles or other external factors such as water temperature (Babcock et al. 1992); however, fertilization can also occur by copulation (e.g., oligochaeta, some polychaeta, and most crustaceans) or by ‘pseudo-copulation’ (e.g., nermertea), whereby adults secrete a common mass of slime within which they spawn their eggs and sperm (Thorson 1950). In certain taxa (i.e., polychaetes), when an individual is unable to reproduce sexually due to environmental conditions, asexual reproduction may be carried out (Thorson 1950). Many species require warmer water temperatures to adequately ripen their gametes before spawning; thus, higher rates of spawning tend to occur in the warmer summer months (Thorson 1950).

For the majority of infaunal and epifaunal invertebrates, development into juvenile stages includes a free-living larval (planktonic) phase (Pechenik 1999). Larvae live in near surface waters, where they can disperse tens or even thousands of kilometres from their source before settling on suitable habitat. Such dispersal is an important process in regulating population dynamics (Roughgarden et al. 1994). The larval phase is typically characterised by high mortality, with 99% of larvae removed before reaching metamorphosis (Mileikovsky 1971), especially due to predation by other invertebrates and post-larval fish (Allen 2008).

[1] Note that the division between meiofaunal and macrofaunal size factions is an operational rather than a functional biological definition (Sutherland et al. 2000)

Most larvae are not capable of undergoing metamorphosis immediately after settlement, and often need to mature in order to become capable of transforming into their adult form. Metamorphosis may be triggered by both external (i.e., thermal, chemical, and nutritive conditions) and internal cues (Pawlik 1992). Newly transformed juveniles of most marine benthic invertebrate species fit into the meiofaunal size range, and may stay there for a period of weeks or months, depending on environmental conditions (Bachelet 1990). Similar to larvae, the juvenile phase generally also experiences high mortality rates (i.e., greater than 90%) due to high predation and desiccation (Gosselin and Qian 1997).

2.2 Variability in the Fraser River Estuary

Fraser River estuary infaunal and epifaunal communities exhibit considerable temporal and spatial variation. Several studies have demonstrated seasonal fluctuations in community characteristics (Green and Hobson 1970, Chapman and Brinkhurst 1981, Ellison 1984, Morrisey et al. 1992*b*). For example, Chapman and Brinkhurst (1981) documented seasonal shifts in benthic invertebrate distributions in relation to the spring freshet. Additionally, Mathot and Elner (2004) found that benthic invertebrate densities at Roberts Bank appeared to peak during western sandpiper (*Calidris mauri*) migration periods (spring and summer), suggesting that migratory timing may be related to productivity cycles at key stopover sites.

The spatial distribution of infaunal and epifaunal invertebrates is often described as ‘patchy’ rather than uniform (Barry and Dayton 1991, McIntosh 1991, French et al. 2004), typified by clumps of high abundance in some areas and total absence in other areas (Morrisey et al. 1992*a*). While scales of variation differ depending on the taxa or species, the greatest spatial variation generally exists over scales of tens of centimetres to kilometres (French et al. 2004). At Boundary Bay, Sewell and Elner (2001) noted significant differences in the relative abundance of taxa at scales of tens or hundreds of metres, but not at the scale of 1 km. Fine-scale spatial variation is thought to be influenced by physical environmental factors, behavioural responses, as well as intra- and interspecific interactions that enhance settling, energetic gains, and fitness (Morrisey et al. 1992*a*, Underwood and Chapman 1996).

Levings and Coustalin (1975) sampled at Sturgeon and Roberts Banks and reported that maximum infaunal and epifaunal invertebrate biomass occurred adjacent to the zone of emergent vegetation in the high intertidal, and that polychaetes, amphipods, and tanaidaceans were major contributors to biomass at these elevations. At Boundary Bay, McEwan and Gordon (1985) also reported highest infaunal and epifaunal invertebrate densities occurring near the leading edges of the salt marshes. In lower intertidal areas, bivalves dominated the biomass, except in eelgrass beds where crustaceans and polychaetes were the most abundant.

2.2.1 Abiotic Factors

Marine infaunal and epifaunal invertebrate communities on intertidal sand and tideflats are influenced by a variety of abiotic variables (Levings and Coustalin 1975, Pearson and Rosenberg 1987, Peterson 1991, Wilson 1991, Eckman 1996, Ricciardi and Bourget 1999, Hyland et al. 2005, Sutherland et al. 2013). Previous studies indicate that five variables repeatedly stand out in their influence of benthic community abundance and composition: sediment grain size, total organic carbon, elevation, salinity (i.e., freshwater input), and eelgrass presence. These variables are discussed in further detail below.

Other abiotic variables also influence the occurrence and distribution of infaunal species, including sediment depth (Calvert 1976, Kennish 1986, Rodil et al. 2008), intertidal slope (Fréchette and Bourget 1985, McLachlan 1990, McLachlan et al. 1993, Ricciardi and Bourget 1999), wave exposure (i.e., shear stresses; Palmer and Molloy 1986, Fegley 1987, Peterson 1991, Leonard et al. 1998, Ricciardi and Bourget 1999), water temperature (Ricciardi and Bourget 1999), and natural and anthropogenic physical sediment disturbances associated with storm events, oceanographic currents, dredging and sediment disposal (Thrush 1986, Salomons et al. 1988, Turnpenny 1988, Elliott et al. 1990, Peterson 1991, Thrush and Dayton 2002, Burd et al. 2008).

2.2.1.1 Sediment Grain Size

Invertebrate communities are often structured according to sediment grain size distributions (Pinedo et al. 2000). Ricciardi and Bourget (1999) found grain size to be the single best predictor of total biomass on tidal flats. The correlation between marine infaunal and epifaunal invertebrates and grain size can be either positive or negative depending on the prevalent particle size and taxa present. For example, Yates et al. (1993) found that the density of oligochaetes was positively related with clay content while Sutherland et al (2013) found a negative correlation between infaunal densities and increasing silt content at Roberts Bank. Sediment grain size is considered a particular driver of meiofaunal distribution and community characteristics by inflicting physical impositions on meiofauna with interstitial or burrowing lifestyles (Warwick 1984). The sediment grain size directly influences its porosity, and hence rate of exchanges between sediment interstitial water and the overlying water within the benthic boundary layer. The degree of sorting is sometimes overlooked in the interpretation of soft bottom benthic community dynamics but can be extremely important as a determinant of sediment pore space and porosity.

2.2.1.2 Organic Carbon

Infaunal and epifaunal marine invertebrate abundance, biomass, and species richness can be influenced by total organic carbon. Since living and detrital organic matter is an important food source for infauna and epifauna, a moderate increase in organic matter typically results in an increase in abundance, biomass, and species richness; however, an overabundance of organic matter can result in high rates of microbial decomposition along with the associated buildup in sediment interstitial water of potentially toxic by-products (ammonia and sulphide) and a reduction in oxygen concentration (Hyland et al. 2005). Therefore, high concentrations of organic matter are considered sub-optimal, and are often associated with reduced species richness, abundance, and biomass (Hyland et al. 2005).

2.2.1.3 Intertidal Elevation

Tidal elevation is strongly correlated with physical gradients that may influence infaunal and epifaunal intertidal communities, including aerial exposure, light intensity, temperature, current velocity and wave action, silt proportion, and the presence and absence of eelgrass (Sutherland et al. 2013). Peterson (1991) documented instances where clear patterns exist between taxonomic abundance and intertidal elevation. In a study off of the coast of Spain, Rodi et al. (2008) found that polychaetes were most abundant at low intertidal elevations whereas bivalves were more abundant at low-mid tide levels. Similarly, the abundances of gastropods and crustaceans was greatest at higher elevations (Rodil et al. 2008). Recent research by Sutherland et al (2013) on infaunal invertebrate communities at Roberts Bank demonstrated a negative correlation between tidal elevation and taxon-specific abundance variables considered in their analyses.

2.2.1.4 Salinity

Estuaries, such as the FRE, are characterised by changing water flow patterns, either from seasonal (e.g., freshet) or diurnal and circatidal (e.g., river inputs, tidal cycles) events that cause large fluctuations in salinity (Burd et al. 2008). Infaunal invertebrates are not influenced directly by salinity changes in the water column, but rather by salinities within sediments (i.e., interstitial water salinity), which exhibit dampened oscillations in salinity compared to the water column (Chapman and Brinkhurst 1981).

In the FRE, Chapman and Brinkhurst (1981) found that seasonal variations in interstitial salinities, driven largely by the spring freshet, are correlated with the distribution of benthic infaunal species. The authors showed that distributions of two freshwater oligochaete species shifted downstream during freshet (i.e., when interstitial salinities are lowest), and distributions of three marine polychaete species shifted upstream during winter (i.e., when interstitial salinities are highest). The phenomenon of seasonal shifts in benthic populations is not restricted to the FRE. Birtwell (1972) and Gillis (1978) documented movements of communities in response to interstitial salinity variations in the estuaries of the Thames and St. John rivers in England.

2.2.1.5 Eelgrass

Eelgrass (*Zostera* sp.) beds are important habitat for various infaunal and epifaunal invertebrates, such as harpacticoid copepods (Webb and Weaver 1988, Webb 1991b). Leduc and Probert (2011) found that meiofaunal biomass was higher within eelgrass beds than outside, and that eelgrass presence altered community composition. A recent study at Roberts Bank by Sutherland et al. (2013) found direct correlations between eelgrass attributes (i.e., root biomass, leaf area index) and faunal abundance (e.g., for bivalves, amphipods, harpacticoid copepods).

2.3 Ecological Role

2.3.1 Trophic Interactions

As herbivores, and as prey for fish, shellfish, and birds, infaunal and epifaunal invertebrates are key intermediate consumers, linking higher trophic levels to basal food resources (Galvan et al. 2008). They have a range of feeding modes, including surface and subsurface deposit feeding, and suspension feeding, which allow them to exploit an array of living or detrital primary producers (Fauchald and Jumars 1979). The type of feeding mode utilized may vary with season, tidal flow, habitat, presence of predators, and phytoplankton abundance (Esselink and Zwarts 1989, Smith et al. 1996, Vedel 1998); therefore, the diet of infaunal and epifaunal invertebrates may vary over space and time (Carman and Fry 2002) and may among species and habitats (Galvan et al. 2008). Relatively recent isotope studies have revealed the importance of microphytobenthos (i.e., biofilm) and benthic algae as dominant food resources (Galvan et al. 2008). At Roberts Bank, Sutherland et al. (2013) showed that the abundance of *Polydora* (a polychaete) and harpacticoid copepods increased with components that comprise biofilms (i.e., chlorophyll, mucous, silt).

Infaunal and epifaunal invertebrates, in turn, are consumed by a variety of bird and fish species (Stickney et al. 1975, Bell and Coull 1978, Alheit and Scheibel 1982, Kennish 1986, Smith and Coull 1987, Coull 1990). Harpacticoid copepods and cumaceans, for example, are favoured prey resources for juvenile Pacific salmon during their nearshore residence period (Gee 1989, Webb 1991, Sutherland et al. 2013). Several taxa of infaunal and epifaunal invertebrates have also been shown to be important food sources for migratory western sandpipers (Sutherland et al. 2000) and Pacific dunlin (*Calidris alpina pacifica*; Mathot et al. 2010). Stomach content analyses suggest that three phyla account for the most ingested invertebrates: molluscs (including both gastropods and bivalves), annelids (i.e., polychaetes worms), and arthropods (including amphipods, cumaceans, ostracods, harpacticoid copepods, and tanaids; Mathot et al. 2010). Despite being one of the most abundant taxa on tidal flats, nematodes are generally avoided as prey items by both western sandpiper and dunlin (Quammen 1984, Senner et al. 1989, Sutherland et al. 2000, Davis and Smith 2001, Wolf 2001).

3.0 METHODS

3.1 STUDY AREA

3.1.1 Intertidal Study Sites

The study area for infaunal and epifaunal invertebrates encompasses the FRE, broken down into six strata (**Figure 3-1**), including:

(i) Sturgeon Bank (north of Canoe Passage);

(ii) Westham Island;

(iii) Brunswick Point (directly north of the Roberts Bank causeway to Canoe Passage);

(iv) Inter-causeway Area (directly south of the Roberts Bank causeway to the BC Ferries Terminal causeway);

(v) Boundary Bay; and

(vi) Mud Bay (eastern-most end of Boundary Bay).

These strata were chosen based on distinct environmental conditions within each area that are thought to influence invertebrate community characteristics (e.g., abundance, composition), and are consistent with those used for the assessment of shorebird foraging opportunity, as outlined in the Western Sandpiper Foraging Opportunity Technical Data Report (LGL and Hemmera 2014).

3.1.2 Subtidal Study Sites

Macrofaunal subtidal sampling effort employed a random stratified design, with twelve points located between 0 and −20 m CD within the proposed terminal and dredge basin footprint (**Figure 3-1**).

3.2 TEMPORAL SCOPE

3.2.1 Intertidal Surveys

The timing of intertidal surveys was intended to coincide with western sandpiper northward (April to May) and southward (July to September) migrations, and one dunlin overwintering period (February). Studies were conducted during daytime low tides during five sampling events in 2012 to 2013; survey dates are listed in **Table 3-1** and **Table 3-2**.

3.2.2 Subtidal Surveys

The subtidal survey was intended to capture current baseline conditions within the study area. As subtidal macrofaunal communities are expected to show seasonal variation in abundance, and/or depth distribution, the present survey component supplements seasonal data on subtidal faunal density and diversity collected during previous Disposal at Sea (DAS) characterisation studies (Hemmera 2014*a*).

3.3 SAMPLING DESIGN

The greatest sampling effort was focused on Roberts Bank (i.e., Brunswick Point, Inter-causeway Area (**Figure 3-2**). The other three strata (i.e., Westham Island, Boundary Bay and Sturgeon Bank) were sampled to a lesser extent in order to frame Roberts Bank in an estuary-wide context (**Figure 3-3** and **Figure 3-4)**.

The most intensive use of Fraser River delta tideflats by shorebirds tends to be concentrated in the upper intertidal zone, within 1 km of shore (Pomeroy 2005). To ensure adequate spatial resolution within areas of most intensive shorebird use, intertidal sampling effort was stratified by distance from shore, with 60% of sampling locations sited between 0 and 1 km from shore and the remaining 40% between 1 and 3 km. A combination of 'nested random stratified' and 'systemic stratified transect' sampling designs were employed at each strata to maximize sampling efficiency and ensure adequate spatial coverage. Infaunal and epifaunal invertebrate field data collection was integrated with sediment and biofilm sampling to the extent possible. To maximize synergies of data collection among the three disciplines, effort was made to co-locate a portion of sampling locations, though each discipline maintained additional sites to achieve specific survey objectives. For more detailed information on sediment chemistry and quality, refer to the Sediment and Water Quality Characterisation Studies Technical Report (Hemmera 2014*b*) and for biofilm, refer to the Biofilm Physical Factors Technical Data Report (WorleyParsons 2015).

There were differences in sampling design between 2012 and 2013, with changes in 2013 made to increase the efficiency of data collection. In 2012, sample locations were based on a random stratified grid design and, because some sites were located kilometres apart, field crews had difficulty reaching all planned points within the low tide period. In 2013, sample locations were based on a randomised transect design, where points were spaced in such a way to ensure all sampling locations could be reached in a timely manner.

Details and rationale regarding sampling designs employed within different strata in 2012 and 2013 are outlined in **Table 3-1**.

Table 3-2 summarizes the sampling events by date, location, and number of samples collected. In some instances, the number of sampling locations presented in these tables don't align with those presented in **Figures 3-2 to 3-4** because particular locations were sampled multiple times, and it is not possible to capture this overlap on a figure.

Figure 3-1 A Map of Study Area Strata Including Sturgeon Bank, Westham Island, Brunswick Point, Inter-causeway, Boundary Bay, and Mud Bay

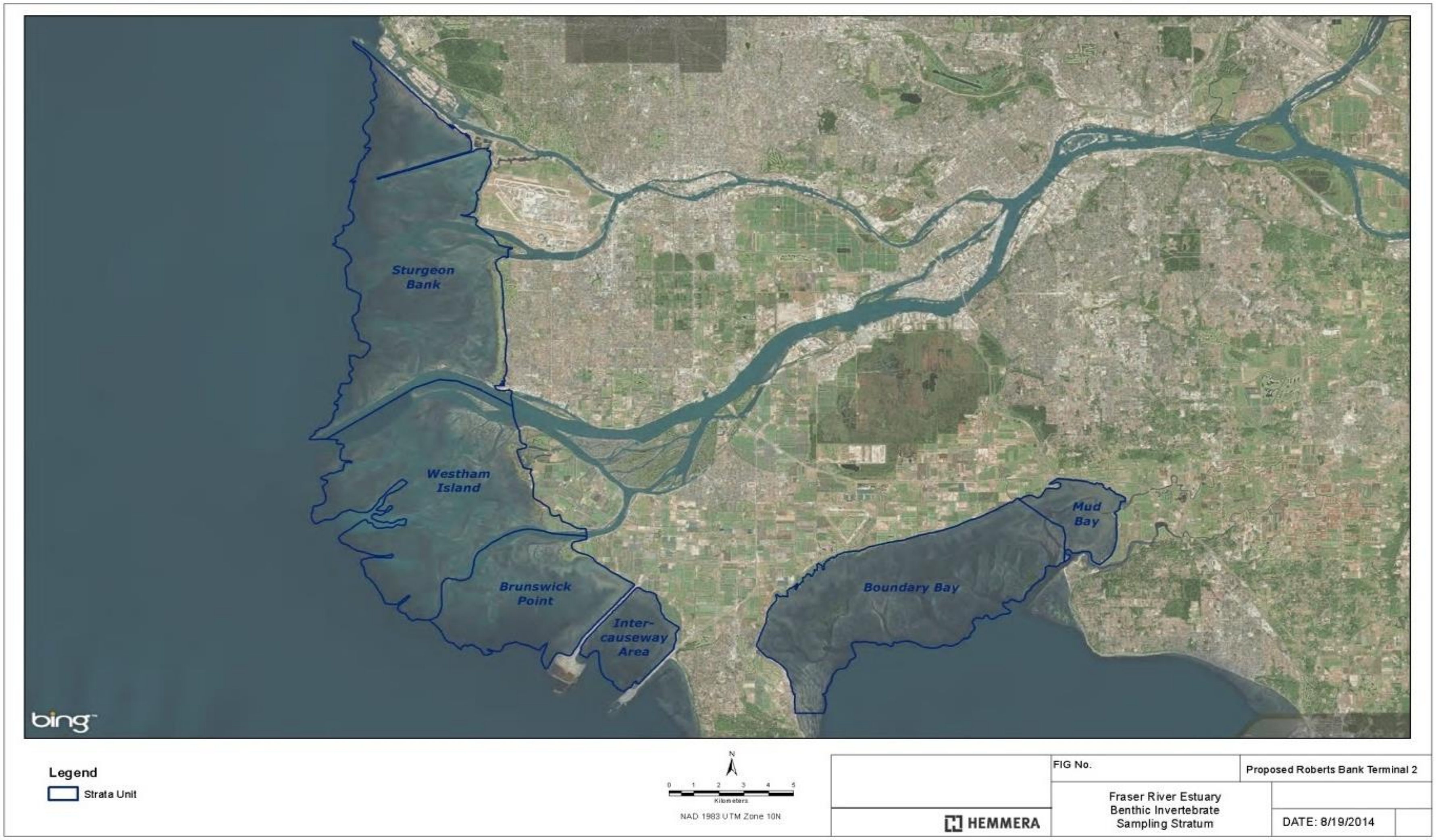


Figure 3-2 Sampling Locations at Roberts Bank by Survey Date

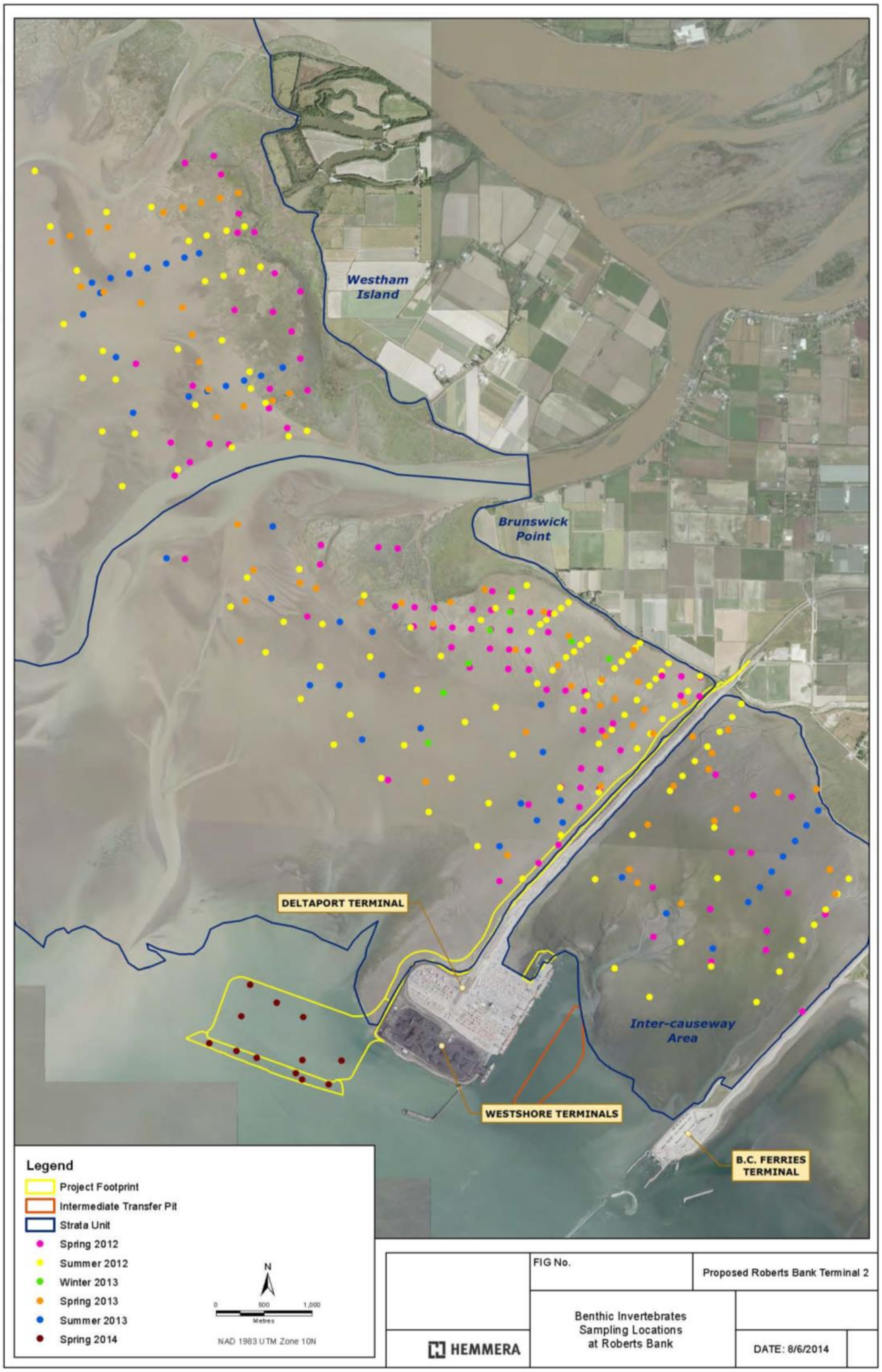


Figure 3-3 Sampling Locations at Boundary Bay by Survey Date

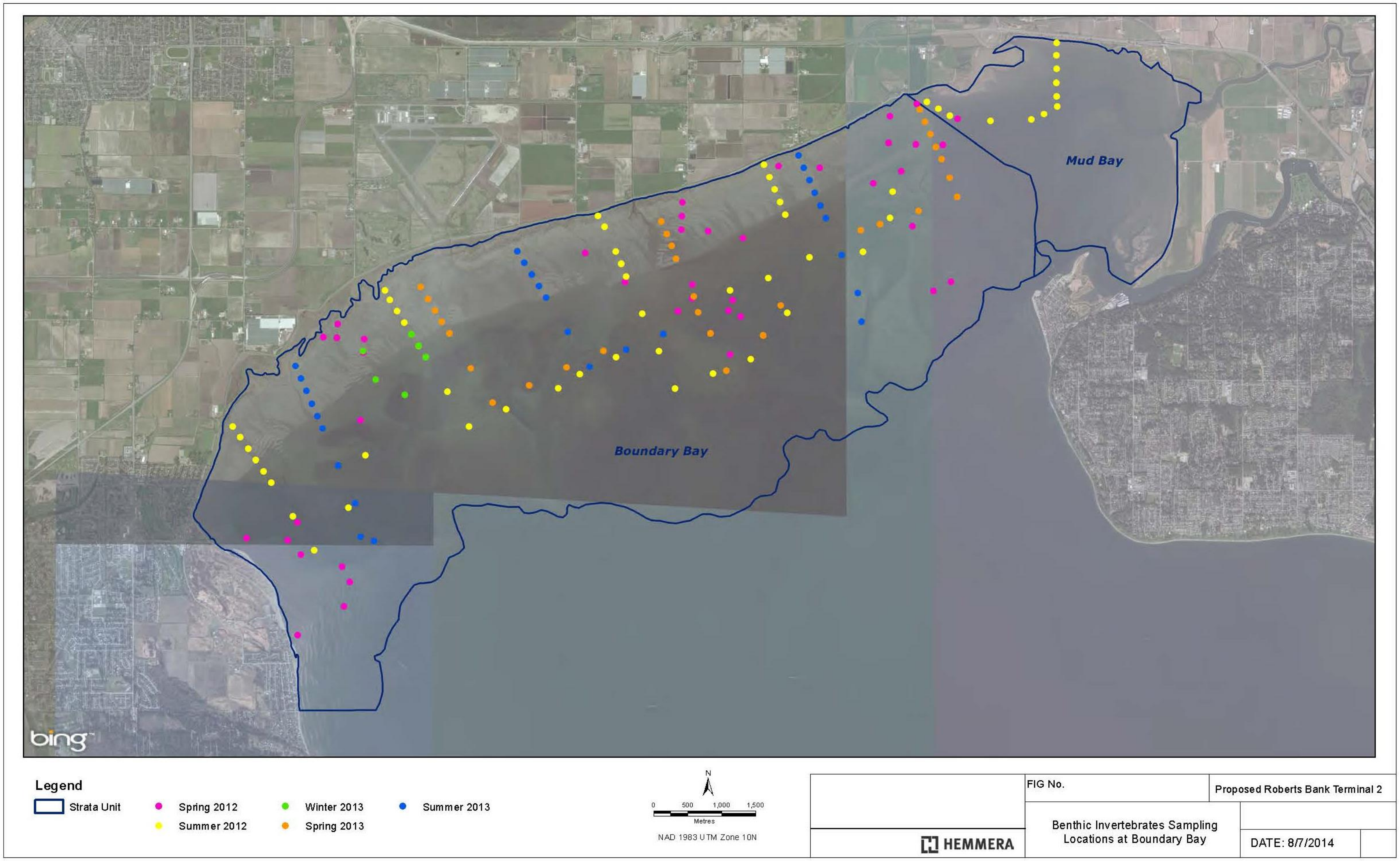


Figure 3-4 Sampling Locations at Sturgeon Bank by Survey Date

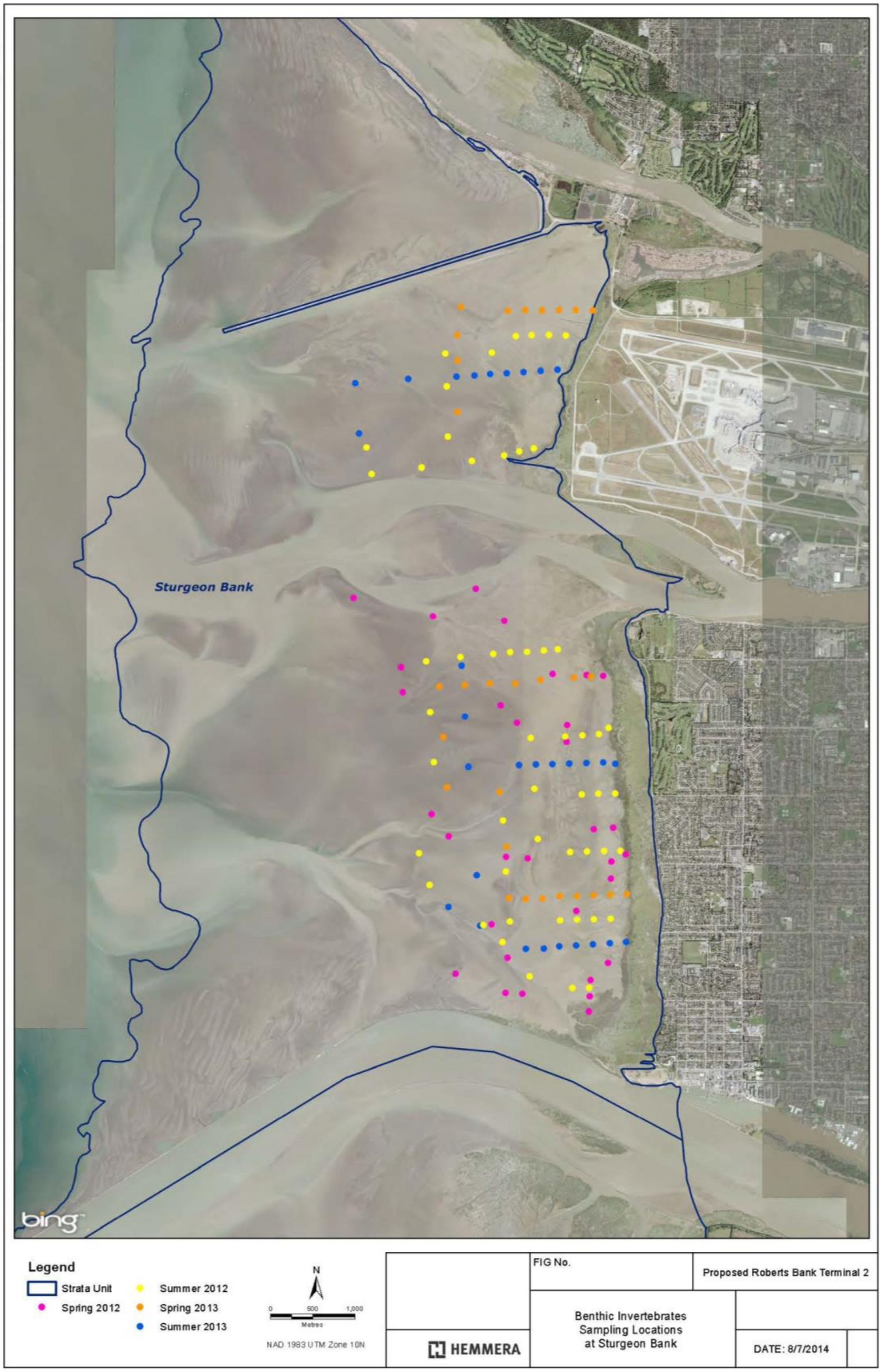


Table 3-1 Summary of Intertidal Sampling Design and Rationale Employed within Strata in 2012 and 2013

Season	Survey Dates	Strata Sampled	Sampling Design	Sampling Design Rationale and Details
Spring	April 17 to May 6, 2012	Inter-causeway Brunswick Point Westham Island Boundary Bay Mud Bay Sturgeon Bank	Nested Random Stratified	Sampling locations were derived using a modified random grid, to ensure adequate sampling coverage
Summer	July 2 to Aug. 26, 2012	Inter-causeway Brunswick Point Westham Island Boundary Bay Mud Bay Sturgeon Bank	Systemic Stratified Transect	Predetermined transects were employed to maximize sampling efficiency. Transect start points were randomly generated from the same sampling grid used in spring 2012 sampling design. Sample points were established along each transect at an interval of approximately 200 m within 1 km from the shore, and an interval of approximately 600 m between 1 to 3 km from the shore.
Winter	February 1 to 2, 2013	Brunswick Point	Nested Random Stratified	Sample locations selected from previously sampled locations (i.e., spring 2012) to co-locate with biofilm sampling. Five sample locations were selected within 1 km of shore and three were selected 1 to 3 km from shore.
		Boundary Bay	Nested Random Stratified	Sample locations selected from previously sampled spring and summer 2012 sample locations at most 1 km apart, to ensure sampling could be completed within one day.
Spring	April 16 to May 7, 2013	Inter-causeway	Nested Random Stratified	Sample locations selected from previously sampled locations to co-locate with biofilm sampling. Eleven sample locations were selected within 1 km of shore and four were selected 1 to 3 km from shore.
		Brunswick Point	Nested Random Stratified	Sampling locations were randomly selected based on hyperspectral habitat classifications and co-located with biofilm sampling locations.
		Westham Island Boundary Bay Sturgeon Bank	Systemic Stratified Transect	Predetermined transects based on sampling design employed during summer 2012.
Summer	July 11 to September 6, 2013	Inter-causeway	Systemic Stratified Transect	Predetermined transects based on sampling design employed during summer 2012.
		Brunswick Point	Nested Random Stratified	Sampling locations were randomly selected based on hyperspectral habitat classifications and co-located with biofilm sampling locations.
		Westham Island Boundary Bay Sturgeon Bank	Systemic Stratified Transect	Predetermined transects based only sampling design employed during Spring and Summer 2012

Table 3-2 Summary of Study Strata, the Number of Samples Collected in 2012 and 2013, and Survey Dates

Area	2012		2013			TOTAL
	Northward	Southward	Northward	Southward	Winter	
Boundary Bay	42	58	30	28	6	**164**
Brunswick Point	55	66	28	33	8	**190**
Inter-causeway	14	23	15	15		**67**
Sturgeon Bank	32	52	30	30		**144**
Westham Island	23	31	20	17		**91**
All Areas Combined	**166**	**230**	**123**	**123**	**14**	**656**

3.4 Sampling Techniques

3.4.1 Intertidal Sample Collection

Field sampling techniques were adapted from those employed by Mathot and Elner (2004) and Sutherland (2000) to characterise forage availability for wading shorebirds. Descriptions of infaunal and epifaunal invertebrate communities are strongly influenced by the sampling and sample processing methods used. The techniques described below were specifically designed to assess the numerical densities and composition of intertidal meiofaunal and macrofaunal species that are focal prey species for western sandpipers, Pacific dunlin, and other wading shorebirds. The techniques would not capture larger bodied (and larger biomass) macroinvertebrates such as cockles or deeper burrowing species such as lug worms and ghost shrimp, which serve as prey for other vertebrate species. Complementary observations of marine macrofauna based on different observational techniques are described in companion technical data reports listed in **Section 1.0: Project Background.**

The sampling team worked with Dr. Kim Mathot, shorebird expert at the Max Planck Institute of Ornithology, to develop sediment sampling, faunal preservation, and sorting/enumeration approaches. At each sampling location, small cores constructed from 60 mL syringes (26 mm x 40 mm) with the luer tip ends cut off were used to collect sediment and biota samples. The infaunal prey of western sandpipers generally ranges in size from 0.1 to 5 mm, and syringes used in this study were selected to capture prey within this size range (Mathot and Elner 2004). Syringes were held perpendicular to the sediment with the plunger pulled up several centimetres inside the syringe barrel. The barrel of the syringe was then pushed into the sediment to a depth of 4 cm and then extracted. A Whirl-Pak sample bag was placed around the syringe and, using the plunger, the sample was ejected into the bag. This was repeated two more times at each sampling location, and the triplicate core samples were pooled to create a composite sample at each location. Bagged samples were stored on ice in the field and subsequently transferred to formalin for preservation.

A Garmin GPS, without differential correction, was used to record the sampling site location and elevation. The UTM NAD83 position coordinates are generally expected to be accurate within approximately ± 5 m in any direction. Additional field observations were collected using an electronic PDA (‘personal digital assistant’) device. All data collected in the field were synced with the Hemmera server daily.

Field data collected at each sampling location included:

- Date and time;
- Habitat composition (%);
- Temperature (°C);
- Conductivity (µs/cm);
- Dissolved oxygen (%)*;
- ORP (mV)*;
- Salinity (ppt);
- pH;
- Weather Conditions;
- Shorebird Droppings**; and
- Incidental Observations.

* data collected only in the summer 2013 field study
** data were not collected in the winter 2013 field study

The sediment samples with infauna were shipped to Biologica Environmental Services Ltd. (Victoria, B.C.) for sorting, enumeration, and taxonomic identification. The samples were transferred from fixative (formalin) to ethanol within two weeks of receipt at Biologica. During this process, samples were size fractionated by wet sieving on 500 µm and 63 µm stainless steel sieves. These fractions were processed separately. Samples were stained with Rose Bengal to aid in sorting.

3.4.1.1 Intertidal Laboratory Analyses

500 µm fraction

The 500 µm fraction (fraction retained on a 500 µm sieve as a result of wet sieving and gentle washing) was sorted whole (i.e., no subsampling) under a dissecting microscope (20 to 60x magnification). During sorting, 1 to 2 mL of sample debris was removed at a time. This debris was placed into a Bogorov tray in a single layer for sorting and was passed under the microscope at least three times at progressively higher magnifications to maximize the recovery of infauna from the sediment samples. All organisms were identified to their major natural taxonomic grouping (i.e., to phylum for rare taxa, class for mollusca and annelida, and order for crustacea). Specimens were removed from the sample and retained to obtain direct measurements of biomass. Twenty-five percent of samples were randomly spot-checked to ensure >95% sorting efficiency (percent of total organisms recovered). During spot checks, 25 to 100% of the sample debris was checked under the dissecting scope. Samples falling below 95% sorting efficiency were re-sorted and the resulting additional taxonomic data were included in the final abundance counts.

Wet biomass of the 500 µm fraction was measured directly to the nearest 0.1 mg (0.0001 g). All taxa were pooled to obtain one estimate of total biomass per station. Ten percent of samples (n=16) were randomly selected for re-weighing both to ensure no technician bias was introduced, and to obtain an estimate of measurement error.

63 µm fraction

Subsamples of the 63 µm fraction (that portion passing through a 500 µm sieve and retained on a 63 µm sieve) were prepared with a Folsom splitter. Suspended samples of infauna and finer sediment were gently mixed and split into half five times sequentially to obtain subsamples that were 1/64th of the original volume (the remaining sample was archived for future analysis, as needed). The subsamples were processed under a dissecting microscope at a magnification of 20 to 60x. All organisms were identified to major taxonomic group by technicians trained in marine taxonomy.

As with the 500 µm fraction, the 63 µm fraction was sorted directly under the microscope in a Bogorov tray, which allowed for recovery of all types of organisms. Elutriation and density gradient (e.g., Ludox) centrifugation do not necessarily recover organisms with hard calcified tests or shells (e.g., foraminifera, bivalvia) (Burgess 2001, Giere 2009). In addition, these methods do not necessarily have consistently high recovery rates across different sediment types, especially those with high clay or organic content (Burgess 2001).

The biomass of the 63 µm fraction was estimated indirectly from volumetric conversions of length and width measurements of all major taxa (Warwick and Price 1979, Feller and Warwick 1988, Giere 2009, Du et al. 2012). Average biomasses were estimated for each major taxonomic group, then multiplied by the abundance of each group in each sample, and summed to obtain whole-sample biomass estimates that are comparable with the 500 µm biomass estimates.

Measurement

Technicians were instructed to measure the largest and smallest specimens from each taxonomic group from each sample under a compound microscope using an ocular micrometer calibrated to 0.0025 µm (at 100 to 400x magnification). To make these measurements, specimens were mounted on slides with glycerin. The length and maximum width of all specimens was recorded. The location of these measurements was standardized for each major group.

Estimation of wet weight

The volume of each measured individual (Giere 2009) was calculated according to the empirical equation:

$$\text{Body volume} = C \times L \times W^2 \qquad [1]$$

Where: C is a dimensionless conversion factor specific to each taxon,

L is the total individual length, and

W is the maximum width of an individual

Wet weight was estimated by multiplying the estimated biovolume by known/estimated values of specific gravity of that taxon (Baguley et al. 2004, Giere 2009).

Average biomass estimates obtained in this manner were compared with: 1) direct biomass measurements for nematoda, harpacticoida, ostracoda, and polychaeta (these estimates ranged from 3.9 to 15.9% different); and 2) with existing values for 250 µm subtidal meiofauna.

Taxa that were not measured for volumetric conversions were generally rare, and their biomass was estimated based on estimates for other similar or related organisms. Given their rarity, the contribution of these taxa to overall biomass was low in comparison with more abundant taxa.

3.4.2 Subtidal Sample Collection

Sediment samples for infaunal macroinvertebrate quantification were collected on March 30 and 31, 2014. Benthic macrofauna sampling consisted of 12 Van Veen sediment grabs within the RBT2 terminal and dredge basin footprints. Sampling stations ranged in depth from approximately −5 to −20 m CD (**Figure 3-2**).

Infaunal macroinvertebrate sample sieving and preservation were performed on board by a contract staff from Biologica Environmental Services (Biologica). Samples were collected using a 0.1 m^2 Van Veen sediment grab sampler deployed from a boat. A single Van Veen grab sample was obtained from each station, the full contents were emptied into a large plastic container, and the entire sample was sieved for infaunal macroinvertebrates. Samples were labelled immediately upon collection using waterproof paper and pencil to ensure the labels will not fade in preservative.

Sediments were gently washed, small portions at a time, into a 1.0 mm screen using filtered seawater. Given the differences in sieve size between the intertidal and subtidal sampling events (500 µm vs 1.0 m), the biomass of retained macrofauna are expected to be different. In particular, the use of a 1.0 mm sieve for the subtidal benthos sampling would not capture macroinvertebrates in the 500 µm to 1.0 mm length range, which constrains density, biomass, and diversity comparisons between the intertidal and subtidal samples.

Samples were washed using a moderate flow (1.5 to 2.5 gallons per minute) to preserve tissue and structure integrity of samples, and to separate specimens from the sediment. Once washing was complete, samples were transferred to a 500 mL or 1 L plastic jar with a screw top lid. Samples were preserved in 5 to 10% formalin solution, which was prepared from full-strength formaldehyde (i.e., 37%) diluted directly with seawater, and buffered to pH 7.0 with Borax. The sample was adequately mixed by gently inverting the container several times. A chain of custody and/or sample list was prepared for each container of samples, including: Sample ID, Number of Jars, Date Sampled, presence of a picking vial (with delicate organisms), plus any applicable instructions and/or notes. The samples were transferred within the same week as sampling to Biologica's laboratory in Victoria, B.C. for quantification and taxonomic identification, as outlined in **Section 3.4.1.1** above.

3.5 DATA ANALYSIS

Analyses of infaunal and epifaunal invertebrate data were conducted separately for samples from the meiofaunal (63 to 500 µm) fraction and the macrofaunal (>500 µm) fraction, as it was assumed that these operationally defined size ranges may have implications for foraging opportunity and preferences of different predators such as shorebirds and fish. The separation of the overall infauna into these two size fractions may align with the ecophysiology of some taxonomic groups (e.g., virtually all mature bivalves fall within the macrofaunal size class while their settled larvae are generally less than 500 µm in length) but be less biological meaningful for some taxa (e.g., adults of species of both parasitic and predatory nematodes occur within both the meiofaunal and macrofaunal size classes). All taxa were categorized to major natural taxonomic groupings corresponding to phylum, class or order for the purpose of data analyses; i.e., polychaete (class), nematode (phylum), oligochaeta (class), harpacticoida (order), ostracoda (class), bivalvia (class), cumacea (order), and foraminifera (phylum).

3.5.1 Spatial Analysis

The spatial distribution of infaunal and epifaunal invertebrate biomass, abundance and diversity was mapped using bubble plots and pie charts of the relative taxonomic composition (i.e., diversity and abundance). The spatial distribution of meiofauna and macrofauna biomass and diversity was also mapped using inverse distance weighting inference (IDW) of diversity across the estuary. Inverse distance weighting calculations interpolate the quantity of a parameter across an unknown surface based on the quantity of that parameter at nearby data points (Childs 2004). The main assumption of the IDW method is that locations that are closer to one another are more alike than points that are farther apart. All spatial mapping was conducted using the software package ArcGIS.

Linked to, but outside the scope of, this particular study, infaunal and epifaunal invertebrate data were also used in geospatial analyses of shorebird foraging opportunity. Regression kriging models were used to: 1) evaluate relationships between the distribution of meiofaunal and macrofaunal biomass across the FRE and relevant abiotic (predictor) variables; and 2) generate spatial estimates of food abundance under existing and with-Project conditions. Refer to the Shorebird Foraging Opportunity Model Technical Data Report (LGL and Hemmera 2014) for more information.

3.5.2 Statistical Analyses

The statistical analyses outlined below were conducted using the statistical analysis software R, version 3.1.0 (R Core Team 2014). Analyses examined spatial and temporal variability across six strata (**Figure 3-1**) in the FRE, and focused on summary univariate community statistics including biomass, abundance, and diversity index based on community metrics calculated for each sampling location.

Taxonomic diversity was calculated using the Shannon's Diversity Index (Hill 1973), a metric that captures diversity and evenness at a sampling location. Total abundance was analyzed for all individuals sampled at each location. Additionally, taxon-specific measures of abundance were also analyzed for eight smaller taxa (63 to 500 µm) and seven larger taxa (>500 µm) that have documented ecological importance in the estuary (i.e., polychaeta, nematoda, oligochaeta, harpacticoida, ostracoda, bivalvia, cumacea, and (for 63 to 500 µm only) foraminifera.

Prior to running parametric statistical analyses, all data were tested for normality using a Shapiro-Wilk normality test (Shapiro and Wilk 1965) and examined for degree of skewness by plotting a frequency histogram for each parameter. To reduce skew, data transformations were performed as appropriate.

3.5.2.1 Spatio-temporal Pairwise Comparisons

Analysis of variance (ANOVA) was used to examine the proportion of variation in biotic parameters such as biomass, abundance, and diversity between versus within the six strata. When the ANOVA indicated significant difference in the biological variable of interest between strata, a pairwise t-test was used to identify where the differences occurred. Pairwise-t-tests were two tailed, and p-values were corrected using a Bonferroni correction for multiple tests. Consistency among results was evaluated qualitatively by visually examining graphical representations of differences in biotic parameters among strata broken down by sampling period. ANOVA and paired t-tests were also used to examine the proportion of variation in biotic parameters that could be explained among sampling periods.

3.5.2.2 Univariate Linear Regression

Univariate linear regression analysis was used examine the strength of the relationship between biotic variables (i.e., biomass, abundance, and diversity) and environmental variables. For linear regression analyses, this study focused on a subset of key abiotic variables previously identified as being important drivers of estuarine infaunal and epifaunal invertebrate community structure (see **Section 2.0: Review of Existing Literature and Data**), including:

- salinity (measured as saturation adjusted chloride concentration)*;
- sediment grain size (measured as percent sand);
- tidal elevation (measured as distance from shore)*;
- freshwater source (measured as distance to freshwater); and
- total organic carbon (TOC).

* **Note**: where direct measurement of a variable was not possible, proxies were used; specifically, distance from shore was used as a metric for tidal elevation and interstitial sediment chloride concentration, corrected for sediment saturation, was used as a proxy for salinity.

3.5.2.3 Multivariate Modeling of Biotic and Abiotic Variables

Multiple linear regression analyses were performed to assess the relative importance of key abiotic variables in predicting the variability in biotic parameters such as biomass, abundance, and diversity of infaunal and epifaunal invertebrate taxa. Key abiotic variables considered in multivariate analyses include those listed in **Section 3.5.2.2** above with the addition of eelgrass presence. Biotic variables included summary metrics such as biomass, abundance, and diversity. Biofilm, or diatomaceous mats, are another important biotic component of the higher intertidal zone in portions of several of the strata. Relationships between infaunal invertebrates and biofilm are examined in detail in LGL and Hemmera (2014), in the context of foraging opportunity for migratory shorebirds, since both biofilm and tideflat invertebrates provide forage for various bird species.

Multivariate linear regression was conducted for polychaete abundance, oligochaeta abundance, nematode abundance, harpacticoid abundance and (for meiofauna only) foraminifera abundance. Each biotic variable was analysed using the entire dataset (i.e., all sampling periods and strata) and independent multivariate regressions were run within each stratum to capture the influence of spatial variability. For the Brunswick Point stratum, samples were further broken down by sampling period to determine whether patterns in multivariate relationships changed among seasons or among years.

The statistics package MASS in R (R Core Team 2014) was used to perform an automated stepwise model selection using AIC (Akaike Information Criterion)[2] for each combination of biotic variable and the set of six abiotic parameters (Venables and Ripley 2002). A stepwise model selection technique was used, starting with the full model, including all candidate variables and then adding and deleting parameters from the full model until a model with the lowest AIC (best fit) value was found. The adjusted R^2 value measures the proportion of the response variable (biotic variable) that can be explained by the linear model (predictor variables) and is adjusted for the number of parameters in the model. In the case of the full model, using all strata and sampling periods, and the model that included all sampling periods at Brunswick Point, the relative contribution of predictor variables of the best fit model to the overall R^2 value was calculated using the Pratt method using the statistical package relaimpo in R (Gromping 2006, R Core Team 2014).

3.5.2.4 Principle Components Analysis

Two Principle Component Analysis (PCA) were carried out, for the meiofaunal and macrofaunal fractions to examine the underlying structure of all biotic and abiotic data, and test for redundancies among 67 biotic and abiotic variables in the larger dataset. Detailed methodologies, additional abiotic parameters considered, and the results of these analyses are provided in **Appendix A.**

[2] The metric AIC measures the quality of a given model relative to other potential models (with greater or fewer predictor variables) and allows for model selection (Akaike 1974).

4.0 RESULTS

4.1 INTERTIDAL INFAUNAL AND EPIFAUNAL COMMUNITIES

4.1.1 Spatio-temporal Variation

A total of 656 intertidal locations were sampled in 2012 and 2013. The highest mean meiofaunal biomass was recorded in the Roberts Bank Inter-causeway Area (54.9 g/m^2) while the lowest was recorded at Westham Island (15.8 g/m^2). Highest mean macrofaunal biomass was recorded at Boundary Bay (86.6 g/m^2) and, again, the lowest was recorded at Westham Island (24.4 g/m^2). Maximum meiofaunal biomass recorded among strata and sampling periods was 275.4 g/m^2 at Sturgeon Bank, while maximum macrofaunal biomass was 689.7 g/m^2, recorded at Boundary Bay. The results are summarised in **Table 4-1** below.

