APPENDIX AIR10-C
Technical Data Reports Containing Habitat Maps at Local and Regional Scales

TDR MF-6 - Marine Fish
Benthic Fish Trawl Survey TDR

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Technical Data Report

Roberts Bank Terminal 2 Project

Marine Fish

Benthic Fish Trawl Survey

December 2014

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Technical Report/Technical Data Report Disclaimer

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

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

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

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

Acknowledgements

Field work conducted by Jeff Reynolds, Steven Roias, Kevin Romanin, Jen Paton, Margo Elfert, Jen Tyler, Matt Drake, Ashley Park, Ross Wetzel, and Dave Wheeler is greatly appreciated.

Executive Summary

The Benthic Fish Trawl Survey was conducted as part of the environmental assessment for the proposed Roberts Bank Terminal 2 Project (Project or RBT2), and focused on collecting information to develop 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.

Roberts Bank has a diverse fish community, including many species of flatfish, which are highly mobile and have varied habitat preferences depending on season or life history stage. The seabed within the proposed RBT2 footprint and immediate vicinity (0 to 30 m depth chart datum (CD)) is predominantly sandy subtidal habitat, with over 50% of the area inhabited by orange sea pen (*Ptilosarcus gurneyi*) at varying densities. Benthic fish use of the intertidal and subtidal sand habitat at Roberts Bank has been documented in previous studies.

Trawl studies conducted in 2003 and 2004 within the proposed RBT2 footprint involved collection of data across, rather than parallel to, depth strata; therefore, examining historical catch composition by depth was not possible. The purpose of the Benthic Fish Trawl Survey was to document and compare seasonal use, by depth strata, of the subtidal sand habitat by benthic fish that may be affected by activities associated with the proposed RBT2 project.

Benthic fish sampling was conducted with an otter trawl at 11 locations, at different depth strata inside and out of the proposed Project footprint. Four sampling events were conducted seasonally over a one-year period: summer 2012; fall 2012; winter 2012/2013; and spring 2013. Of the nine benthic fish trawl sites (three in each of the depth strata) originally selected for the summer 2012 survey, only three sites were fished due to intensive commercial crab fishing in the area. Consequently, two new sites outside the commercial crab fishing area were added to the summer survey and all 11 sites were fished in the remaining surveys. The 11 sites were located across three different depth strata and gradients: 0 to 5 m depth CD on a relatively flat area; 5 to 10 m depth CD on a shallow slope; and 10 to 25 m depth CD on a steeper slope. Six of the 11 sites were located in the proposed RBT2 fill and dredge footprint. Eight of the sites were located in areas with sea pens at varying density and distributions.

All fish captured were identified and enumerated, and a subsample of up to 30 of each species were measured. A ponar grab (8.2 L volume) was used to collect sediment samples at each of the trawl sites to quantitatively assess substrate type. Incidental capture of macroinvertebrates were also identified and enumerated.

A total of 3,312 fish representing 40 species were captured over the four sampling events. Flatfish comprised the largest proportion (75%) of catch and consisted of nine species: English sole (*Parophrys vetulus*); Pacific sanddab (*Citharichthys sordidus*); speckled sanddab (*C. stigmaeus*); rock sole

(*Lepidopsetta bilineata*); starry flounder (*Platichthys stellatus*); Dover sole (*Microstomus pacificus*); butter sole (*Pleuronectes isolepis*); sand sole (*Psettichthys melanostictus*); and flathead sole (*Hippoglossoides elassodon*). English sole and sanddab species dominated the catch in most of the tows across all sites and seasons, comprising 40% and 25% of total catch respectively. The majority (> 65%) of flatfish species caught were juveniles, suggesting that Roberts Bank provides rearing habitat. Many of the flatfish species and other fish were caught in low abundance and not in all seasons, indicating that they may only be utilising sandflat habitat at Roberts Bank on a seasonal or transient basis.

Fish species richness (number of species), evenness (relative abundance of each species in an area), diversity (index calculated from the number of species in an area and their relative abundance), densities (number of fish/area), and fish community assemblages were compared between seasons and different habitat types (i.e., depth strata, substrate type, and sea pen benthic distribution). For flatfish species caught in highest abundance during the survey, individual comparisons of density and length measurements between different seasons and habitats were conducted.

Seasonal differences in density, species richness, and other parameters were observed. Benthic fish density was highest in the summer, while density, richness, and diversity was lowest in the winter, when species evenness was highest. Species assemblages varied significantly by season, with some species predominating in different seasons.

Data analysis showed differences in fish distribution in relation to depth. Fish density, species richness, and species diversity were all lower at the shallowest sites (0 to 5 m). Some species showed greater association with different depth strata. English sole, sanddab species, and rock sole densities increased with depth. Tidal state did not appear to influence any of the fish parameters.

Substrate type influenced fish community assemblages, with differences observed between communities collected at sites with sand and mud substrates versus those with any gravel content. The density of benthic fish was higher in predominantly sand substrate than substrates with a mix of sand, mud and/or gravel.

The densities of the most common flatfish observed (i.e., English sole, sanddab species, and rock sole), were highest at the most eastern sites located closest to Roberts Bank terminals and artificial reefs.

Benthic fish density (as well as for rock sole and sanddab species separately), was significantly higher in areas with continuous to dense sea pen distribution as compared to areas with no sea pens.

This survey identified significant seasonal and habitat differences in benthic fish density and distribution, and was the only survey conducted in the vicinity of the proposed terminal that specifically addressed benthic fish use, in particular flatfish, related to depth strata.

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1 Introduction

This section provides project background information and an overview of the Benthic Fish Trawl 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. (Archipelago) to undertake marine fish and fish habitat studies to inform a future effects assessment for the Project. This technical data report (TDR) describes the results of the Benthic Fish Trawl Survey.

1.2 Benthic Fish Trawl Survey Overview

A review of available information was completed for the Benthic Fish Trawl Survey to identify key data gaps within the Roberts Bank area. This TDR describes the study findings for key components identified from this gap analysis. Study components, major objectives, and a brief overview are provided in **Table 1**. The overall objective of this study was to ensure that sufficient information is available to inform a future effects assessment of the Project.

Roberts Bank has a diverse fish community. Use of the shallow subtidal sand habitat at Roberts Bank by benthic fish (fish that live on or near the sea floor) has been documented in studies from the late 1970s and 1980s (Greer et al. 1980, Levings et al. 1983, Gordon and Levings 1984, MacDonald 1984) and 2000s (Triton Environmental Consultants 2004, Hemmera 2009), with the most detailed work relevant to the RBT2 project area conducted for the Deltaport Third Berth (DP3) Environmental Assessment (Triton Environmental Consultants 2004). Flatfish caught by beam trawl in the vicinity of the proposed RBT2 footprint (2003/2004) over four seasons of surveys included starry flounder (*Platichthys stellatus*), rock sole (*Lepidopsetta bilineata*), sand sole (*Psettichthys melanostictus*) and juvenile flounders (Triton Environmental Consultants 2004). These species, along with Dover sole (*Microstomus pacificus*), English sole (*Parophrys vetulus*), and C-O sole *(Pleuronichthys coenosus*), were also observed on towed underwater video collected in early September 2003 (Triton Environmental Consultants 2004).

Trawl studies conducted in 2003 and 2004 within the proposed RBT2 footprint involved fishing across depth strata (i.e., shallow to deep; Triton Environmental Consultants 2004); therefore, determining catch composition by specific depth strata was not possible. The purpose of the Benthic Fish Trawl Survey was to document benthic fish seasonal use (i.e., summer, fall, winter, and spring) of the shallow subtidal sand habitat by specific depth strata in areas that may potentially be affected by the RBT2 project.

Table 1. Benthic Fish Trawl Survey components and major objectives.

Component	Major Objective	Brief Overview
Review of available literature	Build a seasonal species list for benthic fish that have been documented utilising Roberts Bank.	Identify key papers from studies between 1979 to 2011 that include fish sampling at Roberts Bank and extract benthic fish distribution and abundance data.
Benthic Fish Trawl Surveys (2012 to 2013)	Document and compare seasonal benthic fish use in the sandflat and slope environments south and southwest of the existing Roberts Bank terminals at a range of depths (0 to 25 m depth CD).	Capture benthic fish species at numerous sites in the study area, across three depth strata (0 to 5 m, 5 to 10 m, and 10 to 25 m), and in four seasons (August 2012, November 2012, February 2013, and April 2013). Analyse differences in fish parameters by season and habitat type (depth strata, substrate type, and sea pen (*Ptilosarcus gurneyi*) distribution). Parameters include: • Density (number of fish/area); • Richness (number of species); • Evenness (relative abundance of each species in an area); • Diversity (index calculated from the number of species in an area and their relative abundance); • Fish species assemblages; and • Size of fish.
	Characterise fish habitat at each trawl location in each season.	Obtain two sediment samples per site to characterise sediment particle sizes. Sample water quality parameters including temperature, salinity, and dissolved oxygen. Relate observed habitat characteristics to fish parameters.
Integrate historical data	Use historical and current baseline data to identify benthic fish species potentially affected by RBT2 project construction.	Compare and collate historical benthic fish species occurrence at Roberts Bank with benthic fish species collected in the current (2012/2013) baseline survey.

2 Review of Available Literature and Data

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

2.1 Flatfish

Flatfish species present along the Pacific Coast of North America belong to two broad categories: right-eyed flounders (family Pleuronectidae); and left-eyed flounders (family Bothidae). A total of 31 species of right-eyed flounders are found along the Pacific Coast including several commercially important species such as Pacific halibut (*Hippoglossus stenolepis*), arrowtooth flounder (*Atheresthes stomias*), Dover sole, rock sole, English sole, and petrale sole (*Eopsetta jordani*) (Kramer 1995). Two species of left-eyed flounders are found along the Pacific Coast, namely Pacific sanddab (*Citharichthys sordidus*) and speckled sanddab (*C. stigmaeus*), neither of which are commercially targeted in B.C. (Lamb and Edgell 1986). Many species of flatfish are highly mobile and can have varied habitat preferences depending on season or life history stage (Gibson 1994).

Flatfish are found across a wide range of depths, which can differ by season, species, and life history stage (Gibson 1994). **Table 2** provides a summary of the spawning and rearing habitat characteristics of key species found along the B.C. coast. Seasonal migrations from deeper spawning grounds in the winter to shallower feeding grounds in the summer are common for many species (**Table 2**; Hart 1973, Horton 1989). Juvenile stages of most flatfish species concentrate in shallow nursery areas (Gibson 1994). For example, juvenile Pacific sanddab, speckled sanddab, and C-O sole only occupy the shallower part (0 to 25 m) of the adult depth range, which spans from 0 to 549 m depth for sanddabs and 18 to 350 m depth for C-O sole (**Table 2**; Kramer 1991, PFMC 2005).

Spawning typically takes place between winter and spring for most flatfish species including English sole, rock sole, Pacific sanddab, speckled sanddab, and starry flounder; however, the exact timing is specific to location and species (PFMC 2005; see **Table 2**). Flatfish species are oviparous (lay eggs) and iteroparous (reproduce more than once) with external egg fertilisation (PFMC 2005). The reproductive life history of Pacific and speckled sanddabs are very similar, with the eggs of both species being pelagic (i.e., inhabits open water) and common in shallow bays and estuaries (Rackowski and Pikitch 1989, PFMC 2005). The eggs of rock sole are demersal and adhesive in order to attach to the substrate (Horton 1989). The eggs of English sole are buoyant and pelagic, with spawning taking place in depths of 50 to 70 m (PFMC 2005). Starry flounder eggs are epipelagic and are typically found near the surface over depths of 20 to 70 m (PFMC 2005).

Typically, juvenile flatfish exhibit similar habitat preferences to adults, although juvenile distribution (including depth preferences) changes during development for some species (Gibson 1994). Generally, shortly after metamorphosis (when both eyes travel onto either the left or right side of the head), the juvenile flatfish will recruit to nearshore nursery areas (e.g., estuaries and protected bays) with fine-grained sediments, where there is higher food availability (Norcross et al. 1997). The advantages associated with shallower water for juveniles include: warmer water temperature, increased food availability, and preferred substrate (Gibson 1994). Once juvenile flatfish settle on the bottom, there appears to be a positive relationship between fish length and water depth (Gibson 1994). Recruitment by juvenile flatfish to shallow nursery areas may also be for increased cover, escape from predation, and decreased intraspecific food competition (Norcross et al. 1997).

Habitats of fine sediment and small grain size allow for increased burying capability by juvenile flatfish and protection from predation (Gibson and Robb 1992, Gibson 1994, Stoner and Ottmar 2003). Several studies have shown that sediment preference can be species-specific but is also related to the size of the fish and their ability to bury (Gibson and Robb 2000, Stoner and Ottmar 2003). Moles and Norcoss (1995) suggest that sediment grain size is one determinant in habitat selection in nearshore nursery areas by juvenile flatfish. Particle size selection increases with fish size in juvenile starry flounders, with larger juveniles (i.e., > 150 mm) selecting fine sand. **Table 2** provides a summary of habitat characteristics for juvenile and adult stages of key flatfish species.

The mud/sand environment is the preferred habitat for infaunal feeding species of flatfish (e.g., starry flounder, English sole, butter sole (*Pleuronectes isolepis*), C-O sole, Pacific sanddab, and speckled sanddab) due to the abundance of prey such as polychaetes, clams, and other invertebrates (Hart 1973). Only a small number of flatfish species (e.g., English sole, rock sole, C-O sole, and Pacific halibut) are found in rocky habitats, but they are not the primary habitat for any of these species (Horton 1989, IPHC 1998).

Along with substrate type, the structural complexity of benthic habitats can have an important role in determining the distribution and density of juvenile flatfish species in nearshore areas (Pappal 2006). The presence of structuring epifauna, such as tube building polychaetes, can result in improved sediment stability and increased hydrodynamic flow along the bottom (Eckman et al. 1981). Changes in flow can have important effects on sedimentation, food availability, and the recruitment, survival, and growth of flatfish larvae (Rabaut et al. 2013). The habitat complexity associated with emergent structures (features that provide 3-D complexity to the relatively planar seafloor, such as tube building by the polychaete *Lanice conchilega*) can also provide increased shelter from predators for juvenile flatfish (Rabaut et al. 2013). Pirtle (2005) suggests that the presence of orange sea pens (*Ptilosarcus gurneyi*) may also provide additional habitat complexity and structural relief for fish (including flatfish) that favour emergent structures. Stoner et al. (2007) found that densities of age-0 rock sole were greatest in habitats with low to medium density of worm tubes and lower in habitats with high worm tube density. The authors hypothesised that structural complexity from low to moderate densities of worm tubes provides refuge from predators for rock sole, while high densities of worm tubes prevent flatfish from burying.

Speckled sanddabs have been associated with artificial structures and are found in higher densities around rock pilings, pier pilings, and canyons (Rackowski and Pikitch 1989, PFMC 2005); however, the use of vegetated areas by speckled sanddabs is not well known in the literature (Rackowski and Pikitch 1989). Flatfish are often more abundant in bare sand habitat as they have adapted to unvegetated habitats by burrowing or camouflaging (Valle et al. 1999, Johnson et al. 2005).

2.2 Other Demersal Species

There are other species commonly associated with sandy and muddy bottoms and include species of pricklebacks (family Stichaeidae), poachers (family Agonidae), sculpins (family Cottidae), and sand lances (family Ammodytidae) (Lamb and Edgell 1986, Johnson et al. 2005). Due to their low commercial value there is little information on habitat distribution of the pricklebacks, poachers and sculpins. However, it is known that Pacific snake prickleback (*Lumpenus sagitta*) is a common inhabitant of sandy and muddy bottoms in the Pacific Northwest (Lamb and Edgell 1986, Johnson et al. 2005).

Pacific sand lance (*Ammodytes hexapterus*) occur in nearshore waters in the spring and summer, alternating between pelagic schooling and burrowing into intertidal or subtidal sand habitat and fine gravel (Field 1988, Robards and Piatt 1999, Haynes et al. 2007). Burrowing is carried out to avoid predation and conserve energy, as Pacific sand lance lack a swim bladder (Field 1988, Robards and Piatt 1999, Haynes et al. 2007). Sand lance are thought to remain in the substrate in a state of dormancy during winter when prey is scarce, leaving the subtidal burying habitat for short periods to spawn in the intertidal zone (Robinson et al. 2013). On the south coast of B.C. and in Washington State, Pacific sand lance have been documented to spawn between November and February (Penttila 2007, Thuringer 2004). In the shallow subtidal zone, sand lance prefer habitat based on grain size and sorting. Results from Haynes et al. (2007) suggest that sand lance avoid sites with no sediment in the subtidal zone and prefer sites with a mean particle size of ≤ 1.29 mm with mixed sand sediments with very little silt.

2.3 Roberts Bank Regional Studies

Documented use of subtidal sand and mudflats in the vicinity of the RBT2 study area by benthic fish has been previously described in three studies. Initial studies occurred in the 1970s (Greer et al. 1980) and were conducted prior to expansion of Pods 3 and 4 at Roberts Bank terminals and modification to the B.C. Ferry

Terminal. Subsequent studies (**Table 3**) occurred in the 2000s during the DP3 and RBT2 expansion projects (Triton Environmental Consultants 2004, Archipelago 2014a).

In April to July 1979, 34 benthic trawls were conducted along Sturgeon and Roberts banks using an otter trawl to compare data on fish communities (e.g., distribution and use) between the two sites (Greer et al. 1980). Roberts Bank, namely the borrow pit (a term used in Greer et al. (1980) to describe an area associated with historic construction activities at Roberts Bank) in the inter-causeway area, and areas north and northwest of Roberts Bank terminals, were only sampled in April, with 15 tows performed between depth strata 2 to 15 m. The exact depths of these sites relative to CD were not specified. Overall, catch per unit effort on Roberts Bank was seven times lower to the catch on Sturgeon Bank. Flatfish were the main species group caught at Roberts Bank, with starry flounder comprising 65% of total catch, followed (in order of abundance) by rock sole, Pacific sanddab, and English sole.

Triton Environmental Consultants (2004) investigated seasonal patterns and habitat use by adult and juvenile benthic fish between July 2003 and May 2004 in the subtidal and intertidal sandflats north of Roberts Bank terminals, and in the dredge basin of the inter-causeway area. The survey was a part of an environmental assessment on the potential impacts of the proposed DP3 Project. Sixteen beam trawls (sites) were replicated across four seasons for a total of 64 tows, plus an additional four tows in the inter-causeway dredge area during spring 2004 (**Figure 1**). A combined total (excluding the additional spring 2004 trawl tows) of five benthic trawls was conducted (due to the smaller area) within the inter-causeway area each season during the period of the study. Eleven tows were located north of the Roberts Bank causeway, of which four were located either within or in the vicinity of the RBT2 Benthic Fish Trawl Survey area. Two of the sites were located in 0 to 5 m depth CD, while one site spanned 2 to 10+ m depth CD[1]. This perpendicular sampling across depth contours precluded a comparison of this study's results with the current study, which sampled along depth contours (**Figure 2**).

Triton Environmental Consultants (2004) captured and identified 27 benthic fish species in a total catch of 4,379 fish. The majority of benthic fish were caught in spring north of the terminal (74%) and in summer, in the inter-causeway area (61%)[2]. Fall and winter catches comprised less than 3% of total catch. Species diversity was highest in spring. The most abundant species caught on the north subtidal sandflats were juvenile flatfish (Pleuronectiformes), pricklebacks (Stichaeidae), Pacific staghorn sculpin (*Leptocottus armatus*), shiner perch (*Cymatogaster aggregate*) and adult starry flounder. Threespine stickleback (*Gasterosteus aculeatus*) were the most abundant species south of Roberts Bank

[1] The fourth trawl site was located in +1 m to 3 m depth.
[2] Abundance caught was not standardised to area. Average trawl distance was 605 m ± 34.9 m SD

terminals followed by shiner perch, juvenile flatfish, pricklebacks, and Pacific staghorn sculpin. Other species of flatfish caught included flathead sole (*Hippoglossoides elassodon*), English sole, sand sole, rock sole, Pacific sanddab, and speckled sanddab. While species assemblages were similar on either side of Roberts Bank terminals, species evenness was lower on the south side, which may have been due to lower habitat heterogeneity and fewer transition zones (depth contours) sampled on the south side.

Archipelago (2014a) conducted four towed underwater video surveys[3] (September 2003, July 2008, November 2011, and September 2012) over a nine-year period in the subtidal and intertidal zones within and in the immediate vicinity of the proposed RBT2 project footprint. Archipelago (2014a) reviewed and classified this video imagery to provide biophysical descriptions of subtidal marine fish habitats that could be potentially affected by the Project. Archipelago (2014a) found that flatfish were common at all depths of the survey, ranging from 0 to 35 m depth CD. Deeper sand slopes with coarser substrate appeared to support different species of flatfishes than the finer substrate of shallow subtidal sandflats. Starry flounder was most common at shallow depths less than 5 m depth CD, while English and Dover sole were most common at depths greater than 10 m CD and appeared to occupy substrate with a greater mud content. Other species of flatfish observed included rock sole, Pacific sanddab, rex sole (*Errex zachirus*), flathead sole, curlfin sole (*Pleuronichthys decurrens*), and C-O sole. Many of the flatfish appeared to be juveniles (estimated to be less than 30 cm in length) with the exception of starry flounder, most of which appeared to be adults.

[3] Video surveys were conducted using the same methodology described in detail in the Marine Fish Habitat Characterisation Study (Archipelago 2014a) using SIMS.

3 Methods

Descriptions of the spatial and temporal scopes of the Benthic Fish Trawl Survey and study methods are provided below.

3.1 Study Area and Sampling Locations

The survey area for the Benthic Fish Trawl Survey was the subtidal zone from 0 to 25 m depth CD extending south and southwest from the corner of the existing Roberts Bank terminals (**Figure 2**). Sampling occurred at eleven sites within three depth strata: three sites (T1 to T3) were located in the 0 to 5 m depth CD strata in a relatively flat area; four sites (T4 to T6 and T10) were located in the 5 to 10 m depth CD strata on a shallow slope; and four sites (T7 to T9 and T11) were located in the 10 to 25 m depth CD strata on a steeper slope. Details on what sites were sampled in different seasons are presented in **Section 3.3.1**. Six sites in total (i.e., two in each depth stratum) were located inside the proposed terminal fill and dredge footprints, namely sites T2, T3, T5, T6, T8, and T9. Depth strata selected corresponded to those recommended in guidelines for sampling soft-bottom demersal fish in Puget Sound[4] (PTI Environmental Services 1990). T6 and T9 were located in an area where orange sea pens were continuously to densely distributed, while T2, T4, T5, T8, T10, and T11 were located in an area with few to patchy distribution of sea pens[5] (**Figure 3**; Archipelago 2011, Archipelago 2014a). T1, T3, and T7 were located outside the sea pen bed. For emergent structure in the survey area, only sea pens were considered; however, there are tubeworms and large shell fragments also present in the survey area (Archipelago 2011) that may influence flatfish distribution, but were not quantified.

3.2 Temporal Scope

Seasonal variation in fish abundance and species assemblages was expected, based on the literature for numerous species of benthic fish (Hart 1973, Horton 1989, Gibson 1994, PFMC 2005). The temporal scope of this study was seasonal sampling in summer, fall, winter and spring between August 2012 and April 2013.

In the literature, the seasons are defined as follows (Triton 2004):

- Summer (June 1 to August 31);
- Fall (September 1 to November 30);
- Winter (December 1 to February 28); and
- Spring (March 1 to May 31).

[4] Recommended methodologies are frequently used in Puget Sound to identify temporal and spatial changes in demersal fish assemblages and to evaluate possible causes for changes observed over time.

[5] There may be differences in benthic fish catch related to the distribution of sea pens, as these provide emergent structure to the subtidal habitat.

To assess temporal variability in fish parameters among seasons, sampling events were chosen to fall within each defined seasonal period, recognising that there is considerable temporal variability within each season. The Benthic Fish Trawl Survey was carried out in summer (August 2012), fall (November 2012), winter (February 2013), and spring (April 2013). Fish parameters were also compared across different tidal states (i.e., slack, flood, and ebb).

3.3 Study Methods

3.3.1 Trawl Survey

For the Benthic Fish Trawl Survey, a small otter trawl was used to collect benthic fish species during daylight hours on:

- August 8 and 9, 2012;
- November 13 to 16, 2012;
- February 19 and 20, 2013; and
- April 17 to 20, 2013.

The otter trawl measured 4.0 m in horizontal length, with a 1.6 m vertical opening and 3.8 cm mesh, and 0.6 cm mesh at the cod-end liner. Sampling occurred during low amplitude tidal exchanges (between 0.1 and 2.1 m exchange) to minimise the effects of currents on the movement of the trawl net along the bottom (**Table 4**). Originally, sites T1 to T9 were to be sampled every season; however, due to the intensive commercial crab trap fishery at Roberts Bank during summer (August) sampling with the associated risk of gear entanglement, the proposed 5 to 10 m and 10 to 25 m sites (i.e., sites T4 to T9) could not be sampled. Two sites (T10 and T11; **Figure 2**) located east of T6 and T9, and outside of the proposed footprint and intensive crabbing area, were added during the summer survey to allow characterisation of fish parameters in similar habitat for these depth strata. In the fall and spring surveys, all eleven sites (the original nine plus the two sites outside the footprint) were sampled. During the winter survey, it was not possible to trawl all proposed transects due to challenging weather conditions (i.e., > 25 knot winds and > 0.5 m waves); therefore, only sites T1, T2, T4, T5, T7, and T8 were sampled. The trawl transects conducted in each season are presented in **Figure 3**.

For each tow, the trawl net was deployed from a 10 m herring skiff and towed over the sea bed for 15 minutes at a constant speed of approximately 1.0 knot. Typical distances travelled were around 500 m. Vessel speed during trawling was sometimes adjusted to compensate for strong wind and current where higher trawl speed was needed to move forward in a straight trajectory. Photographs showing trawl sampling technique are in **Appendix A** (**Photos 1 to 4**).

Two replicate tows were conducted at each site. The second replicate tow at each site was typically conducted within 30 m and parallel to the first one; however, waves, currents, and placement of commercial crab trap fishing gear sometimes prevented this. A Solinst M30 Levelogger was attached to the backside of one of the trawl doors to log the depth range for each tow. The depth profiles of the trawl, obtained from the level logger, were plotted to ensure that trawls were within the specified depth strata. Examples of plotted depth profiles for each tow at all sites for the fall season are shown in **Figure 4** to **Figure 6**. Information on each tow, including tow duration, distance, vessel speed, and min/max depth of trawl, is summarised in **Table 4**.

3.3.2 Fish Enumeration and Site Parameters

After each tow, the catch was transferred immediately to aerated containers. To avoid recapture of fish, fish were held during and between replicate tows, and released following identification, enumeration, and length measurement of all fish from the last replicate tow. Photographs (**Photos 5 to 20**) of representative fish species are shown in **Appendix A**.

Detailed information collected for each tow included the following:

- Date and tow trackline (dGPS);
- Time fished (start/end of tow time), bearing, and speed of vessel;
- Water quality parameters collected near bottom, just off the seabed, using a Professional Plus YSI multimeter. Parameters included water temperature (°C), salinity (ppt (parts per thousand)), and dissolved oxygen (DO) (mg/L) measurements. Water quality parameters were obtained to characterise the seasonal, spatial, and tidal variation in temperature, salinity, and DO, and identify any anomalies in these parameters that may relate to the benthic fish results;
- Water depth (m) profile at time of tow sample;
- Digital photos and photo numbers;
- Invertebrates identified to lowest taxonomic level possible, and enumerated; and
- For all fish:
    - Identification to the lowest taxonomic level (typically species);
    - For flatfish species, identification to stage (adult/transitional/ juvenile) (PFMC 2005, Love 2011). A transitional stage was assigned to fish that were within the size range of transition into sexual maturity, dependent upon gender;
    - Enumeration; and
    - Measurement (mm; fork length or total length). A sub-sample of a maximum of 30 fish per species was measured.

Macroinvertebrates were collected incidentally, and those not identifiable in the field were preserved and sent to Biologica Environmental Services Ltd. for taxonomic identification. All data were recorded on pre-designed waterproof data sheets, and digital photos were downloaded daily and labelled by site and date. Geo-referenced site location data collected on a hand held GPS were downloaded daily and plotted to check for errors. Data from the field sheets were transcribed into Excel tables.

3.3.3 Sediment Collection

An 8.2 L volume ponar grab was used to collect two sediment samples at the 11 trawl sites (**Figure 2**) during each seasonal sampling event, even if trawling at each site was not possible. Eight sediment samples were taken at each site over the one-year period (two samples collected at each site over four seasons). Due to the nature of the sediment type in the survey area, the ponar grab never penetrated the sediment enough to obtain a full 8.2 L sample, meaning deeper sediments were not sampled. However as fish species primarily associate with surface sediment characteristics this is not thought to be an appreciable study limitation. Sampling at one site was repeated until approximately two liters of sediment was obtained overall as this volume was required for grain size analysis. Labelled Ziploc sample bags containing the sediment were sent to Thurber Engineering Ltd. in Victoria, B.C. after each collection period for grain size analysis. Photographs showing sediment sampling technique are in **Appendix A** (**Photos 21 to 22**).

Samples were air-dried and split, while still moist enough to prevent airborne loss of fines, into masses appropriate to determine maximum particle size in each sample in accordance with ASTM C-136 and C-117 protocols (ASTM 2004, ASTM 2006). Samples were then oven dried prior to sieving or washing. Sieve sizes used were 37.5 mm, 25 mm, 16 mm, 8 mm, 4 mm, 2 mm, 1 mm, 0.5 mm, 0.25 mm, and 0.063 mm. Intermediate sieve sizes were used to lessen the weight of sediment on any one sieve. If required, silts and clays were washed using the 0.063 mm sieve. Tabulated grain size analysis results providing percent retained or passing by grain size per sample were supplied by Thurber Engineering.

The average percentages of gravel (> 2.000 mm), sand (0.063 to 2.000 mm), and mud (clay and silt; < 0.063 mm) were calculated for each of the eight samples obtained for each site. Samples were then categorised into one of 15 sediment types based on Folk (1954) according to their gravel, sand, and mud content (**Figure 7**; **Table 5**), which were used to examine relationships between fish parameters and sediment characteristics.

3.3.4 Data Quality Assurance and Quality Control

The following measures were taken to ensure 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 by crew to field laptop of digital photos labelled by site and date, geo-referenced site location data, and water quality data from YSI meter;
- Daily review of hard copy field sheet information by field crew lead;
- Post field debrief with discipline lead to review data prior to entry from hard copy field sheet to electronic format; and
- Post data entry quality check.

3.4 Data Analysis

All univariate analyses were 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 benthic fish assemblages (Clarke and Warwick 2001). PRIMER is applicable for interpretation of data on community structure and uses the density or abundance values for species sampled to examine the biological relationships between the samples (Clarke and Warwick 2001, Murray et al. 2006). Relationships between the samples are illustrated in scatter plot diagrams from the multidimensional analysis (MDS). MDS show the 'clustering' of samples, plotting similar samples close together and dissimilar samples further apart. The stress measure on the MDS plot assesses the 'fit' of the 2-dimensional graphic depiction of the data. A stress value near zero indicates an excellent representation of the sample grouping while a stress value of > 0.3 indicates points are nearly arbitrarily placed in the 2-dimensional plot (Clarke and Warwick 2001).

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.

The dependent variables included:

- Density of all fish caught. Fish were enumerated from each replicate set, which was the lowest unit of comparison. Density (number of fish per m^2)

was calculated by dividing the number of fish caught by the area the trawl swept. Area was determined by multiplying the distance the trawl travelled along the seafloor with the width of the trawl opening. Fish density was used as the metric for comparison rather than number of fish caught per unit time because it was not possible to maintain a consistent travel speed with the boat due to currents and weather. Differences in distance travelled by the trawl on the seafloor when time was similar is evidence of this speed variability within each trawl (**Table 4**). For abundant fish species, separate species-specific comparisons of density were made. A linear mixed effects model, with season as the random effect to account for the increased similarity of fish catch within seasons versus between seasons, was used to analyse differences in species density based on the factors listed below. When data were not normally distributed or variances were unequal, they were first transformed (mathematical function applied to each data point). If this was not successful, data were analysed using a non-parametric Kruskal-Wallis test. If the Kruskal-Wallis test was used, a post-hoc test using Mann-Whitney tests with Bonferroni correction was conducted to examine pairwise comparisons between groups;

- Fish species richness (number of species). The number of fish species caught was enumerated from each replicate tow, which was the lowest unit of comparison. Richness was not standardised by area as calculations were not based on abundances and the habitat trawled was fairly uniform; therefore, there was no assumption that the number of species caught would increase with area trawled. Differences in species richness were analysed based on the factors listed below using a generalised mixed effects model (GLMM) with a Poisson distribution;
- Fish species evenness (measure of the relative abundance of each species in an area). Species evenness was calculated for each replicate tow 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 factors listed below using a linear mixed effects model similar to the model used for fish density;
- Fish species diversity (index calculated from the number of species in each tow 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 factors listed below using a linear mixed effects model similar to the model used for fish density;
- Fish community assemblages. Differences in community assemblages were compared based on density and 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 were made. Differences in length were analysed based on the factors listed below using a linear mixed effects model similar to the model used for fish density.

Fish parameters were assessed based on a number of factors:

- Season – spring, summer, fall or winter;
- Depth – shallow (0 to 5 m depth CD), mid (5 to 10 m depth CD), and deep (10 to 25 m depth CD);
- Sediment type – categories based on sediment grain size analysis;
- Sea pen distribution – none, few to patchy, or continuous to dense;
- Tide – flood, ebb, and slack; and
- Site – individual site comparisons of 11 sites.

Frequency of occurrence (FO) was calculated for all species caught over the survey period. FO represents the number of trawl tows in which a species was captured divided by the total number of trawl tows multiplied by 100.

