3.0 EXISTING ENVIRONMENTAL CONDITIONS

3.1 STUDY AREA

As noted in Section 1, the overall Roberts Bank Expansion Program includes two separate study areas: *Deltaport Third Berth Study Area* and *Container Terminal 2 Study Area.* The Deltaport Expansion Program is distinct from, and in addition to, the Terminal 2 Study Area. However, given the proximity to one another and the initial timelines for development, these two components of the overall expansion program were initiated as a single marine studies work plan. The results of these studies are documented in this report although only information relevant to the Deltaport Third Berth project is used in the environmental assessment.

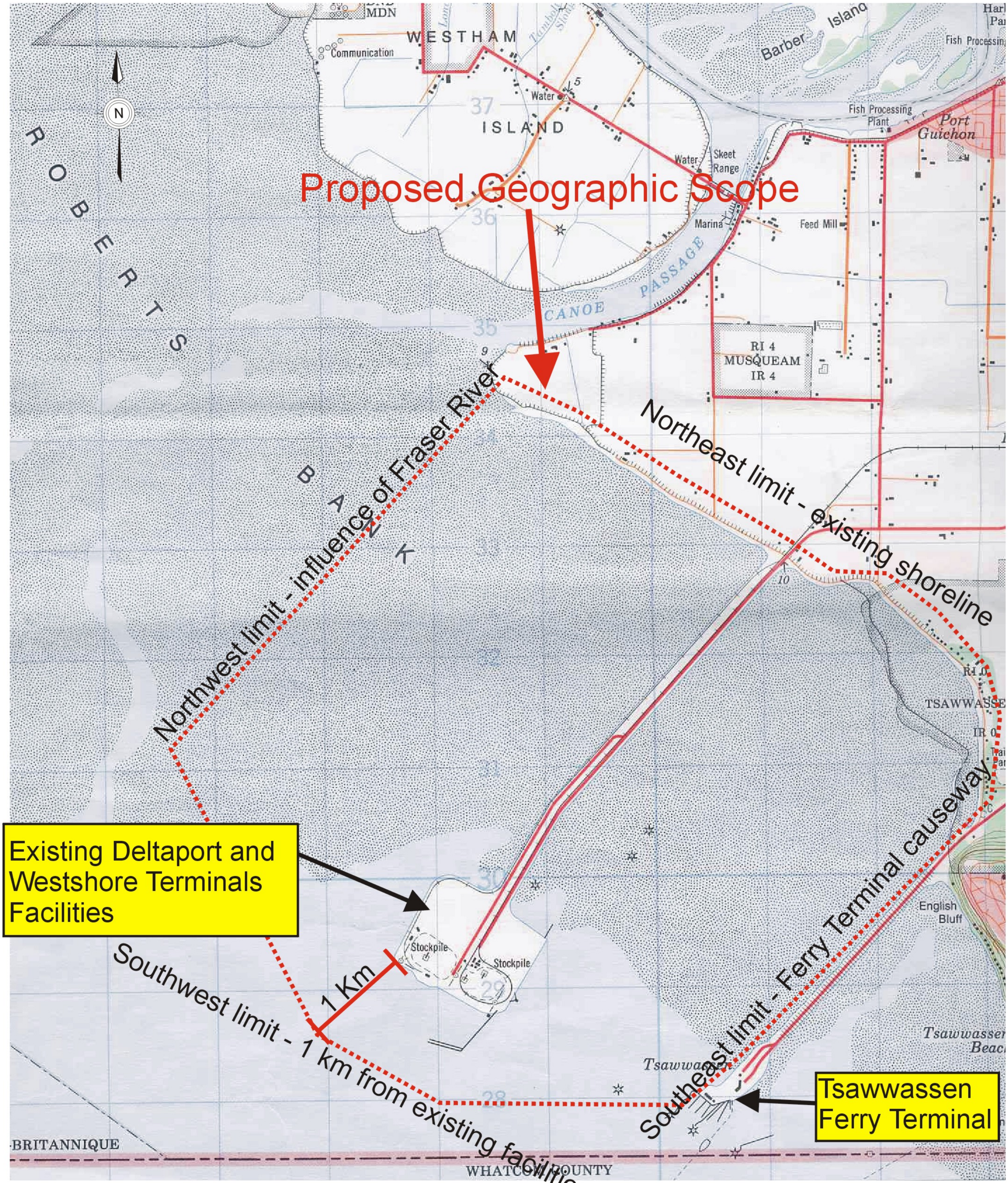
Deltaport Third Berth Study Area

Deltaport is an existing two-berth container terminal located at Roberts Bank. The Deltaport terminal expansion would create up to 32 hectares (80 acres) of land for terminal infrastructure development, including three to four new cranes and enhanced on-site container storage (Figure 2.1-2).

Definition of the study area for the environmental assessment was based on the aerial extent of the project activities and their likely effects. For the Roberts Bank Container Expansion Program, the study area included:

- areas proposed for the placement of fill,
- the immediate dredge area including ship channels and turning basins,
- those specific areas in which the effects of the project may be felt, and
- a wider area for comparison purposes when assessing the significance of those effects.

In addition to the assessment of impacts within the footprint of the proposed expansion options, the geographic scope of the assessments was limited to the northwest by the influence of the Fraser River through Canoe Passage. It is expected that outflows from the Fraser would prevent any sediments or operational effects from influencing habitats to the north of this point. The existing ferry terminal causeway would limit potential marine effects to the southeast, while they are bounded to the northeast by the existing shoreline. Due to increasing depth and the turbid waters from the Fraser River influence, we have estimated that a study area within 1 to 5 km of the existing port facilities will be sufficient to document potential project effects on most marine resources. An outline of the proposed geographic scope of the marine studies is provided in Figure 3.1-1.



Roberts Bank Container Expansion Program	Map # 3450-3.1-1	Created by: P. Frederiksen 6/11/03 Revised by: E. Rousseau 9/01/04 Source: NTS, 92G2, Edition 2

FIGURE 3.1-1. PROPOSED GEOGRAPHIC SCOPE OF MARINE ASSESSMENT

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3.2 METHODOLOGY

The marine studies program for the Roberts Bank Container Expansion project was divided into several ecological components:

- Backshore Vegetation and Intertidal Salt Marsh;
- Intertidal Sand/Mud Flats;
- Eelgrass;
- Intertidal/subtidal Rocky Habitats;
- Subtidal Sand/mud Flats; and,
- Dredge Basins.

A further component, marine mammals, was also studied, but as marine mammals are users of different, offshore habitats, they are described in a separate section.

The main goal of the field program was to confirm the extent, quality and use of existing fish habitats, benthic and macroinvertebrate habitats, marine vegetation and ecology, and marine mammal use of the project area. The methods used in these particular aspects are detailed in the appropriate sections. The level of detail of field investigation was based on the quantity and quality of existing information for the project area.

Background Information Review

The background information review consisted of two phases:

1. compilation and review of published information from the primary and grey literature, and
2. communication with VPA staff, regulatory agencies, the Tsawwassen First Nation to solicit other sources of existing information.

Background information sources included:

- Canadian Institute of Scientific and Technical Information (CISTI),
- UBC Library Catalogue,
- FOC's *WAVES* catalogue,
- Aquatic Sciences and Fisheries Abstracts,
- Oceanic Abstracts,
- Science Citation Index (Web of Science),
- BIOSIS (Biological Abstracts)
- Library catalogue at Triton,
- BC Provincial publications,
- National Technical Information Service (NTIS),
- National Oceanic and Atmospheric Administration (NOAA),

- Corps of Engineers Library Information online (CELIO – US Army Corps),
- A Roberts Bank bibliography of 600+ titles compiled by the Port of Vancouver and Hemmera Envirochem Inc. and,
- Relevant reports prepared for the Vancouver Port Authority.

Search terms included, but were not limited to, "Roberts Bank", "Tsawwassen", "Fraser Estuary", "Fraser River Estuary"; also references to "Dredging", "Port Development", "Disturbance", "Sediment", "Salt Marsh", "Mudflats", "Eelgrass", "Seagrass", "Dungeness Crab" (and many other species) delimited by "Pacific Northwest", "British Columbia", "Washington", "Alaska", "Strait of Georgia", etc.

The citations and abstracts (where available) of the literature search were compiled into a bibliographic database using ProCite 5© software. This database was used to print subject bibliographies which were distributed to the members of the Marine Environment Study team. Hard copies of journal articles, books, reports and theses were obtained as needed. Identified gaps in the available information were used to guide the field programs (to refine the focus and/or or sampling intensity of the proposed studies).

The review of background information also allowed the team to identify mitigation and compensation strategies that were developed and/or implemented in other jurisdictions, and which may be applied to the proposed VPA Deltaport Third Berth project.

3.2.1 Backshore Vegetation and Intertidal Salt Marsh

The main objective of the study was to identify dominant species and collect biophysical data in each area of habitat or "polygon" that had been initially identified by air photo-interpretation. These data were then used to modify the classification of the GIS polygons and complete the initial mapping of the various habitats.

Backshore vegetation and intertidal salt marshes were studied using two techniques:
- Mapping different habitats from existing aerial photography; and,
- "Ground truthing" of the different habitats once the initial mapping was complete.

Mapping

Habitats were mapped using the 2002 FREMP shoreline habitat inventory maps as base maps. The maps were prepared from digital air images taken near low tide on April 29, 2002 and were transformed into compressed digital, geo-rectified, stereoscopic air photos for use with a DiAP viewer. The specialized hardware and software system, developed by Integrated Mapping Technologies (IMT) of Vancouver, allows an air photo interpreter to view the digital air photos in 3-D (Stereo) on a computer monitor. This permits more accurate and mapping capabilities, including zooming features, height determinations, and colour manipulations to assess image features. Each polygon was assigned a unique identifier code (number) and classified according the FREMP habitat inventory categories. The polygons were mapped in ArcView GIS format.

Ground Truthing of Maps

The FREMP maps were loaded into a Personal Digital Assistant (PDA) to which was connected a Garmin 12 XL for GPS determination. This permitted points in the field to be located on the GIS map. For each point, habitat information was entered by the Geographic Information System (GIS) Technician into the PDA using a pre-determined format consisting of:

- identification number;
- tidal zone;
- substrate;
- salinity;
- type of backshore or intertidal habitat;
- dominant species (maximum of 3);
- % cover according to a Braun Blanquet classification; and,
- photo number.

Supplementary comments and information were recorded in field notebooks.

Field surveys were conducted during daylight low tides during August 26-28, 2003. Supplementary field surveys were conducted on September 10 and October 20, 2003, and on July 2, 2004.

During the September 2003 survey, surface soil samples were also obtained to characterize the mudflat and marsh substrates along the Delta dyke and Roberts Bank causeway, and for the south bank of the causeway mudflat located near the Tsawwassen salt marsh. Seven samples were taken along the Delta dyke, west of the Roberts Bank causeway (established salt marsh), along the developing marsh along the west side of the causeway within the proposed footprint for the expanded rail to access, and on the northeast side of the causeway in the mudflat adjacent the large patch of *Spartina anglica*. All samples were taken to reflect the soils conditions in the upper 10 cm, corresponding to the rooting zone for salt marsh vegetation. Samples were obtained by shovel and stored in plastic bags for transport to the laboratory.

These samples were analyzed by Soilcon Laboratories to determine particle size, moisture content, loss on ignition to estimate organic matter, pH, electrical conductivity and soil salinity, redox, total carbon and nitrogen, and available nutrients including phosphorus, ammonium-nitrogen, and nitrate-nitrite-nitrogen, calcium, magnesium, sodium, and potassium.

3.2.2 Fishes, Nearshore Habitat and Macroinvertebrates

The purpose of this gathering of baseline information was to allow the Marine Environment Study Team to identify and assess the impacts of any proposed expansion in the project area and to identify and develop mitigation and compensation strategies.

The field program for fishes, nearshore habitat and macroinvertebrates was designed to:

- determine the composition and distribution of marine resources in the project area;
- identify the relative value of marine habitats in the project area;
- identify seasonal patterns of habitat use by fishes and macroinvertebrates in the project area;
- identify the occurrence and spatial extent of each distinct habitat type in the project area (e.g., intertidal, subtidal, eelgrass and marsh, silt/sand substrate, rip rap shoreline);
- identify any blue (sensitive and vulnerable) and red (endangered) listed species in the project area;
- identify sensitive or rare habitats, including habitats which are highly sensitive to mechanical disturbance and/or sedimentation, or small habitats with critical functions, and;
- where appropriate, confirm and compare the results of previously completed marine studies in the project area with those of the present studies.

The nearshore marine resources logically fell into two large groups: fishes and macroinvertebrates. Fishes' distribution and habitat use were sampled and inferred through beach seine, beam trawl, minnow traps and occasionally through crab and prawn traps. Macroinvertebrates' distributions and habitat use were sampled and inferred primarily through intertidal quadrats, point sampling, crab and prawn traps and occasionally through beach seining and beam trawling. The type of information and whenever appropriate, the number of samples collected as part of this sampling program are summarized in Table 3.2.2-1. Details are provided in the subsequent sections.

Fish and Fish Habitat

The objectives of the fish sampling program were:

1. To identify fish species present in the study area, and to determine whether or not any of these species were rare or endangered;
2. To determine seasonal variations in ichthyofauna composition and habitat use in the study area; and,
3. To determine the habitat use (e.g., rearing, spawning, migration) of fish species present in the study area.

Table 3.2.2-1. Summary of sampling effort for nearshore and intertidal sampling programs.

SAMPLING METHOD	MAIN OBJECTIVE(S)	SAMPLING EFFORT	TOTAL
Beach seining	Describe seasonal and diel variations in ichthyofauna composition among selected habitats	8 beach seining sites, two replicates per site, day and night, four seasons	128 beach seines
Beam trawls	Describe seasonal variations in ichthyofauna composition and fish habitat use	16 tows replicated in four season; four additional transects in	68 transects
Minnow traps	Describe seasonal variations in ichthyofauna and fish habitat use near rip rap and in shallow water	12 sites, 2 minnow traps per site, replicated in four seasons	96 minnow traps contents
Intertidal quadrats sampling	Estimate macroinvertebrates location, abundance and diversity relate invertebrates to habitat composition	5 transects	91 0.25 m^2 quadrats contents collected 50 quadrats contents analyzed
Point samples	Estimate substrate composition, vegetation cover and biological indicators densities (siphon holes, ghost shrimp, polychaetes, etc.)	Georeferenced points on both sides of the Roberts Bank causeway	165 samples
Dungeness crab juveniles quadrat density measurements	Estimate juvenile Dungeness abundance and locate principal area of settlement in Deltaport Third Berth project footprint	59 0.25m^2 quadrats collected	59 quadrats sorted for juvenile Dungeness crabs
Neotrypaea burrow density assessment	Relate opening density to occupancy	37 burrow openings injected with Fluorescine	37 measures
Crab traps	Describe seasonal variations in macroinvertebrates in deep (20 m CD) water	5 sites replicated in four seasons	20 stations (2 crab traps tied together per station)
Prawn traps	Describe seasonal variations in macroinvertebrates in deep (20 m CD) water	5 sites replicated in four seasons	20 stations (2 prawn traps tied together per station)
Salinity / water temperature stations	Measure variations in oceanographic parameters between east and west sides	3 sites replicated in four seasons; temperature and salinity measured from surface to bottom	12 stations

Fish species, their seasonal distribution and fish habitats were described and mapped in the project area. This was done through:

- beach seining;
- trapping (crab, prawn and minnow traps);
- trawling (3 m beam trawl tows); and,
- underwater surveys;

all conducted between July, 2003, and May, 2004, in subtidal and intertidal habitats in and adjacent to the proposed development options. The first three methods are addressed in the following sections. Underwater survey methodologies are detailed in Sections 3.3.6 and 3.3.7.

Beach seining

The main objective of the beach seining program was to record seasonal and diel variations in ichthyofauna composition in nearshore habitats of the intertidal zone. The ichthyofauna seasonality and diel use is important to ensure the effectiveness of mitigative measures.

Eight beach seining sites were sampled (Figure 3.2.2-1). These sites were selected to ensure coverage all intertidal habitats (mudflats, start of eelgrass and salt marsh) within the options considered for future expansion of both container terminal and railway line. Additionally, an effort was made to use previously sampled sites (Jacques Whitford 2001) whenever possible to ensure the comparison of the results with past studies, as this provides insights into cumulative environmental effects.

Beach seining was conducted by a four-person crew using a 30 m long x 2.0 m deep net (6.35 mm stretch mesh). The net was deployed from the shoreline at flood tide (see Photo P3.2-1) to sample fishes moving into the intertidal area from deeper waters. There were two sets (replicates) per site per time period.

All sites were sampled at night and during the day during the four seasons to document seasonal and temporal variations in habitat use. Day and night samplings were conducted as close in time as possible (same date whenever feasible). The tidal cycle amplitude along the Roberts Bank causeway meant that sampling could only be conducted a few days per season on average, as the tide rarely reached the levels necessary to allow sampling of all sites at the same period.

All fishes captured were identified to species and enumerated. A sub-sample of 30 fish per species was measured (fork length or total length as appropriate) and weighed on an electronic scale (0.1 g) (see Photo P3.2-2) when large numbers of fish were captured. All fishes were released near the point of their capture.

The present report does not expound on Length-Weight relationships nor analyses of these parameters. These data will however prove useful for monitoring the ichthyofauna's health (e.g., fish condition indices), abundance and habitat use in subsequent years and to monitor the effectiveness of the chosen mitigation or compensation methods.

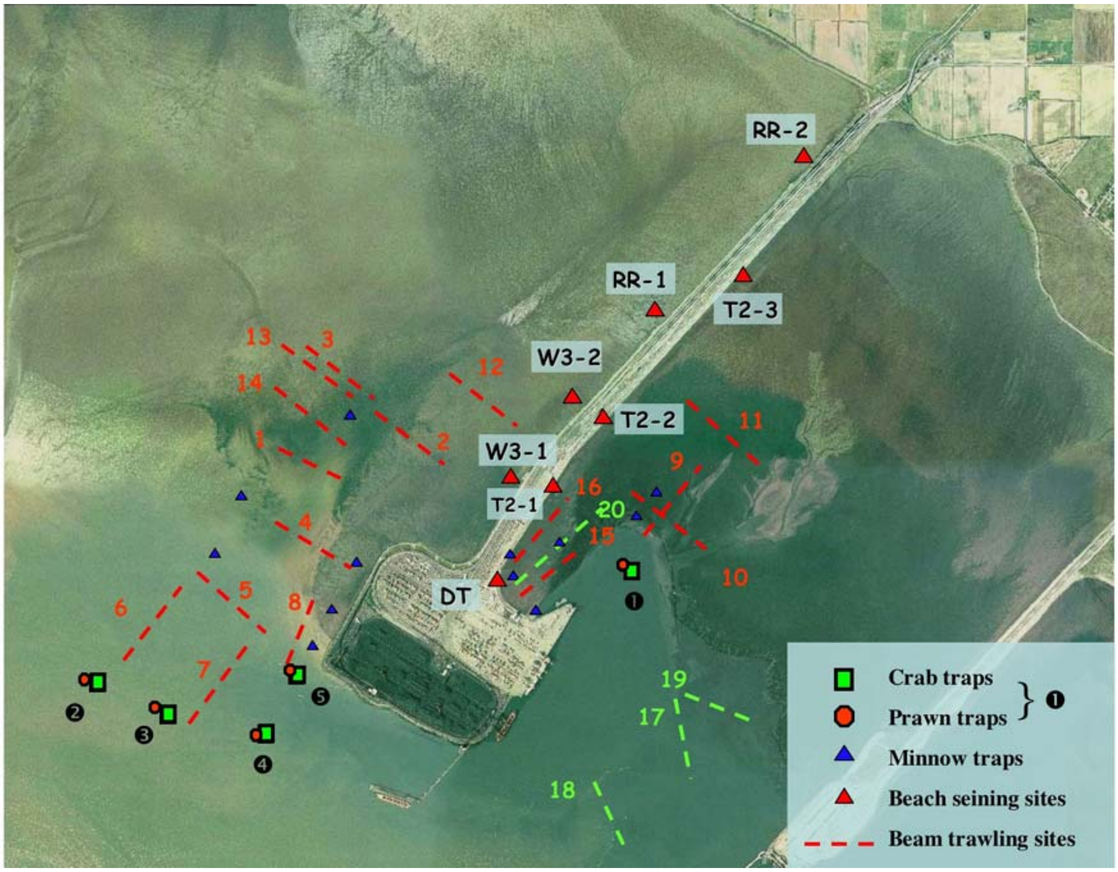

Figure 3.2.2-1. Location of sampling sites for macroinvertebrate and fish sampling.

Beam trawls

The main objectives of the beam trawl sampling were to:

- describe seasonal use of fish habitats in and adjacent to the project area
- quantify epibenthic fish populations in the area.
- An ancillary goal was to sample macroinvertebrate epifaunal abundance and composition.

A three meter beam trawl (net dimensions: 1 m x 3 m x 6 m, with mesh size tapering from 12 mm to 3 mm in a 1.5 m cod end) was towed behind an 18' Kellaghan jet boat (Photo P3.2-3). The beam trawl was dragged over the bottom to sample benthic fishes. Fishes such as salmonids which make more extensive use of the water column were sampled through beach seining.

The start and end of each tow were geo-referenced, the bearing and the speed of the boat were noted to allow for exact replication among seasons. Tows averaged 605 m in distance (median

613 m, SD 34.9 m). Tow contents were sorted in the boat and, after recovery, all animals were returned to the water near the point of capture.

Standardized data forms were developed to ensure consistent and complete data collection throughout the proposed field study. For each catch, the following information was noted:

- Time and date of sampling, direction of tow, tow length, sky cover, boat speed, depth at beginning and end of tow;
- Estimate of tow volume;
- Vegetation composition (percent of vegetation present);
- Type of substrate;
- Estimate of small invertebrate numbers (amphipods, mysids, ctenophores, etc.);
- Macroinvertebrates size: crab – carapace width (mm); echinoderm, average of two aboral diameter measures; bivalve –postero-anterior length (mm); and,
- Fishes: all animals identified to species, enumerated and measured (Total Length or Fork Length as appropriate). Subsample of 30 fish per species where large numbers caught.

The age class distribution data of various species are not documented in this report. These data will however prove invaluable for monitoring the ichthyofauna's health, abundance and habitat use in subsequent years and to monitor the effectiveness of the chosen mitigation or compensation methods.

Tows were distributed randomly among strata (random stratified sampling), strata being particular habitats such as eelgrass, mudflats, etc. There were 16 beam trawl tows replicated among four seasons, eleven of which were on the west side of the causeway. The uneven sampling effort was a consequence of the larger area to cover on the west side (three potential options for the port expansion had been identified on that side at the time of sampling design) and the density of the eelgrass beds in the intercauseway area which hampered jet boat propulsion. Four additional tows were added in the dredge area and surroundings for the Deltaport Third Berth project in the spring of 2004. The location of the tows is shown in Figure 3.2.2-1.

Minnow traps

The purpose of the minnow or 'gee' trapping program was to describe seasonal use of fish habitats in areas of complex cover (intertidal habitats along rip rap shorelines and within eelgrass beds) in the project area which could not be effectively sampled by other more active fish capture techniques such as beach seining or trawling. The gee traps used consisted of two cylindrical trap halves made of 1/4 inch wire cloth, with a funnel shaped entrance at each end of the trap. Each assembled trap was approximately 42 cm in length and 23 cm in diameter.

There were twelve stations, six on each side of the Roberts Bank causeway (see locations in Figure 3.2.2-1). Each station was sampled by two traps placed together, separated by approximately 1.5 m, and tied together on a single float to facilitate retrieval. Traps were baited with salmon roe prior to deployment and their location was geo-referenced to allow for exact replication during subsequent seasonal sampling. Traps were left to soak undisturbed for an average of five hours during flood tide.

Upon retrieval all fish in each trap were enumerated, measured (nearest mm; Total Length or Fork Length as appropriate) and weighed. All fish were released soon after capture. Crustaceans (usually grapsid crabs) were measured (carapace width) and sexed.

The age class distribution data of various species are not documented in this report, but as noted earlier these data will prove invaluable for monitoring the ichthyofauna's health, abundance and habitat use in subsequent years and to monitor the effectiveness of the chosen mitigation or compensation methods.

Macroinvertebrate sampling

The main objectives of the macroinvertebrate sampling program were to:

- determine invertebrate composition and distribution in the intertidal and subtidal zones in and adjacent to the project area;
- identify any rare or endangered blue and red listed species in the project area;
- identify the occurrence and distribution of distinct habitats in the project area;
- identify sensitive or rare habitats in the project area, and;
- confirm and compare the results with previous studies completed by Triton and FOC (where appropriate).

Additionally, the survey allowed the identification and description of potential mitigation and compensation strategies for species and habitats that may be affected by the terminal expansion.

Intertidal quadrat sampling

Macroinvertebrates were sampled in August and early September 2003. These dates were chosen to ensure coverage of the period of greatest species abundance and diversity in the project area.

Intertidal habitats in the project area were first characterized through a reconnaissance survey of the area based on examination of the substrate, flora and fauna via transects and point sampling.

There were five areas sampled through seven transects (Table 3.2.2-2 and Figure 3.2.2-2). These were established perpendicular to the shore in representative areas. The location of each transect was first geo-referenced and the limits of each habitat type or stratum within the area covered by the transect were recorded along the transect line. Transects length varied from 220 m to 1.3 km in length (Table 3.2.2-2). Some of these transects purposely overlapped areas sampled by previous studies to add to the cumulative environmental impact assessment database.

Table 3.2.2-2. Location, timing of sampling and sampling and analysis efforts of intertidal transects surveyed on both sides of the Roberts Bank causeway, August to December 2003. Refer to Figure 3.2.2-2 for locations.

Transect	Location and approximate length (m)	Timing of sampling	Number of samples collected	Number of samples analyzed	Comments
W2-1	Options W1 & 2; *300 m*	Aug 2003	11	6	Analysis temporarily deferred until Terminal-2 project option is selected.
W2-2	Option W 2; *370 m*	Aug 2003	17	9	Analysis temporarily deferred until Terminal-2 project option is selected.
W3-1	Terminal 2 option W 3; *1,050 m*	Aug 2003	18	5	Replicate of transect surveyed in 2000 (Jacques Whitford, 2001). Analysis temporarily deferred until Terminal-2 project option is selected; transect surveyed (point samples) over 1,300 m linear length.
E2-1	Option E-1; *320 m*	Aug 2003	16	4	Replicate of transect surveyed in 2000 (Jacques Whitford, 2001). Samples analyzed are in zones of high *Zostera marina* and Z. *japonica* density; analysis deferred when it became apparent that this option was unlikely to be chosen.
DT-1	DeltaPort Third Berth project footprint; *480 m*	Sept 2003	14	11	Analysis of 3 samples collected close to shore temporarily delayed. This transect was given priority when the VPA decided that Deltaport Third Berth project would be treated as a separate application and be submitted earlier than the other application. The presence of juvenile Dungeness crabs gave the analysis of samples collected further from shore a high priority.
DT-2	DeltaPort Third Berth project footprint; *280 m*	Dec 2003	11	11	Supplementary sampling in zone of high juvenile Dungeness abundance to confirm seasonal presence of these animals.
DT-3	DeltaPort Third Berth project footprint; *220 m*	Dec 2003	4	4	Replicate of a transect surveyed in the winter of 1996 where juvenile Dungeness had been collected.
Total			**91**	**50**	

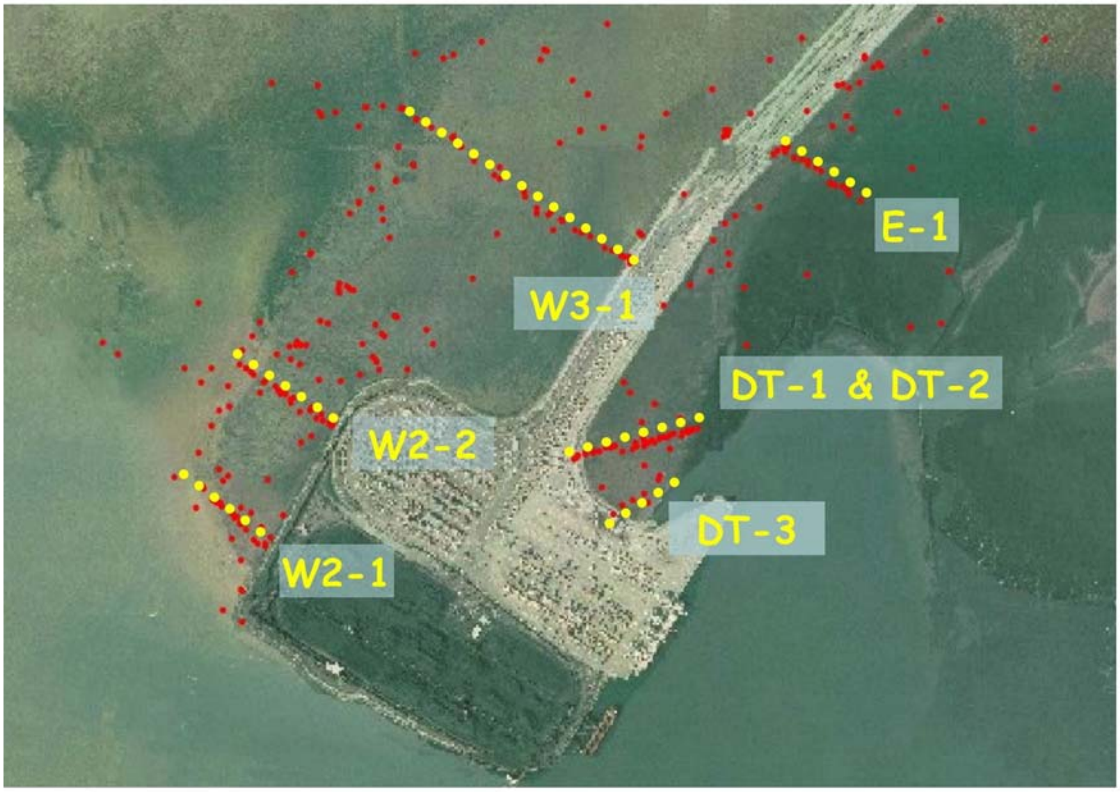

Figure 3.2.2-2. Transects and points sampled in the intertidal area on both sides of the Roberts Banks causeway, August – December 2003. Transects are dotted yellow lines, all point samplings, including quadrats, are red dots.

The location of all 0.25 m^2 quadrats was chosen according to a stratified random design. The following information was recorded before sampling each quadrat: georeference, picture, estimate of macrophyte cover (and when appropriate, eelgrass blade length and width), count of siphon holes, polychaetes fecal castings and other biological indicators.

Large invertebrates were identified and measured onsite whenever possible and subsequently released. All other invertebrates requiring detailed morphological assessments for positive species identification were collected down to 10 cm into the substrate and sieved through a 860 microns sieve. All quadrat contents were transported the same day to the laboratory where they were fixed in a 10% formalin solution and preserved two days later in a solution of 70% ethanol mixed with glycerine.

The analysis of selected samples was conducted on the Tsawwassen First Nation premises from November 2003 to February 2004. It consisted of sorting all animals and plants from specific samples (the rationale for analyzing particular samples is detailed in Table 3.2.2-2), and identification to the lowest possible taxon. All animals and plants/algae in the samples chosen for sorting were counted, measured (e.g., shell length) and photographed where appropriate. Plant material was weighed. All sorted and unsorted samples were labelled and preserved in a mixture of ethanol 70% and glycerine. Animals from sorted samples were further preserved and labelled in individual vials. All samples are presently stored in Triton's warehouse.

Once the analyses are completed, the results will allow, among other possibilities, correlation of macrophyte cover and biomass with biodiversity indices to explain patterns of animal abundances and facilitate mitigation strategies.

Point samples

The purpose of point sampling was to acquire a general view of the ecosystems present and to obtain more precise estimates of some parameters (e.g., bivalve density) in particular areas while covering as large an area as possible.

Substrate composition, macrophyte cover and various biological indicators (siphon holes, *Neotrypaea* burrows, polychaete fecal castings, polychaetes, and *Clinocardium* densities) were measured at randomly selected locations on both sides of the Roberts Bank causeway. All data were georeferenced on site and entered into the ArcPad ™ software. No quadrat was used for these measurements. The observer's bias was measured three times (10 quadrats each time) and estimated to be within 10% of the actual values.

The location of all point samples is shown in Figure 3.2.2-2.

Juvenile Dungeness densities

Fifty-nine 0.25 m^2 quadrats were sampled in the Deltaport Third Berth project proposed footprint in June 2004 to supplement the sampling done in the area in September and December, 2003. The goals were twofold:

1. Locate the principal area of Dungeness crab settlement in the Deltaport Third Berth project footprint; and,
2. Estimate juvenile Dungeness crab abundance.

The sampling was conducted in areas of known juvenile Dungeness crab presence near the northern end of the footprint. The quadrats were located in a systematic fashion every 30 m along a 150 x 150 m grid. The procedure followed that outlined for macroinvertebrate sampling (quadrats georeferenced and photographed, macrophyte cover estimated, content sieved) except that only juvenile Dungeness crabs were selected, measured and sexed. Once a juvenile Dungeness crab was found in a quadrat, quadrats were randomly sampled within a 3 m radius. All animals were returned intact to their location of origin after measurements.

The dataset thus collected, in conjunction with concurrent geomorphological and current studies, will enable the determination of the optimal conditions for juvenile Dungeness crab settlement. This in turn will help focus mitigation and or compensation measures particular to Dungeness crab life history.

Neotrypaea burrows

Neotrypaea californiensis (ghost shrimp) individuals typically have more than one opening to their burrows (Dumbauld *et al.* 1996) and any measure of density of these animals based on burrow openings is potentially biased. To reduce this bias the number of openings per burrow was estimated through injection of 60 ml of Fluorescine ™ in 17 burrows on August 11 and in 20 burrows on August 13, 2003. This work was completed on the west side of the Roberts Bank causeway. In each case, a photograph was taken approximately 1 m above the burrow before injection and once the dye started to exit from an opening. The number of openings and the distance between point of entry and point(s) of exit of the dye were recorded. There was on average one extra opening per burrow (average = 0.97, median = 1, SD = 0.75).

Crab and prawn traps

The objectives of the crab and prawn trap sampling were to describe the seasonal distribution of macroinvertebrates (mostly crustaceans) and fishes in deeper waters along the drop off in the project area and in the dredge channel (> 10 m Chart Datum (CD)) where sampling by other more active means (trawling, or seining) was not possible. The crab traps used in this study were typical recreational crab traps consisting of a rectangular wire frame approximately 1 meter by 1 meter square by 40 cm deep with four one-way hinged entrance doors located on each of the four sides. Each prawn trap was approximately 60 cm in length by 40 cm in width and 20 cm deep, and had two funnel shaped entrances at each end.

There were five geo-referenced sampling stations (refer to Figure 3.2.2-1 for locations), each consisting of two crab traps or two prawn traps linked together by a 1.6 meter re-bar (Photo P3.2-4) to minimize the probability of overturning, and attached to a single float to facilitate retrieval. Prior to deployment traps were baited with halibut or flounder as seasonally available and left to soak 18 hours on average. Crab and prawn traps were separated by 75 m on average at each station.

All macroinvertebrates and fishes were enumerated and measured (nearest mm; CW for crustaceans or average of two diameter widths in the case of echinoderms) and sexed (crustaceans only).

Temperature and salinity measurements

Temperature and salinity measurements were taken to assess some of the oceanographical differences between the west and east side of the causeway at approximately the same time and to thus gain insight on the physical processes affecting the biological communities. All measures were done with a YSI 85D DO, Conductivity, Salinity, Temperature meter. Water temperatures and salinities were measured at the crab & prawn stations 01, 02 and 04 (refer to Figure 3.2.2-1 for locations) at every meter from the surface to the bottom.

