Technical Data Report

Roberts Bank Terminal 2 Project

Marine Fish

Eelgrass Fish Community Survey

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Prepared for: Hemmera
Suite 250 – 1380 Burrard Street
Vancouver, B.C., V6E 2H3

Prepared by: Archipelago Marine Research Ltd.
525 Head Street
Victoria, B.C., V9A 5S1 Canada
Telephone: +1 250 383 4535
Email: amr@archipelago.ca
Internet: www.archipelago.ca
Technical Report/Technical Data Report Disclaimer

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

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

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

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

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Executive Summary

The Eelgrass Fish Community Survey was conducted as part of the environmental field study program for the proposed Roberts Bank Terminal 2 Project (Project or RBT2), which focused on developing an understanding of existing conditions in the study area. The Project, part of Port Metro Vancouver’s Container Capacity Improvement Program, is a proposed new three-berth marine container terminal located at Roberts Bank in Delta, B.C.

Eelgrass beds are considered important fish habitat as many commercially and ecologically important fish species utilise eelgrass during part of their life cycle. Fish communities in eelgrass beds are usually more abundant and diverse than in surrounding un-vegetated habitats. Previous studies have characterised fish communities in a large eelgrass bed (Zostera marina) adjacent (north-northwest) to the existing Roberts Bank terminals. The purpose of this study is to provide additional site-specific, seasonal (i.e., spring, summer, winter and fall) baseline data on fish species’ abundance, distribution, and habitat use in the eelgrass beds, and to build upon previous studies in the area.

Fish sampling was conducted at five sites, with a beach seine, on the intertidal sandflat north-northwest of Roberts Bank terminals: four sites were located within the Z. marina eelgrass bed, and one reference site on the sandflat without eelgrass approximately 500 m northwest of the eelgrass bed. Fish sampling occurred seasonally over a one-year period (i.e., spring, summer and fall of 2012 and winter of 2013). Sampling also occurred at all sites during the RBT2 juvenile salmon distribution survey (a component of the Juvenile Salmon Surveys) in spring and summer of 2013.

A total of 6,067 individual fish were captured over the six sampling events: 1,640 fish during the Eelgrass Fish Community Survey and 4,427 fish during the juvenile salmon distribution survey. Many of the fish species caught, such as shiner perch (Cymatogaster aggregata), bay pipefish (Syngnathus leptorhyncus) and gunnel species, are commonly associated with eelgrass habitat. Juvenile fish comprised a large portion (> 50%) of the catch during all seasons, indicating the importance of eelgrass at Roberts Bank as rearing habitat. Overall, the fish catch was dominated by a few species that were caught in large numbers, namely surf smelt (Hypomesus pretiosus) in spring 2012 and 2013 and winter 2013, shiner perch in summer 2012 and 2013, and northern anchovy (Engraulis mordax) in fall 2012. The majority of species caught at Roberts Bank were less common or transient species that may only be utilising eelgrass habitat on a temporary or seasonal basis.

Abundance, species richness, species evenness, species diversity, and community assemblages were compared among seasons and habitat types. Community parameters were not compared between years because of the differences in the sampling gear used in the Eelgrass Fish Community Survey and juvenile salmon
distribution survey. For species caught in the highest abundances, comparisons of abundance and length among seasons and habitats were conducted.

Fish communities in the survey area at Roberts Bank differ across seasons. In both surveys, average abundance of all species of fish caught was similar between seasons. However, species richness (number of species) was significantly higher during the spring and summer, and fish diversity (an index calculated from the number of species in an area and their relative abundance) was significantly highest during the summer. In the 2012 Eelgrass Fish Community Survey, calculations of species’ evenness (i.e., relative abundance of species in an area) indicated that species were more evenly distributed in the summer season than in the spring, while for the 2013 juvenile salmon distribution survey, species evenness was similar between spring and summer at sites with eelgrass cover.

Different fish species make up the majority of the fish population in different seasons. Differences in community assemblages in the Eelgrass Fish Community Survey were mainly driven by large numbers of surf smelt caught during the spring and winter, and the higher diversity of fish in summer. The differences between community assemblages in the spring and summer seasons in the juvenile salmon distribution survey were due to the high abundance of surf smelt in the spring and shiner perch in the summer.

Results indicate that fish use of different habitats depended on the season. During spring and summer 2012, all habitats surveyed (i.e., patchy eelgrass, continuous eelgrass, and bare sandflat) were used equally by fish species. During the fall and winter, fish were only caught in habitats with eelgrass cover. In spring and summer 2013, significantly more fish species were caught in habitats with eelgrass than bare sand, and significantly more fish overall were caught in habitats with continuous eelgrass distribution. Calculations of species’ evenness from the Eelgrass Fish Community Survey indicated that distribution of species was similar between the different habitat types, however, for the juvenile salmon distribution survey, species evenness was significantly more evenly distributed in the summer at the bare sandflat site.

Community assemblages were similar between the different habitat types. However, some species, specifically shiner perch, threespine stickleback (*Gasterosteus aculeatus*), snake prickleback (*Lumpenus sagitta*), bay pipefish, tubesnouts (*Aulorhynchus flavidus*), and gunnel species showed greater association with the eelgrass habitat than bare sand habitat.

Results suggest fish presence and abundance can vary notably according to tidal cycle. More fish and species were caught on flood tidal states than ebb tidal states in summer and spring 2013 during the juvenile salmon distribution survey. Comparisons between fish community data from the summer (June) Eelgrass Fish Community Survey and a summer (August) survey conducted in the same
area in 2008 and in a similar manner by Martel (2009) identified significant variability in fish abundance and community composition.

To date (1979 to 2013), 57 fish species have been documented utilising eelgrass habitat as permanent or temporary residents at Roberts Bank. Many of these species caught at Roberts Bank have also been observed in eelgrass beds in other regions of B.C., despite the considerable differences in physical attributes of habitats between Roberts Bank (a large intertidal sandflat) and the other regions studied (some being coves and bays with rocky features). This suggests the importance specifically of eelgrass to the life history of these fish species.
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1 Introduction

This section provides project background information and an overview of the Eelgrass Fish Community Survey.

1.1 Project Background

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

Port Metro Vancouver (through Hemmera) has retained Archipelago Marine Research Ltd. to undertake marine fish and fish habitat studies to inform a future effects assessment for the Project. This technical data report describes the results of the Eelgrass Fish Community Survey.

1.2 Eelgrass Fish Community Survey Overview

The RBT2 Project may directly and/or indirectly affect the *Zostera marina* eelgrass bed, and associated fish communities, located adjacent (north-northwest) to the existing Roberts Bank terminals (Figure 1). Initially a review of available information and state of knowledge was completed as part of the Eelgrass Fish Community Survey to identify key data gaps and areas of uncertainty within the general RBT2 area. This technical data report describes the review findings and field study results for key components identified from this gap analysis. Study components, major objectives, and a brief overview are provided in Table 1.

The objectives of the Eelgrass Fish Community Survey were to document over a one-year period (spring 2012 to winter 2013) the seasonal presence, distribution, and abundance of fish communities within the eelgrass bed and sandflat adjacent to Roberts Bank terminals. In spring and summer 2013, additional sampling was conducted with similar objectives at the same sites as part of the juvenile salmon distribution survey (part of the Juvenile Salmon Surveys; AMR 2014). Though the focus of the juvenile salmon distribution survey was juvenile salmon species, data was also collected on other fish species caught in the eelgrass bed and sandflat habitats.
### Table 1. Eelgrass fish community survey components and major objectives.

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<th>Major Objective</th>
<th>Brief Overview</th>
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<tr>
<td>Review of available literature</td>
<td>Build a historical seasonal species list for fish that have been documented utilising eelgrass habitat at Roberts Bank.</td>
<td>Identify key papers from studies between 1979 and 2011 that include sampling of eelgrass habitat at Roberts Bank and extract seasonal fish distribution and abundance data.</td>
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| Eelgrass Fish Community Survey, (2012 to 2013) | Document the fish community seasonally within the intertidal portion of the Zostera marina bed adjacent to the existing Roberts Bank terminals. | Using beach seine methods, capture fish species at five sites north-northwest of Roberts Bank terminals: four sites in the Z. marina eelgrass bed with varying eelgrass cover and distribution, and one reference site in the sandflat with no eelgrass. Repeat sampling seasonally: spring – April 2012, summer – June 2012, fall – October 2012, and winter – January 2013). Identify differences in the following among habitat types and seasons:  
- Fish community assemblages;  
- Abundance (all species combined);  
- Species-specific abundance and size of species identified as the most abundant during some or all the seasons;  
- Species richness (the number of species);  
- Species evenness (relative abundance of each species in an area); and  
- Species diversity (index calculated from the number of species in an area and their relative abundance). |
| Integrate results from the juvenile salmon distribution survey (Juvenile Salmon Surveys; AMR 2014). | Analyse fish community data collected in spring and summer 2013 as part of the juvenile salmon distribution survey, from the same eelgrass and non-eelgrass habitat sites sampled during the Eelgrass Fish Community Survey. Since the net mesh size is different between the two studies, datasets to be analysed separately and compared qualitatively between the two years to provide information on seasonal distribution of species and relative use of habitats. Identify differences in the following among habitat types, seasons, and tidal states:  
- Fish community assemblages;  
- Abundance (all species combined);  
- Species-specific abundance and size of species identified as the most abundant during some or all the seasons;  
- Species richness (the number of species);  
- Species evenness; and  
- Species diversity. |
Table 1 continued. Eelgrass fish community survey components and major objectives.

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<th>Component</th>
<th>Major Objective</th>
<th>Brief Overview</th>
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<td>Eelgrass Fish Community Survey, (2012 to 2013) continued.</td>
<td>Characterisation of water quality at each beach seine site.</td>
<td>Collect water quality parameters including temperature, salinity, and dissolved oxygen at each location seasonally. Relate observed water quality parameters to fish results.</td>
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<td>Collect supplemental information on the eelgrass bed (e.g., eelgrass shoot measurements) at the fish sample sites to determine linkages between fish community and eelgrass characteristics.</td>
<td>Eelgrass shoot measurement data collected in April and June 2012 during the Eelgrass Fish Community Survey were provided for the Marine Vegetation Survey Technical Data Report. Eelgrass was not collected post summer 2012 due to high turbidity conditions and depth of water. Eelgrass cover and density characteristics from the Marine Vegetation Survey were not available yet for comparison to fish community results from this survey, so historical data was used.</td>
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<td>Integrate historical and 2012/2013 baseline data</td>
<td>Using historical and current baseline data identify eelgrass fish community species potentially affected by the RBT2 project.</td>
<td>Compare historical fish species occurrence in eelgrass habitat at Roberts Bank with species collected in the current baseline survey, particularly fish data collected in summer 2008 (Martel 2009) and summer 2012 at the same eelgrass sites with the same gear.</td>
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Review of Available Literature and Data

This section provides a review of available literature and data considered in the Eelgrass Fish Community Survey.

2.1 Eelgrass and Fish Communities

Eelgrasses (\textit{Zostera} spp.) are marine flowering plants, belonging to the larger polyphyletic group of seagrasses, which can grow in extensive beds within shallow coastal (marine or estuarine) habitats. Eelgrass beds grow predominantly in sand and mud, but may also be found in areas with gravel and cobble (Durance 2002, DFO 2009). Eelgrass beds grow in exposures varying from quiet bays to shores with moderate wave action (Durance 2002). There are two species of eelgrass in British Columbia; the native species \textit{Zostera marina} and the introduced species \textit{Z. japonica}. \textit{Z. marina} is typically a perennial species, while \textit{Z. japonica} is a small, annual or short-lived perennial (Durance 2002, 2004). The cover of \textit{Z. marina} eelgrass beds varies seasonally as shoot length and width increase in summer and decrease in winter (Durance 2002).

Eelgrass beds provide a variety of ecological services that assist in maintaining healthy estuarine and nearshore marine habitats (Costanza et al. 1997, Heck et al. 2003), and are important for many commercially and ecologically important fish species that utilise eelgrass during part of their life cycle (Levings et al. 1983, Wyllie-Echeverria and Ackerman 2003, Gillanders 2006). Seagrass beds have permanent fish residents, and temporary fish residents that utilise the beds for foraging or refuge from predation for only part of their lifecycle (Jackson et al. 2001, Gilllanders 2006). Permanent residents are often cryptic, small, and represent a small portion of overall fish abundance (Kikuchi 1974, Edgar and Shaw 1995, Jenkins et al. 1997, Lee and Lee 2003). The majority of commercially important species are temporary residents that use the beds during their juvenile stages (Jackson et al. 2001).

juveniles, and their increased growth and survival in seagrass habitats, suggests the importance of this type of habitat as a nursery ground. As body size increases the refuge effectiveness of seagrass declines, which may explain why juveniles of most commercially important species are only temporary residents (Jackson et al. 2001).


Predictors of fish abundance in seagrass habitats are spatially scale dependent. At the small spatial scale (centimetres to several metres), the structural components of seagrass such as shoot density, blade size, and biomass are important predictors of fish abundance (Adams 1976, Orth and Heck 1980, Bell and Westoby 1986, Murphy et al. 2000, Gillianders 2006). At larger spatial scales (metres to tens of metres), percent cover of seagrass, and the size, shapes, and orientation of seagrass patches, are more important in predicting abundance and species composition (Bell and Westoby 1986, McNeill and Fairweather 1993, Irlandi 1997, Eggleston et al. 1999, Tanner 2003, Gillianders 2006). Some fish species can benefit from more heterogeneous seagrass habitats where a mix of patchy and homogenous seagrass stands balances the costs and benefits of protection from predators and increasing visibility for successful foraging (Holt et al. 1983, Jackson et al. 2001). At the landscape scale (tens of metres to kilometres), degree of seagrass patchiness, seagrass patch isolation, water circulation patterns, temperature, salinity, depth, larval settlement patterns, geographical location within a bay/estuary, and adjacent habitat distance play important roles in determining fish abundance and diversity (Bell and Westoby 1986, Jenkins et al. 1997, Bell et al. 1998, Hannan and Williams 1998, Vallet al. 1999, Raposa and Oviatt 2000, Gillianders 2006). Fish abundance in seagrass habitats can also vary across large spatial scales (tens to hundreds of kilometres; Ferrell and Bell 1991, Goldberg et al. 2002, Robinson et al. 2011) due to factors such as larval supply and wave exposure (Worthington et al. 1992, Jenkins et al. 1998, Johnson et al. 2005, Gillianders 2006).

Temporal scale, including differences between day and night, tides, seasons, and years, may also influence fish abundance (Gillianders 2006). Several studies have reported greater abundances of fish in seagrass beds at night (Weinstein and
Heck 1979, Orth and Heck 1980, Olney and Boehlert 1988); however, in eelgrass habitat in Alaska no differences were observed in fish abundance, species richness, or diversity between diurnal and nocturnal sampling (Thedinga et al. 2011). Similarly, in Australian *Zostera* beds, there were no differences in fish assemblages between day and night (Gray et al. 1998). Semi-diurnal tides have been shown to affect the abundance of nekton (i.e., free swimming) fish species but not epibenthic (i.e., on sea floor) species (Sogard et al. 1989). A higher species richness and higher abundance of some species groups were observed at low tide compared to high tides in eelgrass beds in Clayoquot Sound in British Columbia (Yakimishyn et al. 2004); however, some shallow subtidal and intertidal seagrass beds may only be accessible to fish when they are inundated at high tides (Jackson et al. 2001).

There is significant seasonal variation in fish communities in eelgrass habitats, with greater abundances observed in the summer and fall compared to winter (Adams 1976, Orth and Heck 1980, Conlin et al. 1982, Gordon and Levings 1984, Johnson and Thedinga 2005). Seasonal differences are usually due to species specific spawning times and juvenile recruitment periods (Jackson et al. 2001, Gillianders 2006). Interannual variation in fish abundance may be caused by changes in weather patterns (El Niño vs. La Niña), freshwater input, or coastal upwelling that can affect eelgrass habitat and larval recruitment (Jenkins et al. 1997, Thom et al. 2003). Long-term fish data sets in eelgrass habitats are limited; however, in a multiyear study in British Columbia, Robinson and Yakimishyn (2013) found that fish assemblages in eelgrass meadows can persist and be stable in abundance for at least a five-year period even with large interannual variation in oceanic conditions. A decade long Australian survey of fish assemblages in an estuary with *Zostera* sp. habitat found that fish assemblage structure over time remained stable, despite considerable interannual variability in individual species abundance likely due to recruitment success (Jackson and Jones 1999). Fish assemblages studied over a 14-year period in eelgrass habitat in Newfoundland were found to have less variability, more predictable cyclical seasonal transitions, and lower inter-annual changes in community structure compared to un-vegetated habitats, demonstrating that fish community dynamics are more stable and resilient in eelgrass habitats (Cote et al. 2013).