Differences in water quality parameters (i.e., temperature, salinity, and DO) were compared among seasons, depth strata, and tidal states using a linear mixed effects model. Season was used as the random effect to account for the increased similarity of water quality parameters within seasons compared to between seasons. Water quality parameters were qualitatively compared to fish parameters.

4 Results

Results of the Benthic Fish Trawl Survey are presented below.

4.1 Overview

During the Benthic Fish Trawl Survey, 3,312 fish representing 40 species were caught in 66 trawl tows over the four seasonal sampling events between summer 2012 and spring 2013 (**Table 6** to **Table 8**).

Seasonal fish composition by species groupings (based on density) for the trawl data is displayed in **Figure 8**. Major fish species groups collected during the survey included flatfish, forage fish, pricklebacks, sculpins, perch, and poachers. The majority of fish were flatfish species, comprising between 56 and 80% of the proportion of all fish caught depending on season, with the dominant species being English sole and sanddab species. Sculpin also made up a large proportion of the catch compared to other fish groupings, comprising between 1 and 29% of the proportion of all fish caught in the spring, summer, fall, and winter. The majority of sculpins caught were padded sculpin (*Artedius fenestralis*) and buffalo sculpin (*Enophrys bison*). Pricklebacks, a group composed of one species, snake prickleback, were relatively abundant in spring, summer, and fall compared to other fish groups (between 8 and 15% of the proportion of fish caught). In the fall, there was also a high relative proportion of bay pipefish (*Syngnathus leptorhynchus;* 10%), and in the winter, forage fish made up 8% of the proportion of fish caught during that season, with Pacific sand lance being the only species caught.

Fish composition by species groupings based on density for each of the depth strata is displayed in **Figure 9**. Flatfish species comprised the majority of the species composition across all depth strata (between 70 and 80%). Sculpin comprised a large proportion of catch (between 8 and 9%) at the mid and deep depth sites (> 5 m), while prickleback comprised a large proportion (14 to 18%) at the shallow and mid-range depth sites.

Across all sampling events, English sole comprised 40% of total catch across all sites and seasons, and sanddab species comprised 25%, followed by snake prickleback (10%), rock sole (6%), bay pipefish (5%), padded sculpin (4%), starry flounder (2%), and buffalo sculpin (2%) (**Table 6**).

For all four seasonal sampling events, the majority of species caught (i.e., 74%) had a low FO (FO < 25%; **Table 9**). Only ten species were present in more than 25% of catches: English sole (FO = 95%), sanddab species (FO = 77%), rock sole (FO = 64%), snake prickleback (FO = 58%), padded sculpin (FO = 53%), starry flounder (FO = 41%), bay pipefish (FO = 36%), buffalo sculpin (FO = 33%), sand sole (FO = 32%), and pygmy poacher (*Odontopyxis trispinosa*) (FO = 32%). These species were observed in all seasons during the survey except buffalo sculpin, bay pipefish, and snake prickleback, which were only found in three of the four sampling events.

Invertebrate species that were incidentally captured in the otter trawl are summarised in **Table 10** to **Table 13**. Species caught in high abundance over the whole survey included sand shrimp (*Crangon* spp.), Hippolytidae shrimp (*Heptacarpus brevirostris, Heptacarpus herdmani, Heptacarpus tenuissimus, Spirontocaris lamellicornis*), Dungeness crab (*Metacarcinus magister*; megalops, juvenile, and adult stages), graceful decorator crab (*Oregonia gracilis*), Pacific lyre crab (*Hyas lyratus*), gammarid amphipods, mysids, sea gooseberries (*Pleurobrachia bachei*), unidentified jellyfish, Pacific wingfoot snail (*Gastropteron pacificum*), Venus clams (*Nutricola* spp.), and polychaete species.

4.2 Water Quality Parameters

Water quality data for the four sampling events are summarised in **Table 14**. Measurements are localised in time and are not representative of the overall seasonal variations.

Water temperature ranged from 7.1 to 17.5 °C over the sampling events. Water temperatures ranged from 13.3 to 17.5 °C in summer 2012, 8.0 to 9.3 °C in fall 2012, 7.1 to 7.7 °C in winter 2012/2013, and 8.3 to 10.0°C in spring 2013. Water temperature was significantly different between seasons (**Table 15**), with summer being the warmest (15.4 °C ± 0.9 standard error (SE)) and winter being the coldest (7.5°C ± 0.1 SE). Temperatures in the spring (9.0 °C ± 0.2 SE) and fall (9.0 °C ± 0.1 SE) did not differ significantly. Water temperature was not significantly different between different tidal states or depth strata.

Overall, salinity ranged from 11.6 to 30.5 ppt across all sampling events. Water salinity ranged from 19.3 to 26.3 ppt in summer 2012, 21.4 to 30.5 ppt in fall 2012, 22.4 to 27.9 ppt in winter 2012/2013, and 11.6 to 29.9 ppt in spring 2013. Water salinity was significantly higher in the fall (29.0 ppt ± 0.8 SE) than all the other seasons (average salinity ranged from 22.8 to 25.9 ppt; **Table 15**). There was no significant difference in water salinity between the other seasons. Water salinity was not significantly different between different tidal states, but was significantly different by depth with lower salinity in shallow sites (0 to 5 m depth CD; 23.8 ppt ± 1.2 SE) compared to the other depth strata (average salinity ranged from 26.8 to 28.8 ppt).

Overall, DO values ranged from 6.5 to 13.5 mg/L over the sampling events. DO ranged from 7.5 to 9.8 mg/L in summer 2012, 6.5 to 10.2 mg/L in fall 2012, 7.7 to 9.9 mg/L in winter 2012/2013, and 8.5 to 13.5 mg/L in spring 2013. DO was significantly higher in the spring (10.5 mg/L ± 0.6 SE) than the other seasons (average DO ranged from 8.1 to 8.8 mg/L) (**Table 15**). DO did not differ significantly between any of the other seasons. DO was significantly highest in shallow sites (0 to 5 m depth CD; 10.1 mg/L ± 0.5 SE) and lowest at deep sites (> 10 m depth CD; 8.1 mg/L ± 0.3 SE), but did not differ between tides.

4.3 Sediment Grain Size Data

Based on the sediment categories described in Folk (1954), five sediment types were collected at Roberts Bank: sand (T1, T2, T10 and T11); muddy sand (T3); slightly gravelly sand (T4 and T5); slightly gravelly muddy sand (T6, T8 and T9); and gravelly sand (T7) (**Table 16**). Generally, the shallow sites (T1 to T3) and sites closest to Roberts Bank terminals (T10 and T11) were predominantly sand (sand or muddy sand), while the mid-range depth and deeper sites were sand with a higher component of gravel and sometimes mud. Due to small sample size, quantitative analyses on the differences in sediment type among sites or seasons was not possible; however, based on average percent composition for all samples collected within a site, sand is the predominant grain size (80 to 97%) at all locations (**Table 16**).

4.4 Benthic Fish Data

Overall fish density, species richness, species evenness, species diversity, and species assemblage results are presented below, followed by a more detailed analysis of specific flatfish species and other species of interest.

4.4.1 Fish Density, Richness, Evenness, and Diversity

For comparisons between overall fish density, species richness, evenness, and diversity, site T11 was removed from analysis as there was evidence that hard substrate was encountered with the trawl near the southwest side of the pile-supported loading wharf of the existing coal port. The substrate encountered could have been part of a 60 m reef that was built out of broken concrete pipes in 1983 (Naito 2001). Anemones, which are typically associated with rocky substrate, were caught during trawling at site T11, and the trawl snagged repeatedly on the bottom, evidence that a hard substrate was likely present. As fish species assemblages, diversity, and abundance can differ significantly between rock and soft substrates, the removal of site T11 from further analyses eliminated this bias.

Table 17 summarises density of each fish species, with catch standardised by the area swept for each tow. When seasonal differences in fish density were compared using data from all sites, benthic fish were caught in highest densities in the summer and lowest densities in the winter (**Figure 10**; **Table 18**). When fish densities between different depth strata were compared using data from all sites and seasons, density was significantly lower at the shallow (0 to 5 m depth CD) sites, and highest at the mid-depth (5 to 10 m depth CD) sites (**Figure 11**). Fish density was similar between the different tidal states (**Figure 12**). Fish density was significantly higher in predominantly sand substrate, than in substrates of sand mixed with mud or gravel, and in locations with continuous to dense sea pen distribution, as compared to areas with few to patchy distribution and no sea pens (**Figure 13** and **Figure 14**). Density of benthic fish was also significantly higher at sites T7, T9, and T10 than all other sites sampled (**Figure 15**).

Species richness differed significantly across seasons, with fewer species caught in winter than in other seasons (**Figure 10**; **Table 19**). When data across all seasons and sites were combined, species richness was also significantly lower at shallow sites (0 to 5 m depth CD) than at sites located in water depths greater than 5 m (**Figure 11**). There was no difference in species richness at different tidal states, sediment types, or sea pen distributions (**Figure 12 to Figure 14**). Species richness was significantly different between sites with more species caught across all seasons at mid-depth sites (T4, T5, and T10) and deep sites (T7 and T9), and fewer species caught at all shallow depth sites (T1 to T3), the mid-depth site (T6), and the deep site (T8) (**Figure 15**).

Evenness scores were similar between the different depths, tidal states, sediment types, sea pen distributions, and sites (**Figure 11 to Figure 15; Table 18**), but were significantly different between seasons, with higher evenness in the winter than all other seasons (**Figure 10**). This difference indicates that species present during the winter season were more evenly distributed than those present in the other seasons.

Fish diversity was significantly different between seasons, with diversity lowest in winter (**Figure 10; Table 18**), but similar between all other seasons. Fish diversity was significantly different between water depth strata, with higher diversity at deep sites (10 to 25 m depth CD) than sites < 10 m depth CD (**Figure 11**). Fish diversity also significantly varied between sediment types, with the highest diversity observed in slightly gravelly sand substrates (**Figure 13**). Diversity was similar between all other substrate types. Fish diversity was not significantly different between tidal states or sea pen distribution levels (**Figure 12** and **Figure 14**). Fish diversity was significantly lower at shallow sites (T1 and T2) and mid-depth sites (T6 and T10), while diversity was highest at mid-depth sites (T4 and T5), and the deep site (T8) (**Figure 15**).

4.4.2 Species Assemblages

Differences in the richness and diversity indices can be further described by assessing fish species assemblages. Site T11 was removed from analyses of fish species assemblages, for the reasons described in **Section 4.4.1**.

While not strongly separated, species assemblages were significantly clustered by season (**Figure 16;** ANOSIM; R = 0.351, p = 0.001); however, as the stress value of the MDS plot was high (0.19), little reliance was placed on the details of the plot (Clarke and Warwick 2001). Instead, subsequent analyses pertaining to all factors (i.e., depth, sediment type, tide state, and sea pen distribution) focused on ANOSIM results. SIMPER analysis indicated that species assemblages across all sites were most similar to each other in summer and least similar to each other in the winter. English sole and sanddab species were the two species (or species groups) that contributed the most to within-season similarity in all seasons (**Table 20**; SIMPER). In addition, important contributing species seasonally were snake prickleback (summer and spring), bay pipefish (fall), and starry flounder (winter).

Fish species assemblage was significantly different at shallow sites relative to sites in the other two depth strata (**Figure 16**; ANOSIM; R = 0.368, p = 0.001). SIMPER analysis indicated that, while English sole were associated with all depths, starry flounder and snake prickleback had the highest density at the shallow (0 to 5 m depth CD) sites (**Table 21**; SIMPER). Sanddab species were more characteristic of sites deeper than 5 m.

Finally, there was a small but significant clustering of fish assemblages when compared by sediment categories including fish assemblages at sand sites versus sites with sediment containing gravel, and at muddy-sand sites versus sites with trace or slight amounts of gravel (**Figure 16; Table 22**; ANOSIM; R = 0.286, p = 0.001). English sole was associated with all sediment types, while snake prickleback was characteristic of sand and muddy sand substrates. Species more characteristic of gravel type substrates included padded sculpin and rock sole.

No differences were found in species assemblages of fish caught during different tidal states (ANOSIM; R = 0.026, p = 0.234) or between sites with different sea pen distributions (**Figure 16**; ANOSIM; R = 0.087, p = 0.028).

4.5 Flatfish-Specific Data

Nine species of flatfish were collected over all the sampling events, namely English sole, Pacific sanddab, speckled sanddab, rock sole, starry flounder, Dover sole, butter sole, sand sole, and flathead sole. Species-specific comparisons of density, FO, and average length across factors were carried out where possible based on sample sizes, and are described below. Density was compared with site T11 (where the old broken concrete artificial reef is likely located), which was included and excluded to see if it influenced results. Length frequencies for specific species were also examined seasonally.

4.5.1 English Sole

English sole, one of the most abundant flatfish species caught during the survey, was caught at every site in every season, and in the majority of tows, with their FO ranging from 91% in spring to 100% in summer and winter (**Table 9**).

When the density of English sole was compared across seasons, density was significantly higher in summer and fall than in winter and spring (**Figure 17; Table 23**). Combining all seasonal data, English sole were caught at significantly lower density at shallow sites, and at significantly higher density at sites with sand and muddy sand substrate composition than sites with slightly gravelly sand or mud/sand composition. There were no significant differences in English sole density between tidal states or sea pen distribution levels. Results for density of English sole across seasons, depths, tidal states, and sea pen distributions was similar if site T11 was included or excluded, although results were different for site-specific comparisons. When site T11 was included, density of English sole was significantly highest at site T10 and T11. When T11 was excluded, density was significantly highest at sites T2, T9, T7, and T10.

When data from all sampling events were combined, 99% of English sole caught were juveniles measuring < 210 mm (PFMC 2005; Love 2011). The remaining 1% were either adults or in transitional stages. Seasonally, English sole caught were in the following size ranges:

- Summer 2012 - fork length ranged from 38 to 298 mm with the majority between 38 and 126 mm fork length;
- Fall 2012 - fork length ranged from 15 to 374 mm, with the majority of fish measuring between 73 and 120 mm fork length;
- Winter 2012/2013 - fork length ranged between 22 to 115 mm with no noticeable peaks in the length-frequency distribution; and
- Spring 2013 - the majority of fish were between 46 to 116 mm fork lengths with several individuals up to 420 mm fork length.

The size of English sole differed significantly by season, with larger fish caught in spring (93 mm ± 5.1 SE) and summer (90 ± 2.6 SE) than in fall (90 mm ± 1.2 SE) and winter (79 mm ± 3.8 SE) (**Figure 18; Table 24**). A smaller size class between 15 and 32 mm fork length was observed in the fall and winter that was not present in the spring and summer. Combining data across all seasons and sites, the size of English sole was significantly related to depth, with the smallest fish caught at shallow sites (77 mm ± 2.3 SE), and the largest fish caught at deep sites (95 mm ± 1.0 SE). The size of English sole was also significantly different between different densities of sea pens with the largest fish caught in the continuous to dense sea pen bed (99 mm ± 2.9 SE) and the smallest in areas with no sea pens (80 mm ± 1.9 SE).

An observation of interest was the presence of tumour-like growths on a large percentage of the English sole caught in the fall season (**Appendix A, Photos 23 to 26**). The presence of growths was not quantitatively assessed. Further investigation would be required to determine if this was an abnormal event, or whether tumour growth is a regular occurrence during the fall season or year round. Epizootic skin tumours have also been observed on juvenile English sole in Puget Sound, Washington, with peaks of the disease in October (Angell et al. 1975).

4.5.2 Pacific Sanddab and Speckled Sanddab

Pacific and the speckled sanddabs were caught during the survey. Due to morphological similarities between the two species, species identification is difficult in the field, especially for juveniles (< 75 mm for speckled sanddab and < 190 mm for Pacific sanddab). Because habitat utilisation is also similar between the two species (Rackowski and Pikitch 1989; Kramer 1995), they were combined for analyses.

Sanddabs were caught in high abundance during the survey and were commonly observed in all seasons. The FO of sanddabs ranged from 50% in winter to 100% in summer (**Table 9**). The inclusion or exclusion of site T11 significantly affected the results, largely because the highest density of sanddabs across all seasons was observed at site T11 (**Table 25**).

When site T11 was included in the analysis, the density of sanddabs was significantly higher in spring and lower in winter, and over all seasons was significantly higher at the deep sites (10 to 25 m CD depth) and lower at the shallowest sites (**Figure 19; Table 25**). More specifically, sanddab density was significantly highest at site T11, followed by sites T9 and T10, and lowest at T1 to T3. In winter and spring, sanddabs were not caught at any of the shallow sites (T1 to T3). When site T11 was included, sanddab density was significantly higher at sites with continuous to dense sea pen distribution than at sites with no sea pens, and was also significantly higher in sediments with no gravel content.

When site T11 was excluded from analysis, seasonal differences were also evident in sanddab density with densities significantly different between all the seasons. Densities were (density in descending order) highest in summer, spring, fall, and lowest in winter. Sanddab densities also differed by depth, with significantly lower densities at shallow sites than other depths. Similar to when site T11 was included, sanddab density was significantly highest at site T9 and T10 and lowest at T1 to T3 (**Table 25**). No difference in sanddab densities was evident across different sea pen densities, sediment types, or tidal state (when site T11 was excluded).

Sanddab length data were analysed by season and by depth. In summer 2012, the majority of sanddabs ranged in fork length size from 72 to 154 mm with some individuals measuring up to 266 mm. In fall 2012, the majority of sanddabs measured between 24 to 68 mm or 85 to 141 mm. In winter, only a few sanddabs were caught, measuring between 37 and 153 mm fork length. In spring 2013, the majority of sanddabs were either between 40 and 88 mm or 94 and 141 mm fork length, respectively, with some individuals up to 230 mm. Sanddabs were significantly larger in the summer (117 mm ± 2.4 SE) than other seasons (average length between 86 and 91 mm) (**Table 26**). Sanddabs were also significantly larger at deep sites (102 mm ± 1.5 SE) than shallow (99 mm ± 4.3 SE) and mid-depth (85 mm ± 1.7 SE) sites, when data from all seasonal sampling events were combined. Sanddab size did not differ between the various sea pen distribution levels.

4.5.3 Rock Sole

When site T11 was included or excluded from analysis, densities of rock sole between seasons, sediment types, and tidal states were similar, while densities were significantly different between depth strata and levels of sea pen distribution (**Figure 21; Table 27**). Rock sole was present in significantly lower densities at shallow sites, and significantly higher densities in sites with continuous to dense sea pen distribution then sites with no sea pens. Rock sole was not caught at shallow sites (T1 to T3) in the summer or in the winter.

Differences in density of rock sole between sites was dependent on whether site T11 was included or excluded from analysis. When site T11 was included in the analysis, rock sole was present at significantly higher density at site T11 relative to sites T1 to T4. When site T11 was excluded from analyses, rock sole were present at significantly higher densities at site T9 than T1 and T2.

The FO of rock sole ranged from 33% in winter to 82% in spring and individuals were caught in every season (**Table 9**).

Combining data from all sampling events, 90% of rock sole caught were juveniles (< 300 mm fork length), 8% were in the transitional stage (300 to 360 mm), and a little over one percent were adults (> 360 mm) (PFMC 2005, Love 2011). In summer 2012, only a few rock sole were caught, ranging from 34 to 311 mm fork length. In fall 2012, the majority of rock sole were between 55 and 89 mm or 263 to 374 mm fork length, respectively. In winter 2012/2013, the few rock sole captured ranged between 64 and 311 mm fork length. In spring 2013, most rock sole were either between 50 and 191 mm or 265 and 390 mm fork length.

Overall, rock sole was significantly smaller in the fall (121 mm ± 11.5 SE) than in the spring (130 mm ± 10.0 SE) and summer (119 mm ± 7.7 SE) (**Figure 22; Table 24**). Across all seasons, the size of rock sole was negatively correlated with depth with significantly larger fish observed at the shallow sites (281 mm ± 35.6 SE), followed by mid-depth sites (155 mm ± 13.5 SE), and the smallest fish at the deepest sites (101 mm ± 5.2 SE). Across all seasons, the largest fish were observed in areas without sea pens (150 mm ± 21.1 SE) and the smallest in areas with continuous to dense sea pen distribution (118 mm ± 15.4 SE).

4.5.4 Starry Flounder

Due to the overall low numbers of starry flounder caught, statistical comparison was not possible between the different factors. Starry flounder was caught in all seasons, and when seasonal data were combined, was caught at every site except T7 and T9. The FO of starry flounder ranged from 20% in summer to 50% in winter (**Table 9**).

Across all sampling events, 33% of starry flounder caught were juveniles (< 220 mm fork length) and 67% were of transitional size (220 to 450 mm) (PFMC 2005, Love 2011). The two starry flounder caught in summer 2012 were 340 and 374 mm fork length, respectively. The size of starry flounder ranged between 133 and 325 mm fork length in fall 2012, between 98 to 265 mm fork length in winter 2012/2013, and between 79 to 400 mm in spring 2013.

Length of starry flounder did not differ significantly by depth or sea pen distribution when data from all sampling events were combined (**Figure 23; Table 26**); however, length did significantly differ by season, with starry flounder largest in summer (357 mm ± 17.0 SE), and smallest in winter (200 mm ± 19.8 SE) and fall (229 mm ± 8.5 SE).

4.5.5 Dover sole

Only six Dover sole were caught during the survey, all in the summer and at site T11. All Dover sole were juveniles (< 300 mm fork length; PFMC 2005, Love 2011) with size ranging from 92 to 111 mm fork length.

4.5.6 Butter Sole

As with starry flounder, statistical comparison was not possible between the different factors for butter sole. Butter sole were not caught in the winter season, and their FO in the other seasons ranged from 9% in spring to 40% in summer (**Table 9**). In total, butter sole were present in less than 25% of the trawl tows.

Across all sampling events, 64% of butter sole caught were juveniles (< 100 mm fork length) and 36% were in the transitional size range (100 to 250 mm) (PFMC 2005, Love 2011). Butter sole ranged in size from 54 to 172 mm fork length during summer 2012, and from 55 to 110 during fall 2012 (**Figure 24**). Only two butter sole were caught in spring 2012, measuring 75 and 149 mm fork length.

4.5.7 Sand Sole

Sand sole were caught in relatively low abundances in all four seasons, but too few for statistical density comparisons by factors. FO ranged from 17% in winter to 60% in the summer (**Table 9**).

Across all sampling events, the majority (81%) of sand sole caught were juveniles (< 200 mm fork length), while 14% were transitional stage (200 to 280 mm) and 5% were adults (> 280 mm) (PFMC 2005, Love 2011). Sand sole ranged in size from 142 to 206 mm fork length in summer 2012, 97 to 370 mm in fall 2012, 57 to 114 mm in winter 2012/2013, and 61 to 255 mm in spring 2013 (**Figure 25**).

4.5.8 Flathead Sole

Only one flathead sole was caught, and it was during the fall season at site T11. The flathead sole was an adult with fork length of 264 mm.

4.5.9 Other Species of Interest

4.5.9.1 Pacific Sand Lance

Nine Pacific sand lance were caught in one trawl tow at site T4 in the winter season; however, Pacific sand lance were observed escaping through the mesh near the opening of the trawl as it was being retrieved. Pacific sand lance retained by the trawl ranged from 69 to 92 mm fork length; therefore, the majority of individuals would have been young-of-year (< 90 mm; Field 1988, Robards et al. 2002).

4.5.9.2 Big Skate

One big skate juvenile, measuring 254 mm total length, was caught in the summer at site T2. Three egg cases were caught in the trawl in winter 2012/2013 at site T7.

5 Discussion

A discussion of the key findings, conclusions and data gaps and limitations are presented below.

5.1 Key Findings

Flatfish comprised the largest proportion of trawl tow catches and nine species were caught during the survey. English sole and sanddab species dominated the catch in the majority of the tows. Rock sole, starry flounder, and sand sole comprised a moderate proportion of the total catch (between 1 to 6%) in more than 25% of tows, while butter sole comprised 1% of the total catch proportion and was caught in only 18% of tows. Flathead sole and Dover sole were very rare during the survey and together comprised less than 0.5% of the catch proportion and were only caught in 2 and 3% of tows, respectively. The majority of the flatfish species caught in the survey area were in the juvenile stage, which is consistent with observations from other studies on Roberts Bank (Triton Environmental Consultants 2004, Archipelago 2014a) and suggesting the importance of this area for rearing.

Season, depth, sediment type, sea pen distribution, and site were all important factors in explaining the density and distribution of benthic fish species observed, and are discussed below.

5.1.1 Seasonality

Densities of the benthic fish community appear to be seasonally driven in the RBT2 study area. Benthic fish density was highest in the summer and lowest in the winter, with species richness and species diversity lower in winter than other seasons. Species evenness, however, was higher in the winter than all other seasons, indicating that species were more evenly distributed in that season. Triton Environmental Consultants (2004) identified that spring and summer seasons at Roberts Bank had the highest fish abundance and diversity. In the present study, species assemblages also differed between the seasons mainly due to the higher density of English sole in the summer and fall, sanddab species and snake prickleback in spring and summer, bay pipefish in the fall, and starry flounder in winter.

Higher density of sanddab species in spring and summer observed in this study is consistent with the literature. In similar habitat near San Diego, California, the highest densities of newly settled speckled sanddabs (< 35 mm) occurred in spring and summer (May to October) (Kramer 1991).

Starry flounder was the predominant species observed in winter in the RBT2 study area, which is not consistent with the literature. Starry flounder catch levels were highest in spring (May) and lowest during the winter in the Deas Slough area of the Fraser River (Birtwell et al. 1993). Towed underwater video imagery from early September 2003 shows starry flounder as the predominant species between 0 and 5 m depth in the area trawled during this survey (Triton Environmental Consultants 2004). Benthic fish collected during beam trawl surveys in 2003 and 2004 at Roberts Bank also had higher abundances of starry flounder in spring and summer than fall and winter (Triton Environmental Consultants 2004). The higher winter densities of starry flounder in the RBT2 survey area were not correlated with water quality parameters; therefore, they may be associated with various biotic or abiotic factors that were not measured.

Unlike densities of English sole, starry flounder, and sanddabs, the density of rock sole did not differ significantly by season in the study area. These results are consistent with those of Abookire and Norcross (1998), who did not find any significant seasonal differences in abundance of rock sole in Kachemak Bay, Alaska.

English sole were present in higher densities in the summer and fall. English sole were larger in the spring and summer than in the fall, possibly due to a recruitment of newly settled juveniles (15 to 32 mm) in the fall. English sole are known to settle at sizes < 35 mm in nearshore shallow estuarine or coastal nursery areas between April and September (Kramer 1991). Juvenile English sole spend their first year (or two) rearing in shallow nursery habitats and do not travel to deeper waters until they reach between 110 to 150 mm in size (Toole et al. 1987, Stewart 2005), indicating that a wide size range of juvenile English sole use these habitats.

Variability in size of English sole between spring/summer and fall could also be associated with differences in food availability. As small juveniles (< 50 mm), English sole feed on copepods and mysids and switch to a predominantly polychaete diet by 70 mm in length (Kramer 1991); therefore, the higher density of larger English sole in the summer could be due to increased availability of their preferred prey, such as polychaetes.

Sanddab species and starry flounder were also larger in the summer than in other seasons, while rock sole in spring and summer were larger than those in the fall. These results are consistent with those from the literature, with sanddab species exhibiting the most rapid growth during the summer and early fall (Rackowski and Pikitch 1989). The larger size of starry flounder found during summer in this study is consistent with Birtwell et al. (1993) who found that the mean size of starry flounder increased through spring, summer, and fall in Deas Slough. The observed larger size of starry flounder in the summer at Roberts Bank could be associated with a number of different abiotic and biotic factors, or simply be a reflection of differences in size class distributions.

Differences in size of rock sole may be linked to seasonal movements, as adults migrate to shallow depths in spring and summer to feed and to deeper waters in the winter to spawn (Forrester and Thomson 1969, Hart 1973, Alton and Mearns 1976).

5.1.2 Depth

Depth is also an important factor influencing fish spatial distribution and density. Although fish were caught in the otter trawl at all depths sampled (0 to 25 m depth CD) in the survey area, significant differences in fish density, species richness, and species diversity were noted by depth.

In the survey area, benthic fish density, species richness and species diversity were all lower at the shallowest sites (0 to 5 m depth CD) than at other depth strata sampled. Fish density was highest at the mid-depth sites (5 to 10 m depth CD), while fish diversity was highest at the deepest sites (10 to 25 m depth CD).

Sanddab species, rock sole, and English sole densities differed significantly by depth, with higher densities at sites > 5 m depth CD than shallow (< 5 m depth CD) sites. These results are consistent with the literature, which found higher densities of juvenile and adult speckled sanddabs at depths > 15 m, possibly due to preference for lower and more stable temperatures (Ford 1965, Rackowski and Pikitch 1989); however, temperature did not differ significantly by depth during this study at Roberts Bank. In California, the density of speckled sanddabs increased twofold at deeper (12 to 14 m) sites than shallow (5 to 8 m) sites (Kramer 1991). Rock sole abundance has been observed to increase with increasing depth between 0 and 30 m (Norcross et al. 1997), with juveniles commonly inhabiting waters between 5 to 20 m (Abookire and Norcross 1998). Juvenile English sole are known to occur across a wide depth range, inhabiting depths between 0 to 20 m CD for the first few years of life (Toole et al. 1987, Stewart 2005). Research on English sole has focused on comparing differences in distribution across larger depth ranges (i.e., 0 to 18 m and > 18 m; Krygier and Pearcy 1986) and not the finer scale ranges for shallower depths fished during this survey.

Starry flounder was identified during the SIMPER similarity analysis as a species characteristic of the shallow 0 to 5 m depth CD sites. Due to the overall low numbers of starry flounder caught, density by depth could not be compared statistically. Triton Environmental Consultants (2004) and Archipelago (2014a) observed a greater abundance of adult starry flounder at shallow depths (< 5 m). Adult and juvenile starry flounders are common inhabitants of shallow estuaries and the lower reaches of coastal rivers, including the Fraser River (Hart 1973, Garrison and Miller 1982, Richardson et al. 2000). The average length of starry flounder did not differ significantly by depth.

During this survey, the size of English sole and sanddab species caught increased with increasing depth sampled, which is consistent with the literature, which found that young-of-year flatfish species were found at shallower depths than older conspecifics (Krygier and Pearcy 1986, Burke et al. 1991).

Rock sole size decreased with increasing depth sampled, contrasting with results for English sole and sanddab species, but consistent with the literature on rock sole. In Alaska, young-of-year rock sole were observed in greatest abundance at

20 m, while larger age-1 rock sole were most abundant at 10 m (Abookire and Norcross 1998). Adult rock sole will spawn in shallow water (intertidal to 30 m) from winter to early spring (March) depending on the stock (PFMC 2005, Fargo et al. 2000), which is consistent with the results from this study with the largest rock sole (390 mm) being caught during the spring sampling.

5.1.3 Sediment Type

Sediment grain size appears to influence some factors related to benthic fish presence and distribution in the survey area, including fish density, species diversity, and species assemblage. Density of benthic fish was generally higher in substrates that were primarily sand than in substrates that were a mix of sand with mud or gravel; however, species diversity was highest in substrates composed of slightly gravelly sand (T4 and T5) at 5 to 10 m depth CD on the west side of the survey area.

Species-specific differences were examined when site T11 was included/excluded from the analysis. Sanddab species were observed in higher density in sand and muddy sand substrates, but there was no difference in density between different substrates if T11 was excluded. Pacific sanddab and speckled sanddab have a preference for sandy or sandy-mud areas (Feder et al. 1974, Rackowski and Pikitch 1989). Regardless of whether T11 was included, English sole was in higher density at sites with sand and muddy sand substrate composition than sites with slightly gravelly sand and slightly gravelly muddy sand composition. This is consistent with the literature as both adult and juvenile English sole prefer soft bottoms composed of fine sand and mud substrate (Ketchen 1956, Becker 1984, Perry et al. 1994). Rock sole density was similar between different substrate types, and they have been associated with sand and mixed sand substrates (Norcross et al. 1997). Larger rock sole exhibit low selectivity for different types of sediment, while juveniles prefer coarse sand and gravel substrate (Moles and Norcross 1995, Fargo et al. 2000, Stoner and Ottmar 2003).

Fish assemblages were similar between sites with different compositions of sand and mud substrates, and similar between sites that had any gravel in their substrate composition. The largest differences were observed between fish communities at sites with predominantly sand and mud substrates (snake prickleback) versus substrates with gravel (padded sculpin and rock sole). English sole and sanddabs were commonly associated with all sediment types when examining species assemblages. The only other species of flatfish associated with gravel type substrates was rock sole. Rock sole are sometimes observed in rocky or gravel habitat, unlike some flatfish species that are only associated with soft substrate (Hart 1973, Garrison and Miller 1982, Horton 1989).

5.1.4 Emergent Structure

Numerous species of juvenile flatfish have been associated with emergent epibenthic structures such as sea pens, worm tubes, sponges, and hydroids (Pirtle 2005, Hinz et al. 2006, Stoner et al. 2007, Rabaut et al. 2013). The habitat complexity associated with emergent structures and epifauna is believed to provide increased prey diversity for juvenile flatfish and potential shelter from predators (Rabaut et al. 2013).

In the survey area, sea pens are the main emergent structures. Sea pen distribution affected overall fish density, with densities higher in areas with continuous to dense sea pen distribution than areas with few to patchy sea pen distribution or no sea pens. Fish species richness, evenness, and diversity was similar between areas with different sea pen distribution levels.