The spatial distribution of meiofaunal biomass, abundance, and diversity during the 2012 spring and summer sampling periods is illustrated in **Appendix B: Figures B1** through **B3,** while 2013 sampling periods are presented in **Appendix B: Figures B4** through **B6**. Similarly, the spatial distribution of macrofaunal biomass, abundance and diversity for 2012 sampling is illustrated in **Appendix B: Figures B10** through **B12**, and in **Appendix B: Figures B7** through **B9** for the 2013 sampling events. A geospatial interpolation (IDW) using data from all sampling locations across all sampling events is presented in **Figures 4-1** and **4-2** for meiofauna and macrofauna, respectively.

Table 4-1 Mean, Maximum, and Minimum Biomass Values Across All Survey Periods by Stratum

Stratum	Meiofauna[1]			Macrofauna[1]		
	Mean Biomass (g/m^2)	Max Biomass[2] (g/m^2)	Min Biomass[2] (g/m^2)	Mean Biomass (g/m^2)	Max Biomass[2] (g/m^2)	Min Biomass[2] (g/m^2)
Sturgeon Bank	21.0	275.4	0	41.5	159.7	0.4
Westham Island	15.8	76.3	0	24.4	236.3	0
Brunswick Point	30.9	195.3	0	37.7	266.3	0.03
Inter-causeway Area	54.9	169.0	0.3	60.4	542.1	4.1
Boundary Bay	31.2	152.7	0.7	86.6	698.7	0
Mud Bay	31.3	74.4	7.8	37.5	91.5	0.6

[1]Includes data from all survey periods; [2]Biomass per sample

Figure 4-1 Inverse Distance Weighted (IDW) Interpolation of Meiofaunal Biomass Based on all Locations Sampled in 2012 and 2013

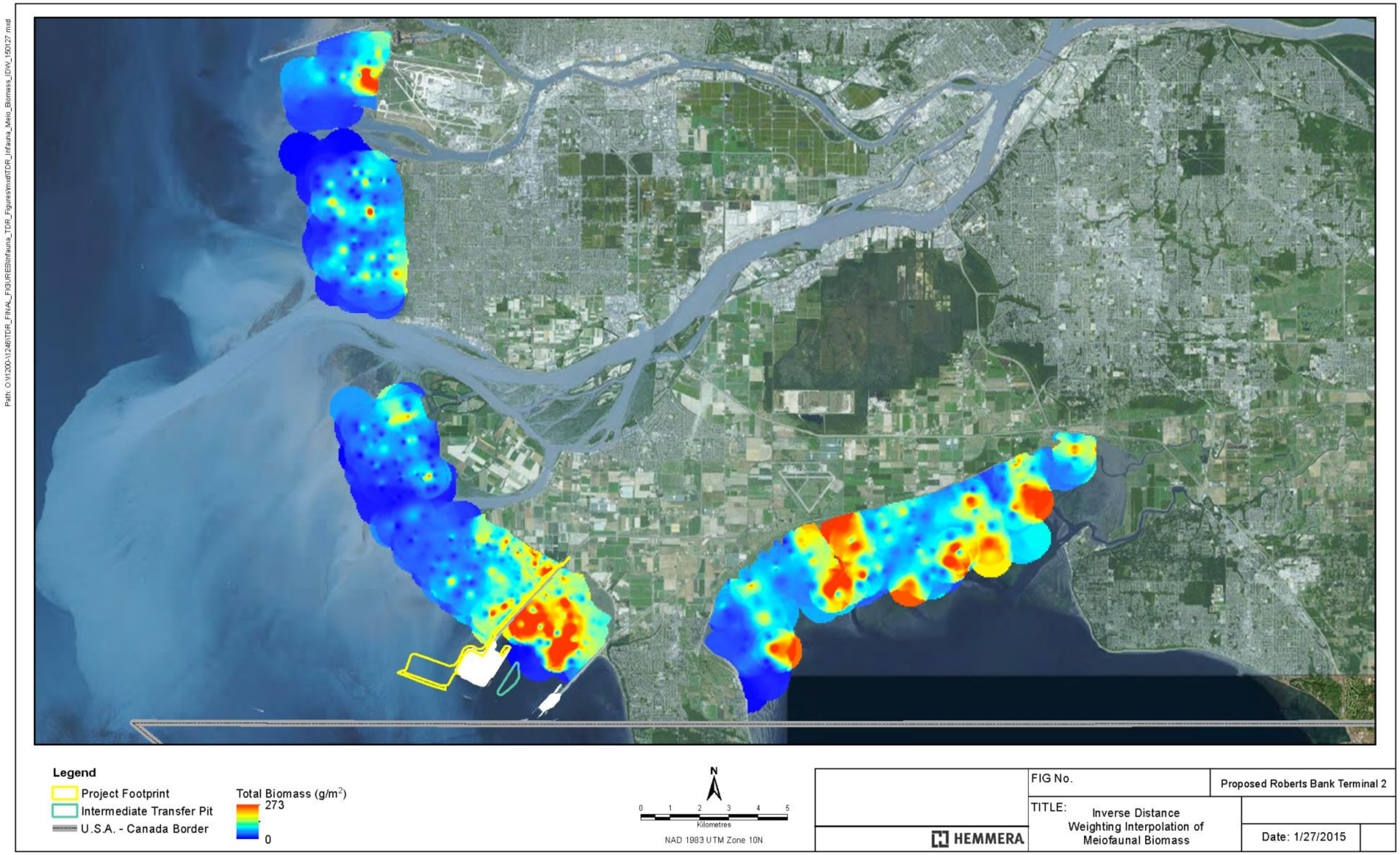
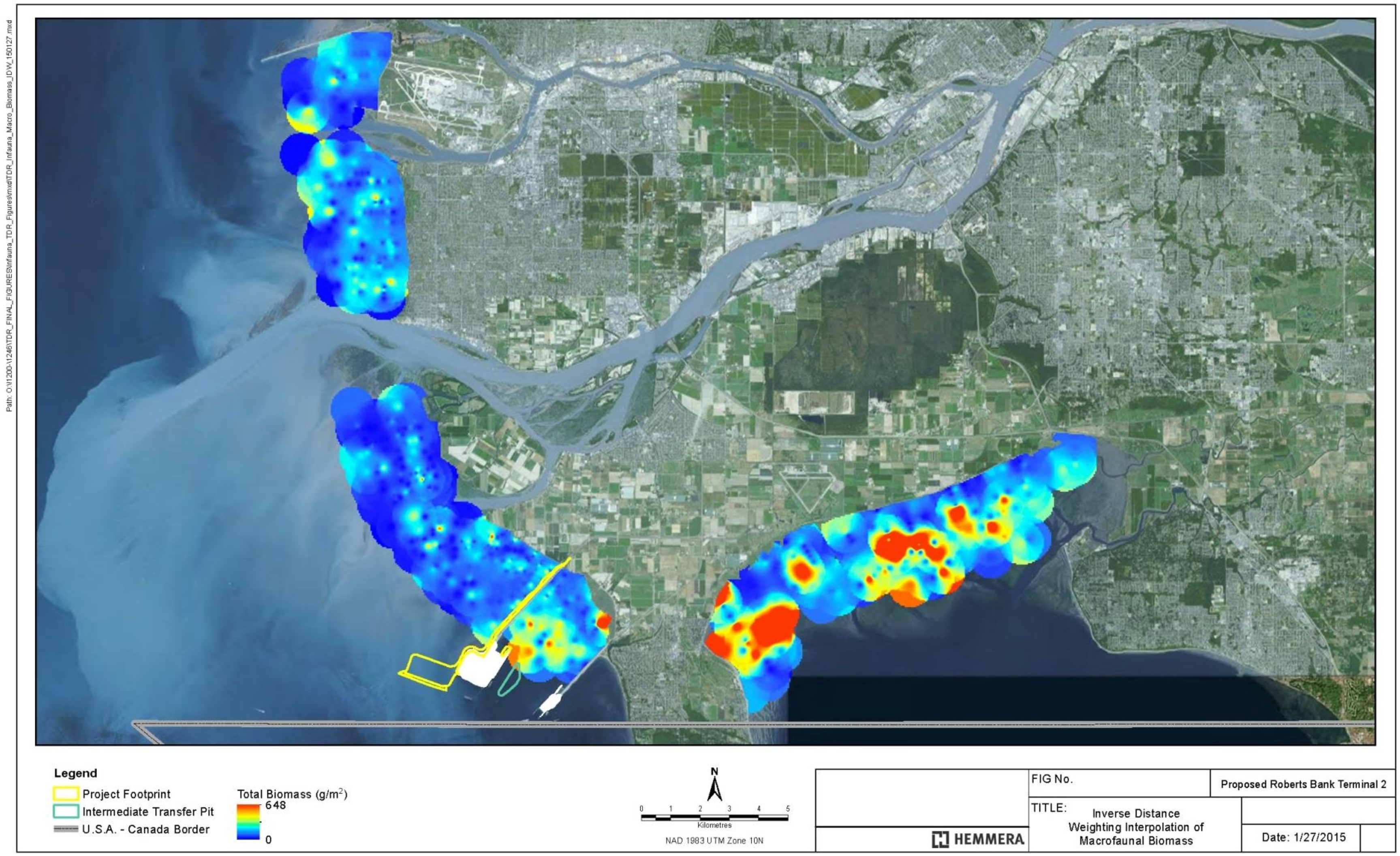


Figure 4-2 Inverse Distance Weighted (IDW) Interpolation of Macrofaunal Biomass Based on all Locations Sampled in 2012 and 2013



Additionally, an IDW of Shannon's Diversity index by individual strata for meiofauna and macrofauna can be found in **Appendix B: Figures B13** through **B18.**

A summary of significance patterns of biomass, total and taxon-specific abundance, and diversity among strata and sampling period, is provided in **Table 4-2.** Where evidence for significant differences in dependent variables among strata or sampling period (i.e., $P \leq 0.05$) exists, the patterns of significance relationships (based on pairwise t-test comparisons) are summarized in the far right column in **Table 4-2**. Relationships between total biomass, abundance, and diversity among strata and sampling period are illustrated in **Figure 4-3** to **Figure 4-5** and **Figure 4-6** to **Figure 4-8**, for meiofauna and macrofauna, respectively.

ANOVA indicated that a statistically significant proportion of variation in all of the biotic variables considered in this analysis could be explained among strata, with the exception of meiofaunal and macrofaunal cumacean abundance (**Table 4-2**). Total meiofaunal biomass and abundance were consistently highest within the Inter-causeway stratum, followed by Brunswick Point, which was not significantly different from Boundary Bay or Mud Bay in both comparisons (**Figure 4-3** and **Figure 4-4)**. While Brunswick Point had the highest total meiofaunal diversity, it was not significantly greater than diversity recorded in the Inter-causeway or Mud Bay strata (**Figure 4-5**).

Total macrofaunal biomass, abundance, and diversity were consistently higher within the Inter-causeway and Boundary Bay than at Brunswick Point (**Figure 4-6** to **Figure 4-8; Table 4-2**). Macrofaunal parameters at Brunswick Point were not significantly different from Sturgeon Bank and Mud Bay. While ANOVA provided some evidence for statistically significant seasonal differences in some biotic parameters (**Table 4-2**), seasonal trends based on the pairwise comparisons were difficult to discern (see also **Appendix C: Tables C1** and **C2**). Variations in meiofaunal and macrofaunal total biomass, abundance, and diversity among strata by sampling period were qualitatively assessed and graphics are presented in **Appendix C: Figures C1** to **C6**.

Trends for meiofaunal and macrofaunal taxon-specific abundance were highly variable among sites, with no consistent patterns of significant differences among strata (**Table 4-2**). Relationships between taxon-specific abundance and strata, sampling period, and strata by sampling period are illustrated in **Appendix C: Figures C7** and **C8** for meiofauna and macrofauna, respectively.

Table 4-2 Summary of Statistical Analyses of Spatio-temporal Variation in Meiofaunal and Macrofaunal Invertebrate Communities in the Fraser River Estuary[3].

Dependent Variable	Analysis of Variance				Pattern of Significant Differences (pairwise-t-test)[4]	
	Strata	Sampling Period	Strata x Sampling Period	Interannual	Strata [5]	Sampling Period
Meiofauna						
Biomass	*P*<0.001	*P*<0.001	qa[2]	*P*<0.001	IC>**BP**>SB, WI (BP not significantly different from MB or BB)	Evidence of statistically significant differences across strata during Spring 2012, Summer 2012, Spring 2013 and Summer 2013 sampling periods. The ANOVA analysis was not significant for samples collected in Winter of 2013 and there were no significant differences among sampling periods in 2013
Abundance	*P*<0.001	*P*<0.001	qa[2]	*P*<0.001	IC>**BP**>SB, WI (BP not significantly different from MB or BB)	Evidence of statistically significant differences across strata during Spring 2012, Summer 2012, Winter 2013, Spring 2013 and Summer 2013 sampling periods. There were no significant differences among sampling periods in 2013
Diversity	*P*<0.001	*P*=0.002	qa[2]	*P*=0.02	**BP**>BB, SB, WI (BP not significantly different from MB or IC)	ns[1]

Dependent Variable		Analysis of Variance				Pattern of Significant Differences (pairwise-t-test)[4]	
		Strata	Sampling Period	Strata x Sampling Period	Interannual	Strata[5]	Sampling Period
Meiofauna cont'd							
Taxon-specific Abundance	*Polychaeta*	*P*<0.001	*P*=0.03	qa[3]	ns[1]	**BP**>BB, WI (BP not significantly different from SB, IC or MB)	ns[1]
	Nematoda	*P*<0.001	*P*<0.001	qa[3]	*P*<0.001	IC, BB>**BP**>SB, WI (BP not significantly different from MB)	Evidence of statistically significant differences across strata during Spring 2012, Summer 2012, Winter 2013, Spring 2013 and Summer 2013 sampling periods. There were no significant differences among sampling periods in 2012, or in 2013
	Oligochaeta	*P*<0.001	*P*<0.001	qa[3]	ns[1]	**BP**>BB, SB, WI (BP not significantly different from IC or MB)	Evidence of statistically significant differences across strata during Spring 2012, Summer 2012, Winter 2013, Spring 2013 and Summer 2013 sampling periods. There were no significant differences among sampling periods in 2013.
	Harpacticoida	*P*<0.001	*P*<0.001	qa[3]	*P*<0.001	**BP**>SB, WI (BP not significantly different from IC, BB or MB)	Evidence of statistically significant differences across strata during Spring 2012, Summer 2012, Winter 2013, Spring 2013 and Summer 2013 sampling periods.
	Ostracoda	*P*<0.001	*P*<0.001	qa[3]	*P*<0.001	**BP**>SB, BB (BP not significantly different from IC, WI or MB)	Evidence of statistically significant differences across strata during Spring 2012, Summer 2012, Spring 2013 and Summer 2013 sampling periods. The ANOVA analysis was not significant for samples collected in Winter of 2013 and there were no significant differences among sampling periods in 2013

Dependent Variable		Analysis of Variance				Pattern of Significant Differences (pairwise-t-test)[4]	
		Strata	Sampling Period	Strata x Sampling Period	Interannual	Strata[5]	Sampling Period
Meiofauna cont'd							
Taxon-specific Abundance	*Bivalvia*	*P*=0.002	*P*=0.001	qa[3]	P<0.001	**BP**>SB, WI (BP not significantly different from IC, BB or MB)	Evidence of statistically significant differences across strata during Winter 2013. There were no significant differences among sampling periods in 2012
	Cumacea	ns[1]	*P*<0.001	qa[3]	ns[1]	**BP** not significantly different from SB, WI, IC, BB or MB	Evidence of statistically significant differences across strata during Spring 2012, Summer 2012, Spring 2013 and Summer 2013 sampling periods. The ANOVA analysis was not significant for samples collected in Winter of 2013.
	Foraminifera	*P*<0.001	*P*<0.001	qa[3]	*P*<0.001	IC>**BP**>WI (BP not significantly different from SB, BB or MB)	Evidence of statistically significant differences across strata during Spring 2012, Summer 2012, Spring 2013 and Summer 2013 sampling periods. The ANOVA analysis was marginally significant for samples collected in Winter of 2013.
Macrofauna							
Biomass		*P*<0.001	*P*<0.001	qa[2]	*P*<0.001	IC, BB>**BP**>WI (BP not significantly different from SB or MB)	Evidence of statistically significant differences across strata during Spring 2012, Summer 2012, Spring 2013 and Summer 2013 sampling periods. The ANOVA analysis was marginally significant for samples collected in Winter of 2013 and there were no significant differences among sampling periods in 2012, or in 2013.

Dependent Variable		Analysis of Variance				Pattern of Significant Differences (pairwise-t-test)[4]	
		Strata	**Sampling Period**	**Strata x Sampling Period**	**Interannual**	**Strata[5]**	**Sampling Period**
Macrofauna cont'd							
Abundance		*P*<0.001	ns[1]	qa[2]	ns[1]	IC, BB>**BP**>WI (BP not significantly different from SB or MB)	ns[1]
Diversity		*P*<0.001	*P*=0.006	qa[2]	P<0.001	IC, BB>**BP** (BP not significantly different than SB, WI or MB)	Evidence for statistically significant difference across strata during Summer 2012, and Spring 2013, but not for Spring 2012, Winter 2013 or Summer 2013
Taxon-specific Abundance	*Polychaeta*	*P*<0.001	ns[1]	qa[3]	*P*=0.037	BB>**BP**>WI (BP not significantly different from SB, IC or MB)	Weak evidence for statistically significant difference across strata during Spring 2013 and Summer 2013, but not for Spring 2012, Summer 2012 and Winter 2013.
	Nematoda	*P*<0.001	*P*<0.001	qa[3]	*P*<0.001	IC, BB, MB>**BP** (BP not significantly different from SB or WI)	Evidence of statistically significant differences across strata during Spring 2012, Summer 2012, Spring 2013 and Summer 2013 sampling periods. The ANOVA analysis was not significant for samples collected in Winter of 2013.
	Oligochaeta	*P*<0.001	ns[1]	qa[3]	ns[1]	**BP**>BB, SB, WI (BP not significantly different from IC or MB)	ns[1]
	Harpacticoida	*P*<0.001	*P*<0.001	qa[3]	*P*<0.001	IC, BB>**BP** (BP not significantly different from SB,WI or MB)	Evidence of statistically significant differences across strata during Spring 2012, Summer 2012, Spring 2013 and Summer 2013 sampling periods. The ANOVA analysis was not significant for samples collected in Winter of 2013,and there were no significant differences among sampling periods in 2012

Dependent Variable		Analysis of Variance				Pattern of Significant Differences (pairwise-t-test)[4]	
		Strata	Sampling Period	Strata x Sampling Period	Interannual	Strata[5]	Sampling Period
Macrofauna cont'd							
Taxon-specific Abundance	*Ostracoda*	*P*<0.001	ns[1]	qa[3]	ns[1]	WI, BB>**BP** (BP not significantly different from SB, IC or MB)	ns[1]
	Bivalvia	*P*<0.001	*P*<0.001	qa[3]	ns[1]	**BP**>IC, BB (BP not significantly different from SB, WI or MB)	Evidence for statistically significant differences across strata during Spring 2012, Summer 2012 and Spring 2013, but not for Summer 2013 and Winter 2013. There were no significant differences among sampling periods in 2013
	Cumacea	*P*=0.027	*P*<0.001	qa[3]	*P*<0.001	BP not significantly different from SB, WI, IC, BB or MB	Evidence for statistically significant differences across strata during Spring 2012, Summer 2012, Spring 2013 and Summer 2013. The ANOVA analysis was not significant for samples collected in Winter of 2013 and there were no significant differences among sampling periods in 2013

[1] No evidence of statistical significance at $\alpha = 0.05$
[2]Relationship qualitatively assessed; Refer **to Appendix C: Figures C1** to **C3** and **Figures C4** to **C6** for meiofauna and macrofauna, respectively
[3]Relationship qualitatively assessed; Refer to **Appendix C: Figure C7** and **C8** for meiofauna and macrofauna, respectively
[4]Paired-t-test comparisons, pattern of significant differences relative to Brunswick Point (**BP**); Refer to **Figures 7** to **12**, and **Appendix C: Tables C1** and **C2** for meiofauna and macrofauna, respectively.
[5] SB=Sturgeon Bank; WI=Westham Island; BP=Brunswick Point; IC=Inter-causeway; BB=Boundary Bay; MB=Mud Bay

Figure 4-3 Relationships between Strata and Sampling Period for Meiofauna Biomass (g/m^2)

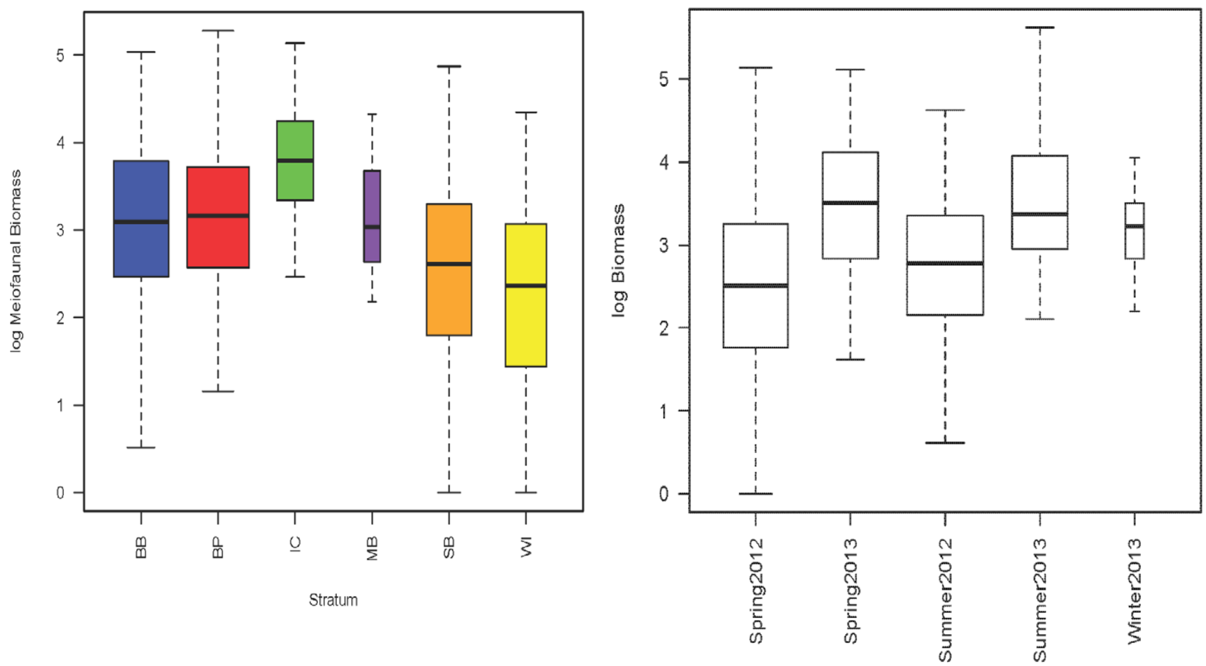
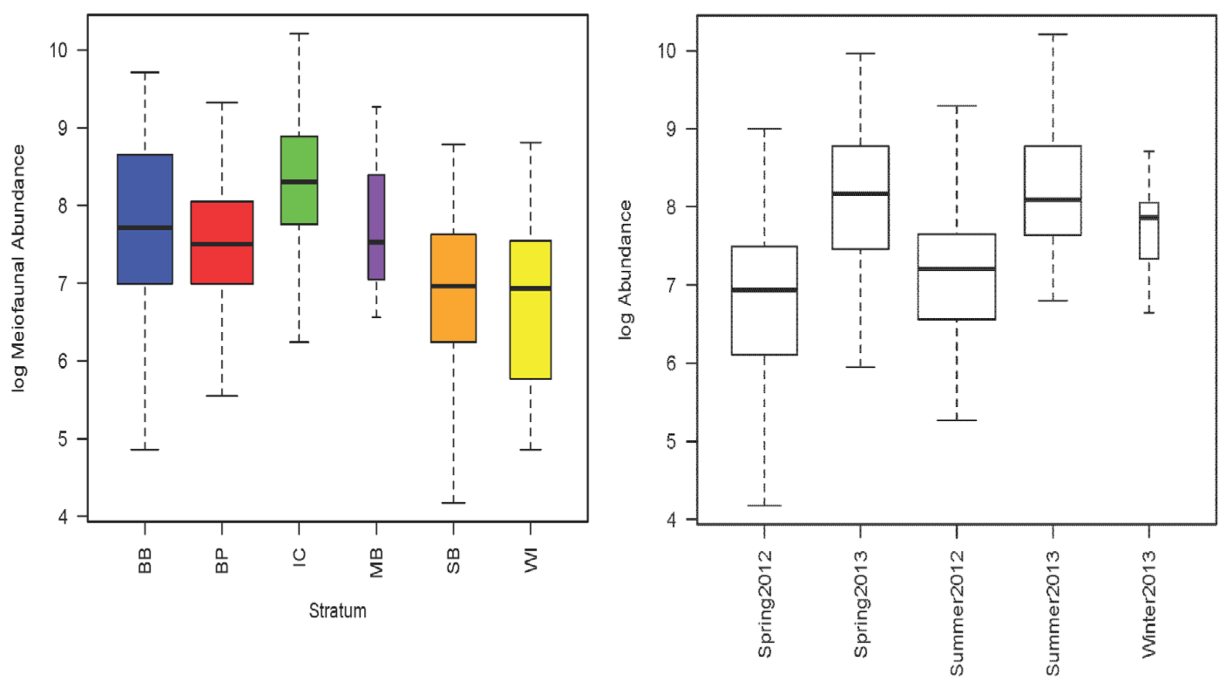


Figure 4-4 Relationships between Strata and Sampling Period for Meiofauna Abundance (number of organisms)



Note: See **Table 4-2** for significance relationships and **Appendix C** for pairwise comparisons.

Figure 4-5 Relationships between Strata and Sampling Period for Meiofauna Diversity (unitless)

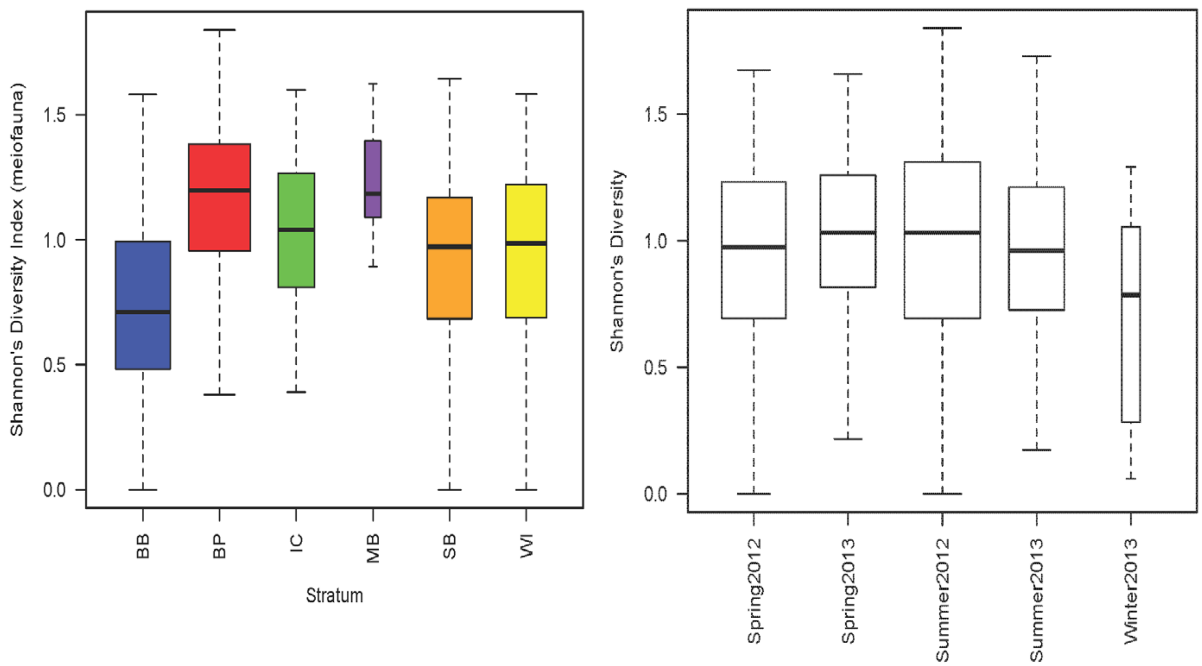
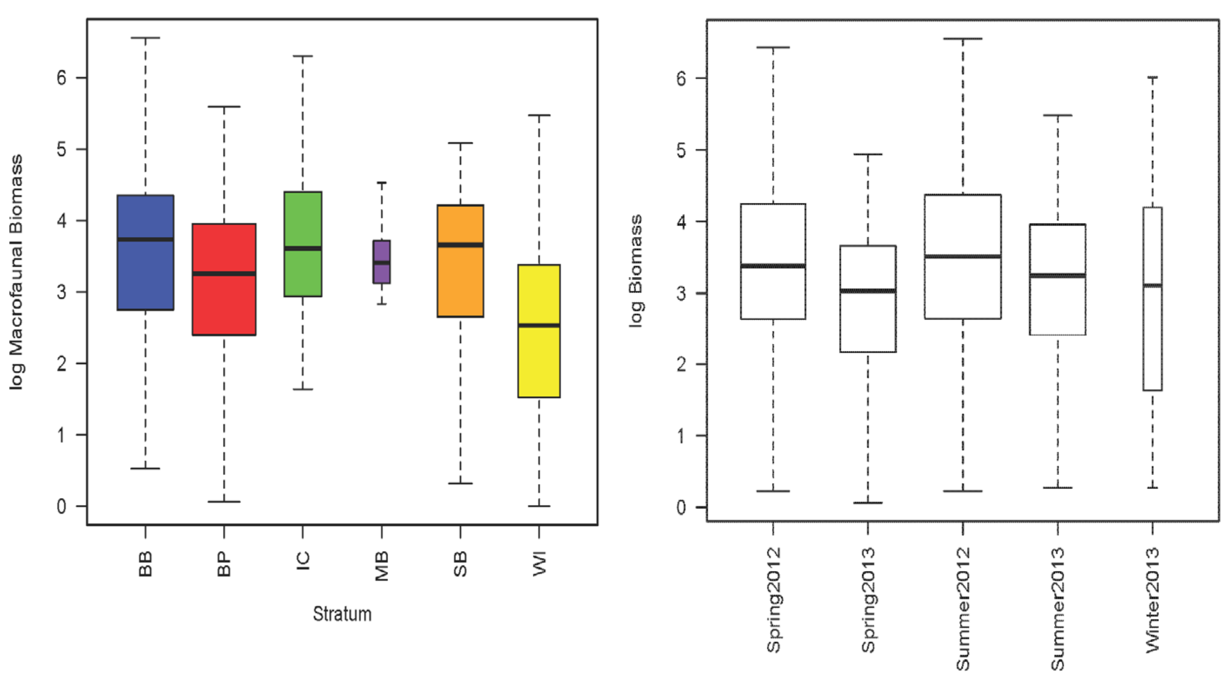


Figure 4-6 Relationships between Strata and Sampling Period for Macrofauna Biomass (g/m^2)



Note: See **Table 4-2** for significance relationships and **Appendix C** for pairwise comparisons.

Figure 4-7 Relationships between Strata and Sampling Period for Macrofauna Abundance (number of organisms)

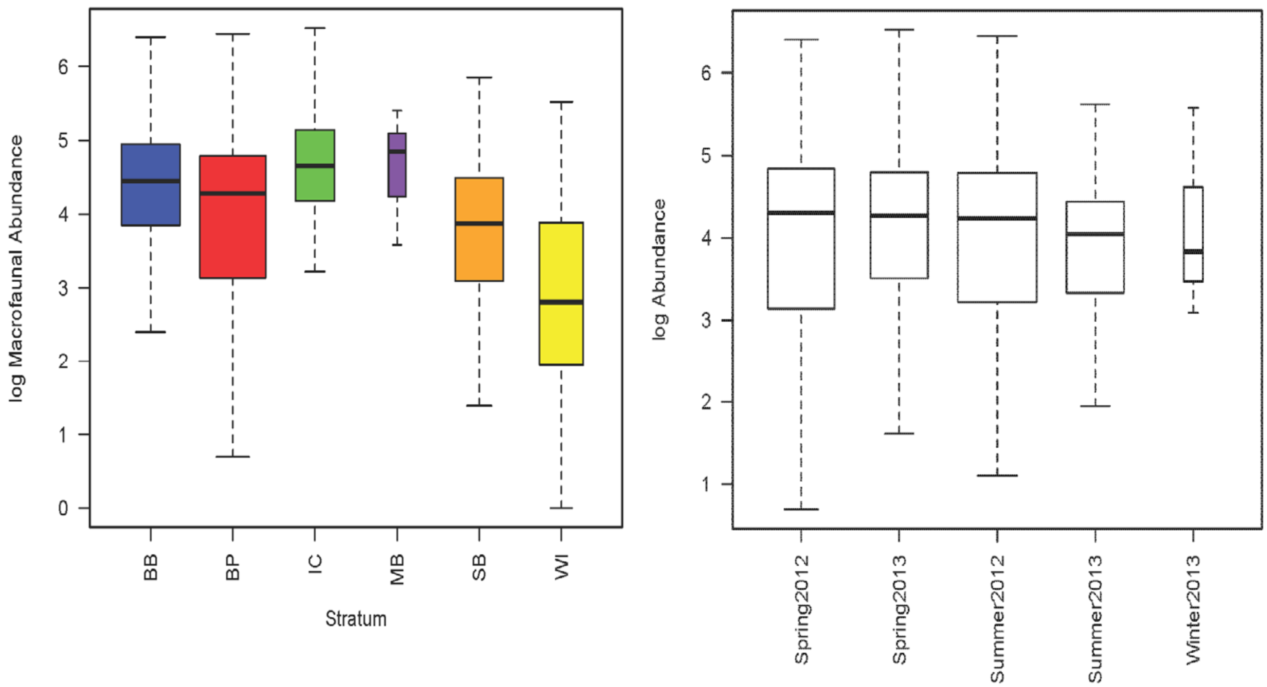
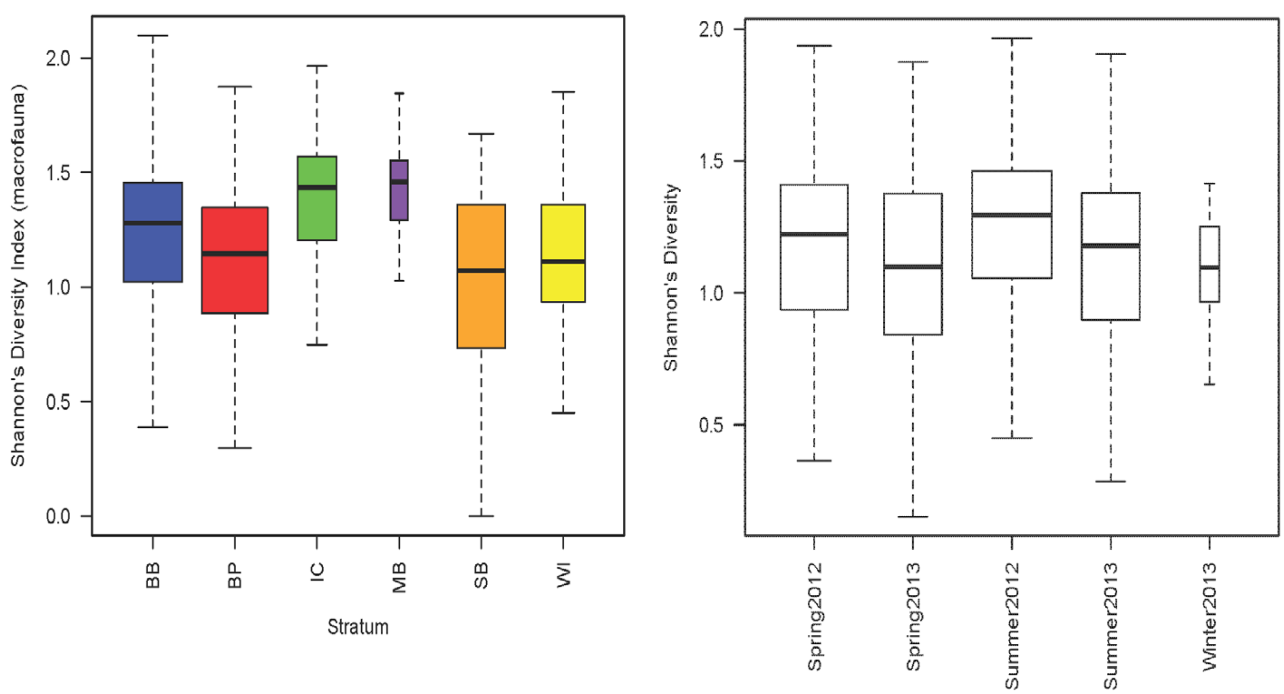


Figure 4-8 Relationships between Strata and Sampling Period for Macrofauna Diversity (unitless)



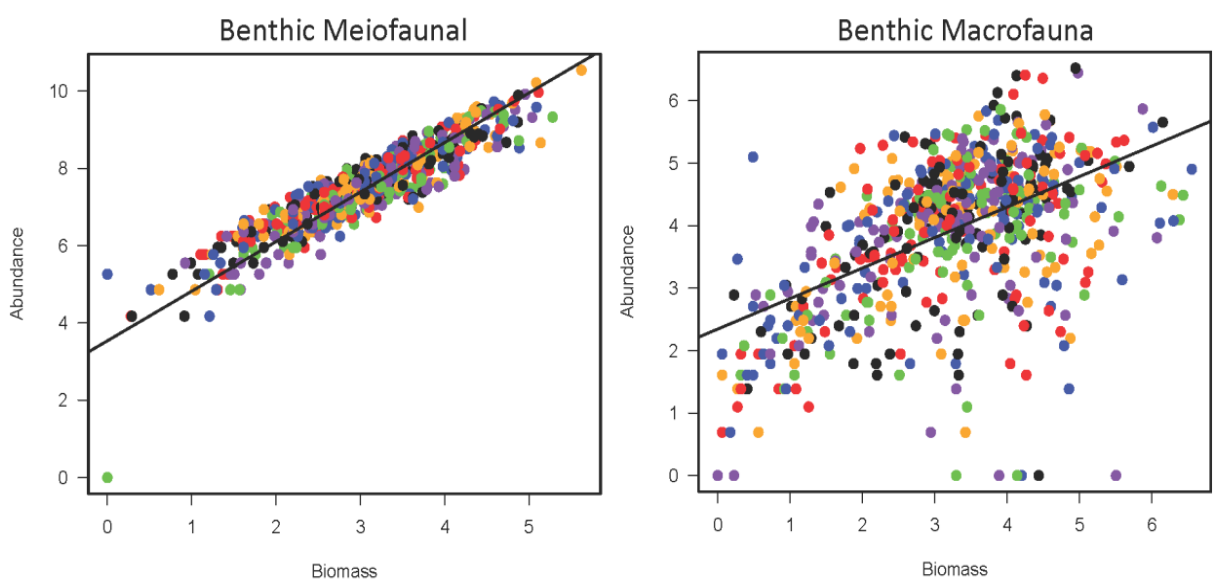
Note: See **Table 4-2** for significance relationships and **Appendix C** for pairwise comparisons.

4.1.2 Taxonomic Composition

A total of 32 taxa were recorded in the meiofaunal size fraction, with 24 taxa observed at Sturgeon Bank, 29 taxa at Roberts Bank (Westham Island, Brunswick Point and Inter-causeway Area), and 25 total taxa at Boundary Bay and Mud Bay collectively. A total of 35 taxa were recorded in the macrofaunal fraction, with 23 taxa at Sturgeon Bank, 30 taxa at Roberts Bank (Westham Island, Brunswick Point and Inter-causeway Area), and 28 total taxa at Boundary Bay and Mud Bay collectively. Detailed figures depicting the relative taxonomic abundance for focal meiofauna and macrofauna considered in this study within each stratum are presented in **Appendix D**. The meiofaunal community was dominated by nematodes, followed by harpacticoid copepods at all tidal elevations (zone limits defined by 1 to 3 km distance from shore) and across all strata in the FRE (**Appendix D: Figures D1** to **D3**). Overall, for meiofauna, there was a strong positive relationship between abundance and biomass (r^2=0.79; P = $2e^{-16}$), but that relationship was weaker for macrofauna (r^2=0.27, P = $2e^{-16}$) (**Figure** 4-9).

The macrofaunal community was dominated by polychaetes across all strata. The second most abundant macrofaunal taxa were oligochaetes at Sturgeon Bank, Brunswick Point, Westham Island ,and Mud Bay, while nematodes were second to polychaetes in the Inter-causeway Area and at Boundary Bay (**Appendix D: Figures D4** to **D6**).

Figure 4-9 Plots of the Relationship between Meiofaunal and Macrofaunal Abundance and Biomass



Note: Colours denote sampling strata: Red = Brunswick Point, Green = Inter-causeway, Blue = Boundary Bay, Purple = Mud Bay, Orange = Sturgeon Bank, Yellow = Westham Island

4.1.3 Linear Regression among Biotic and Abiotic Variables

Table 4-3 provides a summary of the strength and statistical significance of linear relationships between meiofaunal or macrofaunal biotic variables and abiotic environmental variables, including:

- the salinity of the sediment interstitial water (measured using saturated paste extract techniques and back-corrected based on percent saturation of the extracted sample);
- 50^{th} percentile concentration of salinity in the overlying water column based on predictions from hydrodynamic modelling of estuarine salt water – freshwater interactions (Northwest Hydraulics 2014);
- distance to foreshore (m) as a proxy for local tideflat elevation;
- distance to closest freshwater input (m) (e.g., distance to the mouth of Canoe Passage);
- sediment total organic carbon (TOC) content (mg/kg);
- sediment grain size, expressed as percent sand by dry mass; and
- local presence of absence of eelgrass beds.

Analyses were conducted on sample data pooled for all sampling periods and strata. For qualitative comparisons of linear relationships between biotic response and abiotic predictor variables, broken down by stratum and sampling period, refer to figures provided in **Appendix E**.

Linear regression analyses provided some evidence for statistically significant relationships between some biotic variables and abiotic predictor variables as listed above (**Table 4-3**); however, the proportion of variation (based on the co-efficient of determination: R^2) in most biotic parameters that could be explained by the six key abiotic variables did not exceed 20%. Overall, co-efficients of determination were low for all regression models and ranged from 0.005 and 0.189 (**Table 4-3**).

Meiofaunal abundance and biomass were significantly positively correlated with interstitial salinity but not the 50^{th} percentile salinity of the overlying water, distance to freshwater, and total organic carbon, while negative relationships were found with intertidal elevation and sediment grain size, measured as percent sand (**Table 4-3**). Based on ANOVA, the presence of eelgrass explained a significant proportion of variation in meiofaunal total abundance and taxon-specific abundance (i.e., for polychaeta, nematoda, ostracoda, cumacea, and foraminifera; **Table 4-3**). There was a statistically significant negative relationship between the presence of eelgrass and ostracod abundance, while the presence of all other taxa was positively correlated with eelgrass abundance (**Table 4-3**). Meiofaunal diversity, calculated as Shannon diversity, was not correlated with either measure of salinity, distance to freshwater or eelgrass presence/absence. There was a linear correlation with TOC and a negative correlation with percent sand and distance to the foreshore.

Macrofaunal biomass was significantly positively correlated only with water salinity and distance to shore. Macrofaunal abundance was significantly positively correlated with water salinity, intertidal elevation, TOC, and eelgrass presence, and negatively correlated with percent sand (**Table 4-3**). Similar correlations were observed for the abundance of oligochaetes. Water salinity was also a predictor of nematode and ostracod abundance, while TOC was a significant predictor of polychaete, oligochaete, and cumacean abundance.

The only statistically significant predictor of diversity of macrofaunal invertebrates was eelgrass presence/absence.

Table 4-3 Summary of Linear Regression Analyses and Significance Relationships between Meiofaunal and Macrofaunal Biotic Parameters and Key Abiotic Variables. R^2 values Exceeding 0.10 are in Bold.

Dependent Variable		Linear Regression: Abiotic Variable												
		Salinity				Intertidal Elevation (Distance to Shore)		Distance to Freshwater		Total Organic Carbon		Sediment Grain Size[2]		Eelgrass[3]
		Interstitial		Water										
		R^2	*P-value*	R^2	*P-value*	R^2	*P-value*	R^2	*P-value*	R^2	*P-value*	R^2	*P-value*	*P-value*
Meiofauna														
Biomass		0.105 (+)	*P*<0.001	-	ns[1]	0.045 (-)	*P*<0.001	0.007 (+)	*P*=0.013	0.055 (+)	*P*<0.001	0.032 (-)	*P*<0.001	ns[1]
Abundance		**0.115** (+)	*P*<0.001	-	ns[1]	0.028 (-)	*P*<0.001	0.019 (+)	*P*=0.0002	0.022 (+)	*P*<0.001	0.005 (-)	*P*=0.03	*P*=0.0007 (+)
Diversity		-	ns[1]	-	ns[1]	0.019 (-)	*P*=0.0001	-	ns[1]	**0.121** (+)	*P*<0.001	**0.157** (-)	*P*<0.001	ns[1]
Taxon-specific Abundance	*Polychaeta*	0.006 (+)	*P*=0.02	-	ns[1]	0.051 (-)	*P*<0.001	-	ns[1]	**0.124** (+)	*P*<0.001	**0.116** (-)	*P*<0.001	*P*=0.0007 (+)
	Nematoda	**0.138** (+)	*P*<0.001	-	ns[1]	0.006 (-)	*P*=0.023	0.027 (+)	*P*<0.001		ns[1]	-	ns[1]	*P*=0.005 (+)
	Oligochaeta	0.008 (+)	*P*=0.01	-	ns[1]	0.025 (-)	*P*<0.001	-	ns[1]	0.064 (+)	*P*<0.001	0.059 (-)	*P*<0.001	ns[1]
	Harpacticoida	0.022 (+)	*P*=0.001	-	ns[1]	0.028 (-)	*P*<0.001	-	ns[1]	0.037 (+)	*P*<0.001	0.037 (-)	*P*<0.001	ns[1]
	Ostracoda	-	ns[1]	-	ns[1]	-	ns[1]	-	ns[1]	-	ns[1]	-	ns[1]	*P*=0.0016 (-)
	Bivalvia	-	ns[1]	-	ns[1]	-	ns[1]	-	ns[1]	-	ns[1]	-	ns[1]	ns[1]
	Cumacea	-	ns[1]	-	ns[1]	-	ns[1]	-	ns[1]	0.009 (+)	*P*<0.001	-	ns[1]	*P*=0.02 (+)
	Foraminifera	0.028 (+)	*P*<0.001	-	ns[1]	-	ns[1]	-	ns[1]	0.006 (+)	*P*=0.02	-	ns[1]	*P*=0.0016 (+)

Dependent Variable		Linear Regression: Abiotic Variable												
		Salinity				Intertidal Elevation (Distance to Shore)		Distance to Freshwater		Total Organic Carbon		Sediment Grain Size[2]		Eelgrass[3]
		Interstitial		Water										
		R^2	*P-value*	R^2	*P-value*	R^2	*P-value*	R^2	*P-value*	R^2	*P-value*	R^2	*P-value*	*P-value*
Macrofauna														
Biomass		-	ns[1]	0.0128 (+)	*P*=0.0025	-	ns[1]	0.005 (+)	*P*=0.035	-	ns[1]	-	ns[1]	ns[1]
Abundance		-	ns[1]	**0.109** (+)	*P*<0.001	0.096 (+)	*P*<0.001	-	ns[1]	0.083 (+)	*P*<0.001	0.026 (-)	*P*<0.001	*P*<0.001 (+)
Diversity		-	ns[1]	-	ns[1]	-	ns[1]	-	ns[1]	-	ns[1]	-	ns[1]	*P*<0.001 (+)
Taxon-specific Abundance	*Polychaeta*	-	ns[1]	-	ns[1]	0.074 (+)	*P*<0.001	-	ns[1]	0.047 (+)	*P*<0.001	0.014 (-)	*P*=0.001	*P*<0.001 (+)
	Nematoda	-	ns[1]	0.096 (+)	*P*<0.001	0.0096 (+)	*P*=0.0062	-	ns[1]	-	ns[1]	0.049 (+)	*P*<0.001	*P*<0.001 (+)
	Oligochaeta	-	ns[1]	0.025 (+)	*P*<0.001	0.095 (+)	*P*<0.001	-	ns[1]	**0.189** (+)	*P*<0.001	**0.121** (-)	*P*<0.001	*P*<0.001 (+)
	Harpacticoida	-	ns[1*]	-	ns[1]	-	ns[1]	-	ns[1]	-	ns[1]	-	ns[1]	*P*=0.012 (+)
	Ostracoda	-	ns[1]	0.006 (+)	*P*=0.021	-	ns[1]	-	ns[1]	-	ns[1]	0.014 (+)	*P*=0.001	ns[1]
	Bivalvia	-	ns[1]	-	ns[1]	0.043 (+)	*P*<0.001	-	ns[1]	-	ns[1]	-	ns[1]	ns[1]
	Cumacea	-	ns[1]	-	ns[1]	-	ns[1]	-	ns[1]	0.046 (+)	*P*<0.001	0.028 (-)	*P*<0.001	*P*<0.001 (+)

[1] No evidence of statistical significance at α = 0.05
[2] Sediment grain size measured as percent sand
[3] Analysis of variance and linear regression used to identify relationship between biotic variables considered in this analysis and presence and absence of eelgrass.