A TidBit ™ water temperature meter was installed in 1 m depth at the tug boat wharf from December 2003 to June 2004. The water temperature was continuously recorded every 15 minutes.

3.2.3 Eelgrass: *Zostera marina & Zostera japonica*

The objectives of the eelgrass study were:

- to identify the current distribution of native eelgrass (*Zostera marina*) and the introduced Japanese eelgrass (*Z. japonica*) within areas that could be potentially affected, directly or indirectly, by the proposed development;
- to characterize the area, type, and relative value of eelgrass habitat, in each of the areas that could be directly affected by each of the development options; and,
- to collect seasonal baseline data for *Z. marina* in areas that could be affected directly or indirectly, and from a reference site at Boundary Bay.

The following sections review the methodology that was used to meet each of the objectives.

3.2.3.1 Eelgrass Distribution and Mapping

Preliminary eelgrass mapping was completed using digital orthophotos from April 2002[1]. The geo-referenced map was used as a base layer for mapping the current distribution of eelgrass in the study area. The base map was loaded into an integrated PDA-GPS system, which was used in the field to ground truth the digital information. The aerial photos were flown at low tide in April 2002, thus the ephemeral *Z. japonica* (Japanese eelgrass) meadows were not visible; these were geo-referenced with a GPS in the field and added to the base map. Each polygon within the intercauseway and within 2 km to the north of the Coal Port was ground truthed on foot or by boat, to determine presence or absence and distribution of eelgrass during July and August 2003. The lower limit of *Z. marina* (native eelgrass) is not always visible on air photos due to the turbidity of the water. A separate SIMS survey (Section 3.2.4.1) was used to confirm the lower limits of eelgrass within the study area.

Distribution of *Z. marina* within each polygon was classified as either patchy or continuous. In optimal habitat the distribution is continuous; eelgrass shoots are distributed throughout the area. In sub-optimal habitat, or in areas recently colonized, the distribution is typically patchy; plants are clustered in small islands surrounded by either unvegetated sediment or by the other species of eelgrass. The percent cover was estimated visually in the field for patchy polygons during the 2003 field season. The percent cover of patchy polygons within the intertidal areas of the development options was later assessed via transect sampling in July 2004. It is generally accepted that for mapping purposes, *Z. marina* is considered absent when densities decrease

[1] The air photos were scanned at a resolution of 1 pixel = 20cm. The orthophoto process, and Jpg compression decreased the resolution to 1 pixel = 25cm. Additional details are provided in Section 3.2.1.

below 1 shoot per square metre. The guideline was adhered to in this study; polygons with trace amounts of *Z. marina* are not documented in the resulting maps (see Section 3.3), however minimal presence of *Z. marina* within a polygon is documented in Appendix A3.2-1a.

The abundance of *Z. japonica* within polygons was assessed by percent cover, and classified as present <1%, sparse <40%, moderate 41-75%, or dense >75%.

There are several 'transition zones' within the study area and outside of the areas of potential direct effect. These are habitats where *Z. marina* and *Z. japonica* co-dominate. The percent cover of each species within these zones varies seasonally, annually and spatially in response to a variety of environmental parameters. Within each of these polygons the density of *Z. marina* increases with depth, while that of *Z. japonica* decreases. Eelgrass shoot data were not collected within these zones due to the highly dynamic and variable nature of the eelgrass present.

Detailed Eelgrass Habitat Assessment

The habitat provided by eelgrass meadows varies both temporally and spatially. The productivity, and hence fisheries value, of eelgrass may vary by several orders of magnitude from one location to the next. In order to assess the value of eelgrass at each of the potential development sites, the type of native eelgrass habitat present was classified. The classification included ecotype(s) of *Z. marina*, total shoot density, reproductive shoot density, shoot length, width and Leaf Area Index of *Z. marina*, and relative density of *Z. japonica* (absent, sparse, moderate, or dense). The area covered by each species was determined by GIS.

Total shoot density, reproductive shoot density, shoot length, and shoot width were determined via random quadrat sampling within each polygon, using a $0.25m^2$ quadrat. A minimum of 20 replicates was sampled for each parameter in each polygon. Reproductive shoots were excluded from the shoot length and width measurements since the morphology of these shoots varies with level of maturity. The sampling within polygons where the distribution was patchy was restricted to vegetated areas. The mean density within vegetated areas could then be multiplied by the percent cover to obtain an estimate for the mean density within the polygon.

Mean shoot biomass (dry weight of plant material per unit area) estimates are commonly used to assess the productivity of eelgrass beds and detect changes over time. The technique is universally accepted, however it requires destructive sampling and is time consuming. As an alternative to biomass sampling eelgrass researchers often use to estimate productivity is Leaf Area Indices (LAI):

$$\text{LAI} = \text{mean shoot length x mean shoot width x mean density of shoot} /m^2$$

The LAI for *Z. marina* was determined for each polygon located in the areas that could be directly impacted by the development.

The percent cover of *Z. marina* within each polygon classified as patchy was estimated visually during the initial field survey (Summer 2003). In order to obtain current, objective estimates of percent cover, intertidal polygons located within potential development areas were assessed via transect sampling along a 50-metre grid in the intertidal areas during July 2004.

3.2.3.2 Seasonal Baseline Data

The sampling sites at both Roberts Bank and at the Boundary Bay reference site were selected to include a variety of eelgrass habitats. Four sampling sites were monitored in the inner causeway area, four west of CoalPort, and three in Boundary Bay. Sampling sites were selected at high, mid and low elevations to represent the range of habitats at both sites. Several general trends were noted. Sampling was conducted in August 2003, December 2003, and May 2004.

The sampling methodology followed that described for Detailed Habitat Mapping assessment above.

3.2.4 Subtidal Habitat Surveys

The objectives of the subtidal habitat surveys were to confirm the boundaries of important lower intertidal features, such as the lower limit of eelgrass beds, and to delineate and map deeper, subtidal habitats (to 25m depths (CD)). In addition detailed descriptive data were collected on macroinvertebrate and fish communities associated with specific features.

The subtidal habitat surveys had two components: A) mapping of subtidal habitats using geo-positioned towed video survey methods, and B) subsequent habitat specific surveys using intertidal and dive survey methods.

3.2.4.1 Towed Video Survey

The video survey of subtidal habitats was conducted using a towed underwater video system (Seabed Imaging and Mapping System or SIMS). SIMS was developed to carry out systematic mapping of seafloor substrates, morphology and biological features from the intertidal zone to depths of about 40m. The field of view is approximately 1 m by 2 m. The acquired imagery (digital video format) is geo-referenced using DGPS with position and time “burned” onto the video imagery at one-second update intervals. Depth of the towfish is also shown on the image. The towfish is maintained at a height of about 1-1.5m above the seafloor. Tow speed ranges between 1 to 1.5 knots. A 7m vessel was used to conduct the survey. A laptop computer is used for pre-plotting the navigation lines and for showing the vessel track lines during the survey. The position, depth and video time data is stored in an Access database developed for the SIMS classification system.

The video imagery is classified by a geologist and a biologist for substrate, epiflora (macrophytes) and epifauna (including fish), using a substrate and biotic classification system initially developed for the British Columbia Land Use Coordination Office (Harper *et al*. 1998).

The SIMS database (Access format) allows for data entry for each second of video imagery collected. The interpreted data are interfaced with ArcView for map production. The survey products are a portfolio of maps, developed in GIS format, showing sediment type, major vegetative features, macroinvertebrates and fish observations.

The Roberts Bank SIMS survey was conducted from September 3 to 7, 2003, over an area of 365 hectares (Figure 3.2.4-1 – survey area plus grid lines). This area is potentially affected by the various expansion options presented to the study team in the summer of 2003. The survey was conducted along transects laid out in a 100 by 100m grid pattern, generating a total of 75 km of survey track lines and 36 hours of video imagery. The survey ranged in depth from 20 m to +0.5m relative to chart datum. In addition, video tracklines (approximately 6 km) were conducted to the east and west of the target survey area to verify lower extent of eelgrass beds (Figure 3.2.4-1).

3.2.4.2 Dive and Intertidal Surveys

From January 2004 to June 2004 a series of dive and intertidal surveys focusing on detailed assessments of specific habitats and fish and/or macroinvertebrate communities were conducted in the project area. Components of the field survey were:

Rocky Reef Fish Communities

On January 13 and 14, 2004, a series of dive transects were conducted to survey benthic fish (particularly lingcod and rockfish) at four sites around the existing container and coal terminal (Figure 3.2.4-2); a site along the crest protection, north of the dredge basin in the intercauseway, a second site on the east side along the coal terminal rip rap and the base of the third berth at Deltaport, a third site at the existing rocky reef compensation site just off the seaward side of the coal terminal and a fourth site on the western side of the terminal. At each site two 100 m lead line transects with surface buoys were placed along a specific depth contour (see Appendix A3.2-2). The position of the surface buoys was recorded using DGPS. All fishes visible to the diver were counted and recorded by species. Smaller, more cryptic benthic fishes (sculpins, eelpouts) were noted on the data sheets. Fish counts were made by one diver while a second diver collected video imagery of the dive transect and associated fishes.

Lingcod Egg Mass Survey (LEMS)

Previous dive surveys along the rip rap areas of Roberts Bank (Gartner Lee 1992) indicated a relatively high abundance of lingcod, a species for which there are significant conservation concerns in the Strait of Georgia. On February 9 and 10, 2004, a series of seven sites (Figure 3.2.4-2) along the seaward edge of the coal port, including the existing compensation reefs, were surveyed for lingcod egg masses (LEM) using the standard survey protocol for lingcod egg mass surveys conducted annually by the Vancouver Aquarium (*http://www.vanaqua.org /lingcodsurvey*).

Figure 3.2.4-1

Shallow Rock Habitat Surveys

There are two manmade rock habitat features associated with the Roberts Bank port development which may be affected by the proposed port expansion options: (A) the rip rap embankment on the northwest side of the fill area which extends above the high water mark (+7.0m) to depths of –0.5m (relative to chart datum) and (B) the existing crest protection in the intercauseway area. The physical and biological features of these two areas were surveyed during the low tide cycle of June 3 to 4, 2004. A team of two biologists collected data on substrate, major vegetative features and the associated macroinvertebrate community. The timing of the survey allowed for documentation of seasonal vegetative features such as *Ulva* and *Sargassum*. The position of major habitat features (areas of similar substrate, algal zonation) was recoded using DGPS. Vertical elevation was measured using a rod and level and corrected relative to chart datum using tide prediction software (Nobletec) for Tsawwassen.

Beach Spawner Survey (Pacific sand lance/Surf smelt)

In recent years the importance of upper beach habitats (sand and gravel) for spawning of forage fish such as Pacific sand lance (*Ammodytes hexapterus*) and surf smelt (*Hypomesus pretiosus*) has been increasingly recognized. Beach spawning habitats in the Puget Sound Basin are relatively well documented (Penttilla 1997; 2001) and characterization of beach spawning habitat is an important component of the foreshore habitat assessment process. Beach spawning areas in British Columbia are poorly documented (Theriault *et al.* 2002). A recent field study of Pacific sand lance spawning in Baynes Sound by Thuringer (2003) indicates that this species spawns in upper (2-3m above MLLW) intertidal areas with predominately medium (0.25 to 0.5 mm) sand substrate from mid November to mid January. As the proposed Terminal 2 development will involve widening the existing causeway and embankment, there is potential to affect existing spawning habitats if suitable habitat exists. On the other hand it may also be possible to enhance potential beach spawning habitat in the design of an enlarged causeway.

Two intertidal beaches were assessed for suitable upper intertidal spawn habitat during the low tide on November 21, 2003, one within the tugboat basin and the other on the west side of the causeway (causeway/terminal intersection). Upper intertidal habitat on the beach in the tugboat basin did not appear suitable (substrate too coarse, beach <100m length) and was not considered for further sampling. The upper beach in the western corner of the causeway/terminal intersection did have suitable spawn habitat and was sampled for sand lance and surf smelt spawn (see Figure 3.2.4-2, Photo P3.2-5) five times between November 2003 and August 2004 on the following dates: November 21, 2003, December 15, 2003, January 14, 2004, June 3, 2004, August 3, 2004. Between 2-5 samples were collected using protocol developed for the Puget Sound Basin shoreline surveys (Moulton and Pentilla 2001). In brief, a 30 m transect was laid parallel to the shoreline within the upper intertidal zone (9m width from base of the dune grass, *Leymus mollis*, to the base of the beach face). A composite beach spawn sample of four 500 mL of sediment from the top 1.5 cm of substrate within 2.5m on either side of the transect was collected and examined for eggs.

Figure 3.2.4-2

3.3 MARINE HABITATS

The primary habitat classification of the west and east sides of the Roberts Bank causeway are shown in Figures 3.3.1-1 & 3.3.1-2.

3.3.1 Backshore or Marine Riparian

Backshore vegetation above the high tide mark along the dyke and causeway consists of two main zones. The zone at the mean high tide line (Photo P3.3-1) consists of *Elymus (Leymus) mollis* (dunegrass), *Ambrosia chamissonis* (silver burweed) and *Atriplex patula*, with less abundant species such as *Grindelia integrifolia*, *Lathyrus japonicus* (beach pea), *Hypochaeris radicata* (spotted cat's-ear), and *Cakile edentula* (American searocket). This zone also contains perennial accumulations of logs carried up to higher elevations during storms. In the sandy beaches along the north side of the causeway, *Ammophila arenaria* (European beachgrass) grows amongst the dunegrass.

Above this zone is a grass-herbaceous community (Photo P3.3-2), which in the study area does not support appreciable woody vegetation. There are a number of small shrubs, but trees are virtually absent along the seaward facing side of the dyke.

Several species of grasses colonize the zone above the extreme tide level. Common herbaceous species include *Tanacetum vulgare* (tansy), *Achillea millefolium* (yarrow), *Plantago lanceolata* (English plantane) *Circium arvense* (Canada thistle), *Hypericum perforatum* (common St. John's wort). Less common species, which may be abundant where conditions are favourable, include *Grindelia integrifolia*, *Melilotus alba* (white sweet-clover), *Solidago canadensis* (goldenrod), *Solanum dulcamara* (purple nightshade), *Epilobium angustifolium* (fireweed), and *Lepidium densiflorum* (prairie pepper-grass).

The most common shrubs growing along the terrestrial backshore are *Cytisus scoparius* (Scotch broom) and *Rubus discolor* (Himalayan blackberry). Another introduced shrub observed was *Buddleia* sp. (butterfly bush). Common native species include *Malus fusca* (Pacific crabapple), *Crataegus douglasii* (black hawthorn), *Salix hookeri* (Hooker's willow), *Holodiscus discolor* (ocean spray), *Rosa nutkeana* (Nootka rose), *Rubus parviflorus* (thimbleberry), *Sambucus racemosa* (red elderberry), *Symphoricarpos albus* (snowberry).

The only species of trees observed were shrub sized *Acer macrophylum* (bigleaf maple), *Prunus emarginata* (bitter cherry) and *Betula papyrifera* (white birch). Trees are typically removed from the dykes as part of municipal maintenance programs so it is unlikely that trees would survive to maturity.

Figure 3.3.1-1

Figure 3.3.1-2

The backshore vegetation provides cover for birds and wildlife. Wildlife includes small rodents such as mice and voles, and coyotes were observed foraging along the mudflats. Bird usage includes nesting for ducks and passerines, refuge for waterfowl and wading birds, and the seeds, grass and herbaceous species eaten by birds. Several marsh hawks were observed hunting over the log accumulations within the high marsh and backshore zones.

3.3.2 Intertidal Marshes

The distribution of intertidal marshes is shown in Figures 3.3.1-1 and 3.3.1-2. All intertidal marshes within the study area consist of brackish and salt marshes that have developed following the installation of dykes to reclaim agricultural land. Brackish marshes are confined to Brunswick Point, where a large area of marsh vegetation colonizes sand and mud substrate within the outflows of the Fraser River. This area will not be directly affected by port operations, but the marshes provide critical wildlife habitat to fish and waterfowl using the outer section of the Fraser River estuary.

Salt marshes exist as fringe marshes south of Brunswick Point, except between the dykes fronting the Tsawwassen First Nation reserve where a large area has established. North of the Roberts Bank causeway, continuous, narrow salt marshes are distributed along the Delta dyke, eastern half of the shore and in the embayment formed with Deltaport at the western terminal. To the south, between the Roberts Bank and BC Ferries causeways, salt marshes tend to be patchy, located at the eastern terminal of the Roberts Bank causeway, along the Tsawwassen salt marsh dykes, and in the embayment formed by Deltaport. Only the latter salt marsh will be directly impacted by the proposed Deltaport Third Berth project. The BC Ferries compensation marsh is located near the western terminal of the ferry causeway.

Most of the published studies on marshes within the study area were done in the 1970's, focusing on the brackish marsh at Brunswick Point (e.g. Moody 1978) and salt marsh at Tsawwassen (e.g., Hillaby and Barrett 1976). Yamanaka (1975) investigated the primary production and reported selected plant and soil characteristics along a transect north of Roberts Bank causeway and through the Tsawwassen salt marsh. Comprehensive summaries of existing information on salt and brackish marshes in the Fraser River estuary include Hoos and Packman (1974), Glooschenko *et al.* (1988), Luternauer *et al.* (1995).

More recently, the Tsawwassen salt marsh was more intensively studied as part of the dyke improvements to improve flood control (Bernard and Bartnik 1987; Moody 1985) and to construct a waste water treatment system (Anon. 1996; Anon. 1997), including a preliminary assessment of restoration opportunities (Anon. 1996a). The restoration opportunities included removal of fill and log accumulations within the salt marsh.

The majority of the studies report on the species composition of the intertidal marshes and discuss the relative importance of the Fraser fluvial (freshwater) and Strait of Georgia (marine) on marsh structure. Brunswick Point brackish marshes, with reduced salinities from the Fraser plume, demonstrate an increasing salinity gradient from the mouth, where *Typha latifolia* and

Carex lyngbyei dominate, to more saline outer waters, where *Scirpus maritimus* and *S. americanus* dominate. At Tsawwassen, the Roberts Bank causeway deflects the Fraser plume and the marine waters of the Strait of Georgia are more pronounced, resulting in higher salinities. The marsh vegetation is dominated by more halophytic vegetation *Salicornia virginica* and *Distichlis spicata*. More regional analyses of coastal marshes in the Puget Trough, including the Straight of Georgia and Puget Sound, also support the division of coastal marshes into salt (*Distichilis - Salicornia*) and brackish (*Scirpus maritimus - S. americanus*).

3.3.2.1 Brackish Marsh

Based on the observations during the marsh field surveys in August 2003, the brackish marsh at Brunswick Point is characterized by high vegetation diversity, with communities influenced by fluvial processes (e.g., freshwater discharge and sediment transport) from the Fraser River and marine processes (saline water and tides) from the Strait of Georgia. Two main tidal channels dissect the brackish marsh and allow freshwater to flow south from the Fraser River channel (Canoe Pass) onto the Roberts Bank (Photo P3.3-3).

Important biophysical factors influencing the vegetation communities include water salinity, substrate and elevation. Sediments carried by the Fraser River include sand and fines (silt and clay), which make up the marsh soils. Vegetation closer to the mouth of the Fraser and at higher elevations tend to be more freshwater species such as *Typha latifolia* (common cattail) and *Carex lyngbyei* (Lyngbye's sedge) (Photo P3.3-4), while species further from the river where salinities are higher are dominated by *Scirpus maritimus* (seacoast bulrush) (Photo P3.3-5) and *S. americanus* (three-square bulrush) (Photo P3.3-6).

East of the first tidal channel, vegetation is dominated by dense stands of sedge and cattail and *Scirpus validus* (softstem bulrush) with more salt water tolerant species such as bulrushes and *Triglochin maritimum* (seacoast arrowgrass) colonizing the lower elevations along the southern edge. Water salinities in August were measured at 8-13 ‰; indicative of brackish conditions. Along the edge of the marsh, annual salt tolerant pioneers such as *Spergularia canadensis* (sand spurry) and *Cotula coronpifolia* (brass buttons) occur.

Between the two channels, the two species of bulrush dominate, with sedge colonizing the upper elevations closer to the river, where freshwater inflows occur. Salinity was measured at 9 ‰ in a stand of *Carex* at the middle of inter-channel. This section of the marsh is a transition zone, mixed with bulrush and sedge. West of the tidal channel, the vegetation is dominated by *S. americanus*, with patches of *S. maritimus*. At the outer sections of Brunswick marsh, *S. americanus* is smaller (< 50 cm in height) compared with plants further landward, which are 1-1.5 m in height.

During the 2003 field surveys, several species of ducks, Canada geese, and an American bittern were observed. The dense emergent marsh vegetation provides cover for waterfowl and wading water birds, as well as nesting habitat for passerines such as marsh wren (nest observed in the cattail). Several species of waterfowl consume the marsh vegetation: sedge by Canada geese;

bulrush by snow geese; algae by ducks such as mallards and widgeon. The marsh also provides habitat for several species of infauna and epifauna which in turn provide food for water birds and fishes. Of the fishes utilizing the marsh, juvenile salmonids, juvenile ground fish (e.g., starry flounders) and cyprinids are seasonally important. These fishes support a number of piscivorous birds (e.g., mergansers and other diving ducks, great blue herons, etc.).

3.3.2.2 Salt Marsh

The salt marshes along the Roberts Bank causeway and the BC Ferries compensation marsh are comparatively new, having developed since construction of the causeway. The salt marshes along the Delta dyke, including the Tsawwassen salt marsh, are more mature having developed from around the beginning of the 1900's when the dykes were constructed to reclaim wetlands for agriculture.

The dominant vegetation in the salt marsh changes to more salt tolerant species such as *Salicornia virginica* (pickleweed), *Distichlis spicata* (saltgrass), and *Atriplex patula* (orache). *Triglochin maritimum* is a common species, but *Carex lyngbyei* is absent, except in an isolated patch on the north bank of the Roberts Bank causeway at the confluence with the Delta dyke. *S. maritimus* and *S. americanus* have much more patchy and limited distribution east of Brunswick marsh, and total plant length is much reduced.

Water salinity measured in tidal pools in the August 2003 surveys ranged from about 13 ‰ at the eastern edge of the Brunswick marsh to 30 ‰ at the Deltaport embayment on the north side of the causeway, 28-32 ‰ along the outer Tsawwassen dyke between the causeways, and 30 ‰ within the BC Ferries compensation marsh.

Along the Delta dyke north of the causeway, the salt marsh (Photo P3.3-7) consists of a lower zone located at the base of the dyke and an upper zone located on the dyke slop up to approximately the mean tide line. The lower zone is dominated by *Salicornia virginica* and *T. maritimum*, with *S. maritimus* and *S. americanus* occurring as secondary species. The upper zone includes *D. spicata, S. virginica*, as well as *Plantago maritima* (marine plantain), *Grindelia integrifolia* (gumweed), *Atriplex patula* (orache), and salt tolerant grasses.

The salt marsh at the confluence of the Delta dyke and the Roberts Bank causeway supports a higher diversity of species and more luxuriant growth. The edge vegetation is dominated by *Triglochin* and *Salicornia*, but the upper marsh supports *Carex lyngbyei*, *S. maritimus*, *S. virginica*, *A. patula*, and *D. spicata*. The intertidal zone receives some freshwater input from a drainage ditch, which probably reduces salinities and permits less saline tolerant plants to grow (e.g., *C. lyngbyei*).

Along the north bank of the causeway, the salt marsh (Photo P3.3-8) is more recent and much of the upper mudflat supports pioneer species such as the annual *Spergularia canadensis.* The lower marsh is characterized by raised clumps of *Triglochin* and *Salicornia*. *Distichlis* and *Atriplex* occur with slightly raised elevations or where substrates are better drained, usually in the sloping, upper marsh zone. At upper mudflat, just below the cobble beach face, *S. maritimus* or *S. americanus* may form small patches. The former tends to colonize more organic substrates.

Further west along the causeway north bank, in the embayment formed by Deltaport, a more diverse upper and lower marsh community has developed (Photos P3.3-9 and P3.3-10). The lower marsh supports broad bands of *S. americanus* with patches of *S. maritimus*. *Z japonica* and *Ruppia maritima* occur in small tidal pools. Further out, the pioneer vegetation is *Spergularia* with tufts of *Triglochin* establishing. On the upper marsh slope, *Salicornia virginica* is the dominant species with a band of *Triglochin* colonizing the flat immediately at the base on the slope. *Triglochin* and *Distichlis* are interspersed with the *Salicornia*, but the *Distichlis* is found in dense patches at slightly higher elevations. *Atriplex* and *Grindelia* grow at the upper marsh zone. The upper marsh may be colonizing much coarser substrate, consisting of cobble, gravel and sand.

Within the intercauseway area, a small marsh patch, approximately 300 m^2 in area, composed of *Salicornia virginica* and *Distichlis spicata* grows in a cobble, gravel and mud beach at the base of the rip rap (Photo P3.3-11). This marsh is the only marsh patch within the footprint of the proposed Deltaport Third Berth expansion.

Along the south bank of the causeway at the confluence with the Delta dyke, the salt marsh consists of patches of *Salicornia* and *Triglochin*, with patches of *S. americanus* and *S. maritimus* near the shore. The upper mudflat is being colonized by *Spergularia*.

During the August marsh surveys, a new marsh plant for the Fraser River estuary was discovered in this area colonizing the mudflat up to 100 m from the shore. The new species was identified as *Spartina anglica* (English cordgrass) (Photo P3.3-12). It is a very aggressive invader of mudflats, resulting in serious impacts on the marine, unvegetated habitats, by displacing mudflats habitats, reducing habitat value of fish and shorebirds, increasing sediment accumulation and disrupting tidal drainage. It has currently invaded about 120 countries and since 1961 has covered over 6,000 acres in Washington State, where millions have been spent on its control and eradication.

In light of the serious ecological implications, Vancouver Port Authority retained GL Williams and Associates to coordinate a control program in 2003. A pilot study was undertaken in the fall of 2003 to test manual removal techniques. The measures successfully stopped the spread of the *Spartina* and in the fall of 2004, the remaining plants will be removed.

The BC Ferries compensation marsh was constructed in 1993 and consists of a 4 ha salt marsh (Photo P3.3-13), consisting of *S. virginica*, interspersed with *D. spicata*, *T. maritima*, and *G. integrifolia*. The marsh was constructed using sand dredge spoil and surrounded by a rock berm with an eastern opening.

The largest area of salt marsh within the intercauseway area is the Tsawwassen salt marsh. The entire marsh is contained by dykes with two culverted openings that allow tidal flushing of the marsh. The marsh vegetation is characterized by a *Salicornia*, with *Distichlis*, *G. integrifolia*, *A.*

patula present. Several tidal channels dissect the marsh (Photo P3.3-14). There are several large accumulations of wood debris in the northeastern section. Tidal channel flows are impeded by logs and the culvert elevation appears to be limiting tidal discharge at low tide.

Soil samples 8, 10 and 11 along the Delta dyke (see Figure 3.3.1-1 for locations) transect were selected to provide data on the micro-algae substrates, mudflat, and intertidal marsh sediments, respectively. The west causeway samples represented mudflat, *Distichlis* and *Scirpus* sediments. The last sample was selected to provide data on the intercauseway mudflat and was located beside a large clone of *Spartina*.

Soil particle sizes analysis showed that the Delta dyke substrate, which included the microalgae covered mudflat, mudflat and salt marsh had very fine soils, consisting of silt loam texture for mudflat samples and silt clay for the salt marsh (Figure 3.3.2-1; Appendix A3.3-1a). In contrast the west causeway salt marsh, which was more recently established, had sand loam soil texture. The mudflat on the east bank of the causeway had loam texture, comprised of about 50 % sand and 50 % fines (i.e., silt and clay).

The Delta dyke marsh had a higher percent of organic matter, moisture content, percent of carbon and nitrogen, redox (oxygenated sediments), nutrients and salinity than the west causeway marsh. The mudflats on the west side of the Roberts Bank causeway had higher redox and nutrients than the east bank. The pH in the marshes was lower (slightly more acidic) than in the mudflats. Phosphorus was greater in the mudflat samples than in the marshes, suggesting that there is a greater pool of the nutrient available.

Although sample size was small, the data suggest that the older marsh soils contain higher organic matter and nutrients than the more recently established marsh. This would be expected because of the longer time frame available for processing organics and nutrients into the soils. An interesting result was that the phosphorus concentration was higher in the mudflat samples than in the marsh samples. The microalgae covered mudflat contains the lowest amount of phosphorus, possibly caused by uptake of the algae film. These results suggest a complex cycling between the marsh and mudflat.

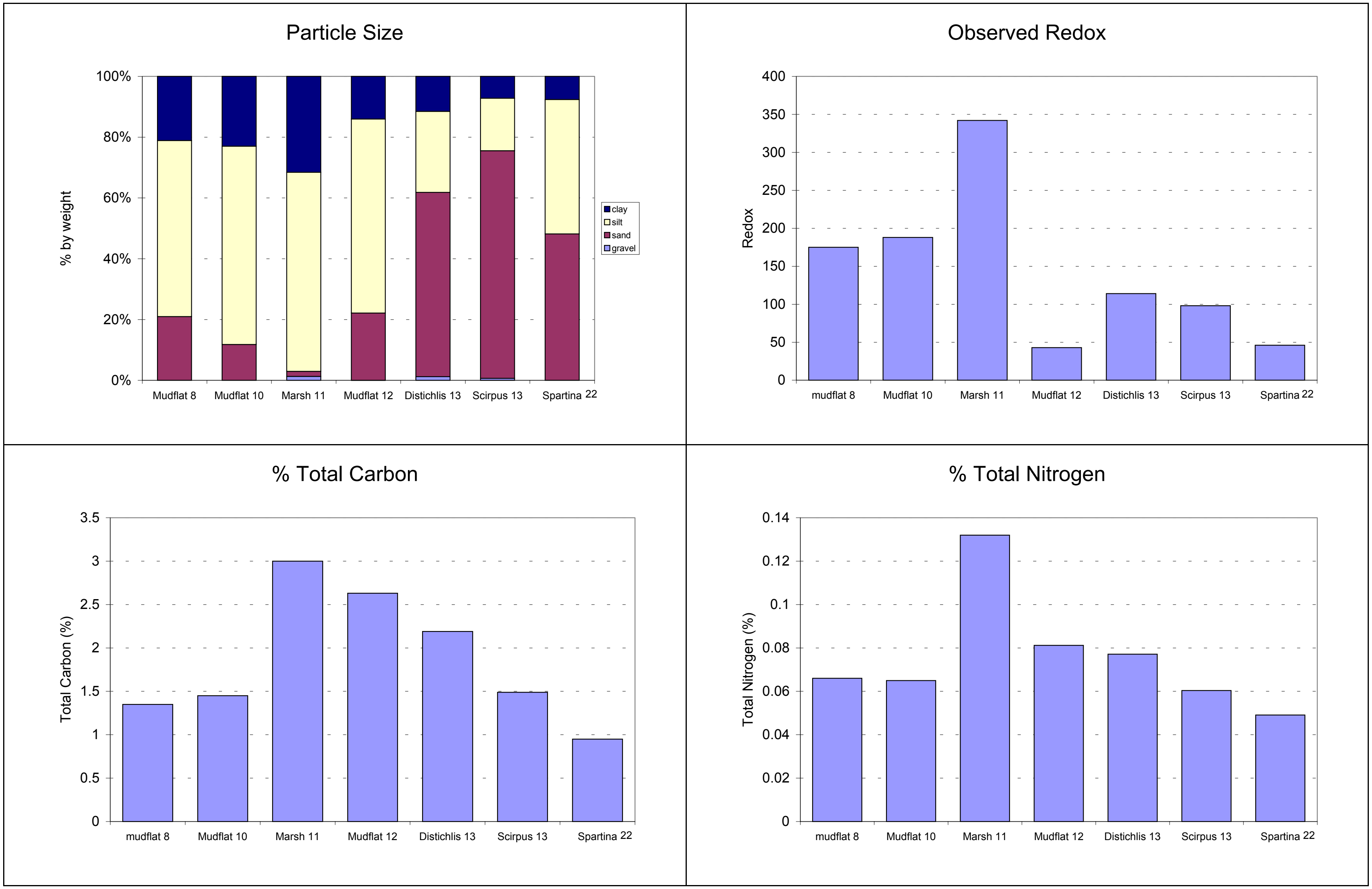

Figure 3.3.2-1. Selected soil parameters for Roberts Bank. Refer to Figures 3.3.1-1 and -2 for sample locations (shown in brackets).

3.3.3 Intertidal sand/mudflats

Sand/mudflats are part of the intertidal marine foreshore. Mudflats are hereby defined as sedimentary intertidal areas with a substrate primarily composed (60% or greater) of fine sediments (sand, silt, mud, clay). They thus encompass sand flats in the rest of the discussion. This ecosystem is the most accessible of the marine ecosystems and extends from the high water mark (Higher High Water Large Tide (HHWLT), Canadian Hydrographic Service 1999; this is often termed splash or spray zone and is considered to be the highest water mark, averaged over 19 years) to the lower low water (LNT, lowest normal tide).

In the Pacific Northwest, the *in situ* high water mark can usually be determined by the presence of the black lichen (*Verrucaria* sp; Kozloff 1983). Most of the study area was approximately 4.5 km from the shore and bordered by rip rap, two factors which negatively affect the presence and abundance of *Verrucaria*. The high water mark was determined from a combination of observed *Verrucaria* when present and the small barnacle *Chthamalus dalli* (typically the barnacle present at the highest point in the intertidal; Harbo 2003) and + 5 m above Chart Datum. The LNT limit was taken to be 0 m Chart Datum.

Most animals and plants encompassing sand and mudflats are adapted to some degree of dessication and to extremes in salinity and temperatures. The marine foreshore in the southern portion of the Strait of Georgia rarely contains endemic species (many are invasive or introduced), but many species have been either commercially or traditionally harvested by Native groups.

The west side of the Roberts Bank causeway is dominated by sand/mudflats (60% of the available substrate within the study area) while eelgrass occupies 66% of the intercauseway area (Table 3.3.3-1a, Figures 3.3.1-1 & 3.3.1-2). Most of the biophysical processes (sediment accretion and consequent ecological zonation) on the west side are along a NNW- SE axis, reflecting the influence of the Fraser River plume whereas they are along a NE-SW axis towards the shore in the intercauseway area. This is evidenced by the large zone of overlap between the two eelgrass species in the intercauseway area (86 ha; Figure 3.3.1-2) a zone presently very thin and practically inexistent on the west side.

The footprint of the proposed Deltaport Third Berth project is subject to sediment accretion in its SW corner (M. Tarbotton, Triton Consultants Ltd., pers. comm.), which explains the large portion of the area covered by mudflats (75% vs. 14% for the whole east side; Figure 3.3.1-2 and Table 3.3.3-1b).

The mudflats on the west and east sides of the Roberts Bank causeway are heterogeneous habitats and host several small ecosystems and species. The most visible of these are the green filamentous alga *Enteromorpha* sp., bivalves, and Dungeness crabs. Although two eelgrass species (*Zostera marina* and *japonica*) are found on mudflats, they are considered separate ecosystems and treated as such (Section 3.3.4).

Table 3.3.3-1a. Substrate composition of west and east sides of the Roberts Bank causeway.