When examining species-specific density differences in relation to sea pen distribution, rock sole and sanddab species had higher densities in areas where sea pens were continuously to densely distributed versus areas with no sea pens; English sole density showed no association with sea pen distribution. Sanddabs species were also some of the primary species observed in the sea pen beds during dive surveys in the study area (Archipelago 2009, Archipelago 2011). Sanddabs are associated with irregularities in habitat structure such as rock pilings and canyons (Rackowski and Pikitch 1989), which may explain the observed positive relationship between sanddab density and sea pen distribution. Rock sole have been observed to be associated with structure, particularly low and medium densities of worm tubes (Stoner et al. 2007). Studies have also found that rock sole prefer habitat with sponge and shell emergent structures (Stoner and Titgen 2003), and are less vulnerable to predation in these habitats (Ryer et al. 2004). In this survey, the smallest rock sole individuals were observed in areas with continuous to dense sea pen distribution, which is consistent with previous studies. Conversely, larger rock sole were observed in areas with no emergent structure provided by sea pens. Ryer et al. (2007) hypothesise that preference for structured habitat by rock sole increases with age, which is contrary to the observed correlation in the current study, which found smaller individuals within the more complex emergent sea pen structure.

5.1.5 Site

Site as a factor in explaining individual species density differences was important for English sole, sanddab species, and rock sole, which were caught in higher densities at site T10 (English sole and sanddab only) and T11 (all species). Site T10 and T11 are closest to the artificial rocky reefs, and wharf and pilling structures of Roberts Bank terminals, which may attract these species as has been observed previously with speckled sanddab (Rackowski and Pikitch 1989), English sole, and rock sole (Walton 1982).

5.1.6 Tidal State

Tidal state did not appear to influence any of the fish parameters as there was no difference in overall fish density, individual species fish density (English sole, sanddab species, and rock sole), species richness, species evenness, species diversity, or species assemblages between flood, ebb, and slack tides.

Tide can affect the movement and distribution of egg and larval flatfish stages, mostly in terms of recruitment into shallow coastal or estuarine nursery areas via tidal transport (Gibson 1997). For juvenile flatfish, a combination of diel and tidal factors can modulate movement, distribution, and behaviour, with fish moving inshore with the tide near sunset and offshore near sunrise (Burrows et al. 1994, Gibson 1997). Since sampling during this survey only occurred during the day, any diel differences in fish parameters would not have been observed. Also, as flatfish grow in size, they are less dependent on tidal currents for movement (Gibson 1997).

Finally, all sampling during this survey occurred over low tidal exchanges (< 2.1 m). Differences in fish parameters may have been more pronounced if sampling had occurred on larger tidal exchanges.

5.1.7 Pacific Sand Lance

Pacific sand lance were not caught in high abundance during this survey, but their presence during the winter survey is important because it may indicate the presence and use of suitable burrowing habitat at or in the vicinity of Roberts Bank.

The majority of sediment samples (64%) collected in the survey area were composed of a large proportion (> 90%) of suitable sized particles (< 1 mm and > 0.063 mm) for sand lance burrowing (Haynes et al. 2007). The amount of silt content (< 0.063 mm) was highly variable between and within sites, with some samples containing no silt and some with up to 51%. Sand lance were caught at site T4, where sediment grain size may be suitable substrate for burrowing; samples were composed of between 87 and 98% suitable sized substrate and a low silt content (between 1 and 12%). Due to the high variability in silt content between samples, and limited number of sediment samples, the extent of suitable substrate available for burying in the subtidal zone could not be determined. A habitat suitability study combining sediment data and other physical characteristics at Roberts Bank is underway to model the potential extent of suitable habitat for sand lance at Roberts Bank (Hemmera 2014).

Why sand lance were not caught in the spring and summer during this survey is difficult to determine; however, due to their pelagic and benthic behaviour, sand lance may have been in the water column feeding during the trawl tows or they escaped the trawl altogether. As noted in the Forage Fish Survey TDR (Archipelago 2014b), there is limited knowledge on Pacific sand lance biology, abundance, and distribution in British Columbia (Penttila 2007).

5.1.8 Water Quality Parameters

There are many variables that can affect marine water quality, including air temperatures, freshwater input, storm activity, and deep water mixing. The north side of Roberts Bank terminals, in the location of the survey area, is more affected by the freshwater plume from the Fraser River than the south side (Triton Environmental Consultants 2004).

During this survey, water temperatures differed across seasons, with summer having the warmest water temperatures and winter having the coolest. Beginning in spring, the sun's elevation, longer daylight hours, and decreased storm activity can increase solar retention in the upper 50 m of seawater in the Strait of Georgia, with maximum water temperatures occurring in the summer (Thomson 1981). In the fall, cooler air temperatures and increased mixing due to storm activity lower the temperature of surface waters (Thomson 1981, Triton Environmental Consultants 2004). In addition, influx from the Fraser River during the fall and winter is very cold as it has travelled through the below freezing temperatures of the B.C. interior (Thomson 1981).

Salinity also varied seasonally, with the highest salinity levels occurring in the fall. Higher salinity during fall has been previously documented in the area (Triton Environmental Consultants 2004). Salinity decreases during the spring and summer in the upper 50 m of seawater in the Georgia Strait due to increased land drainage and river runoff (Thomson 1981, Environment Canada 2010). Salinity begins to increase in late summer as discharge from the Fraser River decreases. There is also increased mixing of higher salinity deep waters with surface waters due to increased storm activity during this period (Thomson 1981). These phenomena may explain the higher salinity observed in the fall season during this survey. Salinity was also expected to be higher in the winter during this survey, but was closer to that of the spring and summer. Heavy rains that were occurring during the winter sampling period may have influenced this result.

DO levels differ seasonally, likely due to input from the Fraser River and water temperatures. The highest DO levels were recorded in spring. River runoff becomes highly oxygenated as rushing water increases contact with air, increasing DO. Oxygen is more soluble in freshwater than in saltwater. The higher levels of DO that were observed in this study in the spring may be explained by the increase in low salinity and highly oxygenated freshet beginning to leave the Fraser River during this time (Environment Canada 2010). In addition, DO levels were lower in the fall, when salinity was at its highest. The solubility of oxygen in water also increases when temperatures decrease. DO levels typically decline in summer as water temperatures increase, as was observed during this study.

Water temperature was similar between depth strata, but at shallow sites (0 to 5 m depth CD) salinity was the lowest and DO was the highest. In the top few metres of the Strait of Georgia, a highly oxygenated brackish layer can form with the Fraser River discharge (Thomson 1981). Water parameters at shallow sites are likely largely dictated by discharge from the Fraser River, accounting for the lower salinity and higher DO levels across all seasons. Lower salinity in the top few metres of water has also been documented previously in the survey area, particularly during the spring, summer and winter seasons (Triton Environmental Consultants 2004). Fish density and number of fish species caught were lowest at the shallowest sites, possibly due to the salinity ranges that these fish tend to inhabit.

Temperature, salinity and DO in the water was similar between flood, ebb and slack tides, as were fish parameters.

To make broader conclusions on water quality parameters in the survey area and their effects on benthic fish parameters, installations that allow continuous measurements over a longer time frame would be required; however, there were no observed anomalies in the point measurement water quality data that could explain variability in the benthic fish data.

5.1.9 Conclusions

Overall, data collected during the Benthic Fish Trawl Survey were used to document the seasonal distribution of fish species that may be either temporary or year-round residents of the sandy habitat south and southwest of Roberts Bank terminals from 0 to 25 m depth CD. Fish data were compared across different seasons and habitat types, with habitat type defined by depth strata, soft bottom substrate type, and sea pen distribution.

Results from the survey include:

- *Diversity*: Forty species were captured over four seasonal sampling events. Many of the species caught (74%) were less common (present in less than 25% of all tows over all seasons), caught in low abundance, and not in all seasons, indicating that they may only be utilising subtidal sand habitat at Roberts Bank on a temporary, seasonal, or transient basis;
- *Common Species*: As expected, flatfish comprised the largest proportion (75%) of the overall catch, in all seasons and at all depths. Nine species of flatfish were caught during the survey: English sole, Pacific sanddab, speckled sanddab, rock sole, starry flounder, Dover sole, butter sole, sand sole, and flathead sole. English sole and sanddab species dominated the catch in most of the tows in all seasons;
- *Age Class*: The majority of the flatfish species caught in the survey area were juveniles, indicating the value of Roberts Bank as a rearing habitat;

- *Seasonality*: As anticipated from the literature, benthic fish communities had significant seasonal variability. Benthic fish density was highest in summer; density, diversity, and species richness was lowest in winter; and species evenness was highest in the winter. Species assemblage varied by season with English sole and sanddab species common in all seasons, snake prickleback more abundant in spring and summer, bay pipefish more abundant in fall, and starry flounder more abundant in winter;
- *Depth strata*: Benthic fish show depth strata preference within the survey area. Fish density, species richness, and species diversity were all lower at the shallowest sites (0 to 5 m depth CD). English sole, sanddab species, and rock sole densities increased with depth. Consistent with literature, the size of English sole and sanddab species increased with increasing depth sampled while rock sole size decreased with increasing depth. Some species showed greater association with different depth strata. English sole was associated with all depths, starry flounder and snake prickleback were associated with shallow (< 5 m CD) depths, and sanddab species were characteristic of depths greater than 5 m;
- *Sediment type*: Overall, sand was the predominant sediment grain size (80 to 97%) at all sites. Typically, density of benthic fish was higher in substrates that were predominantly sand and not a mix of sand with mud and/or gravel; however, English sole and sanddab species were observed in higher density in sand and muddy sand substrate. Substrate type had a slight influence on fish species assemblages with differences observed between communities collected at sites with predominantly sand with mud substrates versus those with any gravel content;
- *Emergent structure*: Benthic fish density (overall, as well as specifically for rock sole and sanddab species) was highest in areas with continuous to dense sea pen distribution. Smaller rock sole inhabit areas with continuous to dense sea pen distribution while larger rock sole was observed in areas with no emergent structure provided by sea pens. There was no association between English sole density and sea pen distribution; and
- *Tidal state*: Tidal state did not correlate with any of the fish parameters.

5.1.10 Data Limitations

The survey was designed to collect seasonal information on benthic fish communities in three depth strata taking into account both the habitat complexity (e.g., depth, sea pen distribution) and trawl locations (i.e., inside and outside terminal footprint). These study design objectives, in combination with the challenges encountered trawling at this site (e.g., crab trap fishery activity, foul weather), resulted in low sample sizes as not all transects could be surveyed every season during this study; therefore, benthic fish temporal information is missing for some key areas during summer and winter seasons. Low sample sizes in combination with the variability in catch composition and abundances of individual species between replicate sets allow the most complex statistical analyses to only include main effects, namely season, depth, tidal state, sediment type, sea pen distribution, and site, and not the interaction between factors. For example, to examine the effects of depth on fish parameters, data from all seasons and sites had to be combined, precluding an analysis of fish parameters at different depths seasonally.

Despite these limitations, the objective of the Benthic Fish Trawl Survey of documenting current seasonal use of shallow subtidal sand habitat by benthic fish that may be affected by the RBT2 project has effectively been fulfilled, 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.

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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 PMV. 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

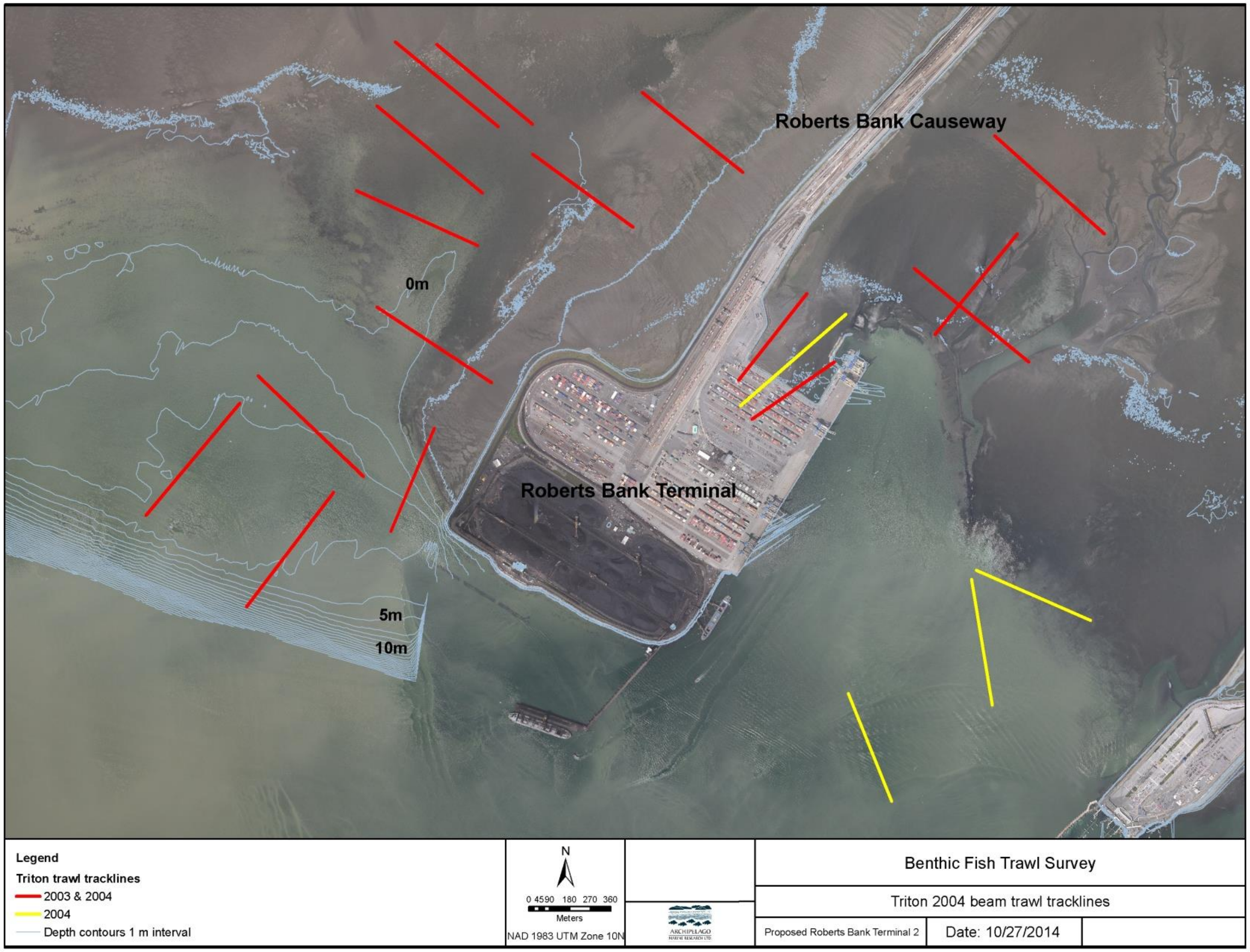

Figure 1. Trawl tracklines from the Triton (2004) beam trawl survey. Note two tracklines in the inter-causeway area extend into the DP3 expansion site. Red lines indicate sites sampled in 2003 and 2004 and yellow lines indicate sites sampled in spring 2004 only.

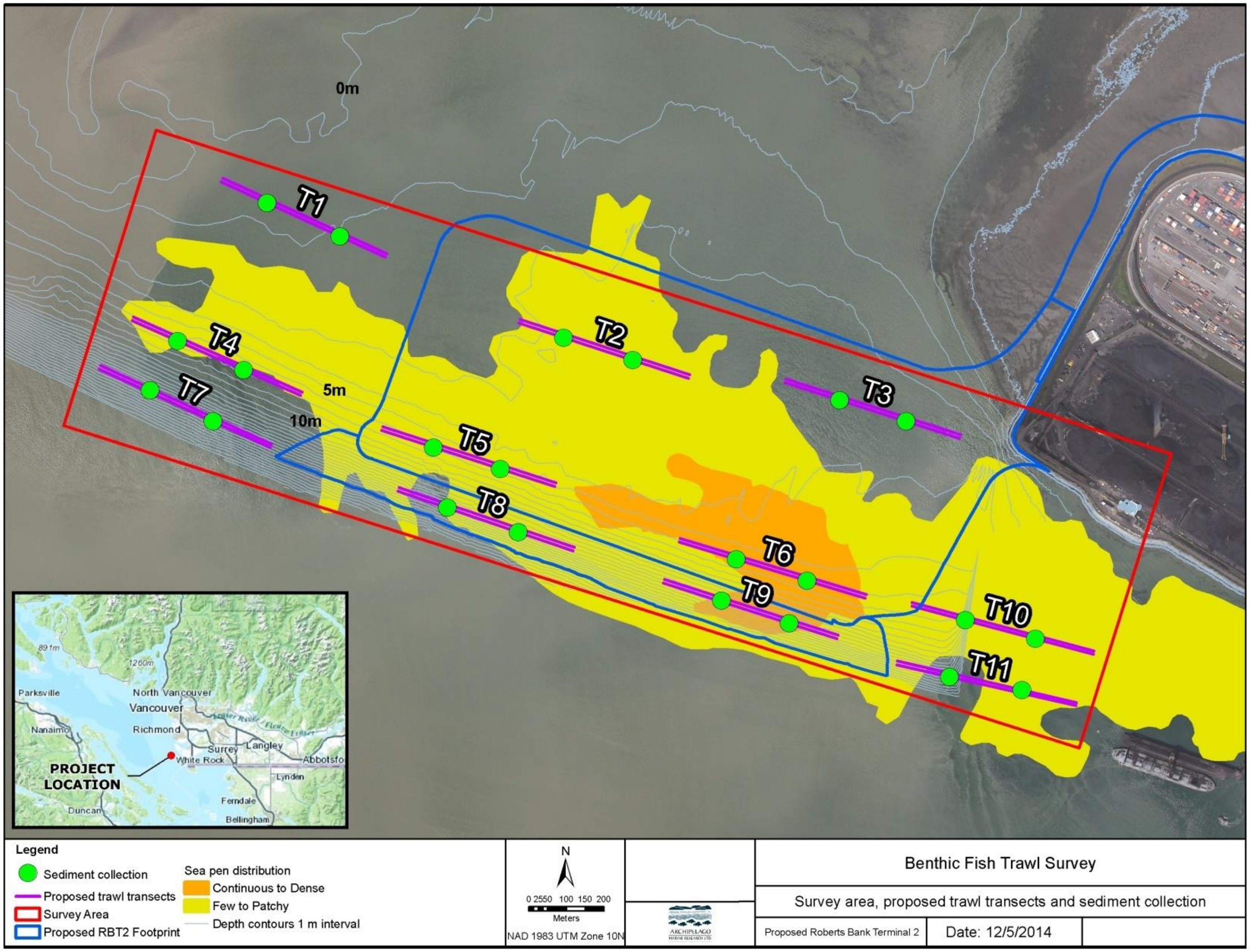

Figure 2. Proposed RBT2 footprint, in relation to sea pen distribution, and proposed trawl and sediment collection sites. Trawls T10 and T11 were added in summer (August) 2012.

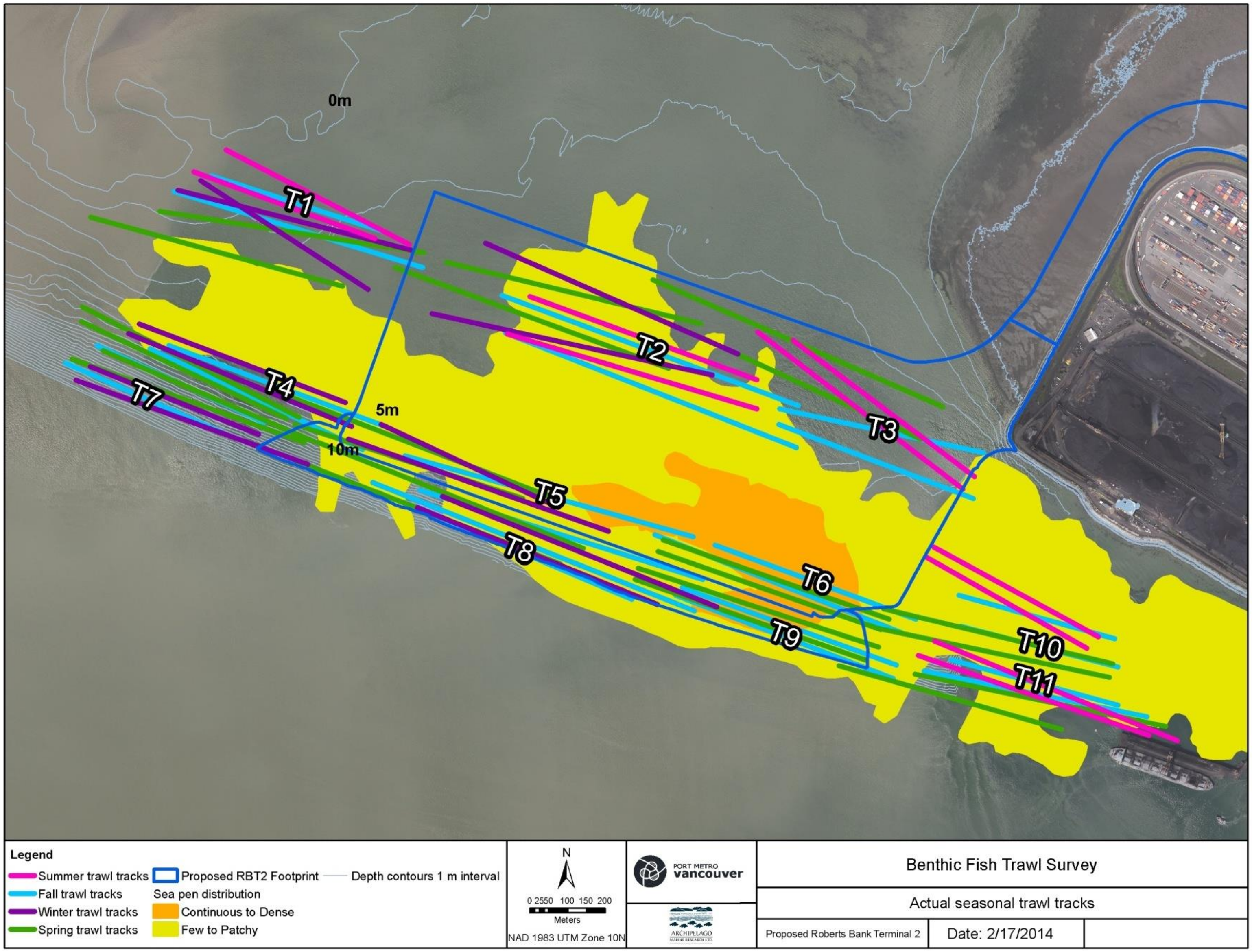

Figure 3. Location of the actual seasonal trawl transects for the Benthic Fish Trawl Survey.

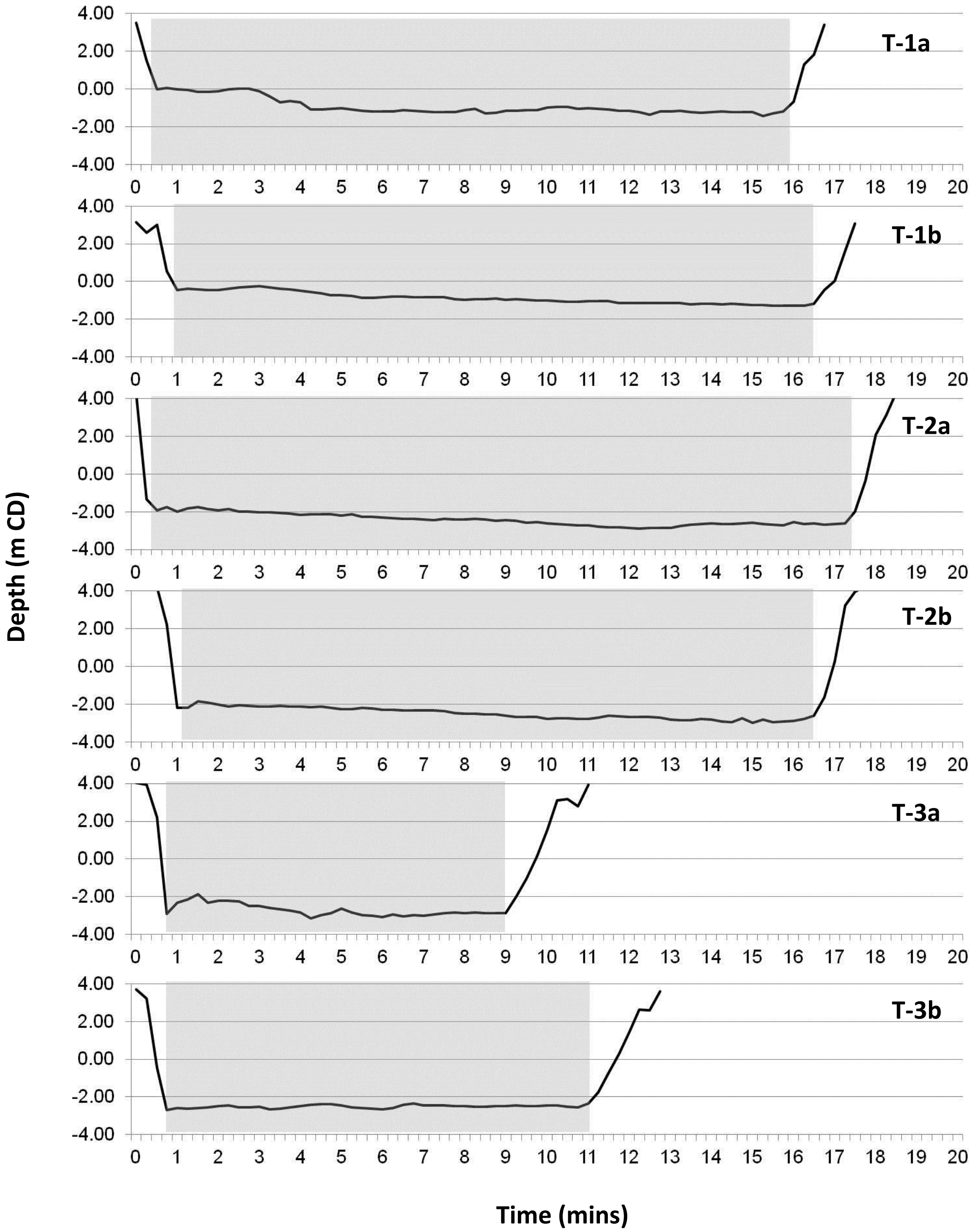

Figure 4. Fall 2012 trawl depth profiles at T1 to T3. Shaded area indicates when otter trawl was actively fishing on bottom. Trawl profiles were taken to verify that each trawl was within the specified depth zone.

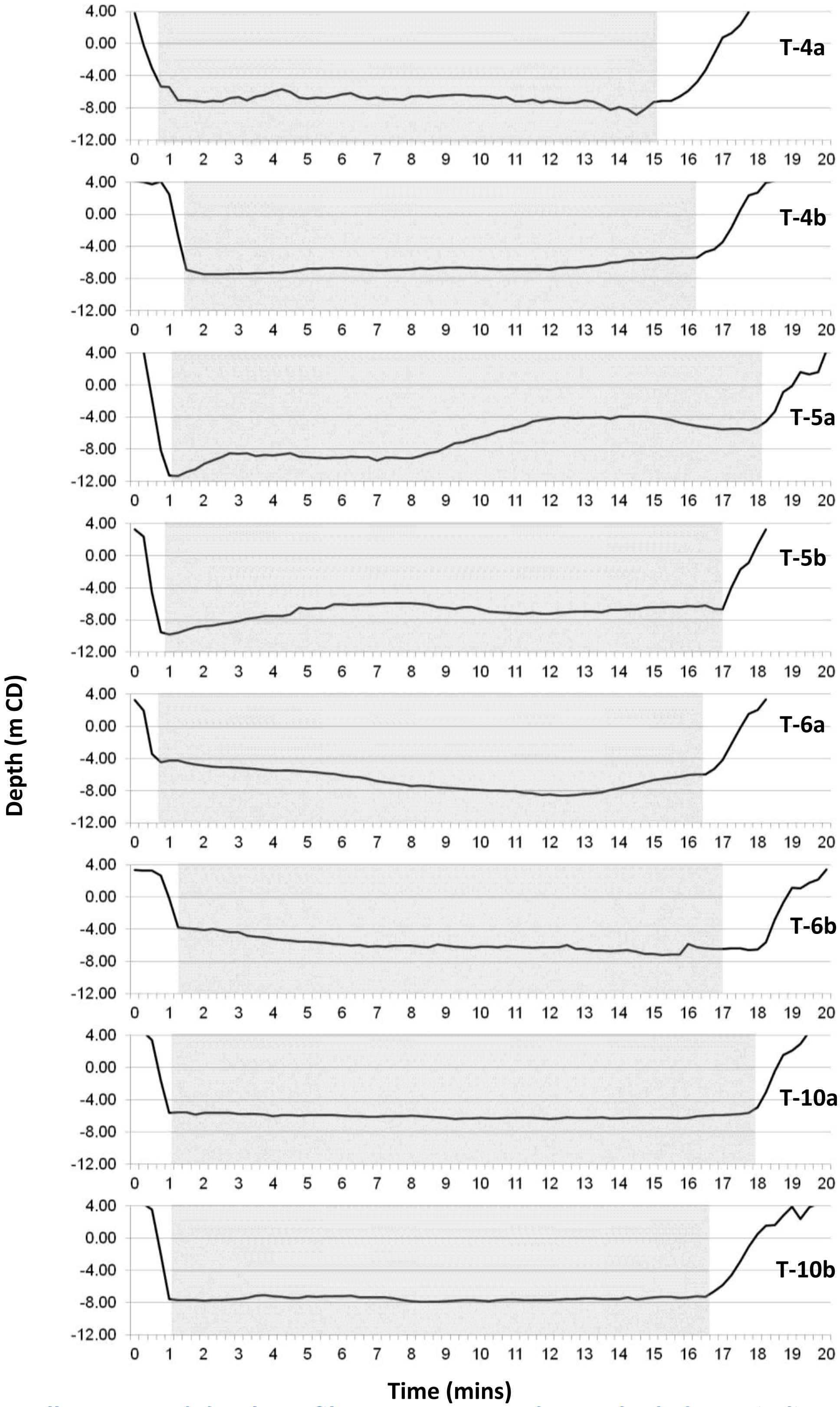

Figure 5. Fall 2012 trawl depth profiles at T4 to T6 and T10. Shaded area indicates when otter trawl was actively fishing on bottom. Trawl profiles were taken to verify that each trawl was within the specified depth zone.

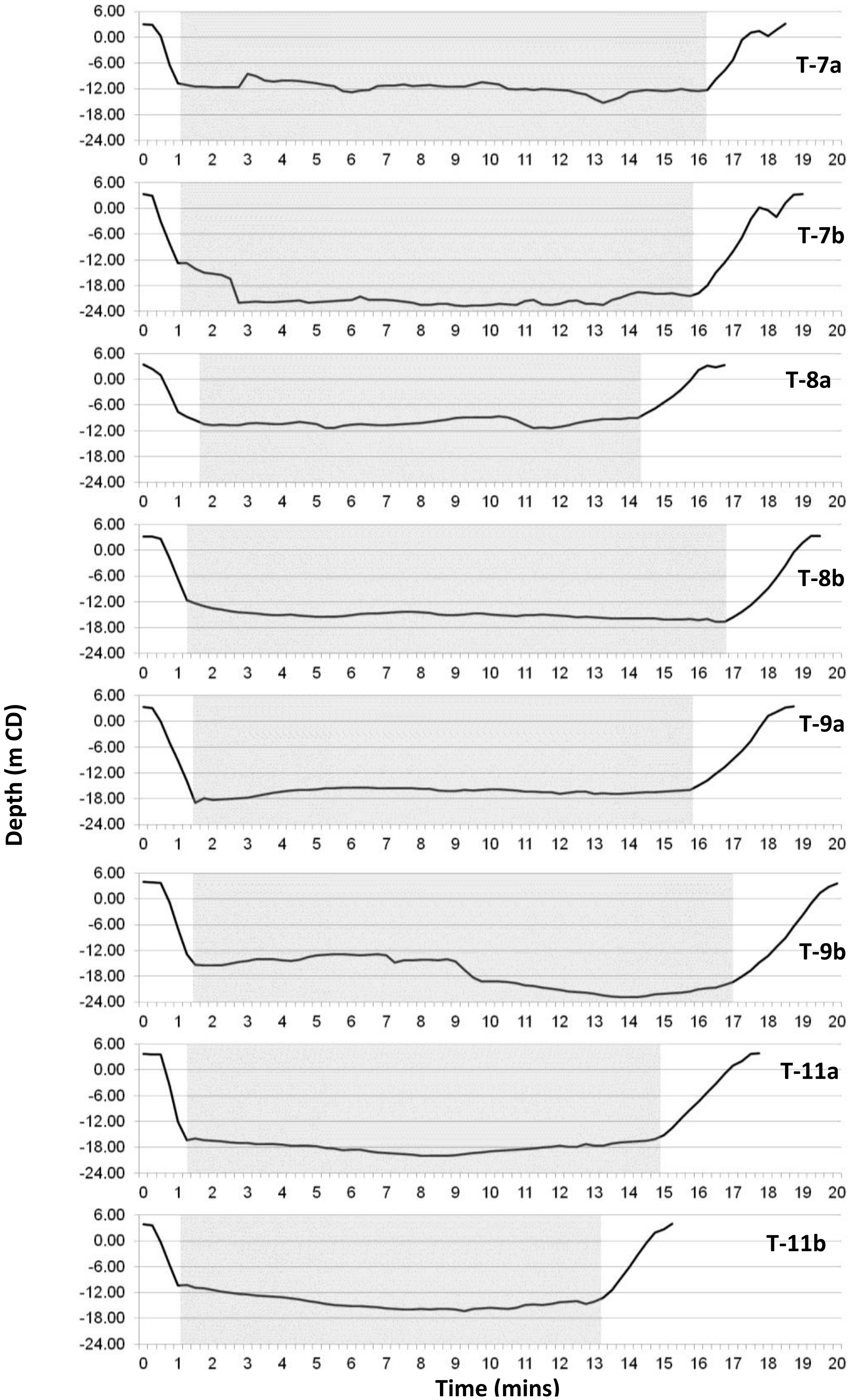

Figure 6. Fall 2012 trawl depth profiles at T7 to T-9 and T11. Shaded area indicates when otter trawl was actively fishing on bottom. Trawl profiles were taken to verify that each trawl was within the specified depth zone.