4.1.4 Multiple Linear Regression Analyses Relating Biotic and Abiotic (Predictor) Variables

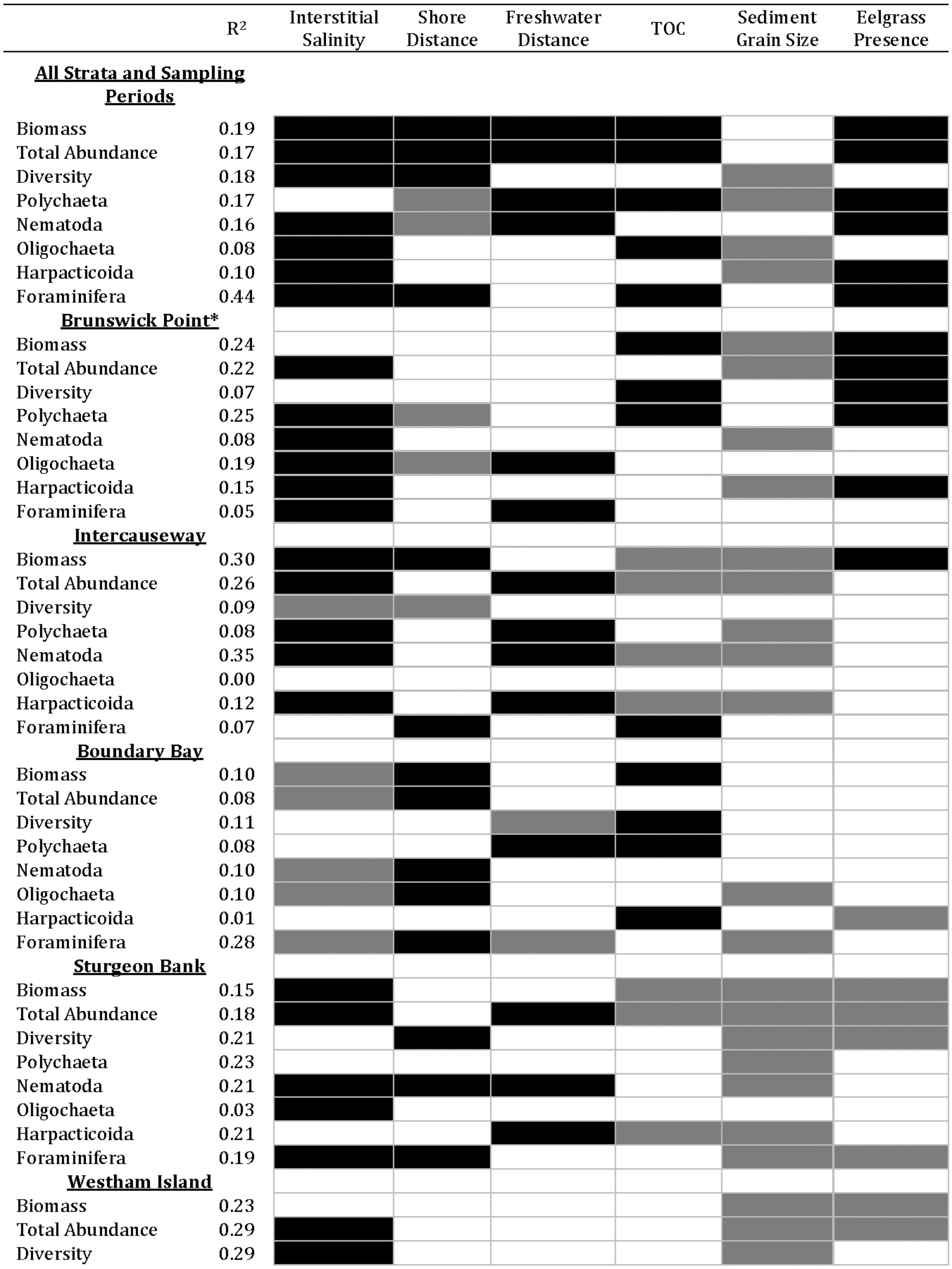
A total of 88 multiple linear regression analyses were performed with meiofaunal abundance, biomass or diversity, or the abundance of major taxa, as independent variables (56 by stratum and 32 by sampling period within Brunswick Point; **Figure 4-10** and **Figure 4-11**).

When the data were combined across the six strata and multiple sampling periods, multiple linear regression models were able to account for no more than 19% of the total variance in meiofaunal abundance, biomass or diversity. For meiofaunal analyses by stratum, R^2 values ranged from 0.00 to 0.87, and only five optimized models had R^2 values exceeding 30%[3] (**Figure 4-10**). In general, there was no evidence for consistent patterns in the relative importance of abiotic variables, either singly or in combination, as predictors of variation in meiofaunal community attributes among strata. There was strong support (R^2=0.87) for the inclusion of all independent abiotic variables (with positive associations) in the best fit model predicting variation in total meiofaunal diversity at Mud Bay (**Figure 4-10**). Overall, the independent variable found in the greatest number of optimized models was interstitial salinity (29 models) and the independent variable found in the fewest number of optimized models was distance to freshwater (15 models). Consistent with linear regression analyses, sediment grain size, as percent sand (29 models), had the highest number of negative associations with dependent variables, while interstitial salinity (23 models) had the highest number of positive associations with dependent variables (**Figure 4-10**).

Figure 4-11 provides a summary of the multiple linear regression models run for the Brunswick Point data only, by sampling event. These analyses were completed to determine whether the seven predictor variables listed above have better predictive power if the meiofaunal community data are not unduly influenced by a high degree of regional or temporal variability. For these models, R^2 values ranged from 0.05 to 0.57 **(Figure 4-11).** While there was statistical support (R^2>0.30) for a greater number of optimized models (n=17; **Figure 4-11**), analyses among sampling period did not reveal consistent patterns in the relative importance of abiotic variables in predicting variation in biotic parameters such as total biomass and total abundance.

[3] Below such a low threshold of R^2<0.30, very little of the variance in the data is explained by the best fit model; therefore, evidence to support a correlation between the biotic parameter and the predictor model cannot be validated.

Figure 4-10 Multiple Linear Regression for Meiofaunal Community Attributes and Abiotic or Eelgrass Predictor Variables - all Strata and Sampling Periods and then by Stratum[4]



4 Each model is presented on a single row and represents the best fit model with the lowest AIC value. The left hand column represents the dependent variable in the model and the top row of biotic variables represents all possible independent variables in the model. White boxes represent abiotic variables that did not significantly contribute to the variability in the dependent variable. Black boxes represent abiotic variables that had a positive association with the dependent variables in the best fit model and grey boxes represent abiotic variables that had a negative association with the dependent variable in the best fit model.

Figure 4-10 Continued

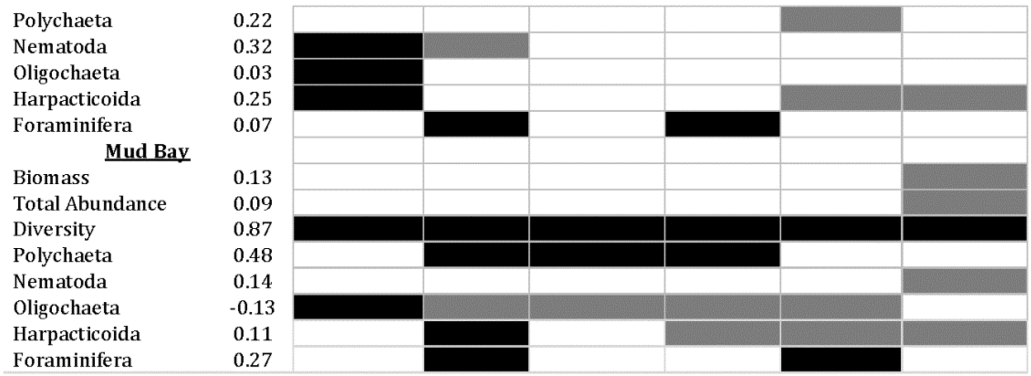
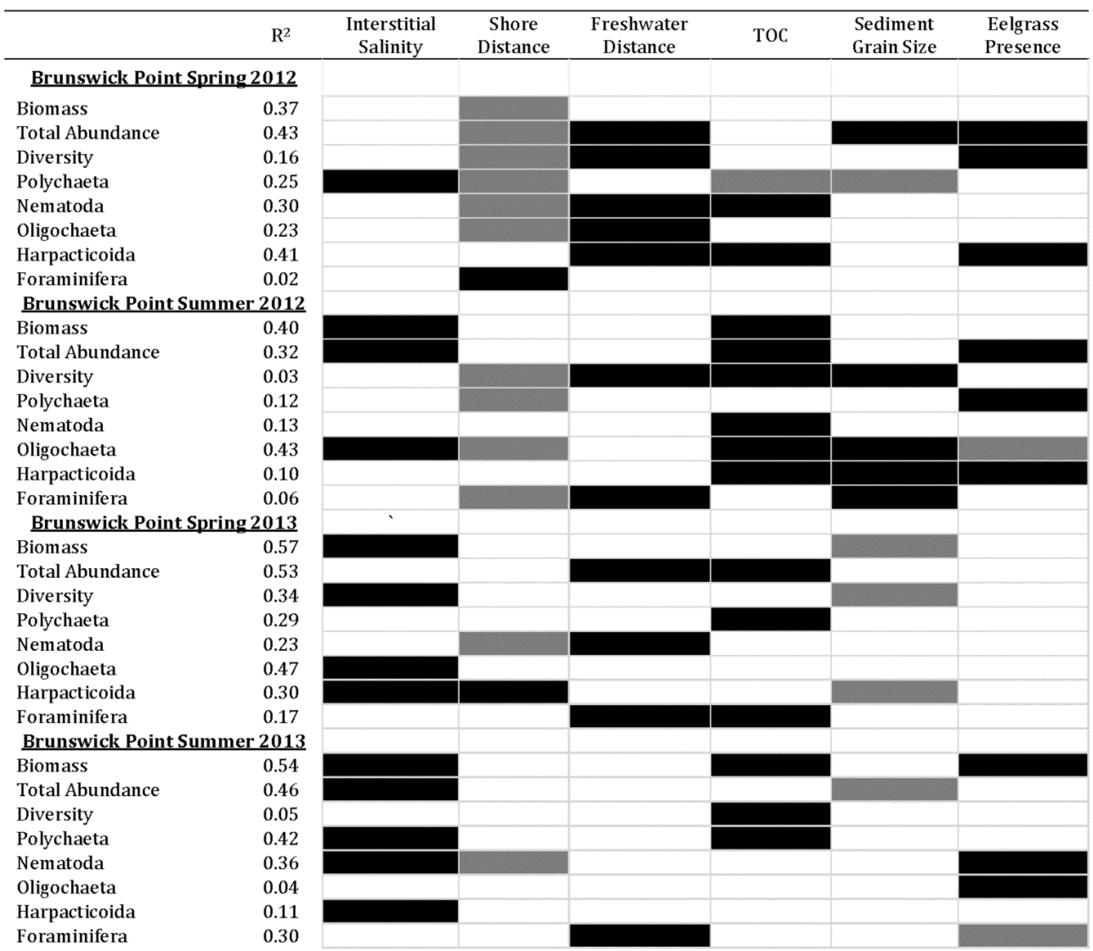


Figure 4-11 Multiple Linear Regression for Meiofaunal Community Attributes and Abiotic or Eelgrass Predictor Variables - Brunswick Point by Sampling Period[5]



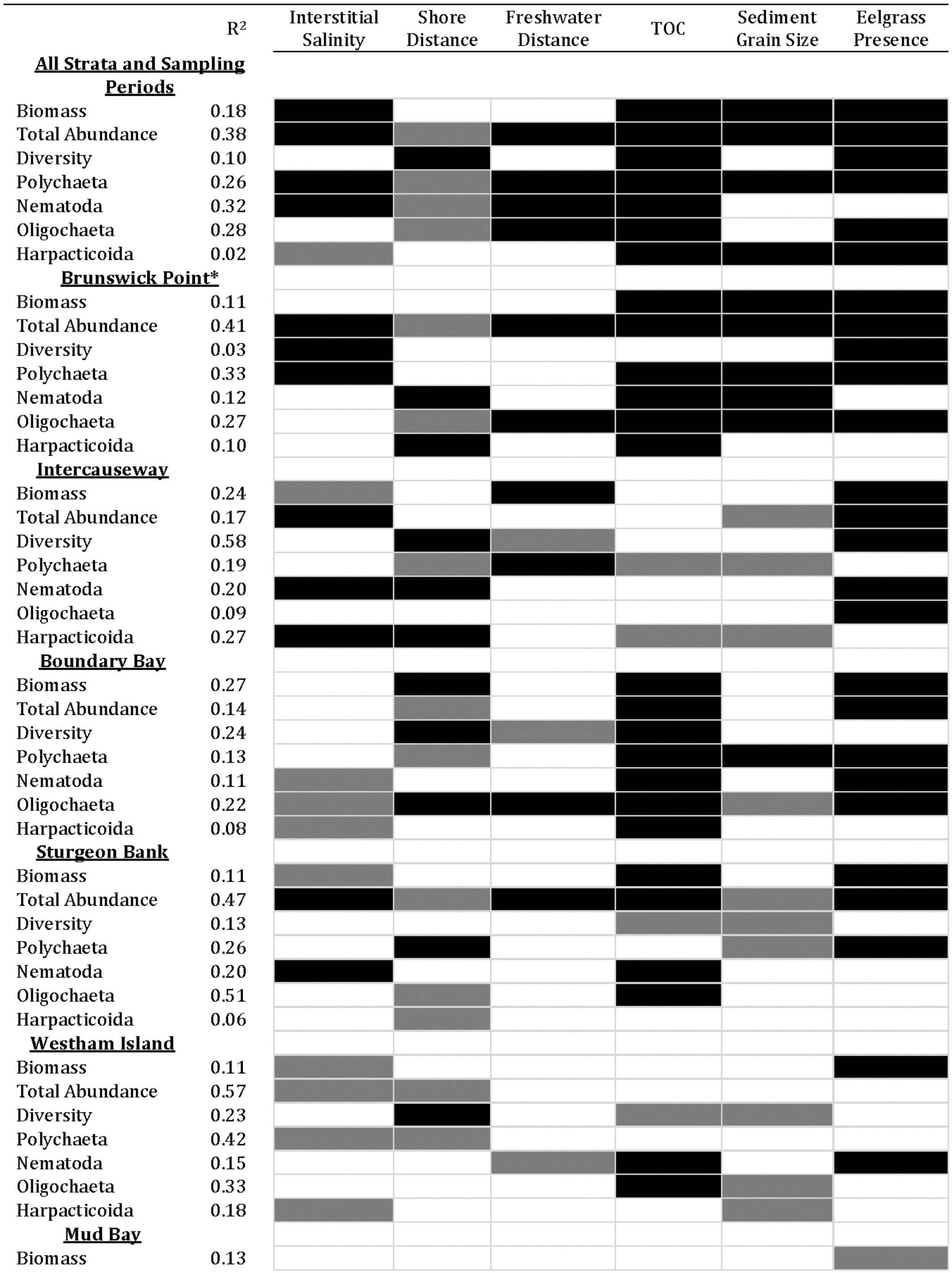
5 Each model is presented on a single row and represents the best fit model with the lowest AIC value. The left hand column represents the dependent variable in the model and the top row of biotic variables represents all possible independent variables in the model. White boxes represent abiotic variables that did not significantly contribute to the variability in the dependent variable. Black boxes represent abiotic variables that had a positive association with the dependent variables in the best fit model and grey boxes represent abiotic variables that had a negative association with the dependent variable in the best fit model.

Overall, for Brunswick Point, specific multivariate analysis of meiofaunal invertebrate communities separated by sampling period, the independent variable found in the greatest number of optimized models was total organic carbon (TOC) (15) and the fewest number of optimized models was sediment grain size (10). Distance to shore (12) had the highest number of negative associations with dependent variables while TOC (14) and salinity (13) had the highest number of positive associations with dependent variables (**Figure 4-11**).

A total of 77 macrofaunal multiple linear regression analyses were performed with macrofaunal abundance, biomass or diversity, or the abundance of major taxa, as independent variables (49 by stratum and 28 by sampling period within Brunswick Point; **Figure 4-12** and **Figure 4-13**). For macrofaunal analyses by stratum, R^2 values ranged from 0.03 to 0.58 (**Figure 4-12**). In general, the relative importance of abiotic factors was highly variable among different strata for the same biotic attributes, with no consistency in these relationships even among the most strongly supported models (R^2>0.30; n=11). For example, there was evidence for the inclusion of all six abiotic variables in the best fit model (R^2=0.41) predicting total macrofauna abundance at Brunswick Point, while only interstitial salinity and distance to shore were included in the best fit model (R^2=0.57) at Mud Bay. Overall, the independent variables found in the greatest number of optimized models was TOC (25 models) followed by eelgrass presence (24 models), while the predictor found to be significant in the fewest number of optimized models was distance from freshwater (10 models).

For macrofaunal multivariate models conducted for each sampling period within Brunswick Point **(Figure 4-13),** R^2 values ranged from 0.10 to 0.80**.** While there was statistical support (R^2>0.30) for ten optimized models, analyses did not reveal consistent patterns in the relative importance of abiotic variables in predicting variation in biotic parameters among seasons. Overall, the independent variable found in the greatest number of optimized models was interstitial salinity (15 models) while the independent variable found in the fewest number of optimized models was distance from freshwater (8 models).

Figure 4-12 Multiple Linear Regression for Macrofaunal Community Attributes and Abiotic or Eelgrass Predictor Variables - all Strata and Sampling Periods and then by Stratum[6]



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6 Each model is presented on a single row and represents the best fit model with the lowest AIC value. The left hand column represents the dependent variable in the model and the top row of biotic variables represents all possible independent variables in the model. White boxes represent abiotic variables that did not significantly contribute to the variability in the dependent variable. Black boxes represent abiotic variables that had a positive association with the dependent variables in the best fit model and grey boxes represent abiotic variables that had a negative association with the dependent variable in the best fit model

Figure 4-12 continued

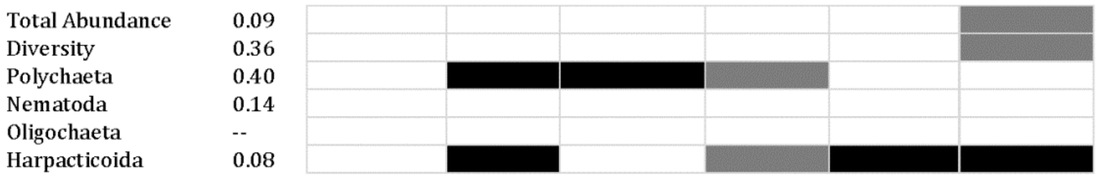
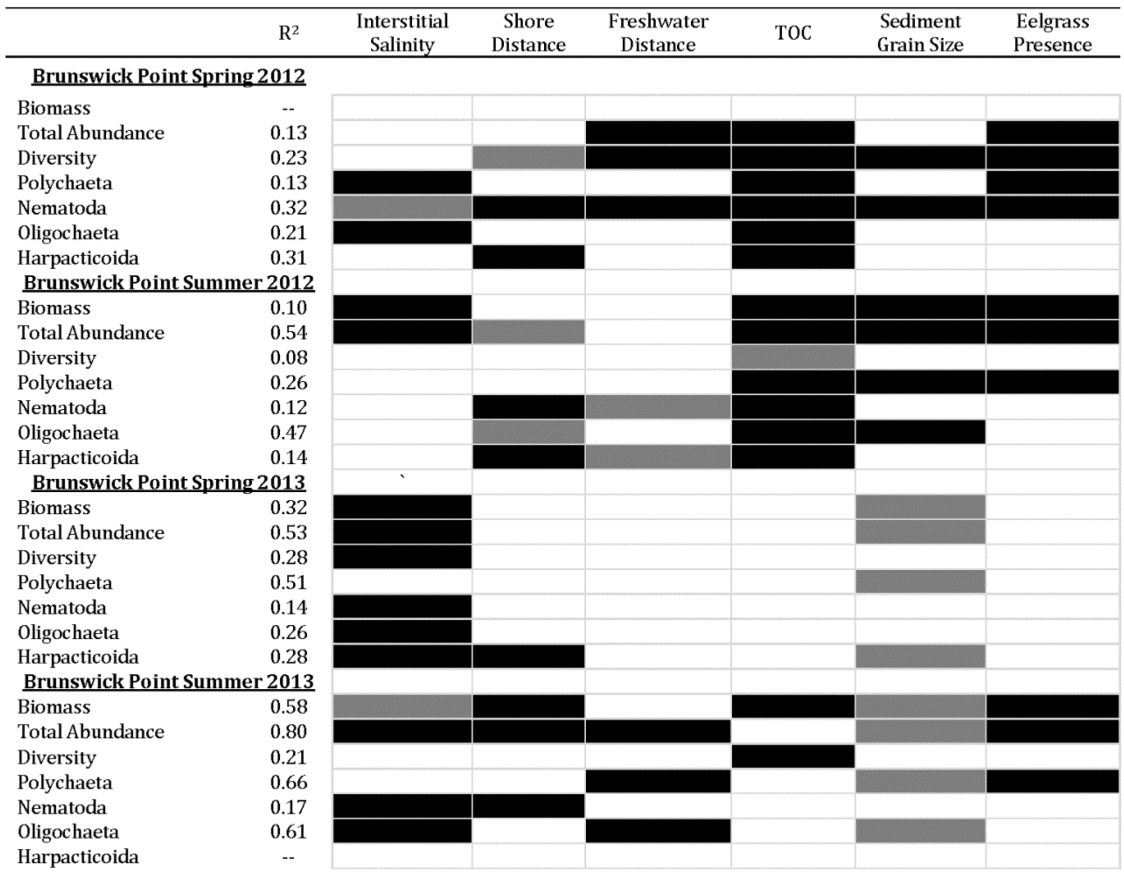


Figure 4-133 Multiple Linear Regression for Meiofaunal Community Attributes and Abiotic or Eelgrass Predictor Variables - Brunswick Point by Sampling Period[7]



4.2 SUBTIDAL COMMUNITIES

As shown in **Figure 3-2**, sampling to characterize the infaunal macroinvertebrate community was completed in the spring of 2014 at twelve stations within the RBT2 terminal footprint (n=6) or berth pocket/caisson trench area (n=6). These samples were sieved through a 1.0 mm sieve for the recovery of macrobenthos only. In addition, the macrobenthic community compositions was measured using different

[7] Each model is presented on a single row and represents the best fit model with the lowest AIC value. The left hand column represents the dependent variable in the model and the top row of biotic variables represents all possible independent variables in the model. White boxes represent abiotic variables that did not significantly contribute to the variability in the dependent variable. Black boxes represent abiotic variables that had a positive association with the dependent variables in the best fit model and grey boxes represent abiotic variables that had a negative association with the dependent variable in the best fit model.

sampling and screening techniques than for the intertidal studies discussed above (significant greater sampling area and depth for each sample; larger sieve size), so abundance, biomass, diversity and other estimates are not directly comparable between subtidal and intertidal samples.

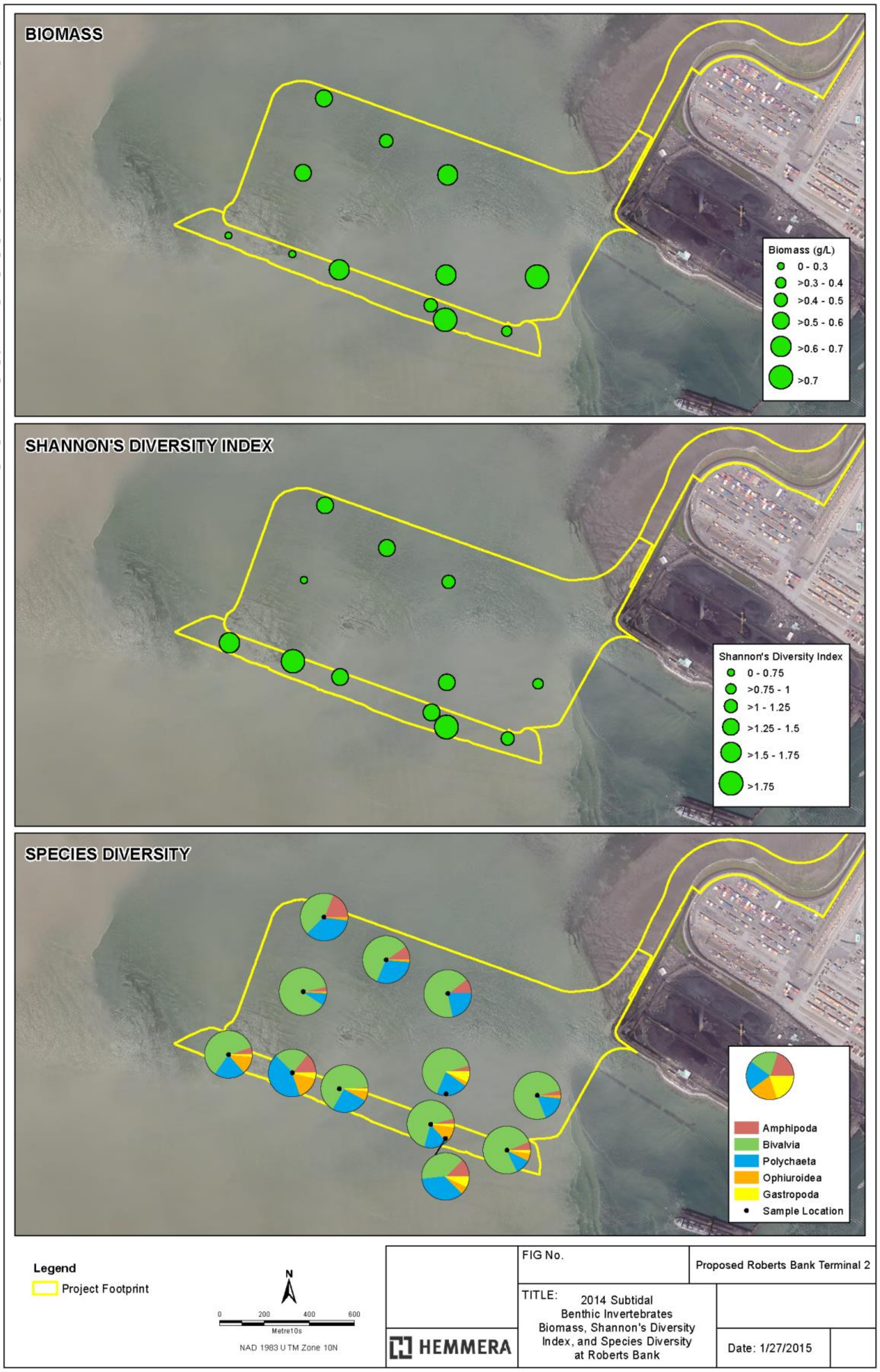
A total of 30 macroinvertebrate taxa were recorded in grab samples collected from within the proposed terminal and dredge basin footprint. The macroinvertebrate community was dominated by bivalves, followed by polychaetes among all sample sites (**Table 4-4; Figure 4-14).**

Table 4-4 Summary of Subtidal Macroinvertebrate Biomass and Diversity within the Proposed Terminal Footprint and Dredge Basin

Location	Taxon	Biomass (g/m^2)[1]				Shannon's Diversity Index[3]		
		Mean [2]	Max	Min	Total	Mean	Max	Min
Roberts Bank	Annelida	2.41	4.48	0.62	28.9	1.32	1.88	0.65
	Anthropoda	0.313	0.96	0.045	3.76			
	Mollusca	2.27	3.90	0.27	27.2			
	Echinodermata	0.22	1.02	0.02	2.69			

[1] Biomass per sample; [2] Includes data from all samples within terminal footprint; [3] Diversity per sample

Figure 4-14 Spatial Trends in Macroinvertebrate Biomass, Shannon's Diversity Index, and Relative Taxonomic Composition within the Proposed Terminal Footprint and Dredge Basin at Roberts Bank. Measurements are Based on Samples Collected in 2014



5.0 DISCUSSION

5.1 DISCUSSION OF KEY FINDINGS

5.1.1 Spatial and Temporal Variability

Based on examination of mapped biomass distributions alone, coherent patterns of spatial variation are difficult to discern. Analysis of variance revealed significant variations in infaunal community attributes (i.e., total biomass, abundance and density) across the six major strata and across sampling periods. For both meiofauna and macrofauna, total biomass, abundance, and diversity were consistently higher at Brunswick Point, the Inter-causeway, and Boundary Bay relative to the other strata sampled; however, pairwise comparisons did not consistently yield evidence for significant differences in biotic parameters among all strata (**Table 4-2**). Stratum was an important component of observed variability for all biotic attributes considered in this analysis, with the exception of meiofaunal and macrofaunal cumacean abundance. Variance across smaller spatial scales (i.e., among transects) may account for weak or absent evidence of differences in taxon-specific abundance among strata (**Table 4-2**). Patchiness across geographical scales ranging from 5 to 1,000 m has been described previously for meiofaunal and macrofaunal communities (Volckaert 1987, Thrush et al. 1989, Morrisey et al. 1992*a*, Ysebaert and Herman 2002, French et al. 2004). For example, at Boundary Bay, Sewell and Elner (2001) noted significant differences in the relative abundance of taxa at scales of tens or hundreds of metres, but not at the scale of 1 km. Hierarchical spatial analyses by Ysebaert and Herman (2002) on macrofaunal communities in the Wadden Sea have also indicated transect-scale variance in species occurrence that is likely driven by differences in habitat quality over small spatial scales.

Variance components among sampling period revealed seasonal differences in meiofaunal and macrofaunal community attributes. While clear trends in temporal variation are difficult to discern based on pairwise comparisons, total meiofaunal biomass and abundance were generally high in Spring and Summer 2013; however, meiofaunal diversity did not vary among sampling years, suggesting that the relative importance of variance associated with season is likely low for meiofaunal community composition. In contrast, macrofaunal diversity was greater in 2012 compared to 2013, while patterns of seasonal variance for biomass and abundance were weak or absent. Although seasonal oscillations in abundance are likely determined by taxon-specific recruitment patterns, these results suggest that annual patterns of absolute abundance and species composition may be less predictable, particularly for macrofauna. Results are consistent with those from other studies that suggest not every site within an estuary is likely to have synchronous annual patterns of species abundance or succession (Coull and Dudley 1985, Coull 1999). Climatic forces, such as annual temperature patterns and oceanographic factors, have also been shown to contribute to variation in seasonal and annual infaunal fluctuations, through impacts on successful recruitment or mortality (Beukema et al. 1996, 2000); however, two years of data collection does not allow for multi-year comparisons, which would enable identification of long-term fluctuations in biotic parameters with greater certainty.

5.1.2 Simple Linear Regression Analysis of Co-variations between Community and Abiotic Variables

Linear regression analyses yielded only limited evidence regarding the role of environmental variables in explaining the observed variability in both meiofaunal and macrofaunal community attributes. The proportion of variation in most community measures that could be explained by the abiotic predictor variables (R^2) never exceeded 20%, suggesting that: 1) the observed variation is poorly explained by a single environmental variable; and/or 2) the predictor variables used in this study were not the best explanatory variables for the particular ecosystem and attributes of interest; and/or 3) responses of individual species (not analyzed in favour of enumerating larger taxonomic groupings) to the environmental variables is diverse based on the specific life histories and physiological ecology.

In general, meiofauna and macrofauna abundance was positive correlated with salinity (interstitial water salinity for meiofauna and average water column salinity for macrofauna), which explained only small part of the observed biotic variation (R^2>0.10). Salinity varies seasonally in the FRE with the lowest concentrations found post freshet between June and July (Hemmera 2014*b*). Salinity measures also appeared to vary substantially among strata (Hemmera 2014*b*), suggesting that changes in salinity regimes may account for some proportion of spatial variation components observed in meiofaunal and macrofaunal parameters (see **Section 4.1.1**).

Macrofaunal diversity varied by season in this study, suggesting that temporal fluctuation in salinity regimes may also drive changes in taxonomic composition. These findings are consistent with previous studies that implicate salinity gradients and salinity fluctuations within estuaries as important predictor variables for infaunal biomass, and community composition across spatial and temporal scales (Chapman and Brinkhurst 1981, Coull 1988, Ysebaert and Herman 2002); however, population-level responses to salinity fluctuations likely vary on a species-to-species basis (Chapman and Brinkhurst 1981, Ysebaert and Herman 2002), and may account for relatively weak association relationships identified in the analyses.

Linear regression models also revealed positive correlations between meiofaunal diversity and total organic carbon, although the proportion of variance explained by this model was low (R^2=0.12). While estuarine environments are typically not limited in organic matter as a food source for resident meiofauna, absolute infaunal abundance has been shown to be correlated with total organic carbon content, as organic matter is a primary energy source for benthic fauna (Giere 1993, Hyland et al. 2005).

Sediment grain size, as percent sand, was negatively correlated with all meiofaunal and macrofaunal community attributes considered (**Table 4-3**), which is consistent with the findings of numerous studies that have found that sediment grain size affects meiofaunal community diversity by inflicting physical impositions on meiofauna with interstitial and burrowing lifestyles (Warwick 1984), specialist feeding modes (Galvan et al. 2008), or tube-forming life stages (Pinedo et al. 2000). These findings are not congruent with results from Sutherland et al (2013), who reported negative correlations between measures of infaunal abundance and increasing silt content at Roberts Bank. Overall, inconsistent relationships between taxa and sediment grain size likely reflect species-specific preferences (Ysebaert and Herman 2002), which could not be captured by higher taxonomic classifications considered in this study.

There was evidence for a positive relationship between meiofaunal abundance (including the abundance of polychaetes, nematodes, ostracods, cumaceans, and foraminifera) and presence of eelgrass. There was also evidence of positive relationship between presence of eelgrass and the diversity and abundance of macroinvertebrates, as well as abundance of all major grouping of macroinvertebrate taxa except ostracods and bivalves.

5.1.3 Multiple Linear Regression Analyses

A large number of discrete multiple linear regression models were run to assess the degree of linear association between interstitial water salinity, water column salinity, local elevation of the tideflat, distance to freshwater sources, TOC, percent sand, and eelgrass presence on meiofaunal or macrofaunal community attributes, across all sites and sampling periods, and within individual strata and time periods. Few models were able to account for more than 30% of the variability in the community attribute of interest, and none were therefore concluded to have a strong degree of predictive or explanatory power that can be generalized across the larger FRE tideflat and across time periods.

While there were general inconsistencies in the combinations of abiotic predictor variables included in optimized models when analyses were conducted among strata, similar relationships with abiotic parameters existed for meiofauna and macrofauna. Positive relationships between specific community attributes and salinity existed for many meiofaunal and macrofaunal invertebrate community members. At Brunswick Point specifically, salinity and level of total organic carbon were most commonly positively associated with meiofaunal and macrofaunal community variations. These findings are generally consistent with those of other researchers, and suggest higher values of salinity and total organic carbon may facilitate increased infaunal and epifaunal invertebrate productivity (Chapman and Brinkhurst 1981, Coull 1988, Ysebaert and Herman 2002).

While the hierarchy of abiotic variables influencing the distribution of specific taxa and overall infaunal community biomass, abundance, and diversity is complex and not easily decoupled, results of this study will help improve future infaunal macroinvertebrate studies in large estuarine settings as well as predictive models of infaunal community variation. Furthermore, these findings contribute to baseline information on environmental factors and processes influencing infaunal components of the Roberts Bank ecosystem, and serve as a reference for evaluating large-scale changes to meiofaunal and macrofaunal communities relating to future development in the area.

5.2 DATA GAPS AND LIMITATIONS

The absence of strong correlations between meiofaunal and macrofaunal biotic parameters and abiotic variables considered in this study was anticipated. Infaunal and epifaunal invertebrates occupy a wide range of habitats, including a variety of soft sediments from fine silt and mud, to coarse sand and cobble sediments. Such preferences have been shown to vary on a species-to-species basis, relating to body size, life history characteristics, and feeding modes that may be restricted by sediment particle size and density (Warwick 1984, Pinedo et al. 2000, Ysebaert and Herman 2002, Galvan et al. 2008). Furthermore, the study area is highly dynamic and experiences large fluctuations in salinity and temperature, as well as substantial variation in the degree to which a specific locale experiences tidal immersion versus emersion, and the influence of wind waves and tidal currents. Because statistical analyses in this study focussed on higher-level taxonomic groupings, they are less likely to elucidate important abiotic and biotic habitat features for individual species. Various studies suggest that the type of feeding mode utilized, and therefore the type of habitat exploited, may also vary seasonally with tidal flow and phytoplankton abundance (Esselink and Zwarts 1989, Smith et al. 1996, Vedel 1998, Galvan et al. 2008).

Patterns in meiofaunal and macrofaunal community characteristics may also be driven by biological interactions, which were not considered in our analyses. Specifically, uncontrolled biological variables such as aggregative or territorial behaviours, predation (Woods and Coull 1992), prey abundance (Levinton 1991, Beukema et al. 2000, Galvan et al. 2008, Evrard et al. 2010), symbiotic relationships (Ott et al. 1991), competitive interactions (Wilson 1991), and resilience to natural physical disturbances (e.g., as associated with bioturbation) may contribute to spatial and seasonal variation in taxon-specific abundance and productivity. For example, variations in microphytobenthic biomass may underlie variations in food quality or foraging opportunity for some benthic taxa (e.g., polychaeta; Galvan et al. 2008, WorleyParsons 2015), and have shown to limit meiofaunal growth and recruitment (Hentschel and Jumars 1994). At Roberts Bank, Sutherland et al. (2013) showed that the abundance of the polychaete genus *Polydora* and harpacticoid copepods increased with components that comprise biofilms (e.g., chlorophyll, mucous, silt).

Univariate and multivariate analyses based on the General Linear Model (GLM) relied on a key assumption of predictor variable independence, despite known spatial and temporal autocorrelations between abiotic variables considered. For example, tidal elevation is strongly correlated with physical gradients that may influence infaunal and epifaunal intertidal communities, including aerial exposure, light intensity, temperature, current velocity and wave action, sediment grain size, and the presence and absence of eelgrass (Sutherland et al. 2013). While the results of multivariate analyses reflected violations of these assumptions through statistical support for the inclusion of multiple abiotic variables in optimized models, the model tests are limited in partitioning the hierarchy of predator environmental variables and possible interaction effects among them; therefore, results should be interpreted with some caution. The GLM methods used herein also assume data normality and homoscedasticity, and especially that co-variations between the variables of interest are generally synoptic (either positively or negatively co-varying through the entire range of variation) and linear in nature. For biological responses to environmental variables such as salinity, such assumptions are likely to be simplistic. In particular, the evolutionary history of various invertebrate species will generally result in an optimal range for feeding, growth, reproduction, and survival, with decreases in physiological performance and fitness when exposed to sub-optimal environmental conditions, either higher or lower than the optimum value.

6.0 CLOSURE

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8.0 STATEMENT OF LIMITATIONS

This report was prepared by Hemmera Envirochem Inc. (“Hemmera”), based on fieldwork conducted by Hemmera, for the sole benefit and exclusive use of Port Metro Vancouver. The material in it reflects Hemmera’s best judgment in light of the information available to it at the time of preparing this Report. Any use that a third party makes of this Report, or any reliance on or decision made based on it, is the responsibility of such third parties. Hemmera accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions taken based on this Report.

Hemmera has performed the work as described above and made the findings and conclusions set out in this Report in a manner consistent with the level of care and skill normally exercised by members of the environmental science profession practicing under similar conditions at the time the work was performed.

This Report represents a reasonable review of the information available to Hemmera within the established Scope, work schedule and budgetary constraints. The conclusions and recommendations contained in this Report are based upon applicable legislation existing at the time the Report was drafted. Any changes in the legislation may alter the conclusions and/or recommendations contained in the Report. Regulatory implications discussed in this Report were based on the applicable legislation existing at the time this Report was written.

In preparing this Report, Hemmera has relied in good faith on information provided by others as noted in this Report, and has assumed that the information provided by those individuals is both factual and accurate. Hemmera accepts no responsibility for any deficiency, misstatement or inaccuracy in this Report resulting from the information provided by those individuals.

APPENDIX A

Principle Component Analyses (PCA)

Principle Components Analysis

Methods:

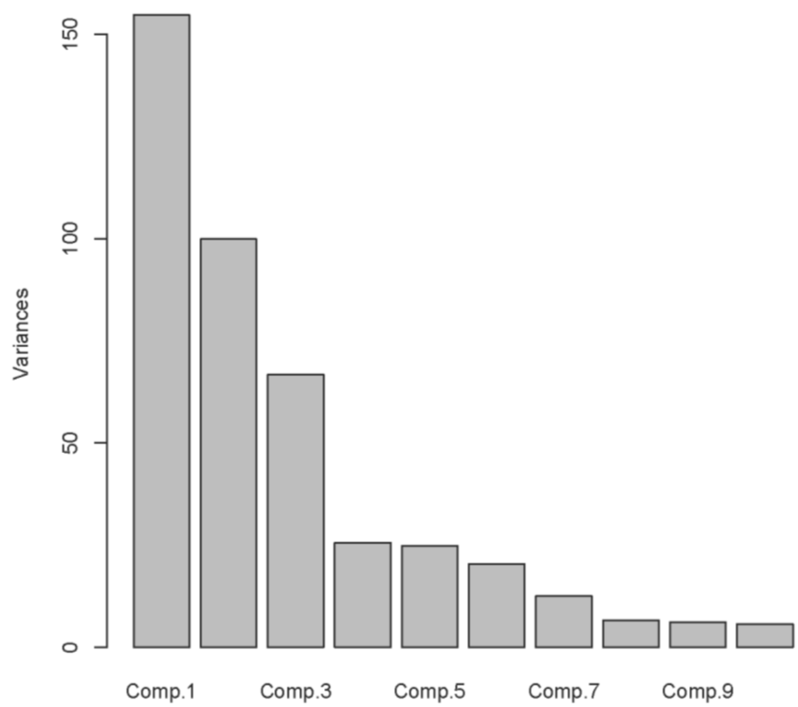
Two principle component analyses were also carried out, one for the meiofaunal size class and one for the macrofaunal size class, to test for redundancies among physical environmental variables in this dataset, based on multicollinearity. These analyses were run independent of stratum and sampling period; however, the analysis was conducted on 181 data points after correction for missing data. Data points consisted of 25 samples from Boundary Bay, 23 samples from the Inter-causeway, 94 samples from Brunswick Point, 29 samples from Sturgeon Bank, and 10 samples from Westham Island. Samples were distributed throughout spring and summer sampling periods of 2012 and 2013. To evaluate the variability, values were chosen from approximately 67 biotic and abiotic parameters for the 63 to 500 µm and the 500 µm fractions respectively.

Results

In the Principle Components Analysis for the meiofauna (63 to 500µm) fraction, principle component axes one through four explained 83% of the variation in the data. Component 1 explained 43% of the variability, component 2 explained 25% of the variability, component 3 explained 7% of the variability and component 4 explained 6% of the variability (**Figure A1**). Distance from shore (-0.76) and distance from freshwater (-0.55) are highly negatively related to principle component axis 1. One variable, temperature (0.12), was weekly positively related to principle component axis 1 (**Figure A2)**. Principle component axis 2 had a strong positive association with distance from shore (0.584), a strong negative association with distance to freshwater, and a weak negative association with total meiofaunal abundance (-0.107), total meiofaunal nematode abundance (-0.12), and total meiofaunal harpacticoid abundance (-0.109) (**Figure A2)**. Principle component axis 3 had a weak positive association with distance from shore (0.192) and arthropod larvae (0.16), and a strong positive association with temperature (0.90). Principle component axis 4 did not have strong relationships with any variables considered in this analysis but had weak positive associations with distance to freshwater, temperature, and percent sand, and weak negative associations with distance from shore, meiofaunal biomass, meiofaunal abundance meiofaunal nematode abundance, arthropod larval abundance, and meiofaunal cladocera, foraminifera, harpacticoid, kinoryncha, oligochaete, ostracod, and polychaete abundance.

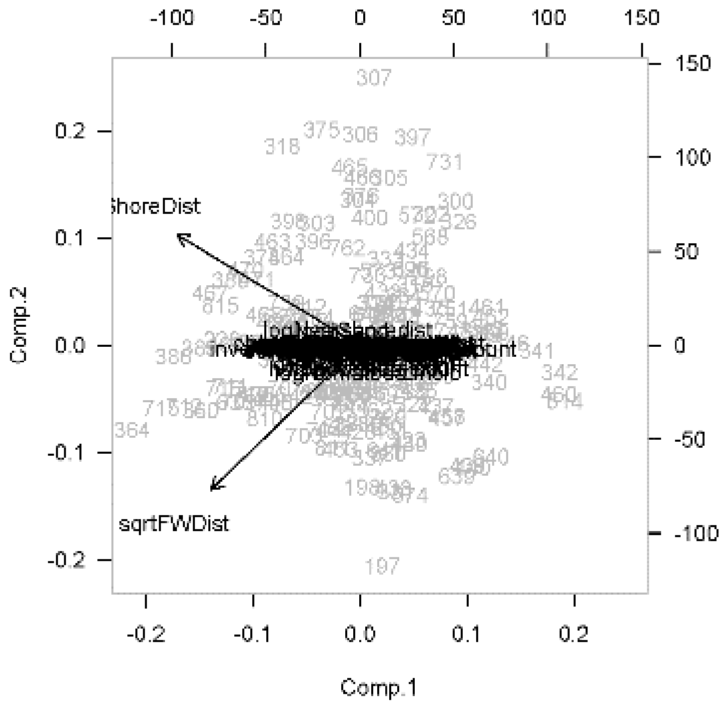
In the Principle Components Analysis for the macrofauna (>500µm) fraction, principle component axes one through 5 explained 92% of the overall variation in the data. Component 1 explained 35% of the variability, component 2 explained 21% of the variability, component 3 explained 19% of the variability, component 4 explained 11% of the variability, and component 5 explained 5% of the variability (**Figure A3**). Principle component axis 1 is highly negatively related to distance from shore (-0.68), highly positively related to sediment saturation (0.58), and weakly negatively related to the distance to freshwater (-0.39) (**Figure A4**). Principle component axis 2 was strongly negatively associated with the density of *Zostera marina* (-0.95), weakly negatively associated with distance from shore (-0.19) and sediment saturation (-0.14), and weakly positively associated with temperature (0.12) (**Figure A4**). Principle component axis 3 was strongly negatively associated with distance to freshwater (-0.90), weakly negatively associated with sediment saturation (-0.359), and weakly positively associated with distance from shore (0.205). Principle component axis 4 was strongly positively associated with distance from shore (0.62) and sediment saturation, and weakly negatively associated with the distance from fresh water, and density of *Zostera marina* and *Zostera japonica*. Principle component axis 5 had a strong positive association with density of *Zostera japonica* (0.55) and temperature (0.79), and weakly positive associations with distance from shore, *Zostera marina*, and sediment saturation.

Figure A1 Bar Plot of Variances for each Meiofaunal Principle Component



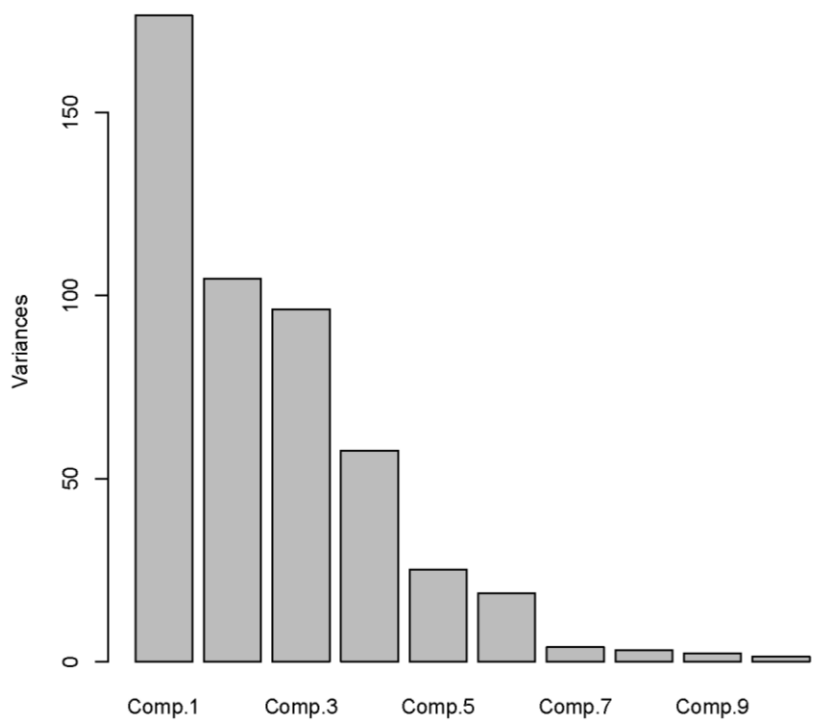
Note: Y-axis values are variance measures from the meiofaunal principle component analysis and x-axis values are binned by principle component.

Figure A2 Biplot of the Principle Components Analysis for Meiofauna



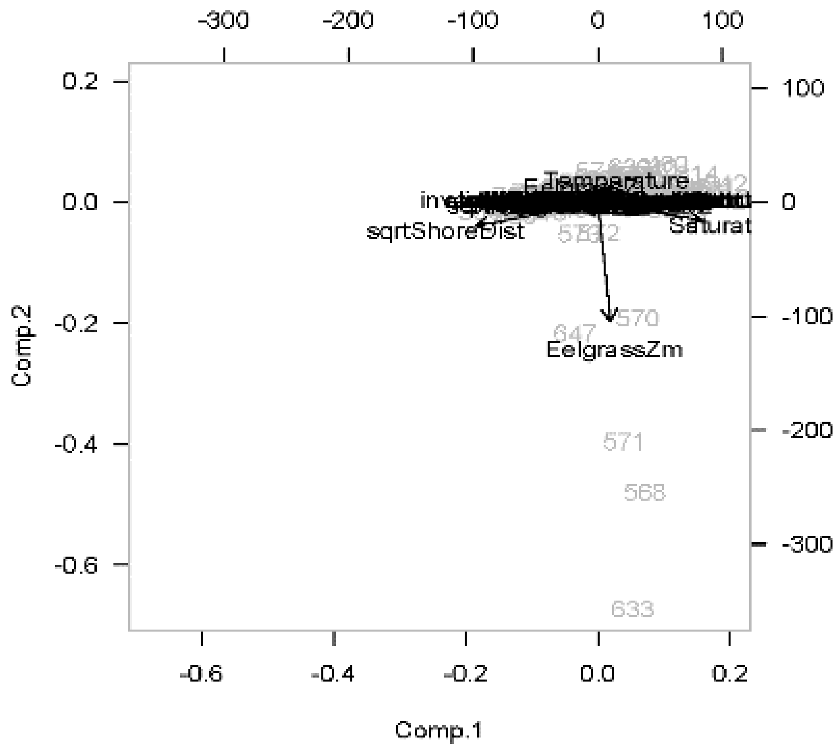
Note: Orthogonal vectors are shown for principle component 1 and component 2.