West			East		
Substrate	Area (ha)	Percent total cover		Area (ha)	Percent of total cover
sand	824.67	49.5%	*Zostera marina*	414.79	37.9%
Zostera marina	223.46	13.4%	*Z. japonica*	310.42	28.4%
Z. japonica	195.70	11.7%	mud	103.03	9.4%
marsh	178.31	10.7%	marsh	86.98	7.9%
mud	173.23	10.4%	*Z. marina & japonica*	85.67	7.8%
microalgae	38.80	2.3%	sand	47.39	4.3%
grass	12.06	0.7%	rip rap	13.28	1.2%
channel	6.85	0.4%	grass	8.14	0.7%
rip rap	5.82	0.3%	subtidal	7.61	0.7%
cobble	3.76	0.2%	cobble	7.32	0.7%
shrubs	2.66	0.2%	shrubs	5.93	0.5%
gravel-sand	1.88	0.1%	channel	2.24	0.2%
			gravel-cobble	2.01	0.2%
total area	1,667.2			1,094.8	

Table 3.3.3-1b. Substrate composition of the Deltaport Third Berth project footprint.

	Area (ha)	Percent of total cover
Sand Flat (Mud)	9.29	42.7%
Mud Flat (below -5m)	3.70	17.0%
Mud Flat (above -5m)	3.45	15.9%
Zostera marina	2.92	13.4%
Rocky habitats	1.18	5.4%
Zostera japonica	1.13	5.2%
Salt marsh	0.07	0.3%
Total area	21.74	

3.3.3.1 Temperature and salinity

Temperature

Water temperatures and salinities were measured during the crab and prawn trap sampling. These results are very localized in time and should not be taken to be representative of the whole seasonal variations. The stations were however measured within one or two hours of each other and the data therefore provide a glimpse of the oceanographic differences between the west and east sides of the Deltaport causeway. The west side is more affected by the freshwater plume of the Fraser River and the data confirm this: the thermocline was more pronounced on the west side than in the intercauseway area (Figure 3.3.3-1). Site 02, closest to the Fraser plume, showed the most variation in water temperature within the water column as the freshwater layer mixed with saltwater. The absence of a thermocline in fall and winter reflected the more thorough mixing of water due to winds and generally lower air temperatures. The water temperatures were consistent with time of year: temperatures were warmer in summer and spring (11°C at depth in both cases) and approximately 3 °C cooler in fall and winter. These temperatures are considered normal for the time of year and area (Thompson 1981).

There was however a significant drop in water temperature in the upper layer of the intercauseway water column in late December to early January (Figure 3.3.3-2). This is partially explained by the shallow depth of the data recorder (1 m) and the slow water movements in the immediate area. Tug boat personnel mentioned that ice often forms around the tug boat wharf during cold periods. Water temperatures measured during the beach seining showed a similar drop in late November (Table 3.3.3-2).

Table 3.3.3-2. Water temperatures (°C) as measured during beach seining.

	November 18, 2003	February 28, 2004
Day	6.7	8
Night	0.5	7.5-8

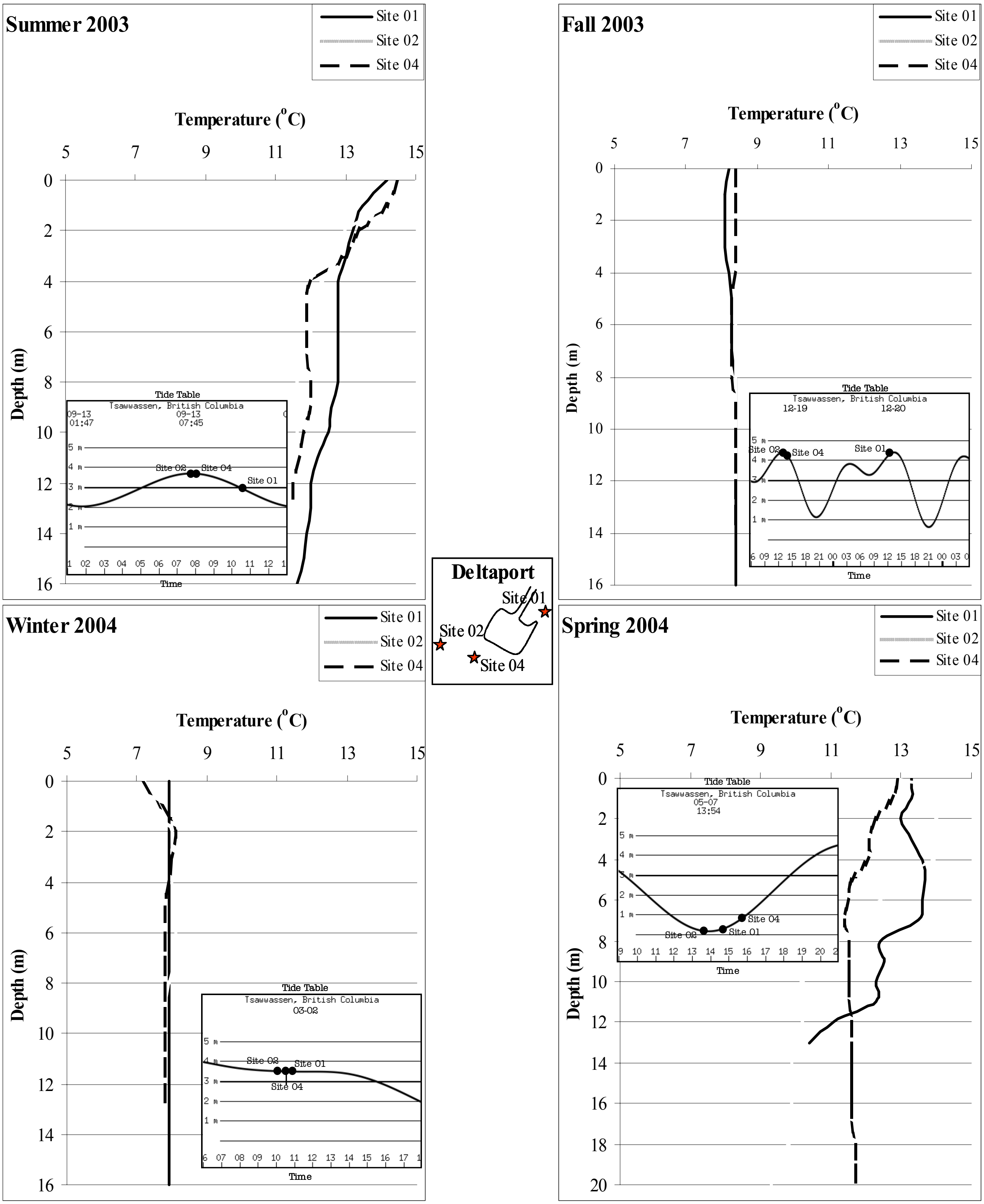

Figure 3.3.3-1. Temperatures measured at three sampling sites. Inserts indicate tidal amplitude at time of sampling.

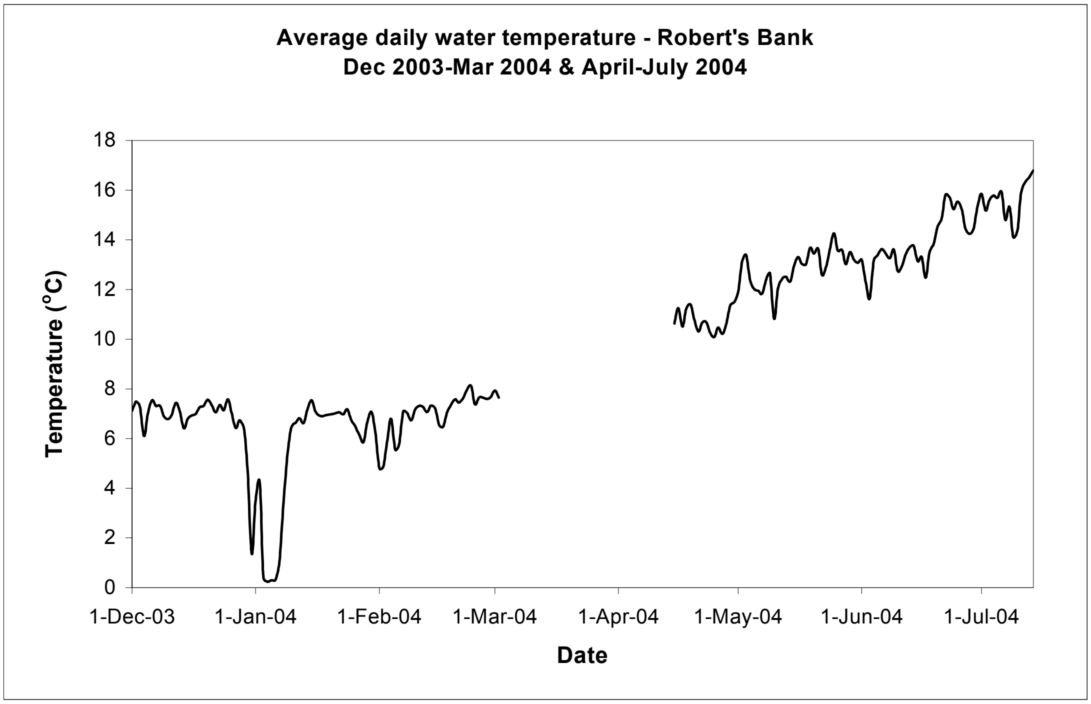

Figure 3.3.3-2. Mean daily water temperatures measured at the tug boat basin, Deltaport Third Berth project, December 2003 to March, 2004. Depth is 1 meter. No data available between March 03 and April 13, 2004.

Salinity

One of the main effects of the Roberts Bank causeway is to deflect the freshwater plume from the Fraser River, resulting in higher salinities in the upper (shallowest) part of the water column. This effect was visible in the salinity measurements (Figure 3.3.3-3): the intercauseway site (site 01) had generally higher salinities than the western sites in the upper three meters. The observed salinities were consistent with those reported for the area (Thompson, 1981; Gordon and Levings, 1984).

In conclusion the water column in intercauseway area (east side of the causeway) differs from the west side in terms of higher salinity and generally less mixing in the upper water column. This oceanographical environment is thus more stable.

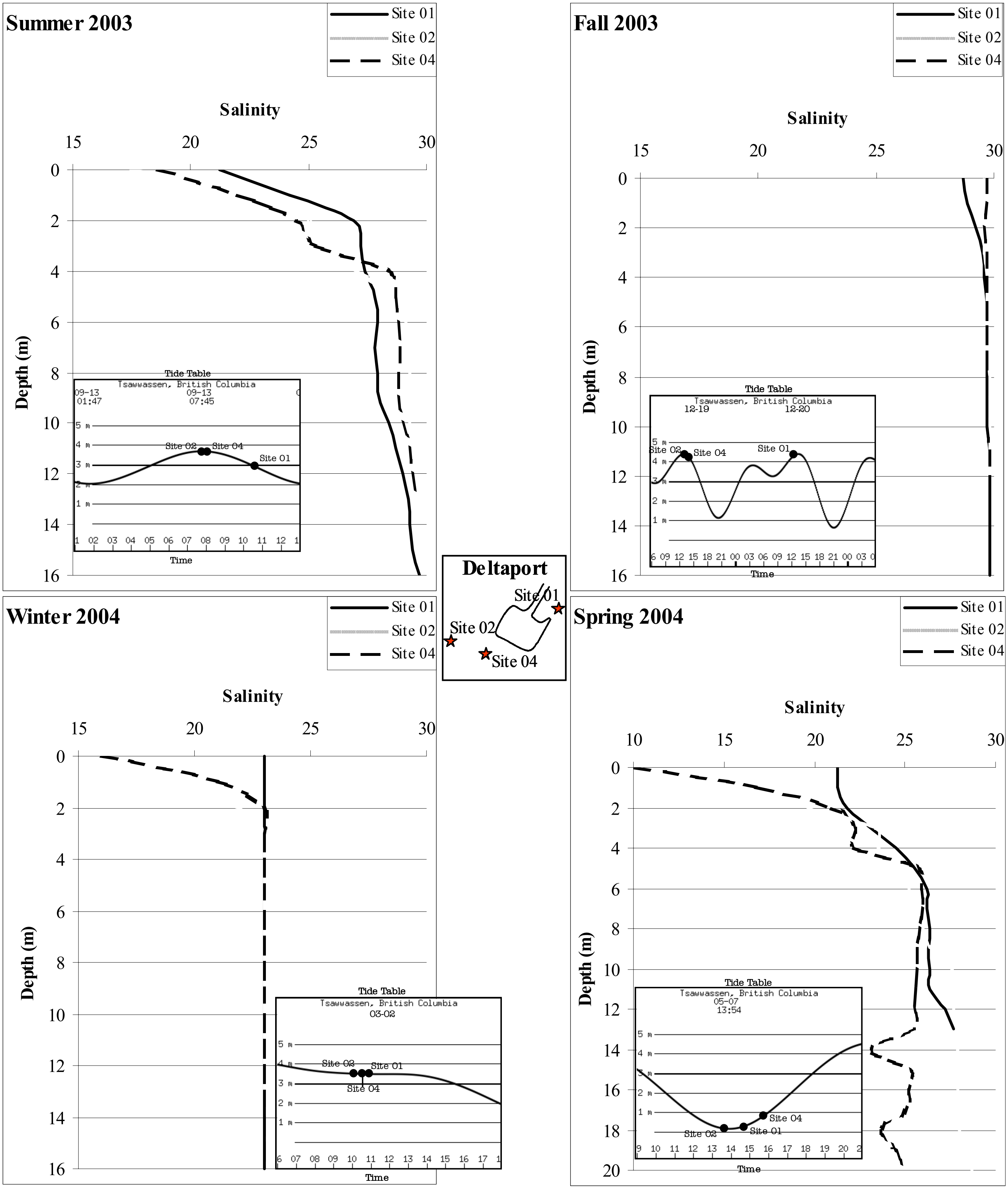

Figure 3.3.3-3. Salinities measured at three sampling sites. Inserts indicate tidal amplitude at time of sampling.

3.3.3.2 Macrophyte cover

Enteromorpha hummocks and patches

The green filamentous alga *Enteromorpha sp*[2] occupies the mid intertidal on both sides of the causeway, at usually higher elevation than the native eelgrass *Z. marina*. Many species of the *Enteromorpha* genus are unattached and free floating (Abbott and Hollenberg 1976). The alga tops hummocks on the west side (these hummocks were observed only on that side of the causeway). The area covered by these hummocks was estimated at approximately 26 ha as of August 2003 (Figure 3.3.3-4). The origin, persistency[3] and ecological importance of these hummocks are at present unknown. Raffaelli (2000) reports negative effects of macroalgal mats primarily composed of *Enteromorpha* sp. on amphipods abundance, the most important prey for estuarine shorebirds. Brachyuran zoea larvae were observed to settle in *Enteromorpha* close to shore on the west side in April, 2004 although neither the extent nor frequency of this phenomenon are known. Similar hummocks have been described in Boundary Bay (Kellerhals and Murray 1969).

Enteromorpha tends to form bands and patches in the proposed Deltaport Third Berth project footprint (Figure 3.3.3-5) and overlaps with the distribution of *Z. marina* at lower elevations. The distribution of *Enteromorpha* appears to be partially limited by that of *Z. marina*.

3.3.3.3 Macroinvertebrates

Invertebrate Literature review

There are more than 200 invertebrate species living in the surroundings of Roberts Bank, based on a literature review of twelve studies carried out in the area in the last 30 years (Appendix A3.3-2). Sampling methods varied from quadrats to ponar grabs. Whenever possible the habitats sampled were noted and species were assigned to the habitats in which they were sampled. Habitats were grouped into four major ecosystems/habitats: eelgrass, salt marsh, mudflats and rip rap/boulders. Not all species could be assigned to habitats, and many species were found in several habitats. Based on this, mudflats harboured the highest biodiversity (120/ 229 species reported), followed by eelgrass (81 species), salt marsh (38) and rip rap (28).

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[2] Specimens of the alga were brought in August, 2003, to Dr. R. E. DeWreede from the Department of Botany, University of British Columbia. They were later tentatively identified as either *Enteromorpha torta* or *E. flexuosa*. The unequivocal identification would require to count the number of pyrenoids per chloroplast (Dr. R.E. DeWreede, pers. comm.), and this was not deemed necessary.

[3] *Enteromorpha* hummocks were present in the same area in 2003 and in 2004. Their areal extent was not measured in 2004.

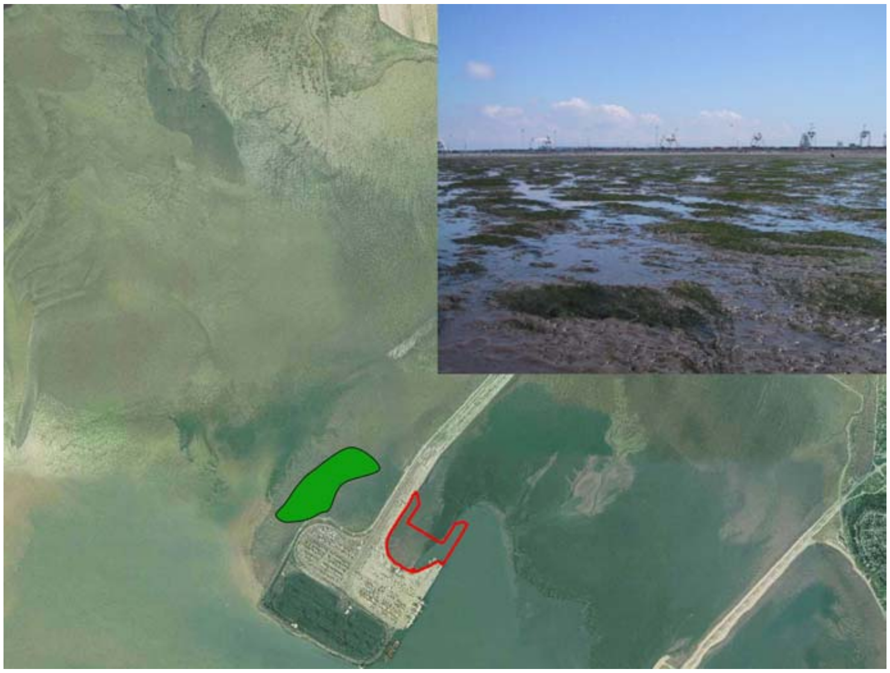


Figure 3.3.3-4. Approximate location of *Enteromorpha* hummocks along the Roberts Bank causeway. The area they cover is estimated at 26 ha as of August 2003. The red outline is the proposed Deltaport Third Berth project footprint. Insert shows a view of a portion of the area: the causeway can be seen in the background.

Figure 3.3.3-5. Distribution of *Enteromorpha* sp. in the intertidal area of the proposed Deltaport Third Berth project (red outline). The area covered by *Enteromorpha* sp. in the lower intertidal as of June, 2004, is green. The blue area shows the distribution of a band of *Enteromorpha sp.* in the higher intertidal. The insert shows *Enteromorpha* (dotted yellow lines) among eelgrass *(Zostera marina*) patches.

Polychaetes and amphipods were the most commonly reported taxa. These are generally common over sandy/silty bottoms, and this reflects both the sampling methods (there were few studies sampling the water column and most could not sample large animals such as sea stars) and the habitats present around Roberts Bank.

Based on the Conservation Data Centre database, none of the blue nor red-listed species recorded for the general Roberts Bank area were observed or recorded in the samples (cf. Appendix A3.3-2B for complete list).

Intertidal quadrats and point samples

Five transects were surveyed on both sides of the causeway from August to early September, three on the west side and two on the east side of the Roberts Bank causeway (Section 3.2.2; Figure 3.2.2-2). Their location was chosen to cover habitats representative of both sides while at the same time sampling areas which had been deemed as potential sites for either the Terminal 2 project or the Deltaport Third Berth project. Two additional transects (DT 2 and DT 3) were later sampled in the Deltaport Third Berth project footprint during the lowest tides of the year (in December).

The point samples were divided among the west and east sides of the Roberts Bank causeway into four general quadrants (Figures 3.2.2-2 and 3.3.3-6). A subset of the data from the east side of the Roberts Bank causeway within the Deltaport footprint was analysed separately. The native eelgrass (*Z. marina*) percent of cover was on average higher to the east of the causeway, as expected (Figure 3.3.3-7). The west quadrant eelgrass cover was primarily accounted for by an eelgrass bed which started roughly 900 m from the causeway. *Enteromorpha sp.* covered a higher percent of the substrate to the east of the causeway, and was highest in the Deltaport Third Berth project footprint. The sand:silt ratio was higher in the southwest quadrant, and was most even in the Deltaport Third Berth project footprint. Ghost shrimp were found in almost equal densities in the southwest and east quadrants and cockles and bivalves siphon holes were more abundant in the west quadrant (Figure 3.3.3-8).

There were 32,336 individuals belonging to at least 76 identified macroinvertebrate species counted on both sides of the causeway, based on 50 intertidal quadrats analyzed. More species are likely to be found when the remaining quadrats are analyzed. A list of invertebrate species found in this study is shown in Appendix A3.3-3a.

Species richness was in general higher to the east of the causeway (Table 3.3.3-3), but this partly reflects the higher effort of analysis (25 of the 50 quadrats analyzed were from the footprint area). Transect DT, on the proposed Deltaport Third Berth project footprint, was rich in bivalves (mostly clams) and polychaetes. The lower number of species found in transect DT-2, also in the Deltaport Third Berth project footprint, can be attributed to the time of year (December) and to fewer habitats sampled — most of the sampling was done near or in the eelgrass zone as *Enteromorpha* was absent at that time of year, whereas DT-1 was sampled more uniformly among habitats.

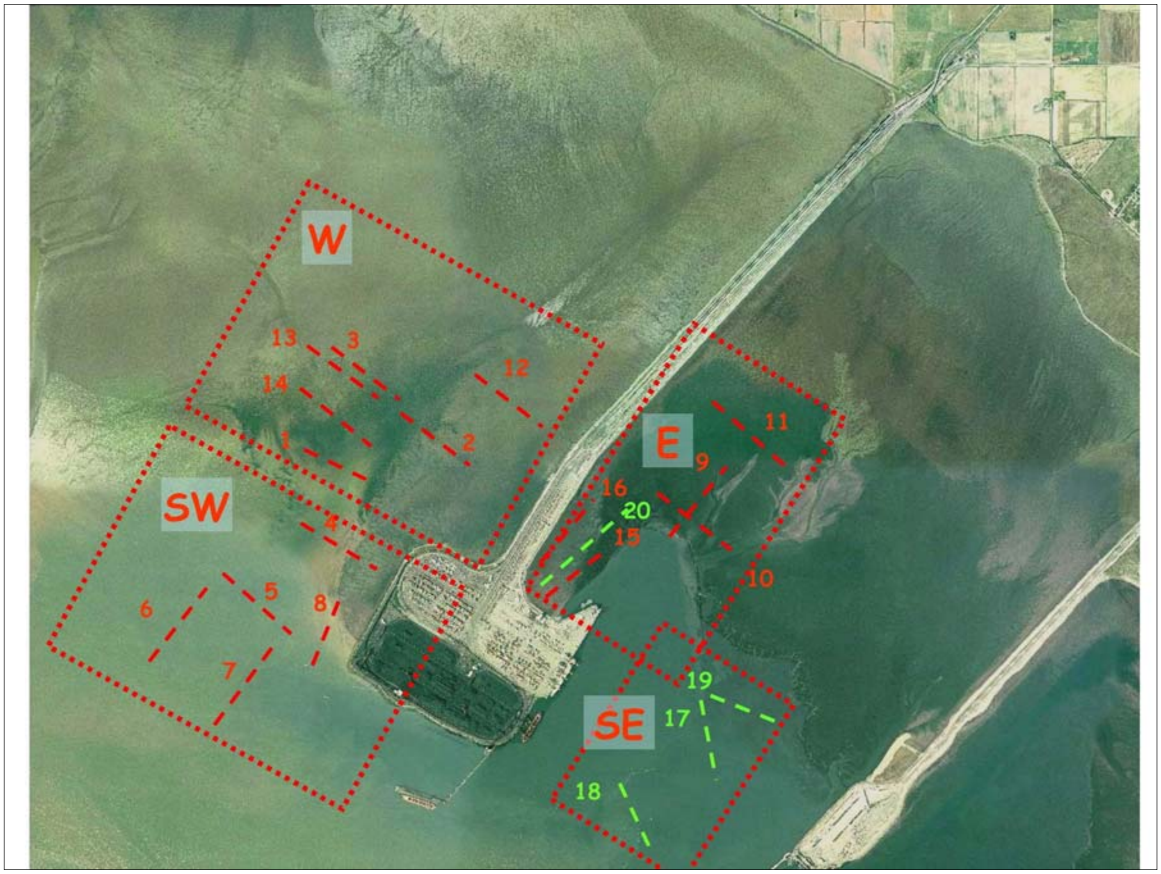


Figure 3.3.3-6. Main quadrants used to summarize beam trawling data. Green beam trawling sites (SE) were only sampled in Spring 2004.

To facilitate data summary, species were grouped into large taxa:

Decapods:	Brachyuran and anomuran crabs, ghost shrimps and Crangonidae, except *Cancer magister*.
Isopods:	*Idotea* and *Synidotea* spp.
Amphipods:	Gammarid and caprellid amphipods
Gastropods:	all gastropods
Bivalves:	all bivalves except *Clinocardium nuttallii* and the *Macoma* genus
Macoma:	bivalves belonging to the *Macoma* genus
Clinocardium:	cockles
Polychaetes:	all polychaetes

and other taxa as shown.

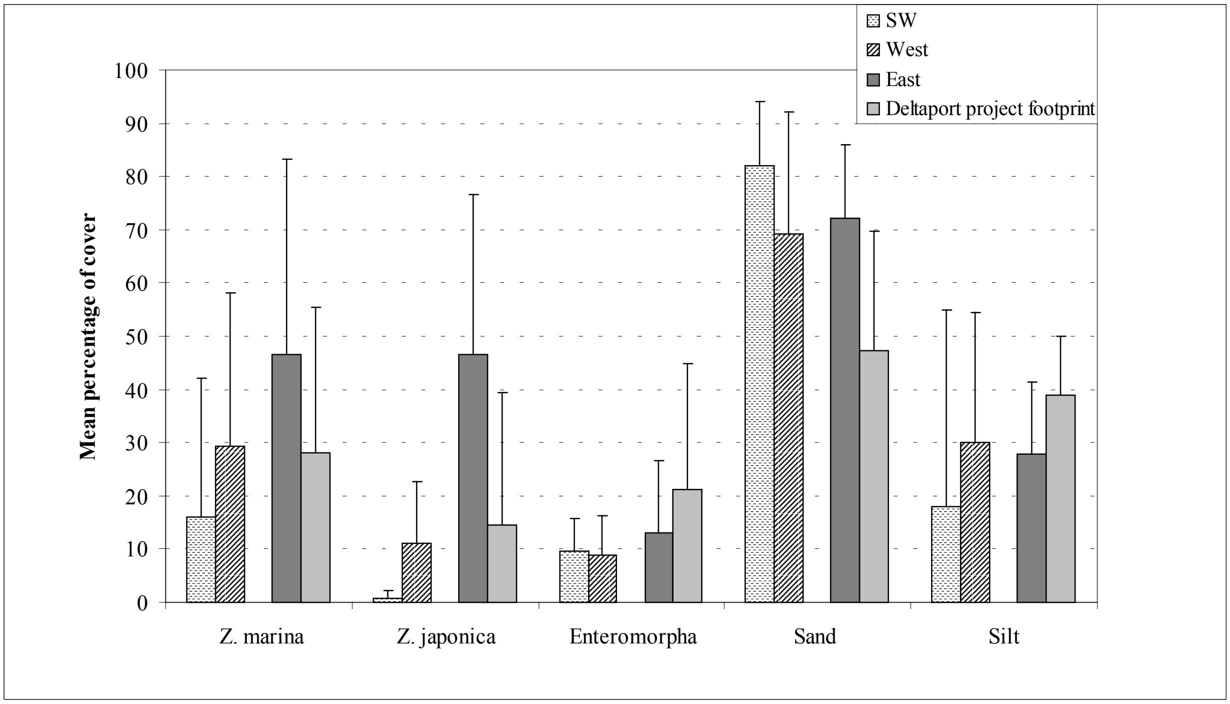


Figure 3.3.3-7. Percent cover (macrophytes) or composition (substrate) as measured by point sampling. Areas divided as per Figure 3.3.3-6 – SE quadrant omitted. Error bars are SD.

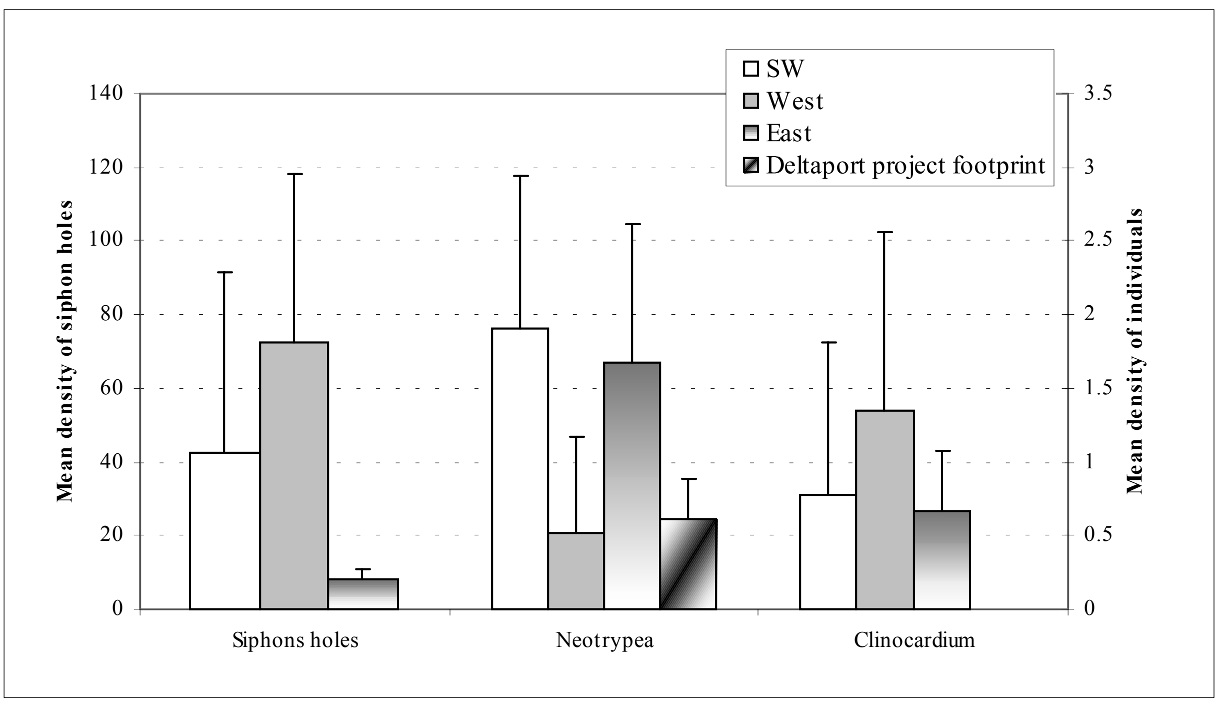


Figure 3.3.3-8. Mean densities of siphon holes, *Neotrypaea* and *Clinocardium* in the west, southwest, and east quadrants, and in the Deltaport project footprint, calculated from point sampling. Note different axes for siphon holes and for *Neotrypaea* and *Clinocardium*.

Amphipods dominated the macrofauna collected to the west of the causeway, whereas species evenness was slightly greater to the east of the causeway (Table 3.3.3-4). When species were grouped per habitat irrespective of the location, the eelgrass habitat appeared more diverse (taxa more evenly distributed than in the other habitats). Dungeness crabs were proportionally more important in *Enteromorpha* than in any other habitat (if amphipods and polychaetes are omitted, Dungeness account for 15% of the total number of individuals collected in that habitat).

Table 3.3.3-3: Number of macroinvertebrate species from quadrats sampled to the west and east of the Roberts Bank causeway, August to December 2003.

	West				East			
	W3-1	**W2-1**	**W2-2**		**E-1**	**DT-1**	**DT-2**	**DT-3**
Taxon	N=5	N=6	N=9		N=4	N=11	N= 11	N = 4
Amphipods	4	6	8		7	9	7	6
Bivalves	6	6	5		7	12	6	6
Bryozoans	0	1	0		1	1	1	0
Decapods	2	5	4		3	4	4	0
Echinoderms	0	1	0		1	0	3	0
Gastropods	2	4	3		5	5	4	3
Isopods	2	1	1		3	3	4	2
Nemerteans	0	0	1		1	2	0	0
Polychaetes	1	10	8		4	19	3	1
Pycnogonids	0	0	0		1	2	0	0
Other	0	0	1		1	1	1	0
Total	***17***	***34***	***31***		***34***	***58***	***33***	***18***

N= number of quadrats analyzed per transect.

Amphipods were the most numerically abundant animals among the majority of transects (Figure 3.3.3-9). These small arthropods are usually scavengers, tend to bury into the substrate and can thus be considered bioturbators as they change the physical texture of the substrate. They also occupy several habitats. Gastropods were proportionally more abundant on the west side. Bivalves were an important part of transect W2-2's fauna — this transect partially bisected an area of high bivalve density whereas polychaetes were especially abundant in the Deltaport Third Berth project's footprint.