Seagrass is vulnerable to effects from coastal development, water pollution, and physical habitat disturbance (Short and Wyllie-Echeverria 1996, Duffy 2006, Orth et al. 2006). Declines of eelgrass and other seagrass populations have been observed worldwide, with declines accelerating in recent decades (Orth et al. 2006, DFO 2009, Waycott et al. 2009, Costello and Kenworthy 2011, Gabecke et al. 2011). There has been little quantification of the impacts of seagrass habitat loss on fisheries (Beck et al. 2001), although some fish and invertebrate species associated with *Zostera* habitat such as flounder, cod, and scallops are in decline (Moore and Short 2006).
2.2 Roberts Bank Regional Studies

Extensive eelgrass habitat is present in the intertidal and shallow subtidal on the north and south sides of Roberts Bank terminals (Harrison and Dunn 2004, Triton 2004). The introduced species of eelgrass *Z. japonica* dominates the higher intertidal (+3.5 m to +1.4 m CD) while *Z. marina* is mainly found in the lower intertidal and shallow subtidal (+1.5 m to -3.0 m CD) with a narrow transition zone where the two species mix (Triton 2004).

Seventy-eight species of fish, including marine, anadromous, and freshwater species, have been documented to use the Fraser River estuary for part of their life cycle (Naito 2004). Roberts Bank has a more diverse fish community with more species than Sturgeon Bank, which may be attributed to the increased habitat complexity of Roberts Bank, including the presence of eelgrass beds (Gordon and Levings 1984).

Table 2 provides a summary of fish studies conducted in the eelgrass beds of Roberts Bank between 1979 and 2008. Fish use, by adults and juveniles, of the eelgrass beds at Roberts Bank has been documented in studies from the late 1970s and the 1980s (Table 2; Greer et al. 1980, Conlin et al. 1982, Gordon and Levings 1984, MacDonald 1984). Studies completed before 1983 were conducted prior to the expansion of Roberts Bank Port facilities on Pods 3 and 4¹ (Hemmera 2004, Figure 3) and expansion of the BC Ferry Terminal. Earlier studies focused on fish distribution between larger regions (i.e., Sturgeon Bank versus Roberts Bank) while later studies focused on seasonal change and habitat use at smaller spatial scales. More recent surveys of eelgrass beds at Roberts Bank were conducted for the Deltaport Third Berth Environmental Assessment (Triton 2004) and RBT2 baseline studies (Martel 2009). These recent surveys targeted the eelgrass bed adjacent to the existing Roberts Bank terminals. A fish species list compiled from the literature for this report and detailing seasonal use of the eelgrass beds near Roberts Bank terminals includes 55 fish species observed from 1979 to 2011 (Table 3).

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¹ Roberts Bank Port facilities Pods 3 and 4 were constructed during 1981 – 84 construction activities but they remained vacant until the 1990’s (developed between 1994 and 2000) (Hemmera 2004).
3 Methods

Descriptions of the spatial and temporal scope of the Eelgrass Fish Community Survey, plus study methods are provided below.

3.1 Study Area

The study area encompasses the Roberts Bank delta and includes the *Z. marina* eelgrass bed and sandflat north-northwest of Roberts Bank terminals (Figure 1). The study area was determined based on the need to sample areas with varying cover and distribution of *Z. marina*, as well as an adjacent reference area with no eelgrass present, both within the immediate vicinity of the proposed RBT2 footprint.

3.2 Sampling Locations

Fish sampling was conducted at five sites: four sites (EG1 to EG4) were located within the *Z. marina* eelgrass bed, and the reference site (EG5\(^2\)) was located on the sandflat approximately 500 m northwest of the eelgrass bed (Figure 1). Sites EG1 to EG4 were first sampled in the spring (April) of 2012 and in all subsequent seasons. Site EG5 was added in the summer (June) 2012 survey in order to compare sites within the eelgrass bed to a site without eelgrass. All five sites were sampled in the fall (October) 2012, and winter (January) 2013 for the Eelgrass Fish Community Survey, and in the spring (April) 2013 and summer (June) 2013 as a component of the juvenile salmon distribution survey. Eelgrass sites were chosen to overlap with sites previously surveyed in 2003 (Triton 2004) and 2008 (Martel 2009), and represent varying levels of *Z. marina* cover and distribution (i.e., continuous versus patchy) (Table 4). EG2 and EG4 were previously sampled from a boat using a 10 m beach seine in 2008 (Martel 2009), and EG1 and EG3 were previously sampled by beam trawl in 2003 (Triton 2004). The same sampling gear and methods used by Martel (2009) were used for the Eelgrass Fish Community Survey to build another year of comparable baseline data. The 2013 spring and summer juvenile salmon distribution survey which also sampled at these sites was conducted with a longer beach seine (20 m) with larger mesh size (6 mm). The larger net was chosen to allow comparisons between previous sampling conducted with this gear in 2012 and winter 2013 as part of the Juvenile Salmon Surveys (juvenile salmon beach seine survey).

3.3 Temporal Scope

The sites were sampled in spring, summer, fall and winter between April 2012 and January 2013. This scope was determined based on the literature that shows seasonal variation in fish presence within eelgrass beds (Adams 1976, Orth and Heck 1980, Conlin et al. 1982, Gordon and Leavings 1984, Johnson and Thedinga 2005).

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\(^2\) Site EG5 is referred to as site SF2 in the Juvenile Salmon Surveys TDR.
In the literature, the seasons were defined as follows (Triton 2004):
- Spring: March 1 to May 31;
- Summer: June 1 to August 31;
- Fall: September 1 to November 30; and
- Winter: December 1 to February 28.

Sampling periods for the Eelgrass Fish Community Survey were chosen to fall within each defined seasonal period, with consideration of the considerable temporal variability encompassed within each season.

As part of the juvenile salmon distribution survey, sites were again sampled in spring (April 2013) and summer (June 2013), and the fish community results are included in this report.

3.4 Study Methods

3.4.1 Equipment and Timing

During the Eelgrass Fish Community Survey, a 10 m long by 3 m deep beach seine net with a mesh size of 3 mm was used to collect data on fish species in the daytime on:
- April 23 to 24, 2012;
- June 21 to 22, 2012;
- October 22 to 25, 2012; and
- January 17 to 18, 2013.

During the juvenile salmon distribution survey, a 20 m long by 2 m deep beach seine net with a mesh size of 6 mm was used to collect fish species at the same five sites (EG1 to EG5). Sampling was also carried out during the daytime, with specific dates as follows:
- April 23 to 26, 2013; and
- June 20 to 23, 2013.

3.4.2 Capture Methods and Fish and Site Sampling Data

Beach seines were deployed from a boat at tides low enough for the net to touch the seabed. Three sets (replicates) were conducted per site per sampling period. For each replicate set, the net was deployed from the boat, walked around the site, brought back to the boat, and hauled onboard (Appendix A: Photos 1 to 4). Replicate sets were carried out approximately 15 minutes apart, at locations adjacent and slightly overlapping to one another, but still within the same habitat type and during the same tidal state. A skiff was used to mobilise the net around the site from the larger boat when tides were not low enough (fall and winter) or wind-driven waves created conditions not suitable for on-foot deployment (Appendix A: Photos 5 and 6). The area sampled with the skiff was similar to the area sampled on foot, with the only difference being that the net was set at a faster rate. Total area seined during each set with the 10 m beach
seine net was approximately 60 m², while the area covered by the 20 m net was approximately 220 m². The catch was transferred immediately to aerated containers (one per set). Photographs showing representative fish species caught are in Appendix A: Photos 7 to 20.

In spring 2012, summer 2012, and winter 2013 sampling, the eelgrass sites were fished only on ebb tides. In the fall 2012 survey, four of the five sites (EG2 to EG5) were sampled on both flood and ebb tides to determine if there was a difference in the abundance and diversity of fish caught during the different tidal periods. In the fall, due to tide height restrictions, EG1 could not be seined on both flood and ebb tides. In spring and summer 2013, all sites were sampled on both flood and ebb tides. All eelgrass sites (EG1 to EG4) were sampled within 3.5 hours of low tide. Due to a higher elevation at EG5, the site was always sampled within 5 hours of low tide, but 54% of the time was sampled within 3.5 hours.

Detailed information collected for each set included the following:

- Date, time fished and site location (dGPS);
- Water temperature (°C), salinity (ppt), and dissolved oxygen (DO) (mg/L) measurements using a YSI Professional Plus handheld multiparameter meter;
- Water depth (m) at time of sample;
- Digital photos and photo numbers;
- Presence/absence of invertebrates incidentally caught; and
- For all fish:
  - Identification to the lowest taxonomic level (typically species) and stage (adult/juvenile);
  - Enumeration; and
  - Measurement (mm; fork length or total length) and weight (g) (a subsample of 30 fish per species if the fish count for a particular species exceeded 30). In spring and summer 2013 only salmon species were measured and weighed.

Fish were held in aerated buckets until the completion of all replicate sets for a given survey site and released following identification, enumeration, measurement, and weighing. All data were recorded on waterproof data sheets. Digital photos were downloaded daily and labelled by site and date. Site location data was collected on a hand-held WASS enabled GPS and downloaded daily and plotted to check for errors. Data from the field sheets were transcribed into Excel tables.

3.4.3 Data Quality Assurance and Quality Control

The following measures ensured data were collected, stored and processed in a consistent and rigorous manner:

- Pre-field meeting with all team members to review sampling protocol and data collection methodologies;
Daily download of digital photos labelled by site and date, geo-referenced site location data and water quality data from instruments to field laptop by field crew;
Daily review of hard copy field sheet information by field crew lead; and
Post-field debrief with discipline lead to review data prior to entry from hard copy field sheet to electronic format (i.e., post data entry quality check).

3.5 Data Analysis
All univariate analysis was completed using statistical computing software R (R Development Core Team 2013). Differences were considered to be significant if \( p < 0.05 \). Model selection in R was undertaken using Akaike Information Criteria (AIC) and a likelihood ratio test to determine best-fit models.

PRIMER was used to conduct a multivariate analysis of the eelgrass fish community assemblages. PRIMER is applicable for interpretation of data on community structure and uses the abundance values for species sampled to examine the biological relationships between the samples (Clarke and Warwick 2001, Murray et al. 2006). PRIMER analysis included zero-adjusting the data in a Bray-Curtis similarity matrix to account for the large number of samples where no fish were caught. Relationships between the samples are illustrated in scatter plot diagrams from the multidimensional analysis (MDS). An analysis of similarity (ANOSIM) within PRIMER was used to test for differences between groups of samples for each factor, using the R value. R values of 1 indicate maximum separation between groups, whereas low values of R (i.e., near to zero) occur when there is little to no separation or clustering between samples (Clarke and Warwick 2001). The significance level of the R value is also reported in ANOSIM, and is equivalent to the \( p \) statistic, where a significance value of 0.1% for the R value is equivalent to a \( p \)-value of 0.001. A similarity of percentages analysis (SIMPER) was used to identify the species which contributed the most to the within-group similarity. Species which contribute the greatest proportions can be considered indicators for the group. Pairwise comparisons between different factors were further used to identify which species accounted for differences and similarities between groups.

Three separate data sets were used for analysis:

- Beach seine data collected at sites EG1 to EG5 during the Eelgrass Fish Community Survey from spring 2012 to winter 2013;
- Beach seine data collected at sites EG1 to EG5 during the juvenile salmon distribution survey from spring to summer 2013; and
- Beach seine data collected at sites EG2 and EG4 during summer 2008 as part of the Martel (2009) survey and summer 2012 data collected during the Eelgrass Fish Community Survey.
The Eelgrass Fish Community Survey and juvenile salmon distribution survey were analysed separately due to the longer beach seine net with larger mesh size used in spring and summer 2013. A larger net may increase the abundance of fish caught due to a larger area covered during seining, and some juvenile fish may not have been captured with the larger mesh size.

The dependent variables of interest in each of these data sets included:

- **Abundance of all fish caught**: Fish were enumerated from each replicate set, which was the lowest unit of comparison. For abundant fish species, separate species-specific comparisons of abundance were made. Differences in abundance were analysed based on the below-listed factors using a generalised linear model (GLM) with a negative-binomial distribution;

- **Fish species richness (number of species)**: The number of fish species caught was enumerated from each replicate set, which was the lowest unit of comparison. Differences in species richness were analysed based on the below-listed factors using a generalised linear model (GLM) with a Poisson distribution or negative binomial distribution;

- **Fish species evenness (measure of the relative abundance of each species in an area)**: Species evenness was calculated for each set using Pielou’s Evenness with values closer to one indicating a very even distribution of abundances among species. Differences in species evenness were analysed based on the below-listed factors using an Analysis of Variance (ANOVA) test. When data were not normal or exhibited heteroscedasticity, data were first transformed;

- **Fish species diversity (index calculated from the number of species in each set and their relative abundance)**: Species diversity was measured using the Shannon-Wiener Index with higher values indicating higher species diversity. Differences in species diversity were analysed based on the below-listed factors using an ANOVA test. When data were not normal or exhibited heteroscedasticity, data were first transformed;

- **Fish community assemblages**: Differences in community assemblages were compared based on the below-listed factors using MDS, ANOSIM, and SIMPER routines in PRIMER; and

- **Fish size**: For abundant fish species, separate species-specific comparisons of length (fork or total length depending on species) were made. Differences in length were analysed based on the below-listed factors using an ANOVA test. When data were not normally distributed or variances were unequal, data were first transformed (mathematical function applied to each data point). If this was not successful, data was analysed using a non-parametric Kruskal-Wallis test.

The following factors were considered for each of the above analyses:

- **Season**: Spring, summer, fall or winter;
- **Habitat type**: Continuous eelgrass (EG3 and EG4), patchy eelgrass (EG1 and EG2), and sandflat (EG5);
- **Tide**: Flood and ebb (for juvenile salmon distribution survey data only); and
- **Year**: For sites EG2 and EG4 from Martel (2009) and Eelgrass Fish Community Survey summer data.

Frequency of occurrence (FO) was calculated for all fish species caught in 2012 and 2013 for eelgrass sites only. The FO represents the number of replicate seine hauls in which a species was captured divided by the total number of replicate seine hauls multiplied by 100.

Water quality parameters (temperature, salinity, and dissolved oxygen) were also compared among the different years, seasons, habitat types, and tidal states (juvenile salmon distribution survey only) using ANOVA.
4 Results

The results of the Eelgrass Fish Community Survey are presented below.

4.1 Study Results

4.1.1 Overview

During the Eelgrass Fish Community Survey, 1,640 fish representing 21 species\(^3\) were caught across all sites and seasons in 57 seine hauls (Table 5). During the juvenile salmon distribution survey, 4,427 fish representing 24 species\(^4\) were caught in 60 seine hauls (Table 6).

Major species groups represented in the catch from the surveys included:

- Juvenile salmon;
- Forage fish;
- Perch;
- Stickleback;
- Flatfish; and
- Sculpin.

For each of the six seasonal sampling events, abundance is displayed for individual species and species groupings (Figure 2 to Figure 5).

Forage fish were commonly caught in all Eelgrass Fish Community Survey seasonal sampling events, except in summer (Figure 2). Surf smelt (*Hypomesus pretiosus*) was the main forage fish species caught in the spring and winter, while northern anchovy (*Engraulis mordax*) was the most abundant species caught in the fall (Figure 3). Other forage fish species caught included Pacific sand lance (*Ammodytes hexapterus*) in the spring and a few individuals in the summer, and one Pacific herring (*Clupea pallasi*) in the summer. In spring and summer 2013 (juvenile salmon distribution survey), forage fish dominated the catch in the spring (Figure 4), and were mainly surf smelt (Figure 5).

In summer 2012 (Eelgrass Fish Community Survey), more fish species were caught than other seasons sampled, with shiner perch (*Cymatogaster aggregata*) and threespine stickleback (*Gasterosteus aculeatus*) comprising a large portion of the catch (Figure 2). Similarly, in summer 2013, shiner perch and threespine stickleback were the most abundant species (Figure 4). Juvenile salmon (chum salmon (*Oncorhynchus keta*) and chinook salmon (*O. tshawytscha*)) were caught only in the spring and summer in 2012 and 2013.