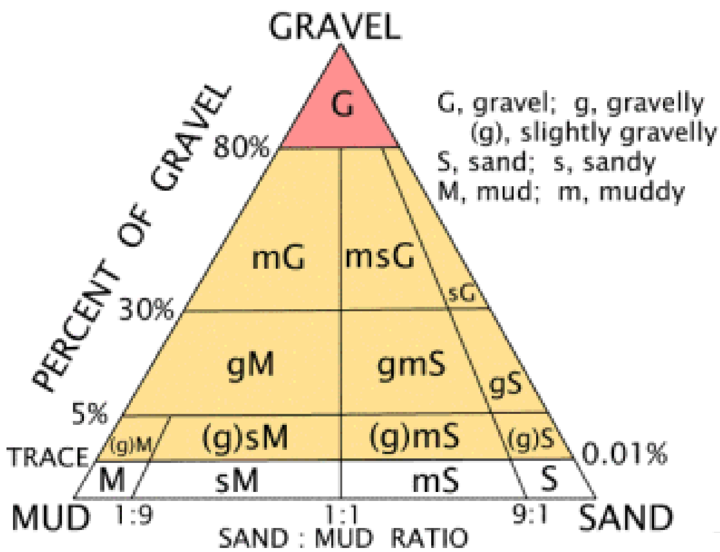

Figure 7. Sediment classification and nomenclature (after Folk 1954).

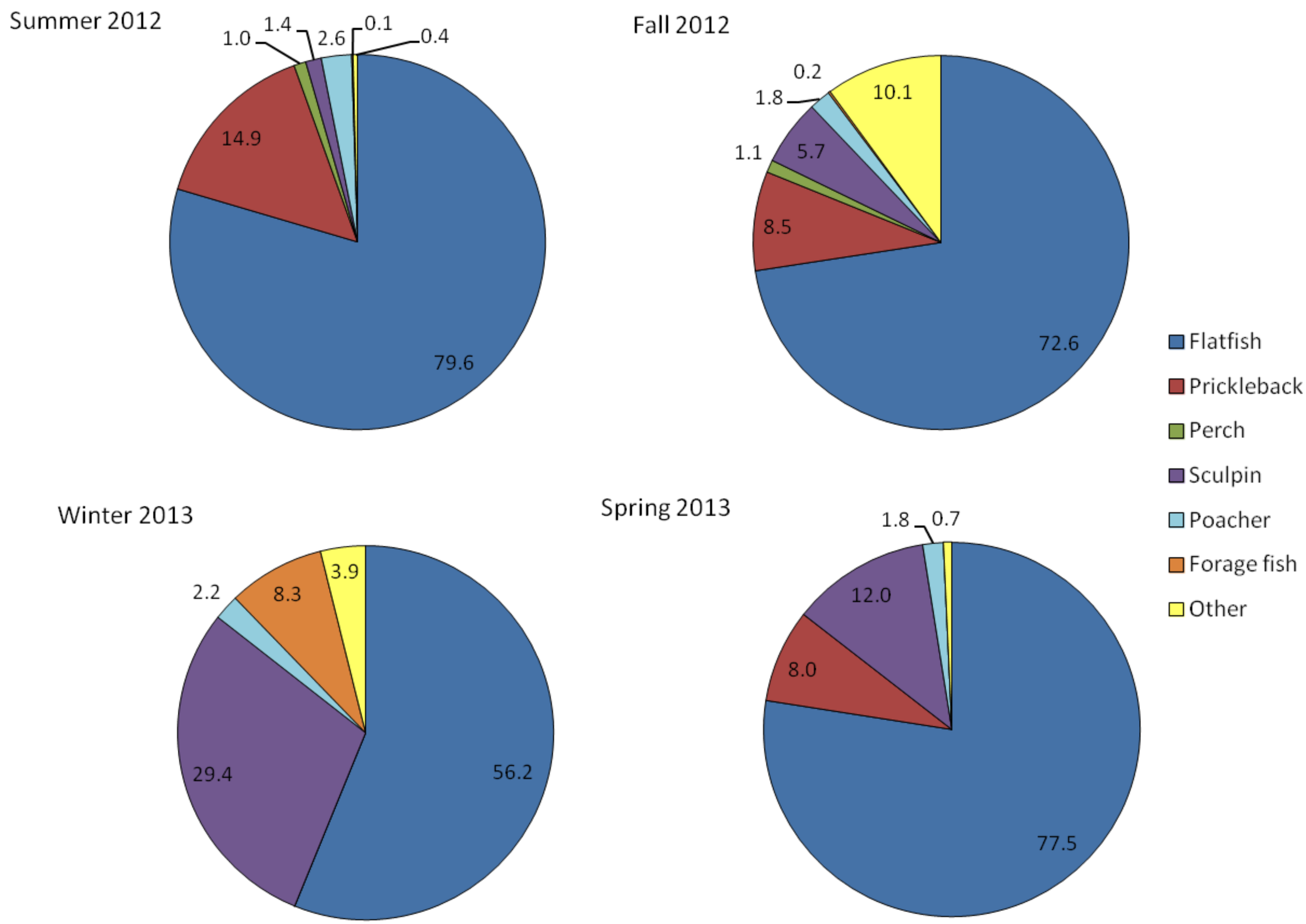

Figure 8. Fish composition proportions (%) by group based on density (number of fish per metre squared), of all fish caught in the four seasonal sampling events (summer 2012, fall 2012, winter 2012/2013, and spring 2013) using a small otter trawl (4 m horizontal and 1.6 m vertical opening).

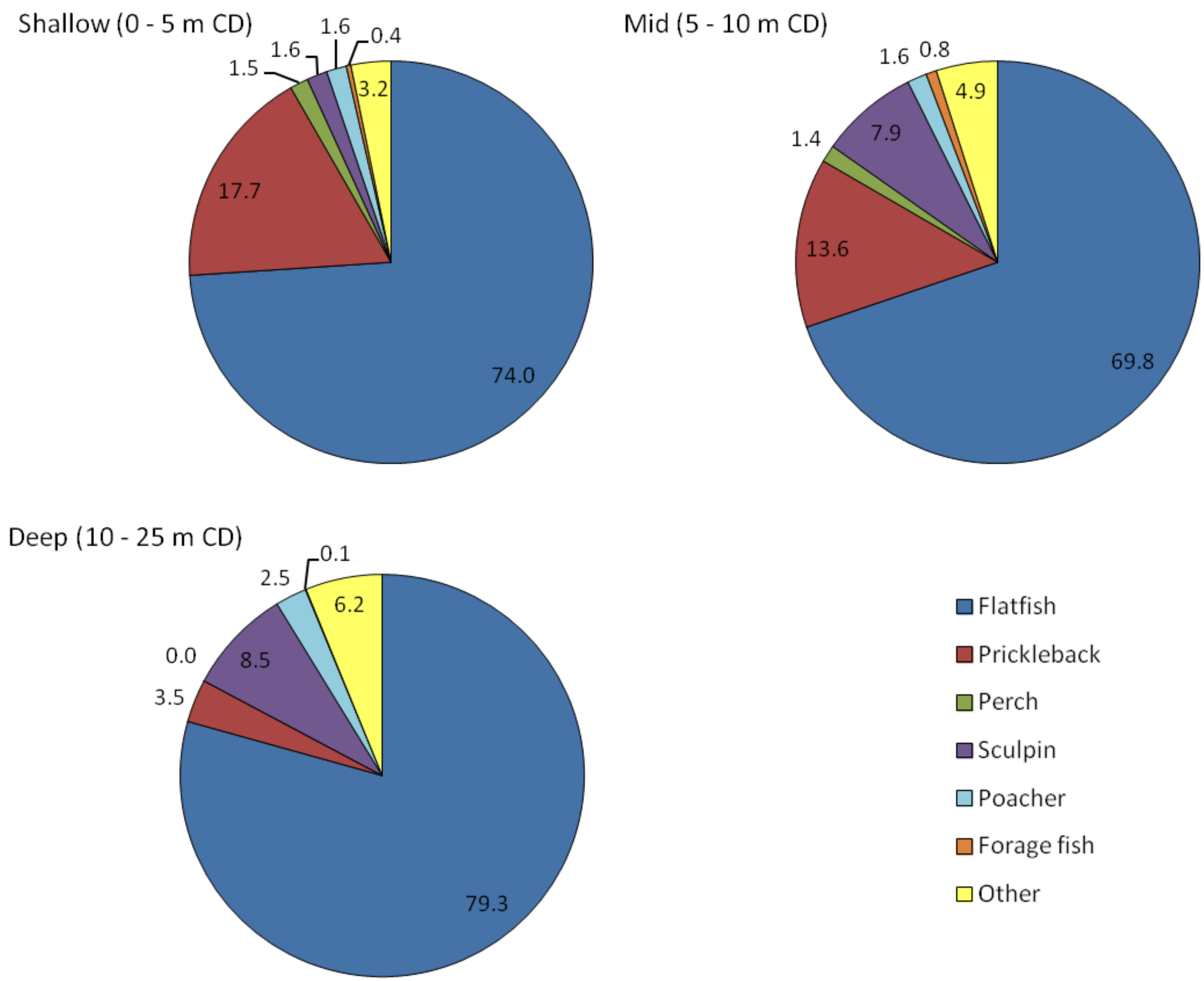

Figure 9. Fish composition proportions (%) by group based on density (number of fish per metre squared), of all fish caught in the four seasonal sampling events (summer 2012, fall 2012, winter 2012/2013, and spring 2013) using a small otter trawl (4 m horizontal and 1.6 m vertical opening) by depth strata.

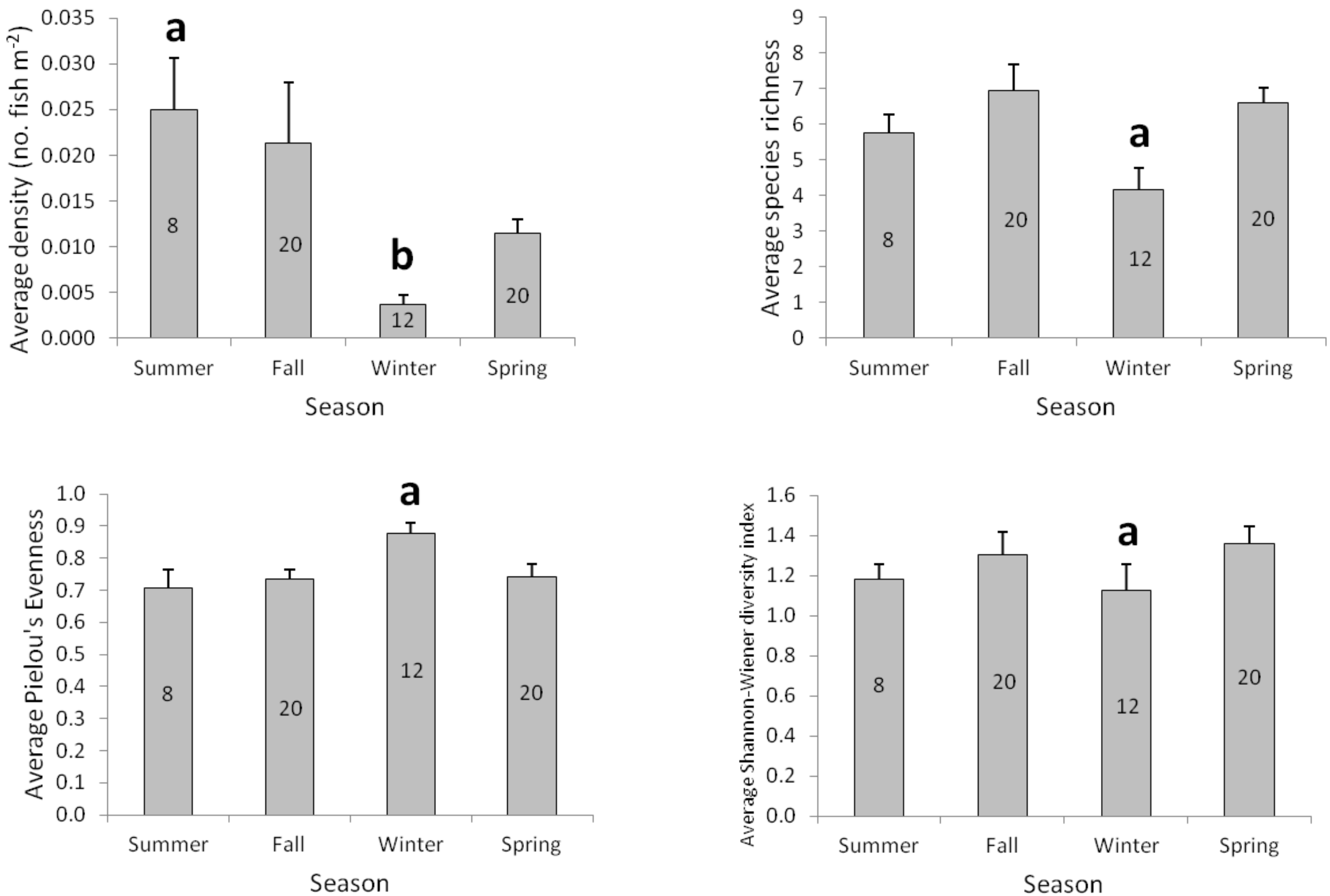

Figure 10. Density, species richness, evenness, and diversity of fish sampled at sites T1 to T10 from summer 2012 to spring 2013 by season. Error bars indicate standard error. Number in bar indicates sample size (number of tows). Significant results denoted by *a* and *b*.

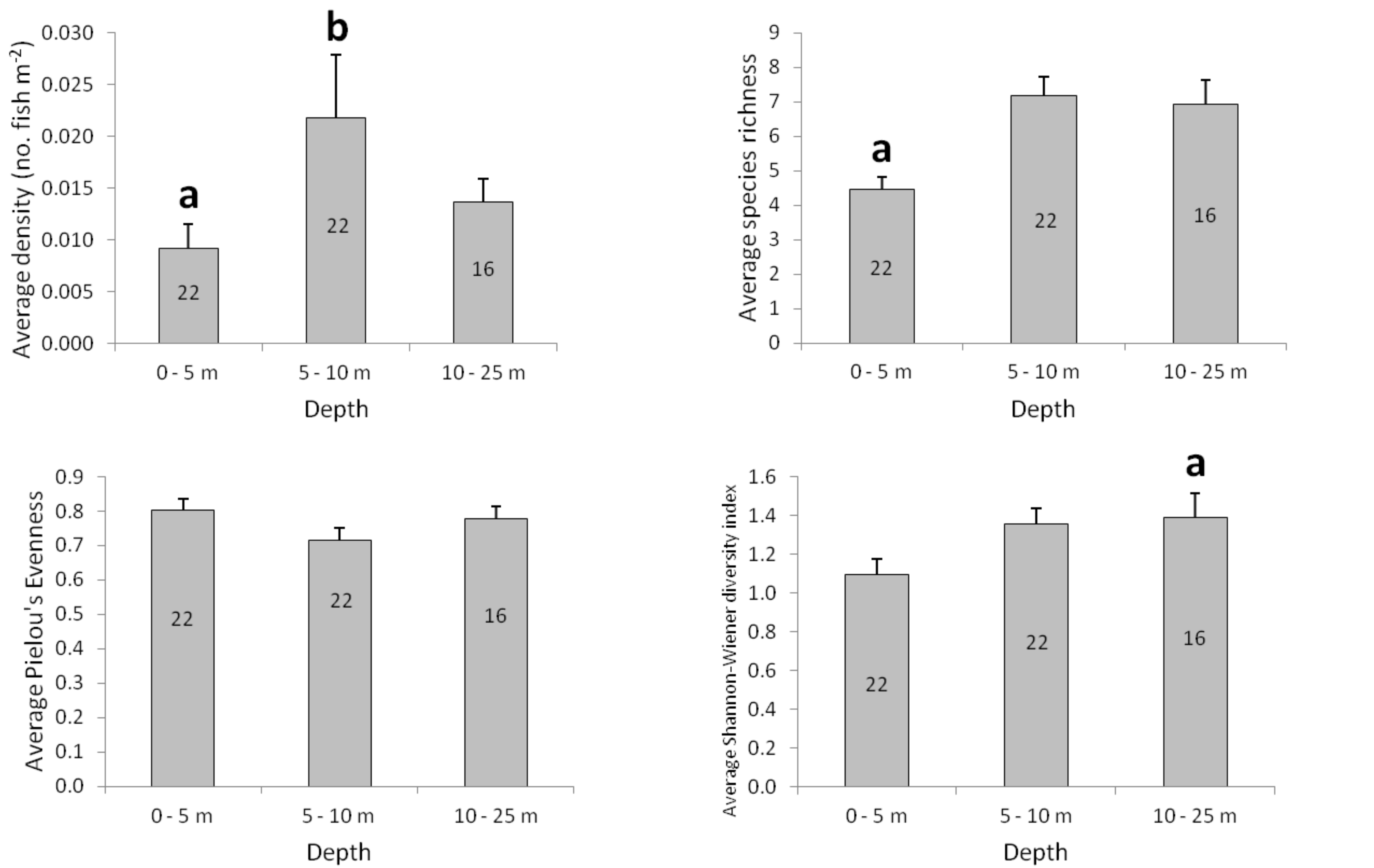

Figure 11. Density, species richness, evenness, and diversity of fish sampled at sites T1 to T10 from summer 2012 to spring 2013 by depth strata. Error bars indicate standard error. Number in bar indicates sample size (number of tows). Significant results denotated by *a* and *b*.

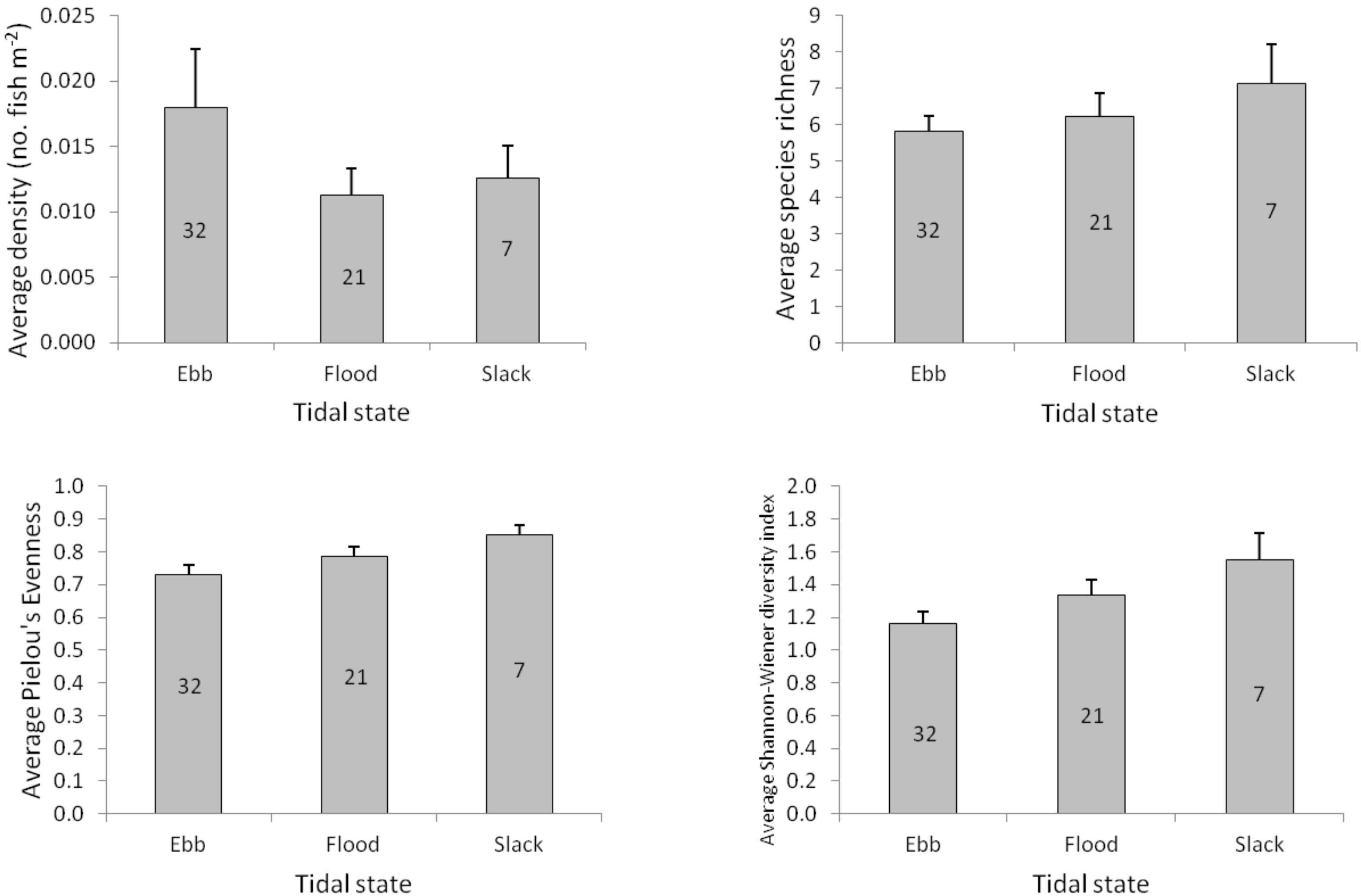

Figure 12. Density, species richness, evenness, and diversity of fish sampled at sites T1 to T10 from summer 2012 to spring 2013 by tidal state. Error bars indicate standard error. Number in bar indicates sample size (number of tows).

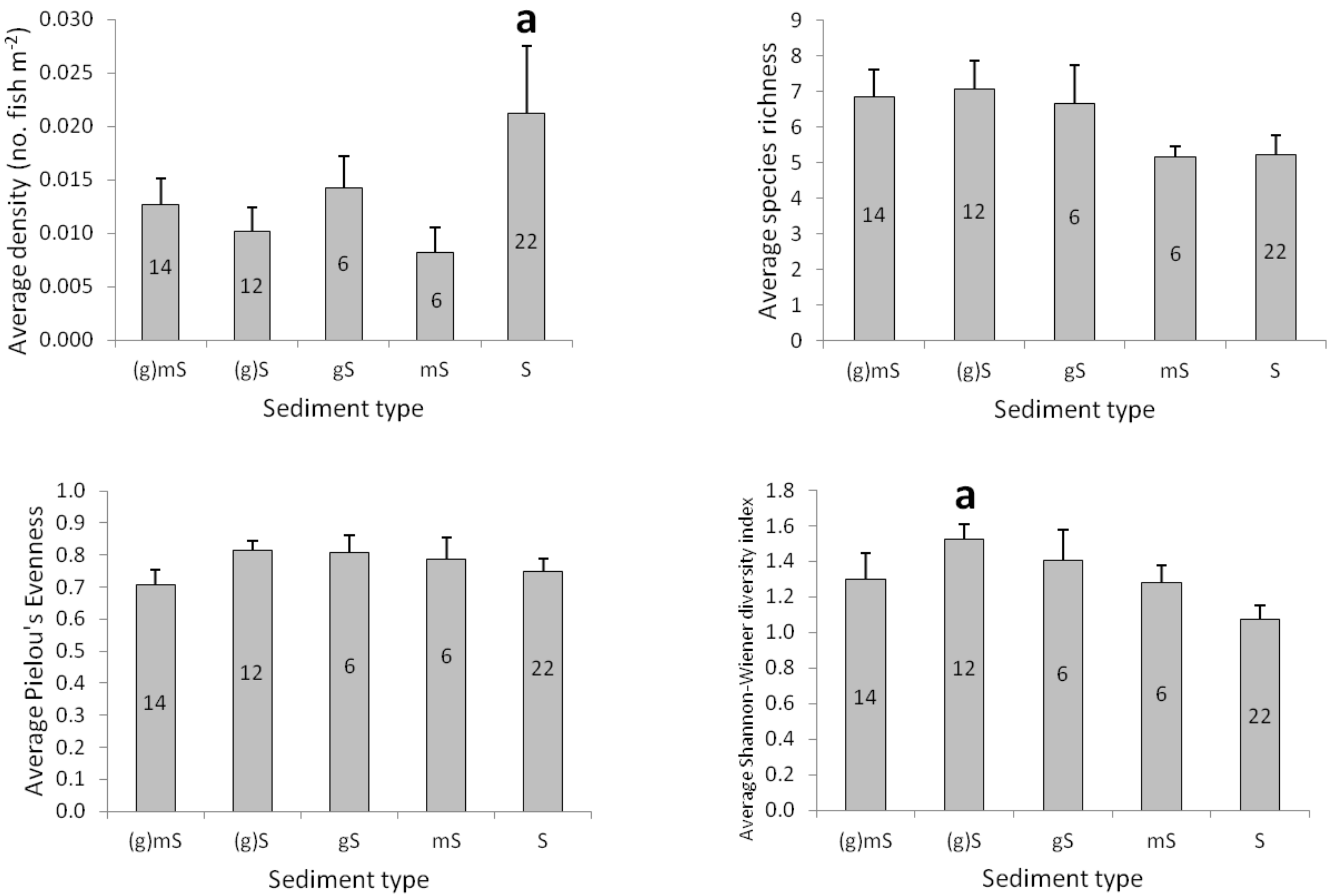

Figure 13. Density, species richness, evenness, and diversity of fish sampled at sites T1 to T10 from summer 2012 to spring 2013 by sediment type (slightly gravelly muddy sand ((g)mS), slightly gravelly sand ((g)S), gravelly sand (gS), muddy sand (mS) and sand (S)). Error bars indicate standard error. Number in bar indicates sample size (number of tows). Significant results denotated by *a*.

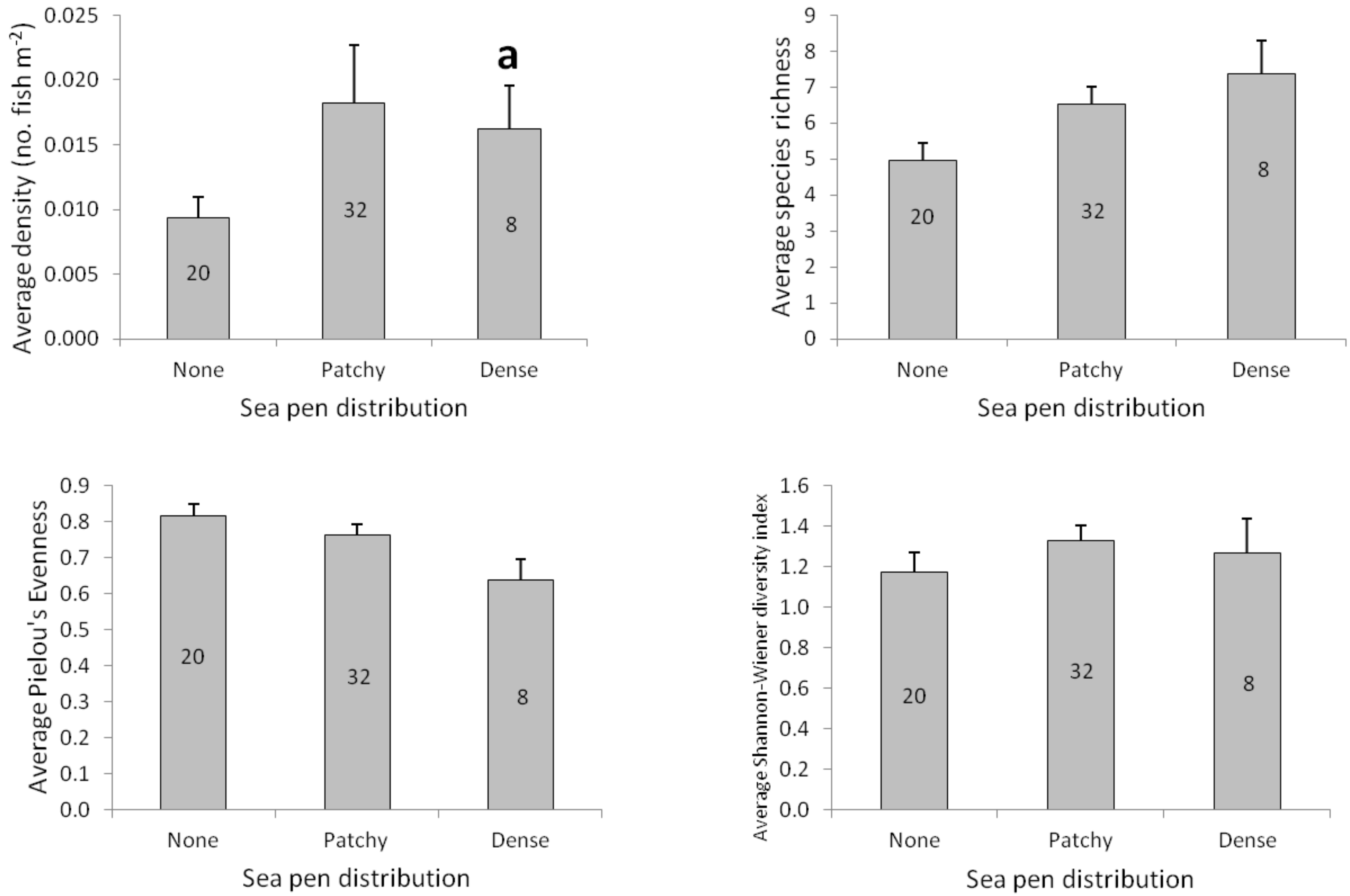

Figure 14. Density, species richness, evenness, and diversity of fish sampled at sites T1 to T10 from summer 2012 to spring 2013 by sea pen distribution. Error bars indicate standard error. Number in bar indicates sample size (number of tows). Significant results denotated by *a*.

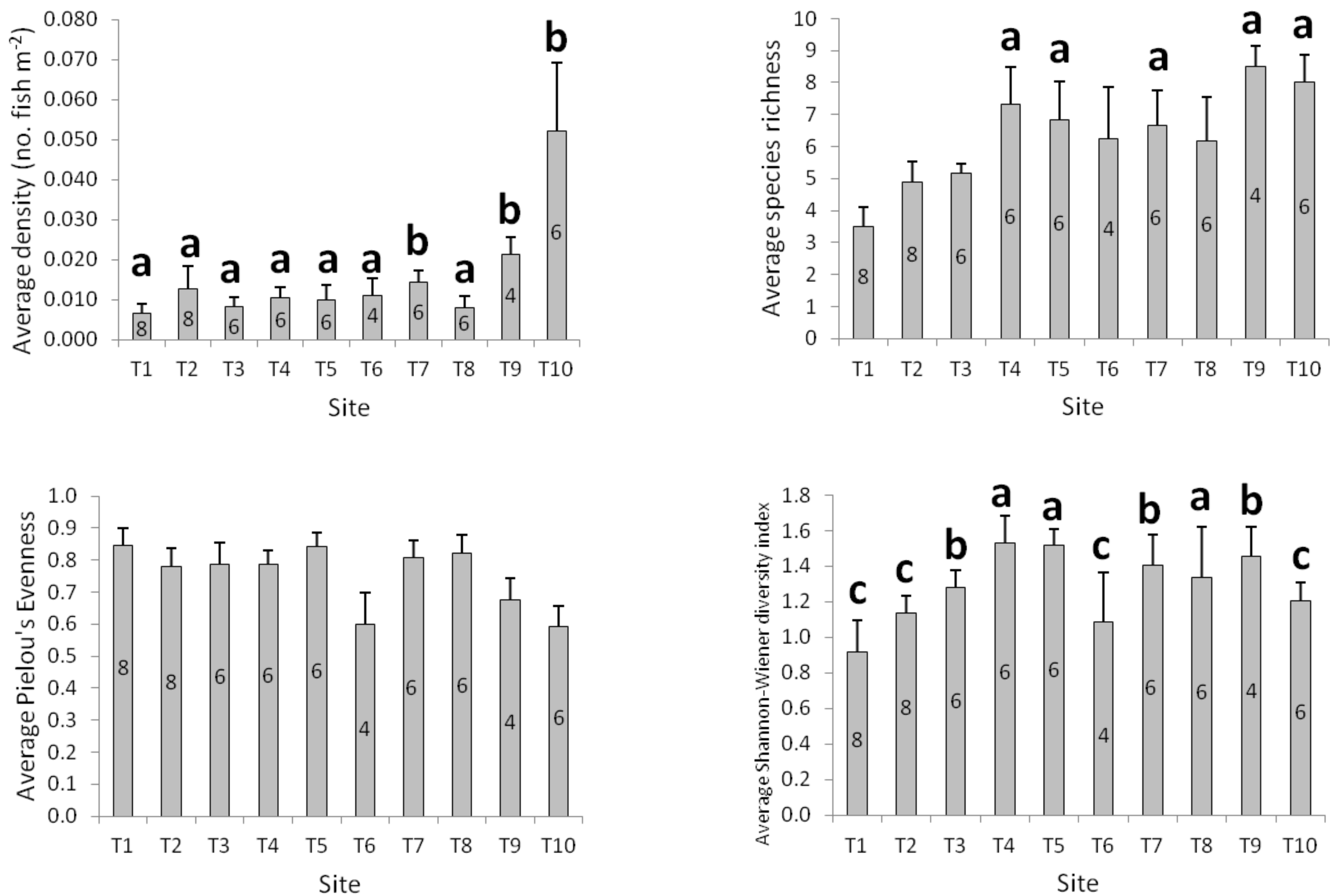

Figure 15. Density, species richness, evenness, and diversity of fish sampled at sites T1 to T10 from summer 2012 to spring 2013 by site. Error bars indicate standard error. Number in bar indicates sample size (number of tows). Significant results denotated by *a, b* and *c*.