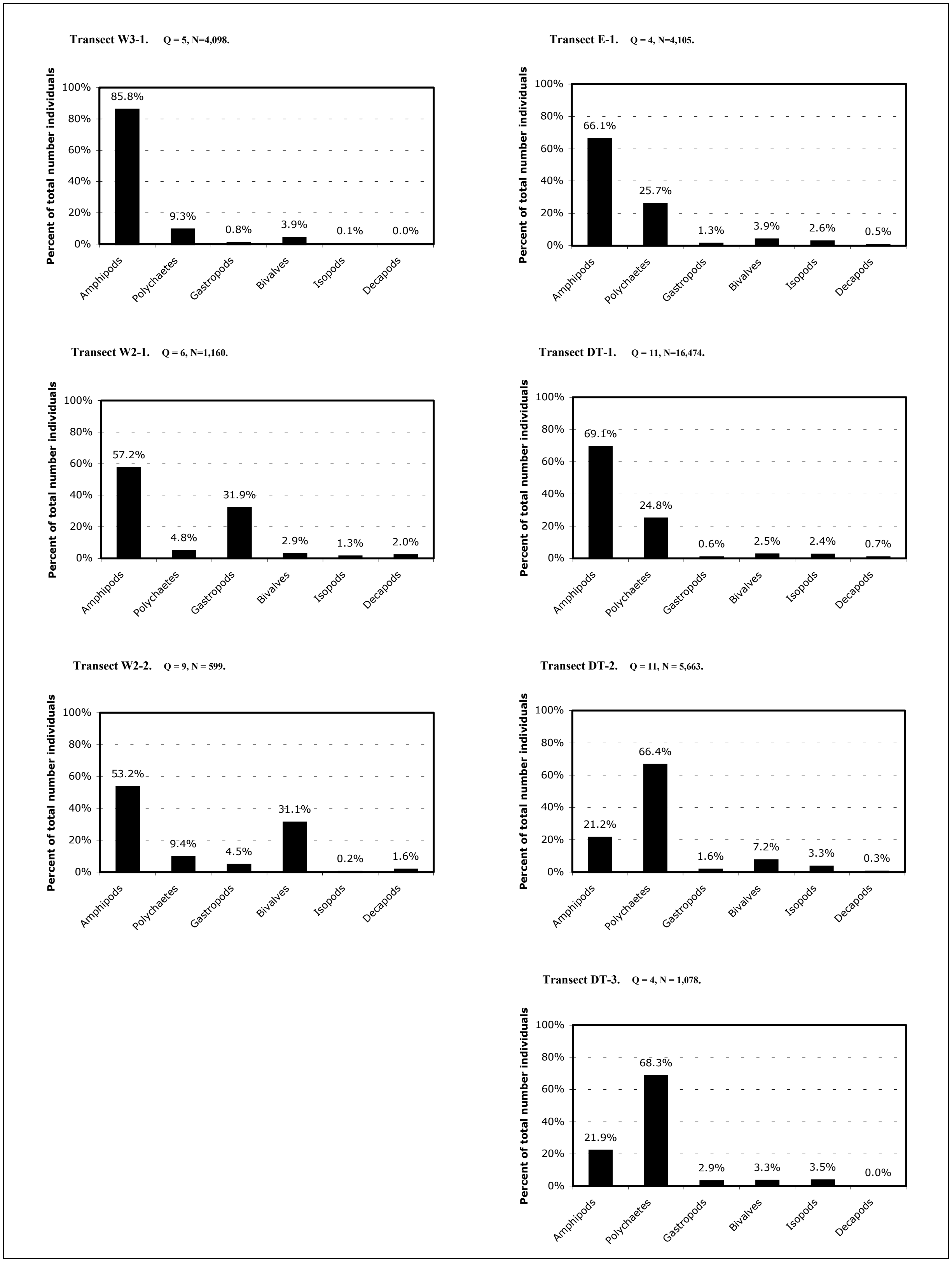


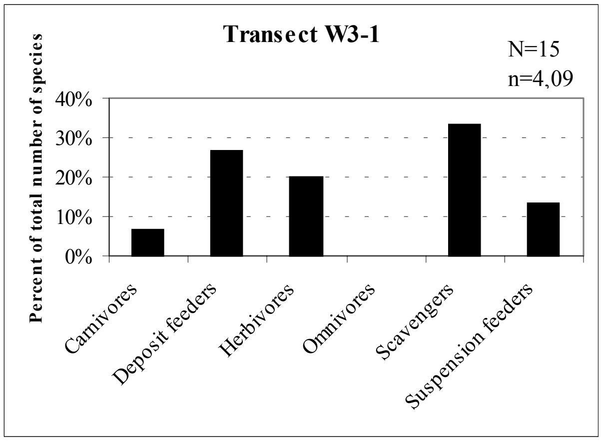
Figure 3.3.3-9. Percent of total number of individuals collected in intertidal quadrats. Q = number of quadrats analyzed, N = number of animals enumerated

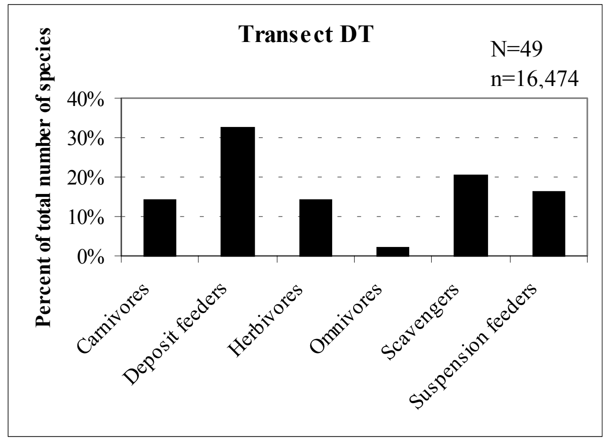
Table 3.3.3-4. **Percent of total numbers of various macroinvertebrate taxa (number of individuals / total number) collected on both sides of the Roberts Bank causeway, August to December 2003.**

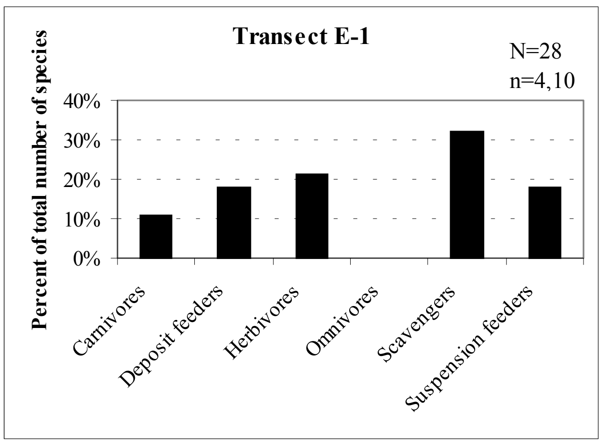
	Side of Roberts Bank causeway				Habitat					
Rank	**West**		**East**		***Enteromorpha***		**Eelgrass**		**Mudflat**	
1	Amphipods	78.6%	Amphipods	57.4%	Amphipods	66.2%	Amphipods	52.0%	Amphipods	69.5%
2	Polychaetes	9.8%	Polychaetes	34.8%	Polychaetes	28.8%	Polychaetes	37.0%	Polychaetes	24.1%
3	Bivalves	4.6%	Isopods	2.6%	Bivalves	2.7%	Isopods	4.6%	Bivalves	2.7%
4	Gastropods	4.5%	Bivalves	2.3%	*Cancer magister*	0.8%	Bivalves	2.7%	Gastropods	1.8%
5	*Macoma*	1.8%	Gastropods	1.0%	*Macoma*	0.5%	Gastropods	1.6%	*Macoma*	1.3%
6	Decapods	0.2%	*Macoma*	0.9%	Gastropods	0.5%	*Macoma*	0.9%	Isopods	0.2%
7	*Clinocardium*	0.2%	*Clinocardium*	0.5%	*Clinocardium*	0.4%	*Clinocardium*	0.7%	Decapods	0.2%
8	Isopods	0.2%	*Cancer magister*	0.3%	Decapods	0.2%	*Cancer magister*	0.3%	*Clinocardium*	0.1%
9	*Cancer magister*	0.1%	Decapods	0.2%	Isopods	0.0%	Decapods	0.2%	*Cancer magister*	0.1%

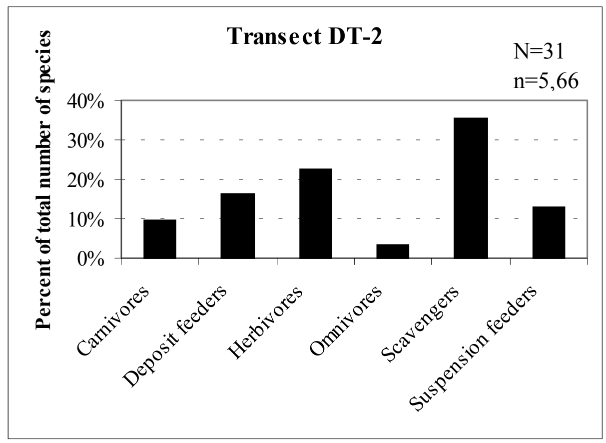
When the main taxa are divided into trophic levels (refer to Appendices A3.3-3a & b for list), scavengers, deposit feeders and herbivores dominate the faunal composition while carnivores and omnivores make up a smaller portion (Figure 3.3.3-10). There appeared to be a shift from a deposit feeders dominated to a scavengers dominated guild in DT from September to December (Transects DT- and DT-2) which reflects the time of year.

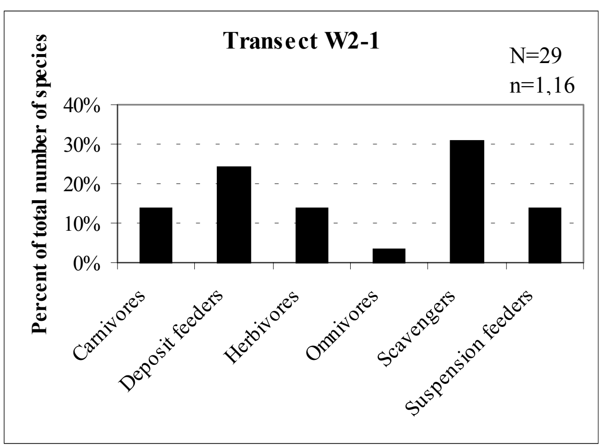
There were on average higher densities of siphon holes to the west of the causeway, especially along transect W2-2 which partially overlapped the area of high bivalve density (Figure 3.3.3-11a). This is partly related to the lower cover of eelgrass to the west of the causeway (Figure 3.3.1-1). The high siphon hole density was not mirrored by any of the bivalve species collected. The animals responsible for these holes (likely *Macoma* or *Tresus*) were probably buried deeper than the 10 cm depth from which the substrate was collected. Cockles were equally dense on both sides of the causeway, although they showed larger variations in density in the DT transect. This is likely due to a locally high abundance of *Clinocardium* juveniles in this transect. Although bivalves in general were present in higher densities to the east of the causeway, most animals collected belonged to small species such *Macoma balthica.*

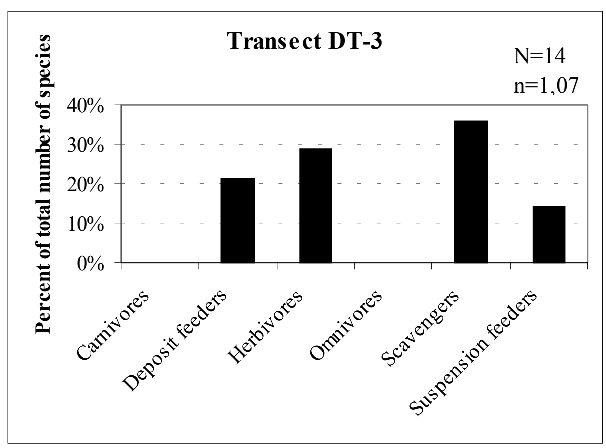












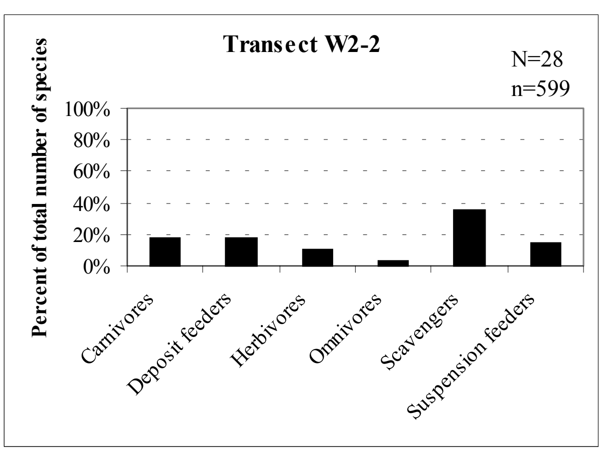


Figure 3.3.3-10. Partition of macroinvertebrate fauna collected from intertidal transects into trophic levels. N= number of species, n = number of individuals.

Most other species were present in higher densities to the east of the causeway (Figure 3.3.3-11b), although this is partially explained by the higher analysis effort on that side (30 vs. 20 samples analyzed). Dungeness crabs, mostly juveniles, were abundant in DT and to a certain extent in the SW side (transect W2-1). Gastropods were also abundant in that latter area, due to locally high densities of *Lacuna sp*. and other gastropods in two quadrats sampled in patches of *Z. marina* and *Z. japonica*.

The two main macrophytes present in the Deltaport Third Berth project footprint were eelgrass (*Z. marina*) and *Enteromorpha* (the latter in patches). To better compare these two ecosystems, the DT (September) quadrats were divided according to their principal macrophyte cover (85% or more): out of the 11 quadrats collected at that time, three were in the eelgrass zone and four in the sea hair zone. Only bivalves were found in somewhat higher densities in the *Enteromorpha* zone (Figure 3.3.3-12), although Macomas and cockles were found in roughly equal densities in both zones. Gastropods and amphipods were more abundant in eelgrass, and Dungeness crabs were present in equal densities in both zones, although early life stages of this species appear to require a combination of both macrophytes to settle.

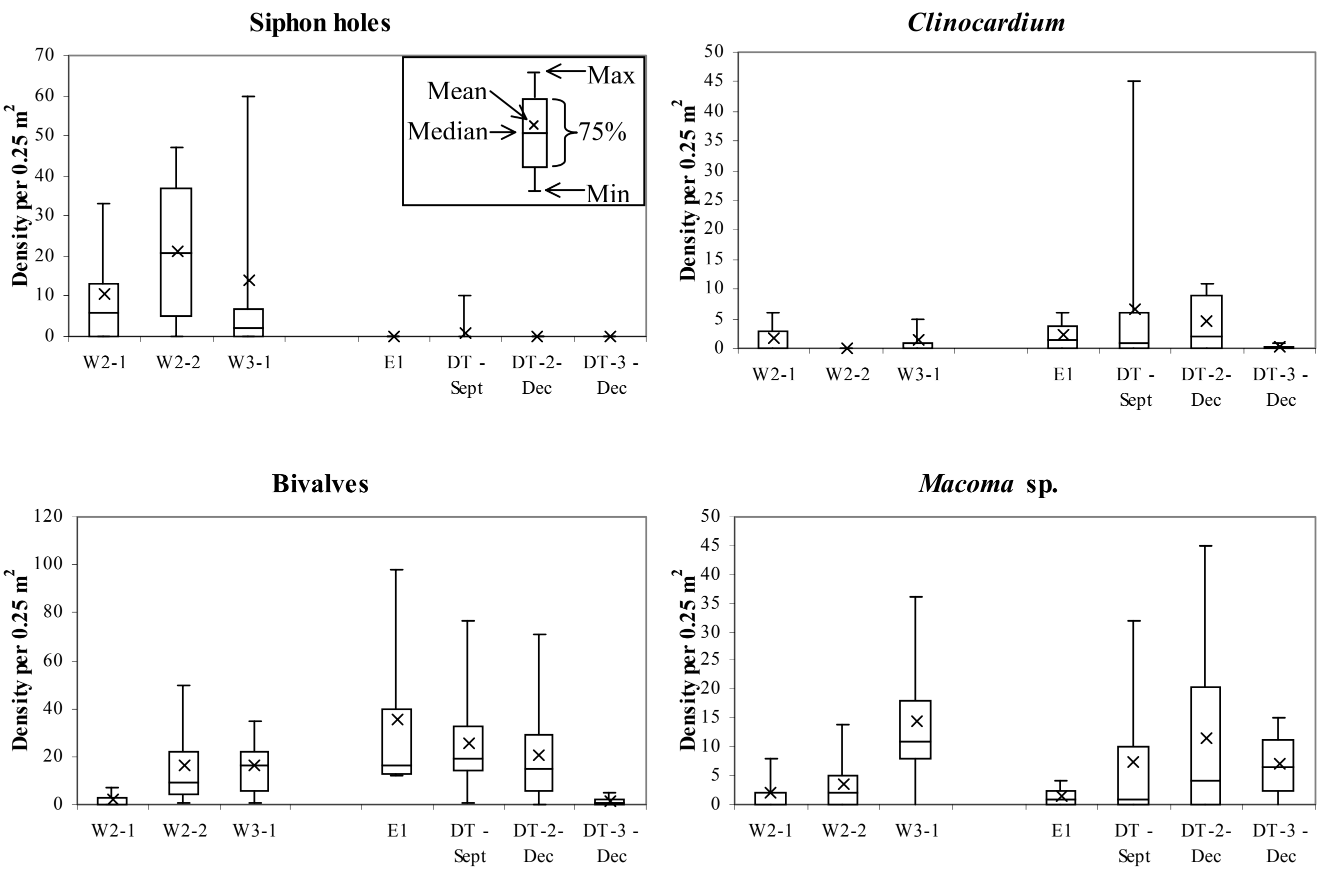


Figure 3.3.3-11a: Average densities per 0.25m^2 of macroinvertebrates collected in transects on either side of the Roberts Bank causeway, August – December 2003.

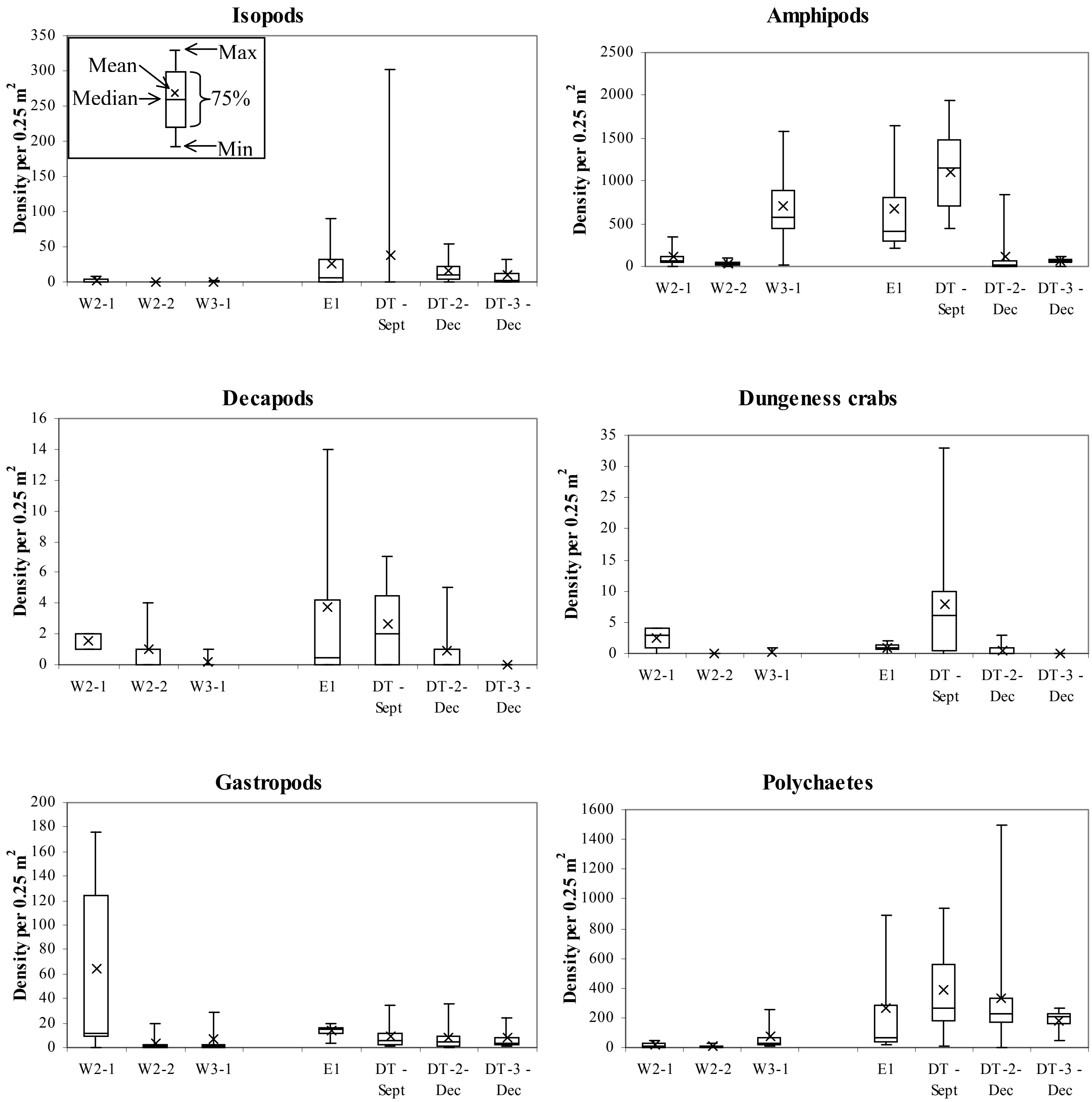


Figure 3.3.3-11b. Average densities per 0.25m^2 of macroinvertebrates collected in transects on either side of the Roberts Bank causeway, August – December 2003.

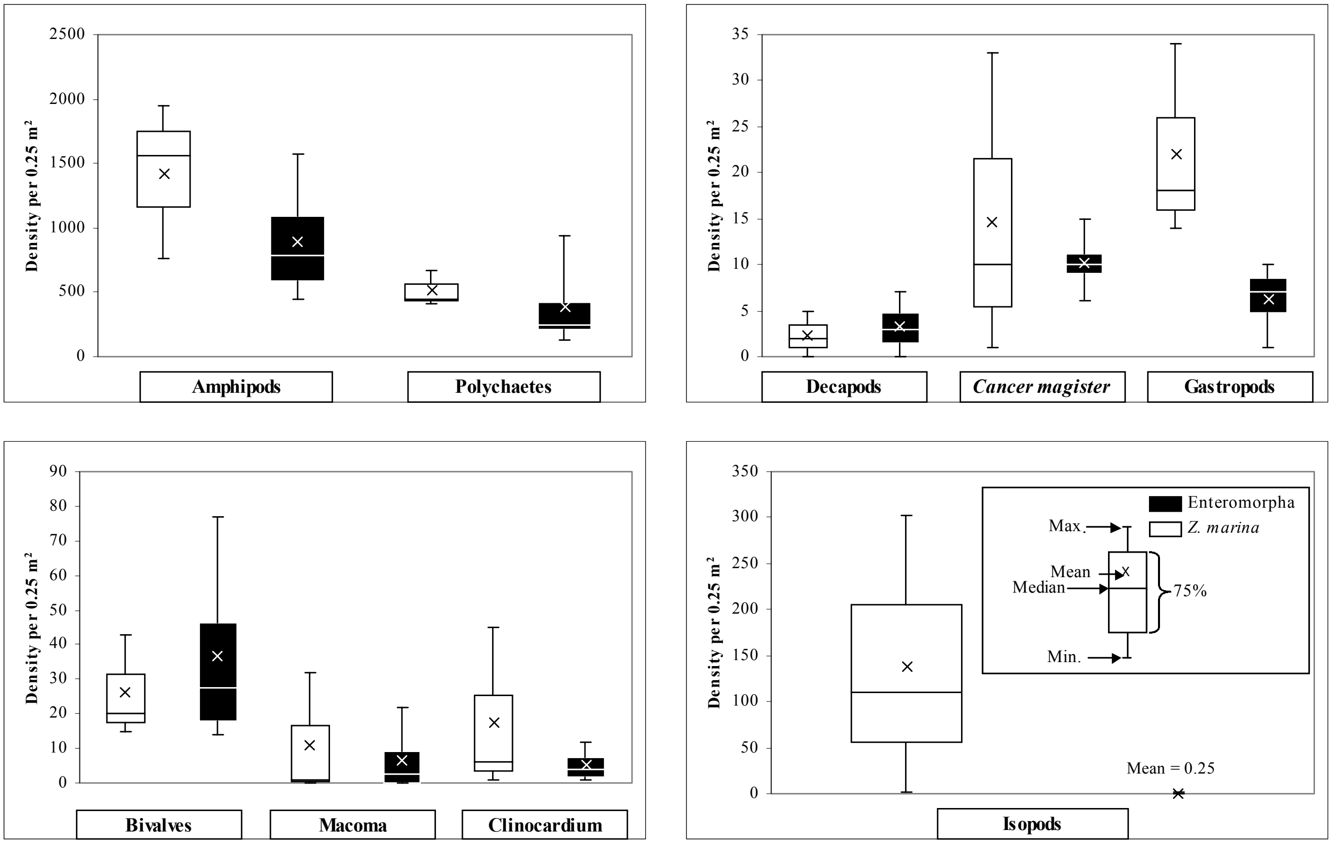


Figure 3.3.3-12. Average densities per 0.25m^2 of macroinvertebrates collected in eelgrass and *Enteromorpha*-dominated quadrats, Deltaport Third Berth project footprint, September 2003.

Beam trawls

Beam trawling affords the quick coverage of large areas and thus the seasonal comparison of the macroinvertebrate epifauna (one disadvantage is that beam trawl mesh size allows many small animals such as polychaetes and amphipods to escape and the apparatus only skims the surface of the substrate sampling the epifauna - the primary purpose of the beam trawls was to sample the demersal ichthyofauna). There were 16 beam trawl tows replicated among the four seasons, eleven of which were to the west of the causeway. The uneven sampling effort was a consequence of the larger area to cover in the west side and the density of the eelgrass beds in the intercauseway area. Once the focus at the proposed development shifted to the Deltaport Third Berth project, four tows were added in the dredge area and surroundings in the spring of 2004. These four trawls are not included in the following table to allow for meaningful comparisons, but all compiled beam trawls results can be found in Appendix A3.3-4.

There were approximately 5,000 macroinvertebrates caught over four seasons in 68 beam trawl tows on both sides of the causeway. Slightly more than 60% of all invertebrates were collected on the east side of the Roberts Bank causeway (Table 3.3.3-5). Given the sampling emphasis on the west side, this points to a higher biomass and biodiversity on the east side.

Table 3.3.3-5. **Seasonal abundance of main macroinvertebrate taxa collected in beam trawls on the east (E) and west (W) sides of the Roberts Bank causeway in 2003-2004**.

Taxon	Common name	Species	Summer E	Summer W	Summer Total	Fall E	Fall W	Fall Total	Winter E	Winter W	Winter Total	Spring E	Spring W	Spring Total	Total
Decapod	Dungeness crab	*Cancer magister*	73	7	80	3	0	3	3	1	4	21	23	44	131
Decapod	Red rock crab	*C. productus*	0	0	0	0	0	0	1	0	1	0	0	0	1
Decapod	Helmet crab	*Telmessus cheiragonus*	4	0	4	0	0	0	0	0	0	10	0	10	14
Decapod	Decorator crab	*Oregonia gracilis*	0	0	0	0	0	0	0	0	0	10	0	10	10
Decapod	Slender kelp crab	*Pugettia gracilis*	0	0	0	1	0	1	0	0	0	9	0	9	10
Decapod	Green shore crab	*Hemigrapsus oregonensis*	3	0	3	1	0	1	0	0	0	0	0	0	4
Decapod	Hermit crab	*Pagurus sp*	6	0	6	24	0	24	23	2	25	7	0	7	62
Decapod	Shrimp	*Crangon sp.*	35	319	354	215	477	692	67	84	151	190	280	470	1,667
Gastropod	Bubble shell	*Haminoea sp*	200	0	200	0	0	0	0	0	0	0	0	0	200
Gastropod	Nudibranch	*Hermissenda crassicornis*	0	0	0	0	0	0	4	0	4	1	0	1	5
Amphipod	Amphipod	Amphipods	0	0	0	0	1	1	31	27	58	150	0	150	209
Isopod	Isopod	*Idotea sp.*	151	2	153	0	1	1	34	11	45	0	15	845	214
Nudibranch	Nudibranch	*Melibe leonina*	50	0	50	620	0	620	55	0	55	76	0	76	801
Ctenophore	Sea gooseberry	*Pleurobrachia*	50	515	565	0	0	0	0	0	0	0	0	0	565
Scyphozoan	Moon jelly	*Aurelia sp*	0	1	1	0	0	0	0	0	0	4	8	12	13
Scyphozoan	Jellyfish	Hydromedusa	0	0	0	0	0	0	0	0	0	0	7	7	7
Scyphozoan	Jellyfish	Scyphozoan	0	0	0	0	0	0	0	0	0	0	5	5	5
Echinoderm	Sea star	*Leptasterias hexactis*	0	0	0	1	0	1	1	0	1	0	0	0	2
Urochordate	Salp	Salps	0	300	300	250	50	300	0	0	0	0	0	0	600
		Total	569	1,144	1,716	1,115	529	1,644	219	125	344	1,308	336	1,646	5,350

Five species accounted for more than 87% of the total numbers of individuals of the invertebrate catch: small shrimp (31%; mainly crangonidae), isopods (19%), nudibranchs (15%; primarily due to a Fall pulse of *Melibe leonina*), salps (11%), and ctenophores (10%). Most of these animals were found in eelgrass or in the water column immediately above eelgrass. Crangonidae, which are bottom dwellers, were sampled through all seasons whereas the other taxa usually showed seasonal abundances. Winter catches were the lowest (6% of the total) and the catch was equally partitioned among the other three seasons.

Of 129 Dungeness crabs caught in the beam trawls in all four seasons, 100 (77%) were caught on the east side of the causeway. Of these, 73 juveniles (carapace width of 20 mm or smaller) were caught in one tow over the Deltaport Third Berth project footprint (Tow 16, Summer).

Bivalves

Cockles (*Clinocardium nuttallii*) are common on both sides of the Roberts Bank causeway (Jacques Whitford 2001). They are collected in the intertidal zone by recreational fishers and have been traditionally exploited by the Tsawwassen First Nation (TFN). One of the traditional Native harvesting methods involved the use of sticks to probe for cockle shells through mats (Harbo 1997) and to collect individuals which clamped onto the sticks (Osbourne 2003). Cockles tend to live near the surface of substrate (Galluci and Galluci 1982) and can be present near and in eelgrass beds but also inhabit more open areas (Kozloff 1983). They have been reported to spawn between April to November in the San Juan Islands (Galluci and Galluci 1982) and from June to October in Oregon (Robinson and Breese 1982). Most of the cockles recorded through the sampling effort (quadrat, point or beam trawling) were adults although there was a large contingent of juvenile cockles (45) in one quadrat from the Deltaport Third Berth project footprint (refer to Appendix A3.3-5 for the preliminary results of the intertidal quadrats survey).

Little neck clams (*Protothaca staminea*) are present and considered abundant in the Roberts Bank area (Bourne and Heritage 1997). They were however not found in any transects in 2003 but their absence is probably due to the emphasis of the analyses on the east side, as they were only found on the west side in 2000 (Jacques Whitford 2001). There are no commercially exploited clam beds near Roberts Bank (DFO 2004).

Macoma clams (*Macoma* sp., *M. iniquita*, *M. balthica* and *M. nasuta*) were common on both sides of the causeway (Figure 3.3.3-11a), although *M. nasuta* was only found in the DT transect in this study (Appendix A3.3-5). This clam was also reported in greater numbers for the intercauseway area than for the west side in 2000 (Jacques Whitford 2001). Hollett (1988) estimated *M. nasuta* densities to range from 17 to 32 per m^2 in the intercauseway eelgrass bed in 1987. The Balthic Macoma, *M. balthica,* is thought to originate from Asia or the Atlantic NW and to have been introduced along the Pacific coast through aquaculture (Carlton 1992; Department of Fish and Game 2002). Most of Manila clams (*Venerupis philippinarum*) were found on the west side of the causeway in this study, but were reported to be equally abundant on both sides in 2000 (Jacques Whitford 2001). This clam is also an introduced species originating from Asia, having been first recorded in BC in 1936 (Harbo 1997) and along the California coast around 1946 (Department of Fish and Game 2002).

Horse clams (*Tresus capax* and *T. nuttallii*) are not commercially exploited but are considered as a potential fishery (Zhang and Campbell 2000). They are usually found in sandy substrate and can be associated with eelgrass beds (Williams 1989). Only one individual was found in the samples analyzed from the Deltaport footprint in September 2003. These clams were reported in the area in 2000, the vast majority of which were found in the west side (Jacques Whitford 2001).

Cancer crabs

Three members of the *Cancer* genus, Dungeness crabs (*Cancer magister*), red rock crabs (*C. productus*) and graceful crabs (*C. gracilis*[4]) are present in the project area, both intertidally and subtidally. Only *C. magister* is considered of commercial value throughout the Fraser estuary, Boundary Bay and the Southern Gulf Islands (Zhang *et al.* 2002) but *C. productus* is harvested recreationally. *C. gracilis* is not considered a commercial nor recreational species, although it is likely caught as incidental catch by the Dungeness recreational fishery.

Red rock crabs preferentially frequent gravelly and rocky substrate (Jensen 1995). Red rock juveniles and adults were observed under the algal canopy near the crest protection (Photo P3.3-15) and in the intertidal on the west side of the causeway, and adults were caught in crab and prawn traps in summer and winter (Tables 3.3.3-6 and 3.3.3-7). None were seen on the footprint of the proposed Deltaport Third Berth project.

Dungeness crabs usually occupy sandy bottoms (Jensen 1995). Dungeness production in a given area is likely related to rearing conditions of juveniles, as cohort strength is not related to spawning population size (McConnaughey *et al.* 1993). Mating tends to be concentrated from May to June (McConnaughey *et al.* 1992). There is delayed implantation and ovigerous females move from deep to shallow waters in the winter (January – March; Armstrong *et al.* 1988; Pauley *et al.* 1988), when they release the larvae in the water column. The planktonic larvae drift with the currents for a period of two to three months during which time they develop into at least five zoeal stages (Reed 1969). The last zoeal stage metamorphoses into the megalops stage. Dungeness megalops usually settle onto the substrate from May to September in British Columbia (Pauley *et al.* 1988).

Zoea larvae have been reported in the causeway area from March to June (Archibald and Bocking 1983; specimens collected in this study and later confirmed by Dr. G. Jensen, University of Washington). Young-of-the-year Dungeness tend to recruit in or near eelgrass beds between June to September (Armstrong *et al.* 1988; Dinnel *et al.* 1993; this study) along Roberts Bank, and both adult and juvenile crabs were documented in eelgrass, rip rap and on the mudflats (Appendix A3.3-2).

Juvenile Dungeness were collected on both sides of the causeway in 2003 (Figure 3.3.3-11b). Given their reduced motility, they should be considered to occupy both areas during their entire recruitment period. They were common in the Deltaport Third Berth project footprint where they were collected in September and December 2003 and in May 2004 (Figure 3.3.3-11b). Their densities ranged from 4 to 16 per m^2 on the west side of the causeway (median of 12 per m^2) to 4 to 120 per m^2 (median of 24 per m^2) in some areas of the Deltaport Third Berth project footprint. Hollett (1988) estimated densities of juvenile Dungeness (CW 21-59 mm) to range from 0.2 to 2 per m^2 in the eelgrass bed in the intercauseway area in June 1987. They were estimated to range from 4 to 8 (median 4) per m^2 in that same area in 2003.

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[4] *C. gracilis* is distinguishable from *C. magister* by its smaller size, the presence of an antero dorsal spine below the widest portion of the carapace and by a sometimes whitish lining along the carapace edge.

Juvenile Dungeness have likely occupied the area for several years (they were found in the proposed Deltaport Third Berth footprint in 1993; Triton 1993). Additional sampling in June 2004 confirmed the presence of newly settled juveniles in the area (Figure 3.3.3-13). Their presence appears to be correlated with both *Enteromorpha sp.* and *Zostera marina* (Figure 3.3.3-14). Juvenile Dungeness in northern Washington State exhibit similar habitat preferences for attached or drifting macrophyte cover (McMillan *et al.* 1995).

Table 3.3.3-6. Summary of brachyuran crab trap catches, Roberts Bank area, Summer and Fall 2003, Winter and Spring 2004. Refer to Figure 3.2.2-1 for locations of traps.

Season	Station	*C. magister*	*C. productus*
Summer	CT-01	1	0
	CT-02	0	1
	CT-03	1	0
	CT-04	0	1
	CT-05	2	0
	Total	*4*	*2*
Fall	CT-01	2	0
	CT-02	2	0
	CT-03	0	0
	CT-04	2	0
	CT-05	3	0
	Total	*9*	*0*
Winter	CT-01	1	0
	CT-02	1	1
	CT-03	2	0
	CT-04	6	1
	CT-05	1	0
	Total	*11*	*2*
Spring	CT-01	5	0
	CT-02	2	0
	CT-03	2	0
	CT-04	7	0
	CT-05	3	0
	Total	*19*	*0*
	Total	**43**	**4**

C. magister Dungeness crab
C. productus Red rock crab

Table 3.3.3-7. Summary of prawn trap catches, Roberts Bank area, Summer and Fall 2003, Winter and Spring 2004. Refer to Figure 3.2.2-1 for locations.

Season	**Station**	*C. magister*	*C. productus*	*T. cheiragonus*	*Leptocottus armatus*	*Pycnopodia helianthoides*	*Theragra chalcogramma*
Summer	PT-01		2		1		
	PT-02		3	1	4		
	PT-03 *						
	PT-04				3		1
	PT-05				3		
	Total	*0*	*5*	*1*	*11*	*0*	*1*
Fall	PT-01	1			1		
	PT-02						
	PT-03				2	1	
	PT-04						
	PT-05				2		
	Total	*1*	*0*	*0*	*5*	*1*	*0*
Winter	PT-01	2			2		
	PT-02				8	2	
	PT-03	3			5	2	
	PT-04	2			10		
	PT-05		1		6		
	Total	*7*	*1*	*0*	*31*	*4*	*0*
Spring	PT-01	3				1	
	PT-02						
	PT-03						
	PT-04	1					
	PT-05						
	Total	*4*	*0*	*0*	*0*	*1*	*0*
	Total	**12**	**6**	**1**	**47**	**6**	**1**

* traps vandalized
Refer to Figure 3.2.2-1 for locations.