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\(^3\) Out of the 21 species caught between April 2012 and January 2013, 18 were identified to species while three were unidentified (one salmonid species, one prickleback species, and one larval fish). It is possible that the three unknown species may have already been represented within the 18 known species.

\(^4\) For April and June 2013 sampling, two of the 24 species caught were unidentified (one unidentified snailfish and one unidentified flatfish). No other snailfish species were caught during this survey; however, the unidentified flatfish may be represented within the 22 known species.
For all six sampling events (four Eelgrass Fish Community Survey events and two juvenile salmon distribution survey events) between spring 2012 and summer 2013, the most abundant species caught across all sites and seasons were surf smelt (66% of total catch) and shiner perch (22%), followed by threespine stickleback (3%), northern anchovy (2%), Pacific snake prickleback (*Lumpenus sagitta*; 2%), juvenile chinook salmon (1%), Pacific sand lance (1%), and Pacific herring (1%). All of the most abundant fish caught were schooling species with the exception of Pacific snake prickleback.

The frequency of occurrence (FO) was low (< 25%) for the majority of species (81%) (Table 7). Only four species were present in more than 25% of catches, and they included surf smelt (FO = 52%), shiner perch (FO = 32%), threespine stickleback (FO = 31%), and chinook salmon (FO = 30%). Species observed in all seasons during this survey included surf smelt and bay pipefish (*Syngnathus leptorhyncus*). All species caught in the six sampling events were observed in the eelgrass bed, except arrow goby (*Clevelandia ios*), which was only observed in the reference sandflat (EG5) but in low numbers (n = 2). Over the six sampling events, 11 species were captured at the sandflat site and included juvenile chinook salmon, threespine stickleback, surf smelt, Pacific sand lance, Pacific staghorn sculpin (*Leptocottus armatus*), arrow goby, Pacific snake prickleback, shiner perch, starry flounder (*Platichthys stellatus*), sand sole (*Psettichthys melanostictus*), and English sole (*Parophrys vetulus*).

Invertebrates that were incidentally captured in the beach seine over the whole sampling period include crangon shrimp (*Crangon* spp.), Dungeness crab (*Metacarcinus magister*), kelp isopod (*Idotea* sp.), unidentified isopods and gammarid amphipods, euphausiids, sea gooseberries (*Pleurobrachia bachei*), unidentified jellyfish, and unidentified snail species.

### 4.1.2 Water Quality Parameters

The water quality data for the six sampling events between spring 2012 and summer 2013 are summarised in Table 8.

Water temperatures ranged from 9.6 to 12.8°C in spring 2012; 14.9 to 17.5°C in summer 2012; 8.7 to 9.7°C in fall 2012; 4.3 to 5.9°C in winter 2013; 10.3 to 14.8°C in spring 2013; and 13.9 to 18.4°C in summer 2013. Water temperature at the sites was similar between seasons sampled in different years (on ebbing tidal states in spring and summer; Table 9), and so were pooled. On ebbing tidal states, water temperature was significantly different between all the seasons (Table 10), with summer being the warmest (16.3°C ± 0.4 SE), followed by spring (11.6°C ± 0.5 SE), fall (9.0°C ± 0.2 SE), and winter (5.2°C ± 0.3 SE). Water temperature was not significantly different between different habitat types (Table 10). When different tidal states were sampled during the juvenile salmon distribution survey, there was no significant difference between water temperatures on flood and ebb tidal states (Table 11).
Salinity ranged from 17.4 to 22.1 parts-per-thousand (ppt) in spring 2012; 3.0 to 19.3 ppt in summer 2012; 14.0 to 28.5 ppt in fall 2012; 21.3 to 28.0 ppt in winter 2013; 16.5 to 25.6 ppt in spring 2013; and 3.2 to 18.1 ppt in summer 2013. Salinity was also similar between the same seasons in different years and so were pooled (ebb tidal states only; Table 9). Salinity was significantly different between seasons (Table 10), with lowest salinity during the summer (11.7 ppt ± 1.7 SE) and highest in fall and winter (both seasons salinity averages were 24.3 ppt). Salinity was also different between habitat types in all seasons with higher salinity in sites with eelgrass cover, than the reference sand site (Table 10). When water salinity was compared between tidal states sampled during the juvenile salmon distribution survey, salinity at different tidal states was dependent on season and habitat type sampled and no clear trend was present (Table 11).

Dissolved oxygen in the water ranged from 7.7 to 9.8 mg/L in spring 2012; 6.6 to 7.7 mg/L in summer 2012; 7.2 to 9.1 mg/L in fall 2012; and 9.6 to 10.8 mg/L in winter 2013. Due to equipment malfunction, dissolved oxygen measurements were not obtained in spring or summer 2013. Dissolved oxygen differed significantly by season (Table 10), being highest in winter (10.3 mg/L ± 0.3 SE) and lowest in summer (7.3 mg/L ± 0.2 SE), with no difference between spring and fall measurements (average between 8.0 to 8.3 mg/L). This is an expected result as the concentration of dissolved oxygen is inversely related to temperature of the water.

4.1.3 Comparison of Habitat Type and Season – Eelgrass Fish Community Survey

All data included in this analysis is for ebb tides only. During the fall 2012 sampling period, sites EG2 to EG5 were also sampled on a flooding tide; however, only five bay pipefish were caught, four from EG2 and one from EG3. Due to the low numbers of fish caught on both flood and ebb tides in fall 2012, the effect of tide on catch could not be compared.

The reference (sandflat) site (EG5) was not sampled in spring 2012 so analyses involving fish parameters measured at this site include summer, fall, and winter data only.

No significant difference in the abundance of fish caught between seasons or habitat types (i.e., continuous eelgrass distribution, patchy eelgrass distribution, and sandflat with no eelgrass) was observed (Figure 6; Table 12).

For species richness, there was a significant interaction between habitat type and season (Figure 6; Table 12). The interaction implies that fish species richness in different habitat types was dependent on season. In the spring and summer, species richness was higher than fall and winter, and the number of species caught was similar between different habitat types. In fall and winter, the number of species caught varied between habitats, largely due to no fish being
caught in patchy eelgrass habitats in winter, and no fish caught at the reference sandflat habitat in both fall and winter.

Due to the low abundance and species richness of fish collected in fall 2012 and winter 2013, evenness scores could not be calculated for the majority of beach seine sets in these seasons, so they were excluded from the analyses of evenness. Evenness scores were similar between different habitat types, but were significantly higher in summer than spring (Figure 6; Table 13), which indicates that species present during the summer were more evenly distributed than those in the spring.

There was no significant difference in fish diversity between habitat types but there was between seasons, with diversity higher in the summer than the other seasons (Figure 6; Table 13).

No significant differences were observed when comparing community assemblages among habitat type (Figure 7; ANOSIM; R = -0.071, p = 0.987); however, significant seasonal differences in community assemblage were observed (Figure 7; ANOSIM; R = 0.326, p = 0.001). All seasonal sampling events differed from each other in terms of community assemblage, except fall 2012 and winter 2013, which had few fish caught (ANOSIM pairwise test; R = 0.01, p = 0.242). Differences in community assemblage between seasons are likely due to the large numbers of surf smelt caught in the spring and winter, and the higher diversity of fish in summer (Table 14; SIMPER).

4.1.4 Comparison of Habitat Type, Season & Tidal State – Juvenile Salmon Distribution Survey

There was no difference in abundance of fish caught between the spring and summer seasons but, in both seasons, more fish were caught in the continuous eelgrass sites than the patchy eelgrass or sandflat sites (Figure 8; Table 15), and more fish were caught on a flooding tide than an ebbing tide (Figure 9; Table 15).

Species richness was not different between spring and summer, but significantly more fish species were caught at sites with eelgrass cover than at the bare sandflat site (Figure 8; Table 15), and on a flooding tide than an ebbing tide (Figure 9; Table 15).

For species evenness, there was a significant interaction between habitat type and season (Figure 8; Table 16). Species evenness was similar between the spring and summer seasons at the continuous and patchy eelgrass distribution sites, but more evenly distributed at the sandflat site in the summer compared to spring. There were no significant differences in evenness scores between different tidal states (Figure 9; Table 16).

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5 The three-way interaction was significant between season, habitat type, and tide but due to the limited sample size and high variability of the data, this interaction overparameterised the model and it was not possible to interpret. Therefore the model was further simplified to two-way interactions, of which none were significant.
The diversity index was not different between tidal states or habitat types during both seasons, but was significantly higher in summer than spring (Figure 8 and Figure 9; Table 16).

No significant differences in community assemblages were observed between different tidal states (Figure 10; ANOSIM; R = -0.001, p = 0.416) or habitat types (Figure 10; ANOSIM; R = 0.075, p = 0.019); however, significant differences were observed by season (Figure 10; ANOSIM; R = 0.451, p = 0.001). This seasonal difference is largely driven by the presence of surf smelt in the spring and shiner perch in the summer (Table 17; SIMPER).

4.1.5 Species Comparisons for All Sampling Events

Individual analyses for each of the most abundant fish species caught between spring 2012 and summer 2013, including surf smelt, shiner perch, chinook salmon, threespine stickleback, northern anchovy, snake prickleback, Pacific sand lance, and Pacific herring, are provided below. Abundance of each species was compared between the different seasons and habitat types, providing a sufficient number of fish were caught for the statistical analysis to be conducted. For comparisons of fish size between different seasons, the low abundance of individuals of each species at each site prohibited comparisons between habitat types or sites; therefore, data from all sites were combined to provide larger sample sizes and only seasonal differences were compared. Length frequencies were compared with available length-at-age data for each species to determine the potential age composition of the catch. Only salmon species were measured in spring and summer 2013, so comparisons of the size of non-salmonid species caught during these sampling events was not possible.

4.1.5.1 Surf Smelt

In the Eelgrass Fish Community Survey, surf smelt were the most abundant in spring 2012 and winter 2013, but were absent in summer 2012 (Table 18). In the juvenile salmon distribution survey, surf smelt was significantly more abundant in spring than summer (Table 18). There was no difference in the abundance of surf smelt caught in different habitat types during the Eelgrass Fish Community Survey or the juvenile salmon distribution survey (Table 18). Surf smelt had the highest FO in spring (Table 7; spring 2012, FO = 92%; spring 2013, FO = 92%).

Surf smelt larval stages are usually smaller than 40 mm, while juveniles are less than 90 mm (Froese and Pauly 2011, Love 2011). In spring 2012, the majority of surf smelt ranged between 15 and 32 mm fork length with some individuals measuring between 45 and 82 mm (Figure 11). The few surf smelt collected in fall 2012 ranged between 28 and 57 mm fork length, while in the winter 2013 surf smelt were between 44 and 65 mm fork length. The majority of surf smelt caught in spring and fall 2012 were still in the larval stage. All other surf smelt caught and measured were still juveniles and had likely not reached maturity.
Surf smelt collected in spring 2012 were significantly smaller (32 mm ± 1.7 SE) than fish caught in fall 2012 (41 mm ± 4.1 SE) and winter 2013 (53 mm ± 0.9 SE) (Figure 12; Table 19). Surf smelt were significantly larger in continuous eelgrass habitats (42 mm ± 1.9 SE) than patchy eelgrass (31 mm ± 1.7 SE) (Figure 13; Table 19). No surf smelt were caught in the sandflat habitat during the Eelgrass Fish Community Survey.

4.1.5.2 Shiner Perch

Shiner perch were only caught in spring (2013) and summer (2012 and 2013), and were more abundant in summer than spring in 2013 (Table 18). The highest FO for shiner perch also occurred in summer, with FO values of 58% (2012) and 88% (2013) (Table 7). In summer 2012, there were no significant difference in abundance between habitats, which is likely due to small sample size and high variability, as shiner perch were caught at the two eelgrass habitat types but not the sandflat site (Table 18). In spring and summer 2013, significantly more shiner perch were caught in continuous eelgrass habitats than in patchy eelgrass or sandflat habitats (Table 18). Since measurements on shiner perch were only made in summer 2012 and the majority (79%) of the catch in 2012 was from one site, length comparisons between habitat type and seasons was not possible. The average length of shiner perch caught in summer 2012 was 96 mm (± 3.3 SE) with the majority ranging from 74 mm to 120 mm (Figure 14). The majority of shiner perch > 40 mm caught in summer 2012 were likely adults (Love 2011), while those less than 40 mm may not have been mature.

4.1.5.3 Chinook Salmon

Chinook salmon were captured in spring (2012 and 2013) and summer (2012 and 2013). There was no significant difference in abundance of chinook salmon between spring and summer seasons in 2012 or 2013 (Table 18) and the FO was similar between spring and summer in both years (Table 7). There was a significant difference in abundance of chinook salmon in different habitat types in 2012, with more chinook salmon caught in continuous eelgrass habitat. No significant difference between habitats was observed in 2013 (Table 18).

All chinook salmon caught were juveniles (< 80 cm; Vronsky 2003). In spring 2012, chinook salmon ranged from 39 to 59 mm fork length, while in summer 2012 they ranged from 44 to 75 mm (Figure 15). Fork length of chinook salmon caught in spring 2013 ranged from 39 to 79 mm and in summer ranged from 54 to 71 mm.

Overall, chinook salmon caught in 2013 were significantly larger (60 mm ± 1.7 SE) than chinook salmon caught in 2012 (52 mm ± 1.6 SE) (Figure 16; Table 20). Since this observation may have been due to the differences in length of beach seine net used in the different years, further length analyses only compared within-year catches. In 2012, chinook salmon were significantly larger in the summer (62 mm ± 1.8 SE) than in the spring (45 mm ± 1.1 SE) and there was no
effect of habitat type on size of chinook salmon caught (Figure 16; Table 20). In 2013, there was no difference in the size of chinook salmon caught in spring and summer, but there was a difference between habitat types with larger fish caught in the patchy eelgrass (63 mm ± 1.7 SE) and sandflat habitats (68 mm ± 3.5 SE) than in the continuous eelgrass distribution sites (54 mm ± 3.1 SE) (Table 20).

4.1.5.4 Threespine Stickleback

Only 12 threespine sticklebacks were caught in the Eelgrass Fish Community Survey sampling events and the majority (83%) were caught in summer 2012. In contrast, 191 threespine sticklebacks were caught during the juvenile salmon distribution survey sampling, allowing statistical comparisons between seasons and habitats in 2013. The abundance of threespine stickleback was significantly greater in summer 2013, and in both seasons significantly greater in patchy distribution eelgrass habitats (Table 18). The majority (90%) of threespine sticklebacks caught in summer 2012 were between 60 and 74 mm fork length (Figure 17). Length at maturity is around 55 mm (Froese and Pauly 2011) so the majority of sticklebacks caught in the summer were likely adults. The two individuals caught in the fall 2012 were juveniles measuring 21 and 27 mm fork length.

4.1.5.5 Northern Anchovy

Northern anchovy were only caught during the fall of 2012 and at one site, EG2, so it was not possible to compare differences in abundance or fork length between seasons or habitat types. All the northern anchovy caught and measured (n = 30) were between 27 and 50 mm long (Figure 18). The length frequency combined with length-at-age data from the literature (Pike 1951) indicate that all northern anchovy sampled in fall 2012 were young-of-year (i.e., born in the current year).

4.1.5.6 Snake Prickleback

Snake prickleback were only caught in spring and summer 2013. Their abundance was significantly greater in spring and in patchy distribution eelgrass habitats during both seasons (Table 18).

4.1.5.7 Pacific Sand Lance

The majority (n = 29; 88%) of Pacific sand lance were caught in spring 2012: 14 individuals were caught at EG2 (patchy distribution), and 15 were caught at EG3 (dense continuous distribution). In addition, two Pacific sand lance were caught in summer 2012 and two in spring 2013. Only one Pacific sand lance was caught at the sandflat habitat site over the entire survey, in summer 2012. Due to low abundances of Pacific sand lance, statistical comparisons abundance between seasons and habitat types was not possible. Most Pacific sand lance caught and measured in spring 2012 were between 40 to 50 mm (Figure 19). Several
individuals caught in summer 2012 were between 55 and 60 mm. The length frequency and length-at-age data (Field 1988, Robards et al. 2002) indicate that all sand lance sampled were young-of-year (< 90 mm).

4.1.5.8 Pacific Herring

Almost all Pacific herring were caught in summer 2013 (n = 31; 98%), but one individual was caught in summer 2012 at EG3. Due to low numbers it was not possible to statistically compare between habitat types; however, no Pacific herring were caught at the sandflat habitat site and the majority were caught at EG1 (n = 19; 61%), a site with patchy eelgrass distribution.