Figure A3 Bar Plot of Variances for each Macrofaunal Principle Component



Note: Y-axis values are variance measures from the macrofaunal principle component analysis and x-axis values are binned by principle component.

Figure A4 Biplot of the Principle Components Analysis for Macrofauna



Note: Orthogonal vectors are shown for principle component 1 and component 2.

APPENDIX B

Geospatial Figures

Figure B1 Spatial Trends in Meiofaunal Invertebrate Abundance, Biomass, and Diversity at Sturgeon Bank. Spring (purple) and Summer (green) Sampling Periods for 2012 are Shown. The Size of the Circles Represents Magnitude of the Respective Measurements.

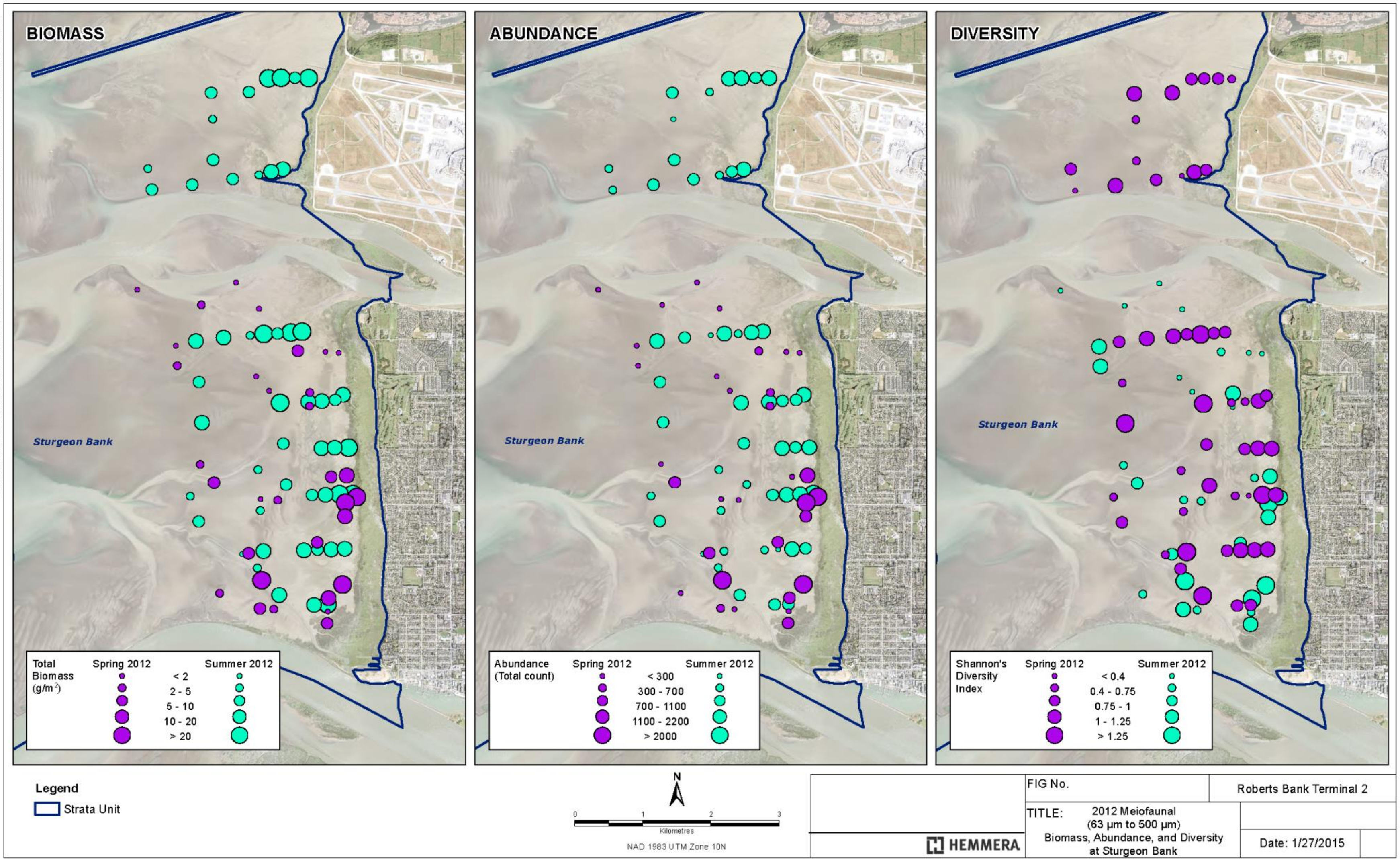


Figure B2 Spatial Trends in Meiofaunal Invertebrate Abundance, Biomass and Diversity at Roberts Bank. Spring (purple) and Summer (green) Sampling periods for 2012 are Shown. The Size of the Circles Represents Magnitude of the Respective Measurements.

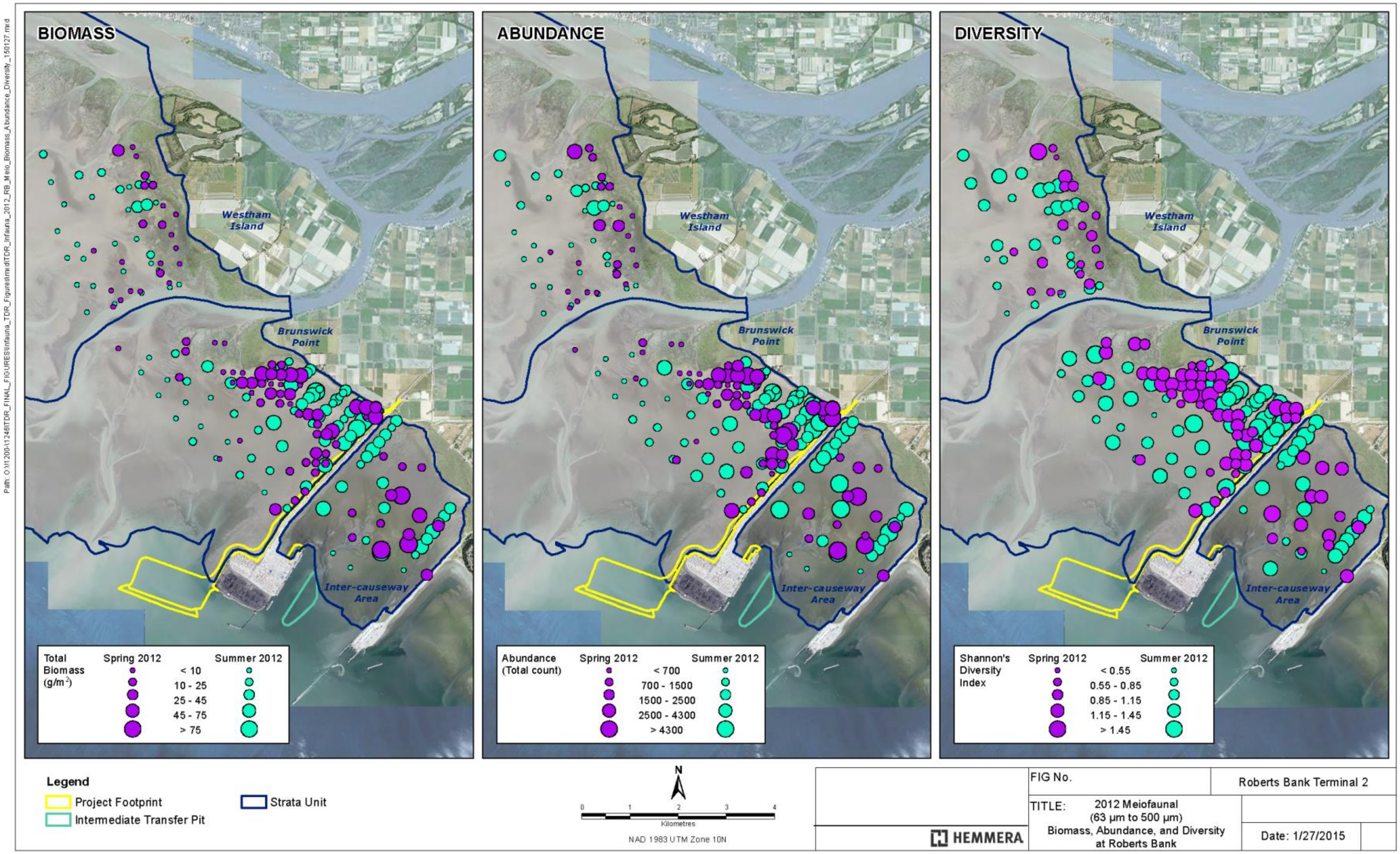


Figure B3 Spatial Trends in Meiofaunal Invertebrate Abundance, Biomass, and Diversity at Boundary Bay. Spring (purple) and summer (green) sampling periods for 2012 are shown. The Size of the Circles Represents Magnitude of the Respective Measurements.

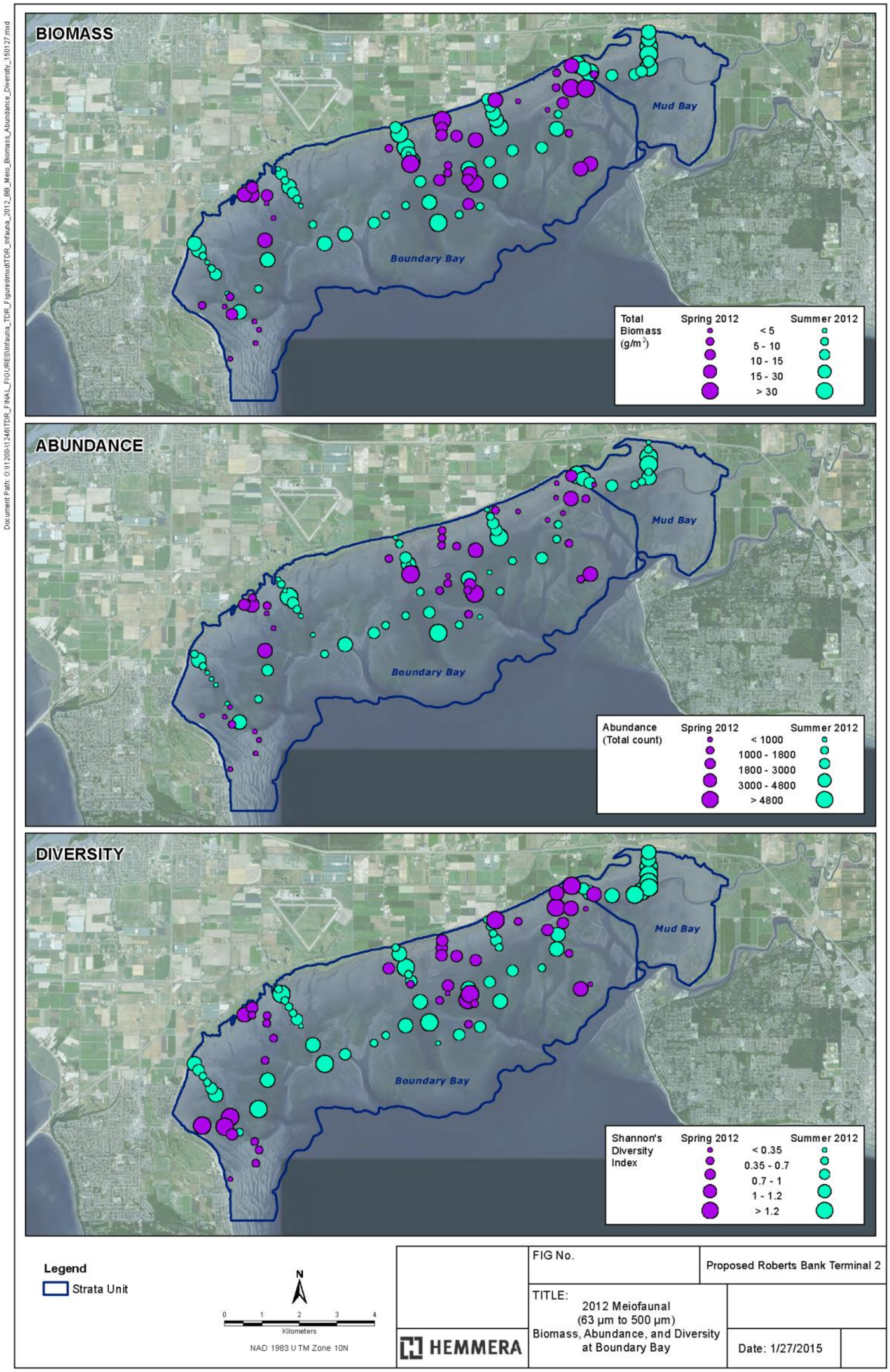


Figure B4 Spatial Trends in Meiofaunal Invertebrate Abundance, Biomass, and Diversity at Sturgeon Bank. Spring (purple) and Summer (green) sampling periods for 2013 are Shown. The Size of the Circles Represents Magnitude of the Respective Measurements.

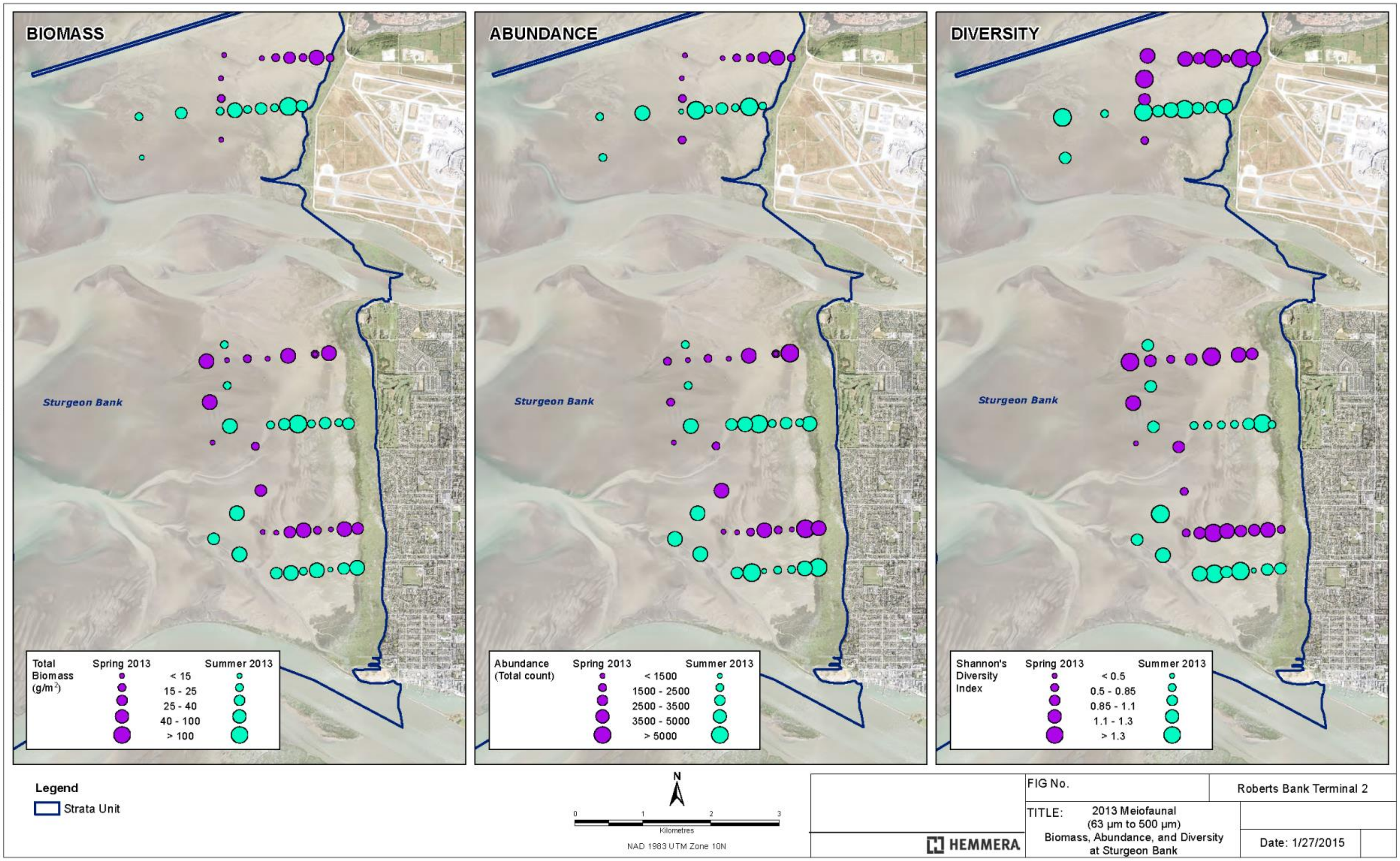


Figure B5 Spatial Trends in Meiofaunal Invertebrate Abundance, Biomass, and Diversity at Roberts Bank. Spring (purple) and Summer (green) Sampling Periods for 2013 are Shown. The Size of the Circles Represents Magnitude of the Respective Measurements.

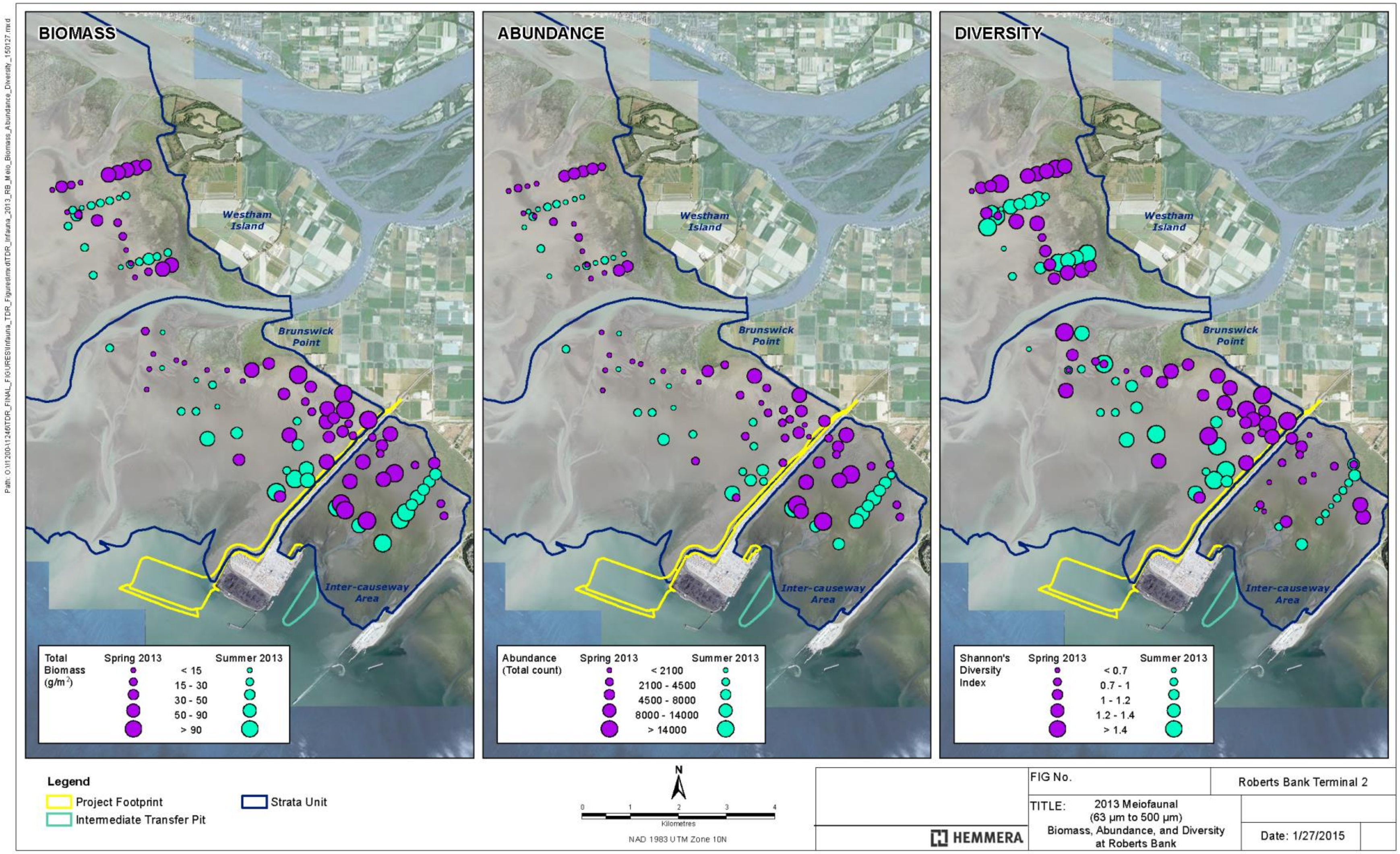


Figure B6 Spatial Trends in Meiofaunal Invertebrate Abundance, Biomass, and Diversity at Boundary Bay. Spring (purple) and Summer (green) sampling periods for 2013 are Shown. The Size of the Circles Represents Magnitude of the Respective Measurements.

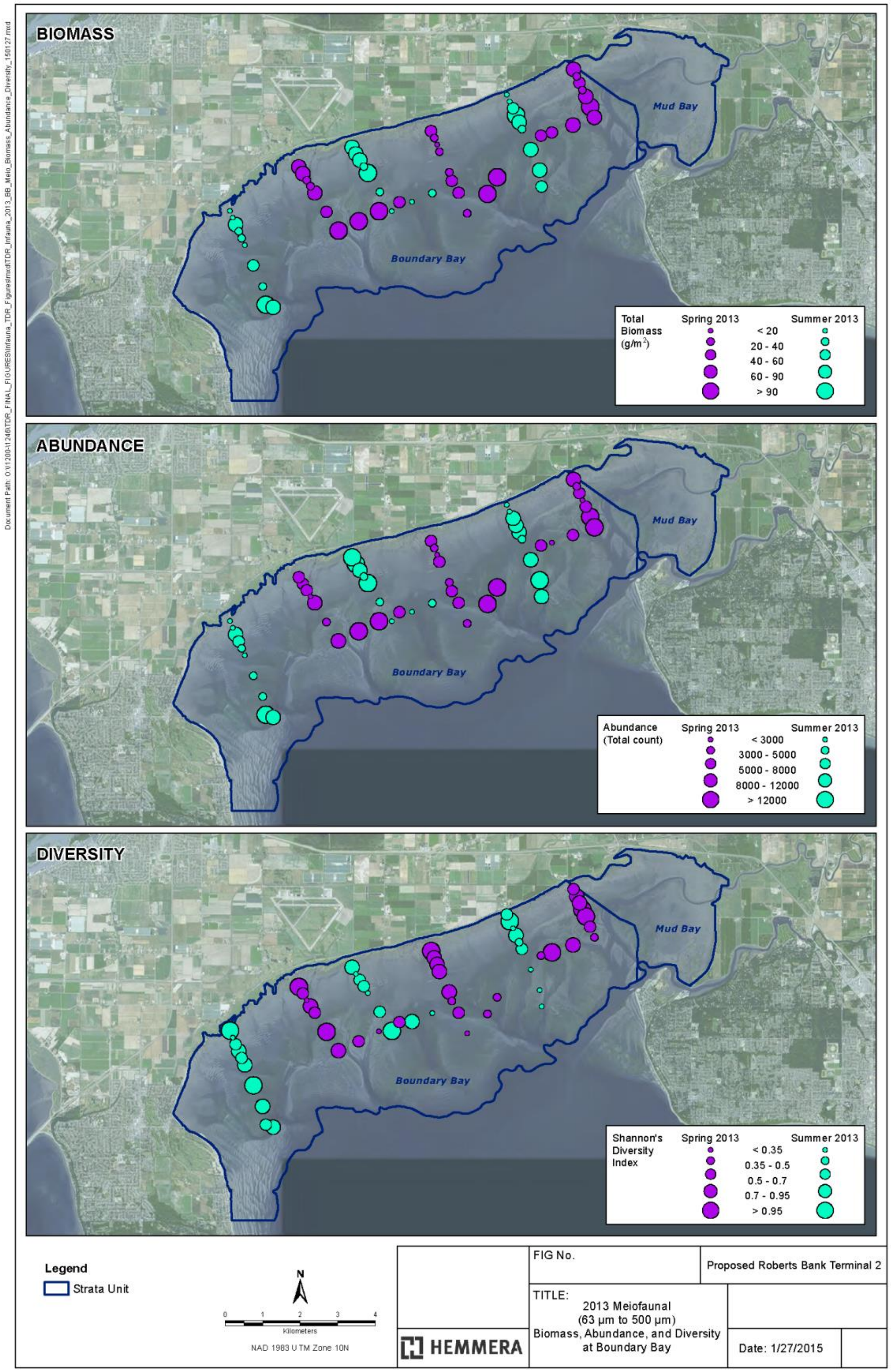


Figure B7 Spatial Trends in Macrofaunal Invertebrate Abundance, Biomass, and Diversity at Sturgeon Bank. Spring (purple) and Summer (green) Sampling Periods for 2012 are Shown. The Size of the Circles Represents Magnitude of the Respective Measurements.

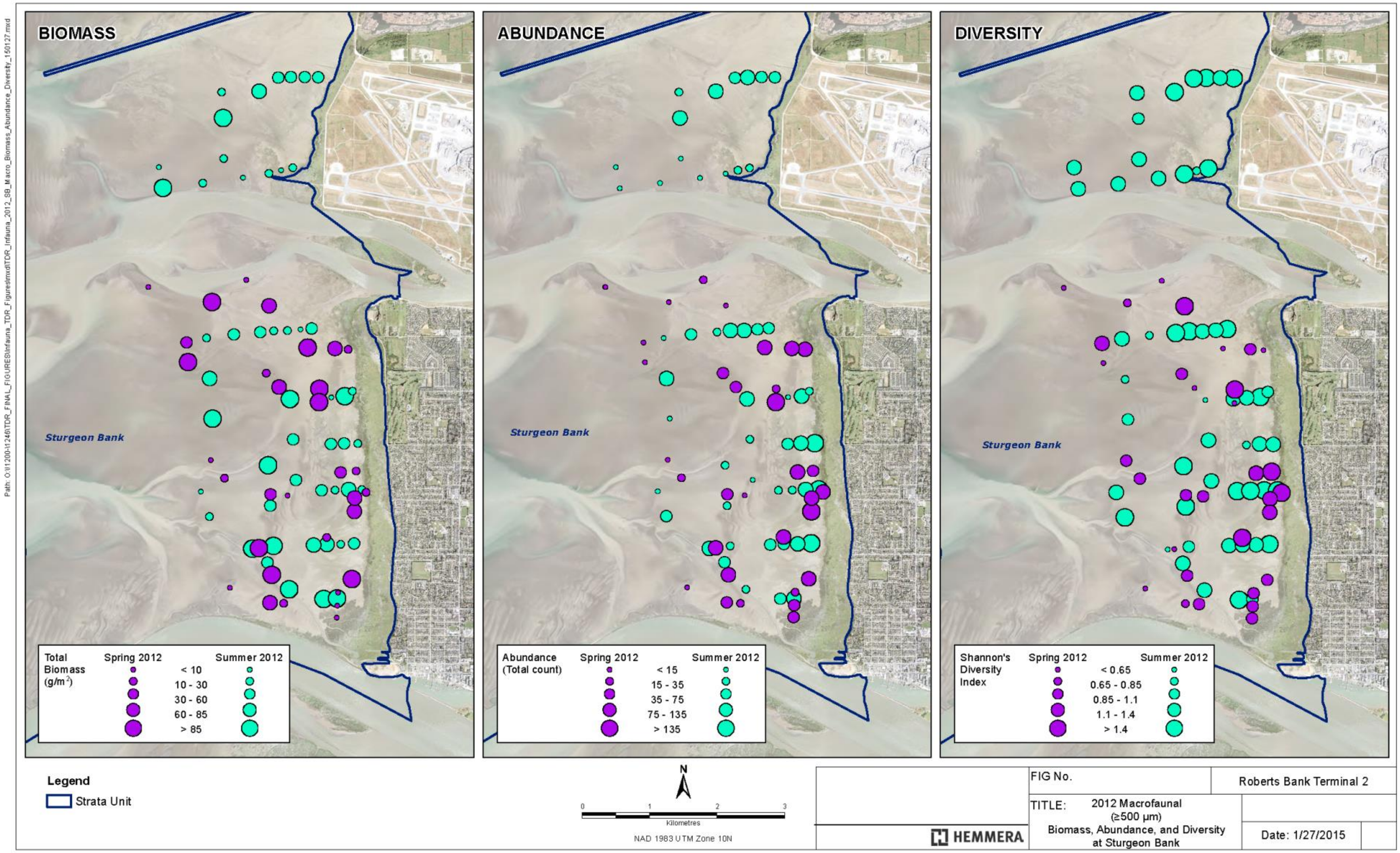


Figure B8 Spatial Trends in Macrofaunal Invertebrate Abundance, Biomass, and Diversity at Roberts Bank. Spring (purple) and Summer (green) Sampling Periods for 2012 are Shown. The Size of the Circles Represents Magnitude of the Respective Measurements.

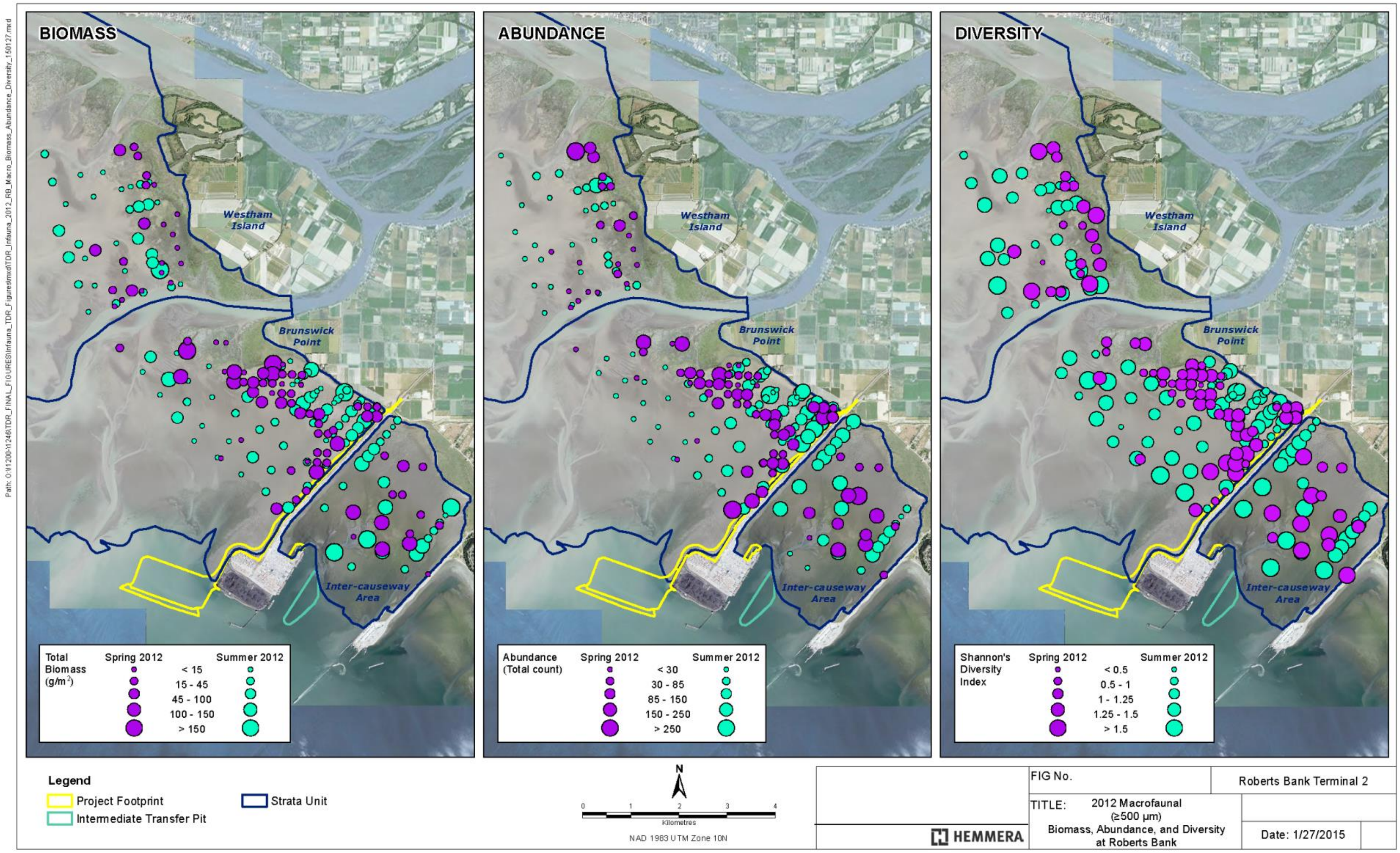


Figure B9 Spatial Trends in Macrofaunal Invertebrate Abundance, Biomass and Diversity at Boundary Bay. Spring (purple) and Summer (green) Sampling Periods for 2012 are Shown. The Size of the Circles Represents Magnitude of the Respective Measurements.

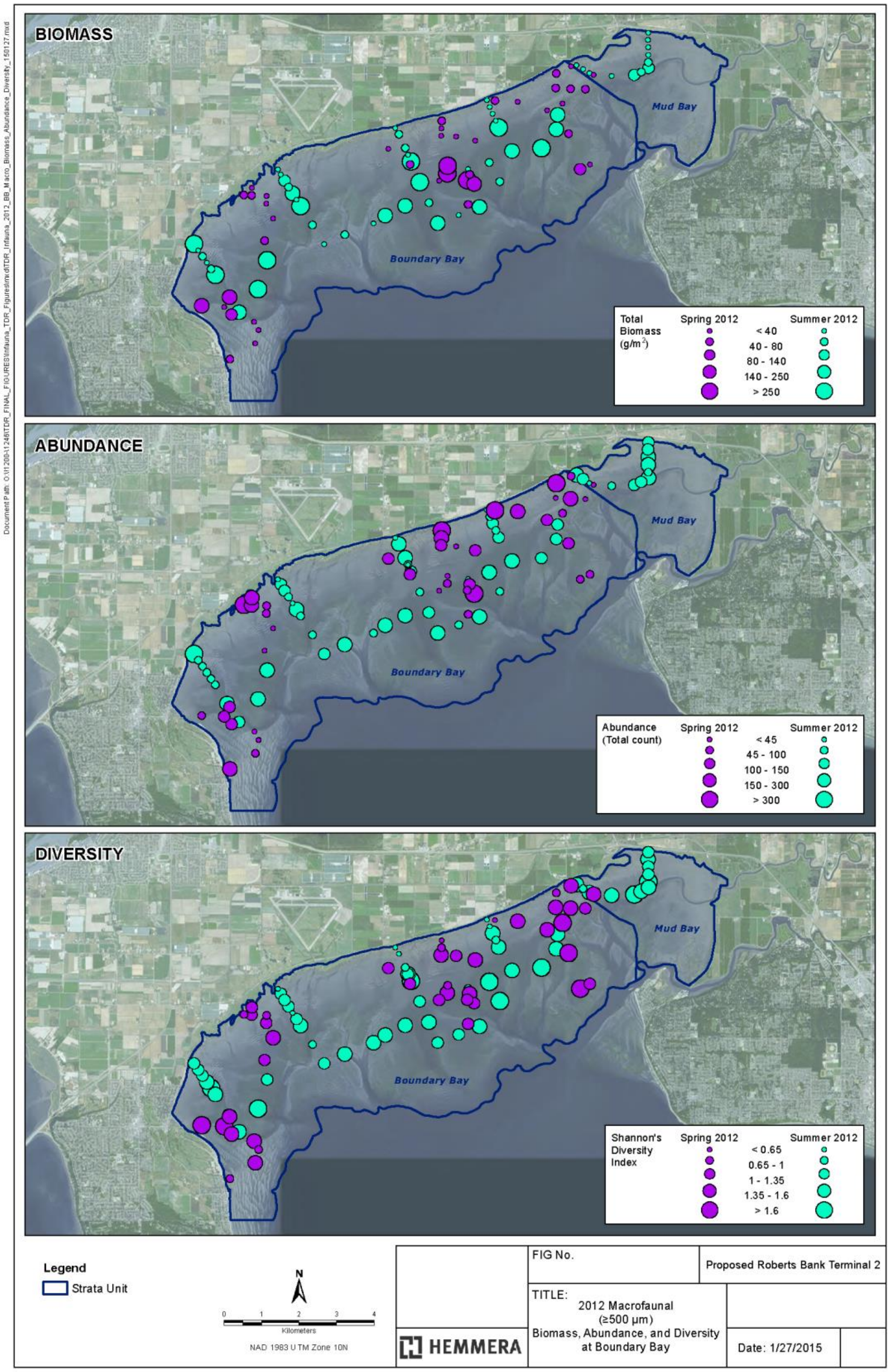


Figure B10 Spatial Trends in Macrofaunal Invertebrate Abundance, Biomass, and Diversity at Sturgeon Bank. Spring (purple) and Summer (green) Sampling Periods for 2013 are Shown. The Size of the Circles Represents Magnitude of the Respective Measurements.

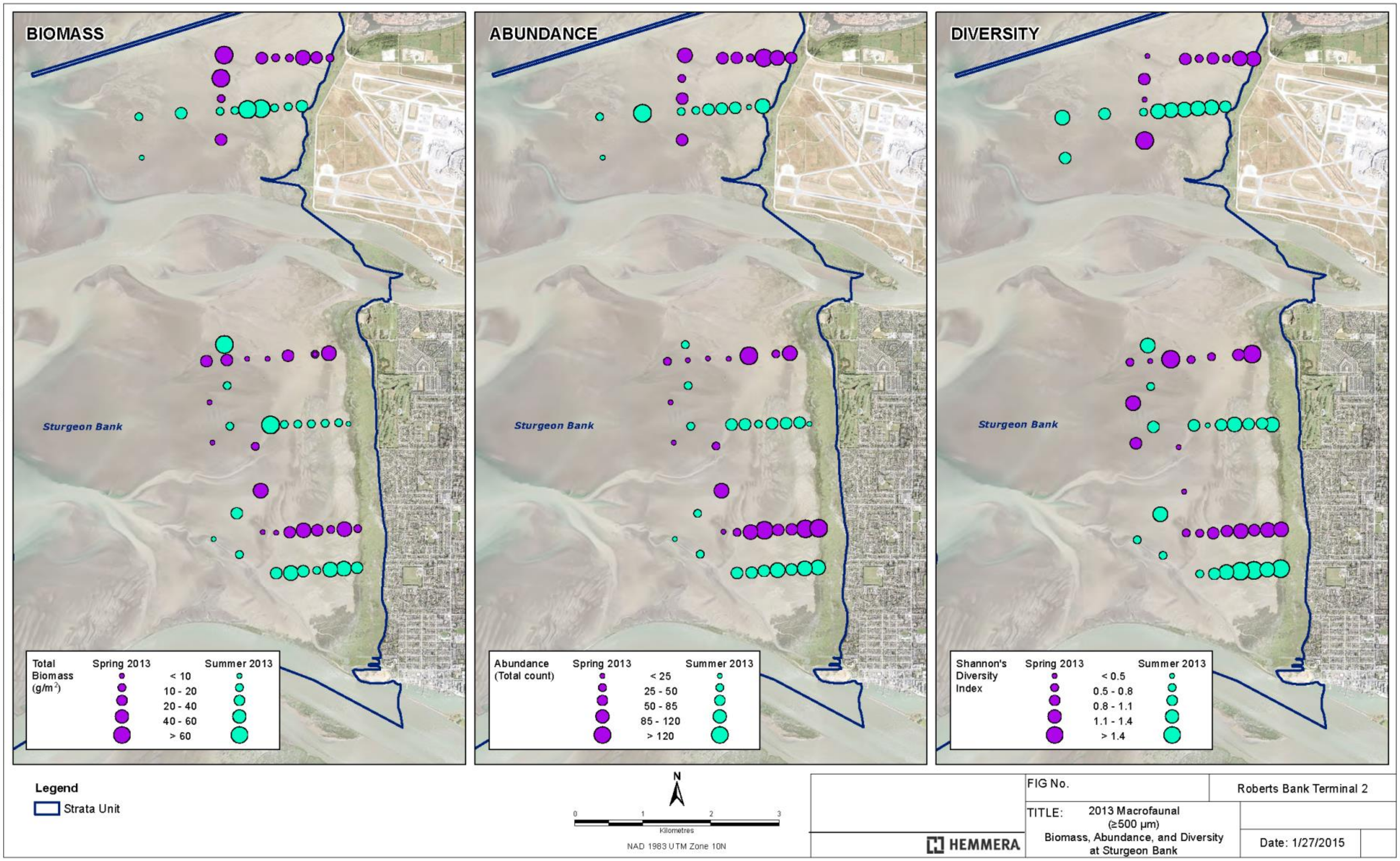


Figure B11 Spatial Trends in Macrofaunal Invertebrate Abundance, Biomass, and Diversity at Roberts Bank. Spring (purple) and Summer (green) Sampling Periods for 2013 are Shown. The Size of the Circles Represents Magnitude of the Respective Measurements.

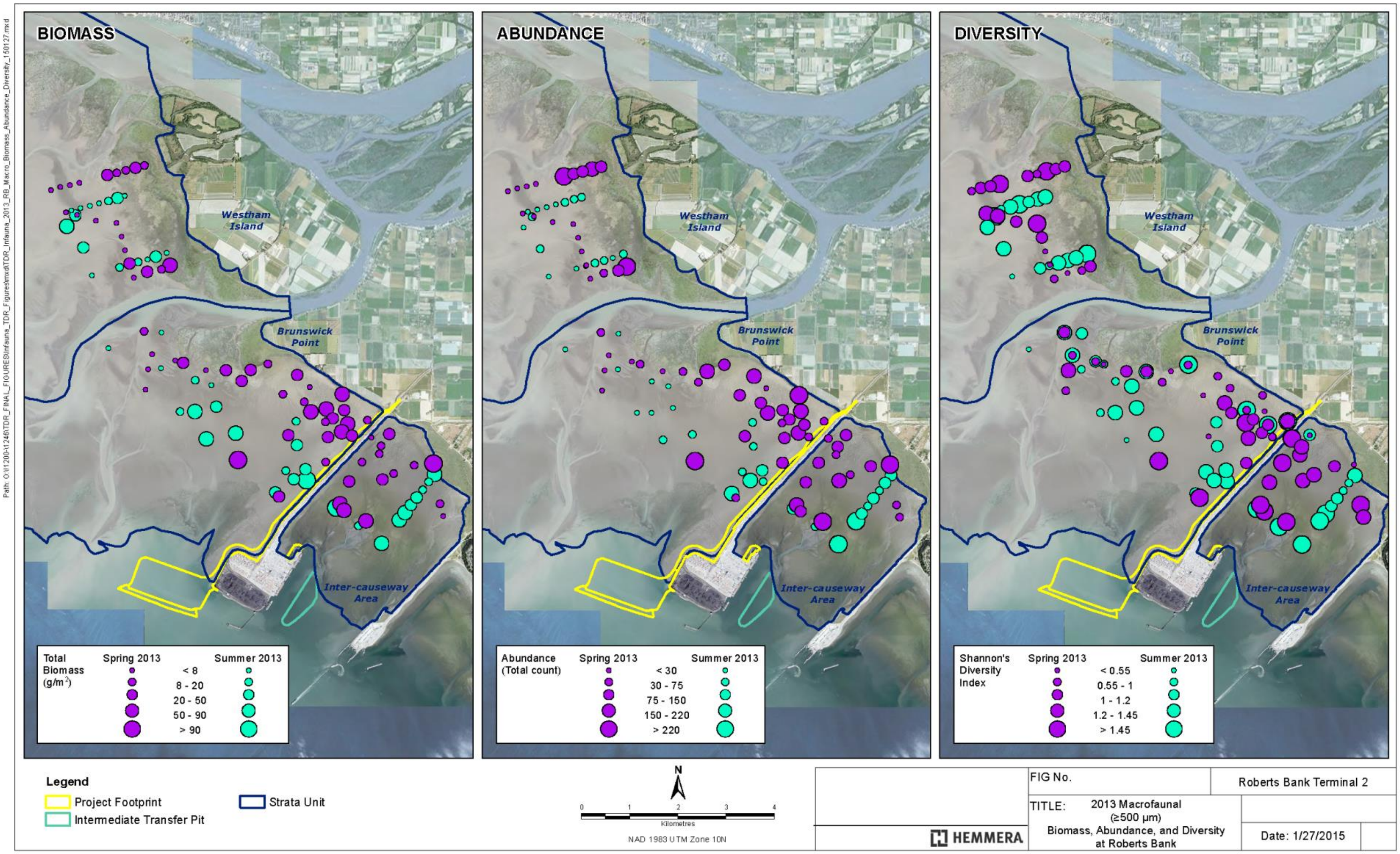


Figure B12 Spatial Trends in Macrofaunal Invertebrate Abundance, Biomass, and Diversity at Boundary Bay. Spring (purple) and Summer (green) Sampling Periods for 2013 are Shown. The Size of the Circles Represents Magnitude of the Respective Measurements.

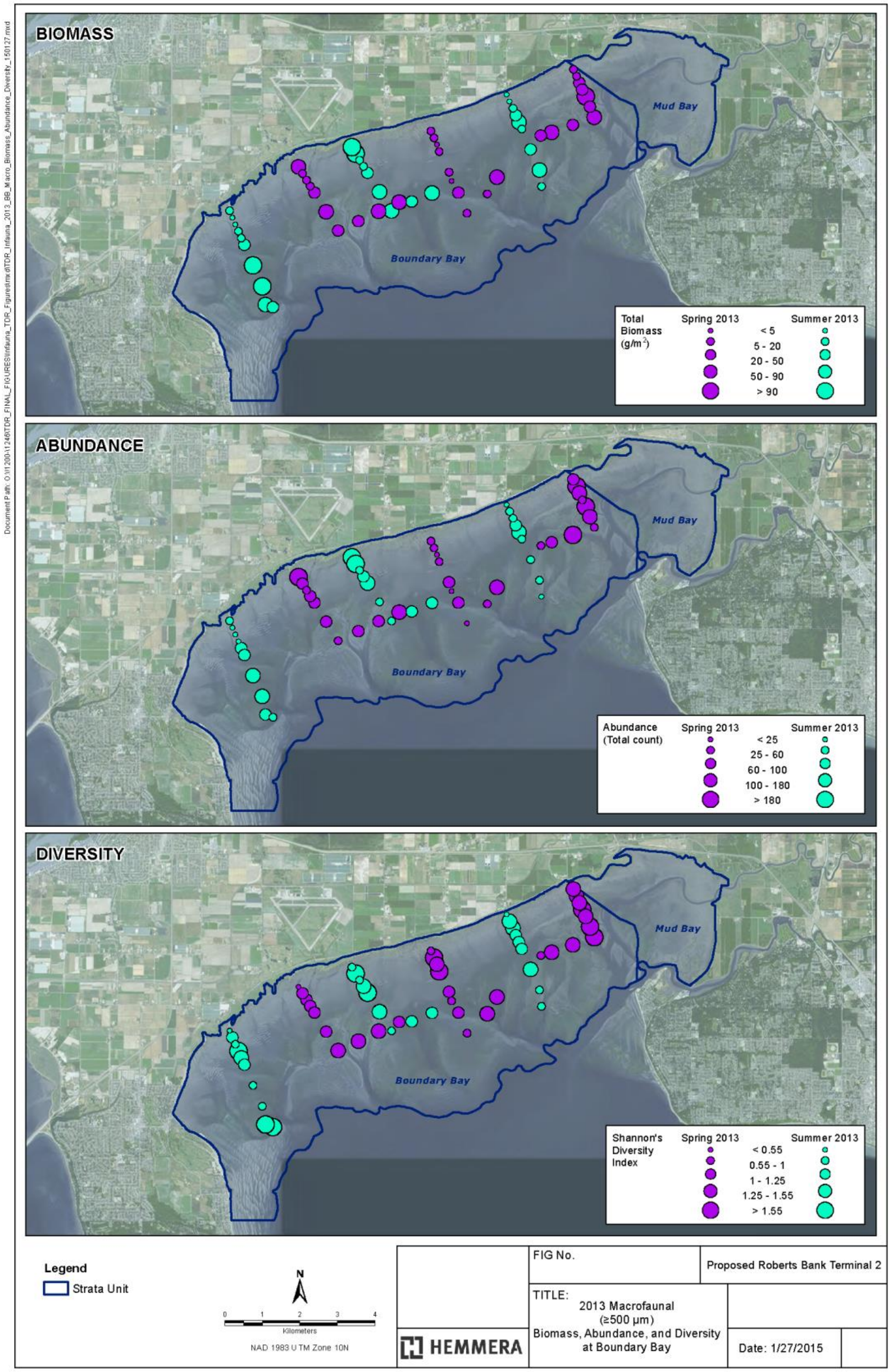


Figure B13 Inverse Distance Weighted (IDW) Interpolation of Meiofauna Diversity at Sturgeon Bank across all Samples Collected in 2012 and 2013

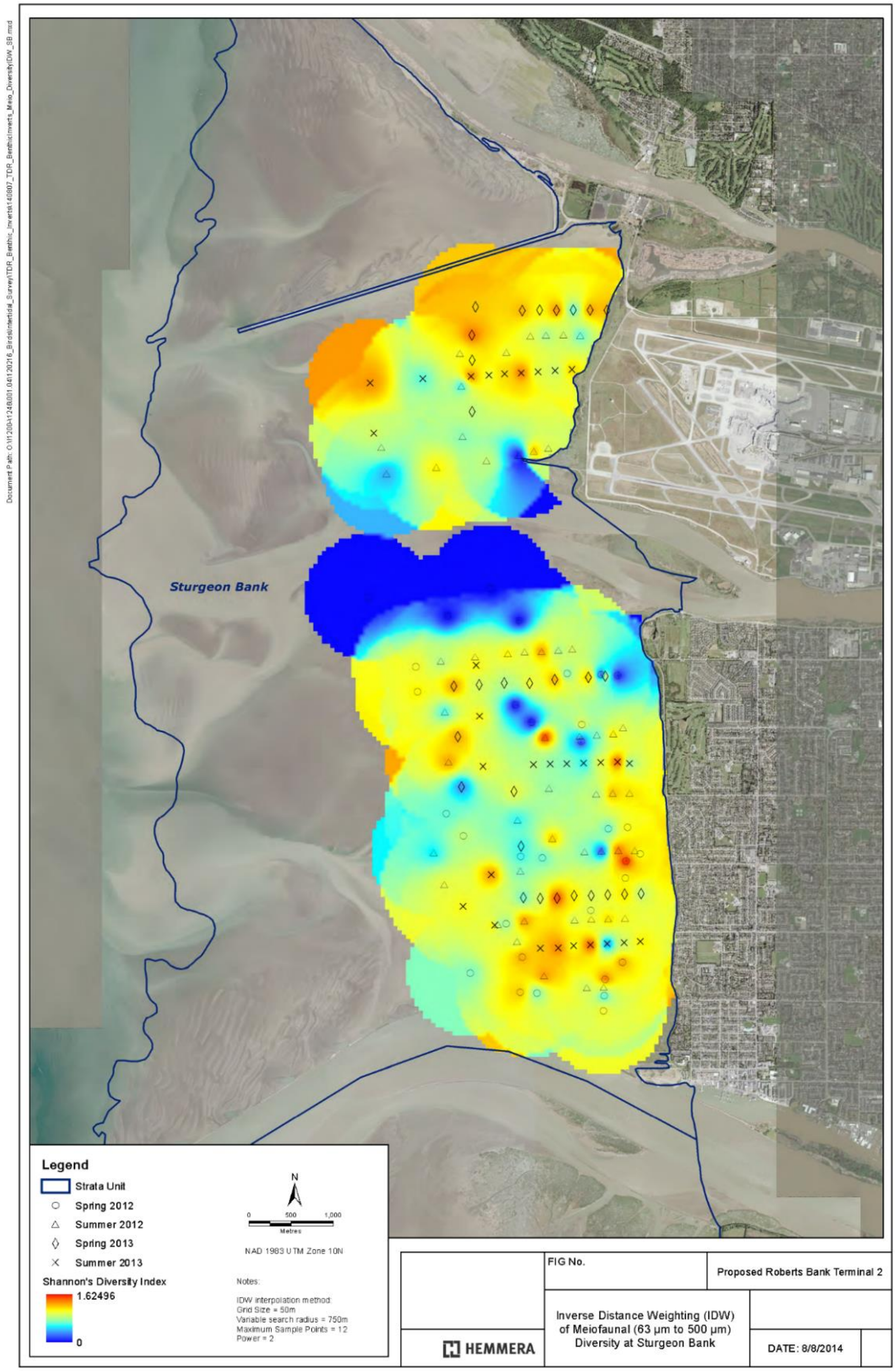


Figure B14 Inverse Distance Weighted (IDW) Interpolation of Meiofauna Diversity at Roberts Bank (Westham Island, Brunswick Point, and Inter-causeway Area) Based on Samples Collected in 2012 and 2013.