C. magister	Dungeness crab	*Leptocottus armatus*	Staghorn sculpin
C. productus	Red rock crab	*Pycnopodia helianthoides*	Sunflower star
T. cheiragonus	Helmet crab	*Theragra chalcogramma*	Walleye pollock

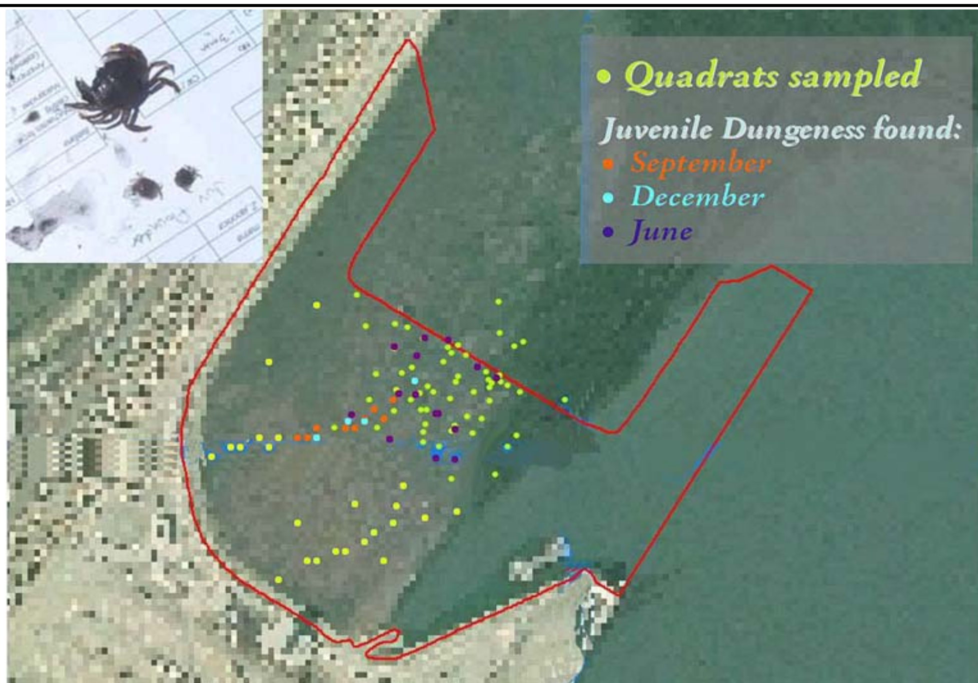

Figure 3.3.3-13. Location of $0.25m^2$ quadrats sampled for juvenile Dungeness crabs (yellow dots) in the footprint of the proposed Deltaport Third Berth project (red outline). Quadrats in which juveniles were found are flagged. Insert shows a juvenile Dungeness (CW 22 mm) and two recently settled juveniles (CW 4-6 mm).

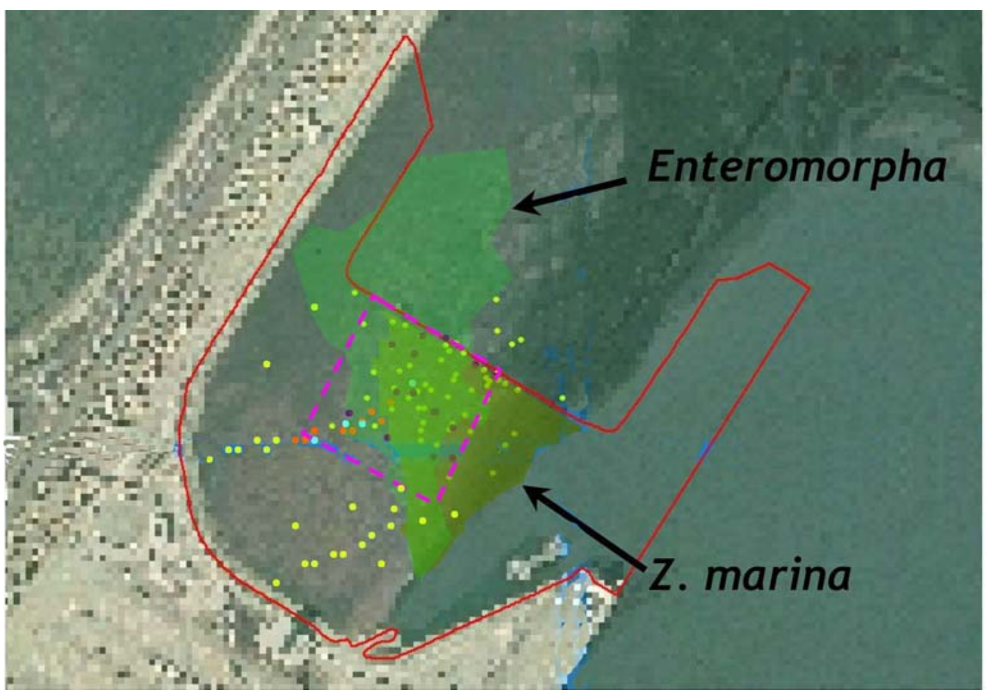

Figure 3.3.3-14. Overlap of *Enteromorpha* sp and *Z. marina* cover and juvenile Dungeness locations in the footprint of the port Third Berth project (red outline). Outlined area is approximately 1.9 hectare in surface area. Other symbols as in Figure 3.3.3-13.

Concurrent studies completed by Northwest Hydraulic Consultants show that the tidal currents decrease in velocity as they pass over the Deltaport Third Berth project footprint (Figure 3.3.3-15). The flood currents likely bring the crab larvae over the general area and the decrease in velocity undoubtedly allows crab megalops larvae to settle in the *Enteromorpha* zone.

Fifty-five adult Dungeness were caught in crab and prawn traps (Tables 3.3.3-6 and 3.3.3-7), 40 males and 15 females. Most crabs (41) were caught in spring and late winter. All traps were in less than 20 m of water (CD), and most were sampled in two stations, station 04 at the southwest corner of Deltaport (18/55 crabs caught) and station 01 in the ship turning basin in the intercauseway area (15 crabs). This is consistent with the movement patterns reported in the literature (Archibald and Bocking 1983; Smith and Jamieson 1991).

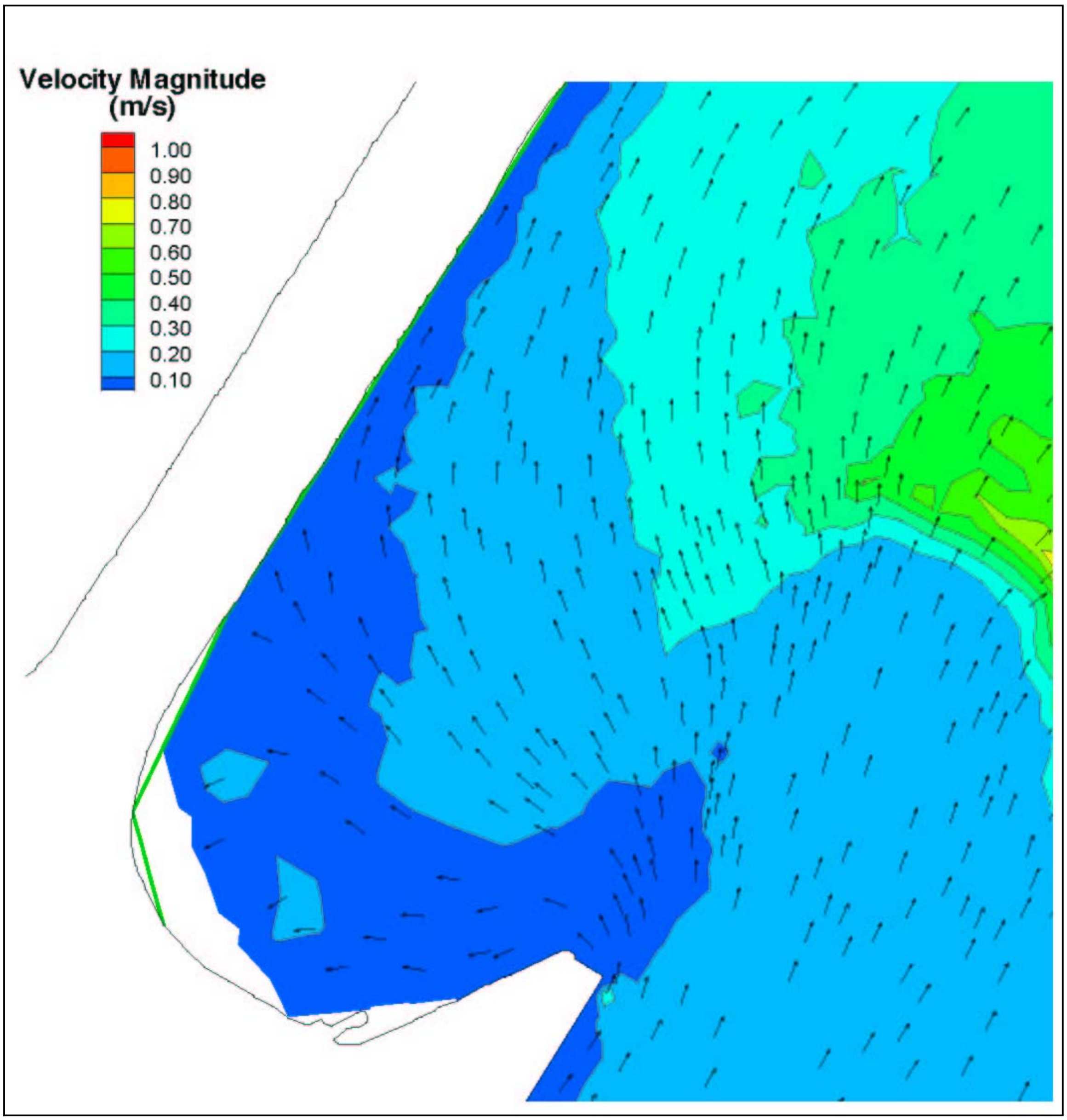

Figure 3.3.3-15. Typical current velocity during flood tide in the proposed Deltaport Third Berth project. Figure courtesy of Northwest Hydraulics Consultants.

Pandalidae

Seven species of prawn (*Pandalus* sp) are exploited in the Strait of Georgia (Fishery Area 18; Morrison *et al*. 1998; Dunham and Boutiller 2001). The fishery consists of prawn traps and trawls. Juveniles of these species may occur in the intertidal area on either side of the causeway. Adults have been caught in the Roberts Bank area (Appendix A3.3-2). Juvenile pandalids may overlap with northern crangon, *Crangon alaskaensis*, a very common intertidal species.

Other invertebrates considered

The following invertebrates were reviewed but it was felt that they did not warrant any special consideration, as they were not unique, their habitat was not considered threatened by the present project and this would thus not threaten the sustainable use of a resource. They may however be of importance to the Tsawwassen First Nation. These species are summarized in Table 3.3.3-8.

- Octopi (*Enteroctopus dofleini)* probably occur south of Deltaport near the artificial reefs (their presence, although likely, was not confirmed in the present study) but are not fished commercially in Area 18 (DFO 2003a).

- There are three commercially important species of sea urchins present in the Roberts Bank area: green (*Strongylocentrotus droebachiensis*), red (*S. franciscanus*) and purple (*S. purpuratus*) and although their habitat is mainly subtidal, juveniles may occupy the intertidal on both sides of the causeway. The importance of the three urchin species fisheries vary (DFO 2003b; Perry *et al*. 2003). The impacts of the Deltaport Third Berth project footprint are considered minimal to this fishery and to the sea urchin populations as few individuals use the area and the sea urchin fishery is not in the immediate surroundings of the project area.

There has been a sea cucumber (*Parastichopus californicus*) fishery in the Strait of Georgia in the 1990's (Archipelago 2000) but its status is at present uncertain. Sea cucumbers are mostly subtidal and were observed along the crest protection, part of which overlaps with the Deltaport Third Berth project footprint. These echinoderms do not occur frequently in the areas potentially impacted. Moreover they are fairly motile, cover a large range of substrates, and are consequently not expected to be significantly affected by the project.

Table 3.3.3-8. Macroinvertebrate species that did not warrant further consideration.

Species name	Common name	Habitat	Known or expected location	Comments
Enteroctopus dofleini	Giant Pacific octopus	Rocky substrate, mostly subtidal	Possibly along subtidal rip rap and caissons, W and E side. Presence as yet unconfirmed	Not frequent and unlikely to be impacted by project
Strongylocentrotus droebachiensis, S. purpuratus, S. franciscanus	Green, purple and red sea urchin	Gravel, rocky substrate; mainly subtidal; juveniles seen in the intertidal	Mainly subtidal but juveniles occasionally seen in eelgrass beds (W and E sides) and in mudflats	Rare within proposed footprint. Contribution to the fishery likely minimal
Parastichopus californicus	Sea cucumber	Sandy, subtidal	Present along crest protection; overlap with Deltaport Third Berth project	Rare within proposed footprint

Conclusions —general macroinvertebrate fauna

The Roberts Bank intertidal area is characterized by a shallow slope over a large distance (cf. Geotechnical report). Coupled with sometimes extensive eelgrass beds, it provides a temporal refuge for many juvenile invertebrates and fishes, and appears to act as a nursery area for Dungeness crabs and other macroinvertebrates.

The influence of the Fraser River plume was evident on the west side of the Roberts Bank causeway as salinities near the surface were lower than on the east side. This latter side is more sheltered and its oceanographic conditions appeared more stable throughout the water column than on the west side of the causeway.

Many of the macroinvertebrate species found in the intertidal area along both sides of the Roberts Bank causeway are typical of low energy level environments. Several of these, such as *Macoma balthica,* are resilient and can accept extensive ranges of environmental stresses (dessication. salinity, exposure to metals, etc.; e.g., Bryant *et al*. 1985). The area hosts numerous introduced or invasive species, most of which are common (e.g., *Nuttallia obscurata, Macoma balthica, Mya arenaria, Battillaria sp., Venerupis philippinarum, Zostera japonica*). There were no blue nor red-listed species observed.

Based on quadrat and beam trawl sampling, it appears that the intercauseway area harbours a more diverse macroinvertebrate fauna and has more biomass than the west side of the Roberts Bank causeway. This is probably due to a combination of a more mature and denser eelgrass bed and different, overlapping habitats such as eelgrass, *Enteromorpha* patches, rocky (crest protection boulders) and mudflat and the transitions zones (edges) between these habitats.

The footprint of the proposed Deltaport Third Berth project also appears to be an area rich in biodiversity but while it encompasses several small, overlapping habitats, its apparent higher biodiversity is also partly due to a higher sampling effort in this area.

Because of the nature and ecological function of the general area as a nursery, the periods most sensitive to anthropogenic disturbances are late winter (period of Dungeness egg release in the intercauseway area) and spring (recruitment and settlement of juvenile invertebrates).

3.3.3.4 Ichthyofauna

Literature review

The Roberts Bank mudflats provide habitat for many fishes. Most fishes found near Roberts Bank are euryhaline and spend the greatest, if not all, portion of their life history in saltwater. Gordon and Levings (1984) found the Roberts Bank ichthyofauna to be richer than that of nearby Sturgeon Bank, a fact they attributed to greater habitat complexity and to stable oceanographic conditions.

Based on a review of twelve studies conducted in the last 25 years in the Roberts Bank area (1979 to 2004), at least 72 fish species use the surroundings (Appendix A3.3-6). Samples were collected in 25 seasons over 25 years[5] during these studies and the principal method of sampling was beach seining (8 out of 12 studies). Only species presences are reported, irrespective of abundance. Based on the percent of occurrence in these seasons, the most common species in the Roberts Bank subtidal and intertidal areas is the staghorn sculpin, *Leptocottus armatus* (collected in all seasons sampled) followed by the starry flounder (*Platichthys stellatus*), threespine stickleback (*Gasterosteus aculeatus*), chum salmon (*Oncorhynchus keta*) and shiner perch (*Cymatogaster aggregata*), all of which were caught in more than 80 % of the samples (Table 3.3.3-9). Given the preponderance of beach seining as the sampling method (which usually precludes sampling in waters deeper than two meters), it is likely that most of these fishes inhabit the intertidal area. Of the 15 most often reported species (Table 3.3.3-9), 12 primarily inhabit mudflats and eelgrass beds (Lamb and Edgell 1986). The three others, chum and chinook (*O. tshawytscha*) salmon and Pacific herring (*Clupea harengus pallasi*) are common over eelgrass or near rip rap. Five of these 15 species are Cottidae, a group of bottom dwellers and expected over shallow, sandy substrates.

[5] One study (Levings et al., 1983) only sampled for salmonids, and although its results were taken into account for species distribution, it was not counted for the percentage of occurrence.

Table 3.3.3-9. Percent of occurrence of the 15 fishes most often reported near Roberts Banks. Based on 12 studies encompassing 25 seasons, 1979 - 2004.

Species	Common name	Percent occurrence
Leptocottus armatus	Staghorn sculpin	100%
Platichthys stellatus	Starry flounder	92%
Gasterosteus aculeatus	Threespine stickleback	88%
Oncorhynchus keta	Chum salmon	84%
Cymatogaster aggregata	Shiner perch	80%
Oligocottus maculosus	Tidepool sculpin	72%
Hypomesus pretiosus pretiosus	Surf smelt	72%
Oncorhynchus tshawytscha	Chinook salmon	68%
Aulorhynchus flavidus	Tubesnout	64%
Citharichthys sordidus	Pacific sanddab	60%
Ammodytes hexapterus	Pacific sand lance	56%
Clupea harengus pallasi	Pacific herring	56%
Artedius fenestralis	Padded sculpin	56%
Psychrolutes paradoxus	Tadpole sculpin	56%
Lumpenus sagitta	Pacific snake prickle back	56%

Beach Seining

Beach seining was conducted during four seasons from Summer 2003, until Spring 2004 (Section 3.2). The beach seining results for all eight sites sorted by seasons are presented in Appendix A3.3-4. There were 4,419 fishes belonging to at least 16 species captured through beach seining, across 8 sites and 4 seasons combined (Table 3.3.3-10; refer to Figure 3.2.2-1 for location of sites). Night catches accounted for 56% of the total. Staghorn sculpins were by far the most abundant catch (55.6% of the total) but this was due to large numbers of recently hatched juveniles in the spring. The juvenile sculpin pulse appeared more concentrated in the east side, although there was evidence for a partial pulse in the W3-1 site (Appendix A3.3-4). This probably reflects habitat use, as the W-3 and East sites are representative of mudflats and eelgrass whereas the RR sites (Figure 3.2.2-1) are more indicative of salt marsh conditions. Although the sites DT and T2-1 (Figure 3.2.2-1) were physically close (both overlap the Deltaport Third Berth project footprint) juvenile salmonids tended to use more the inshore area in the southwest pocket (site DT) in winter and spring than the T-2 site.

The second most abundant fishes were shiner perch and larval surf smelt (10% of the catch each). If the pulse of juvenile staghorn is removed species evenness improves, with sticklebacks, pink juveniles, larval smelt and staghorns accounting for a combined 70% of the catch in roughly equal proportions. This probably indicates that the area acts as nursery habitat for some fishes.

Chum and pink salmon fry were common in winter and spring. The fall sampling was however biased as temperatures were much lower than usual (2°C; Table 3.3.3-2) and few fishes were caught. Juvenile salmonids were more abundant on the west side of the Roberts Bank causeway than along the east side in the spring. Pink juveniles were also more abundant on the west side in winter, and there were not enough chum salmon juveniles caught in winter to warrant any conclusion about their distribution at that time.

Most fishes were caught in the spring (60% of the total) but a significant portion of the catch was accounted for by juvenile staghorn sculpins. When these are omitted, summer catches account for 51% of the total, followed by spring (31%).

Table 3.3.3-10. Summary of beach seining, all sites combined. Total of two sets per sampling episode.

	Season												
	Summer			**Fall**			**Winter**			**Spring**			**Total**
Species	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total	
Chum fry	0	0	0	0	0	0	6	13	19	123	219	342	361
Pink fry	0	0	0	0	0	0	51	35	86	92	26	118	204
Chum salmon[1]	0	0	0	0	1	1	0	0	0	0	0	0	1
Starry flounder	0	4	4	17	2	19	4	7	11	3	7	10	44
Flounder, undetermined	0	0	0	0	0	0	0	0	0	0	1	1	1
Staghorn sculpin	13	42	55	42	1	43	199	36	235	820	1,303	2,123	2,456
Tidepool sculpin	0	0	0	8	0	8	0	2	2	0	0	0	10
Saddleback sculpin	0	0	0	1	0	1	0	0	0	1	0	1	2
Fluffy sculpin	0	0	0	10	0	10	0	1	1	0	0	0	11
Cottids undetermined	0	0	0	2	0	2	0	0	0	0	0	0	2
Pipefish	0	1	1	0	0	0	0	0	0	0	0	0	1
Prickleback	26	0	26	1	0	1	1	1	2	2	6	8	37
Sand lance	0	0	0	2	19	21	0	0	0	0	0	0	21
Shiner Perch	193	249	442	1	0	1	0	0	0	5	9	14	457
Stickleback	47	146	193	3	0	3	121	30	151	10	8	18	365
Surf smelt	10	264	274	26	0	26	26	31	57	79	9	88	445
Dogfish	1	0	1	0	0	0	0	0	0	0	0	0	1
Total number of fishes	290	706	996	113	23	136	408	156	564	1,135	1,588	2,723	**4,419**

[1] adult fish

Deltaport Third Berth project site

This site had a different ichthyofauna composition and thus warrants a brief separate discussion. There were 513 fishes belonging to at least eight species captured during beach seining at this site (Table 3.3.3-11). Unlike most of the other beach seining sites, more fishes were caught during the day than at night (84% of total catch). The species composition was also slightly different: species evenness was more pronounced, with sticklebacks, shiner perch, staghorn sculpins and pink salmon juveniles accounting for 92% of the total catch, the first two species making up 50% of the catch. The spring juvenile staghorn sculpin pulse was not evident in this area.

Fish catches peaked during the winter sampling (45% of the total catch at this site), in contrast with the majority of the other sites (Appendix A3.3-4), stickleback and staghorn sculpins being the most abundant species. Sticklebacks may overwinter in this area, as they were often found buried in the substrate at low tide.

Beam trawls

Sixteen beam trawls were replicated across four seasons[6], with a total catch of 4,379 fishes of 27 different species (Table 3.3.3-12). There were also numerous invertebrates, including 129 Dungeness crabs, the majority of them juveniles (carapace width less than 25 mm).

Most of the ichthyofauna was typical of sandy/silty bottoms and eelgrass beds (flatfishes, sculpins, sticklebacks, pricklebacks). Of note is a fairly important cohort of juvenile whitespotted greenlings (*Hexagrammos stelleri;* average total length 77 mm) in the spring, all caught in eelgrass beds on both sides of the causeway. Relatively few juvenile salmon were caught in beam trawls as compared to beach seining (Table 3.3.3-10): these fish are normally found close to the causeway and to the rip rap and higher in the water column, two habitats not sampled by the beam trawl.

Although only five transects were surveyed on the east side as compared to 11 on west side of the causeway, almost twice as many fishes were caught on the east side (2,771 vs. 1,609). This was mostly due to more sticklebacks being caught on the east side in the dense eelgrass bed. The majority of fishes were caught in spring on the west side (74%) and in summer on the east side (61%) of the causeway. Spring catches on the west side were driven by an abundance of juvenile flounders and pricklebacks, and sticklebacks accounted for a significant portion of summer catches on the east side. Fall and winter catches were low on both sides (less than 3% of the total).

[6] An additional four trawls were added in the spring of 2004 to cover the area potentially affected by any dredging activities related to the Deltaport Third Berth Project.

Table 3.3.3-11. Summary of beach seining catches at the Deltaport Third Berth footprint. Total of two sets per sampling episode.

	Season												
	Summer 2003			Fall 2003			Winter 2004			Spring 2004			Total
Species	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total	
Chum fry	0	0	0	0	0	0	5	1	6	10	5	15	21
Pink fry	0	0	0	0	0	0	28	1	29	73	0	73	102
Chum salmon	0	0	0	0	1	1	0	0	0	0	0	0	1
Prickleback	0	0	0	0	0	0	1	0	1	0	0	0	1
Sand lance	0	0	0	19	0	19	0	0	0	0	0	0	19
Shiner Perch	95	28	123	0	0	0	0	0	0	0	0	0	123
Staghorn sculpin	0	1	1	0	0	0	78	1	79	23	9	32	112
Starry flounder	0	0	0	1	0	1	0	0	0	0	0	0	1
Stickleback	0	17	17	0	0	0	115	0	115	1	0	1	133
Total	**95**	**46**	**141**	**20**	**1**	**21**	**227**	**3**	**230**	**107**	**14**	**121**	**513**

The five most common species caught on the west side of the causeway were juvenile flounders (this was however due to a juvenile recruitment pulse) followed by pricklebacks, adult starry flounders, shiner perch and staghorn sculpins. Sticklebacks were the most abundant fish on the east side of the causeway, followed by shiner perch, juvenile flounders, prickleback and staghorn sculpins. Thus the ichthyofauna was similar on both sides, the species relative abundance was different: stickleback, the most abundant fish on the east side, were sixth in terms of numbers on the west side. The east side showed a lower species evenness than the west side as the three most common fishes accounted for 80% of the catch vs. 54% on the west side. This is likely due to fewer habitats and transition zones sampled on the east side.

The results from the two trawls in the proposed Deltaport Third Berth project footprint (15 and 16) are tabulated in Table 3.3.3-13. There were 758 fishes belonging to at least 27 species caught. Catch composition was similar to that of the east side: sticklebacks were the most abundant species, followed by staghorn sculpins, shiner perch, juvenile flounders and prickleback.

Table 3.3.3-12. Summary of main species caught by 3 m beam trawls

Season	Summer			Fall			Winter			Spring			Total /
Side	E	W	Total	E	W	Total	E	W	Total	E	W	Total	species
Invertebrates													
C. magister	73	7	80	3	0	3	3	1	4	21	21	42	129
Crangon sp.	250	514	549	215	215	215	282	299	366	215	215	215	700
Oregonia gracilis	0	0	0	0	0	0	0	0	0	10	0	10	10
Pagurus sp.	6	0	6	24	0	24	23	2	25	7	0	7	62
Pugettia sp.	0	0	0	1	0	1	0	0	0	9	0	9	10
Telmessus cheiragonus	1	0	1	0	0	0	0	0	0	10	0	10	11
Idotea sp.	151	2	153	0	1	1	34	11	45	0	15	15	214
Idotea resecata	0	0	0	0	0	0	0	0	0	830	0	830	830
Fishes													
Chum fry	0	0	0	0	0	0	0	0	0	9	7	16	16
Staghorn sculpin	43	15	58	4	1	5	1	1	2	68	116	184	249
Stickleback	1,394	109	1,503	6	0	6	9	1	10	430	13	443	1,962
Starry flounder	29	70	99	20	6	26	11	1	12	28	180	208	345
Juvenile flounder	0	0	0	1	0	1	0	0	0	167	342	509	510
English sole	0	1	1	0	0	0	0	0	0	2	4	6	7
Pacific sanddab	0	0	0	0	0	0	0	0	0	6	12	18	18
Speckled sanddab	0	0	0	0	0	0	0	0	0	3	13	16	16
Rock sole	11	22	33	1	0	1	7	7	14	0	0	0	48
Sand sole	0	2	2	0	0	0	0	0	0	0	1	1	3
Whitespotted greenling	1	0	1	0	0	0	0	0	0	46	56	102	103
Juvenile pollock	0	0	0	0	0	0	0	0	0	1	2	3	3
Surf smelt	0	0	0	0	0	0	0	0	0	0	1	1	1
Pacific herring	0	0	0	0	0	0	0	0	0	0	1	1	1
Prickleback	1	1	2	0	0	0	0	0	0	156	265	421	423
Crescent gunnel	0	3	3	0	0	0	0	0	0	0	1	1	4
Penpoint gunnel	10	1	11	0	0	0	0	0	0	1	0	1	12
Rockweed gunnel	0	0	0	0	0	0	0	0	0	24	3	27	27
Saddleback gunnel	0	2	2	0	0	0	0	0	0	6	47	53	55
Shiner perch	186	74	260	0	0	0	0	0	0	24	82	106	366
Pile perch	0	0	0	2	0	2	0	0	0	2	0	2	4
Striped perch	0	5	5	0	0	0	0	0	0	0	0	0	5
Pipefish	5	91	96	22	2	24	4	0	4	6	28	34	158
Liparid	0	0	0	0	0	0	0	0	0	0	10	10	10
Agonus sp.	0	0	0	0	0	0	0	0	0	1	6	7	7
Plainfin midshipman	0	0	0	0	0	0	0	0	0	0	1	1	1
Tubesnout	1	0	1	11	0	11	3	0	3	7	3	10	25
Total number of individual fishes	1,681	396	2,077	67	9	76	35	10	45	987	1,194	2,181	**4,379**

Refer to Figure 3.2.2-1 for locations on both sides (east and west) of the Roberts Bank causeway, 2003-2004.

The beam trawl results were divided into four regions or quadrants — SW, W, E and SE (this latter having been only sampled in the Spring) (Figure 3.3.3-6) — and the fauna was sorted into broad taxa: crabs, flatfishes (flounders, soles and sanddabs), perches, pholids (gunnels), staghorn sculpins, sticklebacks, pricklebacks and all other fishes grouped together. Flatfishes generally dominated the ichthyofauna on the west side (Figure 3.3.3-16a) whereas sticklebacks dominated the east side of the causeway, likely due to the greater proportion of mudflats in the W quadrant. Flatfishes accounted for a lesser proportion of the catch in the SW quadrant, being replaced by pricklebacks and crabs (Figure 3.3.3-16b). Crabs were a more important part of the catch in the SW quadrant and in DT (in E quadrant) in winter, but this was partly due to lower sample sizes in winter. Fauna of the SE quadrat was characterized by flatfishes and pricklebacks, two very mobile groups of fishes. Although summer catches were generally higher (Table 3.3.3-12), spring catches were more diverse.

Salmonids

Most of the salmonids using the Roberts Bank intertidal area are juveniles, the adults preferring deeper and more open water. The salmonids most often reported in the literature (Appendix A3.3-6) were chum salmon (84% of seasons), chinook (68%), sockeye (48%), pink (44%) and coho (20%). Juvenile salmonids use the intertidal and subtidal areas on both sides of the Roberts Bank causeway. They are found over the mudflats, in the eelgrass, salt marsh and by the rip rap at high tide.

Pink, chum and chinook were the only juvenile salmon reported in the area immediately adjacent to both sides of the causeway in the last four years. Chinook juveniles were caught in the summer (June and July; Table 3.3.3-14) whereas pink and chum abundance peaked in the winter and spring.

Table 3.3.3-13. Summary of main species caught by 3 m beam trawls over the Deltaport Third Berth project footprint, 2003-2004.

Season	Summer DT	Fall DT	Winter DT	Spring DT
C. magister	47	2	1	8
C. productus	0	0	0	0
Oregonia gracilis	0	0	0	0
Pagurus sp.	4	1	2	2
Pugettia sp.	0	1	0	0
Telmessus cheiragonus	0	0	0	1
Chum fry	0	0	0	1
Staghorn sculpin	37	4	0	30
Stickleback	384	1	1	84
Starry flounder	2	2	0	8
Juvenile flounder	0	0	0	46
English sole	0	0	0	0
Pacific sanddab	0	0	0	1
Speckled sanddab	0	0	0	1
Rock sole	3	0	0	0
Sand Sole	0	0	0	0
Whitespotted greenling	0	0	0	25
Juvenile pollock	0	0	0	1
Juvenile tubesnout	0	0	0	0
Surf smelt	0	0	0	0
Pacific herring	0	0	0	0
Prickleback	1	0	0	27
Crescent gunnel	0	0	0	0
Penpoint gunnel	0	0	0	1
Rockweed gunnel	0	0	0	5
Saddleback gunnel	0	0	0	1
Shiner perch	65	0	0	1
Pile perch	0	0	0	2
Striped perch	0	0	0	0
Pipefish	2	8	1	1
Liparid	0	0	0	0
Agonus sp.	0	0	0	0
Plainfin midshipman	0	0	0	0
Tubesnout	1	11	0	0
Total	**495**	**26**	**2**	**235**

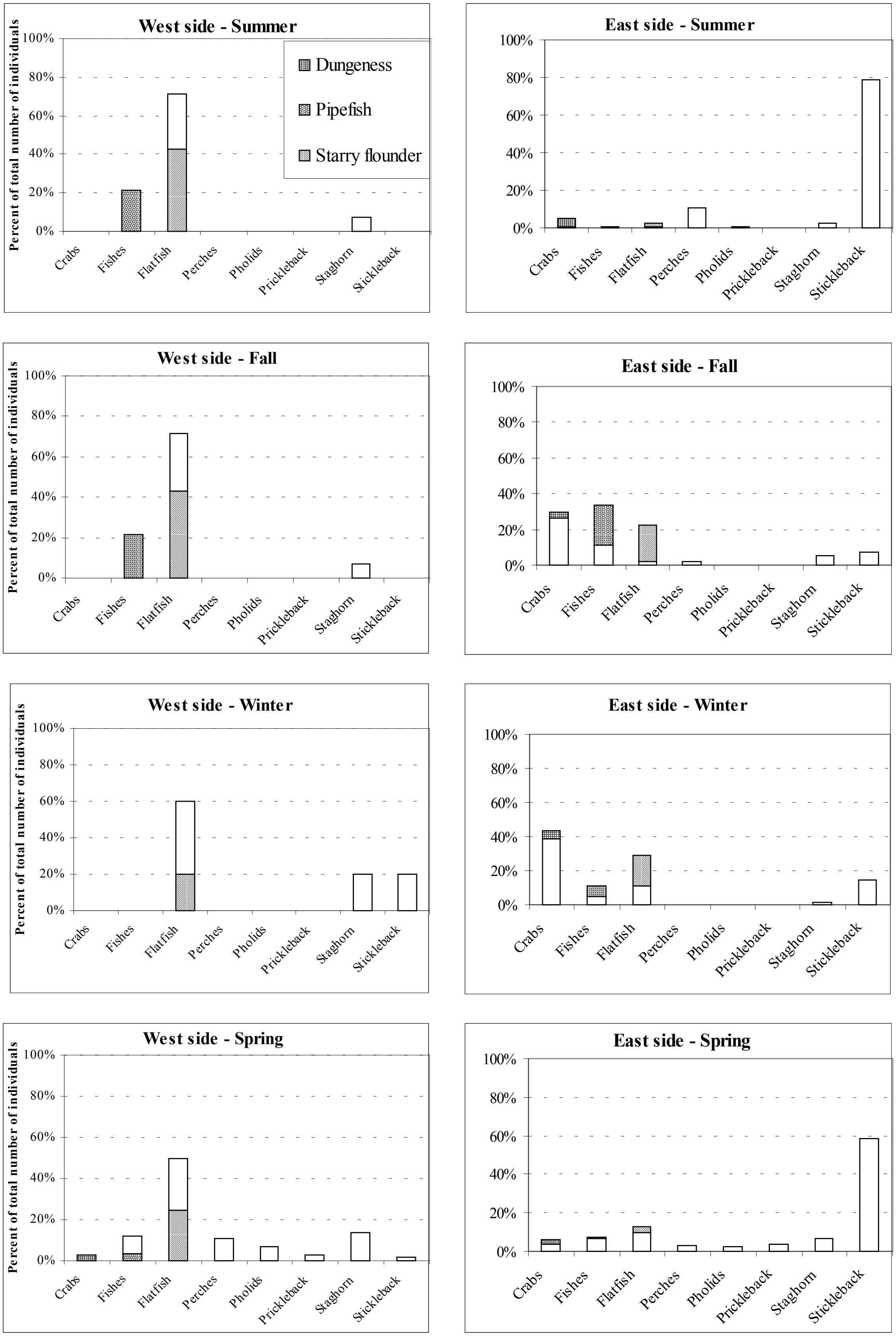

Figure 3.3.3-16a. Relative composition of beam trawls grouped by quadrants.