4.1.6 Comparison of Sites EG2 and EG4 in Summer (August) 2008 and Summer (June) 2012

In summer 2008, 350 fish representing 11 species were caught in three hauls each at sites EG2 and EG4, while in summer 2012, using the same effort at the same sites, 80 fish were caught representing eight species. Abundances of fish grouped by species caught in summer of both 2008 and 2012 are displayed in Figure 20. Abundance of all fish was significantly higher in summer 2008 compared to summer 2012 (Figure 21; Table 21), and significantly higher at EG4 in both years compared to EG2 (Table 21). Species richness was not significantly different between years, but it was different by site, with EG4 having higher species richness in both years (Table 21). Evenness scores were significantly higher in 2012 than 2008, but similar between sites (Table 22). No difference was observed in Shannon-Wiener diversity indices between the different years or sites (Figure 21; Table 22).

The community assemblages were significantly different when compared across sites and between years (Figure 22; ANOSIM; R = 0.789, p = 0.001). Sites EG2 and EG4 sampled in 2012 had assemblages more similar to each other than in 2008. In 2012, assemblages at both sites were composed of shiner perch, chinook salmon, saddleback gunnel (Pholis ornata), and threespine stickleback. In 2008, catch at EG2 was composed mostly of English sole (Parophrys vetulus), and Pacific sand lance, while at EG4 catch was composed mostly of shiner perch, saddleback gunnels, and threespine stickleback (Table 23; SIMPER).

Species present in higher abundance in summer 2008 and 2012 were shiner perch and threespine stickleback, and both species were significantly larger in June 2012 than August 2008 (Figure 23 and Figure 24; Table 24). While there was a difference in size of shiner perch between years, the majority (98% in 2008 and 97% in 2012) of shiner perch were likely sexually mature (> 40 mm; Love 2011). The majority (90%) of threespine stickleback caught in the summer 2012 appeared to be adults, while all of sticklebacks caught in summer 2008 were juveniles (< 55 mm).
4.1.7 Comparison of RBT2 Baseline Data and Seasonal Historic Data

Historically, 55 species have been documented using eelgrass habitat at Roberts Bank (Greer et al. 1980, Conlin et al. 1982, Gordon and Levings 1984, MacDonald 1984, Triton 2004, Martel 2009). Two new species were observed that were not previously documented in the literature in eelgrass habitat at Roberts Bank: Northern spearnose poacher (*Agonopsis vulsa*) and longfin smelt (*Spirinchus thaleichthys*) (Table 25).

Several species historically not observed in April at Roberts Bank were caught in 2012 and 2013 spring surveys, and included sharpnose sculpin (*Clinocottus acuticeps*), sand sole (*Psettichthys melanostictus*), butter sole (*Pleuronectes isolepis*), sturgeon poacher (*Agonus acipenserinus*), and Pacific snake prickleback. Surf smelt and northern anchovy, which historically were not observed in Roberts Bank during the fall and winter, were observed in October 2012 (both species) and January 2013 (surf smelt only).

Species that were observed historically within eelgrass habitat at Roberts Bank but were not present in the 2012/2013 Eelgrass Fish Community Survey or 2013 juvenile salmon distribution survey were:

- Juvenile pink salmon (*Oncorhynchus gorbuscha*);
- Juvenile sockeye salmon (*Oncorhynchus nerka*);
- Juvenile coho salmon (*Oncorhynchus kisutch*);
- Capelin (*Mallotus villosus*);
- 11 sculpin species;
- Pacific sanddab (*Citharichthys sordidus*);
- Rock sole (*Lepidopsetta petraborealis*);
- C-O sole (*Pleuronichthys coenosus*);
- Flathead sole (*Hippoglossoides elassodon*);
- Pile perch (*Rhacochilus vacca*);
- Striped surfperch (*Embiotoca lateralis*);
- Penpoint gunnel (*Apodichthys flavidus*);
- Rockweed gunnel (*Apodichthys fucorum*);
- Kelp greenling (*Hexagrammos decagrammus*);
- Masked greenling (*Hexagrammos octogrammus*);
- Pacific tomcod (*Microgadus proximus*);
- Slender cockscomb (*Anoplarchus insignis*);
- High cockscomb (*Anoplarchus purpurescens*);
- Tidepool snailfish (*Liparis florae*); and
- Lobefin snailfish (*Liparis greeni*).

2011) indicated similarities in species composition between locations. Thirty-six species either presently and/or historically observed on Roberts Bank have also been observed in the Gulf Islands (Robinson and Yakimishyn 2013). Ten species observed in the Gulf Islands have not been documented at Roberts Bank: black prickleback (*Xiphister atropurpureus*), black rockfish (*Sebastes melanops*), copper rockfish (*Sebastes caurinus*), cabezon (*Scorpaenichthys marmoratus*), cutthroat trout (*Oncorhynchus clarkii*), kelp perch (*Brachyistius frenatus*), northern clingfish (*Gobiesox maeandricus*), manacled sculpin (*Synchirus gili*), sailfin sculpin (*Nautichthys oculofasciatus*), and red Irish lord (*Hemilepidotus hemilepidotus*).
5 Discussion

The following section presents a discussion of the key findings of the Eelgrass Fish Community Survey.

5.1 Discussion of Key Findings

Fish catch in eelgrass habitat at Roberts Bank was often dominated by a few species that were caught in large numbers. The majority of species (22 out of 26 species; 81%) were caught less than 25% of the time, possibly indicating that they are less common or transient species. Many species caught during this survey consisted primarily of juveniles, including surf smelt, northern anchovy, Pacific sand lance, threespine stickleback, and chinook and chum salmon, indicating the importance of eelgrass at Roberts Bank as rearing habitat. Martel (2009) also documented that many of the fish caught in eelgrass habitat at Roberts Bank in summer 2008 were young-of-year.

5.1.1 Season

Seasonality is an important factor in fish community composition in the eelgrass bed adjacent to Roberts Bank terminals. While there was no difference in overall abundance between seasons for both the Eelgrass Fish Community Survey and juvenile salmon distribution survey (primarily due to the high abundances of surf smelt caught in spring and winter, shiner perch in summer, and northern anchovy in fall), species richness was significantly higher in spring and summer than in fall and winter. Fish diversity was also highest in the summer during both surveys. During the Eelgrass Fish Distribution Survey, fish species present during the summer were more evenly distributed than those caught during the spring at all sites (fall and winter evenness scores could not be calculated). For the juvenile salmon distribution survey, species evenness was similar between spring and summer at sites with eelgrass cover, but species were more evenly distributed in the summer at the bare sandflat site. Fish assemblages were very different between all the seasons for both surveys, except between fall and winter seasons sampled during the Eelgrass Fish Community Survey. Differences were largely driven by the presence or absence of surf smelt. Significant seasonal variation in species richness in eelgrass habitats at Roberts Bank has been documented in the historical literature with up to 44 species observed in summer, 34 in spring, 16 in fall, and 12 in winter (Greer et al. 1980, Conlin et al. 1982, Gordon and Levings 1984, MacDonald 1984, Triton 2004, Martel 2009).

5.1.2 Habitat Type

Overall, habitat type only appeared to influence some fish parameters at Roberts Bank. No significant differences in abundance, species diversity, species evenness or community assemblages were observed in the different habitats during the Eelgrass Fish Community Survey, and no significant differences in species diversity or community assemblages were observed in the different habitats during the juvenile salmon distribution survey. There were differences
in species richness between habitats in the fall and winter seasons with fish caught only at sites with eelgrass cover in the fall, and only continuous eelgrass cover in the winter. During the spring and summer 2013, the number of fish was higher at sites with continuous eelgrass distribution, and the number of species was higher at sites with eelgrass cover than the reference bare sandflat site. As discussed in Section 5.1.1, species evenness in different habitats sampled in spring and summer 2013 was dependent on season. While many studies have reported differences in fish abundance between seagrass and bare sand habitats (Orth and Heck 1980, Johnson et al. 2005, Cote et al. 2013), this is not always the case (Edgar and Shaw 1995). Often fish species richness and composition are more variable between seagrass and bare sand habitats, than abundance (Jackson et al. 2001). Different species have adapted to these habitats, with smaller juveniles and cryptic individuals inhabiting seagrass beds; and schooling and burrowing species dominating bare sand habitat, some that are also well camouflaged (Jackson et al. 2001).

5.1.3 Tidal State
Tidal state also appeared to influence fish parameters at Roberts Bank. A higher abundance and species richness was observed on flood tides compared to ebb tides (2013), but no differences in species evenness, diversity, or community assemblages were documented. Differences in abundance over different tidal states may be because sampling sites were in an intertidal area and fish may have been leaving the site with the ebb tides to avoid exposure and desiccation, contributing to a lower abundance and species richness.

5.1.4 Forage Fish
Five species of forage fish species were caught: surf smelt, northern anchovy, Pacific sand lance, Pacific herring, and longfin smelt. Surf smelt represented 66% of total abundance across both years, while the other four species together represented 3%. All forage fish provide an important ecological role primarily as prey species for many sea birds, marine mammals, and fish species (Field 1988, Olesiuk et al. 1990, Willson 1999, Therriault et al. 2002a, 2002b, Therriault et al. 2009, Love 2011).

Catches in spring (2012 and 2013) and winter (2013) were dominated by surf smelt, which were caught in all seasons and had the highest FO of all species caught at Roberts Bank. Surf smelt were also the dominant species driving differences in the community assemblage between seasons. Historically on Roberts Bank, surf smelt have only been observed in eelgrass habitat between March and August (Greer 1980, Conlin et al. 1982, MacDonald 1984). Triton (2004) and Conlin et al. (1982) conducted sampling between September and February, but surf smelt were never observed. Observations of surf smelt in fall and winter during this survey extend the observed seasonality in the survey area. The presence of surf smelt in eelgrass habitat is not unique to Roberts Bank as they have also been caught in eelgrass habitat in the summer in other regions of
B.C. including the Gulf Islands, Haida Gwaii, Barkley Sound and Clayoquot Sound (Robinson and Yakimishyn 2013).

Surf smelt are planktivorous, short-lived fish that typically inhabit nearshore coastal waters including marine, estuaries, and freshwater habitats (DFO 2002, Love 2011). They spawn on coarse sand to fine gravel beaches in the upper intertidal zone (Levy 1985, Penttila 1997) and have been documented to spawn in the Lower Mainland during the summer and fall (deGraff 2007, DFO 2012). Once young hatch, they remain near shore. Fish reach maturity at one to two years of age and around 90 mm fork length (Therriault and Hay 2003, Froese and Pauly 2011).

In spring and fall 2012, the surf smelt catch was composed of a high percentage of larval surf smelt with some juveniles, while in winter 2013, the catch was composed of all juveniles. The presence of a high abundance of juveniles in the eelgrass bed at Roberts Bank is consistent with results reported in the existing literature (Greer 1980, Conlin et al. 1982, MacDonald 1984). Surf smelt juveniles move in large discrete schools and are often associated with marine vegetation, including eelgrass and kelp (Love 2011).

In this study, surf smelt abundance was not correlated with habitat type, and were found in continuous and patchy eelgrass habitats, and bare sandflat. Surf smelt did have a low FO at the sandflat site (FO = 19%; 4 of 21 sets) and were only observed at the sandflat site in spring and summer 2013. Eelgrass sites had a higher FO of surf smelt (52%). Higher abundances of surf smelt in eelgrass habitat, compared to un-vegetated, kelp and bedrock habitat, have been observed in southeastern Alaska (Johnson et al. 2005).

Young-of-year northern anchovy were caught in fall 2012 and have not been documented in eelgrass beds at Roberts Bank since the early 1980s (MacDonald 1984). Northern anchovy are primarily a coastal schooling species that enter bays and inlets in summer (Mecklenburg et al. 2002, Therriault et al. 2002b) and are indiscriminate daytime filter feeders (Koslow 1981). Although they are a highly migratory species (Love 2011), juvenile northern anchovy may remain in nearshore areas during the fall and winter (Laroche and Richardson 1980), which would account for their presence on Roberts Bank. During the day, northern anchovy may exhibit more schooling behavior and inhabit shallower inshore locations than at night (Love 2011). There is uncertainty as to whether northern anchovy spawn in British Columbia, as no spawning locations have been identified. Spawning may be occurring offshore or to the south (Therriault et al. 2002b), although Penttila (2007) suggests that spawning and egg incubation may occur in open water in Puget Sound and the Strait of Georgia (Whatcom County).

Pacific sand lance are small, schooling forage fish that are abundant in the nearshore area of the Pacific Northwest (Robards and Piatt 1999). Young-of-year Pacific sand lance were caught in spring and summer seasons during this survey, with most caught in eelgrass habitat as opposed to bare sand. Sand lance have
been documented to spawn in the upper intertidal zone on sand and fine gravel beaches between November and February in locations near the survey area, including Puget Sound, southern Vancouver Island, and the Lower Mainland (Thuringer 2004, deGraff 2007, Penttila 2007). Once hatched, larval sand lance may entrain in the substrate or move to pelagic waters (Garrison and Miller 1982). Juvenile sand lance caught during the survey were possibly hatched nearby and may be remaining in the survey area year-round as they can rear in nearshore water between one to three years (Field 1988).

Historically, Pacific sand lance have been observed in eelgrass habitat on Roberts Bank between April and November, with high abundances recorded in the spring, summer and early fall in the early 1980s (Conlin et al. 1982). They have also been observed in eelgrass habitats during the summer in other regions of B.C. including the Gulf Islands, Haida Gwaii, Barkley Sound, and Clayoquot Sound (Robinson and Yakimishyn 2013), and southeastern Alaska (Johnson et al. 2005).

Pacific herring are a coastal and offshore pelagic schooling species that come inshore to estuaries and bays in spring to spawn (Mecklenburg et al. 2002). Pacific herring were caught only in the summer season during this survey; however, they have been previously observed inhabiting eelgrass habitat at Roberts Bank from April to November (Conlin et al. 1982, MacDonald 1984, Triton 2004, Martel 2009). Herring were not caught in high abundance during the survey, but have been caught in high abundance (up to 4,000 individuals per seine) in the past in eelgrass habitat during the summer season (Conlin et al. 1982). Herring have also been observed in eelgrass habitat in southeastern Alaska (Johnson et al. 2005) and in other regions of B.C. (Robinson and Yakimishyn 2013). Herring spawn mainly on marine vegetation, including eelgrass, in the intertidal and shallow subtidal zone mainly in March and April in the Strait of Georgia, although the spawning time can range from February to May (Therriault et al. 2009). Roberts Bank has not been documented as a major spawning area for Pacific herring, and juveniles occurring in the area likely originate from nearby areas (Gordons and Levings 1984), including spawning grounds at Boundary Bay, the east coast of Mayne Island, and the east coast of Valdes Island (DFO 2013).

### 5.1.5 Perch

Shiner perch were caught in both the spring and summer, with a higher abundance observed in summer. Shiner perch form large schools and appear to be fairly ubiquitous in a variety of habitats including kelp beds, rocky reefs, sandy bottoms, and eelgrass (Lane et al. 2002, Love 2011). Shiner perch migrate to calm shallow waters in spring and summer (between May and August) to mate and birth their live young, but return to deeper waters in the winter (Hart 1973, Lane et al. 2002, Love 2011). Shiner perch have no larval stage as they are born fully developed at around 27 mm size. Males are often mature at birth and can recruit directly into the adult population (Schmitt and Holbrook 1990, Lane et al.
2002, Love 2011). Shiner perch caught in this survey were closely associated with the eelgrass bed, and in summer 2013, were most abundant at sites with dense cover and a continuous distribution of eelgrass. Shiner perch abundance has been found to be positively associated with eelgrass cover in surveys in California (Onuf and Quammen 1983, Valle 1999).

5.1.6 Salmon

Juvenile pink, coho, or sockeye salmon were not captured at the eelgrass sites or bare sand site. Results from the 2012 Juvenile Salmon Surveys indicate that pink salmon are primarily shore-tied, and are largely distributed along the causeway and terminal. Historically, coho and sockeye salmon have rarely been caught during fish surveys at Roberts Bank (Greer et al. 1980, Conlin et al. 1982, Levings et al. 1983, Gordon and Levings 1984, MacDonald 1984, Levings 1985, Triton 2004, Martel 2009). Coho salmon spend little time on Roberts Bank as they tend to disperse rapidly away from the estuary upon exiting the Fraser River (Greer et al. 1980, Sandercock 1991). The majority of juvenile sockeye salmon migrate north from the Fraser River, not utilizing the outer estuary and avoiding Roberts Bank (Rosenau and Angelo 2007). Chum and chinook salmon were the only salmon species caught in the survey area, however, chum salmon are also primarily shore-tied, and were rarely caught in the survey area.