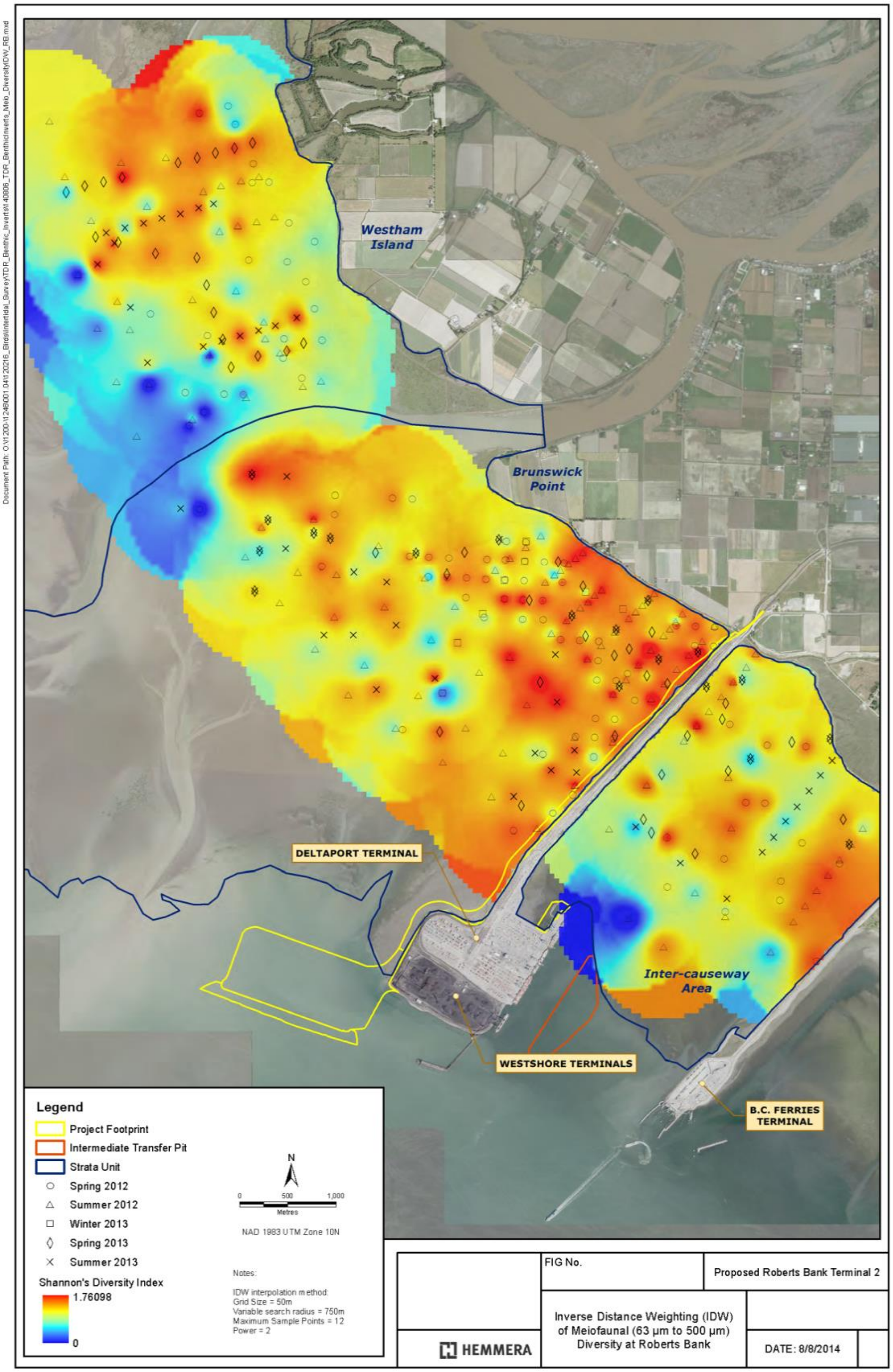


Figure B15 Inverse Distance Weighted (IDW) Interpolation of Meiofauna Diversity at Boundary Bay and Mud Bay Based on Samples Collected in 2012 and 2013

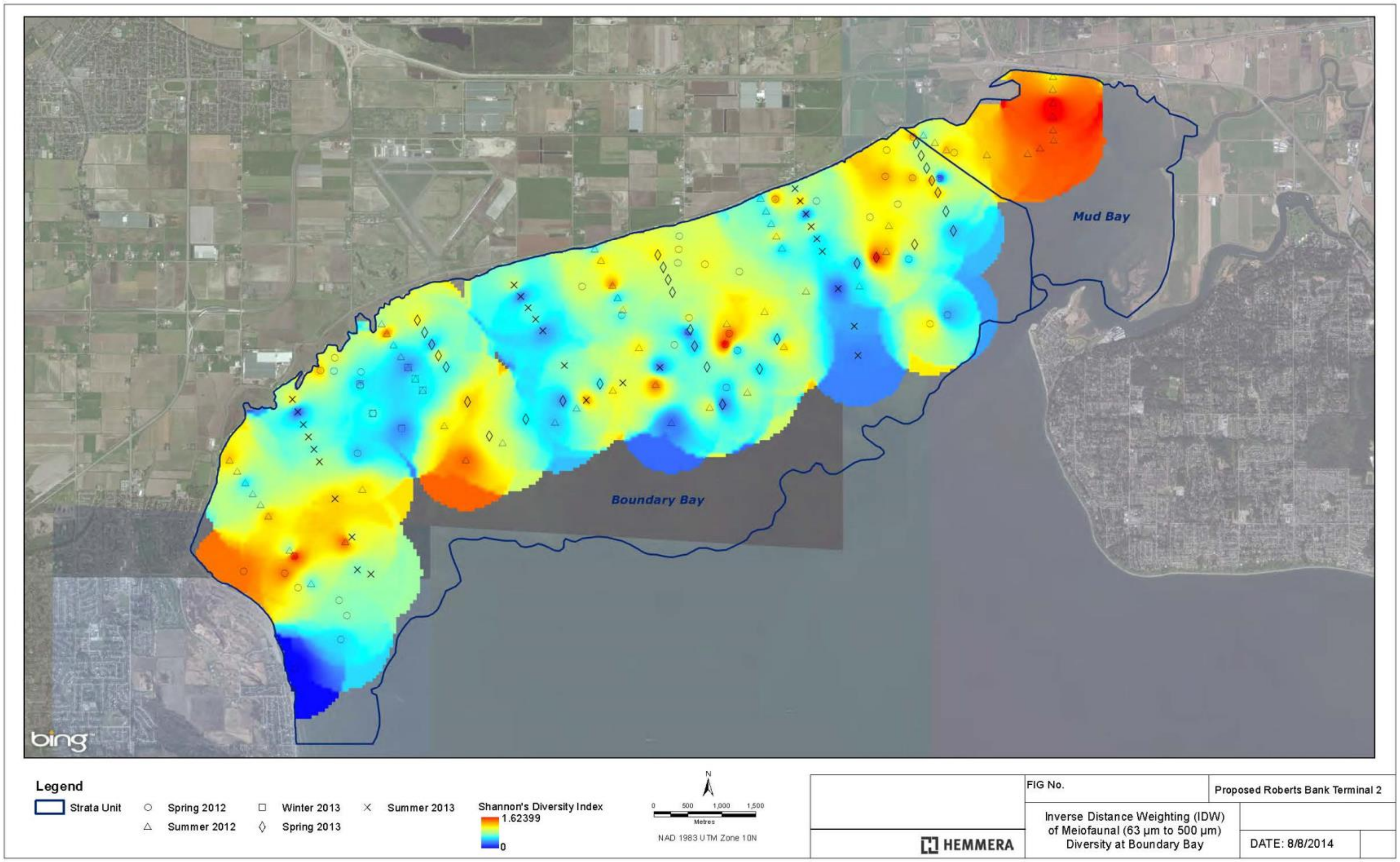


Figure B16 Inverse Distance Weighted (IDW) Interpolation of Macrofaunal Diversity at Sturgeon Bank Based on Samples Collected in 2012 and 2013.

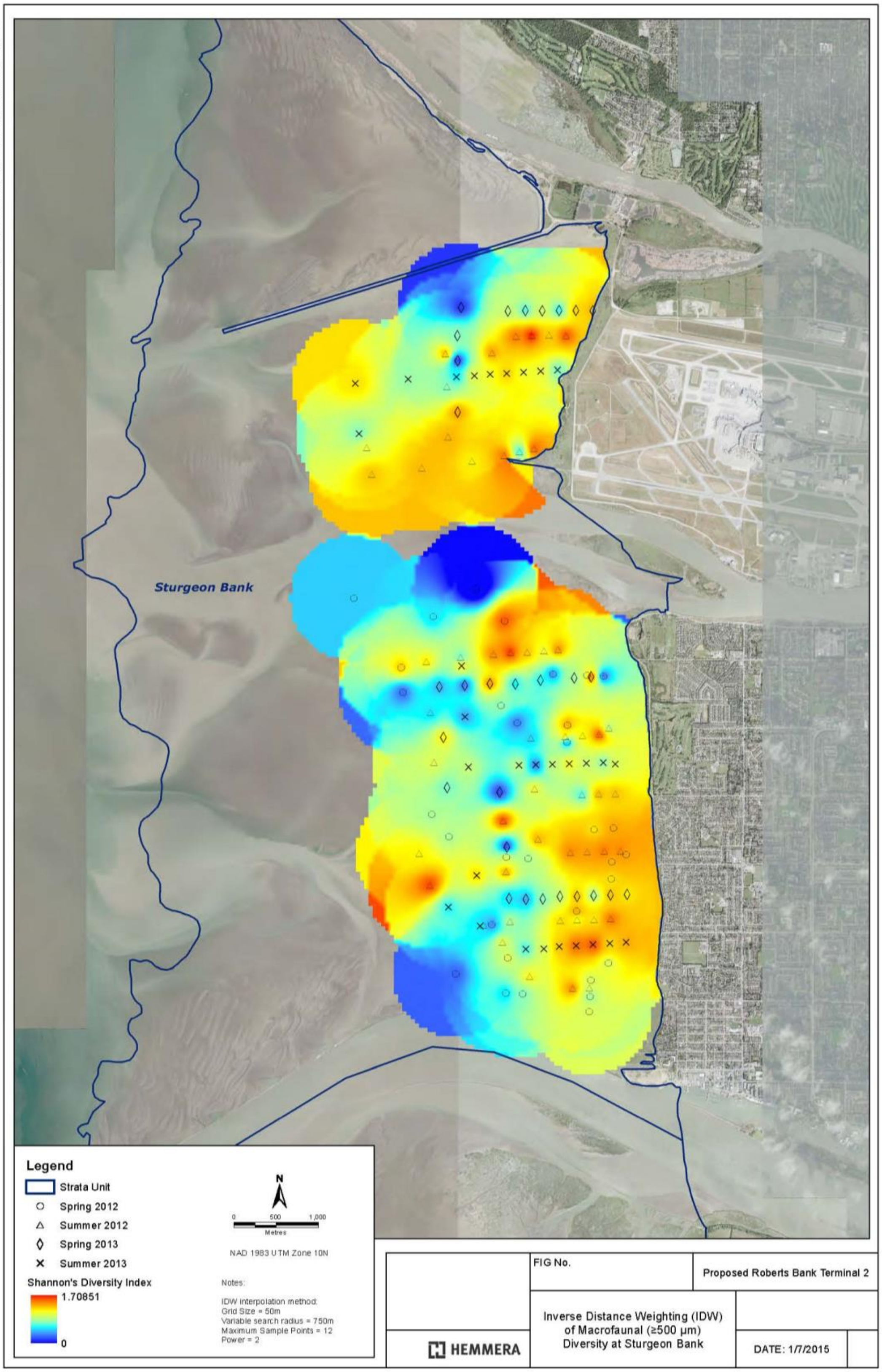


Figure B17 Inverse Distance Weighted (IDW) Interpolation of Macrofaunal Diversity at Roberts Bank (Westham Island, Brunswick Point, and Inter-causeway Area) Based on Samples Collected in 2012 and 2013.

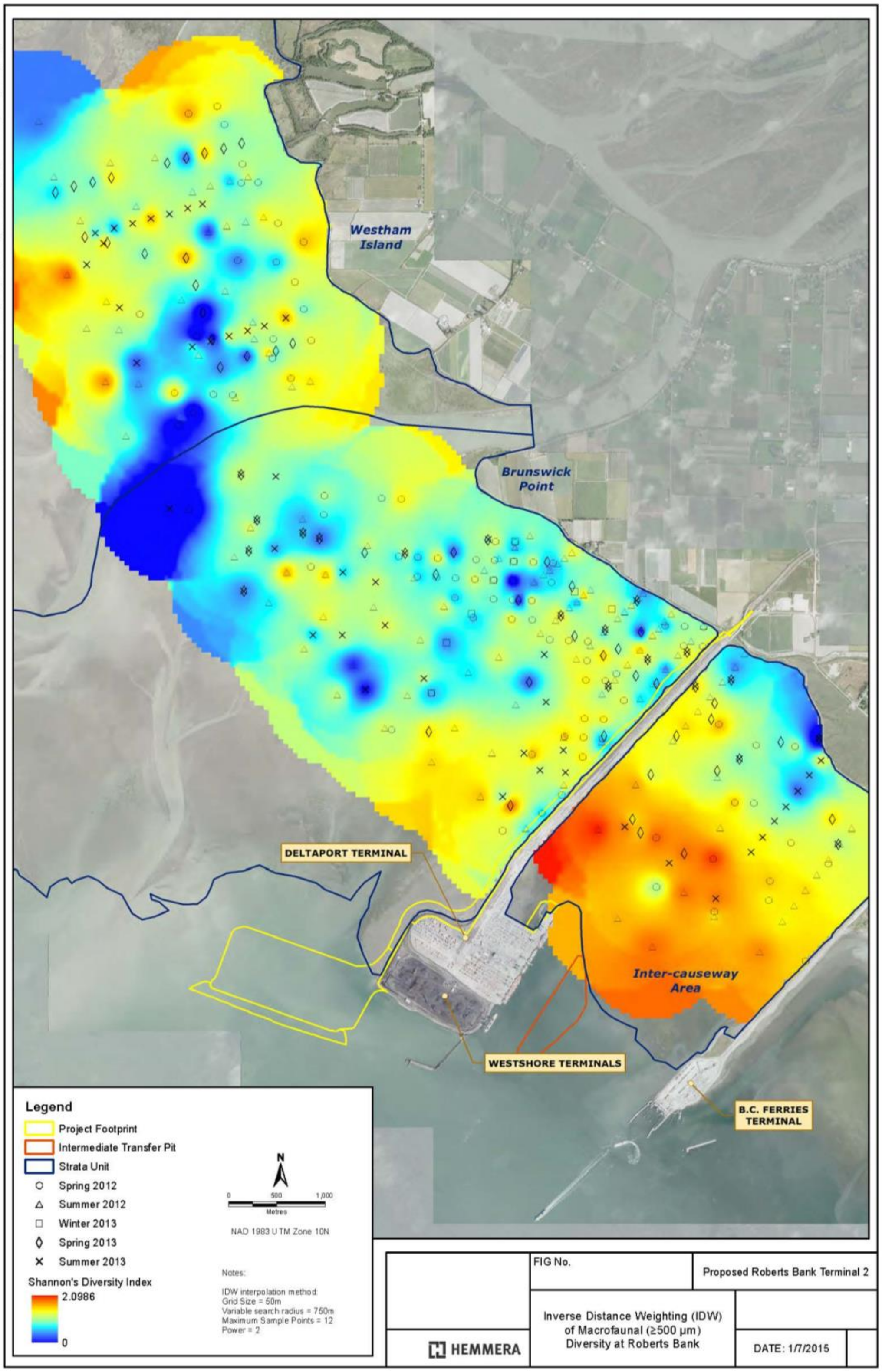
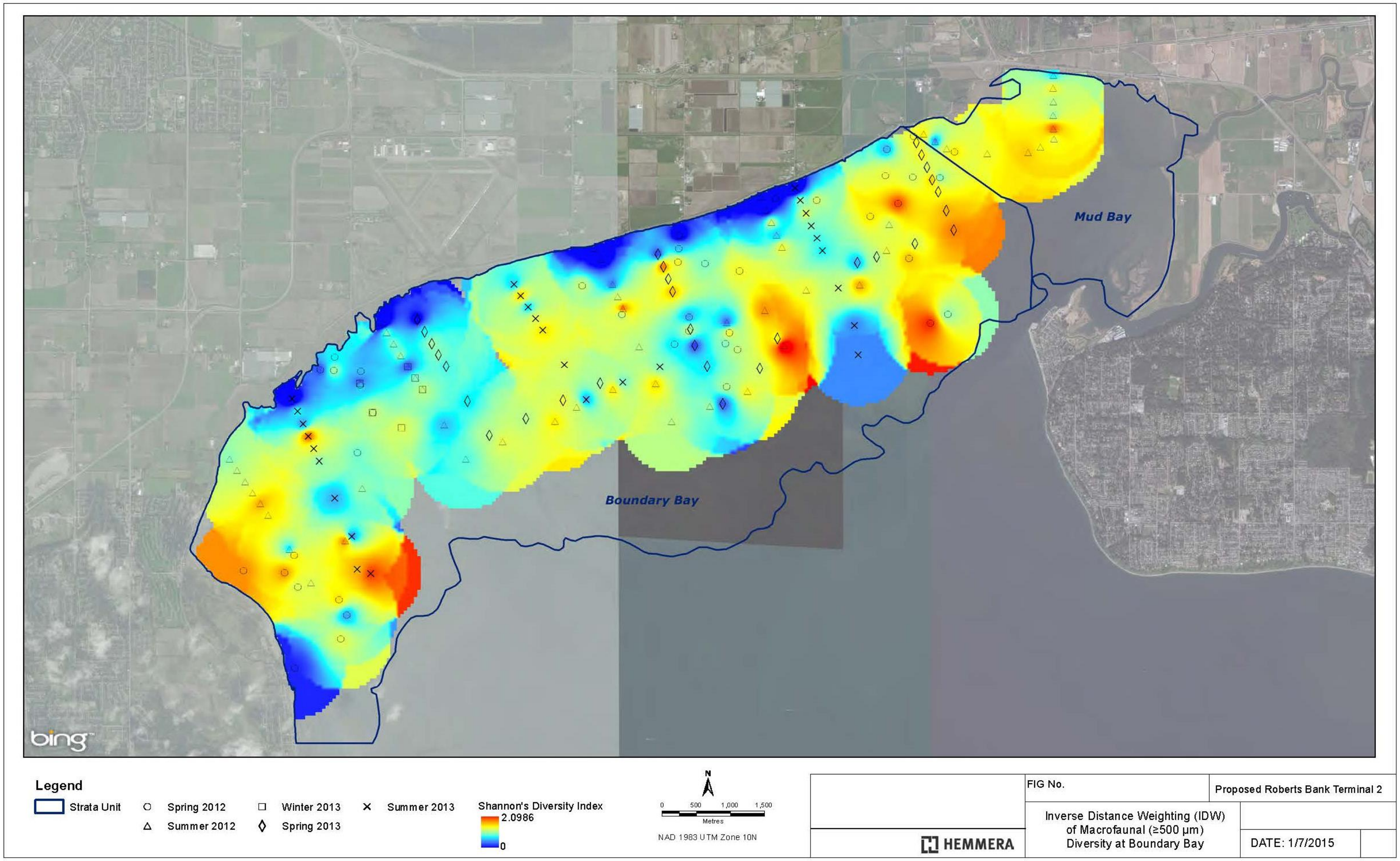


Figure B18 Inverse Distance Weighted (IDW) Interpolation of Macrofaunal Diversity at Boundary Bay and Mud Bay Based on Samples Collected in 2012 and 2013.



APPENDIX C

Analysis of Variance Tables and Figures

Table C1 Pairwise Comparisons Used to Examine the Proportion of Variation in Meiofaunal Biotic Parameters that could be Explained among Strata and Sampling Periods. A: Biomass, B: Abundance, C: Diversity, D: Polychaete, E: Nematode, F: Oligochaete, G: Harpacticoid, H: Ostracod, I: Bivalve, J: Cumacea, K: Foraminifera.

A

	BoundaryBay	BrunswickPoint	Inter-causeway	MudBay	SturgeonBank
BrunswickPoint	1.00000	-	-	-	-
Inter-causeway	8.2e-05	0.00017	-	-	-
MudBay	1.00000	1.00000	1.00000	-	-
SturgeonBank	4.0e-05	2.1e-06	3.1e-14	0.15806	-
WesthamIsland	5.8e-08	1.7e-09	< 2e-16	0.01976	1.00000

	Spring2012	Spring2013	Summer2012	Summer2013
Spring2013	< 2e-16	-	-	-
Summer2012	0.034	2.1e-12	-	-
Summer2013	< 2e-16	1.000	1.4e-13	-
Winter2013	0.060	1.000	0.894	1.000

B

	BoundaryBay	BrunswickPoint	Inter-causeway	MudBay	SturgeonBank
BrunswickPoint	0.21762	-	-	-	-
Inter-causeway	0.37087	0.00044	-	-	-
MudBay	1.00000	1.00000	1.00000	-	-
SturgeonBank	6.7e-10	2.5e-05	2.0e-12	0.10196	-
WesthamIsland	2.6e-11	1.1e-06	8.7e-14	0.03161	1.00000

	Spring2012	Spring2013	Summer2012	Summer2013
Spring2013	< 2e-16	-	-	-
Summer2012	0.00094	2.8e-11	-	-
Summer2013	< 2e-16	1.00000	8.4e-15	-
Winter2013	0.00296	1.00000	0.26439	1.00000

C

	BoundaryBay	BrunswickPoint	Inter-causeway	MudBay	SturgeonBank
BrunswickPoint	< 2e-16	-	-	-	-
Inter-causeway	1.6e-06	0.22678	-	-	-
MudBay	0.00011	1.00000	1.00000	-	-
SturgeonBank	0.01780	1.2e-07	0.27415	0.03826	-
WesthamIsland	0.00157	7.3e-05	1.00000	0.13871	1.00000

	Spring2012	Spring2013	Summer2012	Summer2013
Spring2013	0.537	-	-	-
Summer2012	0.600	1.000	-	-
Summer2013	1.000	1.000	1.000	-
Winter2013	0.434	0.051	0.062	0.176

D

	BoundaryBay	BrunswickPoint	Inter-causeway	MudBay	SturgeonBank
BrunswickPoint	0.01289	-	-	-	-
Inter-causeway	1.00000	0.23560	-	-	-
MudBay	1.00000	1.00000	1.00000	-	-
SturgeonBank	1.00000	0.53964	1.00000	1.00000	-
WesthamIsland	1.00000	0.00039	1.00000	1.00000	0.65787

	Spring2012	Spring2013	Summer2012	Summer2013
Spring2013	0.17	-	-	-
Summer2012	1.00	1.00	-	-
Summer2013	1.00	1.00	1.00	-
Winter2013	1.00	1.00	1.00	1.00

E

	BoundaryBay	BrunswickPoint	Inter-causeway	MudBay	SturgeonBank
BrunswickPoint	3.4e-06	-	-	-	-
Inter-causeway	1.0000	1.7e-05	-	-	-
MudBay	1.0000	1.0000	1.0000	-	-
SturgeonBank	1.3e-13	0.0040	1.3e-11	0.0405	-
WesthamIsland	6.6e-13	0.0038	2.6e-11	0.0319	1.0000

	Spring2012	Spring2013	Summer2012	Summer2013
Spring2013	< 2e-16	-	-	-
Summer2012	0.64424	< 2e-16	-	-
Summer2013	< 2e-16	1.00000	< 2e-16	-
Winter2013	3.9e-05	1.00000	0.00064	1.00000

F

	BoundaryBay	BrunswickPoint	Inter-causeway	MudBay	SturgeonBank
BrunswickPoint	3.8e-05	-	-	-	-
Inter-causeway	1.0000	0.0869	-	-	-
MudBay	1.0000	1.0000	1.0000	-	-
SturgeonBank	1.0000	0.0057	1.0000	1.0000	-
WesthamIsland	0.4565	1.4e-08	0.1557	0.4860	0.1656

	Spring2012	Spring2013	Summer2012	Summer2013
Spring2013	0.00011	-	-	-
Summer2012	1.00000	0.00353	-	-
Summer2013	0.00156	1.00000	0.03670	-
Winter2013	0.03496	1.00000	0.12564	1.00000

G

	BoundaryBay	BrunswickPoint	Inter-causeway	MudBay	SturgeonBank
BrunswickPoint	0.09409	-	-	-	-
Inter-causeway	0.00015	0.18904	-	-	-
MudBay	1.00000	1.00000	1.00000	-	-
SturgeonBank	1.00000	0.00109	1.6e-06	0.34008	-
WesthamIsland	1.00000	0.01436	2.7e-05	0.58108	1.00000

	Spring2012	Spring2013	Summer2012	Summer2013
Spring2013	0.01545	-	-	-
Summer2012	7.9e-05	1.00000	-	-
Summer2013	3.9e-08	0.09448	0.24698	-
Winter2013	0.86244	0.02490	0.00706	0.00029

H

	BoundaryBay	BrunswickPoint	Inter-causeway	MudBay	SturgeonBank
BrunswickPoint	0.02900	-	-	-	-
Inter-causeway	1.00000	1.00000	-	-	-
MudBay	1.00000	1.00000	1.00000	-	-
SturgeonBank	1.00000	0.00063	0.09744	1.00000	-
WesthamIsland	0.00051	1.00000	0.93037	1.00000	1.2e-05

	Spring2012	Spring2013	Summer2012	Summer2013
Spring2013	0.00207	-	-	-
Summer2012	1.00000	0.07594	-	-
Summer2013	6.7e-06	1.00000	0.00057	-
Winter2013	1.00000	0.27266	1.00000	0.06013

I

	BoundaryBay	BrunswickPoint	Inter-causeway	MudBay	SturgeonBank
BrunswickPoint	0.067	-	-	-	-
Inter-causeway	1.000	0.700	-	-	-
MudBay	1.000	1.000	1.000	-	-
SturgeonBank	1.000	0.019	1.000	1.000	-
WesthamIsland	1.000	0.010	1.000	1.000	1.000

	Spring2012	Spring2013	Summer2012	Summer2013
Spring2013	0.21902	-	-	-
Summer2012	1.00000	1.00000	-	-
Summer2013	1.00000	0.07203	0.38866	-
Winter2013	0.02764	0.00093	0.00316	0.06811

J

	BoundaryBay	BrunswickPoint	Inter-causeway	MudBay	SturgeonBank
BrunswickPoint	1	-	-	-	-
Inter-causeway	1	1	-	-	-
MudBay	1	1	1	-	-
SturgeonBank	1	1	1	1	-
WesthamIsland	1	1	1	1	1

	Spring2012	Spring2013	Summer2012	Summer2013
Spring2013	1.0000	-	-	-
Summer2012	5.8e-05	0.0050	-	-
Summer2013	0.0023	0.0416	1.0000	-
Winter2013	0.5495	1.0000	1.0000	1.0000

K

	BoundaryBay	BrunswickPoint	Inter-causeway	MudBay	SturgeonBank
BrunswickPoint	0.4089	-	-	-	-
Inter-causeway	< 2e-16	2.0e-14	-	-	-
MudBay	1.0000	1.0000	0.0340	-	-
SturgeonBank	1.0000	1.0000	2.7e-14	1.0000	-
WesthamIsland	0.8413	0.0021	< 2e-16	0.1982	0.1387

	Spring2012	Spring2013	Summer2012	Summer2013
Spring2013	2.5e-05	-	-	-
Summer2012	1.0000	5.2e-08	-	-
Summer2013	0.0024	1.0000	2.0e-05	-
Winter2013	1.0000	0.0490	1.0000	0.1775

Table C2 Pairwise Comparisons Used to Examine the Proportion of Variation in Meiofaunal Biotic Parameters that could be Explained among Strata and Sampling Periods.. A: Biomass, B: Abundance, C: Diversity, D: Polychaete, E: Nematode, F: Oligochaete, G: Harpacticoid, H: Ostracod, I: Bivalve, J: Cumacea.

A

	BoundaryBay	BrunswickPoint	Inter-causeway	MudBay	SturgeonBank
BrunswickPoint	0.00044	-	-	-	-
Inter-causeway	1.00000	0.02092	-	-	-
MudBay	1.00000	1.00000	1.00000	-	-
SturgeonBank	1.00000	1.00000	1.00000	1.00000	-
WesthamIsland	3.5e-10	0.00569	3.8e-07	0.29619	4.8e-05

	Spring2012	Spring2013	Summer2012	Summer2013
Spring2013	0.03754	-	-	-
Summer2012	1.00000	0.00072	-	-
Summer2013	1.00000	1.00000	0.17456	-
Winter2013	1.00000	1.00000	1.00000	1.00000

B

	BoundaryBay	BrunswickPoint	Inter-causeway	MudBay	SturgeonBank
BrunswickPoint	0.04547	-	-	-	-
Inter-causeway	1.00000	0.00094	-	-	-
MudBay	1.00000	0.26541	1.00000	-	-
SturgeonBank	0.00085	1.00000	2.0e-05	0.04510	-
WesthamIsland	< 2e-16	1.5e-10	< 2e-16	2.0e-06	2.4e-05

	Spring2012	Spring2013	Summer2012	Summer2013
Spring2013	1	-	-	-
Summer2012	1	1	-	-
Summer2013	1	1	1	-
Winter2013	1	1	1	1

C

	BoundaryBay	BrunswickPoint	Inter-causeway	MudBay	SturgeonBank
BrunswickPoint	0.01876	-	-	-	-
Inter-causeway	0.33216	2.2e-05	-	-	-
MudBay	1.00000	0.06664	1.00000	-	-
SturgeonBank	0.00172	1.00000	2.3e-06	0.01709	-
WesthamIsland	0.10059	1.00000	0.00027	0.07851	1.00000

	Spring2012	Spring2013	Summer2012	Summer2013
Spring2013	0.9445	-	-	-
Summer2012	0.2097	0.0011	-	-
Summer2013	1.0000	1.0000	0.1089	-
Winter2013	1.0000	1.0000	1.0000	1.0000

D

	BoundaryBay	BrunswickPoint	Inter-causeway	MudBay	SturgeonBank
BrunswickPoint	0.02329	-	-	-	-
Inter-causeway	1.00000	0.05077	-	-	-
MudBay	1.00000	1.00000	1.00000	-	-
SturgeonBank	0.41440	1.00000	0.37013	1.00000	-
WesthamIsland	< 2e-16	3.6e-10	9.8e-14	0.00049	2.7e-09

	Spring2012	Spring2013	Summer2012	Summer2013
Spring2013	1.000	-	-	-
Summer2012	1.000	0.393	-	-
Summer2013	0.444	0.022	1.000	-
Winter2013	1.000	1.000	1.000	1.000

E

	BoundaryBay	BrunswickPoint	Inter-causeway	MudBay	SturgeonBank
BrunswickPoint	< 2e-16	-	-	-	-
Inter-causeway	0.81	< 2e-16	-	-	-
MudBay	1.00	5.0e-06	1.00	-	-
SturgeonBank	< 2e-16	1.00	< 2e-16	2.7e-07	-
WesthamIsland	< 2e-16	1.00	< 2e-16	3.8e-06	1.00

	Spring2012	Spring2013	Summer2012	Summer2013
Spring2013	1.00000	-	-	-
Summer2012	0.00944	0.00025	-	-
Summer2013	2.9e-06	5.8e-08	0.13024	-
Winter2013	1.00000	1.00000	0.93018	0.08797

F

	BoundaryBay	BrunswickPoint	Inter-causeway	MudBay	SturgeonBank
BrunswickPoint	0.01233	-	-	-	-
Inter-causeway	1.00000	1.00000	-	-	-
MudBay	0.99404	1.00000	1.00000	-	-
SturgeonBank	1.00000	0.02164	1.00000	0.88168	-
WesthamIsland	4.0e-06	1.9e-14	2.2e-07	0.00054	6.4e-05

	Spring2012	Spring2013	Summer2012	Summer2013
Spring2013	0.069	-	-	-
Summer2012	1.000	0.515	-	-
Summer2013	0.612	1.000	1.000	-
Winter2013	1.000	1.000	1.000	1.000

G

	BoundaryBay	BrunswickPoint	Inter-causeway	MudBay	SturgeonBank
BrunswickPoint	0.0060	-	-	-	-
Inter-causeway	1.0000	0.0037	-	-	-
MudBay	1.0000	1.0000	1.0000	-	-
SturgeonBank	0.0081	1.0000	0.0035	1.0000	-
WesthamIsland	1.0000	1.0000	0.2821	1.0000	1.0000

	Spring2012	Spring2013	Summer2012	Summer2013
Spring2013	0.5974	-	-	-
Summer2012	1.0000	0.0590	-	-
Summer2013	2.8e-08	0.0012	2.0e-11	-
Winter2013	0.6782	1.0000	0.3152	1.0000

H

	BoundaryBay	BrunswickPoint	Inter-causeway	MudBay	SturgeonBank
BrunswickPoint	< 2e-16	-	-	-	-
Inter-causeway	< 2e-16	1.00000	-	-	-
MudBay	0.13146	0.10718	0.08026	-	-
SturgeonBank	< 2e-16	1.00000	1.00000	0.03764	-
WesthamIsland	2.9e-10	8.0e-05	0.00064	1.00000	1.9e-05

	Spring2012	Spring2013	Summer2012	Summer2013
Spring2013	0.89	-	-	-
Summer2012	1.00	1.00	-	-
Summer2013	1.00	1.00	1.00	-
Winter2013	1.00	1.00	1.00	1.00

I

	BoundaryBay	BrunswickPoint	Inter-causeway	MudBay	SturgeonBank
BrunswickPoint	7e-08	-	-	-	-
Inter-causeway	1.00000	6e-05	-	-	-
MudBay	1.00000	0.86875	1.00000	-	-
SturgeonBank	2e-06	1.00000	0.00017	0.73808	-
WesthamIsland	0.24569	0.21738	0.57498	1.00000	0.23543

	Spring2012	Spring2013	Summer2012	Summer2013
Spring2013	1.00000	-	-	-
Summer2012	0.00300	0.00035	-	-
Summer2013	1.00000	0.30216	0.92564	-
Winter2013	0.15018	0.06264	1.00000	0.78774

J

	BoundaryBay	BrunswickPoint	Inter-causeway	MudBay	SturgeonBank
BrunswickPoint	1.000	-	-	-	-
Inter-causeway	0.031	0.747	-	-	-
MudBay	1.000	1.000	1.000	-	-
SturgeonBank	1.000	1.000	0.066	1.000	-
WesthamIsland	1.000	1.000	1.000	1.000	1.000

	Spring2012	Spring2013	Summer2012	Summer2013
Spring2013	0.00775	-	-	-
Summer2012	0.00077	1.00000	-	-
Summer2013	2.2e-05	1.00000	1.00000	-
Winter2013	1.00000	1.00000	1.00000	1.00000

Figure C1 Variation in Meiofauna Biomass among Strata by Sampling Period

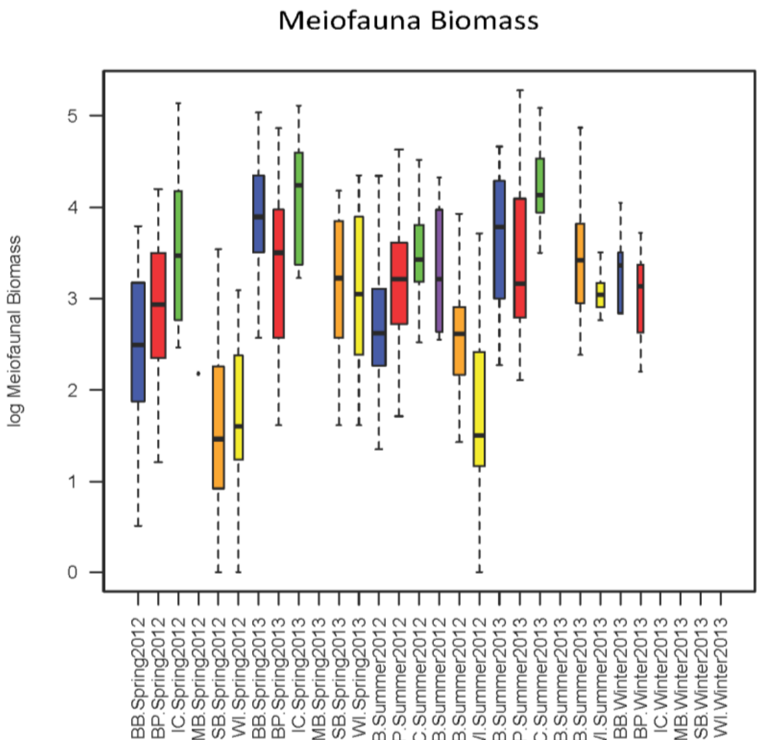


Figure C2 Variation in Meiofauna Abundance among Strata by Sampling Period

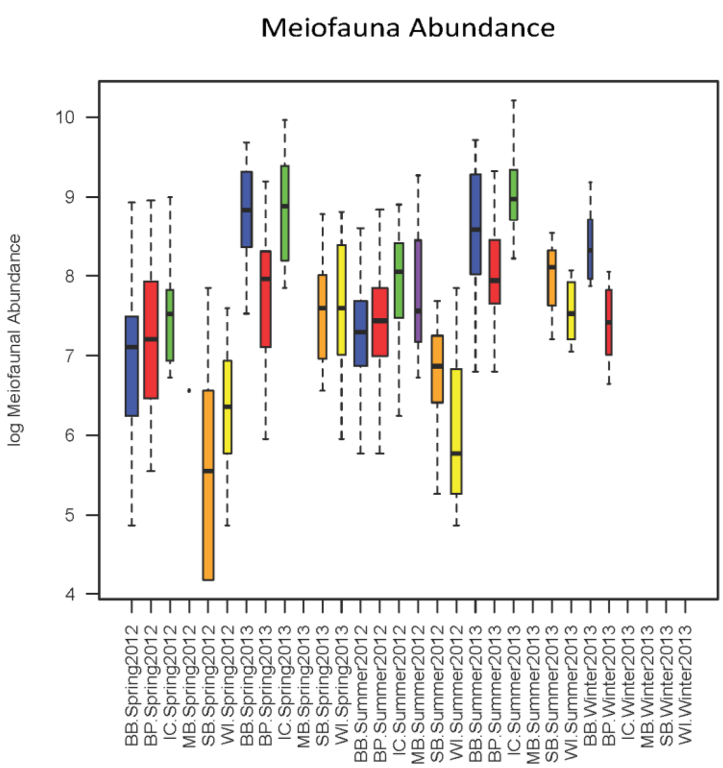


Figure C3 Variation in Meiofauna Diversity among Strata by Sampling Period

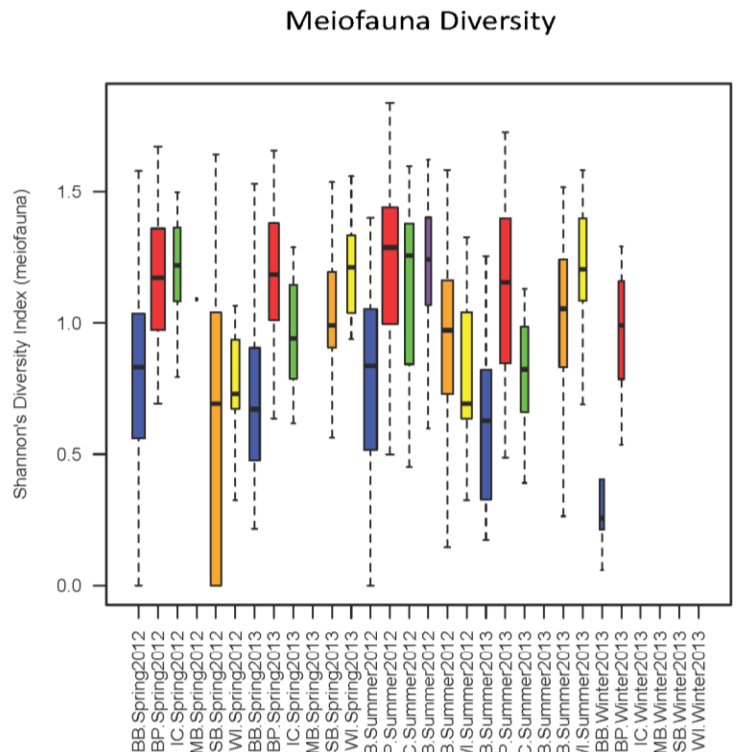


Figure C4 Variation in Macrofauna Biomass among Strata by Sampling Period

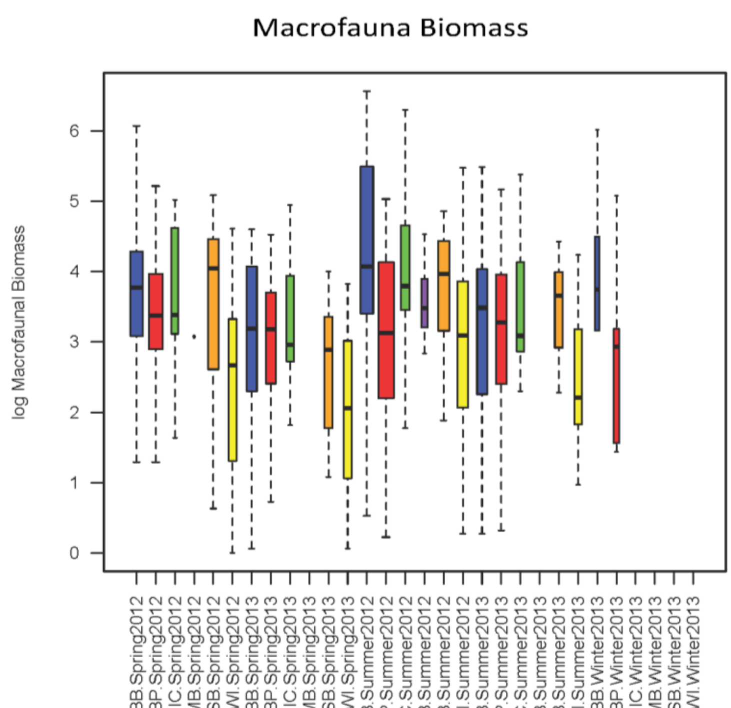


Figure C5 Variation in Macrofauna Abundance among Strata by Sampling Period

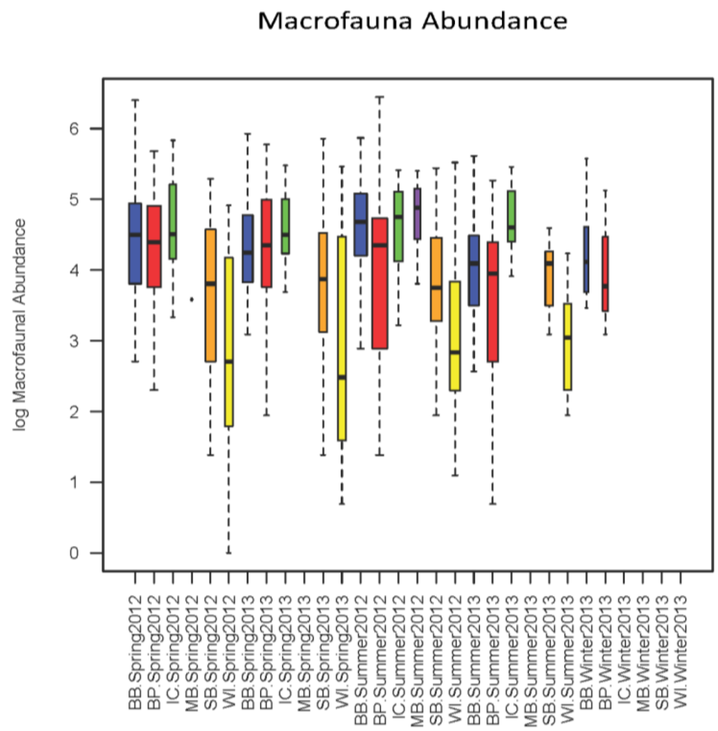


Figure C6 Variation in Macrofauna Diversity among Strata by Sampling Period

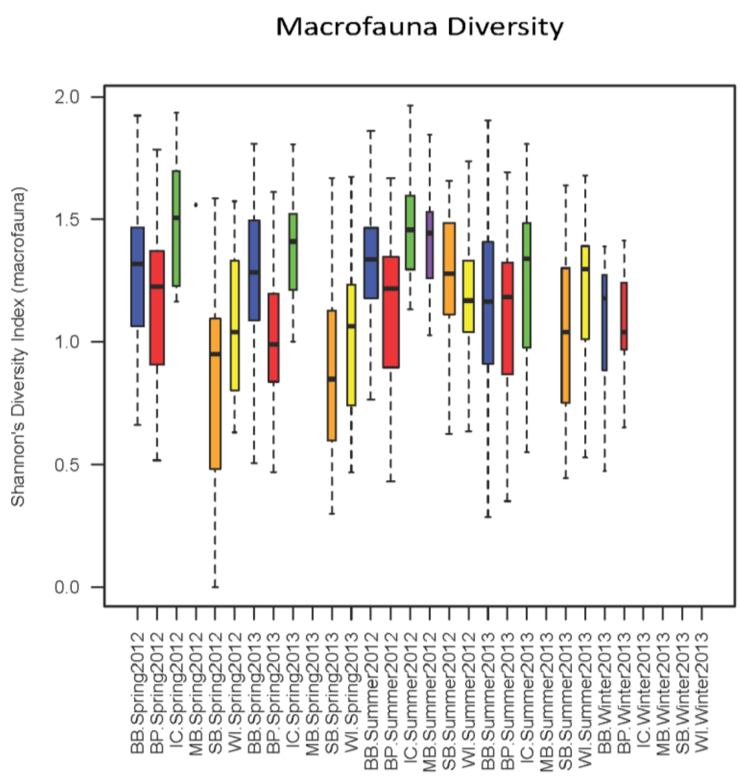
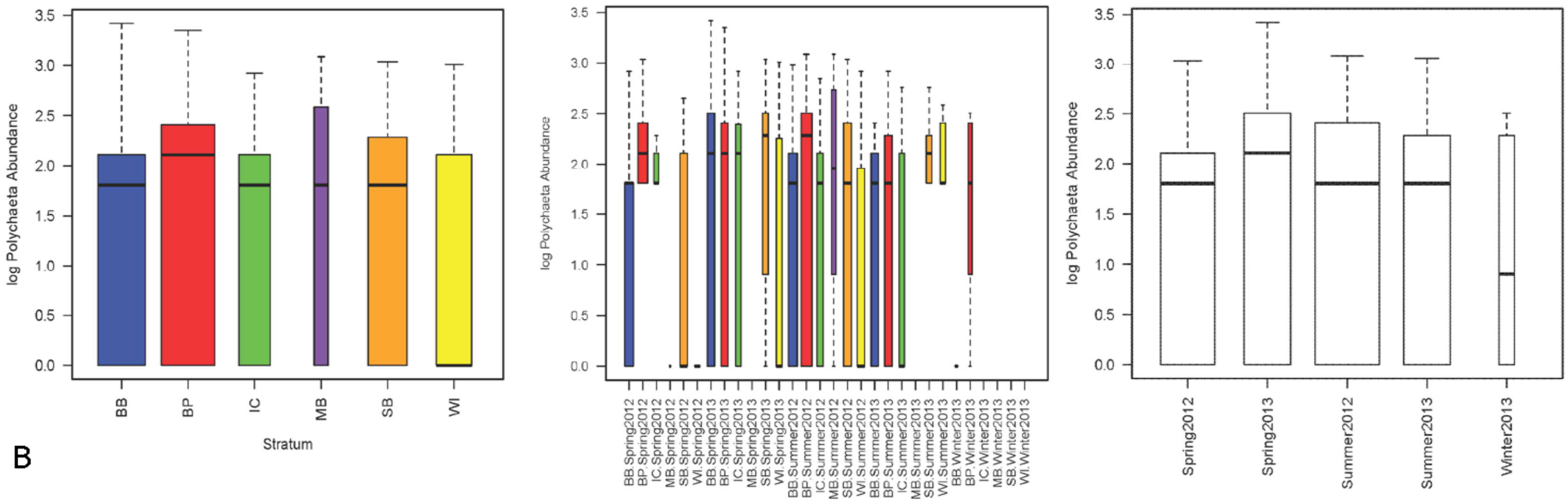