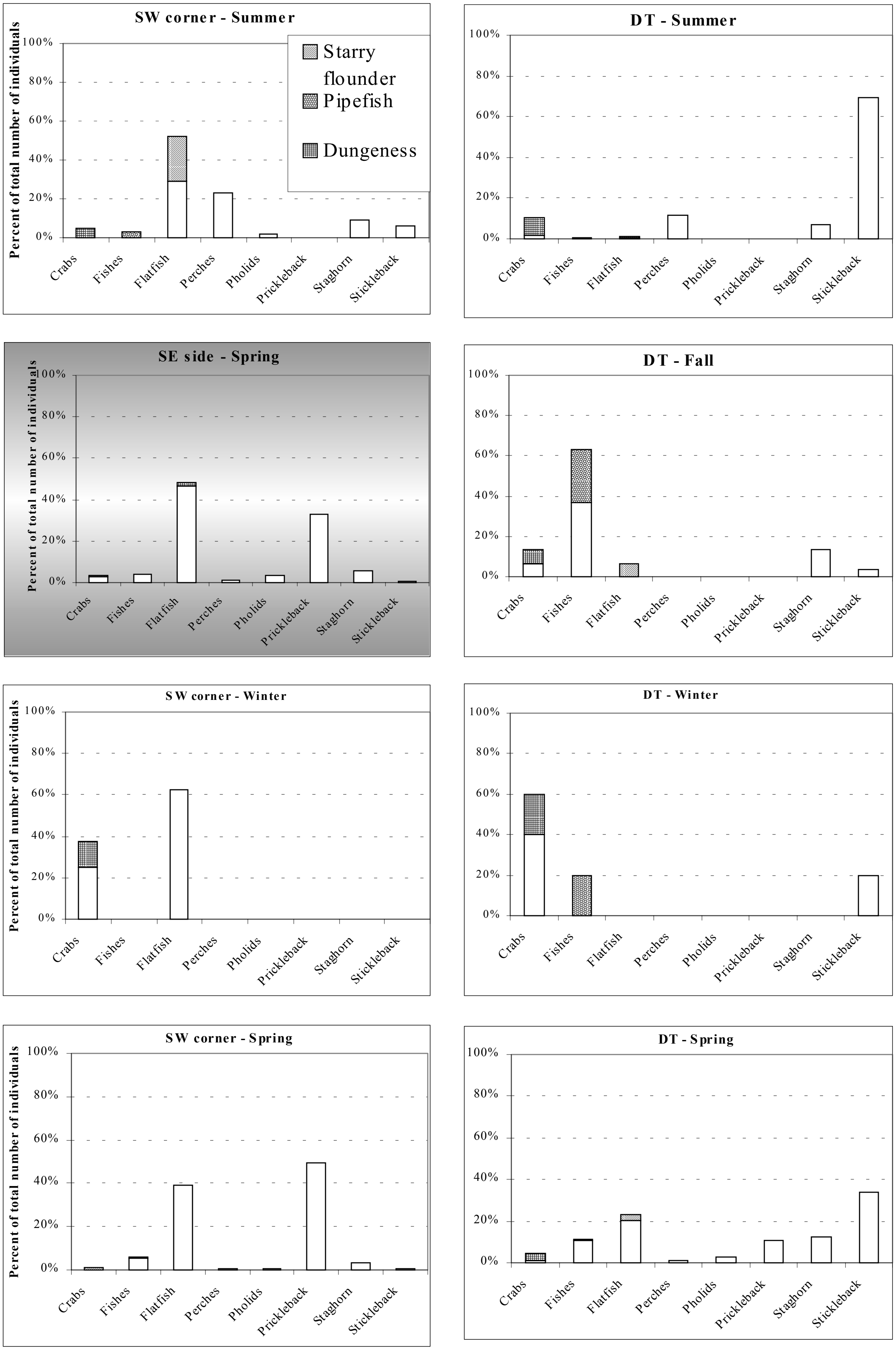

Figure 3.3.3-16b. Relative composition of beam trawls grouped by quadrants. There were no fish caught in the SW corner during spring. The SE side (shaded graph) was only sampled in the spring.

Table 3.3.3-14. Recorded presence of juvenile salmonids on the W and E side of the Roberts Bank causeway, from June, 2000, to May, 2004. Months sampled shown. Absence of data means that no salmonids were caught.

Month	Feb		May		June		July		Aug		Nov	
Side	W	E	W	E	W	E	W	E	W	E	W	E
Pink	2	2	2						2			
Chum	1, 2	2	2	2						2		
Chinook					1		1	1				
Coho												
Sockeye												

1 – Results from Jacques Whitford, 2001
2 – Results from present study

Chum salmon

Chum salmon fry (*O. keta*) generally move to saltwater from estuarine waters within 30 days after hatching in their natal stream (Salo, 1991). They are often associated in mixed schools with pink salmon fry and their early life histories are similar. They remain inshore during the summer, beginning to move offshore in September (Hart 1973). Juveniles tend to remain in shallow waters of the Strait of Georgia until June, when they move into deeper water (20-40 meters; Salo 1991).

Chum salmon were the most abundant salmonid reported in the studies surveyed (21 out of 25 studies; ranked fourth – Appendix A3.3-6). Chum fry were observed and caught along both sides of the causeway between February and May (Table 3.3.3-14; 2003-04 sampling period). An adult chum salmon was also caught in late November 2003, in the proposed Deltaport Third Berth project footprint but this is considered unusual. Juvenile chum were especially abundant in the spring when they made up to 57% of the beach seining catches if the juvenile sculpin pulse is excluded.

Chinook salmon

Chinook fry (*O. tshawytscha*) usually go to sea within 90 days after hatching (Healey 1991), but may remain in freshwater for up to one year (Hart 1973). Seaward movement begins shortly following migration to the estuary in the Strait of Georgia (Healey 1991). Juvenile chinook use the nearshore habitats in the intercauseway area was documented by Levings (1985). They were reported in 17 out of 25 seasons (Appendix A3.3-6) and thus ranked 8th in frequency of occurrence among all fishes.

Chinook juveniles were caught on both sides of the causeway in the summer of 2000-2001 (Jacques Whitford 2001; Table 3.3.3-14) but none were caught in the 2003-04 sampling.

Pink salmon

Following emergence from gravel redds in April - May, pink salmon fry (*O. gorbuscha*) immediately migrate to saltwater. Young pink salmon tend to remain close to shore, moving into deeper water in September (Hart 1973). Although they were only present in 11 of the 25 seasons reported (they ranked 30^{th}, Appendix A3.3-6) pink salmon fry were abundant in the project area and, as mentioned above, were observed and caught along both sides of the causeway between February and August in 2003-04. They were seen in mixed schools with juvenile chum salmon by the rip rap within the proposed Deltaport Third Berth project footprint.

Along with chum fry, they were abundant in the spring when the made up to 20% of the beach seining catches (sculpin pulse excluded).

Sockeye salmon

Fraser River sockeye salmon (*O. nerka*) move to the estuary usually in April and May after their first year spent in lakes and enter the marine environment soon after (Burgner 1991). They probably occupy the Fraser River estuary and have been sampled there (Appendix A3.3-6) but are unlikely to be present near the Deltaport facilities. They were reported in almost half of the samples (12) but have not been caught in the Deltaport area since 1982.

Coho salmon

Coho salmon fry (*O. kisutch*) remain in freshwater streams for around one year and begin to migrate downstream in the spring (Hart 1973; Martel 1996). Juvenile cohos were reported in the area between 1980 and 1984 (Appendix A3.3-6) but have not been caught since. They were only reported in five seasons by two studies.

Pleuronectidae and Bothidae

English sole (*Parophrys vetulus*), rock sole (*Lepidopsetta bilineata)* and starry flounder (*Platichthys stellatus*) make up a significant portion of the trawl fishery of the Strait of Georgia (Ketchen *et al* 1983). Spawning falls within a depth range of 20-90 meters and occurs between February and April (Hart 1973). Both English sole and starry flounder produce buoyant eggs that are carried to intertidal areas where the larvae settle to the bottom and remain until late summer; the eggs of rock soles are adhesive and therefore remain in deeper water (Ketchen *et al* 1983).

Juvenile flatfish larvae were abundant on both sides of the causeway in February, 2004 (Table 3.3.3-12). Starry flounders were the second most reported fish in the surveyed literature

(Appendix A3.3-6, Table 3.3.3-9) and some of the most abundant fishes sampled in both beach seining and beam trawl. These fish are abundant but will usually avoid anthropogenic activities.

Surf smelt

Surf smelt (*Hypomesus pretiosus*) are subject to a small but intensive commercial and recreational fishery (BC Tidal Waters Sport Fishing Guide 2003) focused primarily in Burrard Inlet (Fisheries Management Area 28). Knowledge of surf smelt biology, stock status and distribution in BC is lacking and there is concern that populations may be declining (Theriault *et al.* 2002; Theriault and Hay, 2003). Surf smelt spawn in the upper intertidal zone (2-3m above MLLW, Moulton and Pentilla 2000) on coarse sand and fine gravel beaches (Pentilla 1997; Levy 1985). Documented beach spawning activity in the Puget Sound Basin is year-round (25 years of shoreline survey effort, Pentilla 1997) while documentation of surf smelt spawning in BC has been limited and occurs during the summer months (May to September - Theriault *et al.* 2002). The smelt fishery is closed in Area 29 from June 15 to August 15 to protect peak spawning periods (BC Tidal Waters Sport Fishing Guide 2003).

Surf smelt were one of the most commonly reported species in the area (Table 3.3.3-9; 72% of all seasons sampled). They were common through all four seasons but there are indications of a winter spawning population in the area as there were two cohorts of surf smelt larvae caught, in August and in April. These larvae may point to the existence of a spawning beach in the Deltaport area, but attempts at finding such a site have been so far unsuccessful. Although no eggs were found in the sediment samples taken between November 2003 and August 2004 (see Section 3.2.4.2), a definitive conclusion that surf smelt do not spawn in the area cannot be made as the normal protocol suggests that beaches need to be surveyed for two consecutive years before ruling out a site for beach spawn (P. Thuringer, Archipelago Marine Research Ltd, pers. comm.). However, given that eggs were not present in any of the samples from the winter or summer, it is likely that the beach on the western side of the causeway is not a spawning location.

Pacific herring

A stable herring roe fishery operates in the Strait of Georgia (Sweigert 2001). Herring spawn in a different area every year (EPS 1978), and mature adults (2-5 years) migrate to the Strait of Georgia and return to open waters after spawning (Ketchen *et al* 1983). Spawning generally occurs between February and April at depths between high tide and 11 meters Chart Datum with the sticky eggs sometimes adhering in large masses to eelgrass, kelp and rockweed (Hart 1973). Herring spawn along the coast between the Roberts Bank causeway and Point Roberts (Hay and McCarter 2004) but no egg masses nor juveniles were recorded in the immediate project area. Herring were reported in 14 / 25 seasons (Appendix A3.3-6) near Roberts Bank, mostly in the spring.

Only one adult herring was caught through the whole sampling effort in the present study (Appendix A3.3-4).

Pacific sand lance

There is no commercial or recreational fishery for Pacific sand lance (*Ammodytes hexapterus*) in BC. However sand lance provide an important ecological role primarily as prey for marine birds (e.g., Pelagic cormorants, Glaucous winged gull), marine mammals (e.g., harbour seals, Steller sea lion) and marine fishes (e.g., lingcod, salmon) (Willson *et al* 1999: Hart 1973), all found in the Roberts Bank area. Sand lance spawn in the upper intertidal zone in the winter (November to February; Pentilla 1997; Thuringer 2003) on both pure sand and a mixture of sand and fine gravel similar to habitat used by surf smelt (Pentilla 1997). No eggs were found in the winter beach sediment samples (November 2003 – January 2004), however, as was the case with surf smelt, two years of consecutive sampling at a location is recommended by the Washington State sampling protocol to rule out a potential spawning site. Although beach seine sampling was conducted year-round, sand lances were caught in the fall only (December 2003), most within the Deltaport Third Berth project footprint (Tables 3.3.3-10 and 11).

Embiotocidae

Embiotocidae present in the study area were shiner (*C. aggregata*), pile (*Rachochilus vacca*) and striped (*Embiotoca lateralis*) perch, as indicated by beam trawl catches (Table 3.3.3-13). There are indications that shiner, pile and surf perches were used traditionally by Nuu-chah-nulth people on the west coast of Vancouver Island (Lane *et al*., 2002). There is a recreational fishery from wharves for all perches in British Columbia, and the commercial fishery on pile perch is expanding (Lane *et al*. 2002). There are no seasonal restrictions (BC Tidal Waters Sport Fishing Guide 2003)

Shiner perch are abundant on both sides of the Roberts Bank causeway and were one of the most common fishes caught in beam trawl and beach seine in summer and fall (Tables 3.3.3-10 and 3.3.3-12). These fish are probably the most common surfperch in BC (Buckley and Hueckel 1985, cited in Lane *et al*. 2002). They are reported to move to deeper waters in winter (Gordon 1965), and this appears to be confirmed by the observed decrease in beam trawl and beach seine catches during this season (Tables 3.3.3-10 and 3.3.3-12). The abundance and small size of shiner perch make them available to numerous piscivorous birds and fishes in the Roberts Bank area and as such they should be considered an important ecological resource.

Other fishes

The life histories of other fishes known to be present or abundant near the Deltaport facilities were reviewed but are not included as they are not viewed as unique and their habitat is not considered to be affected by the present project, which would thus not threaten the sustainable use of a resource. For the record these fishes are, in no particular order, walleye pollock (*Theragra chalcogramma*), threespine stickleback (*Gasterosteus aculeatus*), staghorn sculpin (*Leptocottus armatus*), whitespotted greenling (*Hexagrammos stelleri*), snake prickleback (*Lumpenus sagitta*), tubesnout (*Aulorhynchus flavidus*), and spiny dogfish (*Squalus acanthias*), all of which were caught in beach seines or beam trawls in 2003-04 (Tables 3.3.3-10 and 3.3.3-12).

General conclusions

The intertidal habitats on both sides of the Roberts Bank causeway cover a large area characterized by a shallow slope, and are thus submerged intermittently by tidal waters. As such the general area provides a refuge for many small euryhaline fishes. The literature review, our observations and data show the area to be a nursery area for fishes such as sculpins, flounders and salmonids. The periods of highest ichthyofauna productivity and diversity are spring and summer. The period of highest vulnerability to anthropogenic disturbances, due to the abundance of larval fishes, is spring.

3.3.4 Eelgrass: *Zostera marina & Z. japonica*

The results from the eelgrass studies are summarized below. The data are provided in Appendix A3.2-1.

3.3.4.1 Eelgrass distribution and mapping

There are two species of eelgrass within the study area; the native species *Zostera marina* and an introduced species, *Z. japonica*.

Z. marina occurs between –1.5 and +1.25 m (CD) along the western side of the Roberts Bank causeway, and between -0.5 and +2.0 m (CD) in the intercauseway area. The lower limit of *Z. marina* growth is often determined by light availability. Exposure (dessication) at low tide limits the growth of *Z. marina* at higher elevations.

Z. japonica tends to be a much smaller plant; the shorter, narrow leaves enable the species to survive in intertidal areas where *Z. marina* cannot. *Z. japonica* is common within the study area between about +3.0 and 3.5 m along the western side of the Roberts Bank causeway. In the intercauseway *Z. japonica* has colonized the area from +2.0 m (CD) to a height beyond which bathymetric data is currently available. The upper limit of *Z. japonica* is controlled by dessication while the lower limit, in the case of the intercauseway area, is controlled by the density of *Z. marina*. *Z. marina* can outcompete the smaller *Z. japonica* for light. As *Z. marina* is a larger plant with a larger, faster growing foliage, it blocks light penetration to *Z. japonica* where they co-exist, thus *Z. japonica* is unable to survive in areas where *Z. marina* forms a dense canopy. The density of *Z. marina* in the intertidal decreases with increasing elevation as the habitat becomes less suitable, thus there is often a ‘transition area’ between areas of dense *Z. marina* and areas of dense *Z. japonica* where the two species co-exist.

Z. marina's distribution within the study area extends from the ferry causeway to approximately 2.5 km Northwest of the Roberts Bank causeway. *Z. japonica* is distributed from the ferry causeway to Canoe Pass. *Z. japonica* forms a band along a bathymetric gradient in the intercauseway area that extends along each of the causeways and the shore. *Z. japonica* occupies a large area along the Roberts Bank causeway to the west, and pockets of suitable habitat between the causeway and Canoe Pass.

There are three ecotypes or genetic races of *Z. marina* that occur in British Columbia: *phillipsi*, *latifolia* and *typica*. The optimal habitat for each type is slightly different. The majority of the eelgrass within the study area was *phillipsi; latifolia* was noted in some of the deeper areas.

A total of 65 eelgrass polygons (native and Japanese) were mapped. The distributions of *Z. marina* and *Z. japonica* are shown in Figures 3.3.1-1 and 3.3.1-2. The data used to construct the map are provided in Appendix A3.2-1a.

3.3.4.2 Detailed eelgrass habitat assessment

The field survey documented a variety of eelgrass habitat types within the study area (Appendix A3.2-1b). Eelgrass morphology, density, and distribution respond to minor changes in elevation, substrate and/or currents. Shoot length and width tend to increase with depth. The density of eelgrass is usually greatest in areas that are slightly submerged at low tide. Suboptimal substrate may also limit the density of eelgrass. Exposure to currents or waves may result in a patchy distribution, whereas quiescent areas generally support a continuous meadow.

Shoot length, width, density, and distribution (patchy vs. continuous) varied between polygons. The mean shoot length of *Z. marina* per polygon varied from 31 to 219 centimetres, and width from 5.5 to 12 millimetres. Mean density values ranged from 0.24 to 83 shoots/0.25m^2. The productivity and habitat value of an area that supports large dense shoots is much greater than one where the shoots are small and sparse. A method commonly used to assess the relative productivity of eelgrass beds is the Leaf Area Index (LAI). The index is the product of shoot length, width, and density.

Leaf Area Indices (LAI) were calculated for each polygon within potential development areas (Appendix A3.2-1). The relative productivity of *Z. marina* per unit area varied by a factor of 392 between the most and least productive polygons (Table 3.3.4-1).

Table 3.3.4-1. Leaf Area Indices (LAI) of the most and least productive eelgrass (*Z. marina*) polygons surveyed in the study area. Calculations are based on July and August 2003 data.

Relative Productivity	Length (cm)	Width (mm)	Density (#/0.25m^2)	LAI (/0.25m^2)	LAI (m^2)	Percent cover	Net LAI
most	52	6.5	8	2,704	10,816	0.03	324.5
least	219	9.5	18	37,449	149,796	0.85	12,7326.6

3.3.4.3 Seasonal baseline data

The sampling sites at both Roberts Bank and in Boundary Bay were selected to include a variety of eelgrass habitats. Four sampling sites were monitored in the intercauseway area, four west of Coal Port, and three in Boundary Bay. Sampling sites were selected at high, mid and low elevations to represent the range of habitats at both sites.

High Elevation Sites

Eelgrass at the high elevation baseline sites tended to be shorter, narrower, and denser than in lower areas. The percentage of shoots that became reproductive was high: >75% by May and > 85% by August. The mean density of shoots in December was half that recorded during Spring and Summer sampling.

Mid Elevation Sites

The density at most of the mid elevation sites remained relatively constant throughout the year, but the winter shoots were approximately 60% shorter and slightly narrower than during the spring and summer seasons. The percent of plants flowering in August, 2003 ranged from >1% to 16%, and from 3 to 5% in May, 2004.

Low Elevation Sites

Eelgrass shoots at the lower elevations varied less in term of both shoot density and length over the seasons, but the decreases in width over winter were comparable to those at mid locations in winter. Reproductive shoot density varied from 3-5% in August, 2003, and from 5 to 16% in May, 2004.

The seasonal baseline data for each of the reference sites are summarized in Appendix A3.2-1c.

Comparisons of the data from the Roberts Bank and Boundary Bay sites indicate that the plant density and shoot morphology were similar.

3.3.5 Intertidal/subtidal rock

Three survey techniques (SCUBA, SIMS, intertidal-low tide) were used to characterize intertidal and subtidal rocky habitats at the Roberts Bank Container facility. All rocky habitats described are anthropogenic in origin. There were no areas of bedrock or bedrock outcrops observed. Below is a description of these habitats summarized from observations made during a summer low tide survey, a winter fish survey, a lingcod egg mass survey (LEMS), and a SIMS survey (see methods, Section 3.2.4.1). Figure 3.2.4-1 shows the SIMS survey area and Figure 3.2.4-2 shows the location of fish and intertidal surveys.

3.3.5.1 Crest protection

Figure 3.3.5-1 shows the crest protection that was placed landward of the dredge basins in 1982 to help prevent the formation of erosional channels that could have resulted in draining the tidal flats (Mike Tarbotton, Triton Engineering, pers. comm., 2004). The crest protection was constructed with rip rap and is at an elevation of approximately 0.5 to 1.0 m above chart datum (CD). Algal and invertebrate assemblages were characterized along 1.3 km of the crest protection, from the boat basin to the dendritic channel outflow during one of the lowest tides of the year (+0.10m CD).

Algal and invertebrate community composition was similar along most of the rip rap, with differences in species present dependent on elevation, concentration and orientation of the crest protection. In general, there is diverse algal cover (moderate to dense) on the crest protection (Photo P3.3-16) which includes *Sargassum muticum*, *Laminaria saccharina*, *Fucus sp*., *Ulva sp*., and filamentous and foliose red algae (*Odonthalia sp*., *Mastocarpus pappilatus* (blade and crust), *Mazzaella splendens*, *Chondracanthus exasperatus*). The most abundant invertebrate species present include plumose anemones (*Metridium sp*.) (Photo P3.3-17), orange encrusting bryozoans (*Schizoporella sp*.), and orange sea cucumbers (*Cucumaria miniata*). Other invertebrates common along the rip rap include ochre stars (*Pisaster ochraceus*), anemones (*Urticina crassicornis*), calcareous tube worms (*Serpula vermicularis)*, hydroids, chitons (*Mopalia muscosa*), and dogwinkles (*Nucella lamellosa*) with eggs. Several of these species are typically found in current dominated marine environments.

Although the general description of algal and invertebrates species provides an overview of the biotic features along the crest protection, there are some differences in substrate and species composition. As a result, four habitat areas based on changes in biophysical features along the crest protection are identified in Figure 3.3.5-1. The main differences in community assemblages and substrate size and composition among these habitats, are described (clockwise from the boat basin) as follows:

1. The crest protection is non continuous (320m linear length) with the substrate comprised of sporadic boulders on sand (first 150m linear distance) (Photo P3.3-18) and a mixture of cobble/boulder (50%) and sand (latter 125m linear distance) (Photo P3.3-19). *Sargassum* is the dominant algae present in the first half of this area with sparse *Ulva*, *Fucus* and *Mastocarpus* growing on boulder. With the increase in boulder and cobble in the latter portion, *Sargassum* continues along the landward edge of the rip rap. Bladed kelp (*Laminaria saccharina*) is absent in most of this section (first 250 m) while barnacles are more abundant than in other areas.

2. The northwest corner of the crest protection (350 m linear length) is characterized by dense *Sargassum* draped over the substrate (Photo P3.3-20) and algae understory, primarily the filamentous red algae, *Odonthalia floccosa.* There are four main drainage channels (Photo P3.3-21) with algae and invertebrates

typically found in current dominated areas including coralline red algae, *Prionitis lanceolata*, *Metridium*, bryozoans (*Bugula sp.*) and sponges.

3. The next section is a relatively short section of the crest protection (50m linear length) and is characterized by smaller substrate ranging from pebble to boulder (< 50 cm diameter). Diverse algae and invertebrates are present with *Laminaria saccharina* the dominant alga (Photo P3.3-22).

4. The final section of rip rap (575m linear length) is continuous with larger substrate (cobble/boulder >50 cm diameter) and greater relief than the eastern portion (Photo P3.3-23). Diverse algae and invertebrates are present in this area. Due to the higher relief, *Sargassum* is dense on both the seaward and landward side. There is a sand drape along the seaward edge of the crest protection (Photo P3.3-24) where several soft bottom invertebrate species were noted (see below).

Although there were no fishes observed on the crest protection during the winter fish survey, given the documented fish use in the area (Gordon and Levings 1984), this rocky feature is likely used by several species of nearshore fishes (both juvenile and adults) for refuge and foraging. During the intertidal survey, one saddleback gunnel (*Pholis ornata*) was seen in the *Sargassum* along the western portion of the rip rap. Several juvenile flatfishes (< 40 mm length) were observed within the eelgrass bed landward of the crest protection and Pacific sand lance (*Ammodytes hexapterus*) were buried in the sand seaward of the rip rap. Invertebrates observed in the sand seaward of the crest protection include horse clams (*Tresus sp*.), aggregating anemones (*Anthopleura elegantissima*), and tube worms forming dense mats.

Although this rocky feature provides some habitat complexity and refuge opportunities on a large tidal flat, the presence of this rip rap ridge on the tidal flat has potential to influence the coastal process (drainage and sediment transport) in the area. A recent report by NHC (2004) describes the dynamic nature of tidal drainage and channel formation within the intercauseway in the vicinity of the crest protection and the likelihood for continued channel transformation.

3.3.5.2 Terminal 2 rip rap

Approximately 1.1 km (linear distance) of rip rap along the western terminal was surveyed to characterize algal and invertebrate communities as the proposed Terminal 2 Project will potentially impact this area. Seven transects commencing from the top of the rip rap (+7.2m CD) to the base (+2.8m to –0.5m CD) of the rip rap were completed (Figure 3.2.4-2). Algal and invertebrate species were documented within each biotic band (i.e., algal/invertebrate zonation). Information on the vertical extent and width of each band along with abundance of dominant species present were recorded (Appendix A3.2-2).

Figure 3.3.5-1

There is continuous algal and invertebrate banding along the entire length of the rip rap surveyed (Photo P3.3-25, Figure 3.3.5-2). Seven bands were identified and are listed in Table 3.3.5-1 with the vertical elevation and a summary of the dominant species found within each band. A detailed summary of transect information is provided in Appendix A3.2-2.

Table 3.3.5-1. Summary of biotic bands observed on the rip rap along the western terminal (see Figure 3.3.5-2)

Transect	**Biotic Bands**	**Intertidal Zone**	**Average Tidal Range (m-CD)**	**Dominant algal and invertebrate species observed**	
				Latin Name	Common Name
T0-T6	Bare	splash/upper intertidal	+7.2 to +4.6		
T0-T6	*Verrucaria*		+4.6 to +4.0	*Verrucaria*	black lichen
T0-T6	Filamentous green algae		+4.0 to +3.5	Filamentous green algae *Porphyra sp.*	 purple laver
T0-T6	*Fucus*	mid intertidal	+3.5 to +2.1	*Fucus sp.* *Mastocarpus pappilatus* *Balanus glandula* *Crassostrea gigas* *Mytilus sp.*	rockweed Turkish washcloth acorn barnacle Pacific oyster blue mussel
T4-T5	Barnacle		+2.4 to +1.6	*Balanus glandula* *Mytilus sp.* *Crassostrea gigas*	acorn barnacle blue mussel Pacific oyster
T5-T6	Filamentous / foliose red algae	lower intertidal	+1.7 to +0.3	*Mazzaella splendens* *Cryptopleura ruprechtiana* *Plocamium cartilagineum*	splendid iridescent hidden rib sea comb
T5-T6	Red algae /bladed kelps		+0.3 to	*Cryptopleura ruprechtiana* *Odonthalia floccosa* *Palmaria callophylloides* *Alaria marginata* *Laminaria saccharina/groenlandica*	hidden rib sea brush frilly red ribbon ribbon kelp sugar/split kelp

Four of the seven bands within the upper to mid intertidal zone are continuous (Figure 3.3.5-2) with similar species composition and abundance (see Appendix A3.2-2). Two of these bands are vegetated, with algae in the mid intertidal *Fucus* band predominantly a mixture of both *Fucus sp*. and red foliose algae *M. pappilatus*. Invertebrates common to this band include acorn barnacles (*Balanus glandula*), Pacific oysters (*Crassostrea gigas*) (Photo P3.3-26), and blue mussels (*Mytilus sp*.).

As the elevation at the base of the rip rap increases (from +2.6m at T0 to +0.5m at T5) and wave exposure changes south of T5, a diverse group of filamentous and foliose red algae (Photo P3.3-27) are present in conjunction with bladed kelps (*Alaria marginata* and *Laminaria saccharina/groenlandica*), *S. muticum* and bull kelp (*Nereocystis luetkeana*). *Laminaria* and *Nereocystis* first appear near the western corner of the terminal 50m north of T5. A band of bull kelp is present along the southern face of the terminal (field observations, Gartner Lee 1992) and on the two artificial reefs. Invertebrates including chitons (*M. muscosa*, *Tonicella lineata*, *Katharina tunicata*), hydroids and dogwinkles (*N. lamellosa*) were noted in the lower intertidal zone. Similar invertebrate and algal species would likely colonize any new rip rap placed at the same elevation and orientation as the existing terminal embankment

No fish were observed at T5 during the winter fish survey (Figure 3.2.4-2 for survey location), but fish use along the rip rap between T5 and T6 from the lingcod egg mass survey, SIMS survey and previous studies is described in detail in Section 3.3.5.3.

3.3.5.3 LEMS and fish survey

A lingcod egg mass survey (LEMS) and a fish survey (winter) were conducted to document fish use in the rip rap along the southern and eastern edges of the terminal rip rap (Figure 3.2.4-2). Although the focus of these surveys was to locate and describe lingcod nests and enumerate benthic fishes (primarily lingcod and rockfish), general habitat information was also.

Table 3.3.5-2 summarizes the LEMS results from the seven survey sites. Appendix A3.3-7a provides a detailed description of each of the egg masses in accordance with Vancouver Aquarium LEMS protocol. Lingcod nests were documented at six of the seven sites, with two to nine nests found per site. In total 27 nests were located, all at <2m depth excluding a nest at Site 1. The majority (89%) of the nests appeared to be new (white in colour) and were situated in crevices in the rip rap (Photo P3.3-28) as opposed to being loose or out in the open. With the exception of the two nests found along the coal loading dock (Site 1), 76% of the nests were watermelon size (Photo P3.3-29) suggesting 5+ year old spawning females (Malcolm and Martell 2004). Lingcod were observed at all sites (Photo 3.3-30) with 26% of the nests guarded by a male (Photo 3.3-31).

Figure 3.3.5-2

Table 3.3.5-2. Summary of lingcod egg nesting survey February 9-10, 2004. Egg nest characteristics detailed in Appendix 3.3-7.

Transect	Total # nests	Depth range (m-CD)	Fish observed (common name)	Invertebrates observed (common name)	Vegetation observed (species)	Substrate
1	2	-6.0, -1.0	Lingcod Quillback rockfish Copper rockfish Unidentified sculpin Black eyed goby	Oregon triton Swimming scallops Green sea urchins Orange sea cucumber Mottled star	*Laminaria* sp. *Lithothamnion*	Rip rap and rubble (<0.25m diameter)
2	9	-0.4 to – 1.8	Lingcod Striped perch Red Irish Lord	Hydroids Sunflower star Mottled star Blood star Spiny Pink star Plumose anemone Dogwinkle Kelp crab	*Laminaria* sp. Filamentous and foliose red algae *Sargassum muticum*	Predominantly large rip rap, up to ~2m diameter, increased crevice and interstitial space
3	2	-0.7	Lingcod	Similar to artificial reef (site #2)	Diverse filamentous and foliose red algae[1]	Mixture of large /small rip rap (0.25m to 2m)
4	6	-0.2 to – 0.8	Lingcod	Similar to artificial reef (site #2)	Diverse filamentous and foliose red algae	Mixture of large /small rip rap (0.25m to 2m)
5	3	+0.2 to – 0.5	Lingcod	Similar to artificial reef (site #2)	Diverse filamentous and foliose red algae	Mixture of large /small rip rap (0.25m to 2m)
6	5	-0.3 to – 1.4	Lingcod Striped perch	Similar to eastern artificial reef (site #2)	Similar to eastern artificial reef (site #2)	Similar to eastern artificial reef
7	0	N/A	Lingcod Copper rockfish	Similar to artificial reef (site #2)	Diverse filamentous and foliose red algae	Mixture of large /small rip rap (0.25m to 2m)

[1]including *Cryptopleura ruprechtiana, Palmaria callophylloides* and *Odonthalia floccosa*

With the exception of Site 1, where invertebrates including swimming scallops (*Chlamys hastata*), orange sea cucumbers (*Cucumaria miniata*) and Oregon triton (*Fusitriton oregonensis*) and the encrusting coralline red algae (*Lithothamnion*) indicated a high current influence along the eastern edge of the terminal, all lingcod nesting sites had similar filamentous and foliose red algae and abundant invertebrate species including several sea stars, hydroids, and dogwinkles (see Table 3.3.5-2). However, there were some notable differences in the rocky habitat provided by the reef and the terminal rip rap. With the exception of Site 1, the base of the rip rap along the southern edge of the terminal (Sites 3-5, Site 7) was shallow, ranging between 0.5m and 0.9m depth as opposed to 2m to 2.6m depth along the section of reef surveyed. The reefs are predominantly constructed from larger sized rip rap (2 m diameter) and configured in a way that provides increased crevice and interstitial space for fish use.

All lingcod nesting sites surveyed had suitable habitat for spawning, characterized by abundant rocky crevice space for egg attachment and strong tidal flushing to ensure oxygen delivery to the centre of the nests (Case *et al.* 1990). However, the larger sized rip rap in the artificial reef structure may enhance the suitability of nesting sites and should be considered during any compensation planning.

Table 3.3.5-3 summarizes fish counts by species for each site (see Figure 3.2.4-2) from the winter fish survey. Detailed survey information is included in Appendix A3.3-9b. No fish were observed at either the crest protection (transects 1A/1B) or along the western terminal rip rap (transects 4A/4B). Lingcod were observed at both reef locations (3A/3B) and at the coal loading terminal (2B), with two egg masses observed on the outside of both reefs. Kelp greenling (*Hexagrammos decagrammus*), copper and quillback rockfish (*Sebastes caurinus/malinger*), cabezons (*Scorpaenichthys marmoratus*) and pile perch (*Rhacochilus vacca*) were all noted at the reef sites.

Table 3.3.5-3. Summary of fish counts by species for each transect surveyed January 13-14, 2004. Transect locations shown in Figure 3.2.4-2.