Chinook salmon juveniles use the Fraser River estuary during outmigration (Macdonald 1984, Levings 1985) and are likely using the area for rearing. In general, the nearshore area, including bays and estuaries, is important habitat for salmonids during the juvenile phase (Healy 1991).

Chinook salmon were observed in the spring and summer. Due to their small size (< 80 mm fork length), all captured chinook salmon were juveniles (Vronsky 2003). There are two chinook salmon life history strategies; a ‘stream-type’ and an ‘ocean-type’ (Healy 1991, McPhail 2007). Ocean-type chinook salmon hatch earlier in the spring with a short residency period (< 3 months) in the river before migration to estuarine waters at a size range between 20 and 100 mm (Healy 1991, McPhail 2007). Ocean-type chinook salmon may take residency in estuarine waters for weeks to several months prior to offshore migration (Levy and Northcote 1982, Healey 1991, Boehlert 1997, Hering et al. 2010, Volk et al. 2010). Stream-type juvenile chinook salmon reside and feed in the river for one and sometimes two years prior to outmigration at a size range between 45 and 175 mm (Healy 1991, Boehlert 1997). Since the majority (78%) of the chinook salmon caught during this survey were between 45 mm (lower reported range of stream-type outmigrating chinooks; Healy 1991) and 79 mm (largest chinook salmon caught during this survey) it is not possible to determine from size alone whether these fish were stream-type or ocean-type. The rest of the chinook caught (22%) were between 39 and 44 mm and would likely have been ocean-type.
Juvenile chinook salmon have been documented to utilise eelgrass habitat from March to September at Roberts Bank (Greer et al. 1980, Conlin et al. 1982, MacDonald 1984). Juvenile salmon species may be sensitive to changes in eelgrass cover (Plummer et al. 2013) as it provides refuge and foraging habitat (Simenstad and Fresh 1995, Fresh 2006, Semmens 2008). In field experiments, juvenile chinook salmon preferentially stayed within Z. marina habitat compared to other structured habitat types (Semmens 2008).

The patterns of habitat use by chinook salmon at Roberts Bank remain unclear. Significantly more chinook salmon were found in continuous eelgrass distribution sites in 2012, but no difference in habitat use was found in 2013. In 2013, larger juvenile chinook salmon were caught in the sites with patchy distribution of eelgrass and at the sandflat site, while no trend in size among habitats was observed in 2012.

5.1.7 Other Species

Other species observed in eelgrass habitat at Roberts Bank included threespine stickleback, snake prickleback, flatfish species, and small cryptic species including gunnels and pipefish.

Most threespine stickleback were caught during the summer, with the highest abundance in patchy eelgrass habitat. Threespine stickleback are a schooling species that have been previously observed in greater abundance in eelgrass habitat compared to un-vegetated, kelp, or bedrock habitats (Johnson et al. 2005). They have been observed frequently in eelgrass habitat in other regions of B.C. and Atlantic Canada during the summer (Schein et al. 2012, Robinson and Yakimishyn 2013).

Snake prickleback were caught in both spring and summer in 2013, but were more abundant in the spring. Similar to threespine stickleback, snake prickleback were most abundant in patchy eelgrass habitat, which is supported by the literature (Johnson et al. 2005, Love 2011, Robinson and Yakimishyn 2013).

Flatfish caught during the survey comprised less than one percent of total catch, despite previous reports that documented heavy use of sandflat and eelgrass habitats at Roberts Bank by juvenile English sole and starry flounder (Greer et al. 1980). Species caught in this survey included English sole, sand sole (*Psettichthys melanostictus*), butter sole, speckled sanddab (*Citharichthys stigmaeus*), and starry flounder. Flatfish were only caught in the spring and summer seasons; however, English sole have historically been documented from February to September, while starry flounder have been observed year round in eelgrass habitat at Roberts Bank (Greer et al. 1980, Conlin et al. 1982, MacDonald 1984, Triton 2004, Martel 2009). It is unknown why there was such a discrepancy between flatfish abundance in this study and previous surveys as beach seines were the main gear type used in both, except for the Triton (2004) survey when a beam trawl was used which is more targeted towards catching benthic fish.
such as flatfish. Flatfish are often more abundant in bare sand habitat (Valle 1999, Johnson et al. 2005) as they have adapted to un-vegetated habitats by burrowing or camouflaging; however, due to low numbers of flatfish caught, a comparison between habitat types was not possible.

Cryptic species that often associate with eelgrass habitat (Onuf and Quammen 1983, Johnson et al. 2005, Robinson and Yakimishyn 2013) and were caught in low abundances during this survey were gunnel species (saddleback gunnel and crescent gunnel), tubesnout (*Aulorhynchus flavidus*), and bay pipefish. Bay pipefish, tubesnouts, and crescent gunnel have been previously documented year-round in eelgrass habitat at Roberts Bank (Greer et al. 1980, Conlin et al. 1982, MacDonald 1984, Triton 2004, Martel 2009). Of the species described above, bay pipefish was the only species caught in all seasons. Gunnel species were only observed in spring and summer, and tubesnouts were only observed in spring and winter.

### 5.1.8 Historical Data

Comparisons of the summer 2012 Eelgrass Fish Community data with historical data collected by Martel (2009) in 2008 showed considerable differences, highlighting the large amount of temporal variability at Roberts Bank. Abundance, species richness, species evenness, species diversity, and community assemblages were compared between summer of 2008 (August) and 2012 (June) at sites EG2 (patchy eelgrass distribution) and EG4 (continuous eelgrass distribution). Fish abundance at both sites was significantly higher in 2008 than 2012, due to large catches in 2008 of shiner perch, saddleback gunnel, and threespine stickleback at EG4, and Pacific herring, Pacific sand lance, and English sole at EG2. Fish species were more evenly distributed in 2012 than 2008 at both sites. While abundance and evenness scores were different between years, species richness and diversity were similar in 2008 and 2012 at both sites. In both years, more fish and species were caught at site EG4 than EG2, while species evenness and diversity were similar. Community assemblages were also very different between years, and between sites in 2008 only. Whether these observed differences were due to annual or seasonal (early summer vs. late summer) differences remains unclear. Overall at both sites, shiner perch and threespine stickleback were significantly larger in June 2012 compared to August 2008. The June survey may have been sampling breeding adults inhabiting the eelgrass bed in early summer, while the August survey may have been capturing juvenile stages predominating in late summer.

with eelgrass beds that have very different habitat types with respect to physical attributes. This suggests the importance specifically of eelgrass to the life history of these fish species. Thirty-six species observed on Roberts Bank have also been observed in the Gulf Islands. The majority of eelgrass beds sampled in the Gulf Islands were subtidal and in bays with variable habitat types (Robinson and Martel 2006), while sites at Roberts Bank were intertidal on exposed sandflats. Substrate at Gulf Island sites ranged from mud/sand to pebble/cobble with some sites having sandstone shoreline and rocky outcrops. Eelgrass distribution and cover were variable between Gulf Island sites and other vegetation was often present including *Ulva* sp., *Gracilaria* sp., and laminariales. Most of the species observed in the Gulf Islands that have not been documented at Roberts Bank are typically associated with rocky habitat (rockfish). All these species had low FO (≤13%) over the eight-year Gulf Islands survey, except for kelp perch (52% occurrence), which are largely restricted to kelp forest habitat (Anderson 1994, Anderson and Sabado 1999). Kelp forests are not present near eelgrass habitat at Roberts Bank, so kelp perch were not expected to occur.

5.1.9 Water Quality Parameters

No significant interannual variability was observed at Roberts Bank, as water temperature and salinity were similar at sites in the same seasons sampled in different years.

The summer had the warmest water temperatures and the lowest salinity, likely due to increased freshet inputs from the Fraser River. In addition, dissolved oxygen levels were lowest in the summer and highest in the winter. Water temperature was similar between different habitat types, but salinity was higher in sites with eelgrass cover than bare sand. This difference in salinity may have been due to habitat type or the closer proximity of the bare sand to freshwater input. In spring and summer 2013, water temperatures were similar between different tidal states. Variables explaining differences in salinity over different tidal states were not clear.

There were no observed anomalies in the water quality data that could explain variability in the fish community data.

5.2 Conclusions

Data collected during the Eelgrass Fish Community Survey and a component of the juvenile salmon distribution survey were used to document the seasonal and spatial distribution, and abundance of fish species that may be temporary or year-round residents of the *Z. marina* eelgrass bed adjacent to Roberts Bank terminals.

Major survey results include:

- Seasonal: Results suggest that fish communities in the survey area at Roberts Bank differ across seasons. While abundances of fish caught
were similar between seasons, there were more species present during the spring and summer, and fish diversity was highest during the summer. Different fish species make up the majority of the fish population in different seasons, with surf smelt the most abundant in spring and winter, and shiner perch the most abundant in summer.

- **Habitat**: Results indicate that fish use of different habitats depended on the season. During spring and summer 2012, all habitats surveyed (patchy eelgrass, continuous eelgrass, and bare sandflat) were used equally by fish species. During the fall, fish were only caught in habitats with eelgrass (patchy and continuous), and in winter fish were only observed in sites with continuous eelgrass. Further sampling during spring and summer 2013 revealed that more fish species were caught in habitats with eelgrass than bare sand, and more fish overall were caught in habitats with continuous eelgrass distribution.

- **Tidal distribution**: Results suggest fish presence and abundance can vary notably according to tidal cycle. More fish and more fish species were caught on flood than ebb tidal states.

- **Interannual**: Significant variability in fish catch and composition was observed between this survey and studies conducted in 2008. It is not known if this difference is attributed to interannual or seasonal variability. Fifty-seven fish species have been documented utilising eelgrass habitat at Roberts Bank from 1979 to 2013.

- **Regional**: Results suggest that community composition of fish species in eelgrass habitat can be similar across regions. Many of the same species caught in eelgrass habitat at Roberts Bank from 1979 to 2013 have been observed in eelgrass beds in other regions of B.C., even with considerable differences in habitat. This suggests that there are fish species that specifically associate with and are dependent on eelgrass, despite differences in substrate and the presence of other vegetation.

### 5.3 Data Gaps and Limitations

Interpretation of the results of the Eelgrass Fish Community Survey and juvenile salmon distribution survey was limited by a number of factors including: (1) the need for data on current eelgrass physical characteristics within the Z. *marina* bed; (2) the high variability caused by large sporadic catches of one species that makes statistical analysis and results interpretation challenging; (3) different methodologies; (4) weather conditions; and (5) limited historical data sets for some seasons.

**Eelgrass Distribution and Density**

Due to high water turbidity during sampling, it was not possible to verify if eelgrass distribution and density at sites in 2012/2013 were similar to those
reported previously (Precision Identification 2009). These variables are important predictors of fish abundance and diversity; therefore, eelgrass distribution and cover results from the Marine Vegetation TDR (Hemmera 2014) could be used to verify whether eelgrass distribution and cover have remained consistent over time.

**High Variability**

Fish catch was largely composed of highly mobile schooling species; therefore, it is difficult to accurately determine abundance and distribution of these species, as catches can be sporadic with some sets yielding hundreds of individuals and some none.

**Environmental Conditions**

Water depth was sometimes too deep for on-foot sampling due to high wind driven waves or higher tides during some of the Eelgrass Fish Community Survey seasonal sampling events. When sites were too deep to sample on foot a skiff was used to guide the beach seine net for fish collection. While the area sampled was similar between the two different methodologies, the net was set at a faster rate with the skiff, which may have increased the likelihood of catching faster moving species or scared fish away because of the skiff’s motor. For the juvenile salmon distribution survey, all sites were sampled only on foot. Due to the small number of sites sampled, and that some seasons were entirely sampled by one methodology, the effects of methodology on fish catch could not be examined. For the Eelgrass Fish Community Survey when some or all of the sites in a given season were sampled by skiff, there is some uncertainty in whether differences observed in data were due to methodology or other factors (e.g., season or habitat type).

**Limited Temporal Datasets**

In surveys from 1979 to 2011, more effort was invested in spring and summer surveys at Roberts Bank than in fall and winter; therefore, more information is available on seasonal fish abundance and distribution during spring and summer. Within season fish catch in fall 2012 and winter 2013 was highly variable and comparisons with historic data was challenging, making it difficult to make overall conclusions on spatial and temporal changes in fish abundance and diversity.

In addition to limitations with the current survey, there were also difficulties with the interpretation of historic data. In most cases, descriptions of habitats surveyed in the late 1970s and 1980s on Roberts Bank were either not available or not descriptive enough. As well, fish catch would be summarised by total fish catch or CPUE, rather than by species or life stage, making it impossible to extract species-specific abundance and life stage data; therefore, only presence/absence data could be obtained.
Despite these limitations, the objective of the Eelgrass Fish Community Survey of documenting site-specific, seasonal (i.e., spring, summer, winter and fall) baseline data on fish species’ abundance, distribution, and habitat use in the eelgrass beds has effectively been achieved, and meets the overall need of informing a future effects assessment for the proposed Project.
6 Closure

Major authors and reviewers of this technical data report are listed below, along with their signatures.

Report prepared by:
Archipelago Marine Research Ltd.

Ashley Park, M.Sc.
Marine Biologist

Report senior review by:
Archipelago Marine Research Ltd.

Pam Thuringer, M.Sc. R.P.Bio
Director - Marine Environmental Service Division

Report senior review by:
Archipelago Marine Research Ltd.

Brian Emmett, M.Sc. R.P.Bio
Senior Advisor – Research and Program Development

Report peer reviewed by:
Hemmera Envirochem Inc.

Romney McPhie, M.Sc.
Biologist
7 References


Greer, G.L., C.D. Levings, R. Harbo, B. Hillaby, T. Brown, and J. Silbert. 1980. Distribution of fish species on Roberts and Sturgeon Banks recorded in seine and trawl surveys. Canadian Manuscript Reports of Fisheries and Aquatic Sciences. 1596.


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Martel, G. 2009. Section 7. Fish Communities. In Hemmera Envirochem (Editors), T2 environmental baseline monitoring report - Final report. Prepared for Vancouver Port Authority, Vancouver, B.C.


8 Statement of Limitations

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

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

This Report represents a reasonable review of the information available to Archipelago within the established Scope, work schedule and budgetary constraints. In preparing this Report, Archipelago has relied in good faith on information provided by others as noted in this Report, and has assumed that the information provided by those individuals is both factual and accurate. Archipelago accepts no responsibility for any deficiency, misstatement or inaccuracy in this Report resulting from the information provided by those individuals.
Figures
Figure 1. Location of the proposed RBT2 construction site and Eelgrass Fish Community Survey area and sites (EG1 to EG5) in relation to the existing terminal and *Zostera marina* eelgrass bed. Eelgrass distribution classes are indicated.
Figure 2. Fish composition and abundance by group of all fish caught in spring 2012 to winter 2013 at sites EG1 to EG5 on ebb tides during the Eelgrass Fish Community Survey.
Figure 3. Fish composition and abundance of all forage fish species caught, in spring 2012 to winter 2013 at sites EG1 to EG5 on ebb tides during the Eelgrass Fish Community Survey.
Figure 4. Fish composition and abundance by group of all fish caught in spring and summer 2013 (no sampling in fall and winter) at sites EG1 to EG5 on flood and ebb tidal states as part of the juvenile salmon distribution survey.
Figure 5. Fish composition and abundance by group of all forage fish caught in spring and summer 2013 (no sampling in fall and winter) at sites EG1 to EG5 on flood and ebb tidal states as part of the juvenile salmon distribution survey.
Figure 6. Abundance, species richness, evenness and diversity of fish sampled at sites EG1 to EG5 from spring 2012 to winter 2013 (Eelgrass Fish Community Survey). Sandflat site (EG5) was not sampled in the spring season. Numbers above each bar is sample size. Error bars indicate standard error. Asterisks indicate where there are significant differences (p-value < 0.05) between groups.
Figure 7. Two-dimensional plots of a multidimensional scaling routine (MDS) of fish community data sampled at Roberts Bank during the Eelgrass Fish Community Survey (spring 2012 to winter 2013). Each plot shows separation of one of two factors (a) habitat type, and (b) season. There is spatial overlap between all habitat types indicating no differences in community composition between habitats. There is spatial separation between the different seasons indicating differences in community composition, except fall and winter which had similar fish community composition. Stress level of the 2D plots was 0.09.
Figure 8. Abundance, species richness, evenness and diversity of fish sampled at sites EG1 to EG5 in spring and summer 2013 in different habitat types (juvenile salmon distribution survey). Numbers above each bar is sample size. Error bars indicate standard error. Asterisks indicate where there are significant differences (p-value < 0.05) between groups.
Figure 9. Abundance, species richness, evenness and diversity of fish sampled at sites EG1 to EG5 during flood and ebb tides in spring and summer 2013 (juvenile salmon distribution survey). Numbers above each bar is sample size. Error bars indicate standard error. Asterisks indicate where there are significant differences (p-value < 0.05) between groups.
Figure 10. Two-dimensional plots of a multidimensional scaling routine (MDS) of fish community data sampled at Roberts Bank during the juvenile salmon distribution survey (spring 2013 to summer 2013). Each plot shows separation of one of three factors (a) tidal state, (b) habitat type, and (c) season. There is spatial overlap between all tidal states and habitat types indicating no differences in community composition between these factors. There is spatial separation between the different seasons indicating differences in fish community composition between spring and summer. Stress level of the 2D plots was 0.12.
Figure 11. Length frequency graphs (fork length) for surf smelt (*Hypomesus pretiosus*) caught in spring 2012, fall 2012, and winter 2013. \( n = \) sample size, \( \bar{x} = \) average fork length.
Figure 12. Fork length comparisons for surf smelt (*Hypomesus pretiosus*) by season in spring and fall 2012, and winter 2013. No surf smelt were caught in summer. Numbers above each bar is sample size. Asterisks indicate where there are significant differences (p-value < 0.05) between groups.