Figure C7 Relationships between Meiofauna Taxon-specific Abundance and Strata, Sampling Period, and Strata by Sampling Period, where A: Polychaete, B: Nematode, C: Oligochaete, D: Harpacticoid, E: Ostracod, F: Bivalve, G: Cumacea, and H: Foraminifera

A



B

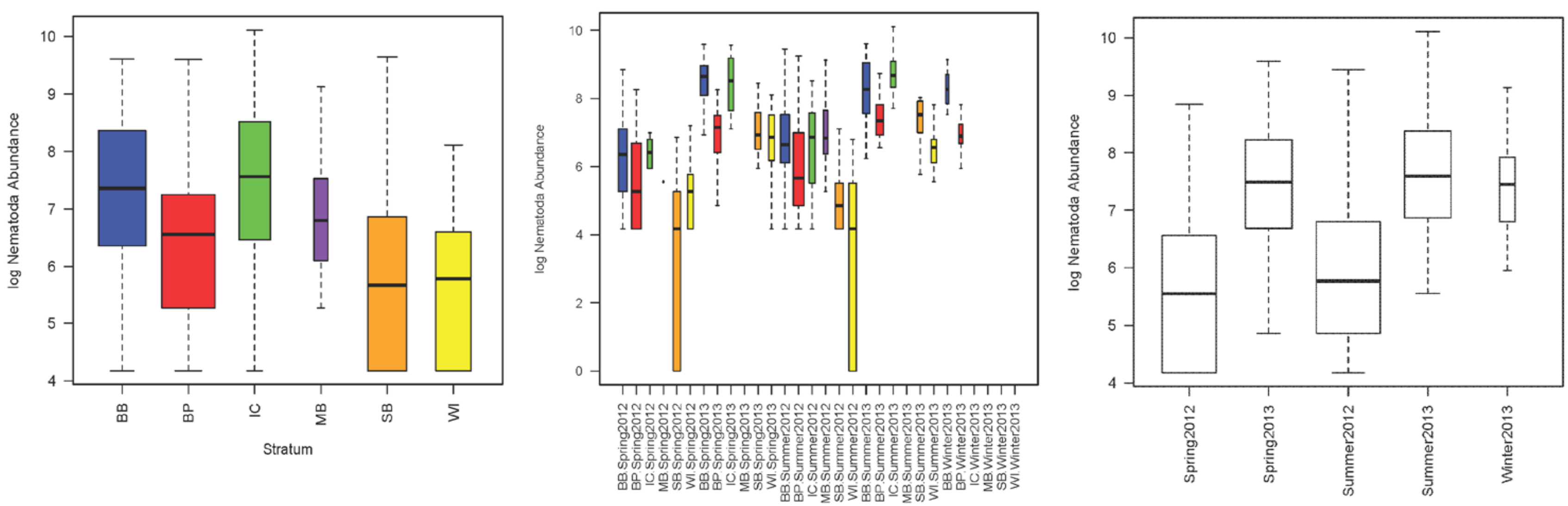
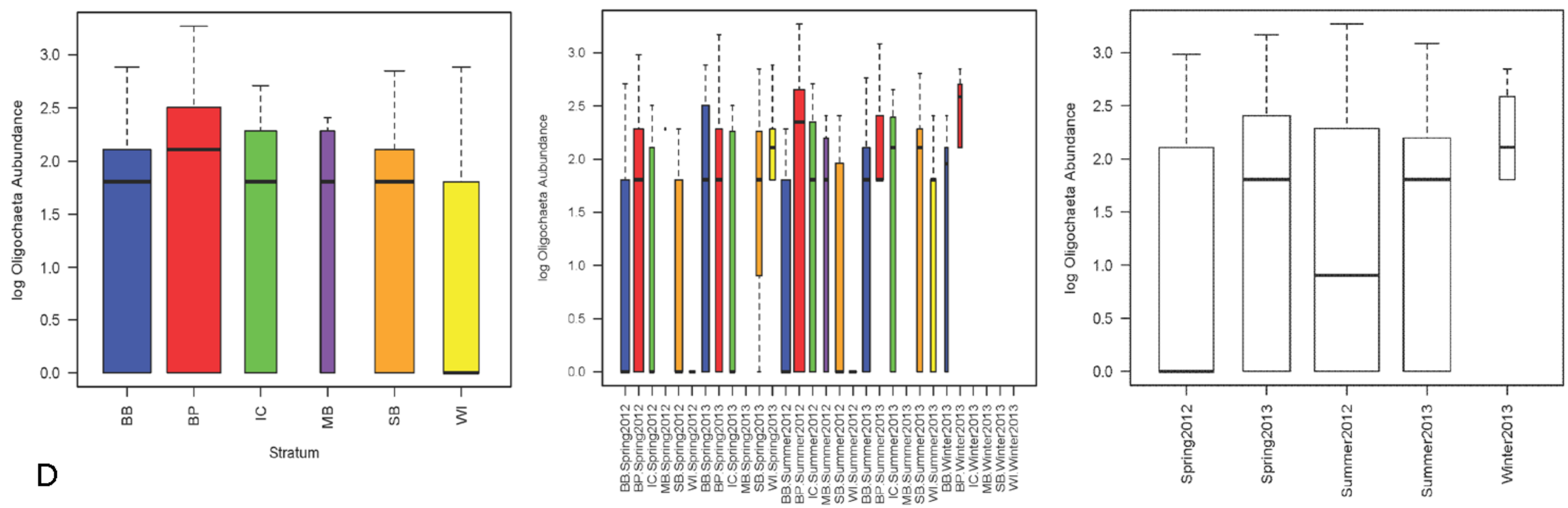


Figure C7 Continued

C



D

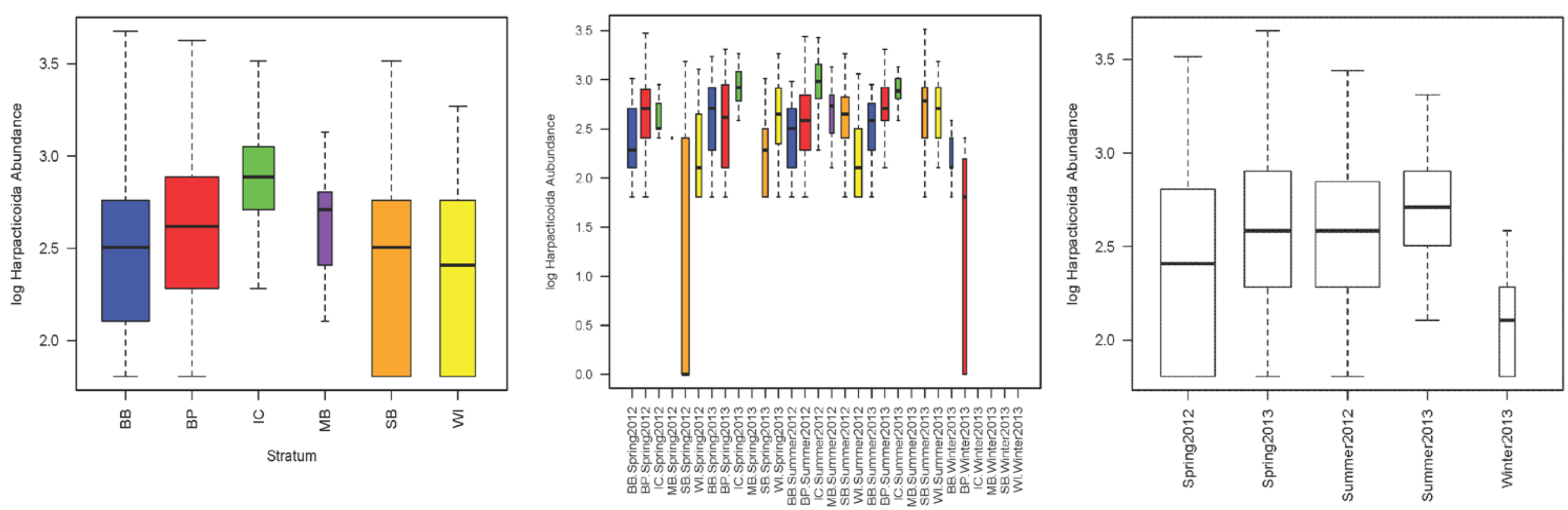
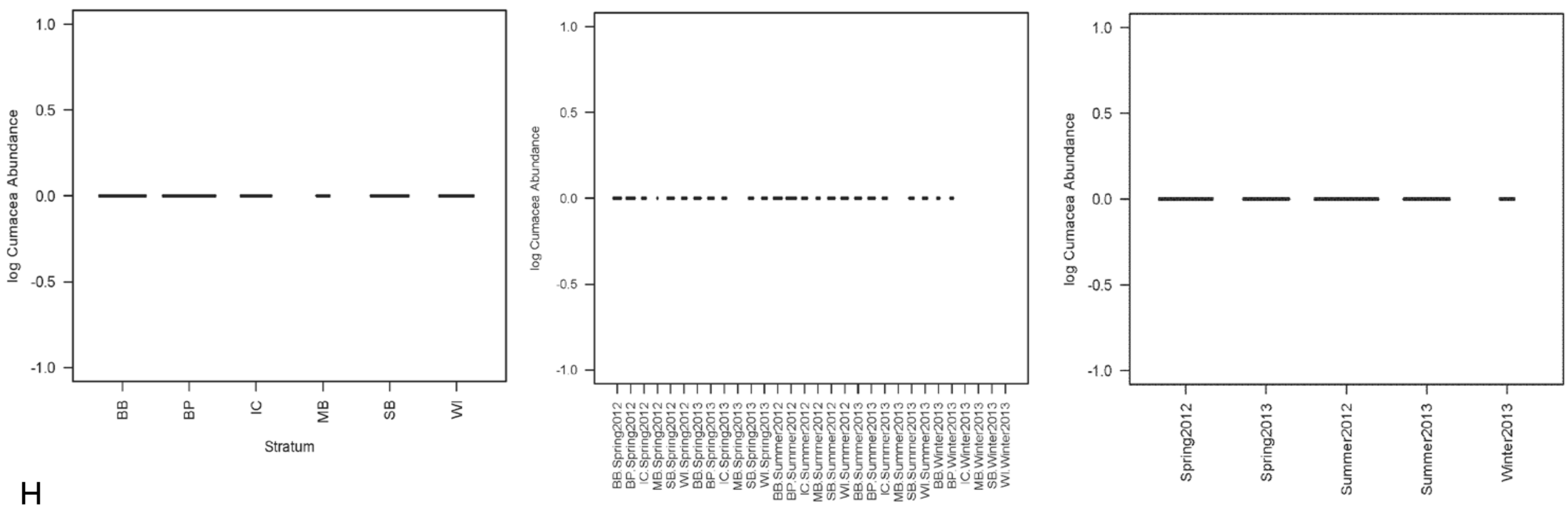


Figure C7 Continued

G



H

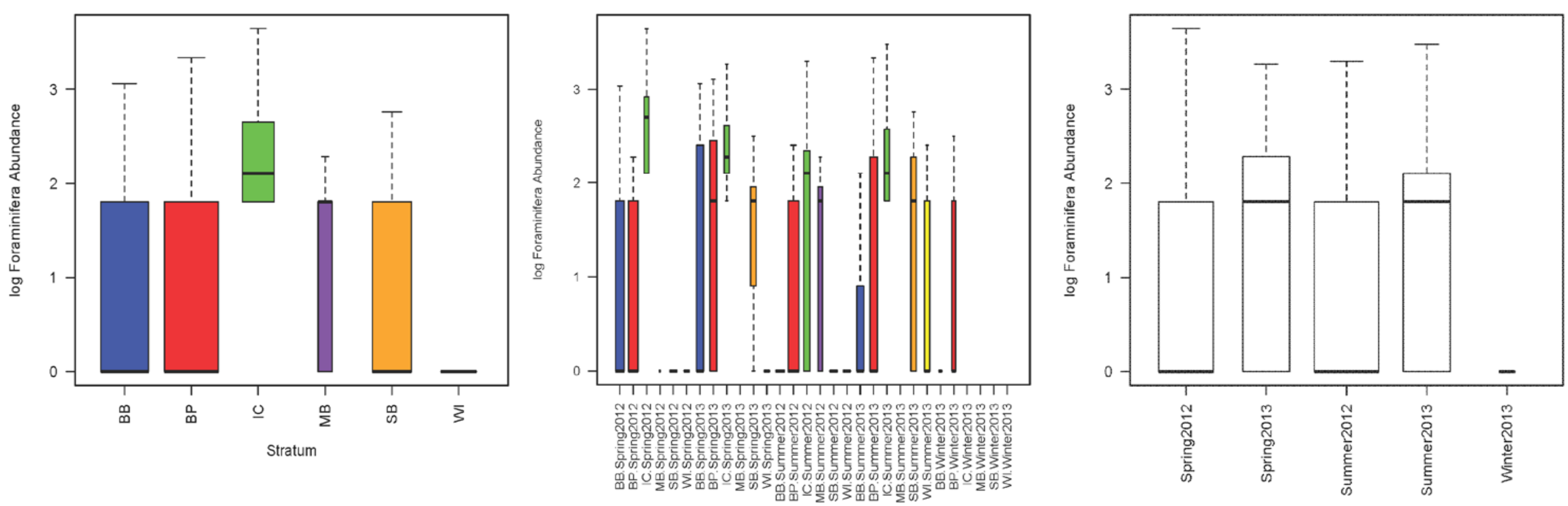
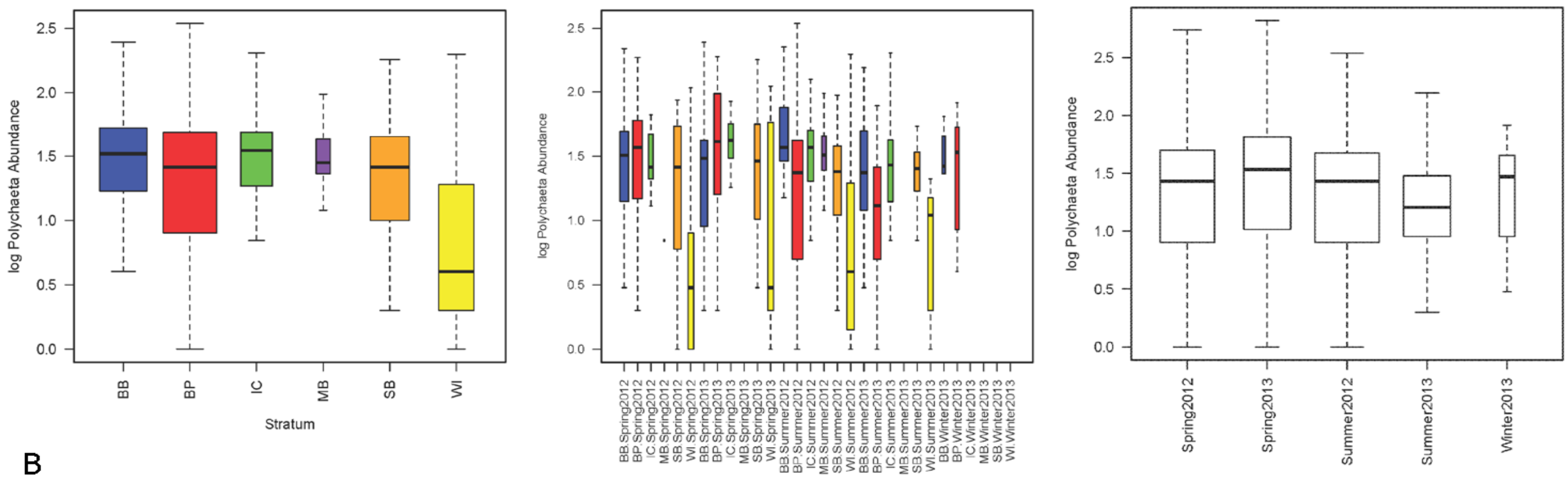


Figure C8 Relationships between Macrofauna Taxon-specific Abundance and Strata, Sampling Period, and Strata by Sampling Period, where A: Polychaete, B: Nematode, C: Oligochaete, D: Harpacticoid, E: Ostracod, F: Bivalve, and G: Cumacea

A



B

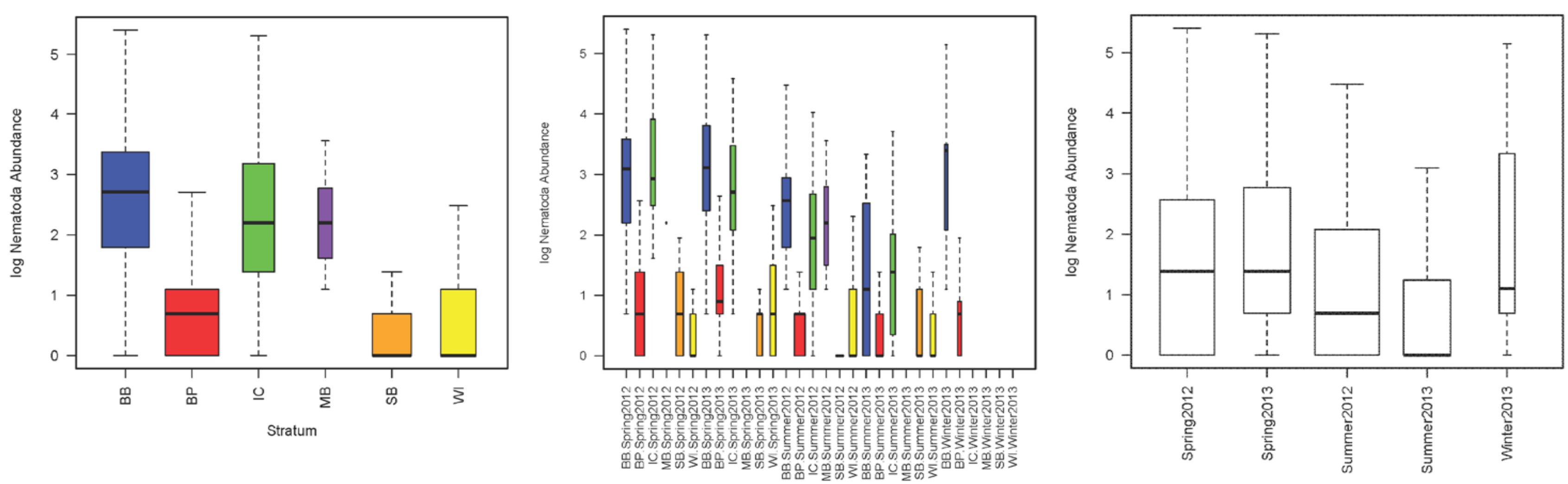


Figure C8 Continued

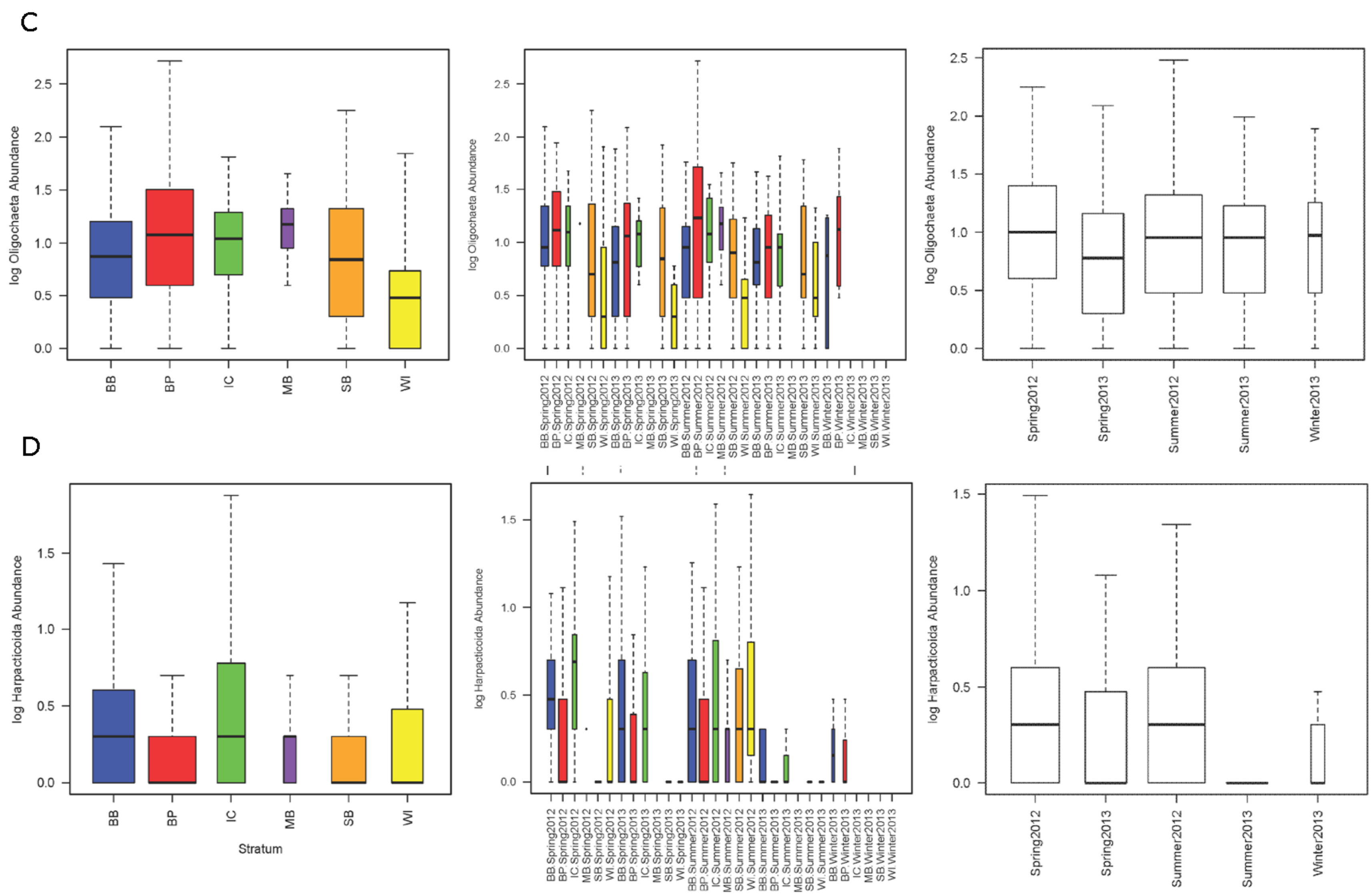
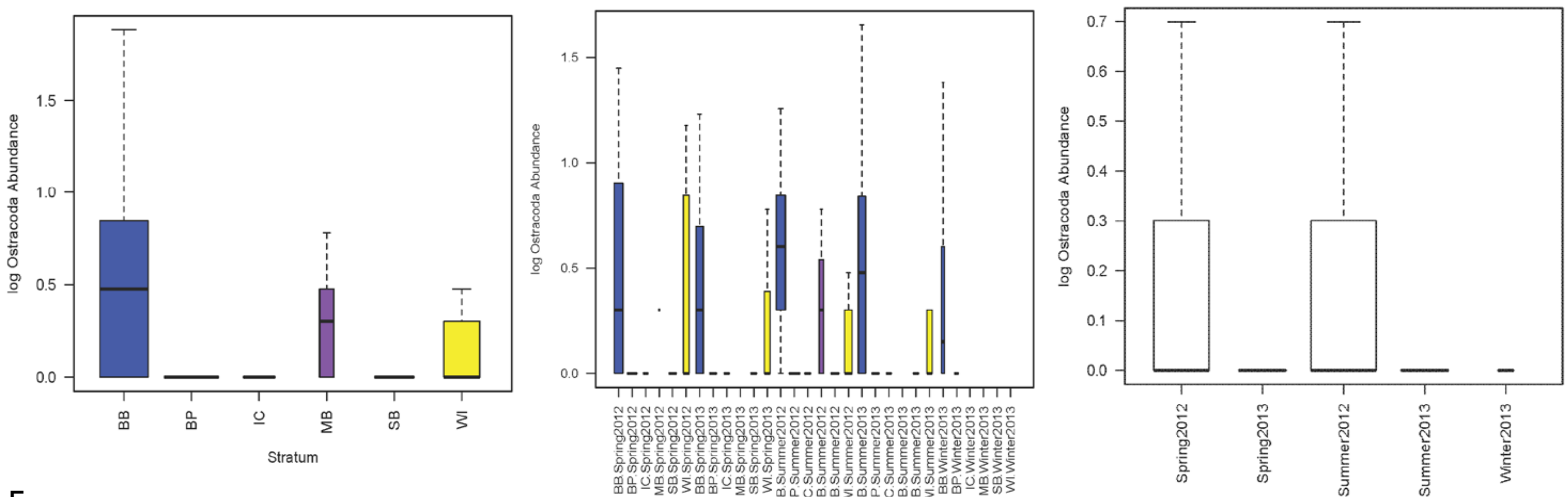


Figure C8 Continued

E



F

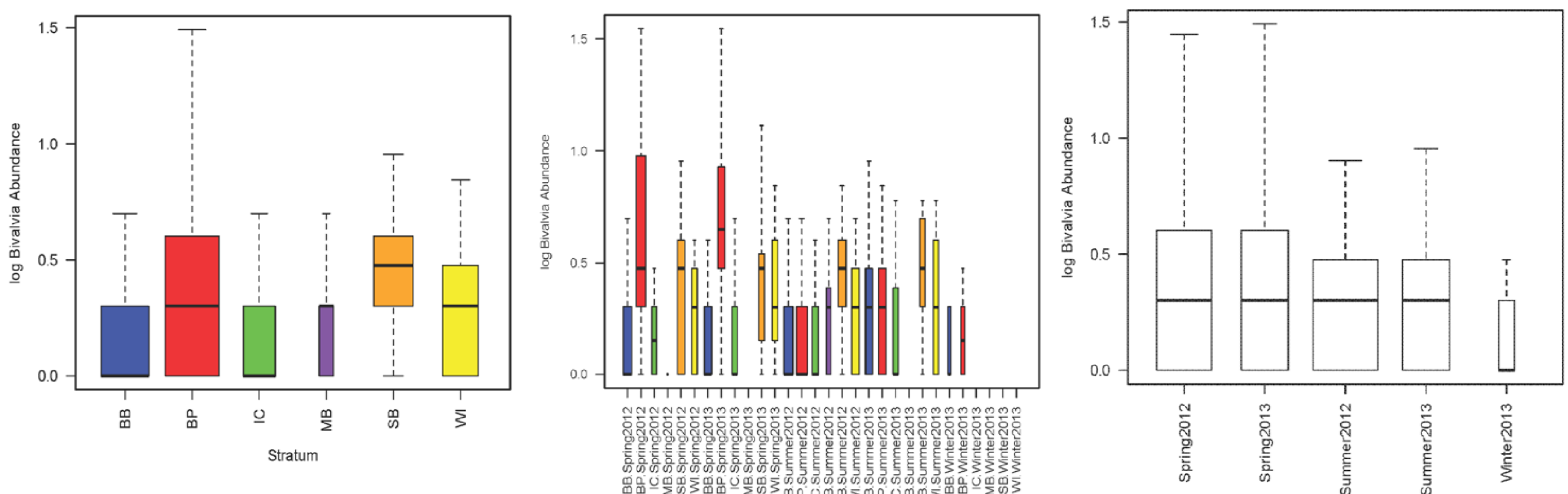
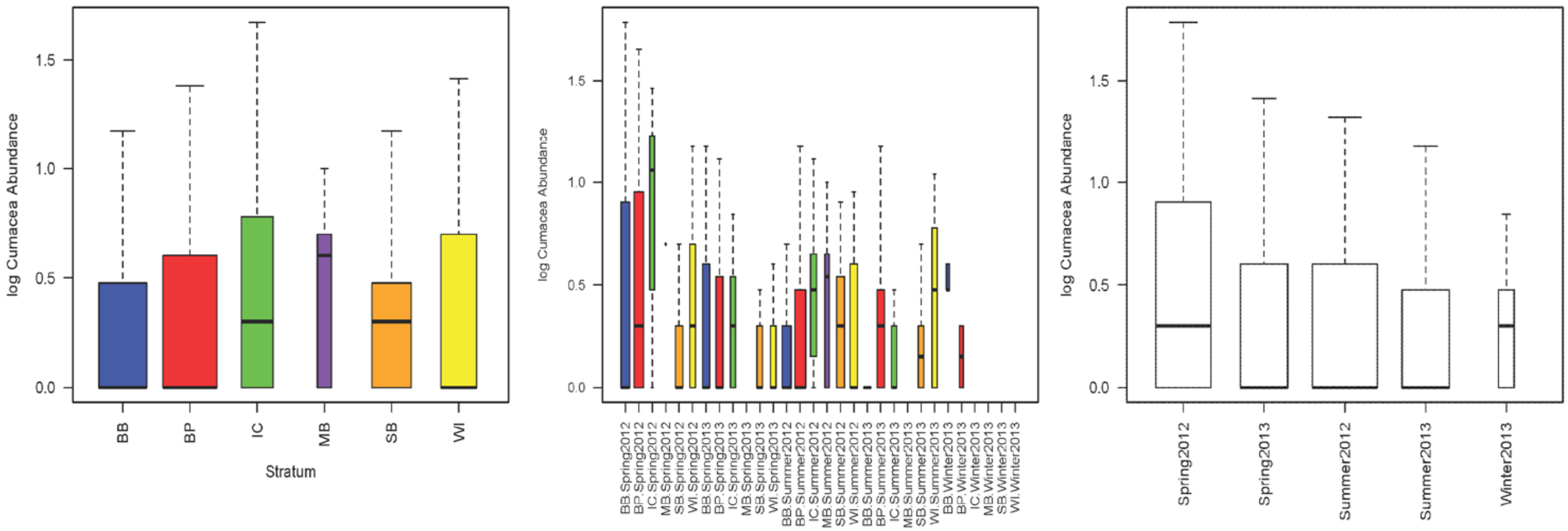


Figure C8 Continued

G



APPENDIX D

Taxonomic Composition Pie Charts

Figure D1 Relative Meiofaunal Taxonomic Composition at Sturgeon Bank Based on Samples Collected in 2012 and 2013

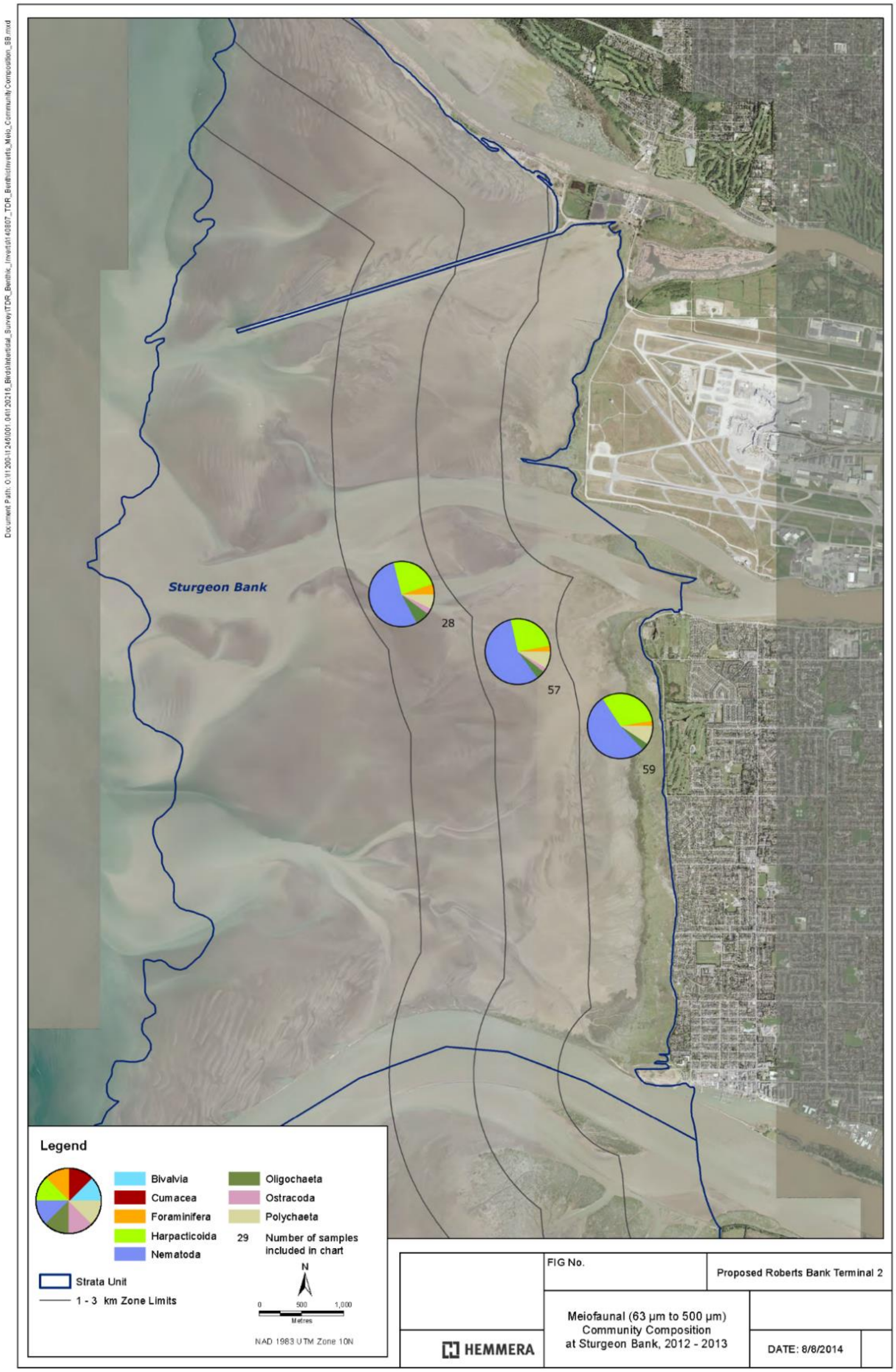


Figure D2 Relative Meiofaunal Taxonomic Composition at Roberts Bank (Westham Island, Brunswick Point, and Inter-causeway Area) Based on Samples Collected in 2012 and 2013

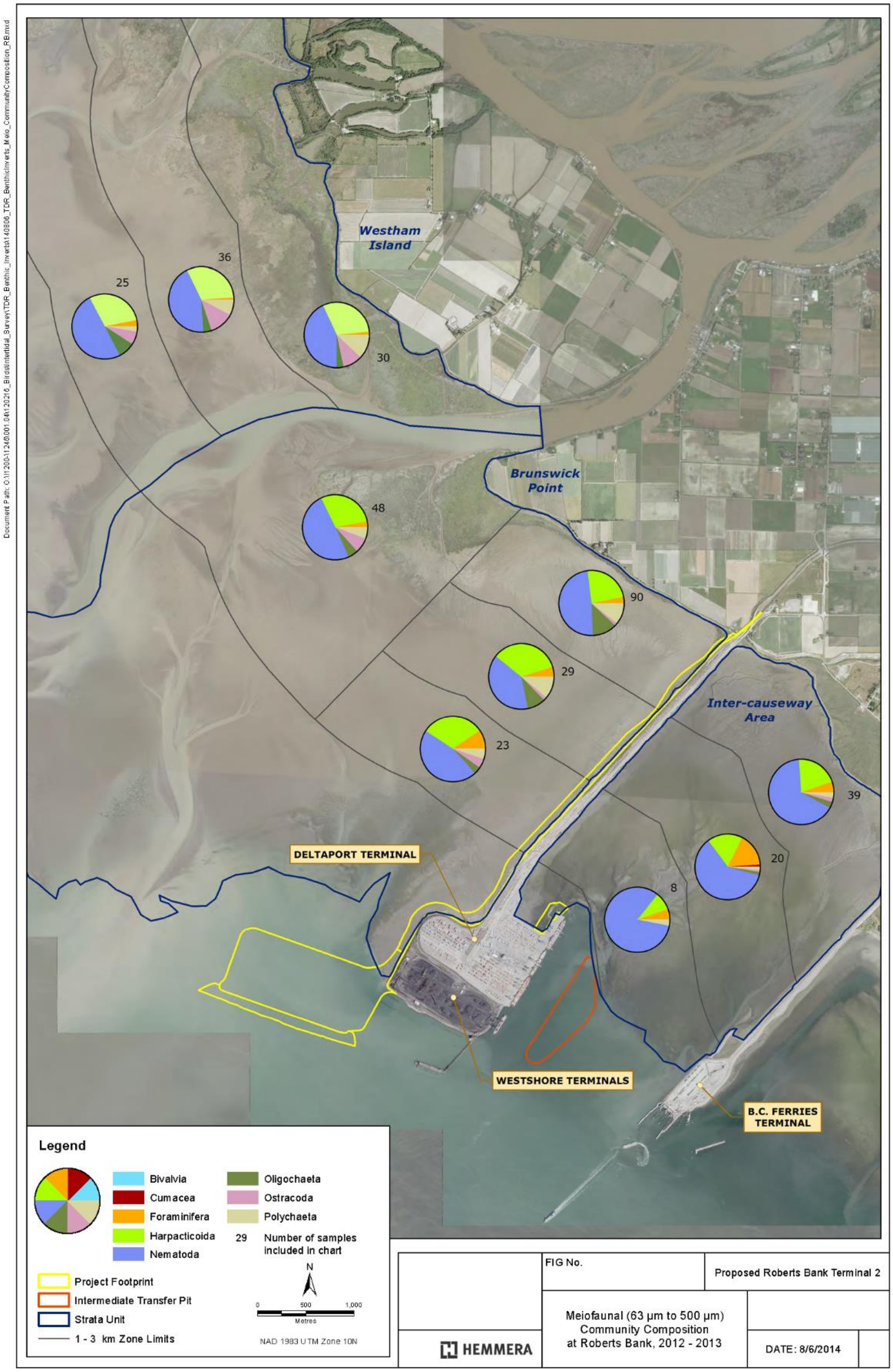


Figure D3 Relative Meiofaunal Taxonomic Composition at Boundary Bay and Mud Bay Based on Samples Collected in 2012 and 2013

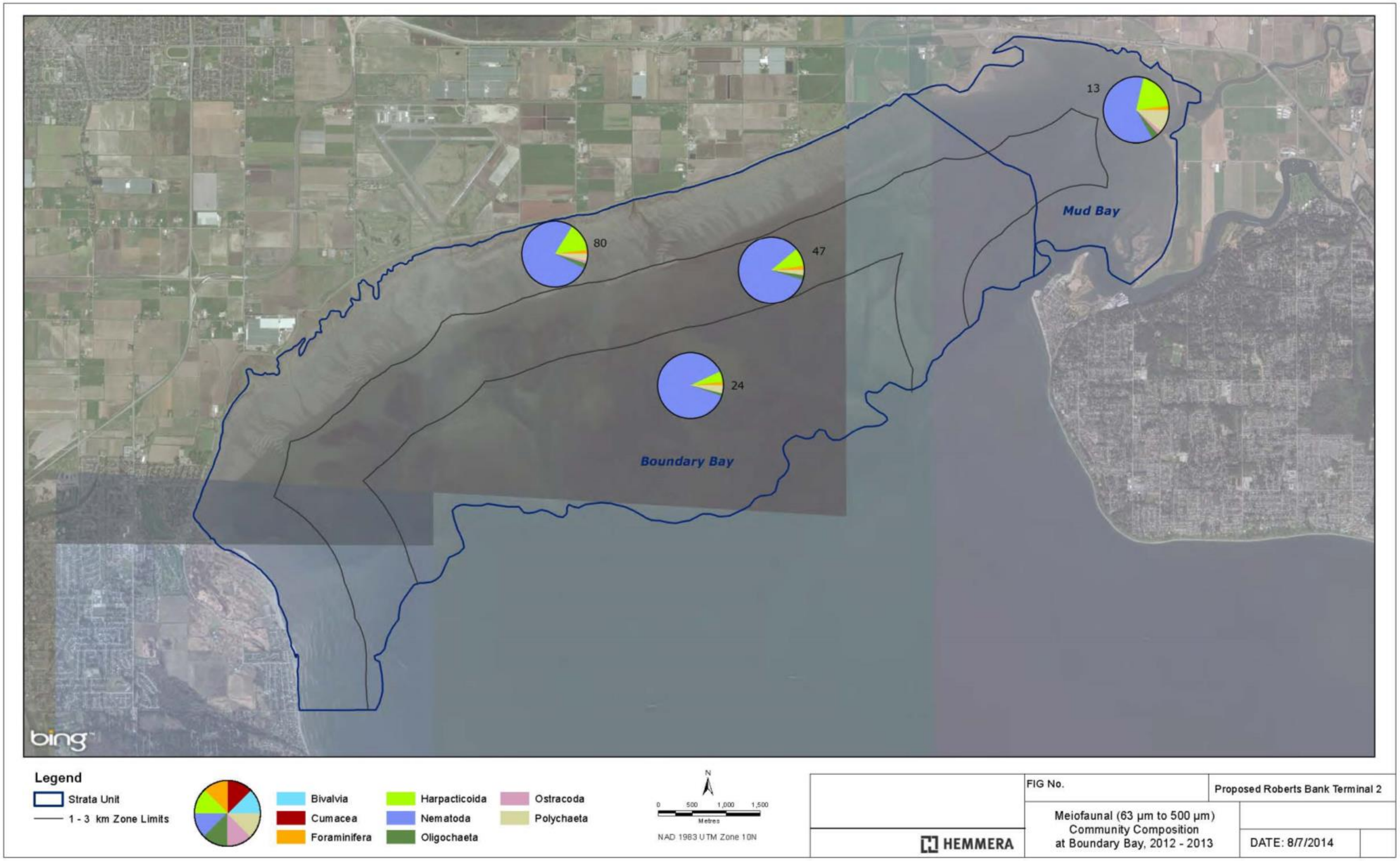


Figure D4 Relative Macrofaunal Taxonomic Composition at Sturgeon Bank Based on Samples Collected in 2012 and 2013

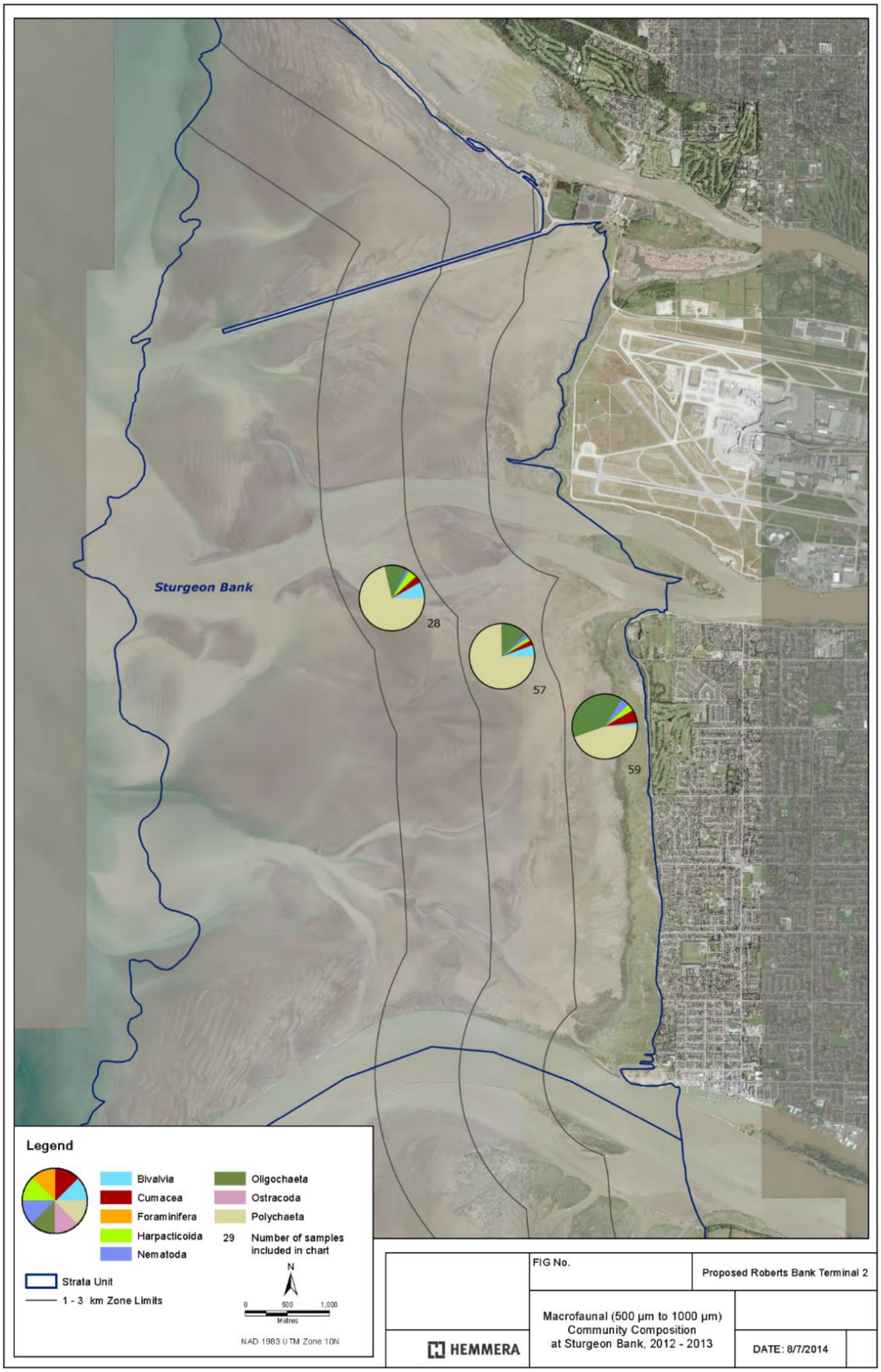


Figure D5 Relative Macrofaunal Taxonomic Composition at Roberts Bank (Westham Island, Brunswick Point, and Inter-causeway Area) Based on Samples Collected in 2012 and 2013