Common Name	Species	Number of Fish Observed by Transect							
		1A	1B	2A	2B	3A	3B	4A	4B
Lingcod	*Ophiodon elongatus*	0	0	0	2	4[1]	6[1]	0	0
Kelp greenling	*Hexagrammos decagrammus*	0	0	2	2	2	0	0	0
Copper Rockfish	*Sebastes caurinus*	0	0	1	0	1	0	0	0
Quillback Rockfish	*Sebastes malinger*	0	0	0	0	0	1	0	0
Unidentified Rockfish	*Sebastes* sp.	0	0	1	0	0	0	0	0
Cabezon	*Scorpaenichthys marmoratus*	0	0	1	0	1	1	0	0
Irish Lord	*Hemilepidotus* sp.	0	0	1	0	0	0	0	0
Unidentified sculpin	Cottidae	0	0	3	1	0	0	0	0
Pile perch	*Rhacochilus vacca*	0	0	0	0	9	5	0	0

[1]Two lingcod egg masses (watermelon size) at each site

Fishes observed in the winter at the base of Berth 3, the deepest of all sites (-17.5m depth), included kelp greenling, copper rockfish and sculpins (see Table 3.3.5-3). As identified from SIMS imagery collected in September 2003, lingcod (*Ophiodon elongatus*), greenling (Hexagrammidae) and a juvenile yelloweye rockfish (*Sebastes ruberrimus*) were also seen among the rip rap material in this area (Figure 3.3.5-3). However, this survey was limited to a 100m X 100m grid, and did not target rip rap habitat.

The presence of lingcod and rockfish in the rip rap along the eastern and southern edges of the terminal has been documented in previous studies. In March of 1992 (Gartner Lee 1992), lingcod, copper rockfish, kelp greenling and cabezons were observed in the rip rap at the base of Berth 3 with lingcod densities reported to be 1.4 -1.6/100m^2. In Golder (1996) lingcod and copper rockfish were commonly observed in the rip rap at the southwest corner of the terminal embankment (November) with survey results indicating lingcod densities at 0.55/100m^2. Lingcod densities from the winter fish survey in January 2004 were between 0.8 and 1.2/100m^2 on the artificial reefs and 0.4/100m^2 at the coal loading area (Site 2B). When compared to densities in rock habitat reported elsewhere in the Strait of Georgia (0.03 to 0.3/100m^2, Golder

1996), lingcod densities at Roberts Bank are generally higher even when differences in seasonality and survey depth are considered.

A similar comparison can be made between the presence of lingcod egg masses at Roberts Bank and elsewhere on the southern coast by comparing lingcod nesting survey results from the Vancouver Aquarium Marine Science Centre (VAMSC) and Fisheries and Oceans Canada (FOC). Unpublished data from the VAMSC of count per unit effort (CPUE = #egg masses/bottom time x 60 minutes) for lingcod nests for sites in Howe Sound and outside Howe Sound reported during a ten year period (1994 – 2004) are as follows: outside Howe Sound 1.94 (1998) – 7.55 (2003) (mean = 4.43), and within Howe Sound, 1.77 (1999) – 6.5 (2000) (mean = 4.58). Compared to a range of 0 – 15.65 (mean=7.86) at the Roberts Bank LEMS survey in February 2004, these data indicate that the density of lingcod egg masses recorded at Roberts Bank is generally higher than reported elsewhere in the Strait of Georgia.

Although data recorded during lingcod nesting surveys at Snake Island (King 2001) by FOC cannot be directly compared with data from VAMSC or results from the present survey at Roberts Bank due to differences in survey design, the medium nest density of 0.0196 nests/m^2 at Roberts Bank (February 2004) is higher than the medium density of 0.0032 nests/m^2 (King 2001), and is generally consistent with results from other LEMS surveys (Malcolm and Martell 2004).

3.3.6 Subtidal sand/mudflat

The substrate in the area west of the terminal was classified from SIMS imagery as predominately sand or "muddy sand" (sand with less than 10% mud content) as shown in Figure 3.3.6-1. Visual observations from this imagery did not permit us to distinguish gradations in sand/mud content within this area. There has been a previous mapping of sediment size class using extensive grab sampling by Geosea Consulting Ltd. (M. Tarbotton, Triton Engineering, pers. comm.), which can be used to obtain further detail on sediment type in this area. The sand/mudflat steepens at approximately 4 m depth where there is an increase in mud content and fragmented shell (<30%) particularly at a depth greater than 10m.

Vegetation in the subtidal sand/mudflat is limited to the shallow subtidal zone (<1.5m depth) and includes eelgrass (Figures 3.3.1-1 and 3.3.1-2) to 0.5m depth and sparse to low cover of foliose green algae to 1.5m depth (Figure 3.3.6-2). Foliose green alga appears to be primarily *Ulva* sp. with some *Enteromorpha* sp. Most of the *Ulva* sp. shown in Figure 3.3.6-2 co-occurs with eelgrass in sandy substrate with the exception of sparse to low cover on the rip rap in the southwestern corner of the terminal. As the video camera was towed above the eelgrass bed, the understory was not always visible and the extent of foliose green algae cover could not always be determined.

Figure 3.3.5-3

Figure 3.3.6-1

Figure 3.3.6-2

3.3.6.1 Fish

This section describes fishes documented during the SIMS survey with reference to beam trawl data results. A detailed analysis of trawl data is provided in Section 3.3.3.

The identification of fishes from the SIMS video imagery provides an indication of the habitat association and location of the fishes at the time of the survey and is not meant to provide quantitative abundance data. Several species may have been buried in the fine substrate (e.g., skates) and not easily identified or disturbed by the towed camera and moved, leaving only a cloud of sediment visible. Fishes were only identified to species level if the view angle or quality of the imagery permitted the biologist to do so; otherwise a fish was typically classified to the family level (e.g., sculpin = Cottidae).

Flatfishes (Figure 3.3.5-3) appeared to be partitioned by depth and substrate. The most abundant flatfishes were starry flounders (*Platichthys stellatus*), which occurred in the sand (both inside and outside the eelgrass beds) usually in depths shallower than 3 m. Some were also seen deeper on the dredge slope and in the dredge basins (see Section 3.3.7). Most of the starry flounders appeared to be adults (Photo 3.3-18) while most of the other flatfishes appeared to be juveniles (<30 cm in length) (Casillas *et al.* 1998). Moles and Norcross (1995) suggest that sediment grain size (conducive for feeding and burying behaviours) is one determinant in juvenile flatfish habitat selection in nearshore nursery areas. Their results indicate that juvenile starry flounders select larger particle size with increased fish size with larger juveniles (>150 mm) selecting fine sand.

Both English sole (*Parophys vetulus*) and Dover sole (*Microstomus pacificus*) were present in deeper water (generally >10m depth) and appeared relatively more abundant in substrate with greater mud content such as the sand/mud slope in this area and the dredge basin in the intercauseway (see Section 3.3.7).

Skates (SIMS imagery) were observed on the sand although only between 3 and 25 m depth in the sand/mudflat west of the terminal (Figure 3.3.6-3) two of the four skates were identified as big skates (*Raja binoculata*), it is very likely that all skates belonged to this species. Big skate egg cases were commonly observed in the sand (<5m depth) off the western corner of the terminal in November 1992 (Gartner Lee 1992) at densities greater than those described off the Oregon coast at similar depths in an area considered a big skate breeding ground (Hitz 1964). As suggested in Gartner Lee (1992), Roberts Bank may be a breeding ground for *R. binoculata*.

Over ten spiny dogfish (*Squalus acanthias*) were observed on the subtidal sand/mudflat and slope, and appeared common.

Figure 3.3.6-3

3.3.6.2 Macroinvertebrates

A dense bed of sea pens (*Ptilosarcus gurneyi*) (Photo P3.3-33) covering approximately 15 hectares was present in the sandy substrate southwest of the terminal, at 2.5 to 18 m depth (Figure 3.3.6-4). A larger area with patchy distribution of sea pens (approximately 66 hectares) surrounded the dense sea pen bed and extended between 2 and 24 m depth. It should be noted that common predators of sea pens such as nudibranchs (*Armina californica* and *Tritonia festiva*) and several species of sea star (*Dermasterias imbricata*, *Crossaster papposus*, *Mediaster aequalis*) were not observed during the survey. A small patch of sand dollars (*Dendraster excentricus*) was observed at approximately 2.5m depth, adjacent the dense sea pen bed. Spiny pink stars (*Pisaster brevispinus*) and starry flounder (*Platichthys stellatus*), both predators of sand dollars, were common in the area.

Literature describing the ecological importance of sea pens beds in nearshore environments is lacking. A commonly cited study by Krieger (1993) describing rockfish distribution and habitat association in the Gulf of Alaska contains a photograph with Pacific ocean perch and sea pens (although possibly white sea pens, *Virgularia* sp., they appear to be sea whips, *Balticina septentrionalis*). The image is meant to imply an association between the two species however there is no text within the document referring to any relationship. Kyte (2001) describes the decline in sea pens beds in Puget Sound resulting in an impact to the local food web, in particular, the disappearance of six predators species (sea stars and nudibranchs). It is likely that sea pens contribute to the local food web at Roberts Bank and provide structure to the benthic community for refuge. Recently, Soto *et al* (2004) and Ryer *et al* (2004) presented data from laboratory and field studies describing juvenile flatfish (including English sole) habitat preference for emergent structures (shell, vegetation) in benthic habitats.

Crabs were observed throughout the SIMS survey area, however, crab density in the tug basin and upper dredge cut appeared to be greater than other locations (Figure 3.3.6.4). The crabs observed represent only a portion of those present, as crabs bury themselves in the fine substrate and are difficult to see and, as mobile invertebrates, occasionally move out of view as the video approaches. Most of the crabs identified appeared to be Dungeness crab (*Cancer magister*) (Photo 3.3-34), ranging in size from approximately 10 cm to legal size (150 cm). Although it is difficult to differentiate this species from *Cancer gracilis* (slender crabs <10 cm carapace width) using video imagery, *C. gracilis* were not documented in any previous studies in the area nor were they identified in current studies, therefore, it is likely the smaller crabs observed were *C. magister*.

Few sea stars (Figure 3.3.6-5) were identified on the sand/mudflat, with none observed in the sand habitat above 2m depth, possibly due to freshwater influence. The most common sea star in this area is the spiny pink star (*Pisaster brevispinus*) and the sunflower star (*Pycnopodia helianthoides*), both present on the sand/mud slope. Although clams are primary prey of *P. brevispinus*, this species reportedly consumes sand dollars (*Dendraster excentricus*). Only one leather star (*Dermasterias imbricata*), a species known to prey on sea pens was identified in this area. The only other macroinvertebrate noted were several plumose anemones, *Metridium giganteum* (Figure 3.3.6-6) which were present only on the sand/mud slope below 10 m depth.

Infaunal sampling was not included in the scope of this project. However, the presence of infaunal holes was noted during SIMS classification. Generally, areas with infaunal burrows were identified at depths <5m in the sand/mudflat. These burrows are created by various species, including marine worms, shrimp, clams and fish, and require sampling to identify occupants. Infauna provides an important food source for benthic communities including several species of flatfish.

3.3.6.3 Biofilms

Figure 3.3.6-7 shows areas of growth of benthic diatom mats, a thin film of single celled plants generally growing on non-vegetated surfaces (sand or mud). On tidal flats and mudflats benthic diatom mats can be the principle source of primary production (Warwick *et al.* 1979). The extent of diatom mats varies seasonally, with the deeper extent controlled by light penetration and upper extent by wave exposure and tidal height. This distribution represents the extent of the diatom mat in September 2003, the distribution in winter, spring and early summer would likely be quite different as a result of seasonal growth, light penetration and wave height.

On the west side of the container port, the diatom mats were most extensive from depths of 2m to 5m relative to chart datum. This is primarily sandy substrate with little to no vegetation cover, however the lower extent of the diatom mats co-occur with the extensive sea pen bed. There was also an area of lower density mat immediately adjacent the eelgrass bed. However, the substrate between this area and the rip rap embankment was formed of clean, white sand with no accumulations of diatom. In contrast most of the rest of the bottom contained trace amounts of diatom mat.

Figure 3.3.6-4

Figure 3.3.6-5

Figure 3.3.6-6

Figure 3.3.6-7

3.3.7 Dredge basins

The substrate in both the upper (10-15m depth) and lower (> 20 m depth) dredged basins in the intercauseway area (including the dredge slope) was predominately mud (with some sand content) (Figure 3.3.6-1). This area is likely depositional. If maintenance dredging is carried out, the frequency and quantities removed will provide an estimate of the rate of sediment deposition. The benthic component of this basin is probably poorly flushed and the sediments anoxic as indicated by the presence of sulphur reducing bacterial mats (*Beggiatoa*) in this area. Vegetation was not observed within the dredge basins with the exception of detritus (see below).

3.3.7.1 Biofilms and organic matter

The colourless sulfur-reducing bacteria *Beggiatoa* spp. formed a mat on the mud bottom in the entire upper dredge basin (10-15 m depth) and in the northern portion of the deeper dredge basin (to 20 m depth) (Figure 3.3.6-7). The mat in the upper dredge basin was continuous and dense, becoming more patchy deeper. The formation of *Beggiatoa* mats indicates anoxic seabed conditions and poor flushing.

The observed organic material (Figure 3.3.6-7) consisted of aggregations of vegetative detritus of marine origin (eelgrass and marine algae). Accumulations were present: (1) below the rip rap in the southwest corner of the coal port where similar aggregations were noted in the same area during dive surveys in November, 1992 (2) just inside the point of the present tug basin, and (3) at the bottom of the upper dredge cut in the intercauseway area. These are likely areas that naturally accumulate drifting detrital material.

In the intercauseway area, a dense diatom mat was observed on the east side of the existing dredge cut. This area was originally interpreted as an eelgrass bed from air photos but, likely, the dense diatom mat darkened the substrate to such an extent that in appeared similar to the adjacent shallower eelgrass bed. Substrates in areas with dense diatom mats are likely quite stable over the short term (weeks to months) in contrast to shallower or more exposed or current scoured areas.

3.3.7.2 Fish

Based on the SIMS survey, fish species within the dredge basins were partitioned into two general categories by depth and substrate. The finer mud substrate below 10m depth supported predominantly either eelpouts (Zoarcidae) and/or prickleback (Stichaeidae) (most unidentified fish are one of these species; Figure 3.3.6-3). Although there is no beam trawl data for this area, >100 pricklebacks were caught at a site east of the dredge cut (Figure 3.3.3-16b). Several Plainfin midshipman (*Porichthys notatus*) were also present within the deeper dredge basin. These fish were not observed in the sandy substrate of the western survey grid. One skate (likely a big skate) was buried within the mud in the shallower dredge basin. Most of the flatfishes below 10m depth that could be identified from the imagery were English and Dover soles, while flatfishes <10m depth were a mixture of these species and starry flounder. Lingcod, greenling and a juvenile yelloweye rockfish were observed in the rock along the base of Berth 3.

3.3.7.3 Macroinvertebrates

As noted in Section 3.3.6.2, crab densities (*C. magister*, from SIMS) within the dredge basins were relatively higher than those observed west of the terminal (Figure 3.3.6-4). Although there was generally poorer visibility in the intercauseway imagery and crabs bury in the substrate, there were generally > 10 crabs observed along the upper dredge cut within a 200m length of trackline compared to < 5 crabs / 200 m west of the terminal. This supports data from the juvenile crab study in the intertidal zone suggesting that this area is an important crab nursery (see section 3.3.3.3).

Several spiny mud stars (*Luidia foliatum*) were observed in the deeper dredge basin where mud content is higher than in the western grid (Figure 3.3.6-5). Spiny pink stars and sunflower stars occurred along the northern edge of the terminal in the dredge cut. A few sea cucumbers (*Parastichopus californicus*) were present in both the mud of the deeper dredge basin and within the rip rap along the eastern edge of the terminal (Figure 3.3.6-6). Plumose anemones were also common in the deeper dredge basin (Figure 3.3.6-6). Other soft bottom species, such as parchment tubeworms, were difficult to identify from video imagery. The characterization of soft bottom communities typically requires infaunal sampling by benthic grabs or dive surveys.

3.4 MARINE MAMMALS

3.4.1 Methods

This section details relevant information about the abundance, distribution, seasonal occurrence and population trends of marine mammals inhabiting the southern Strait of Georgia/Georgia Basin/BC. While good information exists for abundances and for summer distributions of several marine mammals known to inhabit waters proximate to the Roberts Bank container expansion project site (e.g., resident killer whales and harbour seals), most species are generally understudied and little is known about their summer movements and habitat use. Less is known about the distribution and abundance of marine mammals in the waters proximate to the Roberts Bank container expansion project site in other seasons, with winter months being least studied.

Three geographical studies were used to characterize the distribution of the marine mammals:

- **Proximate (within 5 km radius)**. This distance was chosen to reflect the likely zone of influence of construction operations, such as noise from dredging, dredge material dumping, dredge boat traffic, etc. The least amount of information is known about marine mammal use of this area and consequently, year round sighting surveys were conducted to assess possible habitat hotspots (c.f. Section 3.4.3).

- **Southern Strait of Georgia (Locally)**. This area covers the Fraser River and Eastern Gulf Islands, including the nearest large pinniped haul-out at Sand Heads. More information is available on marine mammal occurrences at this geographical scale. This wider area may also be affected by construction operations and by increased ship traffic.

- **Georgia Basin and area (Regionally).** This area covers the entire region and is included mainly in the context of increased ship traffic due to operations. Container ships will move through the Straits of Juan de Fuca towards the project site and thus potentially affect marine mammals occurring in these more distant areas.

Data from grey and white literature sources were complemented by systematic sighting surveys of the proximate area carried out between August 2003 and July 2004 as part of this study. Additional information was gathered by telephone survey interviews of Vancouver Port Authority staff, whale watch operators and marine mammal scientists (Section 3.4.4), and by marine mammal sightings collected during Envirowest bird surveys (Section 3.4.5). To further assess potential VECs (Valued Ecosystem Components), a review of provincial (B.C. Conservation Data Centre), IUCN (International Union for Conservation of Nature and Natural Resources) and Committee on the Status of Endangered Species in Canada (COSEWIC) databases was made to assess threat designations of marine mammals inhabiting the southern Strait of Georgia/Georgia Basin/BC (Table 3.4.1-1).

A review of grey and white literature compiled information on seasonal occurrence of marine mammals at the three geographical scales: proximate (within 5 km) to the expansion site, locally (southern Strait of Georgia) and regionally. This review also gathered information on the abundance, distribution and population trends of marine mammals inhabiting the southern Strait of Georgia/Georgia Basin/BC. IUCN and COSEWIC databases were then reviewed to assess threat designations of marine mammals inhabiting the southern Strait of Georgia/Georgia Basin/BC.

Data on risk designations were compiled from the following sources:

- Government of B.C. provincial listing website (*http://srmapps.gov.bc.ca/apps/eswp/*);
- The World Conservation Union's (IUCN) Red List of Endangered Species (indicating risk status internationally, with a focus on the northeastern Pacific Ocean); and,

- The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) species at risk databases (indicating risk status of local populations in Canada), (*http://www.redlist.org/* and *http://www.cosewic.gc.ca/*).

Table 3.4.1-1. Provincial, COSEWIC and IUCN risk designations for species of marine mammals found in the southern Strait of Georgia/Georgia Basin area ([1]).

Common name	Provincial Listing([2])	National (COSEWIC[3])	International (IUCN[4])	BC numbers	BC trend
Harbour porpoise	Blue	Special concern	Vulnerable	?	↓
Dall's porpoise	Yellow	Not at Risk	Lower risk	?	?
Pacific white-sided dolphin	Yellow	Not at Risk	No listing	?	?
Common dolphin	N/A	Not at Risk	No listing	?	?
False killer whale	N/A	Not at Risk	No listing	1	N/A
Killer whale	N/A	N/A	Lower risk	N/A	N/A
S. Resident killer whale	Red	Endangered	N/A	≈81	↓
Transient killer whale	Red	Threatened	N/A	≈270	?
Fin whale	Blue	Special concern	Endangered	?	?
Humpback whale	Blue	Threatened	Vulnerable	? (low 100s)	↑ ?
Minke whale	N/A	Status pending	Not at risk	?	?
Grey whale	Blue	Special concern	Lower risk	200 residents	↑ or →
Steller sea lion	Red	Special concern	Endangered	8091	↑
California sea lion	Yellow	Not at Risk	No listing	< 3000	→
Northern elephant seal	Yellow	Not at Risk	No listing		→
Harbour seal	Yellow	Not at Risk	No listing	108,000	↑
Sea otter	Red	Threatened	Endangered	1522	↑
River otter	Yellow	Status pending	No listing	?(15-30,000)	?

? = high uncertainty in estimate, ↑ increasing trend, → stable trend, ↓ decreasing trend
[1] Based on BC Species and Ecosystem Explorer, 2003. *http://srmapps.gov.bc.ca/apps/eswp/2004*
[2] Red = Extirpated, Endangered, or Threatened; Blue = Special Concern; Yellow = Not at Risk
[3] Committee on the Status of Endangered Species in Canada
[4] International Union for Conservation of Nature and Natural Resources

Surveys carried out in 2003/2004

The initial workplan methodology called for seasonal above sea surface marine mammal sighting surveys to be carried in a five km radius around the proposed facility. The distance selected was provisionally based on the likely acoustic zone of influence of dredging operations. The methodology was revised after comments from TFN to increase the number of surveys (1+/month) and to widen the study area to 7.5 km. In addition, data were included from land-based sighting surveys carried by Envirowest.

Surveys were carried out by a crew of three, two experienced marine mammal observers and a boat driver. A random zig-zag design was chosen using Distance 4.0[7] to cover the waters deeper than 5 m. Each surveys therefore varied by distance (~14 to 30 km) and route. Observers were placed on the bow of the vessel, vessel speed was set to 8 knots and observers sighted left and right segments (~90° each) independently. The boat driver was requested to call any animals directly in front of the boat and designate an observer to record the sighting. A mobile GPS was used to mark survey routes and to record the time and location of a sighting. Distance and bearing to sighting, group size, species, certainty level of species identification and activity were recorded. Details of weather, cloud cover, Beaufort sea state, swell and wind direction were recorded at the beginning of the survey. If conditions changed (particularly sea state) this was also recorded. Ship traffic moving ahead of the survey was also noted. Photos were taken of Killer whales sighted and pod and individual identifications made using a Photo-ID reference material. Each survey passed the Sand Heads haul out area and numbers of pinnipeds hauled-out were noted and any brands recorded. At least one observer noted any marine mammal sightings in the area between Sand Heads and the start of the designated survey. These sightings were considered "off effort". The locations of sightings made >100 m from the vessel, were calculated using Nobletec plotting software. Seasonal trends were presented by survey date and locations of sightings were converted to UTM coordinates and plotted using Arcview 3.2. Insufficient data were collected to undertake meaningful statistical analysis on seasonal trends.

Anecdotal information gathered from recent local survey interviews

Anecdotal information on marine mammal sightings in the study area were collected by undertaking telephone interviews with port personnel, whale/nature watching operators and marine mammal scientists who have made marine mammal observations in the area.
Interview questions started simply with:

1) Can you tell me about the species of marine mammals you have seen in the vicinity of the port and were any of your sightings in a particular season?

If killer whales were mentioned, the follow up question would ask:

2) Can you tell me about the number of animals seen, their location and whether they were seen more often in any one season?

3.4.2 Historical distribution and abundance of marine mammals in the Southern Strait of Georgia and Georgia Basin

The southern Strait of Georgia/Georgia Basin area is recognized as breeding and/or feeding habitat for a variety of marine mammals (Calambokidis & Baird 1994). Of the 23 species of marine mammals living in B.C. waters (Shore 1999), 16 species inhabit the southern Strait of

[7] Computer package used to design and analyze distance sampling surveys (Thomas *et al*. 2004).

Georgia/Georgia Basin area (Calambokidis & Baird 1994). Of these species, nine are considered common to the area. Marine mammal diversity in this region is relatively high, with five of the seven representative marine mammal sub-order/families present on a seasonal or annual basis. This includes seven[8] odontocete (toothed whale) and four mysticete (baleen whale) cetaceans; two species of otariids (eared seals) and of phocids (true seal); and two mustelid (otter) species.

Seasonal occurrence data suggest that only common dolphin, fin whales and elephant seals do not frequent the local area, but humpback whales and sea otters are believed to be highly sporadic. The majority of sightings of cetaceans both proximate and locally are based on a recent unpublished M.Sc. thesis (Keple 2002), which was based on a single track survey route (Tsawwassen to Duke Point ferry terminals) or on MARES sighting surveys.

Eight of the marine mammal species inhabiting the southern Strait of Georgia/Georgia Basin area are listed as "at risk" nationally or internationally (Table 3.4.1-1). Most notable are killer whales, humpback whales, fin whales, grey whales, harbour porpoises and Steller sea lions (Table 3.4.1-1). Provincially, killer whales, Steller sea lions and sea otters are high risk species, with harbour porpoises and mysticete whales being next highest.

Harbour porpoise

Harbour porpoise are considered a vulnerable (IUCN) coastal species limited to temperate and sub-arctic waters of the northern hemisphere (Gaskin 1984). They are shy and usually seen alone or in small groups of 2 – 5 animals (Gaskin 1984, 1992). Little data are available to assess local trends in harbour porpoise abundance but present levels merit Special concern (COSEWIC) and anecdotal reports demonstrate a decline in some areas of British Columbia. Osborne *et al.* (1988) note that harbour porpoises were once one of the most abundant species of marine mammals in Puget Sound. The abundance estimate for Washington Inland waters stock is 3,509 (CV=0.396) animals and for the Washington and Oregon coast ~29,000 (Laake et al. 1997, 1998). Harbour porpoise sightings around southern Vancouver Island peak in the summer months (A. Hall, UBC, Pers. Comm.). Local year round sightings have been made (Keple 2002).

Dall's porpoise

Dall's porpoises are endemic to the North Pacific and are usually found in deep (greater than 180m), cool (less than 17ºC) waters (Jefferson 1990, Jefferson *et al.* 1993, Ferrero *et al.* 2002), and in small groups, though larger aggregations have been noted. Jefferson (1990) notes a year-round distribution within the deeper waters of inshore B.C., but little research has been done. Movement patterns within the Georgia Basin are unknown, making it difficult to determine if there is a permanent resident population or if individuals transit through the area. One study conducted in Washington and Oregon (Green *et al.* 1992) showed that densities were not significantly different between seasons, though greater densities were noted inshore in the summer and fall. The entire North Pacific population of Dall's porpoises is estimated at

[8] killer whales are split into two groups – resident and transient ecotypes – see Baird 2001b

1,590,000 individuals (Hobbs & Lerczak 1993) although this may be positively biased due to vessel attraction.

Pacific white-sided dolphins

Pacific white-sided dolphins are endemic to the North Pacific and commonly occur in the deep inshore channels of B.C. (Reeves *et al.* 2002). They are often seen in large herds of hundreds of individuals (Jefferson *et al.* 1993) and are regularly seen in the Strait of Juan de Fuca in the summer and fall (Osborne *et al.* 1988). Smaller groups (usually 1-4 animals) are occasionally seen in the waters further inland (Stacey & Baird 1991b). Records exist for sightings in B.C. inshore waters for every month of the year. The Pacific white-sided dolphin is also abundant, with an estimate of 30-50,000 individuals for the entire eastern Pacific produced in 1988 (Stacey & Baird 1991b).

Common dolphins

Common dolphins are a largely oceanic species, found in tropical to warm temperate waters throughout the world (Jefferson *et al.* 1993). They are commonly seen in larger groups of dozens up to thousands. As common dolphins are generally an oceanic species, they are only occasionally found in internal waters (Osborne *et al.* 1988). Since 1994 a handful of sightings have been reported in the Georgia Basin (R. Bates, Marine Mammal Research Group. pers. comm; BC Cetacean Sightings Network, Unpubl. Data). There are currently no available abundance estimates for B.C.

False killer whales

False killer whales have an extensive oceanic range (Jefferson *et al.* 1993), usually inhabit tropical and warm temperate waters deeper than 1,000 m. B.C. is at the outer limits of the normal range of false killer whales. Their inclusion here relates to one individual that frequently inhabits the waters around Roberts Bank Container expansion site. Very little is known about the conservation status of this whale in Canadian waters - with only 10 confirmed records from B.C., mostly stranded specimens from Vancouver Island (Stacey & Baird 1991a).

Killer whales

In the Georgia Basin two sympatric ecotypes of killer whale occur: resident, transient and offshore. They differ in prey choice, behaviour, foraging strategies, genetics and morphology. All ecotypes are long lived and show sexual dimorphism.

Resident Ecotype killer whales

The resident types are piscivorous and travel in larger stable matrilineal groups. The community of southern resident killer whales is the best documented species of marine mammal for the southern Strait of Georgia region (Heimlich-Boran 1988, Bigg *et al*. 1990, Hoelzel 1993, Ford *et al*. 1994, Baird 2001b, Keple 2002). The range of these whales has been determined through several long-term studies. Southern residents use different summer and winter habitats. There is a strong bias towards information gathered in the summer months and far less in the winter and early spring months (Ford *et al*. 1994). Thus, the literature details abundance and distribution information for late spring through early fall. All three pods of southern residents (J, K, and L) have been seen to frequent the waters of the Georgia Basin from late spring through late fall (Krahn *et al* 2002).

One pod in particular (J pod) is seen sporadically in the Georgia Basin throughout the year, while the other two pods are usually seen in May though October- November (Osborne 1999). Most research has been concentrated in the Haro Strait area, but some studies specifically mention distribution in the area of the Deltaport in the late summer and early fall (Heimlich-Boran 1988, Hoelzel 1993, Keple 2002). Keple (2002) traveled between Tsawwassen and Duke point ferry terminals 144 times between May 2000 and April 2001. Killer whales were observed 10 times on the surveys, of which 7 were within a 2-4 kilometers of the port (3 summer, 3 fall and 1 spring sighting). One sighting was a lone animal, suggesting it may have been a transient. The remaining three sightings were all near Gabriola Island in fall.

Resident killer whales specialize in foraging on salmon (Ford *et al.* 1998). Two studies (Felleman *et al.* 1988, Heimlich-Boran 1988) specifically note the importance of the southern Strait of Georgia for these whales during salmon migration. The southern residents seem to use the waters off the mouth of the Fraser River (and thus the waters immediately north of Deltaport) with greater frequency in September – October (Heimlich-Boran 1988). Winter habitat use for southern residents includes Puget Sound and the outer coastlines of Vancouver Island, Washington, Oregon and even California.

Southern resident killer whales have declined at a rate of 20% in the past five years with a population of 81 individuals in 2001 (Krahn *et al.* 2002) and are considered by COSEWIC to be endangered. Northern resident killer whales have a home range encompassing the Northern Strait of Georgia, specifically around Robson's Bight during the summer. They number around 216 individuals.

Transient ecotype killer whales

Transient killer whales forage on marine mammals, travel in smaller groups and are year-round inhabitants of the B.C. coast. While the same species of cetacean as the resident ecotype, the transient killer whale community has a markedly different distribution and abundance (Baird & Dill 1995, Ford & Ellis 1999). The names "resident" and "transient" have become entrenched in the literature despite the fact they are not descriptive of side fidelity or movement patterns of the two ecotypes (Baird 2001b). Transients have been observed throughout the year, though seasonal trends show peaks in use of the Southern Strait of Georgia in the late summer – early fall. The primary prey of transient killer whales in the Georgia Basin is harbour seal (Baird & Dill 1995, Ford *et al*. 1998), thus haul-out sites within the area are likely to be important for foraging. As transients are seen less frequently than the resident ecotype, it is difficult to ascertain exact population numbers, but they are considered threatened by COSEWIC, with the B.C. population numbering ~270 (Ford & Ellis 1999). The ~200 offshore killer whales are far less studied and are believed to eat a mixed diet.

Fin whales

Fin whales are found primarily in oceanic waters of both hemispheres (Jefferson *et al.* 1993). They are often seen closer to shore, usually where there is a deep water approach to the coast. Breeding occurs in temperate waters in winter months. It is believed that fin whales have an annual migration that brings them into the temperate waters of B.C. in the summer months (Osborne *et al.* 1988). Endangered (IUCN) fin whales were the largest numerical take for commercial whaling operations in B.C. and this population has been slow to recover in B.C. (COSEWIC designation special concern). Prior to commercial whaling, fin whales were an occasional visitor to the internal waters of this coast. There is usually one reliable sighting of a fin whale in the Georgia Basin/ Puget Sound area per year (Osborne *et al.* 1988) and COSEWIC reports that some young animals may frequent B.C. coastal waters (see the COSEWIC website http://cosewic.gc.ca). There are no reliable abundance estimates for fin whales in B.C. waters.

Humpback whales

Humpback whales tend to migrate from breeding areas in tropical waters during the winter months to feedings areas in more temperate waters (Jefferson *et al.* 1993). They feed and breed in coastal waters and are considered vulnerable (IUCN). Humpback whales have an annual migration that takes them from temperate waters in the summer months, to the sub-tropical/ tropical waters in the winter months (Osborne 1999). Thus we would expect to only have humpback whales in B.C. waters during the summer with some in late spring and early fall. In the early 20th Century a robust commercial hunt took place in the Georgia Basin for humpback whales (resulting in a COSEWIC threatened designation). Over the intervening years, few if any humpback whales have been seen in this area (Osborne *et al.* 1988). However, in the past five years, these whales have begun to re-appear in the region in the summer months (Network 2003). There has been no systematic research conducted in southern B.C. for humpback whales, with all information gathered on an informal basis. The Georgia Basin would provide good habitat for humpbacks based on past whaling records and predictive modeling (Gregr & Trites 2001), but until 2004, no whales have been recorded closer than Haro Strait (Network 2003). COSEWIC lists the numbers in B.C. to be in the low hundreds of individuals, due to high population segregation. The Canadian Wildlife Service (CWS) web site suggests that the numbers in B.C. is well below historical levels with an incomplete return to all portions of their former range.

Minke whales

Minke whales are widely distributed from the tropics through to ice edges (Jefferson *et al.* 1993). While often seen offshore, minkes tend to aggregate in coastal and inshore areas. Breeding and calving likely occurs in lower latitudes in winter months. Sightings are year round in the Georgia Basin, but primarily from March through November (Osborne *et al.* 1988) and they are the most commonly seen species of baleen whale in inland waters (Osborne *et al.* 1988). It is suspected that this area is a summer feeding ground (Calambokidis & Baird 1994). Inter-annual variations in local distribution have been noted by Osborne *et al*. (1988). No abundance estimates exist for Northeastern Pacific minke whales (Calambokidis & Baird 1994). Over thirty identified individuals inhabit the waters of northern San Juan/ southern Strait of Georgia (Osborne *et al.* 1988).

Grey whales

Grey whales are only found in the North Pacific Oceans and adjacent waters (Jefferson *et al.* 1993). They are primarily bottom feeders so are restricted to coastal or shallow continental shelf areas. They are the most coastal of all great whales, spending most of their life within tens of kilometers from the shore. Grey whales migrate annually from their winter breeding grounds in Baja, Mexico to feeding grounds in the Chukchi Sea. These migrating whales pass through the Pacific Northwest in December/January when southward bound and again in the spring on their way north. Outside of these migration events, summer feeding aggregations of whales have been noted (Calambokidis *et al.* 2002) and they are seen throughout the Georgia Basin all year long (Calambokidis *et al.* 1992) in shallow areas (Calambokidis & Baird 1994). Locally, animals have been sighted in nearby Boundary Bay and in the middle of the Strait of Georgia (Calambokidis *et al.* 2002, Keple 2002). Numbers of grey whales peaked at 27,000 in 1998, declined by 20% through to 2002 and are now stable or rising. Therefore the population estimate for Pacific grey whales or 20,000 individuals (Calambokidis & Baird 1994), with an estimate of under 200 “summer residents” in the outer waters of the Washington and British Columbia. The potential impacts of human activities to grey whales was one reason cited for changing this species COSEWIC designation from not at risk to special concern in May 2004.