Figure 13. Fork length comparisons for surf smelt (*Hypomesus pretiosus*) by habitat type in spring and fall 2012, and winter 2013. No surf smelt were caught in summer or in the sandflat habitat type. Numbers above each bar is sample size. Asterisks indicate where there are significant differences (p-value < 0.05) between groups.
Figure 14. Length frequency graphs (fork length) for shiner perch (*Cymatogaster aggregate*) caught in summer 2012. n = sample size, $\bar{x}$ = average fork length.
Figure 15. Length frequency graphs (fork length) for chinook salmon (*Oncorhynchus tshawytscha*) caught in spring 2012, summer 2012, spring 2013, and summer 2013. n = sample size, \( \bar{x} \) = average fork length.
Figure 16. Fork length comparisons for juvenile chinook salmon (*Oncorhynchus tshawytscha*) by (A) year 2012 and 2013, (B) season and habitat type in 2012, and (C) season and habitat type in 2013. Numbers above each bar is sample size. Asterisks indicate where there are significant differences (p-value < 0.05) between groups.
Figure 17. Length frequency graphs (fork length) for threespine stickleback (*Gasterosteus aculeatus*) caught in summer 2012 and fall 2012. \(n = \) sample size, \(\bar{x} = \) average fork length.

\[ \text{Summer 2012} \\
\text{n} = 10 \\
\bar{x} = 65 \text{ mm} \]

\[ \text{Fall 2012} \\
\text{n} = 2 \\
\bar{x} = 24 \text{ mm} \]

Figure 18. Length frequency graph (fork length) for Northern anchovy (*Engraulis mordax*) caught in fall 2012. \(n = \) sample size, \(\bar{x} = \) average fork length.

\[ \text{Fall 2012} \\
\text{n} = 30 \\
\bar{x} = 42 \text{ mm} \]
Figure 19. Length frequency graphs (fork length) for Pacific sand lance (*Ammodytes hexapterus*) caught in spring 2012 and summer 2012. \( n = \) sample size, \( \bar{x} = \) average fork length.
Figure 20. Fish composition and abundance by group of all fish caught at sites EG2 and EG4 in summer 2008 and summer 2012. Sample size for each site is three.
Figure 21. Abundance, species richness, evenness and diversity of fish sampled at sites EG2 and EG4 in summer 2008 and summer 2012. Error bars indicate standard error.
Figure 22. Two-dimensional plot of a multidimensional scaling routine (MDS) of fish community data sampled at sites EG2 and EG4 at Roberts Bank during the Martel (2009) survey (August 2008) and Eelgrass Fish Community Survey (June 2012). The plot shows separation of the different years (black and white symbols) and different sites (labeled on figure). There is spatial separation between both years, and within 2008 there is spatial separation between both sites indicating differences in community composition. There is spatial overlap between sites EG2 and EG4 sampled in 2012 indicating no differences in community composition between sites in this year. Stress level of the 2D plots was 0.03.
Figure 23. Length frequency graphs (fork length) for shiner perch (*Cymatogaster aggregate*) caught in summer 2008 and summer 2012. \( n = \) sample size, \( \bar{x} = \) average fork length.
Figure 24. Length frequency graphs (fork length) for threespine stickleback (*Gasterosteus aculeatus*) caught in summer 2008 and summer 2012. n = sample size, $\bar{x}$ = average fork length.
Tables
Table 2. Key studies (including fish community surveys) carried out in eelgrass habitat at Roberts Bank between 1979 and 2011.

<table>
<thead>
<tr>
<th>Author</th>
<th>Study Dates</th>
<th>Roberts Bank Survey Area</th>
<th>Sampling Effort</th>
<th>Gear</th>
<th>Study Objectives</th>
<th>Major Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greer et al. 1980</td>
<td>April-July 1979</td>
<td>From the seaward and upper reaches from Fraser River south arm to BC Ferries Terminal</td>
<td>111 beach seines in Roberts Bank (72 of the seines were located at north and south Roberts Bank causeway, Inter-causeway Area and at the BC Ferries Terminal).</td>
<td>Beach seine: 14.7 m long x 3.5 m deep (3 mm mesh). Net deployed by boat and on foot.</td>
<td>Determine distribution of fish species on Roberts and Sturgeon Bank.</td>
<td>Roberts Bank: 14,789 fish caught (CPUE = 133.2). Four beach seines sites located in eelgrass on the north side of the Roberts Bank causeway and Inter-causeway Area (59 to 365 fish caught per haul). Majority of fish captured in eelgrass habitat included Pacific staghorn sculpin, juvenile chum salmon, surf smelt, and English sole.</td>
</tr>
<tr>
<td>Conlin et al. 1982; Gordon and Levings 1984</td>
<td>March 1980 – July 1981</td>
<td>Inter-causeway Area</td>
<td>134 seines at 7 sites in Inter-causeway Area (2 along south side of Roberts Bank causeway, one on BC Ferries Terminal and 5 around borrow pit.) Sites sampled ~ every two weeks (27 sampling events).</td>
<td>Beach seine: 14.7 m long x 3.5 m deep (3 mm mesh).</td>
<td>Determine seasonal distribution of fish species on Roberts and Sturgeon Bank.</td>
<td>53 species found at Roberts Bank. Three sites located in eelgrass bed. Significant temporal variation in fish abundance. Species caught in high abundance in the eelgrass habitat in the summer and early fall (June – September) included Pacific herring, Pacific sand lance, shiner perch, juvenile chinook salmon (until August only), threespine stickleback, tubensnout, snake prickleback, English sole, starry flounder, Pacific staghorn sculpin, bay pipefish, and gunnel species. Abundances of fish declined from October – April (except staghorn sculpin abundances increasing in March and April). Abundances increased again in May with high abundances of Pacific sand lance, Pacific herring, juvenile pink salmon, English sole, tubensnout, and staghorn sculpin observed. Rapid changes in composition and abundance during the spring and summer are due to the influx of juveniles of various fish species.</td>
</tr>
</tbody>
</table>
Table 2 continued. Key studies including fish community surveys in eelgrass habitat at Roberts Bank between 1979 and 2011.

<table>
<thead>
<tr>
<th>Author</th>
<th>Study Dates</th>
<th>Roberts Bank Survey Area</th>
<th>Sampling Effort</th>
<th>Gear</th>
<th>Study Objectives</th>
<th>Major Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>MacDonald 1984</td>
<td>June – August 1981 and April – August 1982</td>
<td>Inter-causeway Area</td>
<td>21 sites in 1981 (three of the sites were sampled twice during sampling season). 38 sites sampled in 1982 (three sites sampled twice and one site sampled three times during sampling season).</td>
<td>Beach seine: 15 m long x 3 m deep (6 mm mesh). Net deployed by boat and on foot.</td>
<td>Seasonal occurrence, relative abundance and distribution of juvenile salmon identified by habitat.</td>
<td>35 species caught in eelgrass bed including juvenile chum, pink, chinook and sockeye salmon. Catches of pink and chum were higher along the causeway beaches then in the eelgrass bed. Forage fish species northern anchovy were observed in summer, while Pacific sand lance, herring and surf smelt were observed in the spring and summer. Three species of gunnel, eight species of sculpin, and five species of flatfish were observed in addition to tubesnout, threespine stickleback, bay pipefish, shiner perch, snake prickelback, white spotted greenling, plainfin midshipman, Pacific tomcod, pile perch, rockfish, and arrow goby.</td>
</tr>
<tr>
<td>Triton 2004</td>
<td>July 2003-May 2004</td>
<td>North side of Roberts Bank causeway and Inter-causeway Area</td>
<td>16 trawl sites (11 off north side of Roberts Bank causeway and five in Inter-causeway Area) sampled over the four seasons in addition to four more in Inter-causeway Area sampled in spring. 68 tows total. Six sites on north side of Roberts Bank causeway were in eelgrass bed.</td>
<td>Beam trawl: 6 m long x 3 m wide opening x 1 m height (mesh size tapering from 12.3 mm in a 1.5 m cod end).</td>
<td>Determine seasonal use of fish habitats.</td>
<td>In eelgrass bed off the north side of Roberts Bank causeway the most fish were captured in spring season followed by the summer. Low catches in fall and winter. Species caught in high abundance during the spring included threespine stickleback, prickleback, Pacific staghorn sculpin, starry flounder, saddleback gunnel, and white spotted greenling; while species caught in large abundances in the summer included threespine stickleback, shiner perch, starry flounder and bay pipefish.</td>
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Table 2 continued. Key studies that have surveyed fish communities in eelgrass habitat at Roberts Bank between 1979 and 2011.

<table>
<thead>
<tr>
<th>Author</th>
<th>Study Dates</th>
<th>Roberts Bank Survey Area</th>
<th>Sampling Effort</th>
<th>Gear</th>
<th>Study Objectives</th>
<th>Major Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Martel 2009</td>
<td>August 2008</td>
<td>North side of Roberts Bank causeway</td>
<td>3 sites, three sets at each site.</td>
<td>Beach seine: 10m long x 3m deep (3 mm mesh). Net deployed on foot.</td>
<td>Establish preconstruction monitoring stations and acquire baseline data for long-term monitoring changes in eelgrass at Roberts Bank terminals.</td>
<td>373 fish caught total representing 14 different species. Most fish were juveniles. Shiner perch most abundant followed by threespine stickleback, English sole and saddleback gunnels. Other species included Pacific sand lance, Pacific staghorn sculpin, bay pipefish, Pacific snake prickleback, whitespotted greenling, Pacific herring, crescent gunnel, plainfin midshipman, starry flounder, and penpoint gunnel.</td>
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<th>Species</th>
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<th>Fall</th>
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<td>Chum salmon</td>
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<td>Chinook salmon</td>
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<td>Latin name</td>
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<td>May</td>
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<td>Lumpenus sagitta</td>
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<td>Porichthys notatus</td>
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<td>Penpoint gunnel</td>
<td>Apodichthys flavus</td>
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<td>Pholus laeta</td>
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<td>1, 2, 3, 4</td>
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<td>Pholus ornata</td>
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<td>1, 2, 3, 4</td>
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<td>Apodichthys fucorum</td>
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<td>Bay pipefish</td>
<td>Syngnathus leptorhyncus</td>
<td>2</td>
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<td>1, 2, 3, 4</td>
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<td>Tubesnout</td>
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<td>Hexagrammos stelleri</td>
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<td>Kelp greenling</td>
<td>Hexagrammos decagrammuss</td>
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<td>Masked greenling</td>
<td>Hexagrammos octagrammuss</td>
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<td>Rockfish sp.</td>
<td>Sebastes sp.</td>
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<td>Sturgeon poacher</td>
<td>Agonus acipenserinus</td>
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<td>Agonopsis vulsa</td>
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<td>Slender cockscomb</td>
<td>Anoplarchus insignis</td>
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<td>High cockscomb</td>
<td>Anoplarchus purpurascens</td>
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<tr>
<td>Lobefin snailfish</td>
<td>Liparis greeni</td>
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<td><strong>Total Number of Species</strong></td>
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<td><strong>22</strong></td>
<td><strong>34</strong></td>
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Table 4. Beach seining site characteristics. Tide height relative to chart datum (CD).

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<tr>
<th>Site</th>
<th>Habitat</th>
<th>Required Sampling Tide Height (m CD)</th>
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<tbody>
<tr>
<td>EG1</td>
<td>Patchy distribution, &gt; 65% cover of eelgrass</td>
<td>1.0</td>
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<tr>
<td>EG2</td>
<td>Patchy distribution, 20-65% cover of eelgrass</td>
<td>&lt; 1.5</td>
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<tr>
<td>EG3</td>
<td>Continuous distribution, dense cover of eelgrass</td>
<td>&lt; 2.0</td>
</tr>
<tr>
<td>EG4</td>
<td>Continuous distribution, dense cover of eelgrass</td>
<td>&lt; 2.2</td>
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<tr>
<td>EG5</td>
<td>Sandflat, no eelgrass</td>
<td>&lt; 2.8</td>
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Table 5. Total abundance of fish species captured in four sampling events at sites EG1 to EG5 between spring 2012 and winter 2013 (Eelgrass Fish Community Survey).

<table>
<thead>
<tr>
<th>Species</th>
<th>Scientific Name</th>
<th>Spring</th>
<th>Summer</th>
<th>Fall</th>
<th>Winter</th>
<th>Total</th>
</tr>
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<tbody>
<tr>
<td>Common Name</td>
<td></td>
<td>EG1  EG2  EG3  EG4</td>
<td>EG1  EG2  EG3  EG4</td>
<td>EG1  EG2  EG3  EG4</td>
<td>EG1  EG2  EG3  EG4</td>
<td>EG1  EG2  EG3  EG4</td>
</tr>
<tr>
<td>Chinook salmon</td>
<td>Oncorhynchus tshawytscha</td>
<td>3   0   19   0</td>
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<td>0   0   0   0   0</td>
<td>0   0   0   0   0</td>
<td>39</td>
</tr>
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<td>Chum salmon</td>
<td>Oncorhynchus keta</td>
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<td>0   0   0   0   0</td>
<td>0   0   0   0   0</td>
<td>0   0   0   0   0</td>
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</tr>
<tr>
<td>Unident. salmon</td>
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<td>0   0   0   0   0</td>
<td>0   0   0   0   0</td>
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<tr>
<td>Threespine stickleback</td>
<td>Gasterosteus aculeatus</td>
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<td>0   1   1   0   0</td>
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<td>Shiner perch</td>
<td>Cymatogaster aggregata</td>
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<td>Clupea pallasi</td>
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<td>Surf smelt</td>
<td>Hypomesus pretiosus</td>
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<td>Pacific sand lance</td>
<td>Ammodytes hexapterus</td>
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<td>0   0   0   1   1</td>
<td>0   0   0   0   0</td>
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<td>Northern anchovy</td>
<td>Engraulis mordax</td>
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<td>0   0   0   0   0</td>
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<td>Pacific staghorn sculpin</td>
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<td>0   0   0   0   0</td>
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<td>Starry flounder</td>
<td>Platichthys stellatus</td>
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<td>0   0   0   0   0</td>
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<tr>
<td>Sand sole</td>
<td>Psettichthys melanosticus</td>
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<td>0   0   0   0   0</td>
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<td>Butter sole</td>
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<td>English sole</td>
<td>Parophrys vetulus</td>
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<td>Crescent gunnel</td>
<td>Pholis laeta</td>
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<td>0   0   1   0   0</td>
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<tr>
<td>Tubesnout</td>
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<tr>
<td>Plainfin midshipman</td>
<td>Porichthys notatus</td>
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<td><strong>Total</strong></td>
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### Table 6. Total abundance of fish species captured in two sampling events at sites EG1 to EG5 in spring 2013 and summer 2013 (juvenile salmon distribution survey).

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<th>Summer</th>
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<td>EG3</td>
<td>EG4</td>
<td>EG5</td>
<td>EG1</td>
<td>EG2</td>
<td>EG3</td>
<td>EG4</td>
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<td>Chinook salmon</td>
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<td>15</td>
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Table 7. Frequency of occurrence (number of seine hauls in which a species was captured divided by the total number of seines hauled x 100) for fish species caught in the six sampling events between spring 2012 and summer 2013 in eelgrass habitat at Roberts Bank.