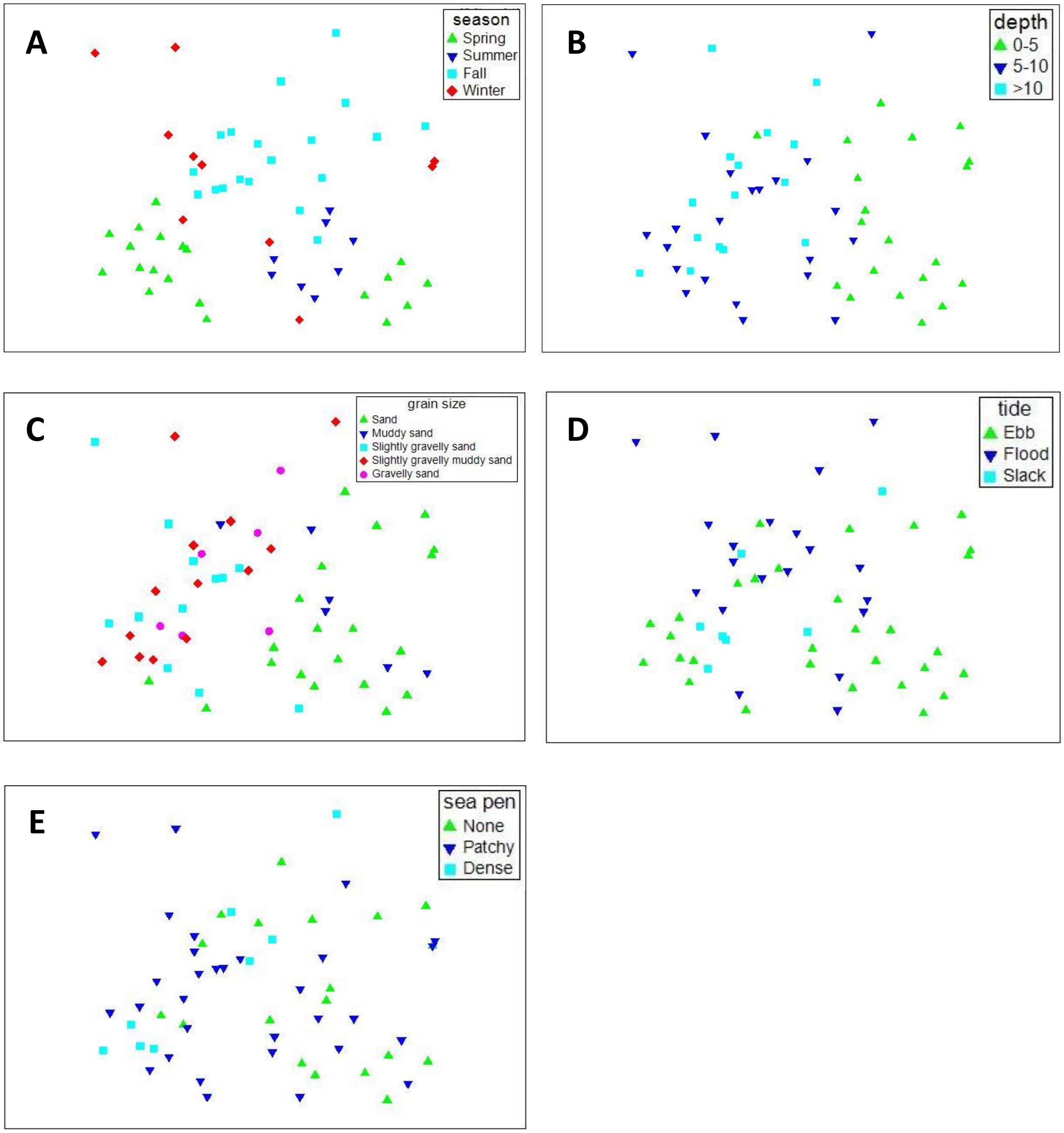

Figure 16. Two-dimensional plots of a multidimensional scaling routine (MDS) of benthic fish community data sampled at Roberts Bank from sites T1 to T10 during the Benthic Fish Trawl Survey (summer 2012 to spring 2013). Each plot shows separation of one of five factors: a) season; b) depth strata; c) sediment grain size; d) tidal state; and e) sea pen distribution. Spatial separation between the different seasons, depth strata, and sediment type indicates differences in fish community composition between these factors. Spatial overlap between tidal states and sea pen distribution indicates no differences in community composition between these factors. Stress level of the 2D plots was 0.19.

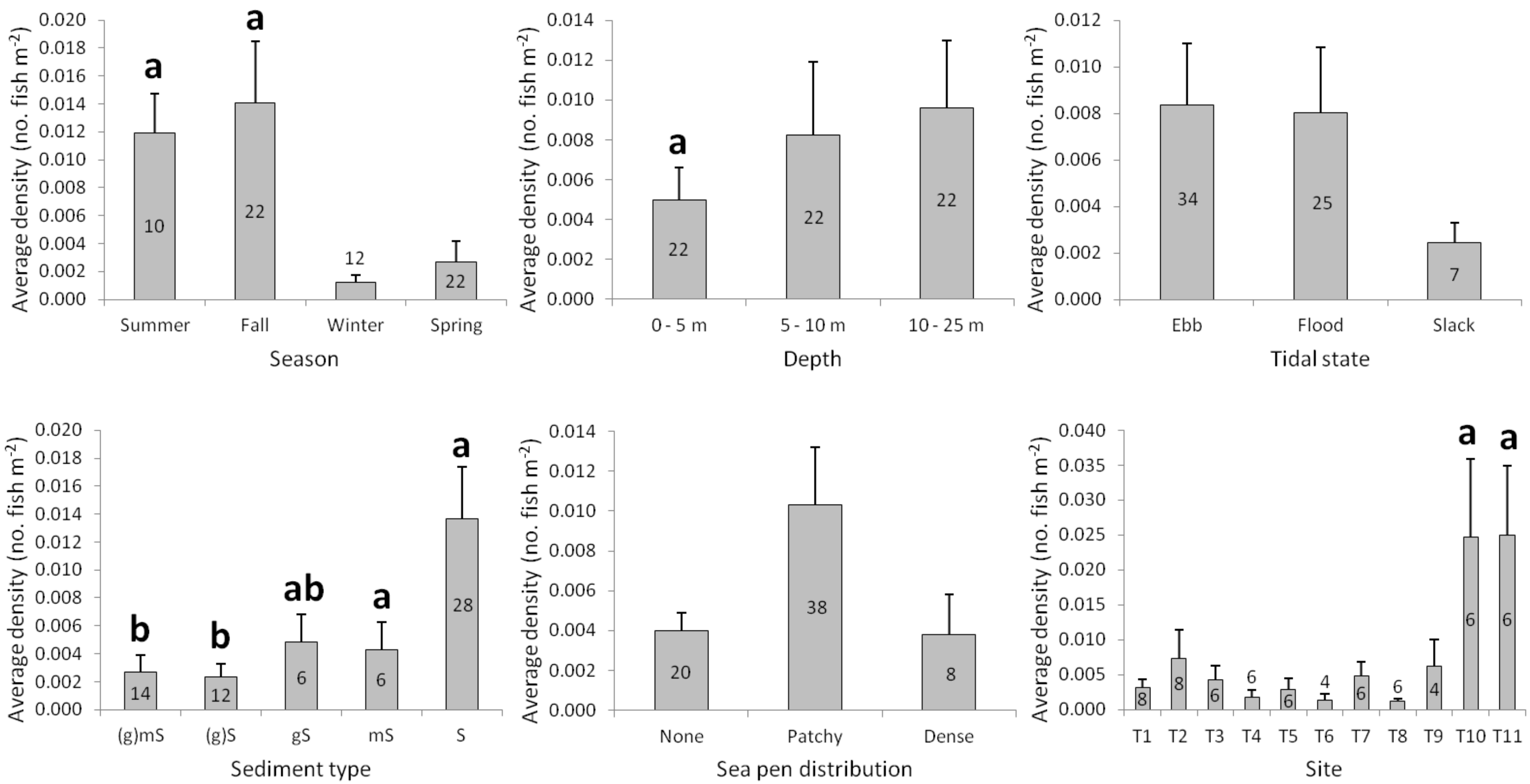

Figure 17. Density of English sole sampled at sites T1 to T11 from summer 2012 to spring 2013 by season, depth, tide state, sediment type (slightly gravelly muddy sand ((g)mS), slightly gravelly sand ((g)S), gravelly sand (gS), muddy sand (mS) and sand (S)), sea pen distribution, and site. Error bars indicate standard error. Number in bar indicates sample size (number of tows). Significant results denoted by *a, ab* (not different from *a* or different from *b*) and *b*.

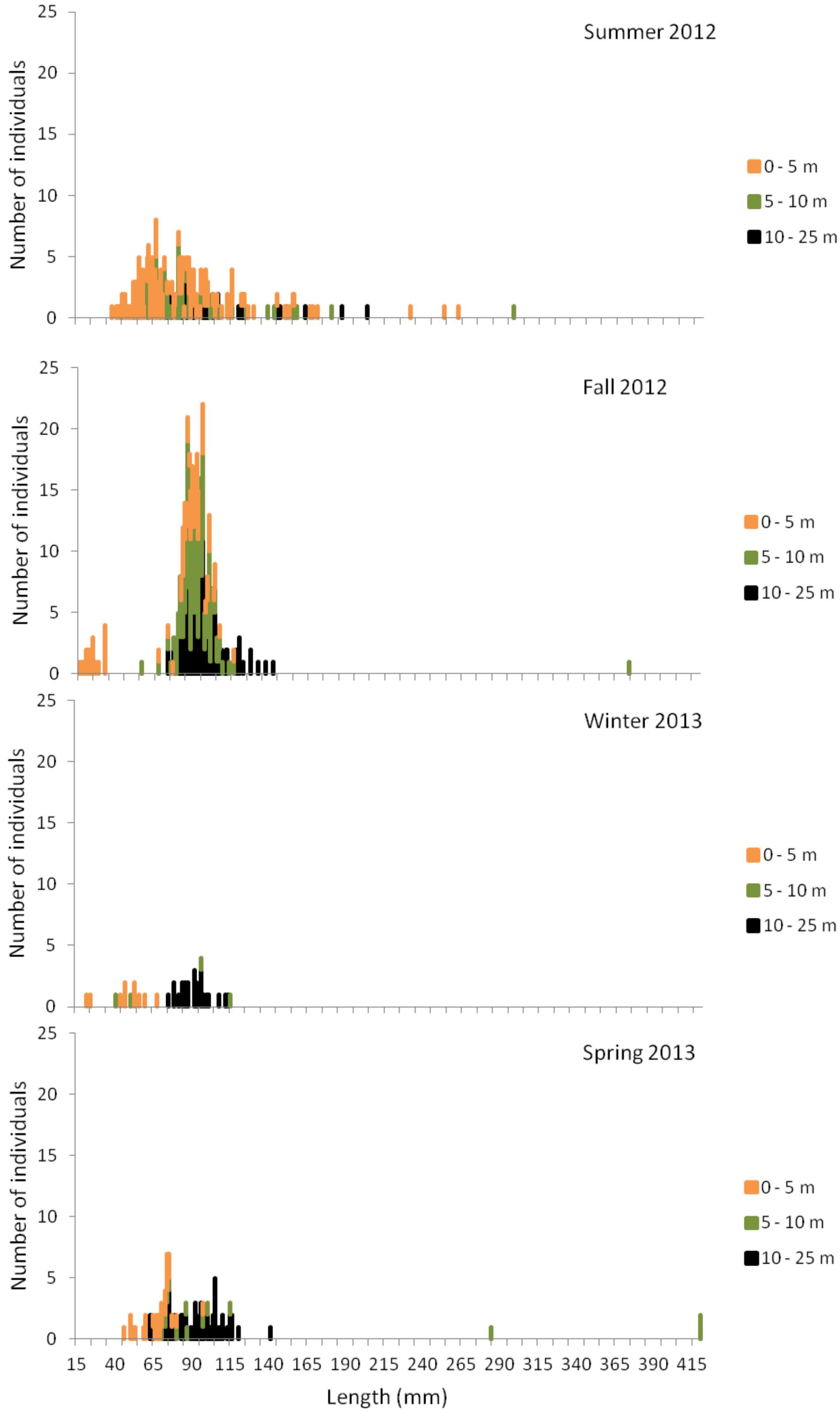

Figure 18. Length frequency graphs for English sole caught in the otter trawl at sites T1 to T11 in summer 2012 (n = 10), fall 2012 (n = 22), winter 2012/2013 (n = 12), and spring 2013 (n = 22).

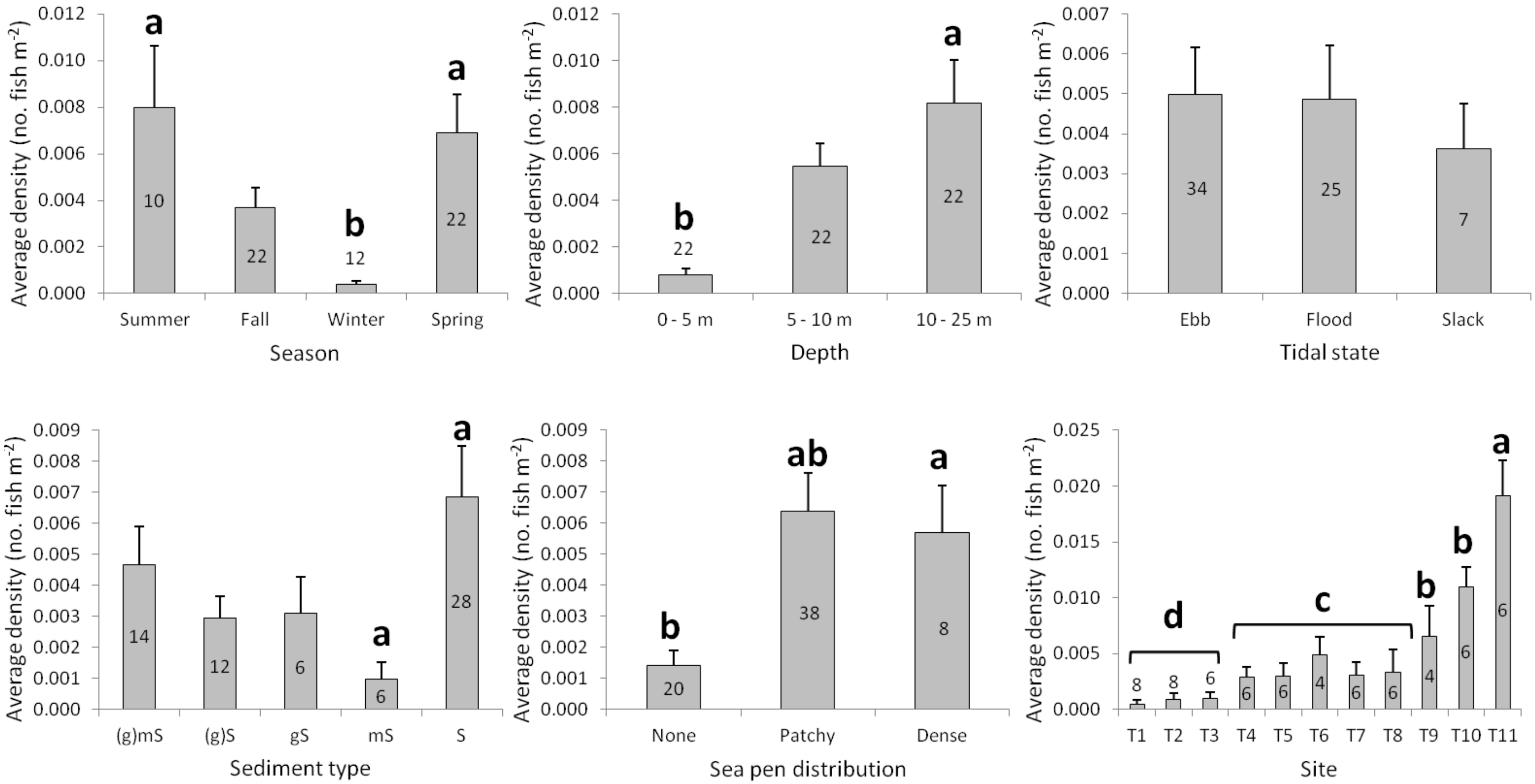

Figure 19. Density of sanddab species sampled at sites T1 to T11 from summer 2012 to spring 2013 by season, depth, tide state, sediment type (slightly gravelly muddy sand ((g)mS), slightly gravelly sand ((g)S), gravelly sand (gS), muddy sand (mS) and sand (S)), sea pen distribution, and site. Error bars indicate standard error. Number in bar indicates sample size (number of tows). Significant results denotated by *a, ab* (not different from *a* or different from *b*), *b, c* and *d*.

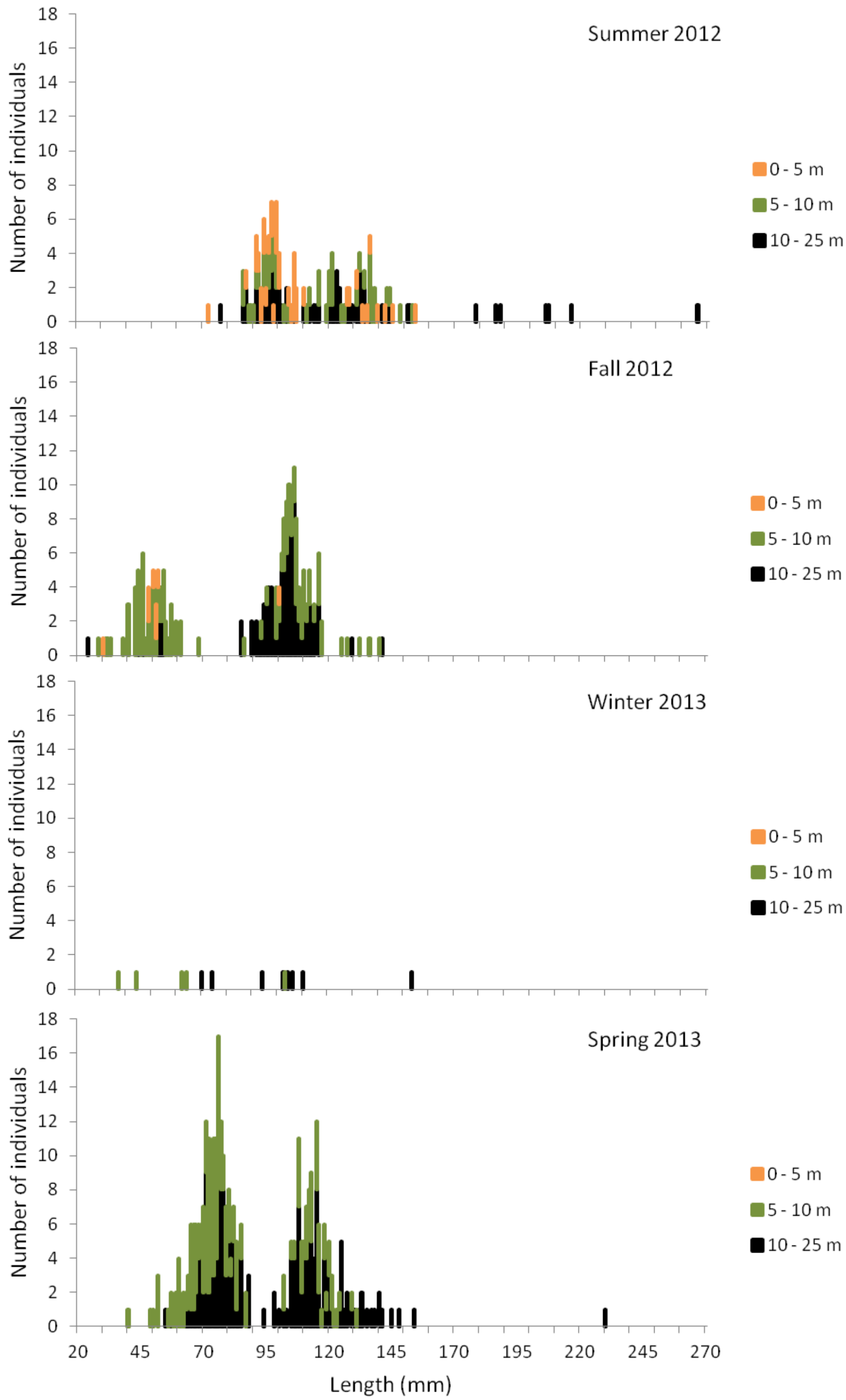

Figure 20. Length frequency graphs for sanddab species caught in the otter trawl at sites T1 to T11 in summer 2012 (n = 10), fall 2012 (n = 22), winter 2012/2013 (n = 12), and spring 2013 (n = 22).

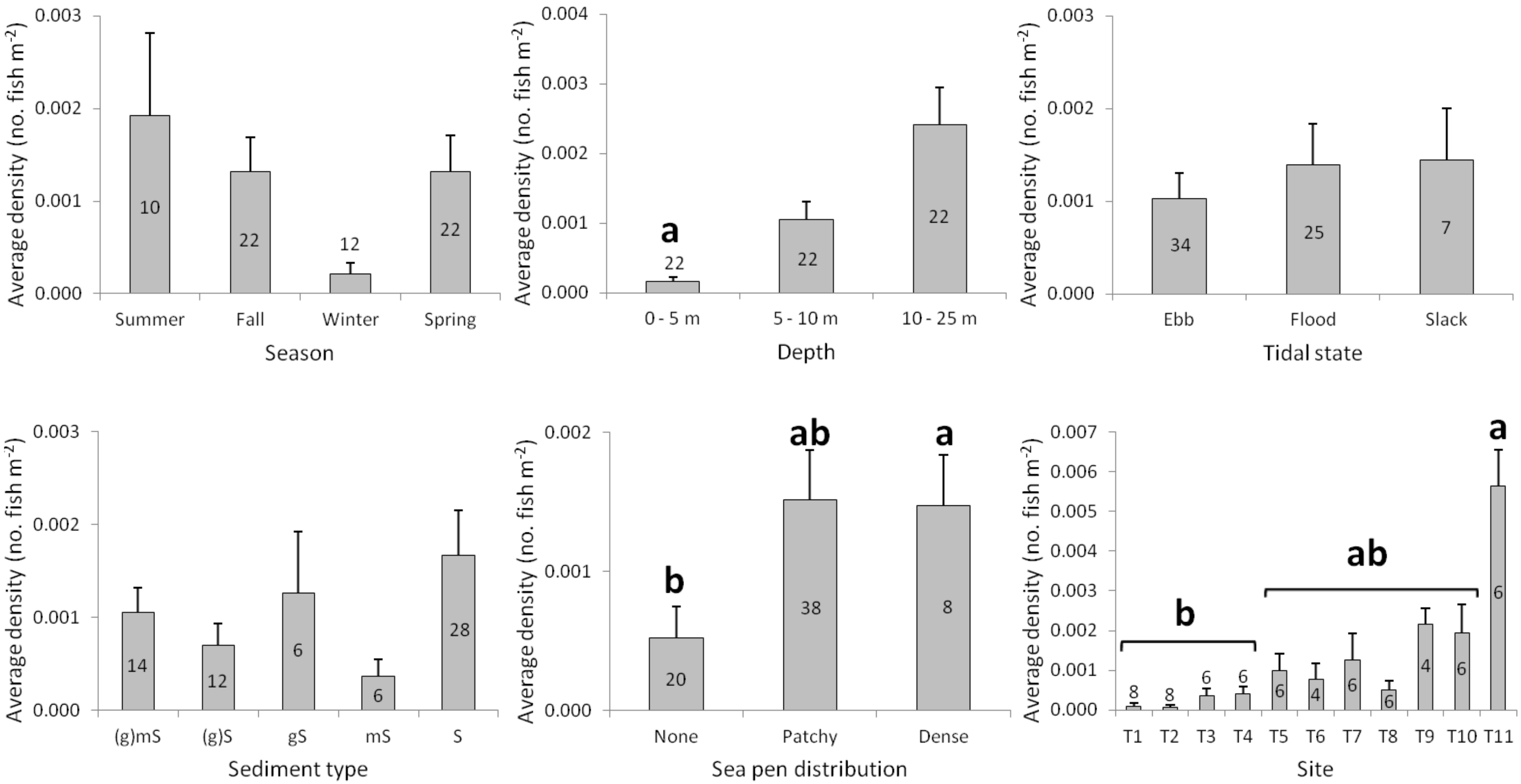

Figure 21. Density of rock sole sampled at sites T1 to T11 from summer 2012 to spring 2013 by season, depth, tide state, sediment type (slightly gravelly muddy sand ((g)mS), slightly gravelly sand ((g)S), gravelly sand (gS), muddy sand (mS) and sand (S)), sea pen distribution, and site. Error bars indicate standard error. Number in bar indicates sample size (number of tows). Significant results denotated by *a, ab* (not different from *a* or different from *b*) and *b*.

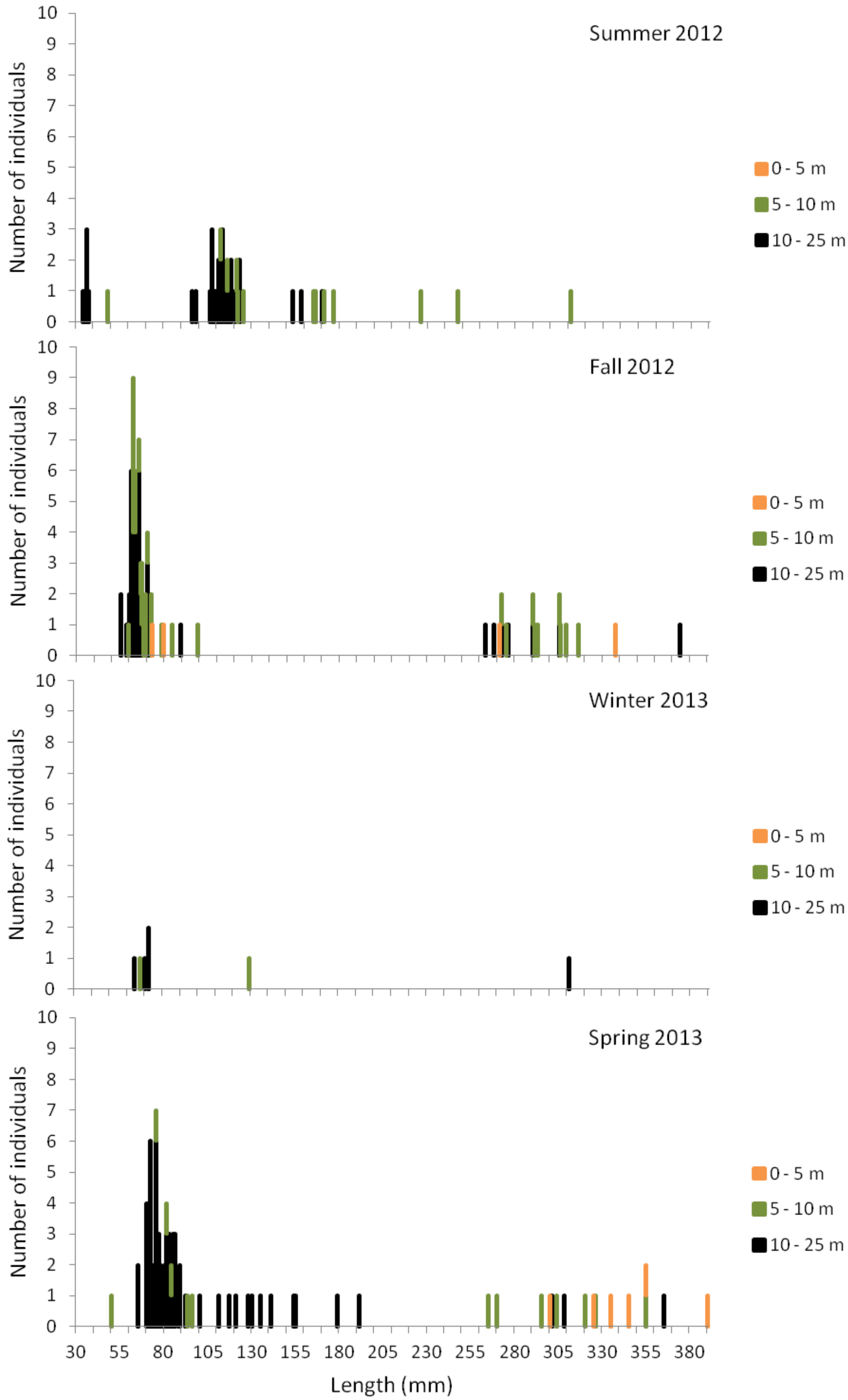

Figure 22. Length frequency graphs for rock sole caught in the otter trawl at sites T1 to T11 in summer 2012 (n = 10), fall 2012 (n = 22), winter 2012/2013 (n = 12), and spring 2013 (n = 22).

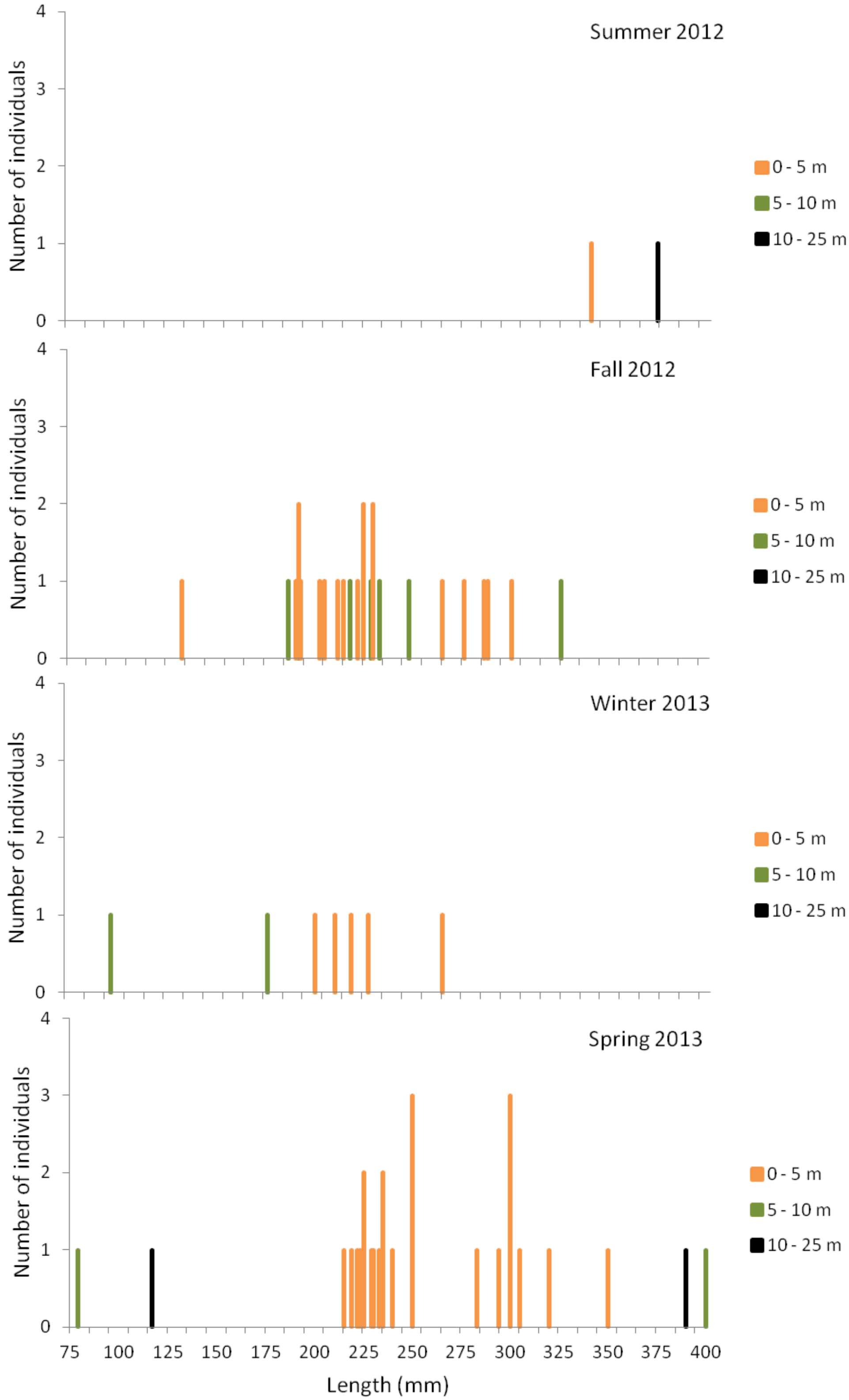

Figure 23. Length frequency graphs for starry flounder caught in the otter trawl at sites T1 to T11 in summer 2012 (n = 10), fall 2012 (n = 22), winter 2012/2013 (n = 12), and spring 2013 (n = 22).