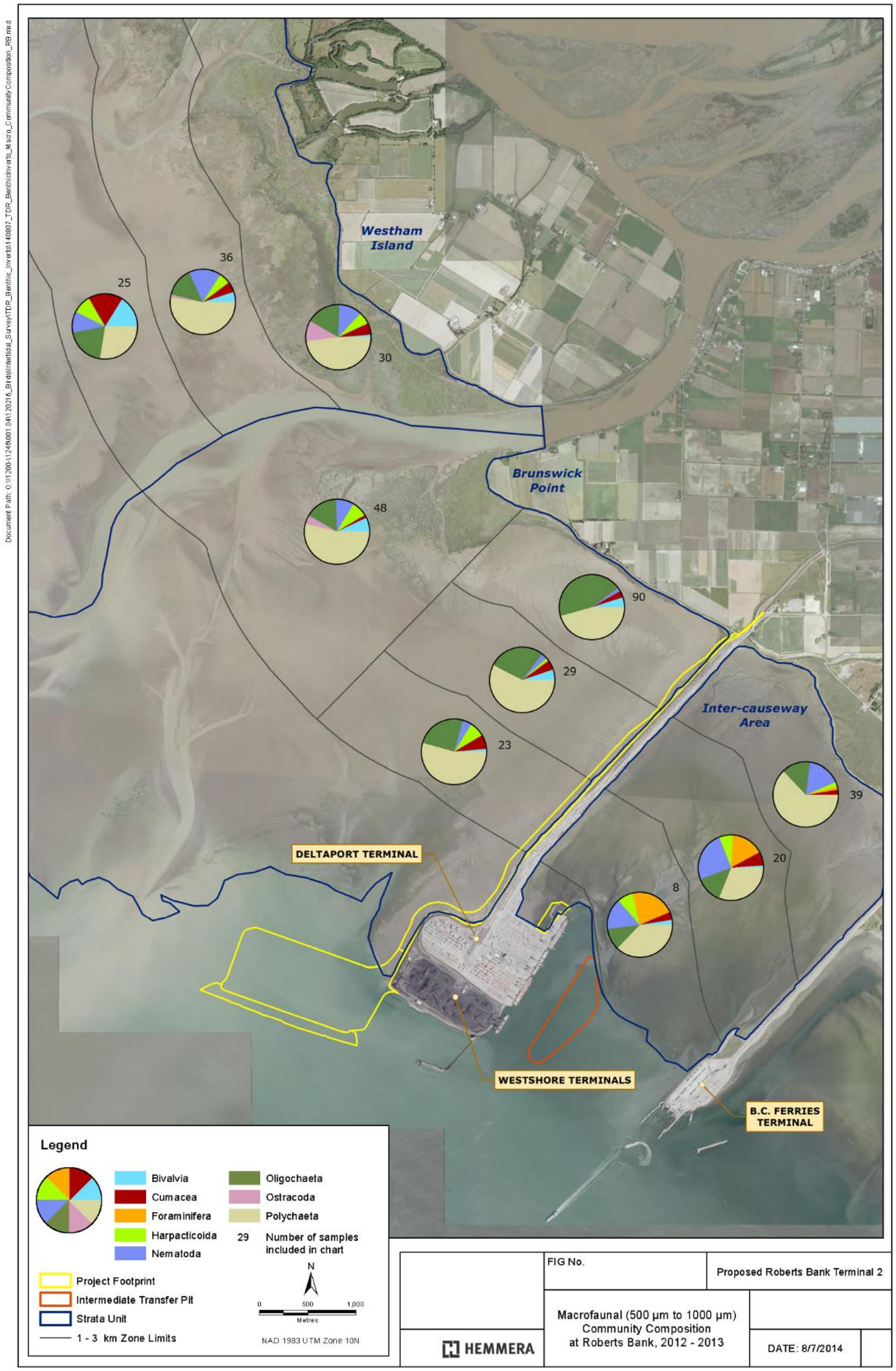
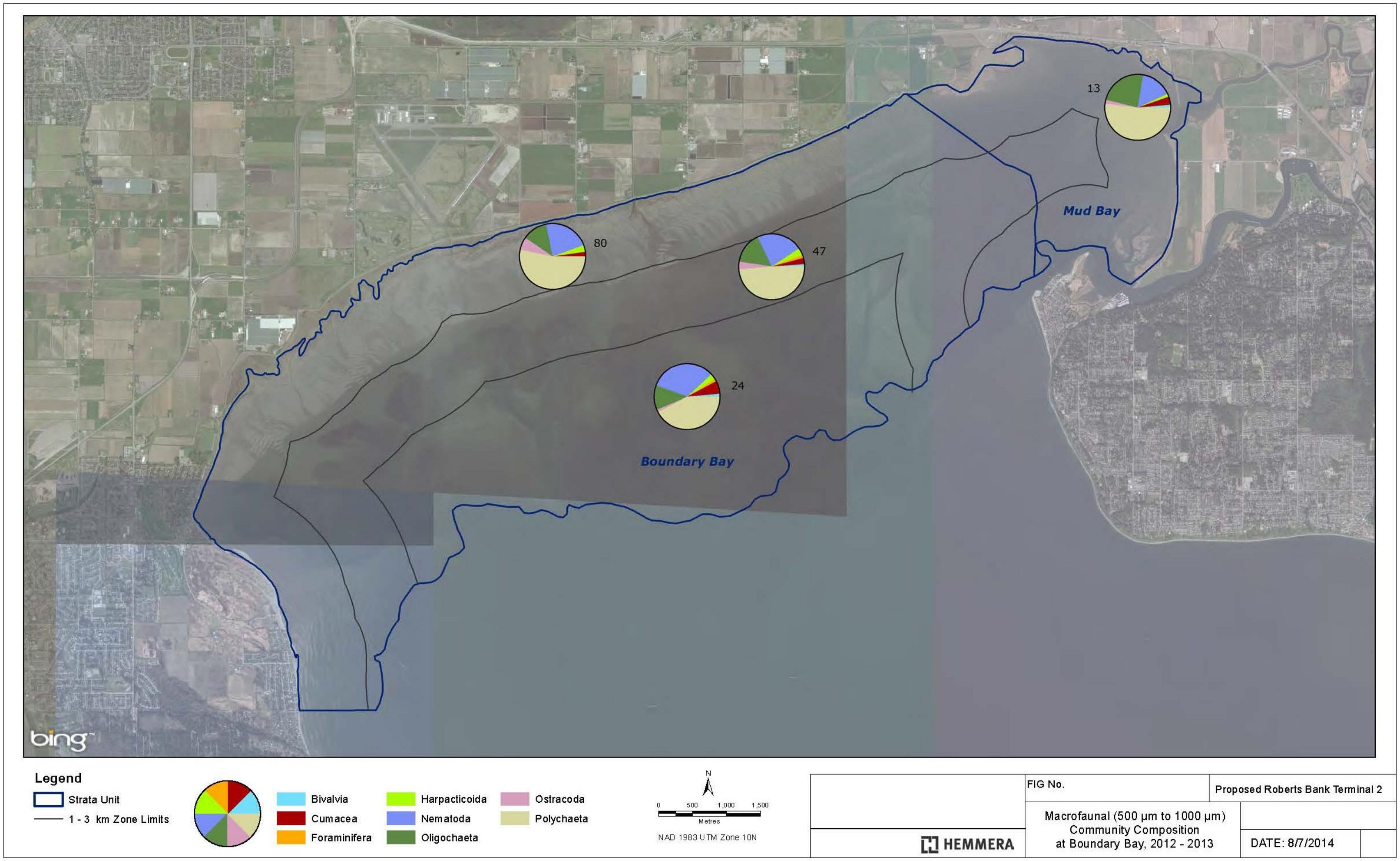


Figure D6 Relative Macrofaunal Taxonomic Composition at Boundary Bay and Mud Bay Based on Samples Collected in 2012 and 2013



APPENDIX E

Univariate Linear Regression Plots

Figure E1 Linear Relationships between Meiofauna Biotic Variables and Salinity (measured as adjusted chloride concentration) Broken Down by Sampling Period (left) and Stratum (right), where A: Abundance, B: Biomass, C: Polychaete, D: Nematode, E: Oligochaete, F: Harpacticoid, G: Cumacea, and H: Foraminifera

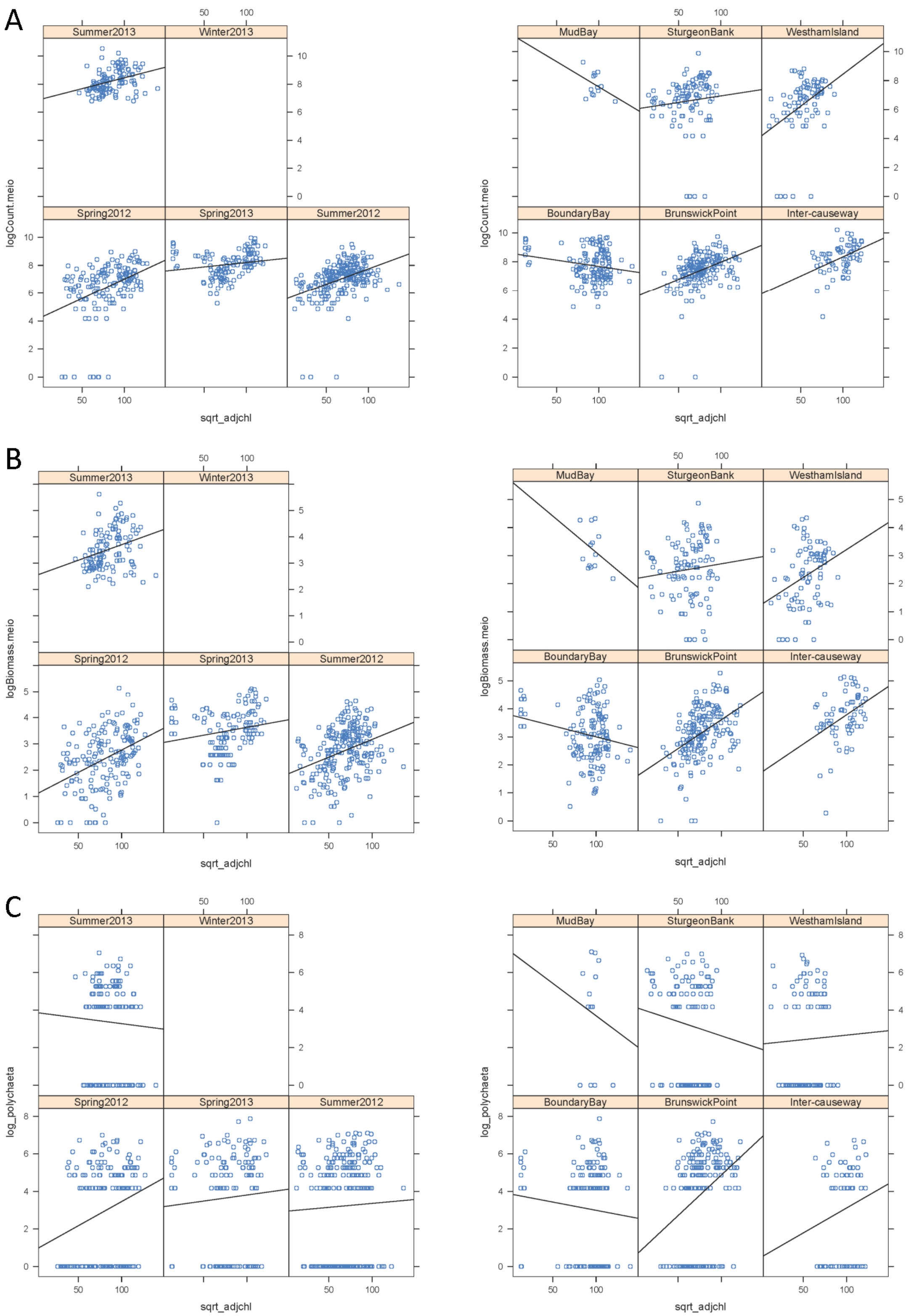


Figure E1 Continued

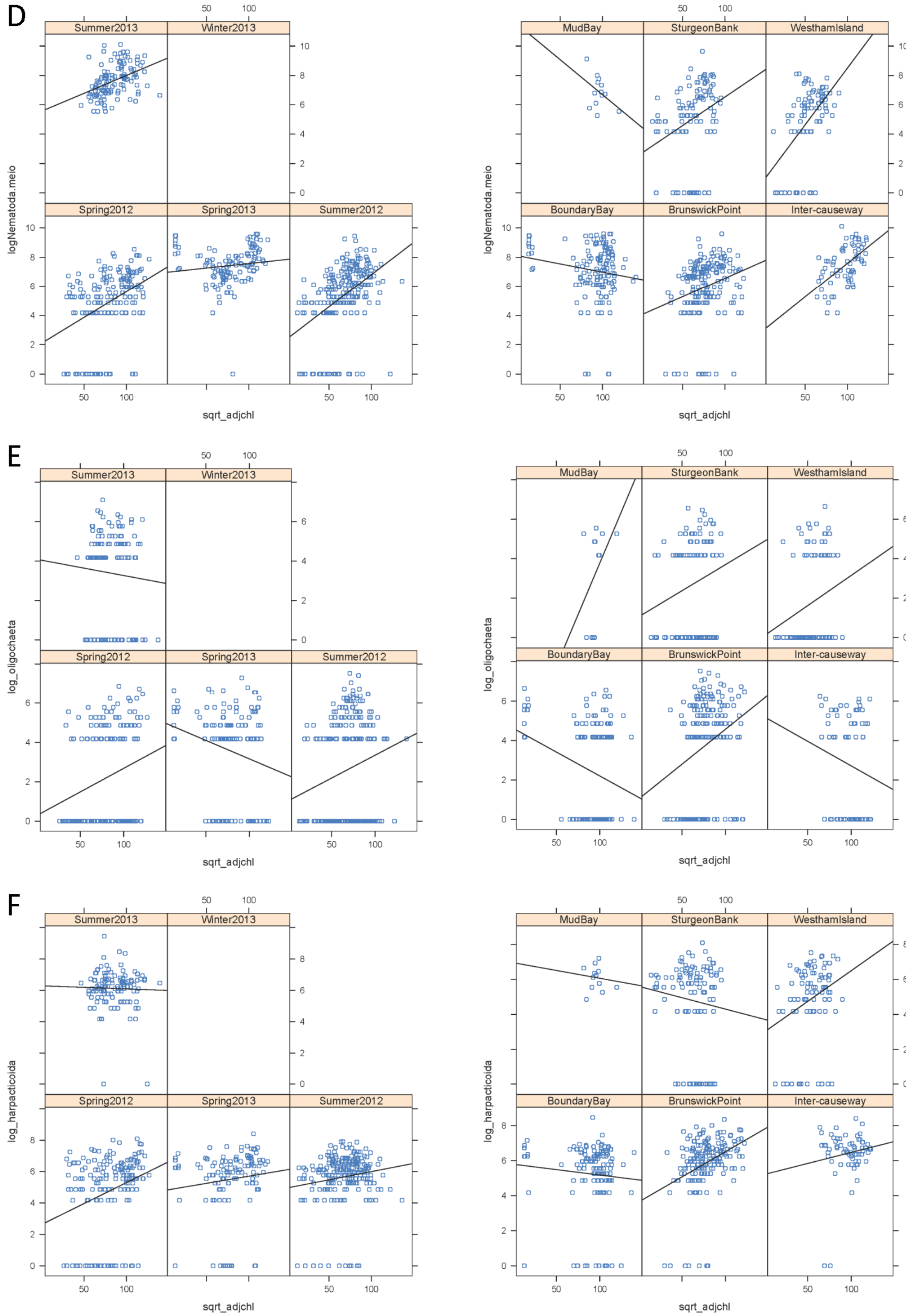


Figure E1 Continued

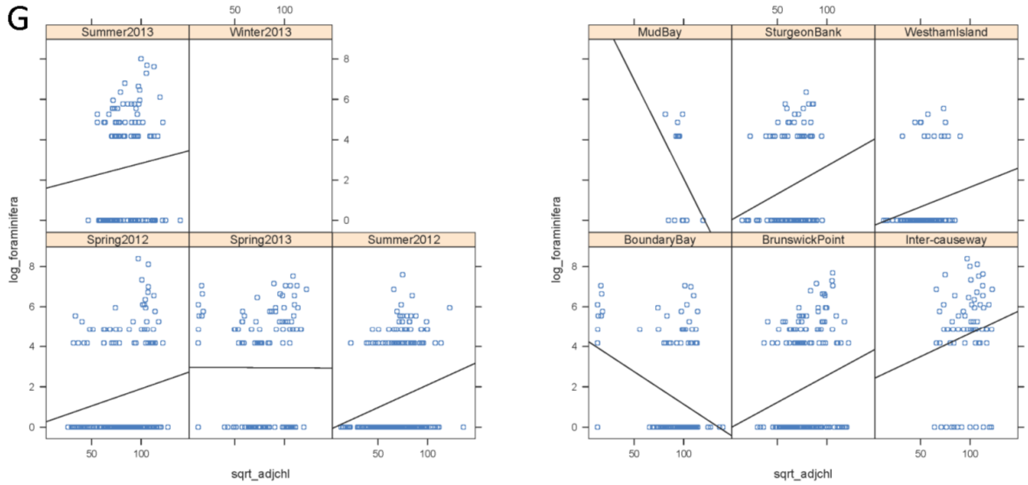


Figure E2 Linear Relationships between Macrofauna Biotic Variables and Salinity (measured as adjusted chloride concentration) Broken Down by Sampling Period (left) and Stratum (right), where A: Abundance, B: Biomass, C: Nematode, D: Oligochaete, E: Ostracoda

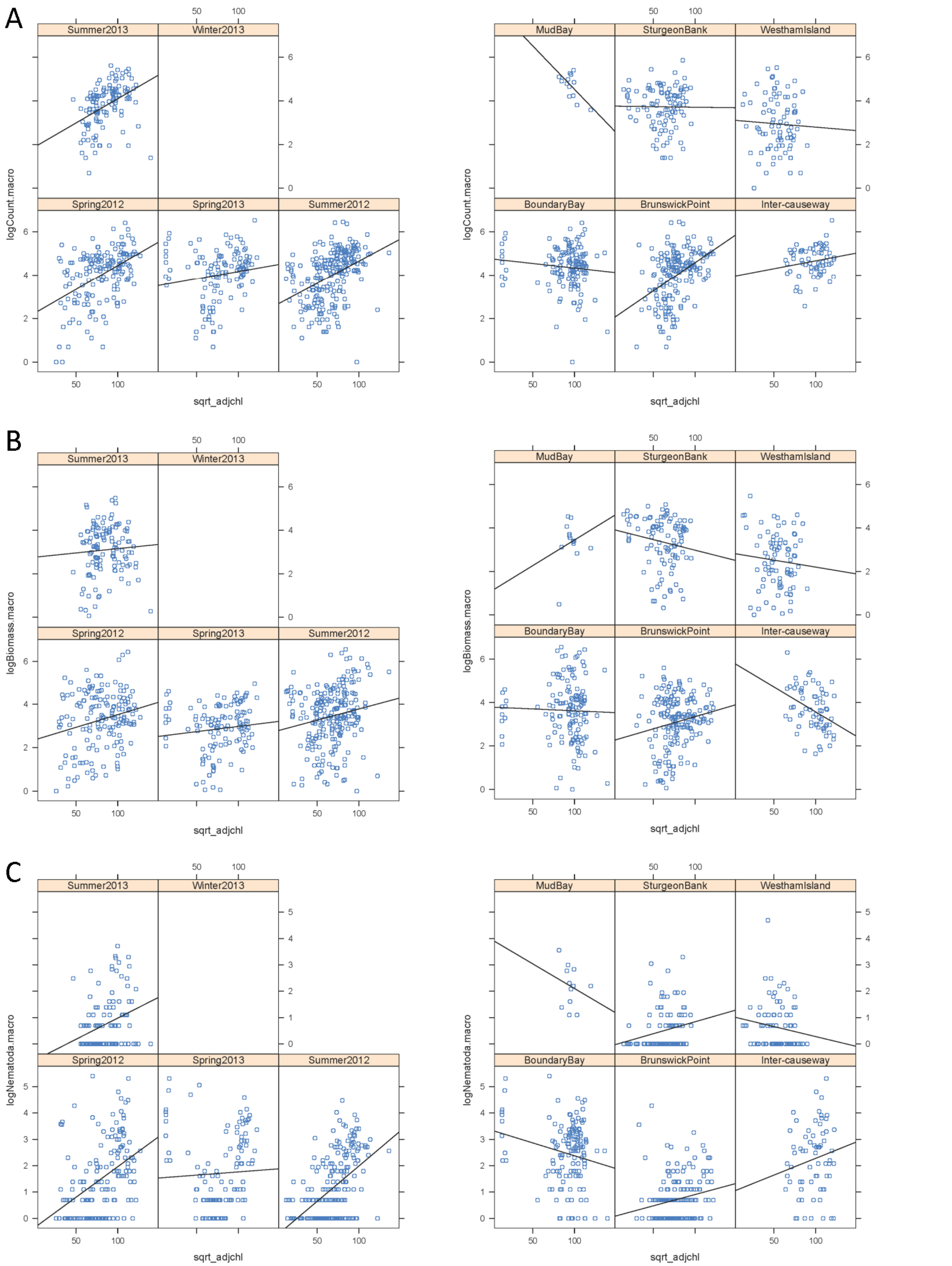
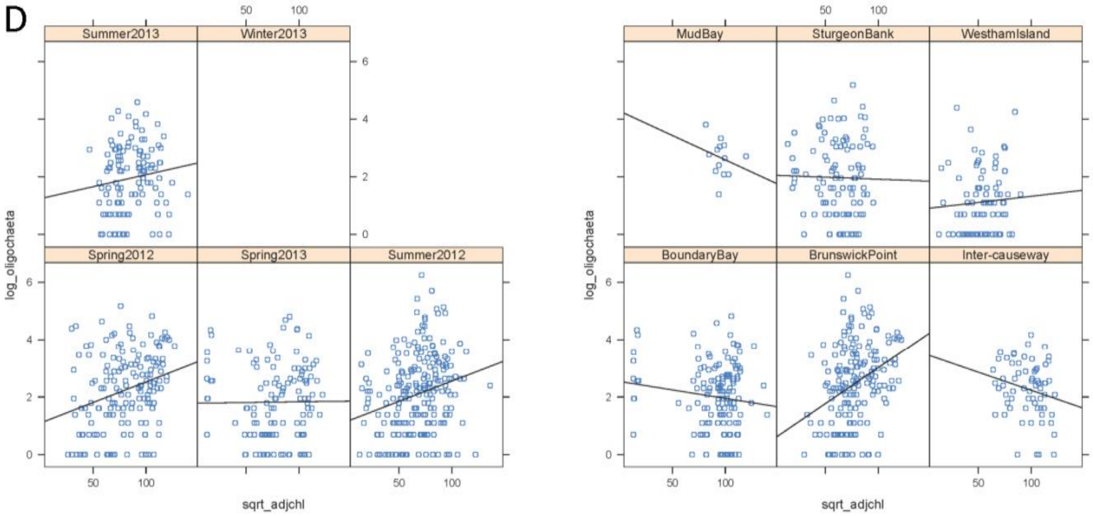


Figure E2 Continued

D



E

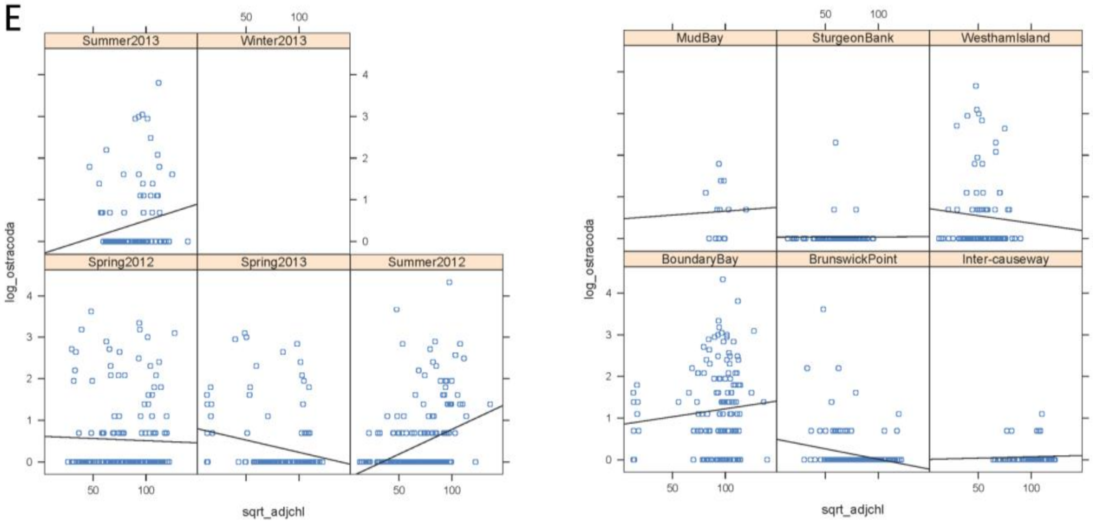
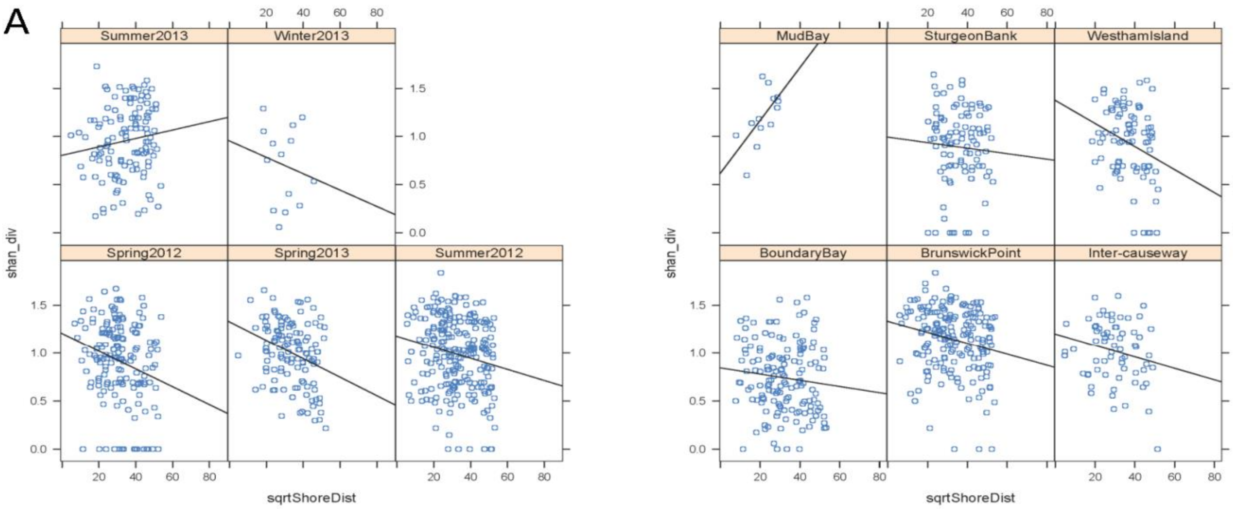
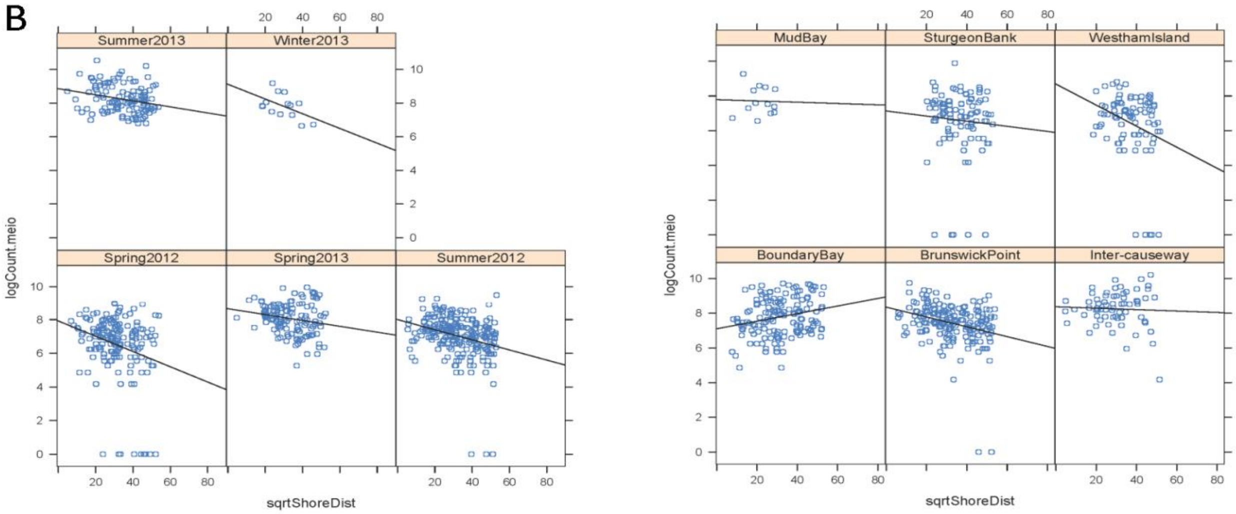


Figure E3 Linear Relationships between Meiofauna Biotic Variables and Tidal Elevation (measured as distance from shore) Broken Down by Sampling Period (left) and Stratum (right), where A: Diversity, B: Abundance, C: Biomass, D: Polychaete, E: Nematode, F: Oligochaete, G: Harpacticoid

A



B



C

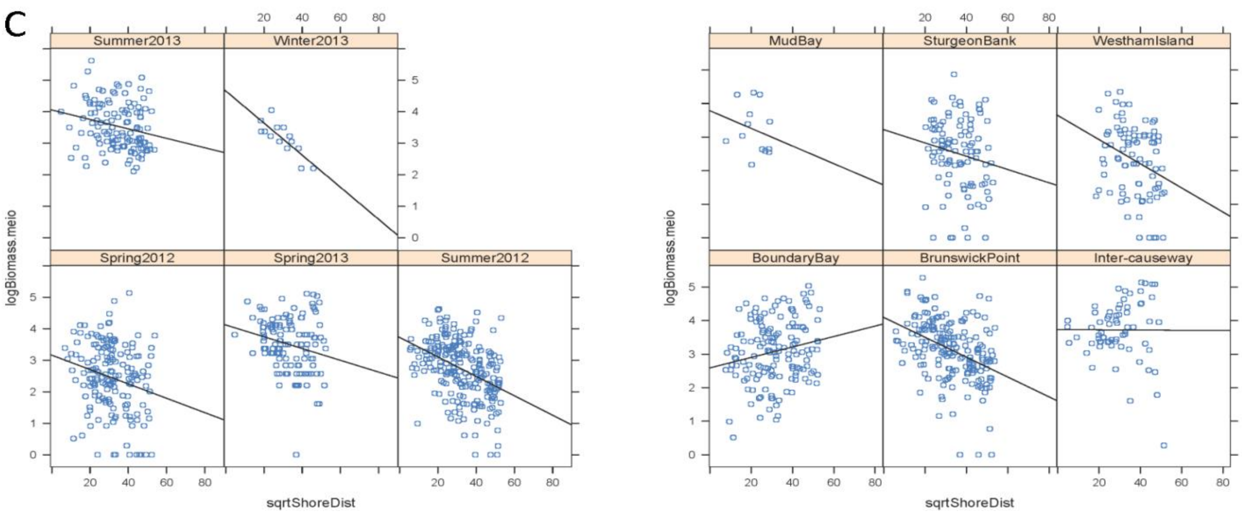
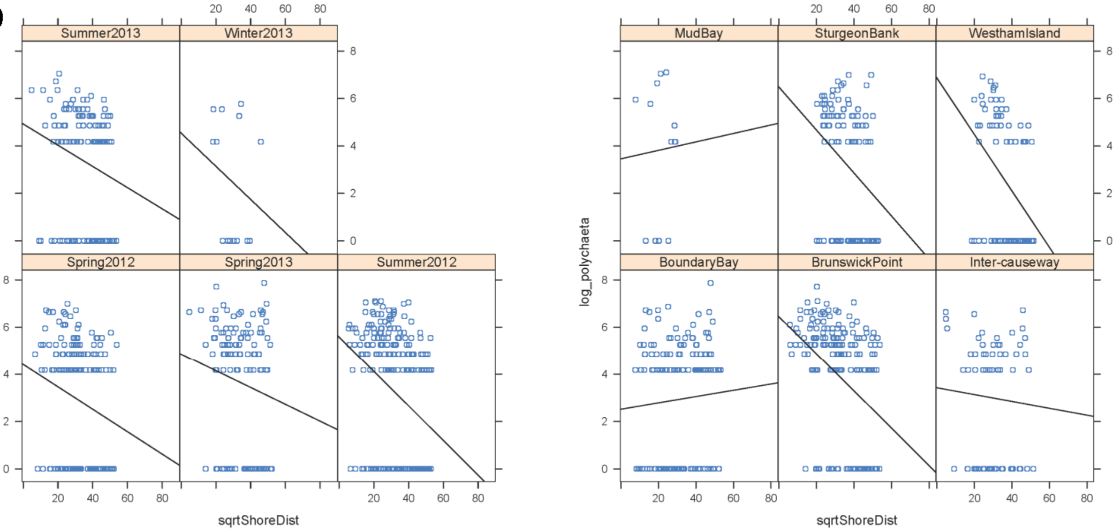


Figure E3 Continued

D



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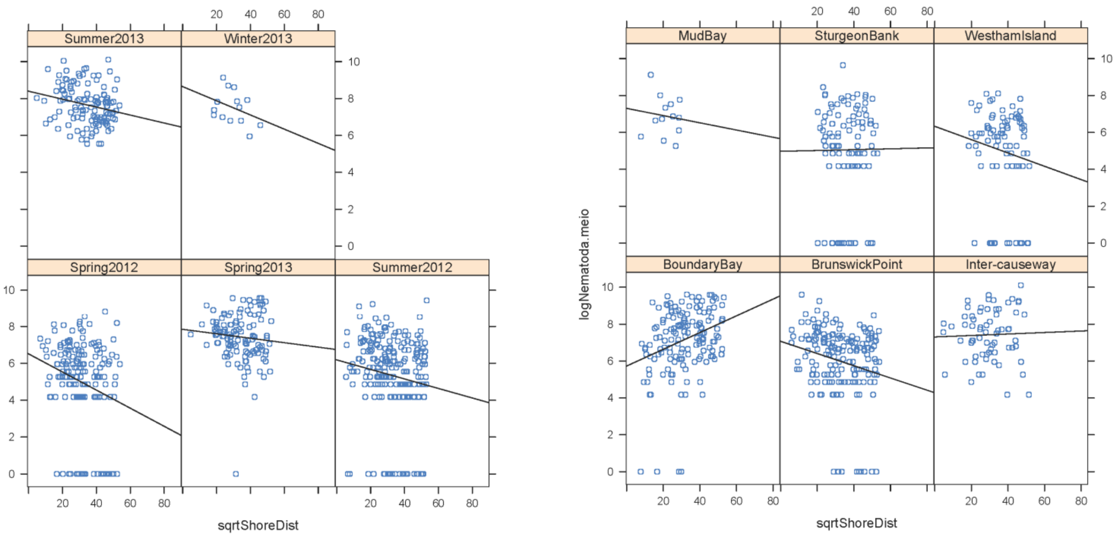


F

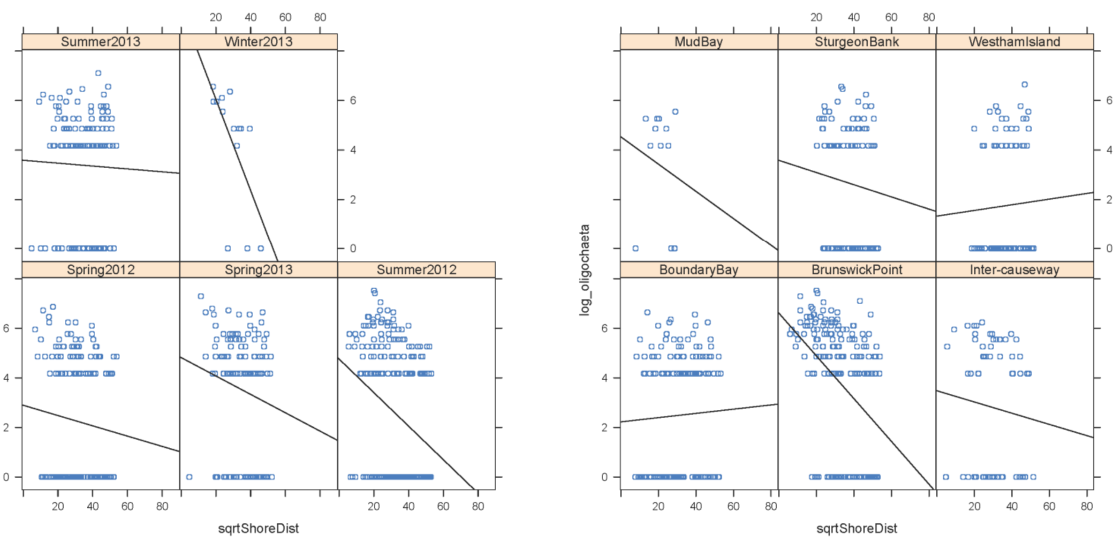


Figure E3 Continued

G

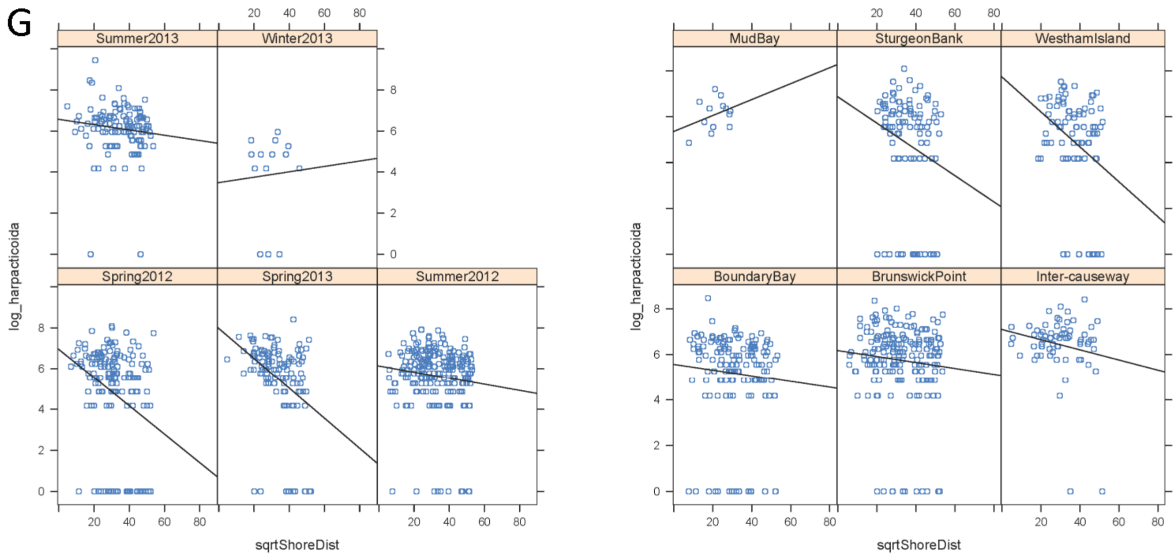


Figure E4 Linear Relationships between Macrofauna Biotic Variables and Tidal Elevation (measured as distance from shore) Broken Down by Sampling Period (left) and Stratum (right), where A: Abundance, B: Polychaete, C: Nematode, D: Oligochaete

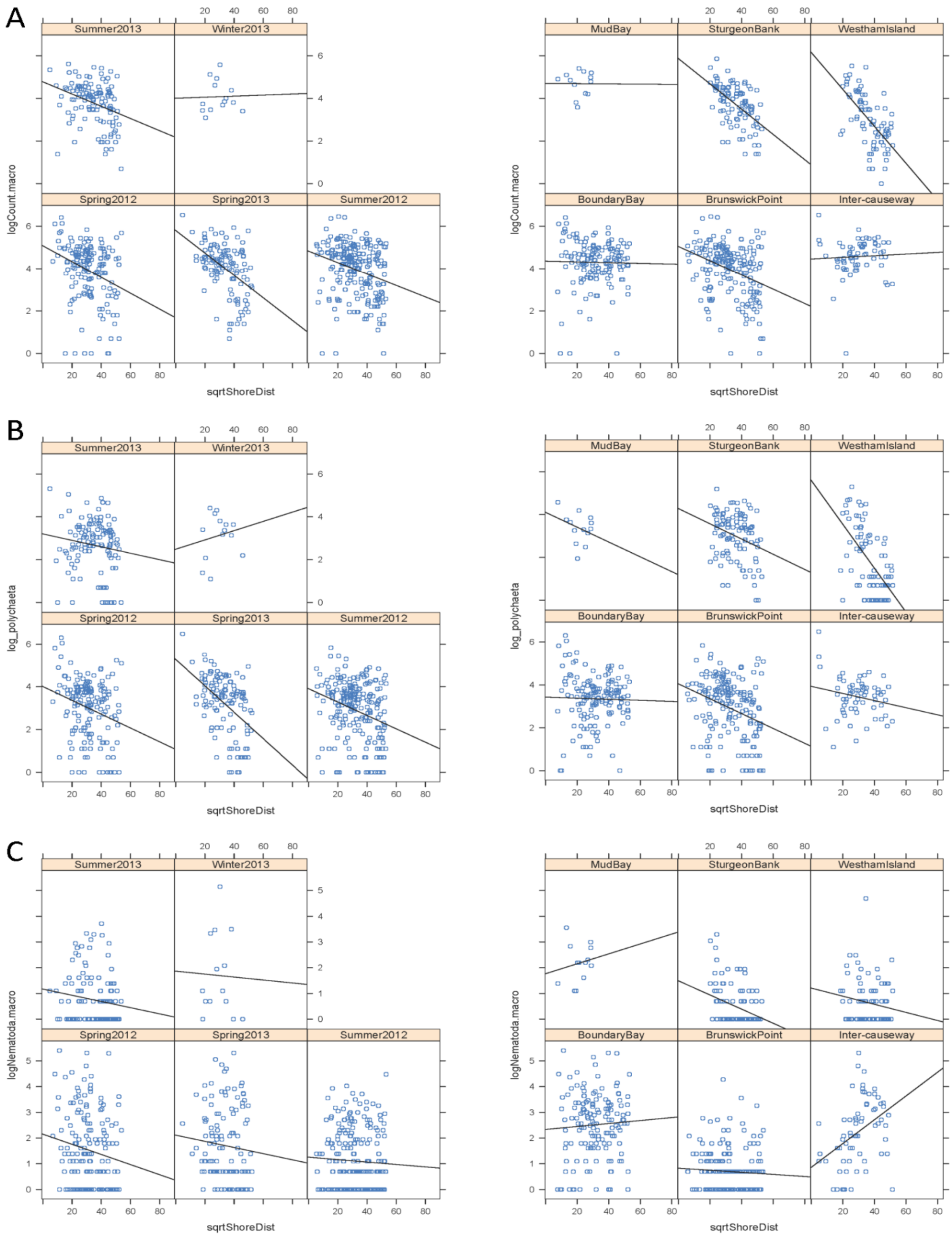


Figure E4 Continued

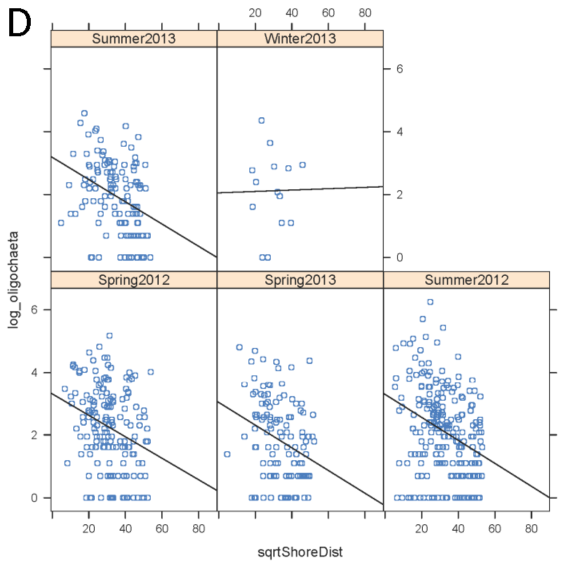
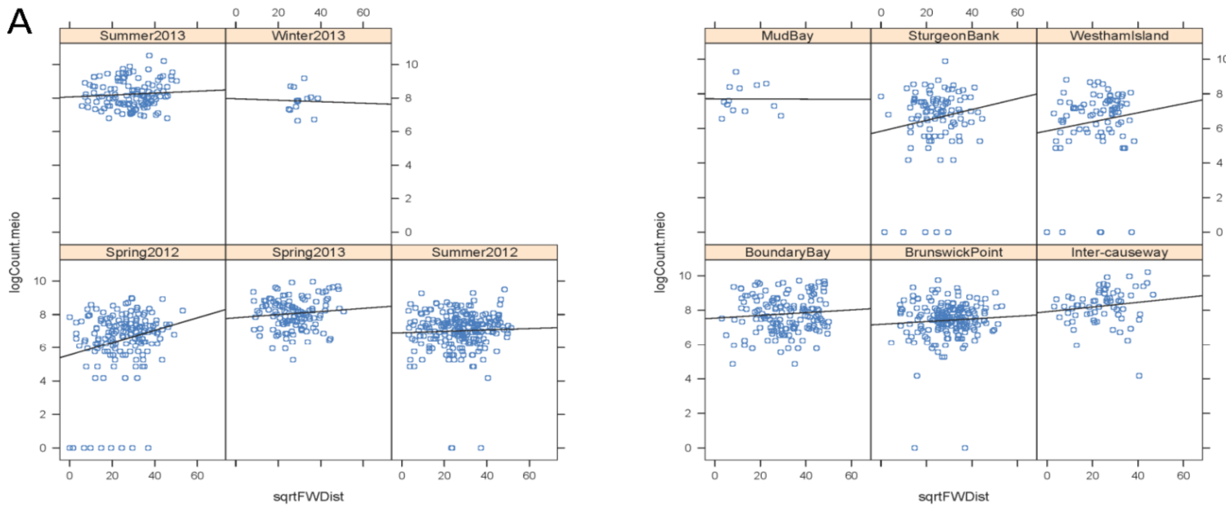
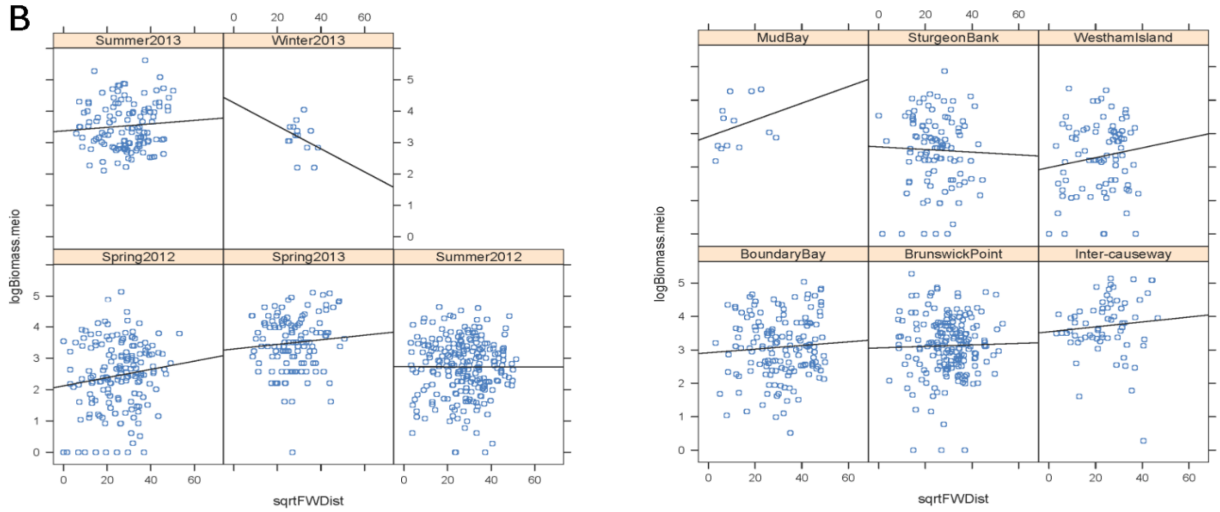


Figure E5 Linear Relationships between Meiofauna Biotic Variables and Freshwater Source (measured as distance to freshwater) Broken Down by Sampling Period (left) and Stratum (right), where A: Abundance, B: Abundance, C: Biomass, D: Polychaete, E: Nematode, F: Oligochaete, G: Harpacticoid

A



B



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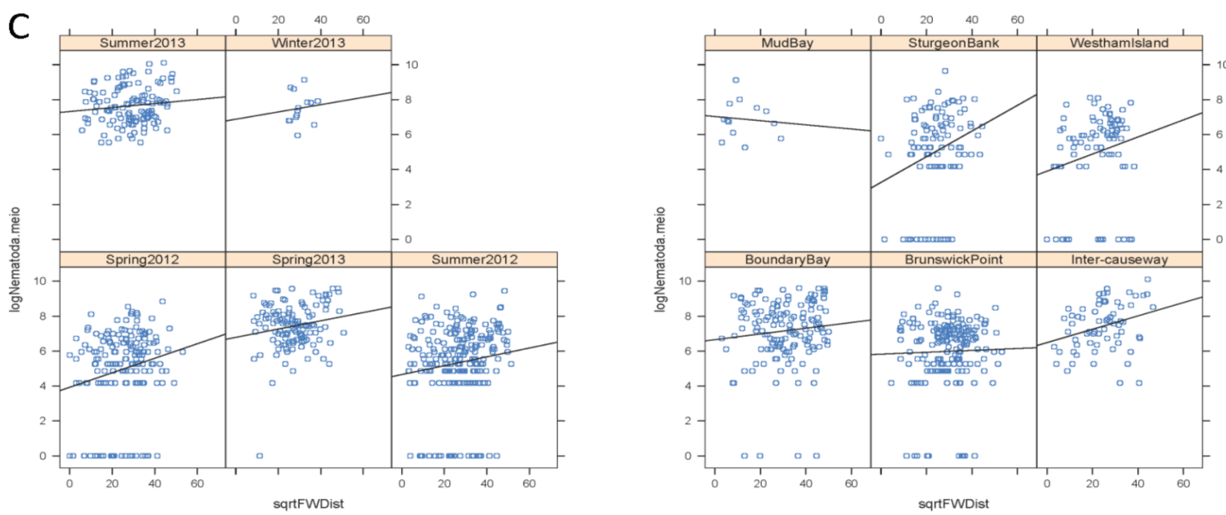
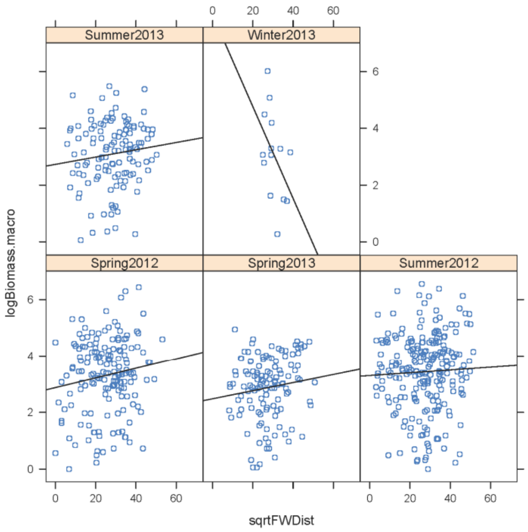


Figure E6 Linear Relationship between Macrofauna Biomass and Freshwater Source (measured as distance to freshwater) Broken Down by Sampling Period (left) and Stratum (right)



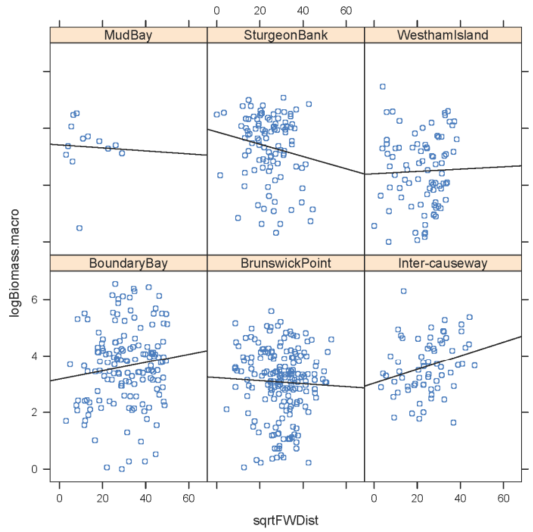


Figure E7 Linear Relationships between Meiofauna Biotic Variables and Total Organic Carbon (TOC) Broken Down by Sampling Period (left) and Stratum (right), where A: Diversity, B: Abundance, C: Biomass, D: Polychaete, E: Oligochaete, F: Harpacticoid, G: Cumacea, and H: Foraminifera