<table>
<thead>
<tr>
<th>Species</th>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Spring 2012</th>
<th>Summer 2012</th>
<th>Fall 2012</th>
<th>Winter 2013</th>
<th>Spring 2013</th>
<th>Summer 2013</th>
<th>Total</th>
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<tbody>
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<td>Oncorhynchus keta</td>
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<td>Northern anchovy</td>
<td>Engraulis mordax</td>
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Table 8. Water quality parameters from six sampling events between spring 2012 and summer 2013.

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<th>Season</th>
<th>Year</th>
<th>Site</th>
<th>Tide</th>
<th>Temperature (ºC)</th>
<th>Salinity (ppt)</th>
<th>Dissolved Oxygen (mg/L)</th>
</tr>
</thead>
<tbody>
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<td>Spring</td>
<td>2012</td>
<td>EG1</td>
<td>Ebb</td>
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<td>Ebb</td>
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<td>17.4</td>
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<td>EG3</td>
<td>Ebb</td>
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<td>2012</td>
<td>EG4</td>
<td>Ebb</td>
<td>12.8</td>
<td>18.3</td>
<td>7.96</td>
</tr>
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<td>19.3</td>
<td>7.24</td>
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<td>Ebb</td>
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<td>Ebb</td>
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<td>Ebb</td>
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<td>Flood</td>
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<td>EG5</td>
<td>Flood</td>
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<td>18.09</td>
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Table 9. Water quality analysis of variance (ANOVA) model with interannual comparisons at sites sampled during the Eelgrass Fish Community Survey and juvenile salmon distribution survey on ebb tidal states. SS is sum of squares, df is degrees of freedom.

<table>
<thead>
<tr>
<th>Model</th>
<th>df</th>
<th>SS</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Temperature: spring 2012 and spring 2013</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A Temperature = year</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B Temperature = 1</td>
<td>1</td>
<td>1.12</td>
<td>0.497</td>
</tr>
<tr>
<td><strong>Temperature: summer 2012 and summer 2013</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C Temperature = year</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D Temperature = 1</td>
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<td>1.47</td>
<td>0.464</td>
</tr>
<tr>
<td><strong>Salinity: spring 2012 and spring 2013</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E Salinity = year</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F Salinity = 1</td>
<td>1</td>
<td>2.60</td>
<td>0.222</td>
</tr>
<tr>
<td><strong>Salinity: summer 2012 and summer 2013</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>G Salinity = year</td>
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<td></td>
</tr>
<tr>
<td>H Salinity = 1</td>
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<td>32.65</td>
<td>0.277</td>
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Table 10. Water quality analysis of variance (ANOVA) model with seasonal and habitat type comparisons at sites sampled during the Eelgrass Fish Community Survey and juvenile salmon distribution survey on ebb tidal states. SS is sum of squares, df is degrees of freedom.

<table>
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<th>Model</th>
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<th>SS</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Temperature both surveys</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A Temperature = season * habitat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B Temperature = season + habitat</td>
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<td>6.35</td>
<td>0.685</td>
</tr>
<tr>
<td>C Temperature = season</td>
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<td>2.96</td>
<td>0.365</td>
</tr>
<tr>
<td>D Temperature = 1</td>
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<td>455.28</td>
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</tr>
<tr>
<td><strong>Salinity both surveys (transformed)</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>E Salinity^2 = season * habitat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F Salinity^2 = season + habitat</td>
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</tr>
<tr>
<td>G Salinity^2 = season</td>
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</tr>
<tr>
<td>H^1 Salinity^2 = habitat</td>
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<td>957634.00</td>
<td>&lt;0.001*</td>
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<td><strong>Dissolved oxygen Eelgrass Fish Community Survey</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>I Log(Dissolved oxygen) = season * habitat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>J Log(Dissolved oxygen) = season + habitat</td>
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<td>0.510</td>
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<tr>
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<td>L Log(Dissolved oxygen) = 1</td>
<td>3</td>
<td>0.33</td>
<td>&lt;0.001*</td>
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^1Compared to Model F
Table 11. Water quality analysis of variance (ANOVA) model with seasonal, habitat type, and tidal state comparisons at sites sampled during the juvenile salmon distribution survey on ebb and flood tidal states. SS is sum of squares, df is degrees of freedom.

<table>
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<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Temperature</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A Temperature = season * habitat * tide</td>
<td>2</td>
<td>7.86</td>
<td>0.280</td>
</tr>
<tr>
<td>B Temperature = season * habitat + season * tide + habitat * tide</td>
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<td>0.80</td>
<td>0.884</td>
</tr>
<tr>
<td>C Temperature = season * tide + habitat * tide</td>
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<td>1.41</td>
<td>0.775</td>
</tr>
<tr>
<td>D Temperature = season * tide + habitat</td>
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<td>1.86</td>
<td>0.387</td>
</tr>
<tr>
<td>E Temperature = season + tide + habitat</td>
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<td>0.42</td>
<td>0.678</td>
</tr>
<tr>
<td>F Temperature = season + habitat</td>
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</tr>
<tr>
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<td>89.47</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>H Temperature = 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Salinity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I Salinity$^2$ = season * habitat * tide</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>J Salinity$^2$ = season * habitat + season * tide + habitat * tide</td>
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<td>35813</td>
<td>0.002*</td>
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</table>

Table 12. Fish abundance and species richness generalised linear models (GLM) with seasonal and habitat type comparisons at all sites sampled by beach seine in spring, summer and fall 2012 and winter 2013 during the Eelgrass Fish Community Survey. df is degrees of freedom.

<table>
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<tr>
<th>Model</th>
<th>df</th>
<th>Deviance</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fish abundance (negative binomial distribution)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A Fish abundance = habitat * season</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B Fish abundance = habitat + season</td>
<td>5</td>
<td>1103.80</td>
<td>0.076</td>
</tr>
<tr>
<td>C Fish abundance = season</td>
<td>2</td>
<td>516.37</td>
<td>0.239</td>
</tr>
<tr>
<td>D Fish abundance = 1</td>
<td>3</td>
<td>1034.00</td>
<td>0.228</td>
</tr>
<tr>
<td><strong>Fish species richness (Poisson distribution)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E Species richness = habitat *</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F Species richness = habitat +</td>
<td>5</td>
<td>12.62</td>
<td>0.027*</td>
</tr>
</tbody>
</table>
Table 13. Fish evenness and species diversity Analysis of Variance (ANOVA) models with seasonal and habitat type comparisons at all sites sampled by beach seine in spring, summer and fall 2012 and winter 2013 during the Eelgrass Fish Community Survey. df is degrees of freedom. SS is sum of squares. Evenness scores could only be calculated for the spring and summer seasons.

<table>
<thead>
<tr>
<th>Model</th>
<th>df</th>
<th>SS</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish evenness (transformed): only spring and summer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A Evenness$^2$ = habitat * season</td>
<td>1</td>
<td>0.02</td>
<td>0.619</td>
</tr>
<tr>
<td>B Evenness$^2$ = habitat + season</td>
<td>2</td>
<td>0.12</td>
<td>0.387</td>
</tr>
<tr>
<td>C Evenness$^2$ = season</td>
<td>1</td>
<td>1.22</td>
<td>&lt;0.001$^*$</td>
</tr>
<tr>
<td>Fish diversity (transformed)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E Sqrt(Diversity) = habitat * season</td>
<td>10.127</td>
<td>0.727</td>
<td></td>
</tr>
<tr>
<td>F Sqrt(Diversity) = habitat + season</td>
<td>2</td>
<td>0.05</td>
<td>0.876</td>
</tr>
<tr>
<td>G Sqrt(Diversity) = season</td>
<td>3</td>
<td>1.66</td>
<td>0.027$^*$</td>
</tr>
</tbody>
</table>

Table 14. Species and abundances for fish sampled in four sampling events between spring 2012 and winter 2013 (Eelgrass Fish Community Survey), summarised from SIMPER.

<table>
<thead>
<tr>
<th>Species</th>
<th>Average Abundance</th>
<th>Total Cumulative % Contribution to Grouping</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Common Name</strong></td>
<td><strong>Latin Name</strong></td>
<td><strong>Spring 2012</strong></td>
</tr>
<tr>
<td>Surf smelt</td>
<td>Hypomesus pretiosus</td>
<td>50.0</td>
</tr>
<tr>
<td>Chinook salmon</td>
<td>Oncorhynchus tshawytscha</td>
<td>1.1</td>
</tr>
<tr>
<td>Shiner perch</td>
<td>Cymatogaster aggregata</td>
<td>3.2</td>
</tr>
<tr>
<td>Threespine stickleback</td>
<td>Gasterosteus aculeatus</td>
<td>0.67</td>
</tr>
<tr>
<td>Surf smelt</td>
<td>Hypomesus pretiosus</td>
<td>0.7</td>
</tr>
<tr>
<td>Surf smelt</td>
<td>Hypomesus pretiosus</td>
<td>48.5</td>
</tr>
</tbody>
</table>
Table 15. Fish abundance and species richness generalised linear models (GLM) with seasonal, habitat type, and tidal state comparisons at all sites sampled by beach seine in spring and summer 2013 during the juvenile salmon distribution survey. df is degrees of freedom.

<table>
<thead>
<tr>
<th>Model</th>
<th>df</th>
<th>Deviance</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fish abundance (negative binomial distribution)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A Abundance = habitat * season * tide</td>
<td>2</td>
<td>372.31</td>
<td>0.180</td>
</tr>
<tr>
<td>B Abundance = habitat * season + habitat * tide + season * tide</td>
<td>2</td>
<td>164.91</td>
<td>0.495</td>
</tr>
<tr>
<td>C Abundance = habitat * season + habitat * tide</td>
<td>1</td>
<td>0.61</td>
<td>0.943</td>
</tr>
<tr>
<td>D Abundance = habitat * season + tide</td>
<td>2</td>
<td>208.75</td>
<td>0.396</td>
</tr>
<tr>
<td>E Abundance = habitat + season + tide</td>
<td>1</td>
<td>227.39</td>
<td>0.166</td>
</tr>
<tr>
<td>F Abundance = habitat + tide</td>
<td>2</td>
<td>863.46</td>
<td>0.038*</td>
</tr>
<tr>
<td>G Abundance = tide</td>
<td>1</td>
<td>664.23</td>
<td>0.025*</td>
</tr>
<tr>
<td><strong>Fish species richness (Poisson distribution)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I Species richness = habitat * season * tide</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>J Species richness = habitat * season + habitat * tide + season * tide</td>
<td>2</td>
<td>8.42</td>
<td>0.015*</td>
</tr>
<tr>
<td>K Species richness = habitat * season + habitat * tide</td>
<td>1</td>
<td>0.01</td>
<td>0.911</td>
</tr>
<tr>
<td>L Species richness = season + habitat * tide</td>
<td>2</td>
<td>0.34</td>
<td>0.842</td>
</tr>
<tr>
<td>M Species richness = season + habitat + tide</td>
<td>2</td>
<td>1.29</td>
<td>0.524</td>
</tr>
<tr>
<td>N Species richness = habitat + tide</td>
<td>1</td>
<td>3.79</td>
<td>0.052</td>
</tr>
<tr>
<td>O Species richness = habitat</td>
<td>1</td>
<td>13.64</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>P Species richness = tide</td>
<td>2</td>
<td>16.96</td>
<td>&lt;0.001*</td>
</tr>
</tbody>
</table>

1 Compared to Model F
2 Compared to Model N
Table 16. Fish evenness and species diversity Analysis of Variance (ANOVA) models with seasonal, habitat type, and tidal state comparisons at all sites sampled by beach seine in spring and summer 2013 during the juvenile salmon distribution survey. df is degrees of freedom. SS is sum of squares.

<table>
<thead>
<tr>
<th>Model</th>
<th>df</th>
<th>SS</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish evenness (transformed)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A Sqrt(Evenness) = habitat * season * tide</td>
<td>1</td>
<td>0.01</td>
<td>0.660</td>
</tr>
<tr>
<td>B Sqrt(Evenness) = habitat * season + habitat * tide + season * tide</td>
<td>1</td>
<td>0.01</td>
<td>0.908</td>
</tr>
<tr>
<td>C Sqrt(Evenness) = habitat * season + season * tide</td>
<td>2</td>
<td>0.01</td>
<td>0.847</td>
</tr>
<tr>
<td>D Sqrt(Evenness) = habitat * season + tide</td>
<td>1</td>
<td>0.02</td>
<td>0.527</td>
</tr>
<tr>
<td>E Sqrt(Evenness) = habitat * season</td>
<td>1</td>
<td>&lt;0.01</td>
<td>0.877</td>
</tr>
<tr>
<td>F Sqrt(Evenness) = habitat + season</td>
<td>2</td>
<td>0.40</td>
<td>0.230</td>
</tr>
<tr>
<td>Fish diversity (transformed)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G Sqrt(Diversity) = habitat * season * tide</td>
<td>1</td>
<td>0.27</td>
<td>0.114</td>
</tr>
<tr>
<td>H Sqrt(Diversity) = habitat * season + habitat * tide + season * tide</td>
<td>1</td>
<td>0.27</td>
<td>0.970</td>
</tr>
<tr>
<td>I Sqrt(Diversity) = habitat * season + season * tide</td>
<td>2</td>
<td>0.39</td>
<td>0.970</td>
</tr>
<tr>
<td>J Sqrt(Diversity) = habitat * season + tide</td>
<td>1</td>
<td>&lt;0.01</td>
<td>0.966</td>
</tr>
<tr>
<td>K Sqrt(Diversity) = habitat * season</td>
<td>1</td>
<td>0.21</td>
<td>0.970</td>
</tr>
<tr>
<td>L Sqrt(Diversity) = habitat + season</td>
<td>2</td>
<td>0.39</td>
<td>0.970</td>
</tr>
<tr>
<td>M Sqrt(Diversity) = season</td>
<td>2</td>
<td>0.10</td>
<td>0.970</td>
</tr>
<tr>
<td>N Sqrt(Diversity) = 1</td>
<td>1</td>
<td>0.82</td>
<td>0.006*</td>
</tr>
</tbody>
</table>

Table 17. Species and abundances for fish sampled in two sampling events in spring 2013 and summer 2013 (juvenile salmon distribution survey), summarised from SIMPER.

<table>
<thead>
<tr>
<th>Species</th>
<th>Average Abundance</th>
<th>Total Cumulative % Contribution to Grouping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common Name</td>
<td>Latin Name</td>
<td></td>
</tr>
<tr>
<td>Surf smelt</td>
<td>Hypomesus pretiosus</td>
<td>83.4</td>
</tr>
<tr>
<td>Shiner perch</td>
<td>Cymatogaster aggregata</td>
<td>42.1</td>
</tr>
<tr>
<td>Threespine stickleback</td>
<td>Gasterosteus aculeatus</td>
<td>6.2</td>
</tr>
</tbody>
</table>
Table 18. Individual species abundance generalised linear models (GLM) with seasonal and habitat type comparisons at all sites sampled by beach seine during both the Eelgrass Fish Community Survey and the juvenile salmon distribution survey. df is degrees of freedom.