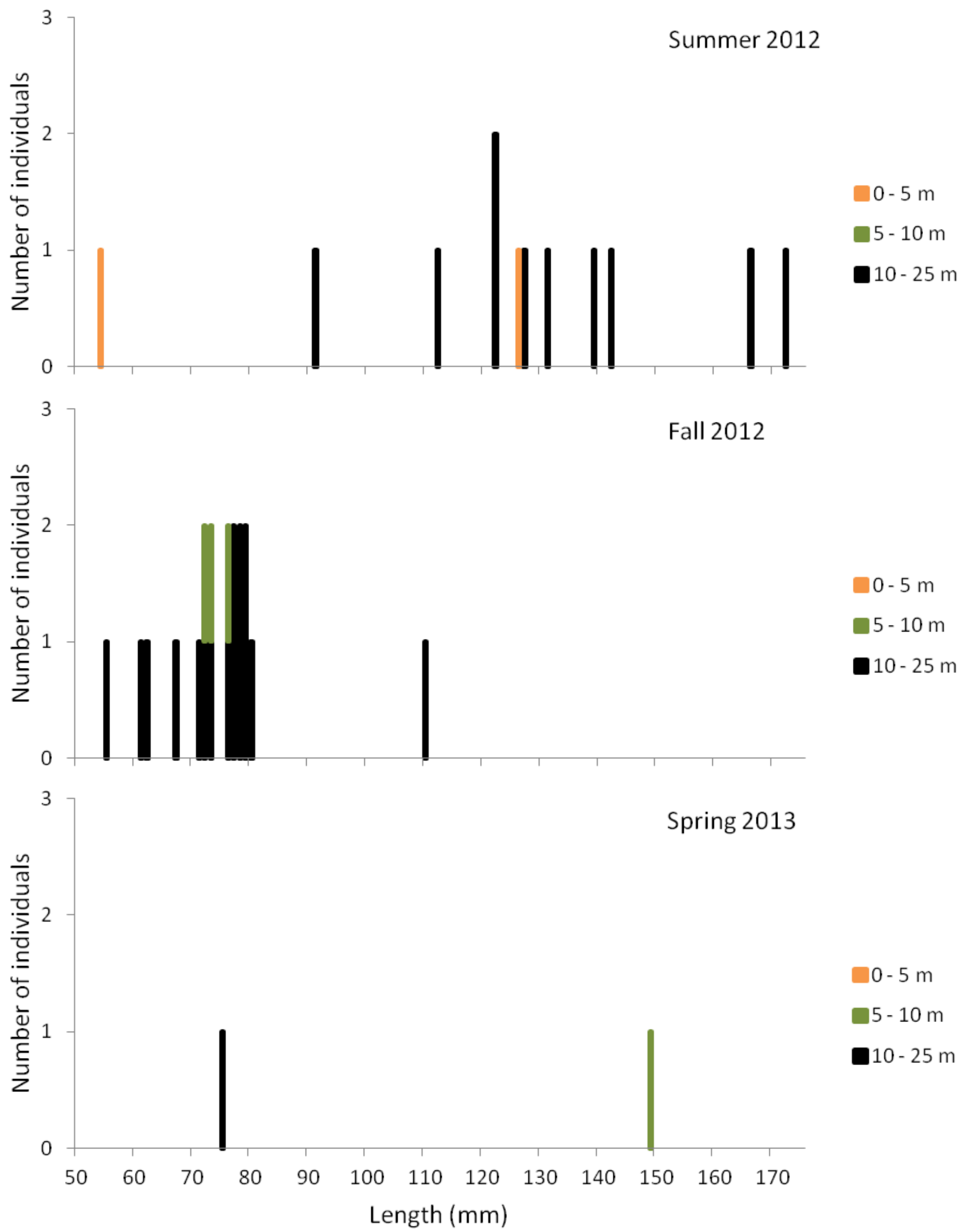

Figure 24. Length frequency graphs for butter sole caught in the otter trawl at sites T1 to T11 in summer 2012 (n = 10), fall 2012 (n = 22), winter 2012/2013 (n = 12), and spring 2013 (n = 22).

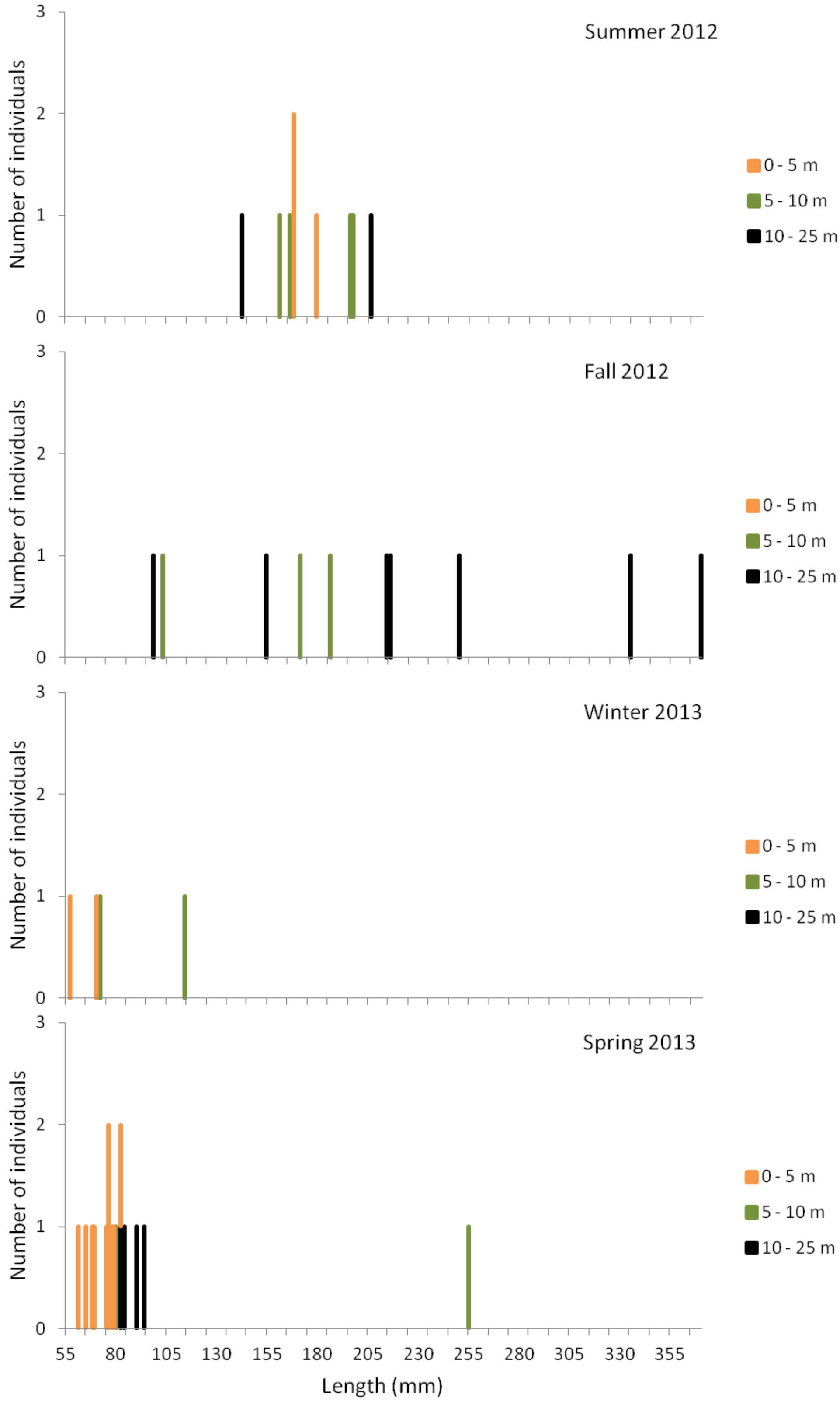

Figure 25. Length frequency graphs for sand sole caught in the otter trawl at sites T1 to T11 in summer 2012 (n = 10), fall 2012 (n = 22), and spring 2013 (n = 22). No sand sole were caught in winter 2012/2013.

Tables

Table 2. Summary of spawning to adult lifecycle and habitat characteristics for key flatfish species.

Species	Spawning Season	Spawning Habitat and Depth (m)	Larvae Characteristics	Juvenile Characteristics	Adult Characteristics	References
English sole (*Parophrys vetulus*)	Winter to spring depending on the location	Soft mud bottom along continental shelf; 50-70 m. Eggs initially pelagic and sink before hatching.	Pelagic 6-10 weeks in <200 m water depth, carried to nearshore waters by tidal currents.	Demersal in shallow coastal bay and estuarine areas (< 16 m), migrate to deeper waters after 6 months.	Limited migrations, found in <250 m and generally move to deeper water with increased fish size and adults generally absent from coastal bays and estuaries. Found in sand and sand-mud bottoms and have been associated with eelgrass.	Kramer et al. 1995 PFMC 2005; Hart 1973
Speckled sanddab (*Citharichthys stigmaeus*)	February to April	Near bottom in bays and open ocean; 35-90 m. Eggs are pelagic and found in shallow bays and estuaries.	Carried by wind and ocean currents, found between 0-88 m, up to 320 km offshore.	Found settling to bottom in spring, summer and fall between 15-25 m.	Not migratory, found over wide range of substrates including sand and sandy-mud and may be associated with rock and pier pilings, from intertidal up to 366 m.	Rackowski and Pikitch 1989; Ford 1965
Pacific sanddab (*Citharichthys sordidus*)	February to April	Near bottom in bays and open ocean; 5-45 m. Eggs are pelagic and found in shallow bays and estuaries.	Carried by wind and ocean currents to offshore waters.	Prefer silty- sand in shallow coastal waters, bays and estuaries; reach maturity around 2 years.	Sand and coarse sediments and low relief rock substrate in estuaries and coastal waters (0-550 m) typically <150 m; limited migrations.	PFMC 2005; Rackowski and Pikitch 1989
Rock sole (*Lepidopsetta* spp.)	Winter to early spring, depending on location; peak in March in Puget Sound	Sand/gravel beaches; From rocky banks to sand/mud bottoms; intertidal to 30 m. Eggs demersal and adhesive.	Pelagic for 4-6 weeks in < 30 m depths. Migrations based on prey.	Shallow coastal waters (10-40 m) over sandy-gravel bottom, move deeper with increased size.	Sedentary with some movement from deeper winter spawning grounds (125 -275 m) to shallow summer feeding grounds (18-80 m). Prefer sandy or gravel substrate and can be associated with steep rock slopes.	PFMC 2005; Penttila 1995
Starry flounder (*Platichthys stellatus*)	February to May (peak in April)	Estuaries or sheltered inshore bays <45 m. Eggs are epipelagic and typically found near the surface over depths of 20 – 70 m.	Estuaries and up to 37 km offshore. May be transported by ocean currents.	Sand to muddy substrates in estuaries and lower reaches of rivers.	Depths up to 375 m, most common < 150 m. Move inshore in late winter-early spring to spawn; offshore in summer and fall. Prefer sandy to coarse substrate including gravel.	PFMC 2005
Dover sole (*Microstomus pacificus*)	November to August depending on location; January to March in Puget Sound; November to April Oregon/California.	Soft bottom in offshore waters; 80-550 m. Eggs are epipelagic and found in upper 50 m of water column.	Offshore in up to 600 m depths, most commonly < 50 m; settle to bottom as juvenile in mid-fall to early spring.	Soft bottoms 100-700 m for <4 yrs old, move to deeper waters with age.	Large depth migrations from shallow (50-225 m) summer feeding grounds to deeper (300-1000 m) offshore spawning grounds. Found over soft mud bottoms. In BC found as shallow as 55 m.	Garrison and Miller 1982; PFMC 2005

Table 2 continued. Summary of spawning to adult lifecycle and habitat characteristics for key flatfish species.

Species	Spawning Season	Spawning Habitat and Depth (m)	Larvae Characteristics	Juvenile Characteristics	Adult Characteristics	References
Butter sole (*Isopsetta isolepis*)	Coastal areas from winter to spring	Soft bottoms; 27-64 m. Eggs are planktonic and float just below the surface.	Pelagic near the surface, abundant in nearshore waters in winter and spring.	Settle to bottom from May to August in 9-60 m, offshore for first year.	Found in coastal waters (within 18 km of shore) on muddy or silty bottoms and sand substrate; up to 425 m; (most common< 55 m in Oregon and Washington)	Kramer 1995; PFMC 1995
Sand sole (*Pegusa lascaris*)	Winter to spring: peak late April to July in BC	Sand and muddy bottoms; 20-30 m. Eggs are pelagic and float up prior to hatching.	Pelagic in upper 10 m of water column in waters < 200 m deep.	Small juveniles remain pelagic for some time, large juveniles demersal in shallow waters (5-20 m) over soft bottoms.	Found in depths < 150 m. Not considered migratory; may move into shallow nearshore areas to spawn in early winter and move offshore to feed. Found over sand and mud substrates.	Garrison and Miller 1982; PFMC 2005
Flathead Sole (*Hippoglossoides elassodon*)	May to June	In water column over 70-130 m depths. Eggs are buoyant and float near the surface.	Larvae settle to bottom in late summer, concentrate at 5-10 m.	30-70 m depths in sand and mud bottoms in estuaries and nearshore coastal areas.	Soft, silty or muddy bottoms, most commonly in depths < 366m but can be found up to 1,050 m; migrate from upper continental shelf in winter to the self in spring/summer.	PFMC 2005
C-O sole (*Pleuronichthys coenosus*)	Late spring to summer	Soft and hard substrate.		Found in shallow water in summer (0-25 m).	Soft and rocky substrates, Adults in deeper depths, range from 18-350 m.	Hart 1973; Eschmeyer et al. 1983
Curlfin sole (*Pleuronichthys decurrens*)	Late April to August	Soft bottoms. Eggs are pelagic.	-	-	Between 7-349 m-533 m, primarily < 90 m on soft bottoms.	PFMC 2005; Eschmeyer et al. 1983
Rex sole (*Glyptocephalus zachirus*)	January to June (peaks March-April)	Soft bottoms; 100-300 m. Eggs are pelagic.	Widely distributed offshore (46-211 km offshore); pelagic for 1 year.	Settle on soft bottoms in winter on outer edge of continental shelf (55-200 m).	Move inshore in summer and offshore for winter spawning; between 0-850 m, most common 50-450 m. Found over sand, mud and gravel substrates and also complexes of mud and boulders.	PFMC 2005; Eschmeyer et al. 1983

Table 3. Information from key studies carried out between 1979 and 2011 at Roberts Bank (RB) that included benthic sampling surveys.

Author	Study dates	Roberts Bank Survey area	Sampling effort	Gear	Study Objectives	Major results
Greer et al. 1980	April-July 1979 (April in RB)	North of Roberts Bank causeway and inter-causeway area including borrow pit.	Only outer edge of banks sampled due to depth limitation. 34 tows performed in total, of which 15 tows (stations 20-34) were performed on RB. All fish were indentified to species, counted and released alive. Average depth trawled: 5.5 ± 3.4 m. Range 2 – 15 m.	Otter trawl, gulf coast style flat trawl. Dimensions: net length 5 m, 3.8 cm mesh size stretched in body and 1.2 cm mesh cod end.	Benthic fish distribution and use of Sturgeon Bank and RB.	631 fish caught in total between Sturgeon Bank and Roberts Bank, comprising 27 species. Six species accounted for 84% of total catch: starry flounder (*Platichthys stellatus*), English sole (*Parophrys vetulus*), Pacific staghorn sculpin (*Leptocottus armatus*), Pacific sanddab (*Citharichthys sordidus*), speckled sanddab (*C. stigmaeus*) and Dover sole (*Microstomus pacificus*). On Roberts Bank, 65% of catch was starry flounder, 14% was rock sole (*Lepidopsetta bilineata*) and 9% was Pacific sanddab. Benthic species mostly utilised sand flat areas on the north side of the Iona (sewage plant) Jetty on Sturgeon Bank, and Sturgeon Pit to the south. Fish utilised Sturgeon Bank more than Roberts Bank (i.e., 90% of catch at Sturgeon Bank; CPUE: 29.9 for Sturgeon Bank and 4.2 for Roberts Bank). The rate of utilisation by benthic fishes of Sturgeon versus Roberts Bank remains uncertain due to non-uniform distribution of trawling effort.
Triton Environmental Consultants 2004	July 2003-May 2004	North and southwest of Roberts Bank terminals and inter-causeway area.	Sixteen sites sampled in four seasons for a total of 64 tows (plus 4 additional tows in dredge area during spring 2004). Eleven sites located on the north side of causeway in intertidal and subtidal zone. Tows averaged 605 m in distance.	Beach trawl net dimensions: 1 m x 3 m X 6 m, mesh size tapering from 12 mm to 3 mm in a 1.5 m cod end.	Distribution of fish and their habitat use on subtidal sand flats and mud flats.	4,379 fish were caught (1,609 (37%) from north side of Roberts Bank causeway) representing 27 species. Most were flatfishes, sculpins (Cottidae), threespine stickleback (*Gasterosteus aculeatus*) and pricklebacks (Stichaeidae). Majority of fishes caught in spring on north side of Roberts Bank terminals (74%) and in summer on south side (61%). Catch composition similar on either side of causeway. Similar abundances due to large number of stickleback caught in the inter-causeway area. Fall and winter catches comprised less than 3% of total. Most abundant species on north side of causeway included juvenile flatfishes, pricklebacks, adult starry flounder, shiner perch (*Cymatogaster aggregata*) and Pacific staghorn sculpin. Starry flounder was the most abundant fish at depths less than 3 m.

Table 3 continued. Information from key studies carried out between 1979 and 2011 at Roberts Bank (RB) that included benthic sampling surveys.

Author	Study dates	Roberts Bank Survey area	Sampling effort	Gear	Study Objectives	Major results
Archipelago 2014a	September 2003, July 2008, November 2011, and September 2012.	Vicinity of the proposed RBT2 footprint, dredge basin, tug basin and shallow subtidal adjacent the dredge basin in the inter-causeway area.	734 hectares of seabed (of which 591 was in the subtidal zone, characterised in a nine year period) sampled over 4 different events. 2003: Transects laid out in 100 x 100 m grids, generating 75 km of survey tracklines. 2008: Transects laid out in 100 x 100 m grids, and wider spacing (between 250 m and 750 m), generating 29 km of survey tracklines. 2011: Transects laid out in 100 x 100 m grids, generating 48 km of survey tracklines. 2012: Transects laid out in 100 x 100 m grids, generating 25 km of survey tracklines.	Video surveys conducted with towed video system (SIMS). Acquired imagery was georeferenced using differential GPS. Video imagery classified by biologist and geologist.	Habitat characterisation survey – map the distribution of flora and fauna (invertebrates and fish) and physical features in four areas of RB to characterise fish habitat.	Proposed RBT2 terminal footprint and vicinity: Sand substrate, large sea pen bed, abundant Dungeness crabs (*Metacarcinus magister*) and juvenile flatfish (Pleuronectiformes). Deeper sand slopes (coarser substrate) host different species of flatfishes than shallow subtidal sandflats. Dredge basin: Mud substrate, Dungeness crab, sea pen and flatfishes present. Species community different than subtidal sandflat due to finer substrate. Starry flounder were the most abundant flatfish throughout the survey area and mostly occurred to a depth of 5 m. English sole and Dover sole were second and third most abundant species, respectively.

Table 4. Trawl tow parameters for sites T1 to T11.

Site	Set	Season	Date	Time of day	Tidal State	Tow sampling effort			Trawl depth (m) CD	
						Time (min)	Distance (m)	Area (m^2)	Min	Max
1	1	Spring	04/17/2013	Morning	Ebb	15.00	858	3432	0.5	1.1
1	2	Spring	04/17/2013	Morning	Ebb	15.25	739	2956	0.6	1.1
2	1	Spring	04/17/2013	Afternoon	Ebb	15.25	792	3168	0.8	2.3
2	2	Spring	04/17/2013	Afternoon	Ebb	15.75	777	3108	1.0	2.0
3	1	Spring	04/17/2013	Afternoon	Ebb	15.00	826	3304	1.5	2.1
3	2	Spring	04/17/2013	Afternoon	Ebb	15.25	794	3176	1.7	2.5
4	1	Spring	04/19/2013	Afternoon	Ebb	15.00	645	2580	5.0	8.4
4	2	Spring	04/19/2013	Afternoon	Ebb	15.25	738	2952	7.0	8.6
5	1	Spring	04/19/2013	Morning	Flood	15.00	822	3288	4.4	7.3
5	2	Spring	04/19/2013	Morning	Slack	15.00	714	2856	4.3	7.4
6	1	Spring	04/18/2013	Morning	Ebb	15.00	686	2744	4.9	8.5
6	2	Spring	04/18/2013	Afternoon	Ebb	14.00	683	2732	4.5	7.5
7	1	Spring	04/18/2013	Morning	Slack	15.75	693	2772	10.1	16.9
7	2	Spring	04/18/2013	Morning	Slack	15.50	808	3232	13.2	19.5
8	1	Spring	04/18/2013	Morning	Flood	15.00	794	3176	9.8	13.7
8	2	Spring	04/18/2013	Morning	Slack	15.25	986	3944	16.5	22.0
9	1	Spring	04/18/2013	Morning	Ebb	14.75	857	3428	10.3	13.6
9	2	Spring	04/18/2013	Morning	Ebb	14.50	726	2904	15.8	21.7
10	1	Spring	04/20/2013	Afternoon	Ebb	15.00	657	2628	5.4	7.6
10	2	Spring	04/20/2013	Afternoon	Ebb	14.75	727	2908	6.5	9.1
11	1	Spring	04/20/2013	Afternoon	Ebb	15.25	688	2752	13.2	18.8
11	2	Spring	04/20/2013	Afternoon	Ebb	15.00	810	3240	20.4	26.6
1	1	Summer	08/08/2012	Morning	Flood	16.25	525	2100	0.4	1.4
1	2	Summer	08/08/2012	Afternoon	Ebb	12.50	560	2240	0.0	1.3
2	1	Summer	08/08/2012	Afternoon	Ebb	17.00	645	2580	1.6	2.7
2	2	Summer	08/08/2012	Afternoon	Ebb	16.25	715	2860	1.8	3.1
3	1	Summer	08/08/2012	Afternoon	Flood	13.75	635	2540	2.3	2.9
3	2	Summer	08/08/2012	Afternoon	Flood	15.00	685	2740	2.2	3.0
10	1	Summer	08/09/2012	Afternoon	Ebb	10.25	540	2160	2.0	7.2
10	2	Summer	08/09/2012	Afternoon	Ebb	14.75	530	2120	3.9	6.3
11	1	Summer	08/09/2012	Morning	Flood	12.50	620	2480	7.9	16.4
11	2	Summer	08/09/2012	Morning	Flood	14.50	730	2920	9.9	18.0
1	1	Fall	11/13/2012	Morning	Ebb	15.25	766	3064	+0.1	1.4
1	2	Fall	11/13/2012	Morning	Ebb	15.50	518	2072	0.2	1.3
2	1	Fall	11/14/2012	Afternoon	Flood	16.75	894	3576	1.7	2.9
2	2	Fall	11/14/2012	Afternoon	Slack	15.50	859	3436	1.9	3.0
3	1	Fall	11/14/2012	Morning	Ebb	8.50	582	2328	1.9	3.1
3	2	Fall	11/14/2012	Morning	Ebb	10.00	630	2520	2.4	2.7
4	1	Fall	11/13/2012	Afternoon	Flood	14.25	602	2408	5.7	8.8
4	2	Fall	11/13/2012	Afternoon	Flood	14.75	701	2804	5.4	7.5
5	1	Fall	11/15/2012	Morning	Ebb	17.00	959	3836	4.0	11.3
5	2	Fall	11/15/2012	Morning	Ebb	15.25	835	3340	5.9	9.8
6	1	Fall	11/15/2012	Afternoon	Flood	15.75	764	3056	4.3	8.6
6	2	Fall	11/15/2012	Afternoon	Flood	16.75	580	2320	3.7	7.2
7	1	Fall	11/13/2012	Morning	Flood	14.75	545	2180	8.5	15.2

Table 4 continued. Trawl tow parameters for sites T1 to T11.

Site	Set	Season	Date	Time of day	Tidal State	Tow sampling effort			Trawl depth (m) CD	
						Time (min)	Distance (m)	Area (m^2)	Min	Max
7	2	Fall	11/13/2012	Afternoon	Flood	15.00	444	1776	12.7	22.8
8	1	Fall	11/14/2012	Morning	Ebb	13.00	1112	4448	8.6	11.3
8	2	Fall	11/14/2012	Afternoon	Flood	15.50	631	2524	12.3	16.7
9	1	Fall	11/14/2012	Afternoon	Flood	14.25	765	3060	15.4	18.9
9	2	Fall	11/14/2012	Afternoon	Flood	15.50	932	3728	12.8	22.8
10	1	Fall	11/16/2012	Morning	Ebb	16.75	416	1664	5.6	6.4
10	2	Fall	11/16/2012	Morning	Ebb	15.50	423	1692	7.1	7.9
11	1	Fall	11/15/2012	Afternoon	Flood	13.25	723	2892	16.0	20.0
11	2	Fall	11/15/2012	Afternoon	Flood	12.00	466	1864	10.2	16.3
1	1	Winter	02/19/2013	Afternoon	Ebb	15.50	838	3352	+0.5	1.7
1	2	Winter	02/19/2013	Afternoon	Ebb	15.50	714	2856	0.2	1.8
2	1	Winter	02/19/2013	Morning	Ebb	16.00	868	3472	1.0	2.7
2	2	Winter	02/19/2013	Morning	Ebb	16.00	854	3416	1.5	2.9
4	1	Winter	02/20/2013	Morning	Flood	15.50	608	2432	5.0	6.1
4	2	Winter	02/20/2013	Morning	Flood	15.25	658	2632	6.2	7.6
5	1	Winter	02/20/2013	Morning	Flood	14.50	730	2920	5.3	8.2
5	2	Winter	02/20/2013	Morning	Flood	14.50	705	2820	5.7	8.7
7	1	Winter	02/20/2013	Morning	Slack	16.50	671	2684	20.7	26.6
7	2	Winter	02/20/2013	Morning	Slack	16.25	566	2264	15.7	21.5
8	1	Winter	02/19/2013	Morning	Flood	15.00	703	2812	17.6	23.5
8	2	Winter	02/19/2013	Morning	Flood	17.50	794	3176	11.3	15.8

Table 5. Sediment classification and nomenclature.

Sediment type	Composition
Gravel	>80% gravel
Sandy gravel	30 – 80% gravel and >90% sand
Muddy sandy gravel	30 – 80% gravel and 50 – 90% sand (the rest mud)
Muddy gravel	30 – 80% gravel and <50% sand (the rest mud)
Gravelly sand	5 – 30% gravel and >90% sand
Gravelly muddy sand	5 – 30% gravel and 50 – 90% sand (the rest mud)
Gravelly mud	5 – 30% gravel and <50% sand (the rest mud)
Slightly gravelly sand	trace to 5% gravel and >90% sand
Slightly gravelly muddy sand	trace to 5% gravel and 50 – 90% sand (the rest mud)
Slightly gravelly sandy mud	trace to 5% gravel and between 10 – 50% sand (the rest mud)
Slightly gravelly mud	trace to 5% gravel and less than 10% sand (the rest mud)
Sand	no gravel and >90% sand
Muddy sand	no gravel and 50 – 90% sand (the rest mud)
Sandy mud	no gravel and between 10 – 50% sand (the rest mud)
Mud	no gravel and less than 10% sand (the rest mud)

Table 6. Total abundance of fish captured by otter trawl at shallow (0 to 5 m) sites T1 to T3 in summer and fall 2012, and winter and spring 2013.

Species		Stage	Site T1								Site T2								Site T3					
			Summer		Fall		Winter		Spring		Summer		Fall		Winter		Spring		Summer		Fall		Spring	
Common Name	Latin Name		1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
English sole	*Parophrys vetulus*	Adult (>350mm)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Transitional (210-350)	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0
		Juvenile (<210mm)	3	17	29	2	2	2	2	11	86	34	17	13	6	2	4	2	34	16	3	6	5	4
Sanddab	*Citharichthys sordidus* and *Citharichthys stigmaeus*	-	2	6	1	0	0	0	0	0	11	5	4	1	0	0	0	0	9	4	1	1	0	0
Butter sole	*Pleuronectes isolepis*	Transitional (100-250mm)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
		Juvenile (<100mm)	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Sand sole	*Psettichthys melanostictus*	Adult (>280mm)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Transitional (200-280mm)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Juveniles (<200mm)	0	0	0	0	0	0	2	5	0	1	0	0	0	0	0	2	2	0	0	0	1	0
Rock sole	*Lepidopsetta* spp.	Adult (>360mm)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
		Transitional (300-360mm)	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	1	0	0	2
		Juvenile (<300mm)	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0
Dover sole	*Microstomus pacificus*	Juvenile (<300mm)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Starry flounder	*Platichthys stellatus*	Transitional (220-450mm)	0	0	4	0	0	1	2	1	1	0	4	2	0	1	5	1	0	0	0	0	9	3
		Juveniles (<220mm)	0	0	1	0	1	0	0	0	0	0	4	2	2	0	0	0	0	0	0	1	1	1
Flathead sole	*Hippoglossoides elassodon*	Adult (>260mm)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Snake prickleback	*Lumpenus sagitta*	-	4	15	0	0	0	0	4	11	22	19	1	0	0	0	4	3	1	1	0	0	6	7
Shiner perch	*Cymatogaster aggregata*	-	0	5	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Pacific staghorn sculpin	*Leptocottus armatus*	-	0	1	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Tidepool sculpin	*Oligocottus maculosus*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Padded sculpin	*Artedius fenestralis*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Grunt sculpin	*Rhamphocottus richardsonii*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Roughback sculpin	*Chitonotus pugetensis*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ribbed sculpin	*Triglops pingeli*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Buffalo sculpin	*Enophrys bison*	-	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Great sculpin	*Myoxocephalus polyacanthocephalus*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Silver spotted sculpin	*Blepsias cirrhosus*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Sailfin sculpin	*Nautichthys oculofasciatus*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Northern sculpin	*Icelinus borealis*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Soft sculpin	*Gilbertidia sigalutes*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tadpole sculpin	*Psychrolutes paradoxus*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Big skate	*Raja binoculata*	Juvenile	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Bay pipefish	*Syngnathus griseolineatus*	-	0	0	2	0	0	0	0	0	0	0	3	9	0	0	0	0	0	0	1	3	0	0
Tubesnout	*Aulorhynchus flavidus*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
White spotted greenling	*Hexagrammos stelleri*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Walleye pollock	*Theragra chalcogramma*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sturgeon poacher	*Agonus acipenserinus*	-	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	2	0	0	0	0
Northern spearnose poacher	*Agonopsis vulsa*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pygmy poacher	*Odontopyxis trispinosa*	-	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0
Smooth alligator fish	*Anoplagonus inermis*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tubenose poacher	*Pallasina barbata*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Saddleback gunnel	*Pholis ornata*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cresent gunnel	*Pholis laeta*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Long fin smelt	*Spirinchus thaleichthys*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Surf smelt	*Hypomesus pretiosus*	-	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pacific sand lance	*Ammodytes hexapterus*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plainfin midshipman	*Porichthys notatus*	-	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Totals			**9**	**44**	**38**	**2**	**3**	**3**	**11**	**30**	**127**	**63**	**34**	**32**	**9**	**3**	**15**	**8**	**49**	**24**	**9**	**12**	**23**	**18**

Table 7. Total abundance of fish captured by otter trawl at mid depth (5 to 10 m) sites T4 to T6 and T10 in summer and fall 2012, and winter and spring 2013.

Species		Stage	Site T4						Site T5						Site T6				Site T10					
			Fall		Winter		Spring		Fall		Winter		Spring		Fall		Spring		Summer		Fall		Spring	
Common Name	Latin Name		1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
English sole	*Parophrys vetulus*	Adult (>350mm)	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2
		Transitional (210-350)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0
		Juvenile (<210mm)	6	19	1	1	1	0	27	28	1	1	1	2	13	1	0	1	22	39	115	80	1	4
Sanddab	*Citharichthys sordidus* and *Citharichthys stigmaeus*	-	7	15	0	1	8	16	8	21	2	2	5	19	18	0	20	17	18	25	10	16	29	55
Butter sole	*Pleuronectes isolepis*	Transitional (100-250mm)	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
		Juvenile (<100mm)	0	0	0	0	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Sand sole	*Psettichthys melanostictus*	Adult (>280mm)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Transitional (200-280mm)	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
		Juveniles (<200mm)	0	0	0	1	0	0	1	0	1	0	0	1	1	0	0	0	1	3	1	0	0	0
Rock sole	*Lepidopsetta* spp.	Adult (>360mm)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Transitional (300-360mm)	0	1	0	0	1	0	0	1	0	0	0	2	1	0	0	1	0	1	1	0	0	0
		Juvenile (<300mm)	0	2	0	1	0	2	4	7	0	1	0	4	5	1	1	0	5	7	6	1	1	1
Dover sole	*Microstomus pacificus*	Juvenile (<300mm)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Starry flounder	*Platichthys stellatus*	Transitional (220-450mm)	0	1	0	0	0	1	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0
		Juveniles (<220mm)	0	0	0	1	0	0	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	1
Flathead sole	*Hippoglossoides elassodon*	Adult (>260mm)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Snake prickleback	*Lumpenus sagitta*	-	0	2	0	0	1	3	0	0	0	0	2	5	2	0	0	0	22	13	60	9	3	3
Shiner perch	*Cymatogaster aggregata*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	5	0	0
Pacific staghorn sculpin	*Leptocottus armatus*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0
Tidepool sculpin	*Oligocottus maculosus*	-	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Padded sculpin	*Artedius fenestralis*	-	2	7	1	6	6	14	5	10	0	1	1	4	0	0	1	1	0	0	1	1	3	0
Grunt sculpin	*Rhamphocottus richardsonii*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Roughback sculpin	*Chitonotus pugetensis*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Ribbed sculpin	*Triglops pingeli*	-	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Buffalo sculpin	*Enophrys bison*	-	3	3	1	2	2	3	3	3	0	0	0	3	0	0	1	0	0	0	0	0	0	0
Great sculpin	*Myoxocephalus polyacanthocephalus*	-	0	1	0	0	1	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Silver spotted sculpin	*Blepsias cirrhosus*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sailfin sculpin	*Nautichthys oculofasciatus*	-	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Northern sculpin	*Icelinus borealis*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Soft sculpin	*Gilbertidia sigalutes*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tadpole sculpin	*Psychrolutes paradoxus*	-	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
Big skate	*Raja binoculata*	Juvenile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bay pipefish	*Syngnathus griseolineatus*	-	2	8	0	1	0	0	3	2	0	0	0	0	24	6	0	0	0	0	9	2	0	0
Tubesnout	*Aulorhynchus flavidus*	-	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
White spotted greenling	*Hexagrammos stelleri*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Walleye polluck	*Theragra chalcogramma*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sturgeon poacher	*Agonus acipenserinus*	-	0	1	0	0	0	0	0	1	0	0	0	0	2	0	0	0	3	3	1	0	0	0
Northern spearnose poacher	*Agonopsis vulsa*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Pygmy poacher	*Odontopyxis trispinosa*	-	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	2	1
Smooth alligator fish	*Anoplagonus inermis*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tubenose poacher	*Pallasina barbata*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Saddleback gunnel	*Pholis ornata*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0
Cresent gunnel	*Pholis laeta*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Long fin smelt	*Spirinchus thaleichthys*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Surf smelt	*Hypomesus pretiosus*	-	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pacific sand lance	*Ammodytes hexapterus*	-	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plainfin midshipman	*Porichthys notatus*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Totals			**20**	**62**	**12**	**14**	**20**	**42**	**52**	**79**	**5**	**5**	**10**	**45**	**71**	**11**	**24**	**20**	**72**	**92**	**214**	**115**	**40**	**69**

Table 8. Total abundance of fish captured by otter trawl at deep depth (10 to 25 m) sites T7 to T9 and T11 in summer and fall 2012, and winter and spring 2013.