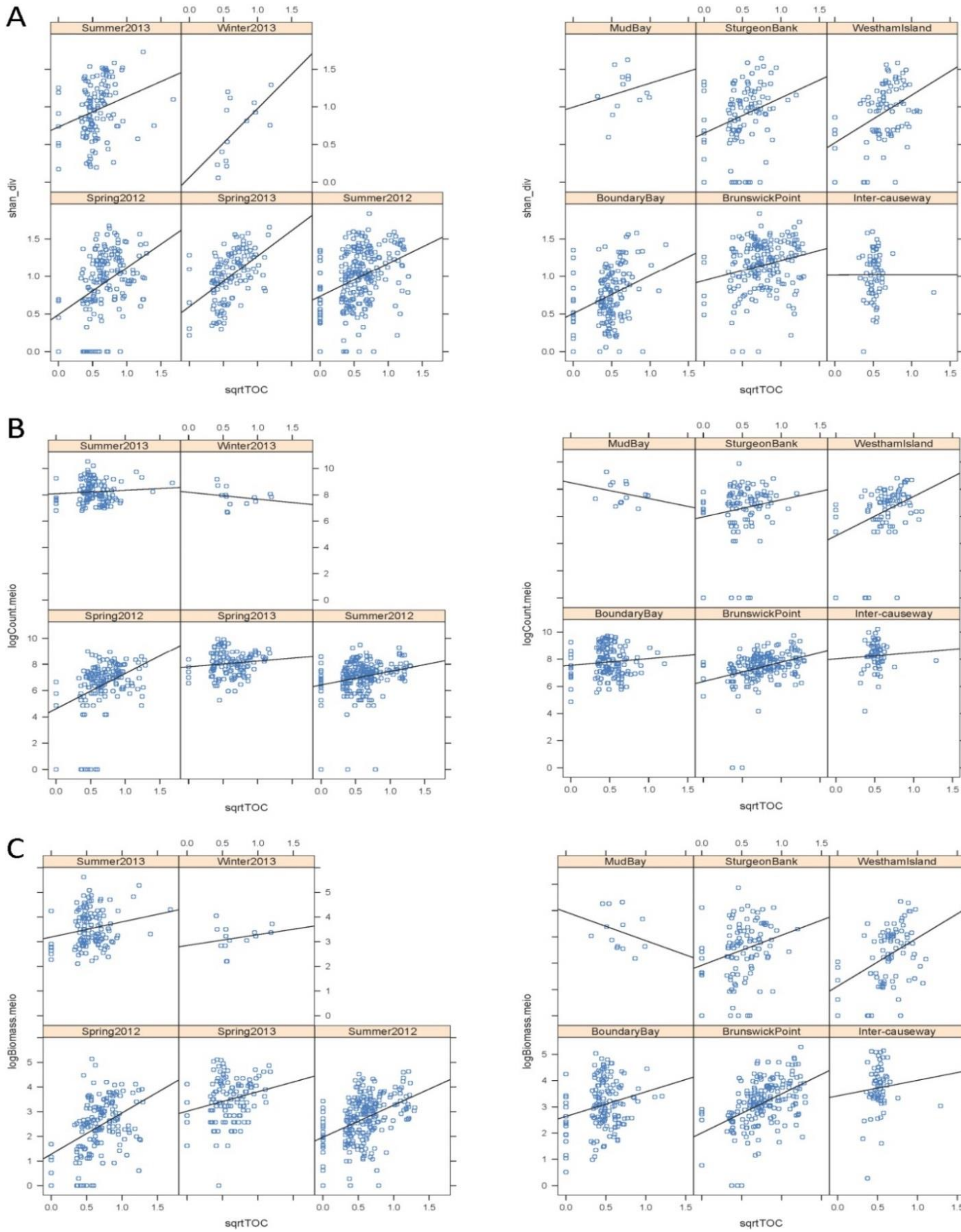
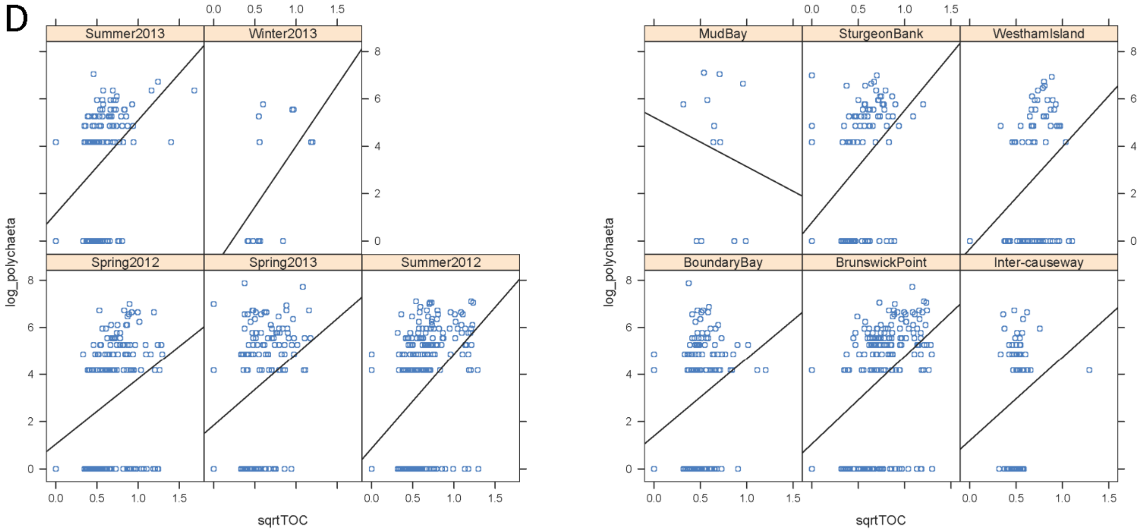


Figure E7 Continued

D



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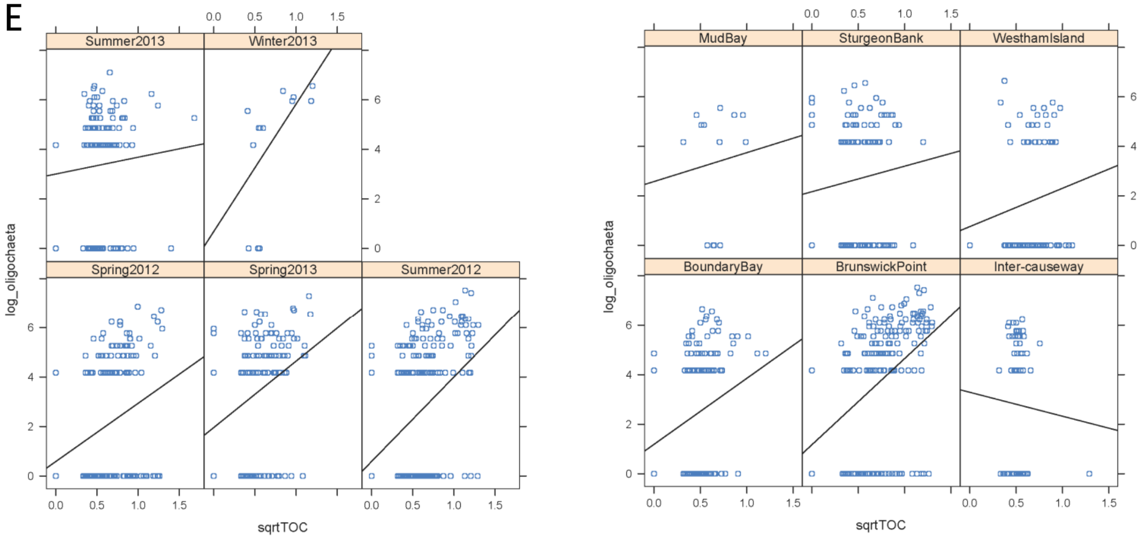


F

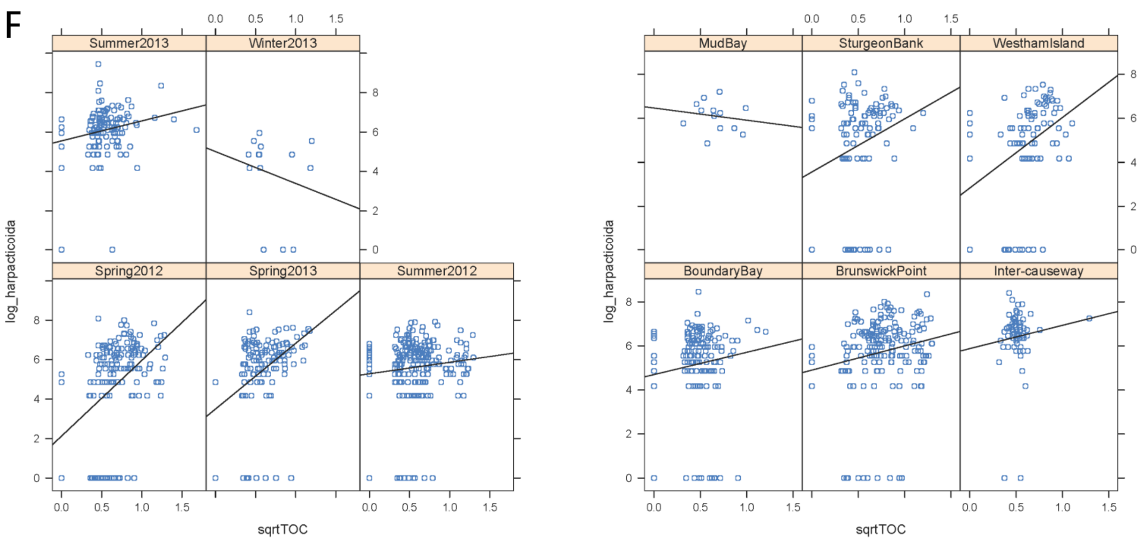
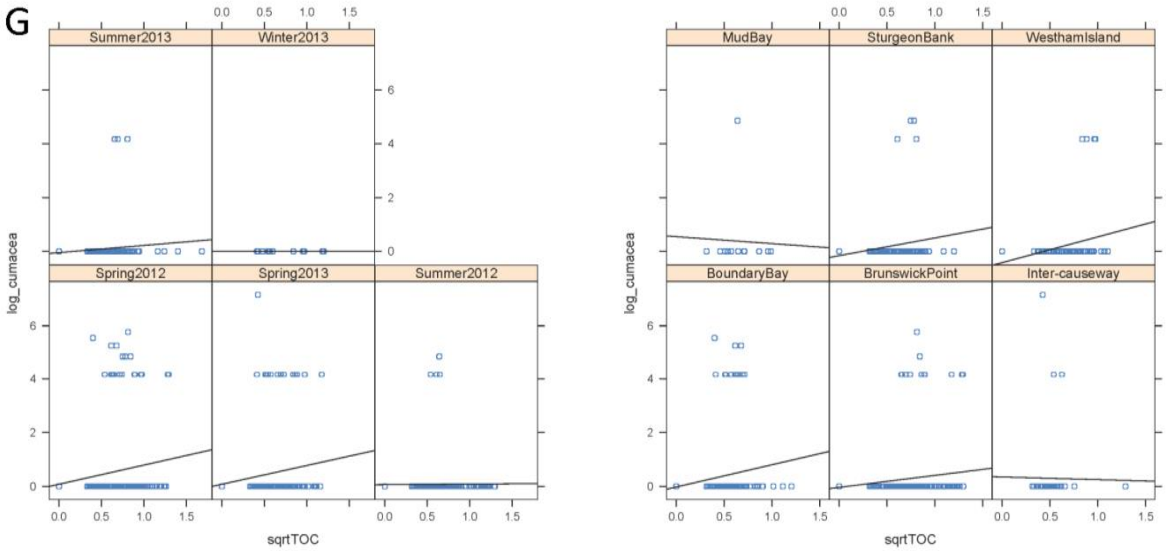


Figure E7 Continued

G



H

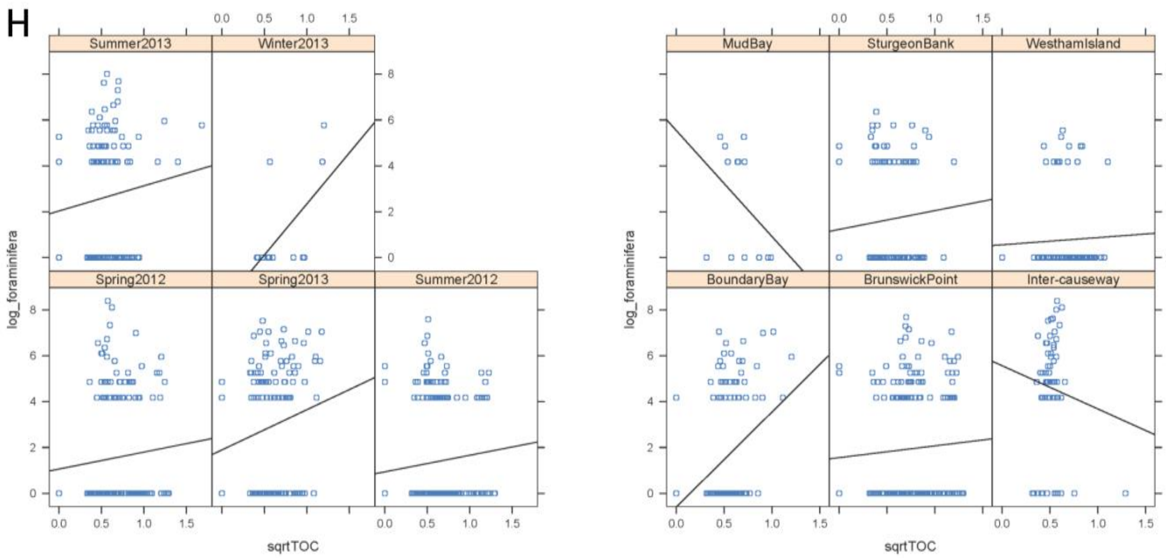


Figure E8 Linear Relationships between Macrofauna Biotic Variables and Total Organic Carbon (TOC) Broken Down by Sampling Period (left) and Stratum (right), where A: Diversity, B: Abundance, C: Biomass, D: Polychaete, E: Oligochaete, F: Cumacea

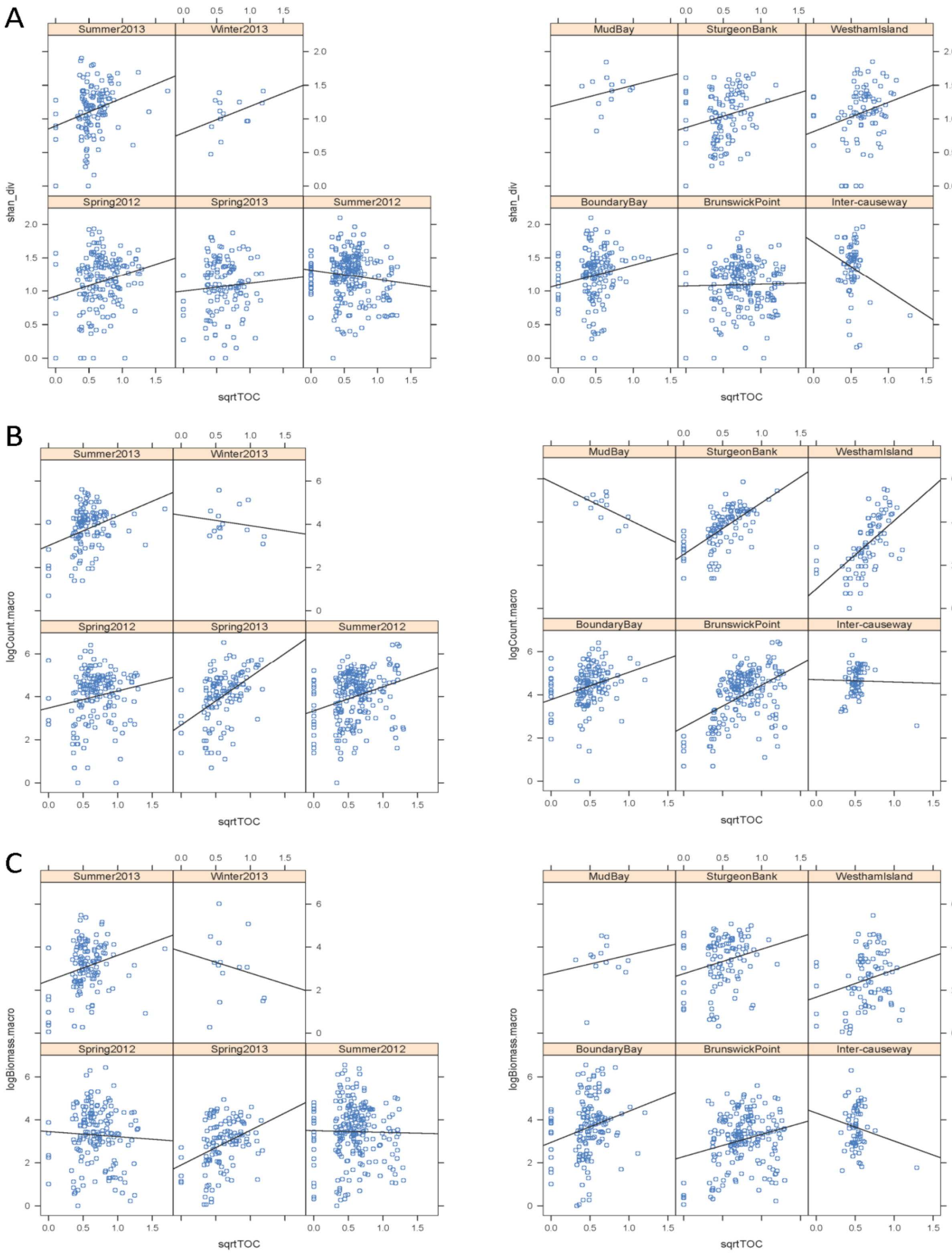
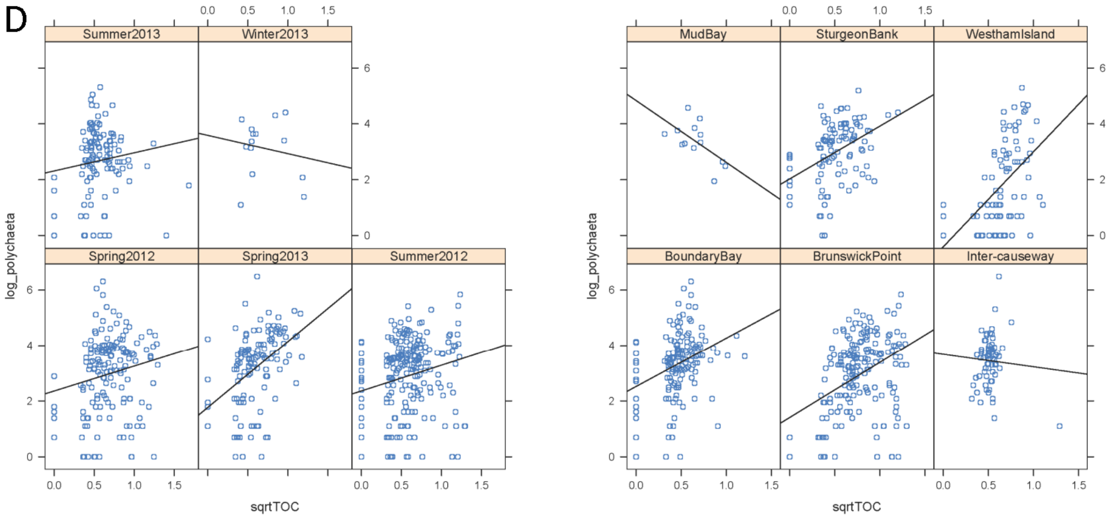
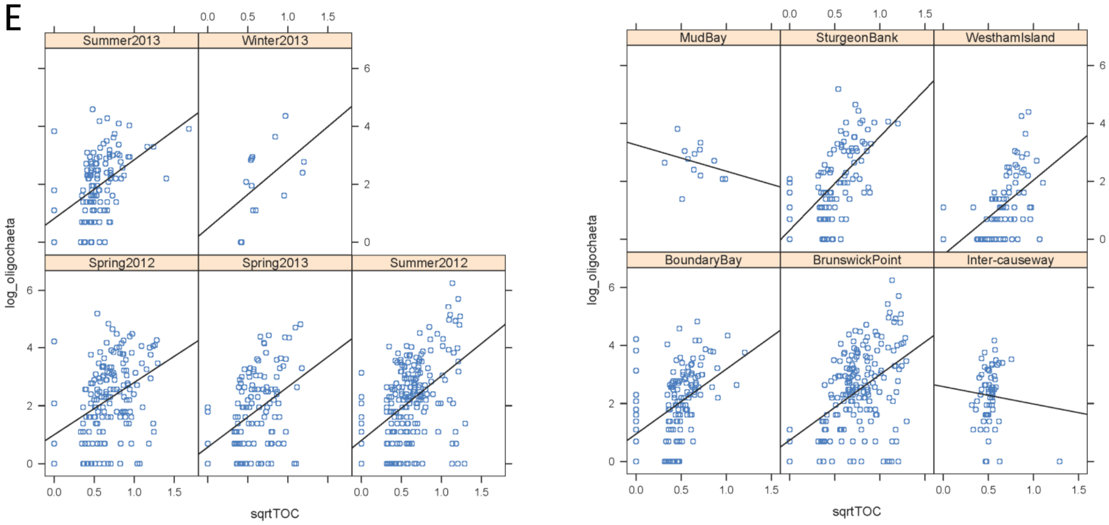


Figure E8 Continued

D



E



F

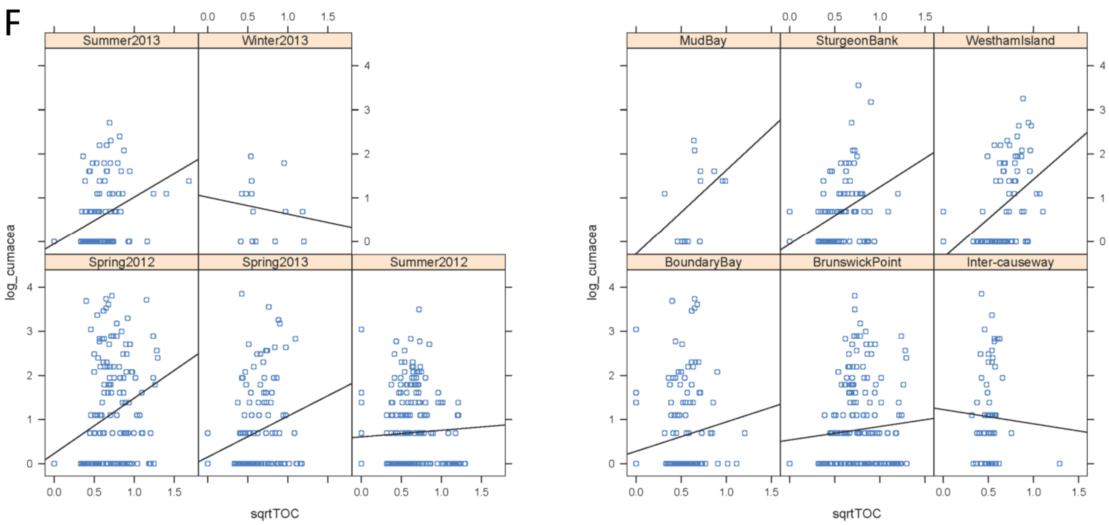
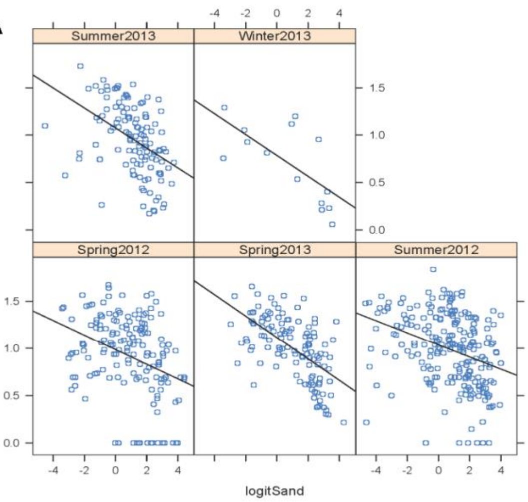
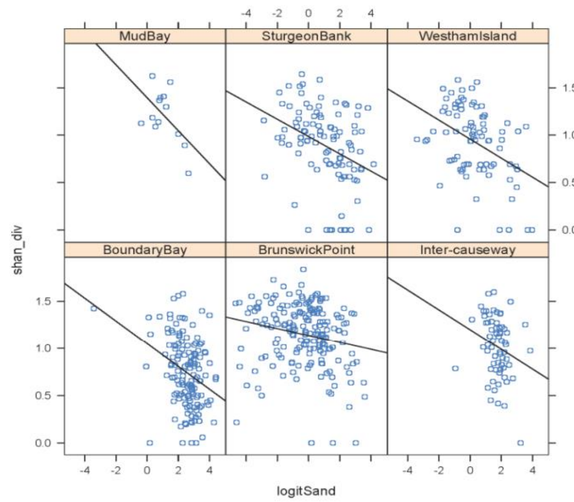


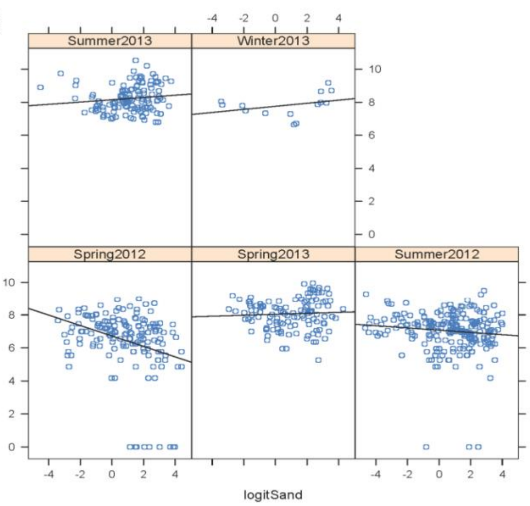
Figure E9 Linear Relationships between Meiofauna Biotic Variables and Sediment Grain Size (measured as percent sand) Broken Down by Sampling Period (left) and Stratum (right), where A: Diversity, B: Abundance, C: Biomass, D: Polychaete, E: Oligochaete, F: Haracticoid

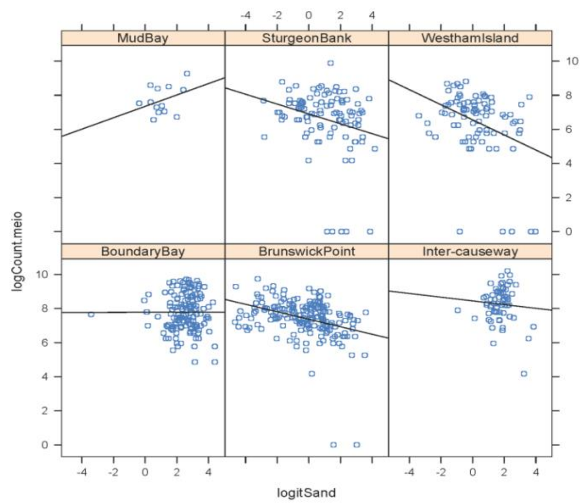
A



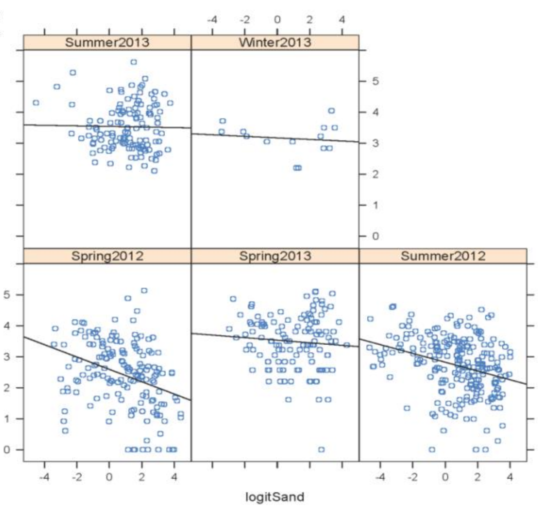


B





C



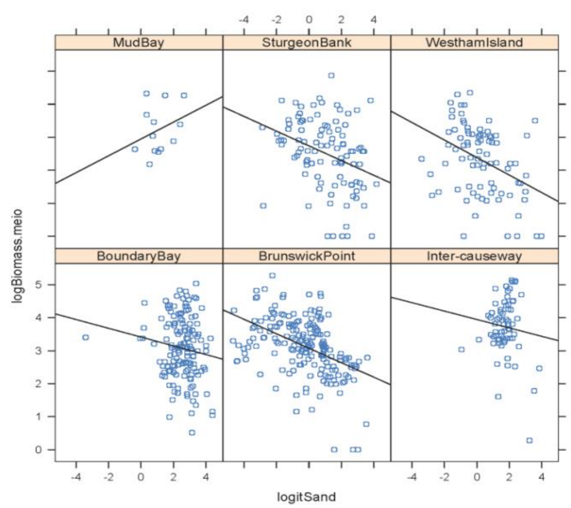
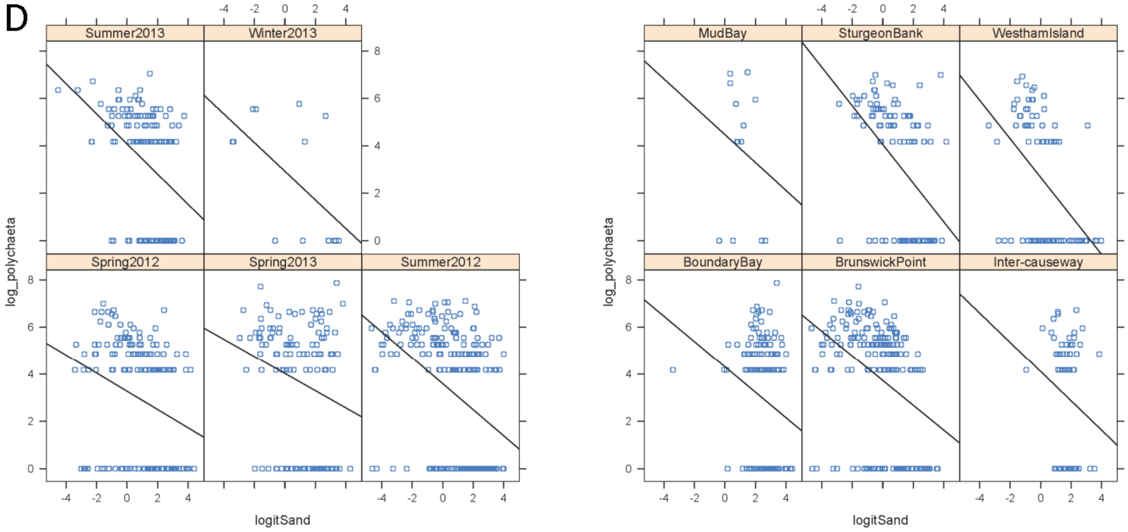
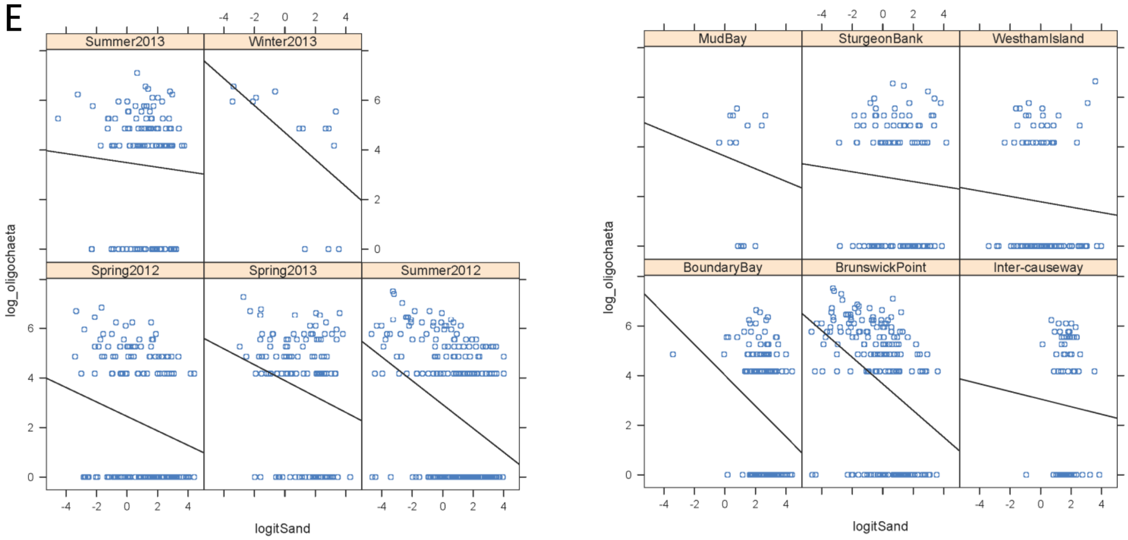


Figure E9 Continued

D



E



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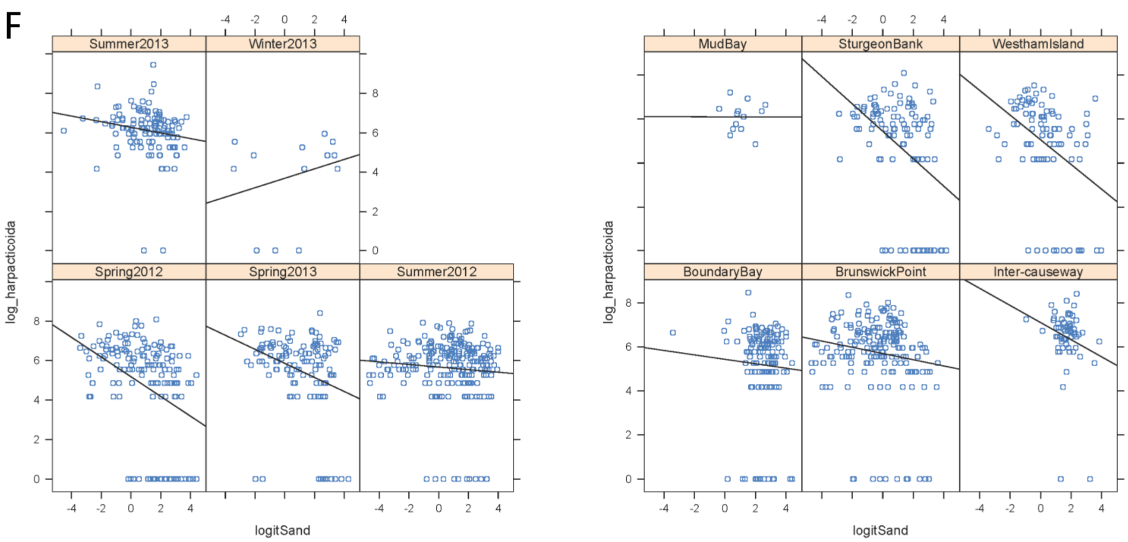
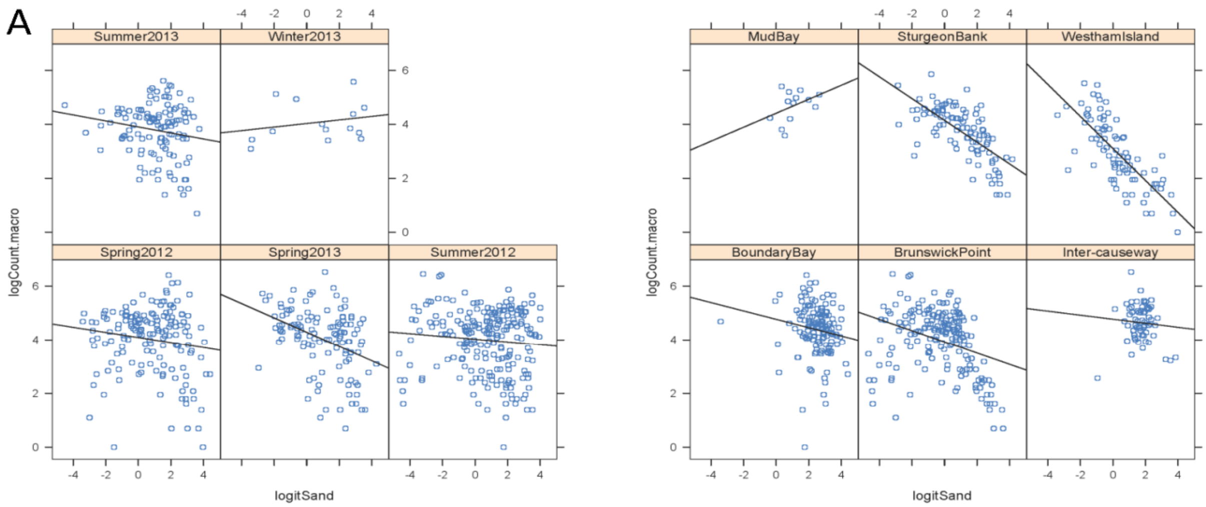
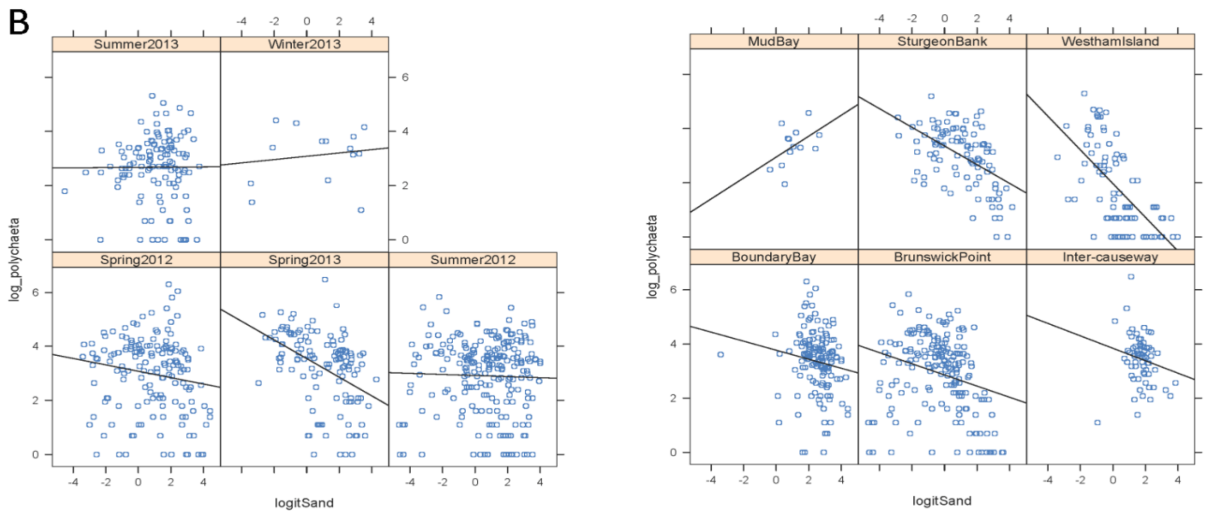


Figure E10 Linear Relationships between Meiofauna Biotic Variables and Sediment Grain Size (measured as percent sand) Broken Down by Sampling Period (left) and Stratum (right), where A: Diversity, B: Abundance, C: Biomass, D: Polychaete, E: Oligochaete, F: Haracticoid





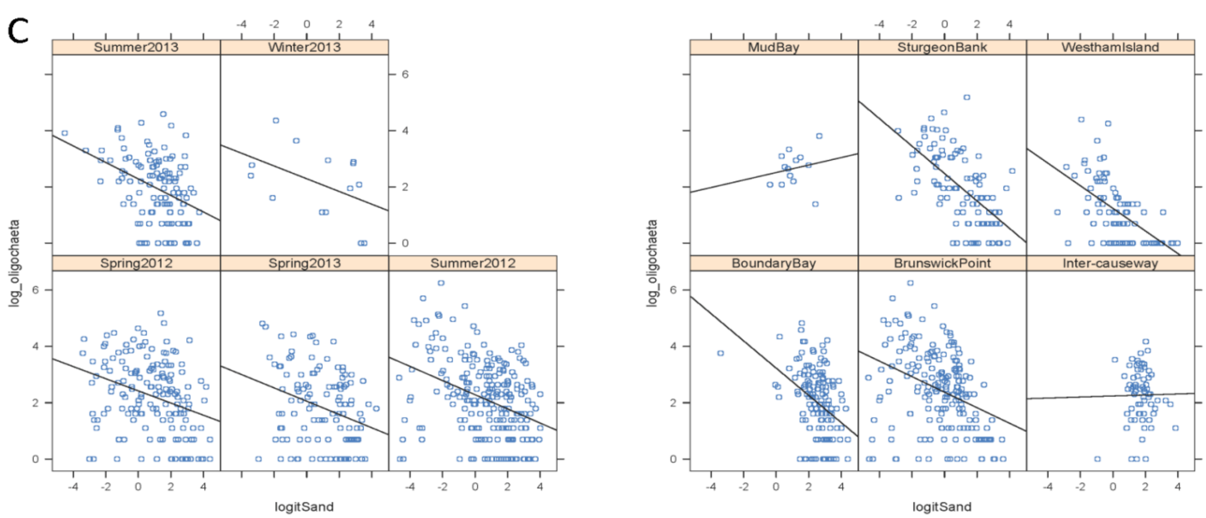
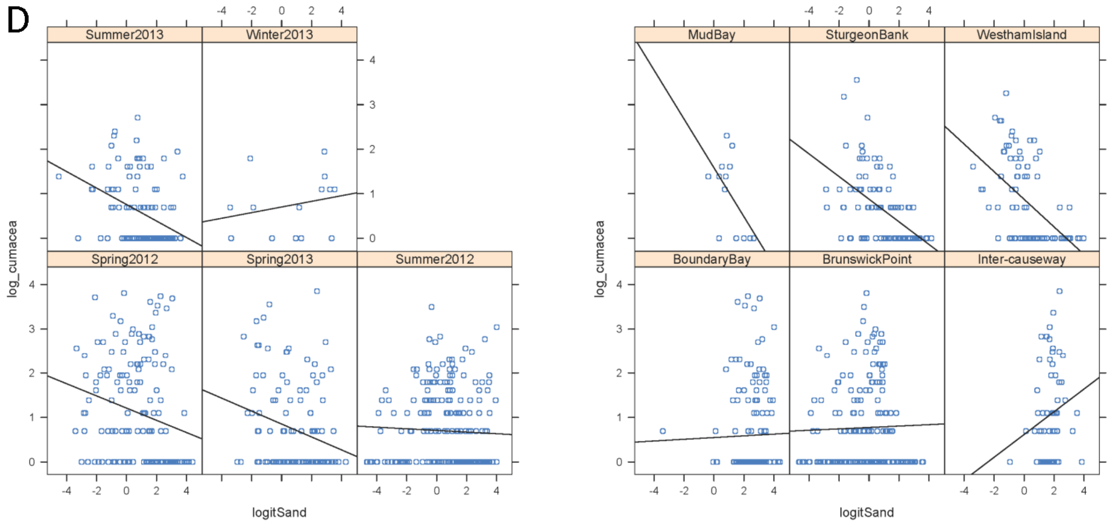
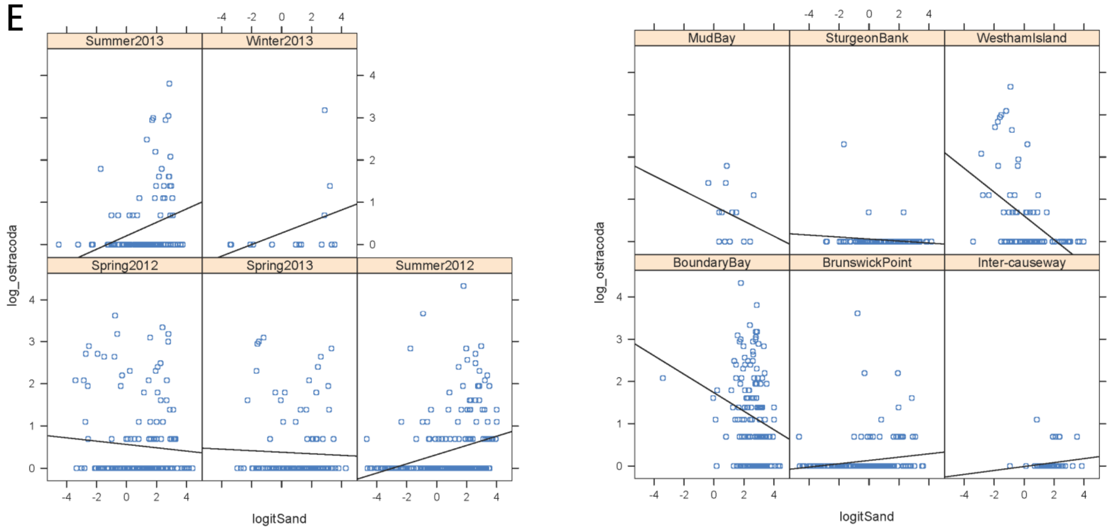


Figure E10 Continued

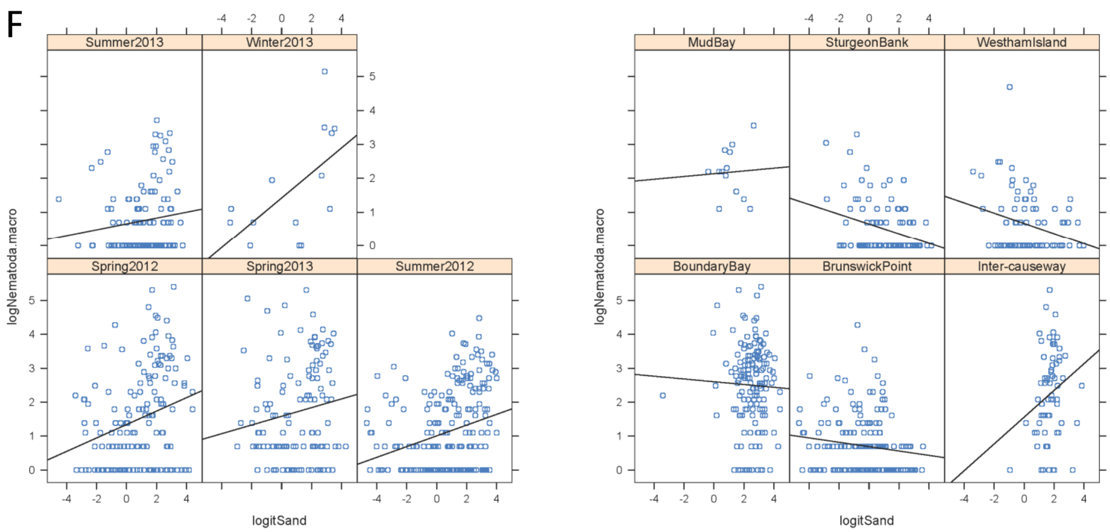
D



E



F



APPENDIX F
Photographs

Photo 1 Infauna Sampling Site at Brunswick Point Stratum in Spring 2012

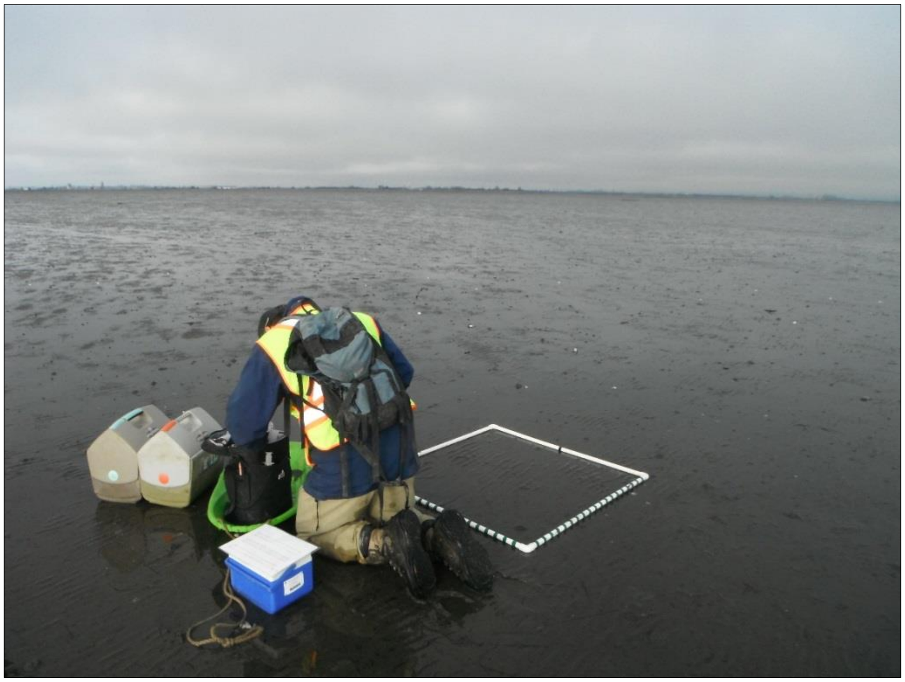


Photo 2 Sampling for Infaunal Using 60 mL Syringes to Extract Sediment Cores at Sturgeon Bank Stratum in Spring 2012

Photo 3 Infauna Sampling Site at Brunswick Point Stratum in Summer 2013

Photo 4 Sediment Core Samples Being Ejected into a Sample Bag and Stored on Ice in the Field

Photo 5 Van Veen Sediment Grab Deployed From a Boat to Collect Subtidal Macroinvertebrates

Photo 6 Sieved Macroinvertebrate Samples in a Plastic Jar Prior to Preservation with Formalin