<table>
<thead>
<tr>
<th>Model</th>
<th>df</th>
<th>Deviance</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Surf smelt abundance Eelgrass Fish Community Survey</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A Abundance = habitat * season</td>
<td>5</td>
<td>823.98</td>
<td>0.147</td>
</tr>
<tr>
<td>B Abundance = habitat + season</td>
<td>2</td>
<td>565.79</td>
<td>0.145</td>
</tr>
<tr>
<td>C Abundance = season</td>
<td>3</td>
<td>1893.70</td>
<td>0.031*</td>
</tr>
<tr>
<td><strong>Surf smelt abundance Juvenile Salmon Distribution Survey</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E Abundance = habitat * season</td>
<td>2</td>
<td>323.33</td>
<td>0.284</td>
</tr>
<tr>
<td>F Abundance = habitat + season</td>
<td>2</td>
<td>430.49</td>
<td>0.266</td>
</tr>
<tr>
<td>G Abundance = season</td>
<td>2</td>
<td>2380.70</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>H Abundance = 1</td>
<td>3</td>
<td>1893.70</td>
<td>0.031*</td>
</tr>
<tr>
<td><strong>Shiner perch abundance Eelgrass Fish Community Survey – only caught in summer season</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I Abundance = habitat</td>
<td>2</td>
<td>44.71</td>
<td>0.189</td>
</tr>
<tr>
<td>J Abundance = 1</td>
<td>1</td>
<td>2.34</td>
<td>0.278</td>
</tr>
<tr>
<td>K Abundance = habitat</td>
<td>1</td>
<td>16.48</td>
<td>0.021*</td>
</tr>
<tr>
<td>L Abundance = habitat + season</td>
<td>2</td>
<td>5.85</td>
<td>0.299</td>
</tr>
<tr>
<td>M Abundance = season</td>
<td>2</td>
<td>108.71</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>N Abundance = habitat</td>
<td>2</td>
<td>1580.80</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td><strong>Chinook salmon abundance Eelgrass Fish Community Survey</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O Abundance = habitat * season</td>
<td>1</td>
<td>0.50</td>
<td>0.624</td>
</tr>
<tr>
<td>P Abundance = habitat + season</td>
<td>2</td>
<td>2.34</td>
<td>0.278</td>
</tr>
<tr>
<td>Q Abundance = season</td>
<td>2</td>
<td>16.48</td>
<td>0.021*</td>
</tr>
<tr>
<td>R Abundance = 1</td>
<td>1</td>
<td>1.50</td>
<td>0.624</td>
</tr>
<tr>
<td>S Abundance = habitat</td>
<td>1</td>
<td>2.34</td>
<td>0.278</td>
</tr>
<tr>
<td>T Abundance = habitat + season</td>
<td>2</td>
<td>16.48</td>
<td>0.021*</td>
</tr>
<tr>
<td><strong>Chinook salmon abundance Juvenile Salmon Distribution Survey</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U Abundance = habitat</td>
<td>2</td>
<td>2.34</td>
<td>0.278</td>
</tr>
<tr>
<td>V Abundance = 1</td>
<td>2</td>
<td>12.11</td>
<td>0.172</td>
</tr>
<tr>
<td>W Abundance = habitat * season</td>
<td>2</td>
<td>19.85</td>
<td>0.087</td>
</tr>
<tr>
<td>X Abundance = habitat + season</td>
<td>2</td>
<td>108.71</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Y Abundance = season</td>
<td>1</td>
<td>211.45</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Z Abundance = habitat</td>
<td>1</td>
<td>133.92</td>
<td>&lt;0.001*</td>
</tr>
</tbody>
</table>

1 Compared to Model L
2 Compared to Model X
3 Compared to Model B1
Table 19. Surf smelt (*Hypomesus pretiosus*) fork length Kruskal-Wallis non-parametric models with seasonal and habitat type comparisons at all sites sampled by beach seine during the Eelgrass Fish Community Survey. Kruskal-Wallis only allows comparisons of main factors and not interaction effects. df is degrees of freedom.

<table>
<thead>
<tr>
<th>Model</th>
<th>df</th>
<th>χ²</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surf smelt length Eelgrass Fish Community Survey</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A Length = habitat</td>
<td>1</td>
<td>8.22</td>
<td>0.004*</td>
</tr>
<tr>
<td>B Length = season</td>
<td>2</td>
<td>42.91</td>
<td>&lt;0.001*</td>
</tr>
</tbody>
</table>

Table 20. Chinook salmon (*Oncorhynchus tshawytscha*) fork length Analysis of Variance (ANOVA) models with interannual, seasonal, and habitat type comparisons at all sites sampled by beach seine during both the Eelgrass Fish Community Survey and juvenile salmon distribution survey. df is degrees of freedom.

<table>
<thead>
<tr>
<th>Model</th>
<th>df</th>
<th>SS</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinook salmon length in both surveys</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A Length = year</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B Length = 1</td>
<td>1</td>
<td>1196.30</td>
<td>0.001*</td>
</tr>
<tr>
<td>Chinook salmon length Eelgrass Fish Community Survey</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C 1/sqrt(length) = habitat * season</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D 1/sqrt(length) = habitat + season</td>
<td>1</td>
<td>&lt;0.01</td>
<td>0.467</td>
</tr>
<tr>
<td>E 1/sqrt(length) = season</td>
<td>2</td>
<td>&lt;0.01</td>
<td>0.641</td>
</tr>
<tr>
<td>F 1/sqrt(length) = 1</td>
<td>1</td>
<td>&lt;0.01</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Chinook salmon length Juvenile Salmon Distribution Survey</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G Length = habitat * season</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H Length = habitat + season</td>
<td>1</td>
<td>71.35</td>
<td>0.400</td>
</tr>
<tr>
<td>I Length = habitat</td>
<td>1</td>
<td>132.86</td>
<td>0.249</td>
</tr>
<tr>
<td>J Length = 1</td>
<td>2</td>
<td>1054.50</td>
<td>0.005*</td>
</tr>
</tbody>
</table>
Table 21. Fish abundance and species richness generalised linear models (GLM) with interannual and site comparisons at sites EG2 and EG4 sampled by beach seine in summer 2008 as part of the Martel (2009) survey and summer 2012 as part of the Eelgrass Fish Community Survey. df is degrees of freedom.

<table>
<thead>
<tr>
<th>Model</th>
<th>df</th>
<th>Deviance</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fish abundance (negative binomial distribution)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A Fish abundance = site * year</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B Fish abundance = site + year</td>
<td>1</td>
<td>0.16</td>
<td>0.910</td>
</tr>
<tr>
<td>C Fish abundance = site</td>
<td>1</td>
<td>182.93</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>D Fish abundance = year</td>
<td>1</td>
<td>177.09</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td><strong>Fish species richness (negative binomial distribution)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E Species richness = site * year</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F Species richness = site + year</td>
<td>1</td>
<td>&lt;0.01</td>
<td>0.973</td>
</tr>
<tr>
<td>G Species richness = site</td>
<td>1</td>
<td>0.17</td>
<td>0.494</td>
</tr>
<tr>
<td>H Species richness = 1</td>
<td>1</td>
<td>4.30</td>
<td>&lt;0.001*</td>
</tr>
</tbody>
</table>

1 Compared to Model B

Table 22. Fish evenness and species diversity Analysis of Variance (ANOVA) models with interannual and site comparisons at sites EG2 and EG4 sampled by beach seine in summer 2008 as part of the Martel (2009) survey and summer 2012 as part of the Eelgrass Fish Community Survey. df is degrees of freedom. SS is sum of squares.

<table>
<thead>
<tr>
<th>Model</th>
<th>df</th>
<th>SS</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fish evenness (transformed)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A Evenness (^3) = site * year</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B Evenness (^3) = site + year</td>
<td>1</td>
<td>0.09</td>
<td>0.216</td>
</tr>
<tr>
<td>C Evenness (^3) = year</td>
<td>1</td>
<td>0.08</td>
<td>0.248</td>
</tr>
<tr>
<td>D Evenness (^3) = 1</td>
<td>1</td>
<td>0.44</td>
<td>0.008*</td>
</tr>
<tr>
<td><strong>Fish diversity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E Diversity = site * year</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F Diversity = site + year</td>
<td>1</td>
<td>0.03</td>
<td>0.660</td>
</tr>
<tr>
<td>G Diversity = year</td>
<td>1</td>
<td>0.24</td>
<td>0.157</td>
</tr>
<tr>
<td>H Diversity = 1</td>
<td>1</td>
<td>0.14</td>
<td>0.303</td>
</tr>
</tbody>
</table>
Table 23. Species and abundances for fish sampled in summer 2008 and summer 2012 at site EG2 and EG4, summarised from SIMPER.

<table>
<thead>
<tr>
<th>Species</th>
<th>Average Abundance</th>
<th>Total Cumulative % Contribution to Grouping</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Common Name</strong></td>
<td><strong>Latin Name</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Summer 2008 Site EG2</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>English sole</td>
<td>Parophrys vetulus</td>
<td>13.0</td>
</tr>
<tr>
<td><strong>Summer 2008 Site EG4</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shiner perch</td>
<td>Cymatogaster aggregata</td>
<td>55.0</td>
</tr>
<tr>
<td>Saddleback gunnel</td>
<td>Pholis ornata</td>
<td>14.7</td>
</tr>
<tr>
<td>Threespine stickleback</td>
<td>Gasterosteus aculeatus</td>
<td>19.3</td>
</tr>
<tr>
<td><strong>Summer 2012 Site EG2</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shiner perch</td>
<td>Cymatogaster aggregata</td>
<td>2.0</td>
</tr>
<tr>
<td>Chinook salmon</td>
<td>Oncorhynchus tshawytscha</td>
<td>0.7</td>
</tr>
<tr>
<td><strong>Summer 2012 Site EG4</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shiner perch</td>
<td>Cymatogaster aggregata</td>
<td>13.3</td>
</tr>
<tr>
<td>Starry flounder</td>
<td>Platichthys stellatus</td>
<td>3.3</td>
</tr>
<tr>
<td>Saddleback gunnel</td>
<td>Pholis ornata</td>
<td>1.7</td>
</tr>
</tbody>
</table>

Table 24. Shiner perch (*Cymatogaster aggregata*) and threespine stickleback (*Gasterosteus aculeatus*) fork length Analysis of Variance (ANOVA) models with interannual comparisons at sites EG2 and EG4 sampled by beach seine in summer 2008 as part of the Martel (2009) survey and summer 2012 as part of the Eelgrass Fish Community Survey. df is degrees of freedom.

<table>
<thead>
<tr>
<th>Model</th>
<th>df</th>
<th>SS</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Shiner perch length (transformed)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A  Sqrt(length) = year</td>
<td></td>
<td></td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>B  Sqrt(length) = 1</td>
<td>1</td>
<td>92.51</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td><strong>Threespine stickleback length (transformed)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C  1/Sqrt(length) = year</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D  1/Sqrt(length) = 1</td>
<td>1</td>
<td>0.05</td>
<td>&lt;0.001*</td>
</tr>
</tbody>
</table>
Table 25. Seasonal distribution of fish species in eelgrass habitat at Roberts Bank. Light grey shading represents historic fish seasonal distribution, dark grey shading represents where 2012 and 2013 baseline surveys overlapped with historic fish distribution, and light blue shading represents new seasonal distribution or presence of fish species not previously documented.

<table>
<thead>
<tr>
<th>Species</th>
<th>Common name</th>
<th>Latin name</th>
<th>Spring</th>
<th>Summer</th>
<th>Fall</th>
<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mar</td>
<td>Apr</td>
<td>May</td>
<td>June</td>
</tr>
<tr>
<td>Chum salmon</td>
<td>Oncorhynchus keta</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chinook salmon</td>
<td>Oncorhynchus tshawytscha</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pink salmon</td>
<td>Oncorhynchus gorbuscha</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sockeye salmon</td>
<td>Oncorhynchus nerka</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coho salmon</td>
<td>Oncorhynchus kisutch</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Threespine stickleback</td>
<td>Gasterosteus aculeatus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pacific sand lance</td>
<td>Ammodytes hexapterus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surf smelt</td>
<td>Hypomesus pretiosus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Longfin smelt</td>
<td>Spirinchus thaleichthys</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northern anchovy</td>
<td>Engraulis mordax</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pacific herring</td>
<td>Clupea pallasi</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capelin</td>
<td>Mallatus villosus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pacific staghorn sculpin</td>
<td>Leptocottus armatus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Padded sculpin</td>
<td>Artedius fenestralis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silverspotted sculpin</td>
<td>Blepsias cirrhosus</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Spinyrose sculpin</td>
<td>Radulinus taylori</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Sharpnose sculpin</td>
<td>Clinocottus acuticeps</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Smoothhead sculpin</td>
<td>Artedius lateralis</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Saddleback sculpin</td>
<td>Oligocottus rimensis</td>
<td></td>
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<tr>
<td>Buffalo sculpin</td>
<td>Enophrys bison</td>
<td></td>
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</tr>
<tr>
<td>Great sculpin</td>
<td>Myxocephalus polyacanthocephalus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tidepool sculpin</td>
<td>Oligocottus maculosus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tadpole sculpin</td>
<td>Psychrolutes paradoxus</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Rosylip sculpin</td>
<td>Ascelichthys rhodorus</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Coast range sculpin</td>
<td>Cottus aleuticus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Starry flounder</td>
<td>Platichthys stellatus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand sole</td>
<td>Psettichthys melanosictus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Butter sole</td>
<td>Pleuronectes isolepis</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Table 25 continued. Seasonal distribution of fish species in eelgrass habitat at Roberts Bank. Light grey shading represents historic fish seasonal distribution, dark grey shading represents where 2012 and 2013 baseline surveys overlapped with historic fish distribution, and light blue shading represents new seasonal distribution or presence of fish species not previously documented.

<table>
<thead>
<tr>
<th>Common name</th>
<th>Species</th>
<th>Spring</th>
<th>Summer</th>
<th>Fall</th>
<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td>English sole</td>
<td>Parophrys vetulus</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pacific sandab</td>
<td>Citharichthys sordidus</td>
<td></td>
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</tr>
<tr>
<td>Speckled sanddab</td>
<td>Citharichthys stigmaeus</td>
<td></td>
<td></td>
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<tr>
<td>Rock sole</td>
<td>Lepidopsetta petraborealis</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>C-O sole</td>
<td>Pleuronichthys coenosus</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flathead sole</td>
<td>Hippoglossoides elassodon</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shiner perch</td>
<td>Cymatogaster aggregata</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pile perch</td>
<td>Rhacochilus vacca</td>
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<tr>
<td>Striped surperch</td>
<td>Embiotoca lateralis</td>
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<tr>
<td>Pacific snake prickleback</td>
<td>Lumpenus sagitta</td>
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<tr>
<td>Plainfin midshipman</td>
<td>Porichthys notatus</td>
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</tr>
<tr>
<td>Penpoint gunnel</td>
<td>Apodichthys flavidus</td>
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<tr>
<td>Crescent gunnel</td>
<td>Pholis laeta</td>
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<tr>
<td>Saddleback gunnel</td>
<td>Pholis ornata</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Rockweed gunnel</td>
<td>Apodichthys fucorum</td>
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<tr>
<td>Bay pipefish</td>
<td>Syngnathus leptorhynchos</td>
<td></td>
<td></td>
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<tr>
<td>Tubesnout</td>
<td>Aulorrhynchus flavidus</td>
<td></td>
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</tr>
<tr>
<td>Whitespotted greenling</td>
<td>Hexagrammos stelleri</td>
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</tr>
<tr>
<td>Kelp greenling</td>
<td>Hexagrammos decagrammus</td>
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</tr>
<tr>
<td>Masked greenling</td>
<td>Hexagrammos octogrammus</td>
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</tr>
<tr>
<td>Pacific tomcod</td>
<td>Microgadus proximus</td>
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<tr>
<td>Arrow goby</td>
<td>Clevelandia ios</td>
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<tr>
<td>Rockfish sp.</td>
<td>Sebastes sp.</td>
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<tr>
<td>Sturgeon poacher</td>
<td>Agonus acipenserinus</td>
<td></td>
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<tr>
<td>Northern spearnose poacher</td>
<td>Agonopsis vula</td>
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<tr>
<td>Slender cockscomb</td>
<td>Anoplarchus insignis</td>
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</tr>
<tr>
<td>High cockscomb</td>
<td>Anoplarchus purpurescens</td>
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</tr>
<tr>
<td>Tidepool snailfish</td>
<td>Liparis florae</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Lobefin snailfish</td>
<td>Liparis greeni</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
APPENDIX A

Photographs
Photo 1. Seine at site EG3 in April 2012 during the Eelgrass Fish Community Survey.

Photo 2. Seine at site EG4 in April 2013 during the juvenile salmon distribution survey.
Photo 3. Seine at site EG4 in June 2012 during the Eelgrass Fish Community Survey.

Photo 4. Seine at site EG4 in June 2012 during the Eelgrass Fish Community Survey.
Photo 5. Boat based seine at site EG1 in June 2013 during the juvenile salmon distribution survey.

Photo 6. Boat based seine at site EG1 in January 2013 during the Eelgrass Fish Community Survey.
Photo 7. Surf smelt (*Hypomesus pretiosus*) caught at EG1 April 2012.


Photo 10. Starry flounder (*Platichthys stellatus*) caught at EG3 April 2012.


Photo 15. Threespine stickleback (*Gasterosteus aculeatus*) caught at EG1 June 2013.

Photo 16. Adult shiner perch (*Cymatogaster aggregata*) caught at EG2 June 2012.

Photo 17. Pacific herring (*Clupea pallasi*) caught at EG3 June 2012.


Photo 20. Tubesnout (*Aulorhynchus flavidus*) at EG1 April 2013.