Species		Stage	Site T7						Site T8						Site T9				Site T11					
			Fall		Winter		Spring		Fall		Winter		Spring		Fall		Spring		Summer		Fall		Spring	
Common Name	Latin Name		1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
English sole	*Parophrys vetulus*	Adult (>350mm)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Transitional (210-350)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Juvenile (<210mm)	9	24	18	1	3	10	7	0	5	2	7	5	24	60	4	0	14	28	191	60	6	111
Sanddab	*Citharichthys sordidus* and *Citharichthys stigmaeus*	-	4	3	4	1	15	25	10	0	3	0	42	13	7	18	50	13	62	58	37	27	32	101
Butter sole	*Pleuronectes isolepis*	Transitional (100-250mm)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	6	1	0	0	0
		Juvenile (<100mm)	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	5	8	1	0
Sand sole	*Psettichthys melanostictus*	Adult (>280mm)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
		Transitional (200-280mm)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	1	0	0
		Juveniles (<200mm)	0	0	0	0	2	1	0	0	0	0	0	1	0	0	0	0	0	1	2	0	0	0
Rock sole	*Lepidopsetta* spp.	Adult (>360mm)	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
		Transitional (300-360mm)	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0
		Juvenile (<300mm)	0	1	1	0	8	11	1	0	3	0	1	4	10	6	5	6	19	16	8	12	8	25
Dover sole	*Microstomus pacificus*	Juvenile (<300mm)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	0	0	0	0
Starry flounder	*Platichthys stellatus*	Transitional (220-450mm)	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
		Juveniles (<220mm)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Flathead sole	*Hippoglossoides elassodon*	Adult (>260mm)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Snake prickleback	*Lumpenus sagitta*	-	0	0	0	0	2	6	0	0	0	0	0	6	1	2	1	3	1	5	12	7	3	9
Shiner perch	*Cymatogaster aggregata*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pacific staghorn sculpin	*Leptocottus armatus*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	1	0	1
Tidepool sculpin	*Oligocottus maculosus*	-	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Padded sculpin	*Artedius fenestralis*	-	0	3	9	0	5	7	2	0	3	4	10	6	6	4	3	5	0	1	1	5	1	1
Grunt sculpin	*Rhamphocottus richardsonii*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Roughback sculpin	*Chitonotus pugetensis*	-	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ribbed sculpin	*Triglops pingeli*	-	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Buffalo sculpin	*Enophrys bison*	-	0	0	3	0	9	6	1	0	1	3	4	3	0	1	0	1	0	0	0	0	0	1
Great sculpin	*Myoxocephalus polyacanthocephalus*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0
Silver spotted sculpin	*Blepsias cirrhosus*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sailfin sculpin	*Nautichthys oculofasciatus*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Northern sculpin	*Icelinus borealis*	-	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	6	0	0
Soft sculpin	*Gilbertidia sigalutes*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Tadpole sculpin	*Psychrolutes paradoxus*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Big skate	*Raja binoculata*	Juvenile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bay pipefish	*Syngnathus griseolineatus*	-	9	1	0	0	0	0	1	0	2	2	1	0	25	14	0	0	0	0	25	7	0	0
Tubesnout	*Aulorhynchus flavidus*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
White spotted greenling	*Hexagrammos stelleri*	-	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	1	3	0	1
Walleye polluck	*Theragra chalcogramma*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Sturgeon poacher	*Agonus acipenserinus*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Northern spearnose poacher	*Agonopsis vulsa*	-	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0
Pygmy poacher	*Odontopyxis trispinosa*	-	1	2	1	0	1	1	0	0	0	0	1	2	4	2	3	0	4	1	3	3	1	0
Smooth alligator fish	*Anoplagonus inermis*	-	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	1	0	0
Tubenose poacher	*Pallasina barbata*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Saddleback gunnel	*Pholis ornata*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0
Cresent gunnel	*Pholis laeta*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Long fin smelt	*Spirinchus thaleichthys*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Surf smelt	*Hypomesus pretiosus*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Pacific sand lance	*Ammodytes hexapterus*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plainfin midshipman	*Porichthys notatus*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Totals			**29**	**35**	**37**	**2**	**46**	**69**	**23**	**0**	**19**	**12**	**68**	**41**	**80**	**109**	**67**	**31**	**112**	**124**	**294**	**145**	**58**	**251**

Table 9. Frequency of occurrence (FO; number of tows in which a species was captured divided by the total number of tows x 100) for fish species caught in the four sampling events between summer 2012 and spring 2013 at sites T1 to T11.

Species			Frequency of occurrence by season (%)				Total across all seasons
Group	Common name	Latin name	Spring	Summer	Fall	Winter	
Flatfish	Sanddab	*Citharichthys sordidus* and *Citharichthys stigmaeuss*	73	100	86	50	77
	English sole	*Parophrys vetulus*	91	100	95	100	95
	Butter sole	*Pleuronectes isolepis*	9	40	27	0	18
	Sand sole	*Psettichthys melanostictus*	36	60	23	17	32
	Rock sole	*Lepidopsetta spp.*	82	40	73	33	64
	Dover sole	*Microstomus pacificus*	0	20	0	0	3
	Starry flounder	*Platichthys stellatus*	45	20	41	50	41
	Flathead sole	*Hippoglossoides elassodon*	0	0	5	0	2
Perch	Shiner perch	*Cymatogaster aggregata*	0	30	9	0	8
Sculpin	Pacific staghorn sculpin	*Leptocottus armatus*	5	30	23	0	14
	Tidepool sculpin	*Oligocottus maculosus*	0	20	9	0	6
	Padded sculpin	*Artedius fenestralis*	68	10	59	50	53
	Grunt sculpin	*Rhamphocottus richardsonii*	0	10	0	0	2
	Roughback sculpin	*Chitonotus pugetensis*	9	0	0	0	3
	Ribbed sculpin	*Triglops pingeli*	14	0	5	0	6
	Buffalo sculpin	*Enophrys bison*	50	0	27	42	33
	Great sculpin	*Myoxocephalus polyacanthocephalus*	14	0	14	0	9
	Silver spotted sculpin	*Blepsias cirrhosus*	5	0	0	0	2
	Sailfin sculpin	*Nautichthys oculofasciatus*	0	0	5	0	2
	Northern sculpin	*Icelinus borealis*	0	0	18	17	9
	Soft sculpin	*Gilbertidia sigalutes*	0	0	5	0	2
	Tadpole sculpin	*Psychrolutes paradoxus*	9	0	0	0	3
Skate	Big skate	*Raja binoculata*	0	10	0	0	2
Pipefish	Bay pipefish	*Syngnathus griseolineatus*	5	0	91	25	36
Tubesnout	Tubesnout	*Aulorhynchus flavidus*	0	0	5	0	2

Table 9 continued. Frequency of occurrence (FO; number of tows in which a species was captured divided by the total number of tows x 100) for fish species caught in the four sampling events between summer 2012 and spring 2013 at sites T1 to T11.

Species			Frequency of occurrence by season (%)				Total across all seasons
Group	Common name	Latin name	Spring	Summer	Fall	Winter	
Greenling	White spotted greenling	*Hexagrammos stelleri*	14	0	14	0	9
Polluck	Walleye polluck	*Theragra chalcogramma*	0	0	5	0	2
Poacher	Sturgeon poacher	*Agonus acipenserinus*	0	60	18	8	17
	Northern spearnose poacher	*Agonopsis vulsa*	9	0	5	8	6
	Pygmy poacher	*Odontopyxis trispinosa*	41	30	36	8	32
	Smooth alligator fish	*Anoplagonus inermis*	9	0	9	0	6
	Tubenose poacher	*Pallasina barbata*	5	0	0	0	2
Gunnel	Saddleback gunnel	*Pholis ornata*	14	0	5	0	6
	Cresent gunnel	*Pholis laeta*	0	0	5	0	2
Prickleback	Snake prickleback	*Lumpenus sagitta*	86	100	41	0	58
Smelt	Long fin smelt	*Spirinchus thaleichthys*	0	0	5	0	2
	Surf smelt	*Hypomesus pretiosus*	0	10	9	0	5
Sand lance	Pacific sand lance	*Ammodytes hexapterus*	0	0	0	8	2
Midshipman	Plainfin midshipman	*Porichthys notatus*	0	20	0	0	3

Table 10. Invertebrates captured in the otter trawl at sites T1 to T3 and T10 and T11 in the summer 2012.

Common Name	Latin Name	T1		T2		T3		T10			T11		Total
		Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 3	Set 1	Set 2	
Arthropoda													
Brachyuran Crabs													
Dungeness crab adult	*Metacarcinus magistar*	0	0	3	3	1	0	3	0	5	5	0	**20**
Dungeness crab juvenile	*Metacarcinus magistar*	0	0	1	0	1	0	0	0	0	0	0	**2**
Dungeness crab megalop	*Metacarcinus magistar*	15	13	8	102	12	7	1	0	0	1	0	**159**
Graceful crab	*Metacarcinus gracilis*	0	0	0	0	0	0	0	0	0	0	1	**1**
Graceful decorator crab	*Oregonia gracilis*	0	0	0	0	0	0	1	0	0	3	4	**8**
Sharpnose crab	*Scyra acutifrons*	0	0	0	0	0	0	1	0	0	0	1	**2**
Pacific lyre crab	*Hyas lyratus*	0	0	0	0	0	0	1	0	0	3	2	**6**
Hermit Crabs													
Splendid hermit crab	*Labidochirus splendescens*	0	0	0	0	0	0	0	0	0	1	0	**1**
Pandalid Shrimp													
Dock shrimp	*Pandalus danae*	0	0	0	0	0	0	0	0	0	7	0	**7**
	Pandalus sp.	0	0	0	0	0	0	0	0	0	0	1	**1**
Hippolytid Shrimp													
Shortspine shrimp	*Heptacarpus brevirostris*	0	0	0	0	0	0	0	0	0	1	0	**1**
Slender coastal shrimp	*Heptacarpus tenuissimus*	0	0	0	0	0	0	0	0	0	1	0	**1**
	Heptacarpus sp.	0	0	0	0	0	0	0	0	0	0	2	**2**
Crangon shrimp													
Unidentified crangon	*Crangon* spp.	20	16	24	4	3	11	6	3	4	61	54	**206**
Gammarid amphipod													
	Gammaridae indet.	1	0	3	0	0	1	0	0	0	0	0	**5**
Mollusca													
Bivalves													
Cockle	*Clinocardium spp.*	6	2	0	0	2	2	0	0	0	0	0	**12**
Venus clams	*Nutricola* spp.	200	200	200	0	500	200	10	0	0	0	5	**1315**
Smooth pink scallop	*Chlamys rubida*	0	0	0	0	0	0	0	0	0	1	0	**1**
Gastropods													
Shaggy dovesnail	*Astyris gausapata*	0	0	0	0	0	0	0	0	0	0	2	**2**

Table 11. Invertebrates captured in the otter trawl at sites T1 to T11 in the fall 2012.

Common Name	Latin Name	T2		T2		T3		T4		T5		T6		T7		T8		T9		T10		T11		Total
		Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	
Arthropoda																								
Brachyuran Crabs																								
Dungeness crab adult	*Metacarcinus magistar*	1	0	0	2	3	2	0	3	9	3	3	0	1	0	3	0	4	6	2	1	5	2	**50**
Dungeness crab juvenile	*Metacarcinus magistar*	0	0	0	1	1	0	0	0	0	1	0	5	0	0	0	0	0	0	0	0	0	0	**8**
Furrowed rock crab	Cancer branneri	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Red rock crab	*Cancer productus*	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Graceful decorator crab	*Oregonia gracilis*	0	0	0	0	2	3	0	0	2	7	4	6	1	1	0	1	2	3	4	1	8	4	**49**
Pacific lyre crab	*Hyas lyratus*	0	0	0	1	0	0	0	1	1	2	1	3	1	1	0	0	11	5	0	0	6	2	**35**
Hermit Crabs																								
Setose hermit	*Pagurus setosus*	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	**2**
Hermit crab unidentified	*Pagurus* sp.	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Pandalid Shrimp																								
Spot prawn	*Pandalus platyceros*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	**3**
Dock shrimp	*Pandalus danae*	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	6	1	0	1	8	50	**67**
Hippolytid Shrimp																								
Stout coastal shrimp	*Heptacarpus brevirostris (spiny)*	0	0	2	5	3	2	0	0	2	0	1	3	0	0	0	0	1	0	0	0	1	0	**20**
Herdman coastal shrimp	*Heptacarpus herdmani*	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Slender coastal shrimp	*Heptacarpus tenuissimus*	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	18	8	0	0	2	13	**44**
Dana's blade shrimp	*Spirontocaris lamellicornis*	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	3	6	**11**
	Hippolytidae indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	**1**
Crangon shrimp																								
Unidentified crangon	*Crangon* spp.	366	139	1296	1060	88	147	221	345	257	297	230	191	189	51	54	0	384	208	126	106	365	528	**6648**
Horned shrimp	*Paracrangon echinata*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	3	7	**11**
Mysid shrimp																								
	Mysidacea	109	9	138	259	2	21	0	2	0	0	19	7	0	0	2	0	0	0	3	1	0	0	**572**
Cumacea																								
	Diastylis bidentata or *Hemilamprops* sp.	1	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**26**

Table 11 continued. Invertebrates captured in the otter trawl at sites T1 to T11 in the fall 2012.

Common Name	Latin Name	T2		T2		T3		T4		T5		T6		T7		T8		T9		T10		T11		Total
		Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	
Arthropoda																								
Gammarid amphipod																								
	Gammaridae indet.	6	5	13	9	8	22	4	3	5	1	2	19	5	0	6	4	0	4	5	0	1	0	**122**
Isopods																								
Kelp isopod	*Idoteasp.*	0	0	0	3	2	1	0	0	0	1	1	0	0	0	0	1	0	0	0	1	0	0	**10**
	Synidotea nebulosa	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**
Mollusca																								
Nudibranchs																								
Brown horned dorid	*Acanthodoris brunnea*	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	3	0	**5**
	Adalaria sp.	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	**2**
	Dendronotus sp.	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	**2**
Opalescent nudibranch	*Hermissenda crassicornis*	0	0	0	0	0	0	1	0	0	1	0	4	0	0	0	0	0	0	0	1	0	0	**7**
	Melanochlamys diomedea	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Bivalves																								
Cockle	*Clinocardium spp.*	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**20**
Venus clams	*Nutricola* spp.	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**200**
Gastropods																								
Shaggy dovesnail	*Astyris gausapata*	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	0	0	0	1	0	0	0	**5**
	Neptunea sp.	0	0	0	0	0	0	0	0	0	1	1	2	0	0	0	0	0	0	0	0	0	0	**4**
Cancellate Hairysnail	*Trichotropis cancellata*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	**1**
	Trochidae indet.	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	**3**
	Gastropoda indet.	0	0	0	0	4	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	1	**8**
Pacific wingfoot snail	*Gastropteron pacificum*	0	0	0	29	0	2	0	0	9	1	0	83	0	0	1	0	0	0	0	0	5	0	**130**
Cephlapods																								
Stubby squid	*Rossia pacifica*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	**1**
Giant Pacific octopus	*Enteroctopus dofleini*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	**1**
Cnidaria																								
Jellyfish and Ctenophores																								
Sea gooseberry	*Pleurobrachia bachei*	257	4	8	7	7	93	148	10	0	19	80	6	343	18	194	24	12	25	11	3	6	3	**1278**
Jellyfish unidentified		1	0	0	4	1	2	17	0	0	1	2	2	9	0	8	3	4	3	0	0	1	0	**58**

Table 11 continued. Invertebrates captured in the otter trawl at sites T1 to T11 in the fall 2012.

Common Name	Latin Name	T2		T2		T3		T4		T5		T6		T7		T8		T9		T10		T11		Total
		Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	
Anemones																								
Painted anemone	*Urticina crassicornis*	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	**3**
Short plumose anemone	*Metridium senile*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	30	**32**
Sea pen																								
Orange sea pen (pieces)	*Ptilosarcus gurneyi*	0	0	0	0	0	0	0	0	0	2	1	1	0	0	0	0	0	0	0	0	0	0	**4**
Orange sea pen (whole)	*Ptilosarcus gurneyi*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	**1**
Echinodermata																								
Sea cucumber																								
	Cucumaria sp.	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	**1**
Sea urchin																								
	Strongylocentrotus sp.	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	**3**
Sea stars																								
Sunflower sea star	*Pycnopodia helianthoides*	0	0	1	0	0	0	1	2	0	0	0	1	0	0	2	0	0	0	0	0	0	0	**7**
Giant pink sea star	*Pisaster brevispinus*	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	**3**
Unidentified sea star		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	**1**
Brittle stars																								
	Ophiura sarsii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	**2**
Unidentified brittle star	Ophiuridae indet.	0	0	0	0	0	0	0	0	0	1	0	3	0	0	0	0	0	0	0	0	0	0	**4**
Annelida																								
Polychaetes																								
	Glycinde picta	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
	Nephtys caecoides	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
	Phyllodoce groenlandica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	**1**
	Platynereis bicanaliculata	0	0	6	4	28	12	2	1	0	0	5	3	0	0	6	0	2	2	11	0	5	4	**91**
	Nicolea zostericola	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	**2**
	Scoloplos acmeceps	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
	Armandia brevis	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
	Harmothoe imbricata	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	**3**
Unidentified Tubeworms																								
		0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	**3**

Table 11 continued. Invertebrates captured in the otter trawl at sites T1 to T11 in the fall 2012.

Common Name	Latin Name	T2		T2		T3		T4		T5		T6		T7		T8		T9		T10		T11		Total
		Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	
Platyhelminthes																								
Flatworms																								
	Leptoplana sp.	0	0	0	0	0	0	0	0	0	2	1	0	0	0	1	0	0	0	1	0	0	1	**6**

Table 12. Invertebrates captured in the otter trawl at sites T1, T2, T4, T5, T7, and T8 in the winter 2012/2013.

Common Name	Latin Name	T1		T2		T4		T5		T7		T8		Total
		Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	
Arthropoda														
Brachyuran Crabs														
Dungeness crab adult	*Metacarcinus magistar*	0	0	0	0	1	3	0	1	1	1	6	6	**19**
Graceful decorator crab	*Oregonia gracilis*	0	0	1	0	1	1	1	0	4	5	1	24	**38**
Pacific lyre crab	*Hyas lyratus*	0	0	0	0	0	2	0	0	1	1	4	13	**21**
Hermit Crabs														
	Pagurus armatus	0	0	1	0	0	0	0	0	0	0	0	0	**1**
Hermit crab indet.	*Pagurus* sp.	0	0	0	0	1	0	0	0	0	0	0	0	**1**
Pandalid Shrimp														
Spot prawn	*Pandalus platyceros*	0	0	0	0	0	0	0	0	0	0	2	0	**2**
Dock shrimp	*Pandalus danae*	0	0	0	0	0	1	0	0	0	0	4	2	**7**
Hippolytid Shrimp														
Stout coastal shrimp	*Heptacarpus brevirostris*	0	0	0	0	1	8	1	0	0	0	0	5	**15**
Slender coastal shrimp	*Heptacarpus tenuissimus*	0	0	0	0	1	1	0	0	2	0	14	13	**31**
	Heptacarpus sp.	0	0	0	0	1	1	0	0	0	0	0	2	**4**
Dana's blade shrimp	*Spirontocaris lamellicornis*	0	0	0	0	1	0	0	0	0	0	1	2	**4**
	Caridea indet.	0	0	0	0	1	0	0	0	0	0	0	0	**1**
Crangon shrimp														
	Crangon spp.	58	48	118	49	76	119	65	50	107	5	75	0	**770**
Horned shrimp	*Paracrangon echinata*	0	0	0	0	0	0	0	0	3	0	0	0	**3**
Cumacea														
	nr. Lamprops triserratus	0	0	0	0	0	0	0	0	0	0	0	1	**1**
Amphipods														
	Gammaridae indet.	0	0	1	0	0	0	0	0	0	0	0	1	**2**
Mollusca														
Nudibranchs														
Brown horned dorid	*Acanthodoris brunnea*	0	0	0	0	0	0	0	0	0	0	0	3	**3**
	Adalaria sp.	0	0	0	0	0	1	0	0	0	0	0	0	**1**
	Dendronotus albopunctatus	0	0	0	1	0	0	0	0	0	0	0	0	**1**
Opalescent nudibranch	*Hermissenda crassicornis*	0	0	0	0	0	1	0	0	0	0	0	0	**1**
	Flabellina amabilis	0	0	0	0	0	0	0	0	0	0	0	1	**1**

Table 12 continued. Invertebrates captured in the otter trawl at sites T1, T2, T4, T5, T7, and T8 in the winter 2012/2013.

Common Name	Latin Name	T1		T2		T4		T5		T7		T8		Total
		Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	
Bivalves														
Venus clams	*Nutricola* spp.	0	200	200	0	3000	0	0	0	0	0	0	0	**3400**
Cnidaria														
Sea pen														
Orange sea pen	*Ptilosarcus gurneyi*	0	0	0	0	0	0	1	0	0	0	0	0	**1**
Echinodermata														
Sea stars														
Sunflower sea star	*Pycnopodia helianthoides*	0	0	0	0	2	2	0	0	0	1	0	1	**6**
Giant pink sea star	*Pisaster brevispinus*	0	0	0	0	0	1	0	0	0	0	0	0	**1**
Mottled sea star	*Evasterias troscheli*	0	0	0	0	0	1	0	0	0	0	0	0	**1**
Annelida														
Polychaetes														
	Glycera nana	0	0	0	0	1	0	0	0	0	0	0	0	**1**
	Harmothoe imbricata	0	0	0	0	0	0	0	0	0	0	0	1	**1**
	Platynereis bicanaliculata	0	0	0	0	0	0	0	0	0	0	0	1	**1**
	Leitoscoloplos pugettensis	0	0	0	0	0	0	0	0	0	0	0	1	**1**

Table 13. Invertebrates captured in the otter trawl at sites T1 to T11 in the spring 2013.

Common Name	Latin Name	T1		T2		T3		T4		T5		T6		T7		T8		T9		T10		T11		Total
		Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	
Arthropoda																								
Brachyuran Crabs																								
Dungeness crab adult	*Metacarcinus magister*	0	1	2	4	12	0	4	1	0	1	1	3	0	2	3	2	4	1	1	0	2	14	**58**
Dungeness crab juvenile	*Metacarcinus magister*	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	7	5	**15**
Red Rock Crab	*Cancer productus*	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0	**3**
Tanner Crab	*Chionoecetes bairdi*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	10	2	**13**
Graceful Kelp Crab	*Pugettia gracilus*	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2	0	0	0	**3**
Graceful decorator crab	*Oregonia gracilis*	1	0	0	0	2	0	0	4	0	0	2	1	1	1	14	5	4	5	2	2	10	3	**57**
Pacific lyre crab	*Hyas lyratus*	0	0	0	0	0	0	0	0	0	3	3	0	3	2	12	2	3	0	0	2	17	2	**49**
Pea Crabs																								
	Pinnixa schmitti	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Hermit Crabs																								
	Pagurus armatus	0	0	0	0	0	0	0	0	0	0	1		0	0	0	0	1	0	0	0	0	0	**2**
	Pagurus sp.	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2	0	**4**
Pandalid Shrimp																								
Spot prawn	*Pandalus platyceros*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	**1**
Dock shrimp	*Pandalus danae*	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	**2**
Hippolytid Shrimp																								
	Eualus pusiolus	0	0	0	0	0	0	1	21	0	1	0	0	4	0	0	0	0	0	0	0	0	0	**27**
Stout coastal shrimp	*Heptacarpus brevirostris*	0	0	0	1	1	0	3	20	0	5	0	0	0	0	6	0	0	0	1	2	2	0	**41**
Slender coastal shrimp	*Heptacarpus tenuissimus*	0	0	0	0	0	0	0	0	0	0	2	2	10	5	22	8	38	9	2	3	2	0	**103**
	Heptacarpus herdmani	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	**5**
	Heptacarpus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	**1**
Dana's blade shrimp	*Spirontocaris lamellicornis*	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	**2**
Crangon shrimp																								
	Crangon spp.	22	72	112	257	893	609	225	434	82	414	347	329	192	67	319	78	507	116	273	642	419	180	**6589**
Horned shrimp	*Paracrangon echinata*	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	1	0	0	0	0	**4**
Glass Shrimp																								
Pacific glass shrimp	*Pasiphaea pacifica*	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	**1**

Table 13 continued. Invertebrates captured in the otter trawl at sites T1 to T11 in the spring 2013.

Common Name	Latin Name	T1		T2		T3		T4		T5		T6		T7		T8		T9		T10		T11		Total
		Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	
Mysid shrimp																								
	Acanthomysis columbia	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	**1**
	Pacifacanthomysis nephrophthalma	1	14	0	1	3	0	0	7	0	4	0	0	0	0	0	0	0	0	1	3	0	0	**34**
	Neomysis mercedis	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
	Mysidacea indet.	4	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	**6**
Cumacea																								
	Lamprops sp.	46	21	0	5	0	1	0	3	0	2	0	0	0	0	0	0	0	0	1	0	0	0	**79**
Amphipods																								
	Family Gammaridae	0	0	0	0	18	0	1	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	**23**
	Anisogammarus pugettensis	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	**3**
	Atylus georgianus	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
	Caprella laeviuscula	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	**1**
	Deflexilodes sp.	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
	Desdimeltia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	**1**
	Dyopedos monacanthus	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	**1**
	Gammaropsis thompsoni	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	**2**
	Kamptopleustes coquillus	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**
	Orchomene sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	**1**
	Protomedeia grandimana	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
	Stenothoidae indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	**2**
	Thorlaksonius depressus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	**1**
Ostracoda																								
	Philomedes dentata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	**1**
Mollusca																								
Gastropods																								
	Astyris gausapata	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	**2**
Wrinkled dogwinkle	*Nucella lamellosa*	0	0	0	0	1	0	0	0	1	2	0	0	52	0	1	0	0	0	0	0	0	0	**57**
Margarita snail	*Margarites pupillus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	**1**
Chitons																								
	Mopalia vespertina	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	**1**
Aglajid slugs																								
	Melanochlamys diomedea	0	8	0	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**12**

Table 13 continued. Invertebrates captured in the otter trawl at sites T1 to T11 in the spring 2013.

Common Name	Latin Name	T1		T2		T3		T4		T5		T6		T7		T8		T9		T10		T11		Total
		Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	
Nudibranchs																								
	Aeolidina indet.	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Pacific wingfoot snail	*Gastropteron pacificum*	0	0	0	0	0	0	0	0	1	2	11	7	0	0	0	0	5	0	8	0	8	0	**42**
Striped nudibranch	*Armina californica*	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	**3**
	Dendronotus albopunctatus	0	0	0	0	3	0	1	0	0	11	9	2	0	0	0	0	6	0	0	3	0	0	**35**
	Dendronotus sp.	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	**5**
Bivalves																								
Venus clams	*Nutricola* spp.	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	1	1	1004	0	0	0	**1009**
	Nutricola lordi	3	21	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**25**
Iceland cockle	*Clinocardium ciliatum*	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**4**
Aleutian mysella	*Kurtiella tumida*	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Cnidaria																								
Sea Anemones																								
Giant Plumose Anemone	*Metridium farcimen*	0	0	0	1	0	0	0	0	1	2	0	1	2	1	1	0	0	0	1	1	0	0	**11**
White-spotted Rose Anemone	*Urticina lofotensis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	**1**
Sea pen																								
Orange sea pen	*Ptilosarcus gurneyi*	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	1	0	2	0	0	0	**6**
Ctenophora																								
Comb Jelly																								
Sea Gooseberry	*Pleurobrachia bachei*	1	7	0	0	0	0	0	4	10	11	6	7	0	0	1	0	10	0	1	18	2	3	**81**
Echinodermata																								
Sea cucumbers																								
Peppered sea cucumber	*Cucumaria piperata*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	**1**
Sea urchins																								
Green sea urchin	*Strongylocentrotus droebachiensis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	**1**
	Strongylocentrotus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	**1**
Sea stars																								
Sunflower sea star	*Pycnopodia helianthoides*	0	0	0	0	0	1	0	1	0	1	2	0	0	0	1	1	3	0	1	0	1	1	**13**
Giant pink sea star	*Pisaster brevispinus*	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Ochre sea star	*Pisaster ochraceus*	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	**2**

Table 13 continued. Invertebrates captured in the otter trawl at sites T1 to T11 in the spring 2013.

Common Name	Latin Name	T1		T2		T3		T4		T5		T6		T7		T8		T9		T10		T11		Total
		Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	
Brittle stars																								
Gray brittle star	*Ophiura luetkenii*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	**3**
	Ophiura spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	**2**
	Ophiuroidea indet.	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	**2**
Annelida																								
Polychaetes																								
	Glycinde picta	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
	Cheilonereis cyclurus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	**1**
	Platynereis bicanaliculata	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**3**
	Diopatra sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	**2**
	Armandia brevis	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	**5**

Table 14. Water quality parameters from four sampling events between summer 2012 and spring 2013.

Season	Site	Time	Tide	Temperature (°C)	Salinity (ppt)	Dissolved Oxygen (mg/L)	Depth Sampled (m)
Summer	T1	12:11	Ebb	17.5	19.3	9.8	7
Summer	T2	8:12	Flood	17.3	20.1	9.4	8
Summer	T3	12:23	Flood	15.6	22.8	8.9	6
Summer	T10	13:45	Ebb	13.3	26.3	8.5	11
Summer	T11	10:00	Flood	13.5	25.8	7.5	15
Fall	T1	9:50	Ebb	8.0	21.4	10.2	1
Fall	T2	16:05	Flood	9.1	29.3	8.5	3
Fall	T3	9:15	Ebb	9.0	29.6	9.0	3
Fall	T4	14:00	Flood	9.0	28.8	7.7	9
Fall	T5	12:15	Flood	9.2	30.5	7.5	10
Fall	T6	13:45	Flood	9.2	30.5	7.5	9
Fall	T7	11:20	Flood	8.9	28.4	8.2	16
Fall	T8	12:45	Flood	9.3	30.5	6.5	25
Fall	T9	15:00	Flood	9.2	29.9	7.4	18
Fall	T10	8:40	Ebb	8.8	30.1	9.2	6
Fall	T11	15:40	Flood	9.2	30.0	7.3	13
Winter	T1	13:15	Ebb	7.1	22.4	9.9	4
Winter	T2	12:00	Ebb	7.4	25.9	8.7	6
Winter	T4	10:15	Flood	7.7	27.0	7.7	9
Winter	T5	11:20	Flood	7.5	26.8	8.8	9
Winter	T7	9:00	Slack	7.7	27.0	7.8	19
Winter	T8	9:25	Flood	7.6	26.5	8.2	19
Spring	T1	11:21	Ebb	10.0	18.0	13.5	2
Spring	T2	13:31	Ebb	9.6	26.2	10.9	3
Spring	T3	14:26	Ebb	9.9	27.3	12.3	3
Spring	T4	13:00	Ebb	9.4	24.0	13.1	6
Spring	T5	11:34	Slack	9.0	11.6	NA	6
Spring	T6	12:14	Ebb	8.6	29.5	9.0	8
Spring	T7	7:08	Slack	8.3	29.9	8.9	19
Spring	T8	9:31	Flood	8.7	29.0	9.5	15
Spring	T9	10:44	Ebb	8.4	29.9	8.5	20
Spring	T10	17:01	Ebb	8.9	29.2	9.8	7
Spring	T11	16:17	Ebb	8.6	29.8	9.2	23

Table 15. Temperature, salinity, and dissolved oxygen water parameters linear mixed effects models with seasonal, depth, and tidal state comparisons at all sites sampled by otter trawl in summer and fall 2012, and winter and spring 2013 during the Benthic Fish Trawl Survey. *df* is degrees of freedom.

	Model	df	χ2	*p* value
Temperature (transformed)				
A	1/sqrt(temperature) = season + depth + tide + (1|season)			
B	1/sqrt(temperature) = season + depth + (1|season)	2	5.79	0.055
C	1/sqrt(temperature) = season + (1|season)	2	4.32	0.115
D	1/sqrt(temperature) = 1 + (1|season)	3	937.13	<0.001*
Salinity (transformed)				
E	$Salinity^{5.5}$ = season + depth + tide + (1|season)			
F	$Salinity^{5.5}$ = season + depth + (1|season)	2	2.64	0.268
G	$Salinity^{5.5}$ = season + (1|season)	2	12.88	0.002*
H[1]	$Salinity^{5.5}$ = depth + (1|season)	3	10.94	0.012*
Dissolved oxygen (transformed)				
I	1/dissolved $oxygen^{1.5}$ = season + depth + tide + (1|season)			
J	1/dissolved $oxygen^{1.5}$ = season + depth + (1|season)	2	3.08	0.214
K	1/dissolved $oxygen^{1.5}$ = season + (1|season)	2	28.33	<0.001*
L[2]	1/dissolved $oxygen^{1.5}$ = depth + (1|season)	3	13.33	0.004*

[1]Compare to Model F

[2]Compare to Model J

Table 16. Grain size results for sediment samples collected from sites T1 to T11.