Steller sea lions

The endangered (IUCN) Steller sea lions are usually found in coastal regions from northern Japan to northern California (Jefferson *et al.* 1993). Numbers in U.S. waters have decreased by 75% over the past 20 years and are not recovering at expected rates (Trites & Larkin 1996). They are considered threatened in the eastern portion of their range and as endangered in the western portion under the U.S. Endangered Species Act. Several causal factors have been implicated as contributors to their lack of recovery, including climate change, fisheries conflicts, nutritional stress and depredation by killer whales (Barrett-Lennard *et al*. 1995, Trites *et al*. 1997, Benson & Trites 2002, Trites & Donnelly 2003).

The population in B.C. appears to be stable or rising, but at levels far below those that existed before intensive exploitation in the early 1900's (Bigg 1988b). A recent assessment put numbers at ~8,000 (Peter Olesiuk, pers. comm.). They breed in late spring and early summer and are highly polygynous with males arriving at rookeries early to defend territories. At haul outs and rookeries they can be found in numbers upwards of thousands of individuals. Numbers of rookeries in and bordering Canadian waters are few, leading to a recent special concern designation under COSEWIC. While year round residents in the waters of B.C., they are only found seasonally in the Georgia Basin area from September to May (Calambokidis & Baird 1994), with Sand Heads (well north of the project area) as a haul out site and males outnumbering females (Bigg 1988b).

California sea lions

California sea lions are found coastally from central Mexico to British Columbia (Jefferson *et al.* 1993). Breeding occurs May through June in southern portions of their range. At haul outs and rookeries they can be found in numbers upwards of thousands of individuals. Populations in BC were low until the late 1970's (Bigg 1988a) and were estimated at under 3,000 individuals by the mid 1980's (Gearin *et al*. 1986). This number has decreased slightly or stabilized (Calambokidis & Baird 1994). Breeding populations are increasing (other than in El Niños years) with a total population estimate >200,000 (Carretta *et al.* 2002). Male and juvenile California sea lions are present in B.C. waters and in major rivers from August through June (Bigg 1988a). Bigg (1988) and Osborne *et al.* (1988) identified Sand Heads as an important haul out. California sea lions come to these waters primarily to feed before returning to breeding areas in California and Oregon.

Northern elephant seals

Northern elephant seals are found within the eastern and central north Pacific. Breeding sites are in Mexico and southern California (Jefferson *et al.* 1993). Most individuals migrate twice yearly – once for breeding (December – March) and once for moulting. There are currently no abundance estimates for Northern elephant seals in Canada although it appears that populations in breeding ranges have recovered from very low levels and appear to be at or near historic highs for this species (Guiguet 1971, Campbell 1987, Allen *et al*. 1989, Mesnick *et al*. 1998). Small, but increasing numbers of northern elephant seals can be found year-round in B.C. waters, but they do not breed here (Guiguet 1971, Campbell 1987, Baird 1990). Only Race Rocks is cited as a regular haul out site (Baird 1990), with infrequent sightings in the Strait of Georgia (Calambokidis & Baird 1994) and north Vancouver Island (Condit & Le Boeuf 1984).

Harbour seals

Found only in the Northern hemisphere, harbour seals are one of the most widespread pinnipeds, numbering more than 500,000 globally (Jefferson *et al.* 1993). They are non-migratory and found in coastal waters. They haul out and breed on low-lying rocks, outcroppings and beaches.

The B.C. population appears to be growing at a rate of 12.5% per annum (Olesiuk *et al.* 1990) or at between 5 and 15% per annum (Calambokidis & Baird 1994), despite being the primary prey of transient killer whales (Baird & Dill 1995). The Canadian pacific population in 1988 ranged between 75,000 to 88,000 individuals (Baird 2001a), but more recent Canadian government stock assessment indicates it has grown to approximately 108,000 individuals (Olesiuk 1999). Harbour seal numbers in the Strait of Georgia have increased greatly in the past 25 years, starting at approximately 3,570 and reaching 37,300 animals in 1998 (Olesiuk 1999) and are the most common species of marine mammal found within the Georgia Basin (Calambokidis & Baird 1994). They are present throughout the year, pup in July and August (Olesiuk *et al.* 1990), and can move widely (Huber *et al.* 1993). August aerial surveys conducted in 1994 around the mouth of the Fraser River at low tide counted as many as 1,323 harbour seals, mostly on Roberts bank (Olesiuk *et al*. 1999). The same report noted a handful of animals hauled out around the ferry terminal.

Sea otters and river otters

Sea otters are found in the shallow nearshore waters of the North Pacific (Jefferson *et al.* 1993). They pup throughout the year, but there are peaks in summer months. Severe hunting along the Pacific coast in the 18th and 19th centuries (Osborne *et al.* 1988) has led to a IUCN designation of endangered and a COSEWIC designation of threatened. A reintroduction of 89 animals to Vancouver Island from 1969 to 1972 has increased at a finite rate of 18.6% per year. In 1995, a minimum of 1,522 sea otters were found in British Columbia, most occurring off Vancouver Island (Watson *et al.* 1997) and recently being sighted as far as the Haro Strait and the San Juan Island (Bates 2003). While not technically classified as a marine mammal, river otters often use nearshore oceanic waters for foraging (Osborne *et al.* 1988). They are commonly seen throughout coastal B.C. and little is understood about movement patterns or breeding. The best estimate for abundance is between 15,000 and 30,000 individuals for the entire B.C. coast (Mos *et al.* 2003). River otters occur widely throughout the Georgia Basin (Osborne *et al.* 1988).

3.4.3 Results of sighting surveys carried out in 2003/2004

Eleven marine mammal surveys were completed between August 2003 and July 2004 (Figure 3.4.3-1). All but one survey were carried out completely in Beaufort sea state two and below. Only 125 sightings (n=143 animals) were made during all eleven surveys (Figures 3.4.3-1 and 3.4.3-2).

A summary of seasonal occurrence of the 16 key marine mammal species at three different geographical scales to the project site is presented in Table 3.4.3-1. Numbers of marine mammals were particularly low in winter. Only harbour seals were seen year-round, with 111 counted in total, mostly individual animals and with a strong seasonal peak in August, their breeding season. Harbour seals appeared to be distributed evenly throughout the study area. Porpoises were next most abundant (n=15), seen in August, September, February and March. Ten animals were seen in September, all associated with a shelf and an observed eddy system west of Point Roberts (in US waters) (Figure 3.4.3-2). Interviews undertaken with whale watching companies confirmed this as a porpoise "hotspot". Dall's porpoises are particularly known to use this area, but were sighted only once off effort (3 individuals just north of the study area). Southern resident killer whales of J pod transited through the survey area during one survey (13/3/04). While photographs were not taken of all animals observed, counts suggested that the whole J pod (n=18) was present. Animals were travelling north, with a calf.

Four Steller sea lions were seen in March, May and June, but none were observed to use the Sand Heads haul-out. In contrast California sea lions were seen in large groups (100+) on this haul-out in April and May. The surveys only spotted a lone California sea lion in February and May. Two unidentified pinnipeds were also sighted. Most sightings of marine mammals were made either on the 20-50 m slope or in water deeper than 50 m. The 11 surveys completed in the area provide additional data on species occurrence, seasonal patterns and potentially important foraging hotspots. However, they cannot be considered sufficient to fully assess seasonal patterns of habitat use or to confirm the full significance of a hotspot to any particular species.

3.4.4 Results of local survey interviews

Twenty-two interviews were undertaken between August 2003 and June 2004. Eleven interviewees were port personnel (e.g., skippers, foremen, harbour masters, deckhands). All had observed harbour seals and 91% had observed killer whales and sea lions. West shore Willy, the single false killer whale resident in the Strait of Georgia had been seen by 82% of interviewees. Porpoises were seen sometimes by one and river otters either once or an odd time by two interviewees. No other marine mammals were mentioned.

Most sightings (70%) of killer whales were believed to be in summer or fall, 20% also mentioned spring sightings and 30% described sightings as "well in". Hunting on salmon for an hour or two near the docks (between the port and the ferry terminal) was mentioned by two interviewees and the link with timing of salmon in the area and sightings was made by an additional two interviewees. Killer whale sighting frequency varied between sometimes to often. Group sizes described were mixed (5-25 individuals).

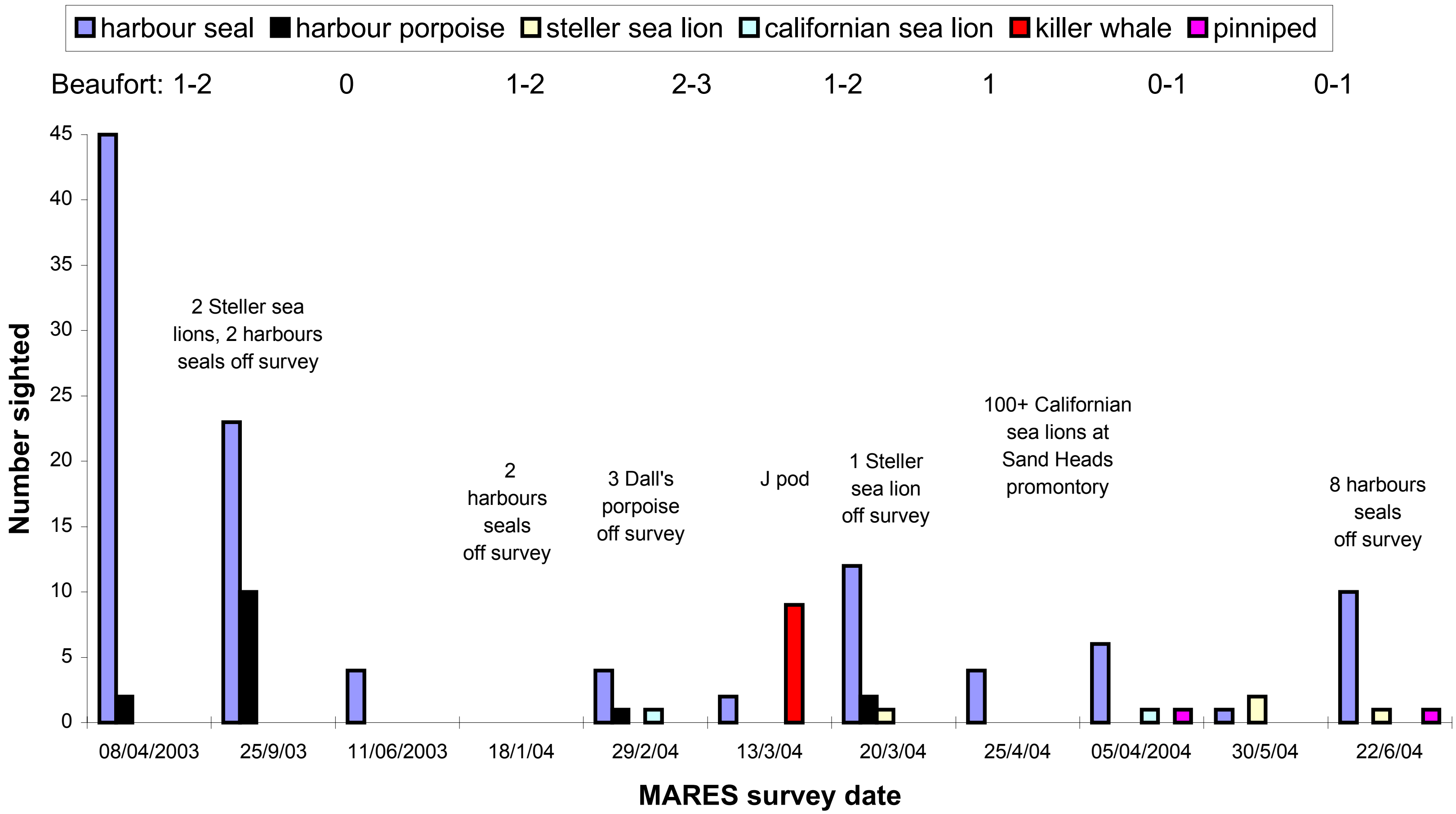

Figure 3.4.3-1. Number of marine mammal sightings by MARES survey

Figure 3.4.3-2

Table 3.4.3-1. Taxonomy (following Rice 1998), common names and seasonal occurrence of 16 key marine mammal species proximate (within five km) to the proposed Deltaport Third Berth project, locally (southern Strait of Georgia) and regionally (Georgia Basin).

Group	Species		Proximate				S. Strait of Georgia				Georgia Basin & area			
	Scientific name	Common name	Sp	S	F	W	Sp	S	F	W	Sp	S	W	F
Odontocete	*Phocoena phocoena*	Harbour porpoise	*	*	*	*	+	+	+	+	+	+	+	+
	Phocoenoides dalli	Dall's porpoise	*	ND	ND	+	+	+	+	+	+	+	+	+
	Lagenorhynchus obliquidens	Pacific white-sided dolphin	+	ND	+	+	+	ND	+	+	+	+	+	+
	Delphinus delphis	Common dolphin	ND	ND	ND	ND	ND	ND	ND	ND	ND	+	ND	ND
	Pseudorca crassidens	False killer whale	+	+	+	+	+	+	+	+	+	+	+	+
	Orcinus orca	Resident killer whale	*	+	+	+	+	+	+	+	+	+	+	+
		Transient killer whale	ND	ND	ND	ND	+	+	+	+	+	+	+	+
Mysticete	*Balaenoptera physalus*	Fin whale	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Megaptera novaeangliae	Humpback whale	ND	ND	ND	ND	+	*	ND	+	+	+	ND	+
	Balaenoptera acutorostrata	Minke whale	ND	ND	ND	ND	+	+	+	+	+	+	+	+
	Eschrichtius robustus	Gray whale	+	+	+	+	+	+	+	+	+	+	+	+
Otariid	*Eumetopias jubatus*	Steller sea lion	*	*	ND	ND	+	ND	+	+	+	+	+	+
	Zalophus californianus	California sea lion	*	+	+	*	+	+	+	+	+	+	+	+
Phocid	*Mirounga angustirostris*	Northern elephant seal	ND	ND	ND	ND	ND	ND	ND	ND	+	+	+	+
	Phoca vitulina richardsii	Harbour seal	*	*	*	*	+	+	+	+	+	+	+	+
Mustelids	*Enhydra lutra*	Sea otter	ND	ND	ND	ND	+	+	ND	ND	+	+	ND	ND
	Lutra canadensis	River otter	+	+	+	+	+	+	+	+	+	+	+	+

Sp = spring, S = summer, W = winter, F = fall
+ = documented sightings (denotes MARES surveys)*
ND = no sightings or no survey effort

Additional interviews provided greater details on killer whale sightings, especially interviews with the Steveston whale watching operators, which operate from May to October inclusively. Killer whales (mainly J pod) and harbour seals were seen "regularly" during the period. Harbour seals (including pups) were regularly sighted in the Deltaport turning basin. J pod members circuited up through the Gulf Islands in spring and passed both Sandheads and the study area "regularly". Sightings of J pod in the Southern Strait of Georgia (up to June 14th 2004) were made April 30th, May 8th, May 14th, May 19-21st (52 individuals counted), June 5-9th and June 11th. Peak killer whale sightings in the southern Strait of Georgia were in July and August. In November it was stated that J pod moved south into Puget Sound. L pod typically joins J pod in the vicinity of the Gulf Islands/San Juan in mid June. In summer, salmon are thought to congregate in the area between the port and the ferry terminal. June 2004 witnessed unusual sightings of a humpback whale with calf (7-12 June) and also a great white shark (unconfirmed FOC sighting) in the Strait of Georgia. California sea lions peak in April and May (~350 individuals counted at Sandheads promontory), but leave by around the end of May. They were assumed to take advantage of the Fraser River's eulachon run. Steller sea lions were spotted less regularly and recently in lower numbers. A shelf ~0.5-1 km south of the ferry terminal is known to concentrate Dall's porpoises, as well as some harbour porpoises during the whale watching season.

3.4.5 Envirowest marine mammal sightings during bird surveys

Sightings of marine mammals were recorded during bird surveys undertaken by Envirowest as part of the Deltaport third berth project up to June 2004, around the Roberts Bank Container Port and on the west side of the ferry terminal. In particular these surveys provide additional information to boat-based surveys because they cover the inaccessible shallower areas of Roberts Bank. Only seven harbour seals were seen, one in September 2003 and December 2003, one in January 2004 and two in October and November 2003.

3.4.6 B.C. Cetacean Sightings Network

This database contains sightings of cetaceans made by the general public and boat operators. The data can be considered anecdotal as there is no correction weighting based on effort. Absolute conclusions about abundance and seasonality are therefore considered unwarranted. Nevertheless it can provide some indication of usage of the area by cetaceans, especially resident killer whales. Sighting data were included in seasonal occurrence of marine mammals in the area. In addition, BCCSN killer whale sighting data were analyzed from 2001 to May 2004. In total, 940 sightings were made of which 55 were thought to be transients and a minimum number of 521 were thought to be southern residents. Only one transient sighting was made in the Fraser River to Roberts Bank area, with one transient also seen in Active Pass. On >30 occasions non-transient killer whale sightings were made in the Fraser River to Roberts Bank area, with an additional 49 sightings around Active Pass. Most of these sightings were from May through September inclusively.

3.4.7 Summary

Southern resident killer whales are a small declining red listed population known to use both the proximate and local area for foraging. Use of the area appears seasonal with regular use through April to October, within which the heaviest period appears to be late summer (coinciding with the Fraser River salmon runs). The waters around Haro Strait are the most important foraging area overall. Transient killer whales are red listed and are known to occur locally in small numbers, taking seals at Sand Heads. While also red listed provincially, Steller sea lions and sea otters both have growing populations and the proximate area does not appear to be an important habitat for them. Neither species is considered at real risk from boat noise or boat collisions. Steller sea lions use the Southern Strait of Georgia from May through September, but Sand Heads is not considered a major haul-out.

Common dolphins, Pacific white-sided dolphins and Northern elephant seals are all abundant, designated not at risk and have zero or highly sporadic sightings in the Southern Strait of Georgia. All three species are not believed to be at risk from ship collisions and like other pinnipeds and odontocetes have auditory systems that are less likely to be affected by low frequency sound produced by ship traffic (Richardson *et al* 1995). The latter statement holds true for California sea lions, harbour seals, river otters and both species of porpoises. Harbour seals are the most abundant marine mammal in the proximate and local area and in the entire region. The population is increasing and is not considered at risk. California sea lions have a healthy breeding population and appear to move seasonally into the local area to take advantage of spring eulachon spawning aggregations. Harbour porpoises and Dall's porpoises also frequent the local area and may utilize an area just south of the Tsawwassen ferry terminal to forage. Harbour porpoises are thought to be under threat with their numbers declining. Dall's porpoises have a large regional population. The four species of baleen (mysticete) whales are most likely to be affected by ship strikes and noise pollution. Grey whales are frequent visitors to the Southern Strait of Georgia area, including Roberts bank and Boundary Bay, while sightings of fin and humpback whales are more often made offshore. There is concern for the populations for all three of these species. Minke whales are typically an abundant species, are considered not at risk, but little is known of their ecology. One false killer whale sometimes utilizes the proximate area, but this species is not considered at risk.

3.5 ECOLOGICAL PERSPECTIVE

An important step in the Marine Environment study program is the synthesis of the various habitat inventory components into an functional ecological assessment to identify the critical interrelationships that may be affected by the proposed development. The Roberts Bank study area, set on the outer edge of the Fraser River estuary, provides habitat for Pacific salmon and other fish species, as well as for commercially important invertebrates such as Dungeness crabs. It is also a staging area for millions of migratory birds using the Pacific Flyway during their northward breeding migration each spring and southward wintering migration each fall. The intertidal flats, salt marshes, eelgrass beds, and subtidal delta front are all critical components that support this diverse marine ecosystem. In completing the environmental assessment, taking an ecological perspective attempts to incorporate the interactions between physical, biological and human processes, including consideration of temporal and spatial factors (Figure 3.5.1-1).

Physical processes include the abiotic factors that create or influence the site (e.g., climate, fluvial processes, tides, chemical reactions, etc.). Biological processes encompass the living components including life stages/histories, food webs, and species/habitat interactions. Although physical processes can establish the conditions for biological communities, the two components can modify each other. For example, the Fraser deposits sediment on Roberts Bank creating mudflats, which are colonized by infauna and *Zostera*, however these biological communities can change the physical conditions by oxygenating sediments or promoting sediment accumulation and changing the initial sediment profile. As well, human processes can have positive and negative effects, but it is important to consider human activities as being necessary and part of the ecological assessment. In this way, habitat impacts as well as habitat mitigation and compensation can be more effectively determined and lead to more sustainable development. These interactions require consideration of temporal (length of time, seasonality) and spatial (site, local, off-site) scales.

As shown in Figure 3.5.1-1, an ecological perspective includes an understanding of the interactions between abiotic (physical) and biological (biotic) processes to determine ecological function followed by assessment of how the project design, construction and operational elements will affect or impact the these functions.

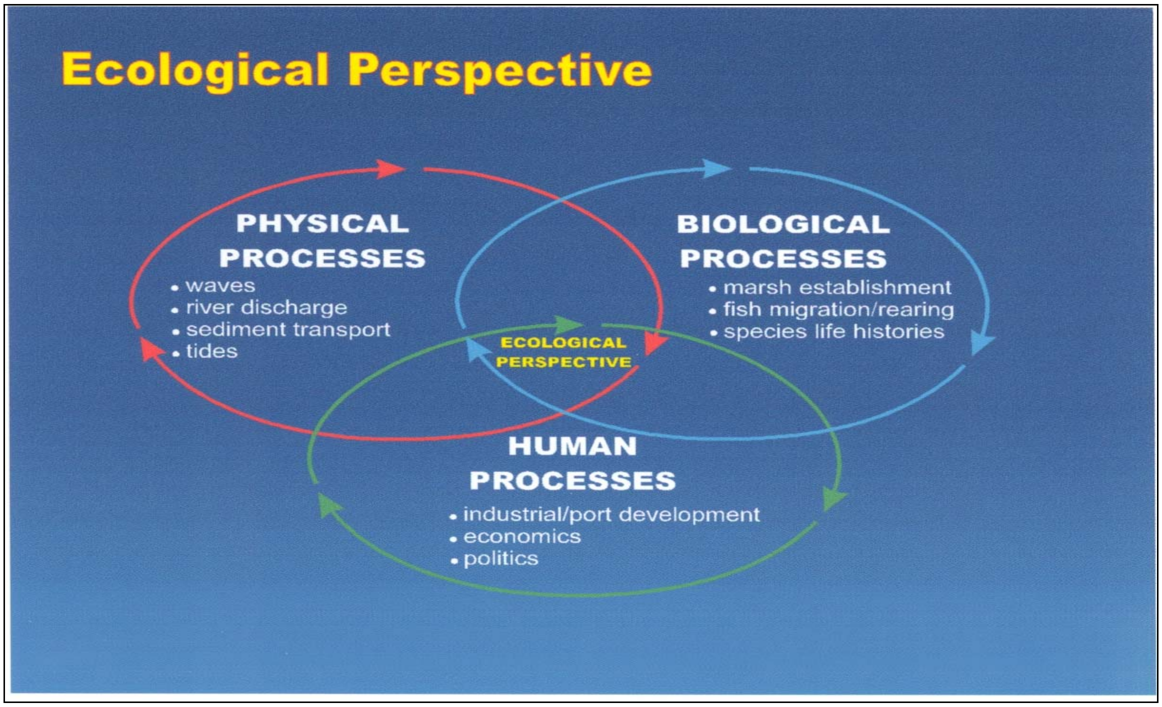

Figure 3.5.1-1. Schematic presentation of an ecological functions perspective. Figure modified from Williams and Colquhoun, 1991.

3.5.1 Physical processes

The ecological functions of the Roberts Bank area are strongly influenced by physical processes. These include processes with geological time scales, such as plate tectonics and glaciation, processes with annual time scales (e.g., Fraser River discharge and sediment transport), and processes with daily or weekly time scales (e.g., tides and currents). Although seismic processes are an important element in project design, it would appear that the dominant geological scale process is glaciation, which set the stage for the establishment of the Fraser River delta and Roberts Bank around 10,000 years ago. The advance of the estuary front post–glaciation is illustrated in Figure 3.5.1-2. The estuary has advanced from the vicinity of modern day New Westminster to its present location (20.3 km) over the past 10,000 years. This shows the steady advance of the estuary, driven by the transport of sediments by the Fraser River into the Strait of Georgia.

With the recession of the glaciers 10,000 years ago, Fraser River fluvial processes such as river discharge and sediment transport have substantially changed the landscape. Today the impact of the Fraser plume, shown at low tide, extends well beyond the Fraser delta, influencing the Gulf Islands, Burrard Inlet, Howe Sound, and US waters.

Figure 3.5.1-2. The Fraser estuary and Roberts Bank. Photo from NASA, public domain. *http://earth.ssc.nasa.gov/sseop/efs*

Development of the estuary by man, while providing economic and social benefits, has also affected the natural processes occurring on Roberts Bank. The construction of the coalport and BC Ferries causeways appears to have had significant effects on the estuarine/marine processes of the site. Most notably, it reduced any direct impact of the Fraser plume on the intercauseway area.

3.5.2 Functional Habitat Assessment

Marine habitats provide numerous ecological functions besides support for fish and wildlife. Ecosystem functions and values to human society for major habitats identified by the habitat assessment (eelgrass, salt marsh, mudflat, macroalgae beds/reefs, and backshore vegetation) are shown below (Table 3.5.2-1 adapted from Short *et al.* 2000). The table provides a list of ecosystem functions and associated values for each major habitat.

In addition to assessing the ecosystem values of the various habitats, it is important to illustrate the interconnectedness between them. For example, a salt marsh generates particulate and dissolved organic matter that is incorporated into the marsh or exported to mudflats, eelgrass beds and subtidal habitats. Infaunal organisms and epifaunal detritivores may use the particulate matter and epifloral organisms (e.g., microbes, diatoms), and microalgae or benthic algae may take up dissolved nutrients transported by tidal currents. A dense covering of macroalgae and eelgrass wrack on the mudflats and along the shores has been observed during these studies. The rip rap protection along the western bank of Deltaport was littered with stalks of bulrush, presumably from the Brunswick Point marsh. These connections are important in understanding relationships between habitats.

Simenstad and Wissmar (1985) used stable isotopes to follow the origin and fate of organic carbon in estuarine and nearshore marine food webs in Hood Canal in Puget Sound and found that eelgrass, epiphytes and macroalgae were the most important sources of organic carbon to primary and secondary consumers.

Marine organisms also use different habitats during their life cycles. For example Dungeness crabs mate from May to August in shallow waters following molting, eggs hatch in January-February from females buried in sand, larvae develop through several planktonic stages and settle in intertidal or shallow subtidal areas with vegetative, rock or shell cover (McConnaughey *et al*. 1992).

Salmonids may feed in the water column, salt marsh, eelgrass beds, over mudflats, or along macroalgae beds. Forage fish species, (e.g., sand lance), may seek out gravel or sand beaches for spawning but generally form schools in nearshore waters where they are preyed upon by numerous fishes and birds. Studies have shown that links between vegetated and non vegetated habitats are important. Diversity and abundance of fauna are greatest in the eelgrass beds, especially at low tide. Reefs are valuable adjacent to seagrass beds, especially important for juvenile fish (Grabowski 2001).

Inter-habitat and species-habitat relationships also require consideration of timing and spatial elements. Seasonal pulsing of nutrients does influence the life cycle of marine flora, which in turn links to the life cycle of grazer species. Fish and invertebrates have definite seasonal periods for spawning, mating, rearing, etc. Knowledge of these seasonal activities is required to determine construction schedules, mitigation measures and spatial configuration and positioning of the port infrastructure.

Table 3.5.2-1. Ecosystem functions and values to human society for major nearshore habitats identified in the project area (adapted from Short *et al*. 2000).

Function	Values	Eelgrass	Salt marsh	Mudflat	Macroalgae beds/reefs	Backshore Vegetation
Canopy structure	Habitat, refuge, nursery, settlement, and support of fisheries	High	Moderate		High	Moderate
Primary production	Food for herbivores & support for fisheries & wildlife	High	High	Moderate	High	Moderate
Epibenthic & benthic production	Support of food web & fisheries	High	Moderate	High	High	
Nutrient & contaminant filtration	Improved water quality & support of fisheries	Moderate	High	Low	Low	High
Sediment filtration and trapping	Improved water quality, counter sea level rise & support of fisheries	Moderate	High	Moderate	Low	High
Epiphyte & epifaunal substratum	Support of secondary production & fisheries	High	Moderate	Moderate	High	Epifaunal Moderate
Oxygen production	Improved water quality & support of fisheries	High	High	Low	Moderate	N/A
Organic production & export	Support of estuarine, offshore food webs, and fisheries	High	High	Low	Moderate	Low
Nutrient regeneration & recycling	Support of primary production & fisheries	Moderate	High	Moderate	Moderate	Moderate
Organic matter accumulation	Support of food webs	Moderate	High		Low	Low
Wave & current energy dampening	Prevents erosion/resuspension & increases sedimentation	Moderate	Moderate		Moderate, but largely confined to *Nereocystis* and *Macrocystis*	Low
Seed production and vegetative expansion	Self-maintenance of habitat & support of fisheries	High	High		High	
Self sustaining ecosystem	Recreation, education, & landscape level biodiversity	High	High	Moderate	High	High

In order to allow the reader to understand the habitat functions and interrelationships, we have presented them graphically in Figure 3.5.2-1. For example, energy flow diagrams show the physical relationships between riverine and coastal processes within estuaries while food webs show predator-prey connections between trophic levels. Table 3.5.2-2 summarizes the dominant physical influences and biotic features for a sand/mud flat typical of the Roberts Bank project area.

The environmental assessment documented in the following section considers the functional ecological inter-relationships in the context of the physical changes to the marine environment due to the proposed Deltaport project and within the scope of the study results presented in this chapter of our assessment report.

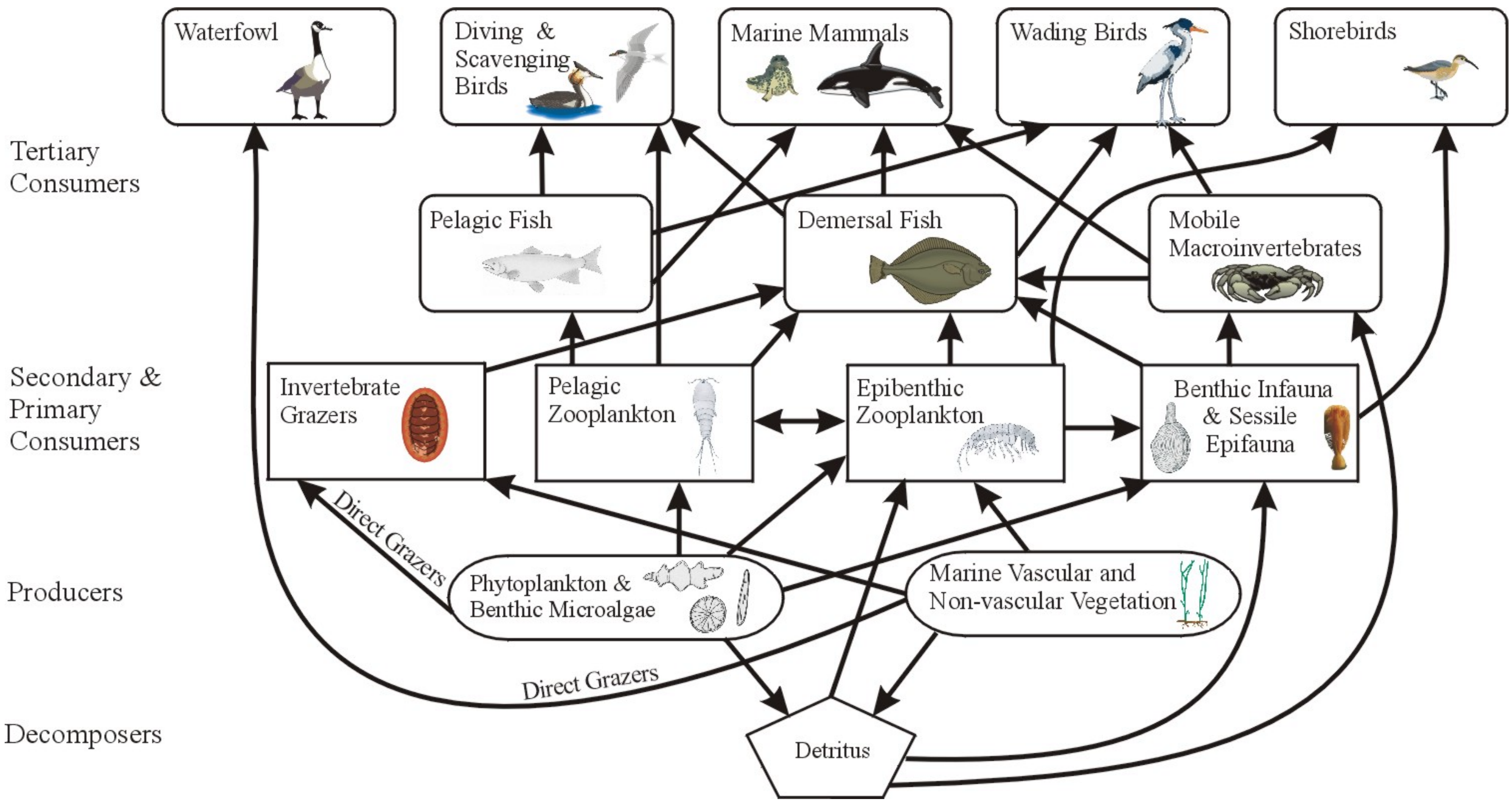

Figure 3.5.2-1. Conceptual marine food web for Roberts Bank (adapted from Simenstad 1983).

Table 3.5.2-2. Typical Components of a sand/mud flat community at Roberts Bank

Zone	Physical Attributes and processes	Flora	Invertebrates	Fishes	Mammals
Backshore	• Usually stable sediments • Occasional storm surge and flooding • Organic litter	• *Elymus (Leymus) mollis* (dunegrass) • *Ambrosia chamissonis* (silver burweed) • *Atriplex patula*	• Terrestrial insects	N/A	• River otter • Raccoon • Muskrat • Mice/voles/rats • Coyote • Marmot
Intertidal	• Depositional environment with sediments from Fraser River, particularly north of causeway • High degree of freshwater influence on the west side of Roberts Bank causeway • Sediments mobilized by storms and tidal currents	• *Salicornia virginica* • *Distichlis spicata* • Eelgrass (*Z. japonica* and *marina*) • *Enteromorpha* • *Ulva* • Diatom mats	• Polychaetes (sedentary and free living) • Ghost shrimp • Isopods • Gammarid amphipods • Macoma clams • Cockles • *Crangon* shrimps • Dungeness crab	• Juvenile pink, chum and chinook salmon • Starry flounders • Juvenile soles (rock and English) • Surf smelt • Sand lance • Three-spine sticklebacks • Shiner perch • Pricklebacks/gunnels • Staghorn sculpins • Pipefish	• Harbour seals • River otter • Muskrat
Subtidal	• Generally finer sediments, due to low wave energy but many deeper areas of Roberts Bank are current swept with fine sand sediment • Predominantly depositional sediments in dredge basins	• Eelgrass (*Z. marina*) • *Ulva* • Diatom mats	• Polychaetes • crabs • Nudibranchs • Sea pens • Isopods • Gammarid amphipods • Macoma clams • Pink sea star • Sunflower star • Spiny mud star (dredge basin) • Plumose anemone	• Starry flounders • Tubesnouts • Whitespotted greenlings • Sanddabs • English soles • Dover (lemon) soles • Spiny dogfish • Big skates • Eelpouts/pricklebacks (dredge basin)	• Harbour seals • Steller sea lions • Harbour porpoise • Dall porpoise • Orca • California sea lion • Grey whale