Season	Site	Side	Actual %			Average %			Sediment type
			Gravel	Sand	Mud	Gravel	Sand	Mud	
Spring	T1	East	0.30	93.70	6.00	0.06	**96.64**	3.30	Sand
Summer	T1	East	0.10	99.60	0.30				
Fall	T1	East	0.00	99.70	0.30				
Winter	T1	East	0.00	97.20	2.80				
Spring	T1	West	0.00	95.90	4.10				
Summer	T1	West	0.00	90.50	9.50				
Fall	T1	West	0.10	99.10	0.80				
Winter	T1	West	0.00	97.40	2.60				
Spring	T2	East	0.00	94.40	5.60	0.04	**92.14**	7.83	Sand
Summer	T2	East	0.10	99.40	0.50				
Fall	T2	East	0.10	82.20	17.70				
Winter	T2	East	0.10	97.90	2.00				
Spring	T2	West	0.00	95.00	5.00				
Summer	T2	West	0.00	85.30	14.70				
Fall	T2	West	0.00	87.70	12.30				
Winter	T2	West	0.00	95.20	4.80				
Spring	T3	East	0.20	59.00	40.80	0.21	**85.79**	**14.00**	Muddy sand
Summer	T3	East	1.30	98.10	0.60				
Fall	T3	East	0.00	62.20	37.80				
Winter	T3	East	0.00	97.80	2.20				
Spring	T3	West	0.10	85.50	14.40				
Summer	T3	West	0.10	98.80	1.10				
Fall	T3	West	0.00	93.60	6.40				
Winter	T3	West	0.00	91.30	8.70				
Spring	T4	East	1.70	90.60	7.70	**3.78**	**90.54**	5.69	Slightly gravelly sand
Summer	T4	East	11.20	88.10	0.70				
Fall	T4	East	0.10	94.70	5.20				
Winter	T4	East	0.20	97.50	2.30				
Spring	T4	West	6.10	86.80	7.10				
Summer	T4	West	0.00	88.50	11.50				
Fall	T4	West	3.80	91.10	5.10				
Winter	T4	West	7.10	87.00	5.90				
Spring	T5	East	0.00	92.00	8.00	**0.89**	**95.28**	3.89	Slightly gravelly sand
Summer	T5	East	1.20	98.60	0.20				
Fall	T5	East	3.50	93.20	3.30				
Winter	T5	East	0.50	97.80	1.70				
Spring	T5	West	0.50	97.40	2.10				
Summer	T5	West	0.40	88.50	11.50				
Fall	T5	West	0.30	99.60	0.10				
Winter	T5	West	0.70	95.10	4.20				

Table 16 continued. Grain size results for sediment samples collected from sites T1 to T11.

Season	Site	Side	Actual %			Average %			Sediment type
			Gravel	Sand	Mud	Gravel	Sand	Mud	
Spring	T6	East	0.10	88.70	11.20	**0.66**	**79.99**	**19.35**	Slightly gravelly muddy sand
Summer	T6	East	0.00	99.60	0.40				
Fall	T6	East	4.40	95.10	0.50				
Winter	T6	East	0.30	97.60	2.10				
Spring	T6	West	0.20	90.60	9.20				
Summer	T6	West	0.10	49.10	50.80				
Fall	T6	West	0.10	63.20	36.70				
Winter	T6	West	0.10	56.00	43.90				
Spring	T7	East	0.00	98.50	1.50	**5.90**	**89.35**	4.75	Gravelly sand
Summer	T7	East	2.00	95.50	2.50				
Fall	T7	East	11.80	85.90	2.30				
Winter	T7	East	4.70	88.00	7.30				
Spring	T7	West	4.50	90.20	5.30				
Summer	T7	West	10.90	82.20	6.90				
Fall	T7	West	3.60	87.70	8.70				
Winter	T7	West	9.70	86.80	3.50				
Spring	T8	East	0.80	56.60	42.60	**1.26**	**80.05**	**18.69**	Slightly gravelly muddy sand
Summer	T8	East	4.50	87.60	7.90				
Fall	T8	East	0.20	65.10	34.70				
Winter	T8	East	0.50	89.70	9.80				
Spring	T8	West	0.00	99.00	1.00				
Summer	T8	West	3.90	94.80	1.30				
Fall	T8	West	0.10	56.10	43.80				
Winter	T8	West	0.10	91.50	8.40				
Spring	T9	East	0.40	87.40	12.20	**1.39**	**85.95**	**12.66**	Slightly gravelly muddy sand
Summer	T9	East	2.50	95.30	2.20				
Fall	T9	East	0.10	97.50	2.40				
Winter	T9	East	0.30	96.30	3.40				
Spring	T9	West	0.10	86.90	13.00				
Summer	T9	West	7.40	91.20	1.40				
Fall	T9	West	0.20	64.80	35.00				
Winter	T9	West	0.10	68.20	31.70				
Spring	T10	East	0.00	88.60	11.40	0.20	**90.25**	9.55	Sand
Summer	T10	East	0.40	84.60	15.00				
Fall	T10	East	0.10	85.00	14.90				
Winter	T10	East	0.10	91.20	8.70				
Spring	T10	West	0.10	93.30	6.60				
Summer	T10	West	0.50	92.60	6.90				
Fall	T10	West	0.30	91.20	8.50				
Winter	T10	West	0.10	95.50	4.40				

Table 16 continued. Grain size results for sediment samples collected from sites T1 to T11.

Season	Site	Side	Actual %			Average %			Sediment type
			Gravel	Sand	Mud	Gravel	Sand	Mud	
Spring	T11	East	0.10	91.50	8.40	0.11	**94.53**	5.36	Sand
Summer	T11	East	0.20	94.90	4.90				
Fall	T11	East	0.10	90.50	9.40				
Winter	T11	East	0.10	91.80	8.10				
Spring	T11	West	0.10	93.40	6.50				
Summer	T11	West	0.10	98.00	1.90				
Fall	T11	West	0.10	97.30	2.60				
Winter	T11	West	0.10	98.80	1.10				

Table 17. Density (number of fish divided by area swept) of fish species captured by otter trawl at sites T1 to T11 in summer 2012, fall 2012, winter 2012/2013, and spring 2013.

Species		Stage	Site T1								Site T2							
			Summer		Fall		Winter		Spring		Summer		Fall		Winter		Spring	
Common Name	Latin Name		1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
English sole	*Parophrys vetulus*	Adult (>350mm)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Transitional (210-350)	-	-	-	-	-	-	-	-	0.0004	0.0007	-	-	-	-	-	-
		Juvenile (<210mm)	0.0014	0.0076	0.0095	0.0010	0.0006	0.0007	0.0006	0.0037	0.0333	0.0119	0.0048	0.0038	0.0017	0.0006	0.0013	0.0006
Sanddab	*Citharichthys sordidus* and *Citharichthys stigmaeus*	Adults and juveniles	0.0010	0.0027	0.0003	-	-	-	-	-	0.0043	0.0017	0.0011	0.0003	-	-	-	-
Butter sole	*Pleuronectes isolepis*	Transitional (100-250mm)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Juvenile (<100mm)	-	-	-	-	-	-	-	-	-	0.0003	-	-	-	-	-	-
Sand sole	*Psettichthys melanostictus*	Adult (>280mm)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Transitional (200-280mm)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Juveniles (<200mm)	-	-	-	-	-	-	0.0006	0.0017	-	0.0003	-	-	-	-	-	0.0006
Rock sole	*Lepidopsetta* spp.	Adult (>360mm)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Transitional (300-360mm)	-	-	-	-	-	-	-	0.0007	-	-	-	-	-	-	0.0003	-
		Juvenile (<300mm)	-	-	-	-	-	-	-	-	-	-	0.0003	-	-	-	-	-
Dover sole	*Microstomus pacificus*	Juvenile (<300mm)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Starry flounder	*Platichthys stellatus*	Transitional (220-450mm)	-	-	0.0013	-	-	0.0004	0.0006	0.0003	0.0004	-	0.0011	0.0006	-	0.0003	0.0016	0.0003
		Juveniles (<220mm)	-	-	0.0003	-	0.0003	-	-	-	-	-	0.0011	0.0006	0.0006	-	-	-
Flathead sole	*Hippoglossoides elassodon*	Adult (>260mm)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Snake prickleback	*Lumpenus sagitta*	-	0.0019	0.0067	-	-	-	-	0.0012	0.0037	0.0085	0.0066	0.0003	-	-	-	0.0013	0.0010
Shiner perch	*Cymatogaster aggregata*	-	-	0.0022	-	-	-	-	-	-	0.0004	0.0003	-	-	-	-	-	-
Pacific staghorn sculpin	*Leptocottus armatus*	-	-	0.0004	-	-	-	-	-	-	0.0012	-	-	-	-	-	-	-
Tidepool sculpin	*Oligocottus maculosus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Padded sculpin	*Artedius fenestralis*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Grunt sculpin	*Rhamphocottus richardsonii*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Roughback sculpin	*Chitonotus pugetensis*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ribbed sculpin	*Triglops pingeli*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0003	-
Buffalo sculpin	*Enophrys bison*	-	-	-	-	-	-	-	0.0003	-	-	-	-	-	-	-	-	-
Great sculpin	*Myoxocephalus polyacanthocephalus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silver spotted sculpin	*Blepsias cirrhosus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sailfin sculpin	*Nautichthys oculofasciatus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Northern sculpin	*Icelinus borealis*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Soft sculpin	*Gilbertidia sigalutes*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tadpole sculpin	*Psychrolutes paradoxus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Big skate juvenile	*Raja binoculata*	-	-	-	-	-	-	-	-	-	0.0004	-	-	-	-	-	-	-
Bay pipefish	*Syngnathus griseolineatus*	-	-	-	0.0007	-	-	-	-	-	-	-	0.0008	0.0026	-	-	-	-
Tubesnout	*Aulorhynchus flavidus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
White spotted greenling	*Hexagrammos stelleri*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Walleye pollock	*Theragra chalcogramma*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sturgeon poacher	*Agonus acipenserinus*	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0003	-	-	-
Northern spearnose poacher	*Agonopsis vulsa*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pygmy poacher	*Odontopyxis trispinosa*	-	-	-	-	-	-	-	-	-	-	-	-	0.0015	-	-	-	-
Smooth alligator fish	*Anoplagonus inermis*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tubenose poacher	*Pallasina barbata*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Saddleback gunnel	*Pholis ornata*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cresent gunnel	*Pholis laeta*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Long fin smelt	*Spirinchus thaleichthys*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Surf smelt	*Hypomesus pretiosus*	-	-	-	0.0003	-	-	-	-	-	-	-	-	-	-	-	-	-
Pacific sand lance	*Ammodytes hexapterus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plainfin midshipman	*Porichthys notatus*	-	-	-	-	-	-	-	-	-	0.0004	-	-	-	-	-	-	-
Total			**0.0043**	**0.0196**	**0.0124**	**0.0010**	**0.0009**	**0.0011**	**0.0032**	**0.0101**	**0.0492**	**0.0220**	**0.0095**	**0.0093**	**0.0026**	**0.0009**	**0.0047**	**0.0026**

Table 17 continued. Density (number of fish divided by area swept) of fish species captured by otter trawl at sites T1 to T11 in summer 2012, fall 2012, winter 2012/2013, and spring 2013.

Species		Stage	Site T3						Site T4					
			Summer		Fall		Spring		Fall		Winter		Spring	
Common Name	Latin Name		1	2	1	2	1	2	1	2	1	2	1	2
English sole	*Parophrys vetulus*	Adult (>350mm)	-	-	-	-	-	-	-	-	-	-	-	-
		Transitional (210-350)	-	-	-	-	-	-	-	-	-	-	-	-
		Juvenile (<210mm)	0.0134	0.0058	0.0013	0.0024	0.0015	0.0013	0.0025	0.0068	0.0004	0.0004	0.0004	-
Sanddab	*Citharichthys sordidus* and *Citharichthys stigmaeus*	Adults and juveniles	0.0035	0.0015	0.0004	0.0004	-	-	0.0029	0.0053	-	0.0004	0.0031	0.0054
Butter sole	*Pleuronectes isolepis*	Transitional (100-250mm)	-	0.0004	-	-	-	-	-	-	-	-	-	-
		Juvenile (<100mm)	-	-	-	-	-	-	-	-	-	-	-	-
Sand sole	*Psettichthys melanostictus*	Adult (>280mm)	-	-	-	-	-	-	-	-	-	-	-	-
		Transitional (200-280mm)	-	-	-	-	-	-	-	-	-	-	-	-
		Juveniles (<200mm)	0.0008	-	-	-	0.0003	-	-	-	-	0.0004	-	-
Rock sole	*Lepidopsetta* spp.	Adult (>360mm)	-	-	-	-	-	0.0003	-	-	-	-	-	-
		Transitional (300-360mm)	-	-	0.0004	-	-	0.0006	-	0.0004	-	-	0.0004	-
		Juvenile (<300mm)	-	-	0.0004	0.0004	-	-	-	0.0007	-	0.0004	-	0.0007
Dover sole	*Microstomus pacificus*	Juvenile (<300mm)	-	-	-	-	-	-	-	-	-	-	-	-
Starry flounder	*Platichthys stellatus*	Transitional (220-450mm)	-	-	-	-	0.0027	0.0009	-	0.0004	-	-	-	0.0003
		Juveniles (<220mm)	-	-	-	0.0004	0.0003	0.0003	-	-	-	0.0004	-	-
Flathead sole	*Hippoglossoides elassodon*	Adult (>260mm)	-	-	-	-	-	-	-	-	-	-	-	-
Snake prickleback	*Lumpenus sagitta*	-	0.0004	0.0004	-	-	0.0018	0.0022	-	0.0007	-	-	0.0004	0.0010
Shiner perch	*Cymatogaster aggregata*	-	-	-	-	-	-	-	-	-	-	-	-	-
Pacific staghorn sculpin	*Leptocottus armatus*	-	-	-	-	-	-	-	-	-	-	-	-	-
Tidepool sculpin	*Oligocottus maculosus*	-	0.0004	-	-	-	-	-	-	0.0004	-	-	-	-
Padded sculpin	*Artedius fenestralis*	-	-	-	0.0004	-	-	-	0.0008	0.0025	0.0004	0.0023	0.0023	0.0047
Grunt sculpin	*Rhamphocottus richardsonii*	-	-	-	-	-	-	-	-	-	-	-	-	-
Roughback sculpin	*Chitonotus pugetensis*	-	-	-	-	-	-	-	-	-	-	-	-	-
Ribbed sculpin	*Triglops pingeli*	-	-	-	-	-	-	-	-	-	-	-	-	-
Buffalo sculpin	*Enophrys bison*	-	-	-	-	-	-	-	0.0012	0.0011	0.0004	0.0008	0.0008	0.0010
Great sculpin	*Myoxocephalus polyacanthocephalus*	-	-	-	-	-	-	-	-	0.0004	-	-	0.0004	0.0007
Silver spotted sculpin	*Blepsias cirrhosus*	-	-	-	-	-	0.0003	-	-	-	-	-	-	-
Sailfin sculpin	*Nautichthys oculofasciatus*	-	-	-	-	-	-	-	-	-	-	-	-	-
Northern sculpin	*Icelinus borealis*	-	-	-	-	-	-	-	-	-	-	-	-	-
Soft sculpin	*Gilbertidia sigalutes*	-	-	-	-	-	-	-	-	-	-	-	-	-
Tadpole sculpin	*Psychrolutes paradoxus*	-	-	-	-	-	-	-	-	-	-	-	-	-
Big skate juvenile	*Raja binoculata*	-	-	-	-	-	-	-	-	-	-	-	-	-
Bay pipefish	*Syngnathus griseolineatus*	-	-	-	0.0004	0.0012	-	-	0.0008	0.0029	-	0.0004	-	-
Tubesnout	*Aulorhynchus flavidus*	-	-	-	-	-	-	-	-	-	-	-	-	-
White spotted greenling	*Hexagrammos stelleri*	-	-	-	-	-	-	-	-	-	-	-	-	-
Walleye pollock	*Theragra chalcogramma*	-	-	-	-	-	-	-	-	-	-	-	-	-
Sturgeon poacher	*Agonus acipenserinus*	-	0.0008	0.0007	-	-	-	-	-	0.0004	-	-	-	-
Northern spearnose poacher	*Agonopsis vulsa*	-	-	-	-	-	-	-	-	-	-	-	-	-
Pygmy poacher	*Odontopyxis trispinosa*	-	-	-	-	-	-	-	-	-	-	-	-	0.0003
Smooth alligator fish	*Anoplagonus inermis*	-	-	-	-	-	-	-	-	-	-	-	-	-
Tubenose poacher	*Pallasina barbata*	-	-	-	-	-	-	-	-	-	-	-	-	-
Saddleback gunnel	*Pholis ornata*	-	-	-	-	-	-	-	-	-	-	-	-	-
Cresent gunnel	*Pholis laeta*	-	-	-	-	-	-	-	-	-	-	-	-	-
Long fin smelt	*Spirinchus thaleichthys*	-	-	-	0.0004	-	-	-	-	-	-	-	-	-
Surf smelt	*Hypomesus pretiosus*	-	-	-	-	-	-	-	-	0.0004	-	-	-	-
Pacific sand lance	*Ammodytes hexapterus*	-	-	-	-	-	-	-	-	-	0.0037	-	-	-
Plainfin midshipman	*Porichthys notatus*	-	-	-	-	-	-	-	-	-	-	-	-	-
Total			**0.0193**	**0.0088**	**0.0039**	**0.0048**	**0.0070**	**0.0057**	**0.0083**	**0.0221**	**0.0049**	**0.0053**	**0.0078**	**0.0142**

Table 17 continued. Density (number of fish divided by area swept) of fish species captured by otter trawl at sites T1 to T11 in summer 2012, fall 2012, winter 2012/2013, and spring 2013.

Species		Stage	Site T5						Site T6			
			Fall		Winter		Spring		Fall		Spring	
Common Name	**Latin Name**		**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
English sole	*Parophrys vetulus*	Adult (>350mm)	-	0.0003	-	-	-	-	-	-	-	-
		Transitional (210-350)	-	-	-	-	-	-	-	-	0.0004	-
		Juvenile (<210mm)	0.0070	0.0084	0.0003	0.0004	0.0003	0.0007	0.0043	0.0004	-	0.0004
Sanddab	*Citharichthys sordidus* and *Citharichthys stigmaeus*	Adults and juveniles	0.0021	0.0063	0.0007	0.0007	0.0015	0.0067	0.0059	-	0.0073	0.0062
Butter sole	*Pleuronectes isolepis*	Transitional (100-250mm)	-	-	-	-	0.0003	-	-	-	-	-
		Juvenile (<100mm)	-	0.0003	-	-	-	-	0.0007	-	-	-
Sand sole	*Psettichthys melanostictus*	Adult (>280mm)	-	-	-	-	-	-	-	-	-	-
		Transitional (200-280mm)	-	-	-	-	-	0.0004	-	-	-	-
		Juveniles (<200mm)	0.0003	-	0.0003	-	-	0.0004	0.0003	-	-	-
Rock sole	*Lepidopsetta* spp.	Adult (>360mm)	-	-	-	-	-	-	-	-	-	-
		Transitional (300-360mm)	-	0.0003	-	-	-	0.0007	0.0003	-	-	0.0004
		Juvenile (<300mm)	0.0010	0.0021	-	0.0004	-	0.0014	0.0016	0.0004	0.0004	-
Dover sole	*Microstomus pacificus*	Juvenile (<300mm)	-	-	-	-	-	-	-	-	-	-
Starry flounder	*Platichthys stellatus*	Transitional (220-450mm)	-	0.0003	-	-	-	-	0.0003	0.0004	-	-
		Juveniles (<220mm)	0.0003	0.0003	0.0003	-	-	-	-	0.0004	-	-
Flathead sole	*Hippoglossoides elassodon*	Adult (>260mm)	-	-	-	-	-	-	-	-	-	-
Snake prickleback	*Lumpenus sagitta*	-	-	-	-	-	0.0006	0.0018	0.0007	-	-	-
Shiner perch	*Cymatogaster aggregata*	-	-	-	-	-	-	-	-	-	-	-
Pacific staghorn sculpin	*Leptocottus armatus*	-	-	-	-	-	-	-	-	-	-	-
Tidepool sculpin	*Oligocottus maculosus*	-	-	-	-	-	-	-	-	-	-	-
Padded sculpin	*Artedius fenestralis*	-	0.0013	0.0030	-	0.0004	0.0003	0.0014	-	-	0.0004	0.0004
Grunt sculpin	*Rhamphocottus richardsonii*	-	-	-	-	-	-	-	-	-	-	-
Roughback sculpin	*Chitonotus pugetensis*	-	-	-	-	-	-	-	-	-	-	-
Ribbed sculpin	*Triglops pingeli*	-	-	-	-	-	-	0.0004	-	-	-	-
Buffalo sculpin	*Enophrys bison*	-	0.0008	0.0009	-	-	-	0.0011	-	-	0.0004	-
Great sculpin	*Myoxocephalus polyacanthocephalus*	-	-	0.0003	-	-	-	-	-	-	-	-
Silver spotted sculpin	*Blepsias cirrhosus*	-	-	-	-	-	-	-	-	-	-	-
Sailfin sculpin	*Nautichthys oculofasciatus*	-	-	-	-	-	-	-	0.0003	-	-	-
Northern sculpin	*Icelinus borealis*	-	-	-	-	-	-	-	-	-	-	-
Soft sculpin	*Gilbertidia sigalutes*	-	-	-	-	-	-	-	-	-	-	-
Tadpole sculpin	*Psychrolutes paradoxus*	-	-	-	-	-	-	0.0011	-	-	-	-
Big skate juvenile	*Raja binoculata*	-	-	-	-	-	-	-	-	-	-	-
Bay pipefish	*Syngnathus griseolineatus*	-	0.0008	0.0006	-	-	-	-	0.0079	0.0026	-	-
Tubesnout	*Aulorhynchus flavidus*	-	-	-	-	-	-	-	0.0003	-	-	-
White spotted greenling	*Hexagrammos stelleri*	-	-	-	-	-	-	-	-	-	-	-
Walleye pollock	*Theragra chalcogramma*	-	-	-	-	-	-	-	-	-	-	-
Sturgeon poacher	*Agonus acipenserinus*	-	-	0.0003	-	-	-	-	0.0007	-	-	-
Northern spearnose poacher	*Agonopsis vulsa*	-	-	-	-	-	-	-	-	-	-	-
Pygmy poacher	*Odontopyxis trispinosa*	-	-	0.0003	-	-	-	-	-	-	-	-
Smooth alligator fish	*Anoplagonus inermis*	-	-	-	-	-	-	-	-	-	-	-
Tubenose poacher	*Pallasina barbata*	-	-	-	-	-	-	-	-	-	-	-
Saddleback gunnel	*Pholis ornata*	-	-	-	-	-	-	-	-	0.0004	-	-
Cresent gunnel	*Pholis laeta*	-	-	-	-	-	-	-	-	-	-	-
Long fin smelt	*Spirinchus thaleichthys*	-	-	-	-	-	-	-	-	-	-	-
Surf smelt	*Hypomesus pretiosus*	-	-	-	-	-	-	-	-	-	-	-
Pacific sand lance	*Ammodytes hexapterus*	-	-	-	-	-	-	-	-	-	-	-
Plainfin midshipman	*Porichthys notatus*	-	-	-	-	-	-	-	-	-	-	-
Total			**0.0136**	**0.0237**	**0.0017**	**0.0018**	**0.0030**	**0.0158**	**0.0232**	**0.0047**	**0.0087**	**0.0073**

Table 17 continued. Density (number of fish divided by area swept) of fish species captured by otter trawl at sites T1 to T11 in summer 2012, fall 2012, winter 2012/2013, and spring 2013.

Species		Stage	Site T7						Site T8						Site T9			
			Fall		Winter		Spring		Fall		Winter		Spring		Fall		Spring	
Common Name	Latin Name		1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
English sole	*Parophrys vetulus*	Adult (>350mm)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Transitional (210-350)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Juvenile (<210mm)	0.0041	0.0135	0.0067	0.0004	0.0011	0.0031	0.0016	-	0.0018	0.0006	0.0022	0.0013	0.0078	0.0161	0.0012	-
Sanddab	*Citharichthys sordidus* and *Citharichthys stigmaeus*	Adults and juveniles	0.0018	0.0017	0.0015	0.0004	0.0054	0.0077	0.0022	-	0.0011	-	0.0132	0.0033	0.0023	0.0048	0.0146	0.0045
Butter sole	*Pleuronectes isolepis*	Transitional (100-250mm)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Juvenile (<100mm)	0.0005	-	-	-	-	-	0.0002	-	-	-	-	-	-	-	-	-
Sand sole	*Psettichthys melanostictus*	Adult (>280mm)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Transitional (200-280mm)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Juveniles (<200mm)	-	-	-	-	0.0007	0.0003	-	-	-	-	-	0.0003	-	-	-	-
Rock sole	*Lepidopsetta* spp.	Adult (>360mm)	-	-	-	-	0.0004	-	-	-	-	-	-	-	-	-	-	-
		Transitional (300-360mm)	-	-	-	-	-	-	-	-	0.0004	-	-	-	-	0.0003	-	-
		Juvenile (<300mm)	-	0.0006	0.0004	-	0.0029	0.0034	0.0002	-	0.0011	-	0.0003	0.0010	0.0033	0.0016	0.0015	0.0021
Dover sole	*Microstomus pacificus*	Juvenile (<300mm)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Starry flounder	*Platichthys stellatus*	Transitional (220-450mm)	-	-	-	-	-	-	-	-	-	-	0.0003	-	-	-	-	-
		Juveniles (<220mm)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Flathead sole	*Hippoglossoides elassodon*	Adult (>260mm)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Snake prickleback	*Lumpenus sagitta*	-	-	-	-	-	0.0007	0.0019	-	-	-	-	-	0.0015	0.0003	0.0005	0.0003	0.0010
Shiner perch	*Cymatogaster aggregata*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pacific staghorn sculpin	*Leptocottus armatus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0003	-	-
Tidepool sculpin	*Oligocottus maculosus*	-	0.0023	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Padded sculpin	*Artedius fenestralis*	-	-	0.0017	0.0034	-	0.0018	0.0022	0.0004	-	0.0011	0.0013	0.0031	0.0015	0.0020	0.0011	0.0009	0.0017
Grunt sculpin	*Rhamphocottus richardsonii*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Roughback sculpin	*Chitonotus pugetensis*	-	-	-	-	-	-	0.0003	-	-	-	-	-	-	-	-	-	-
Ribbed sculpin	*Triglops pingeli*	-	-	0.0006	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Buffalo sculpin	*Enophrys bison*	-	-	-	0.0011	-	0.0032	0.0019	0.0002	-	0.0004	0.0009	0.0013	0.0008	-	0.0003	-	0.0003
Great sculpin	*Myoxocephalus polyacanthocephalus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silver spotted sculpin	*Blepsias cirrhosus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sailfin sculpin	*Nautichthys oculofasciatus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Northern sculpin	*Icelinus borealis*	-	-	-	0.0004	-	-	-	-	-	0.0004	-	-	-	0.0003	-	-	-
Soft sculpin	*Gilbertidia sigalutes*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tadpole sculpin	*Psychrolutes paradoxus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0003	-
Big skate juvenile	*Raja binoculata*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bay pipefish	*Syngnathus griseolineatus*	-	0.0041	0.0006	-	-	-	-	0.0002	-	0.0007	0.0006	0.0003	-	0.0082	0.0038	-	-
Tubesnout	*Aulorhynchus flavidus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
White spotted greenling	*Hexagrammos stelleri*	-	-	-	-	-	-	0.0003	-	-	-	-	-	-	0.0003	-	-	0.0003
Walleye pollock	*Theragra chalcogramma*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sturgeon poacher	*Agonus acipenserinus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Northern spearnose poacher	*Agonopsis vulsa*	-	-	-	-	-	-	-	-	-	-	0.0003	-	-	-	-	-	0.0003
Pygmy poacher	*Odontopyxis trispinosa*	-	0.0005	0.0011	0.0004	-	0.0004	0.0003	-	-	-	-	0.0003	0.0005	0.0013	0.0005	0.0009	-
Smooth alligator fish	*Anoplagonus inermis*	-	-	-	-	-	-	-	-	-	-	-	0.0003	0.0003	0.0003	-	-	-
Tubenose poacher	*Pallasina barbata*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Saddleback gunnel	*Pholis ornata*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0003
Cresent gunnel	*Pholis laeta*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Long fin smelt	*Spirinchus thaleichthys*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Surf smelt	*Hypomesus pretiosus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pacific sand lance	*Ammodytes hexapterus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plainfin midshipman	*Porichthys notatus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total			**0.0133**	**0.0197**	**0.0138**	**0.0009**	**0.0166**	**0.0213**	**0.0052**	**0.0000**	**0.0068**	**0.0038**	**0.0214**	**0.0104**	**0.0261**	**0.0292**	**0.0195**	**0.0107**

Table 17 continued. Density (number of fish divided by area swept) of fish species captured by otter trawl at sites T1 to T11 in summer 2012, fall 2012, winter 2012/2013, and spring 2013.

Species		Stage	Site T10						Site T11					
			Summer		Fall		Spring		Summer		Fall		Spring	
Common Name	Latin Name		1	2	1	2	1	2	1	2	1	2	1	2
English sole	*Parophrys vetulus*	Adult (>350mm)	-	-	-	-	-	0.0007	-	-	-	-	-	-
		Transitional (210-350)	-	0.0005	-	-	-	-	-	-	-	-	-	-
		Juvenile (<210mm)	0.0102	0.0184	0.0691	0.0473	0.0004	0.0014	0.0056	0.0096	0.0660	0.0322	0.0022	0.0343
Sanddab	*Citharichthys sordidus* and *Citharichthys stigmaeus*	Adults and juveniles	0.0083	0.0118	0.0060	0.0095	0.0110	0.0189	0.0250	0.0199	0.0128	0.0145	0.0116	0.0312
Butter sole	*Pleuronectes isolepis*	Transitional (100-250mm)	-	-	-	-	-	-	0.0012	0.0021	0.0003	-	-	-
		Juvenile (<100mm)	-	-	-	-	-	-	-	0.0003	0.0017	0.0043	0.0004	-
Sand sole	*Psettichthys melanostictus*	Adult (>280mm)	-	-	-	-	-	-	-	-	0.0003	0.0005	-	-
		Transitional (200-280mm)	-	-	-	-	-	-	0.0004	-	0.0007	0.0005	-	-
		Juveniles (<200mm)	0.0005	0.0014	0.0006	-	-	-	-	0.0003	0.0007	-	-	-
Rock sole	*Lepidopsetta* spp.	Adult (>360mm)	-	-	-	-	-	-	-	-	-	0.0005	-	-
		Transitional (300-360mm)	-	0.0005	0.0006	-	-	-	-	-	-	-	0.0004	-
		Juvenile (<300mm)	0.0023	0.0033	0.0036	0.0006	0.0004	0.0003	0.0077	0.0055	0.0028	0.0064	0.0029	0.0077
Dover sole	*Microstomus pacificus*	Juvenile (<300mm)	-	-	-	-	-	-	0.0012	0.0010	-	-	-	-
Starry flounder	*Platichthys stellatus*	Transitional (220-450mm)	-	-	-	-	-	-	0.0004	-	-	-	-	-
		Juveniles (<220mm)	-	-	-	-	-	0.0003	-	-	-	-	-	0.0003
Flathead sole	*Hippoglossoides elassodon*	Adult (>260mm)	-	-	-	-	-	-	-	-	0.0003	-	-	-
Snake prickleback	*Lumpenus sagitta*	-	0.0102	0.0061	0.0361	0.0053	0.0011	0.0010	0.0004	0.0017	0.0041	0.0038	0.0011	0.0028
Shiner perch	*Cymatogaster aggregata*	-	-	-	0.0036	0.0030	-	-	-	-	-	-	-	-
Pacific staghorn sculpin	*Leptocottus armatus*	-	-	-	0.0012	0.0006	-	-	-	0.0003	0.0003	0.0005	-	0.0003
Tidepool sculpin	*Oligocottus maculosus*	-	-	-	-	-	-	-	0.0008	-	-	-	-	-
Padded sculpin	*Artedius fenestralis*	-	-	-	0.0006	0.0006	0.0011	-	-	0.0003	0.0003	0.0027	0.0004	0.0003
Grunt sculpin	*Rhamphocottus richardsonii*	-	-	-	-	-	-	-	0.0004	-	-	-	-	-
Roughback sculpin	*Chitonotus pugetensis*	-	-	-	-	-	-	0.0003	-	-	-	-	-	-
Ribbed sculpin	*Triglops pingeli*	-	-	-	-	-	-	0.0003	-	-	-	-	-	-
Buffalo sculpin	*Enophrys bison*	-	-	-	-	-	-	-	-	-	-	-	-	0.0003
Great sculpin	*Myoxocephalus polyacanthocephalus*	-	-	-	-	-	-	-	-	-	0.0003	-	0.0007	-
Silver spotted sculpin	*Blepsias cirrhosus*	-	-	-	-	-	-	-	-	-	-	-	-	-
Sailfin sculpin	*Nautichthys oculofasciatus*	-	-	-	-	-	-	-	-	-	-	-	-	-
Northern sculpin	*Icelinus borealis*	-	-	-	0.0006	-	-	-	-	-	0.0003	0.0032	-	-
Soft sculpin	*Gilbertidia sigalutes*	-	-	-	-	-	-	-	-	-	-	0.0005	-	-
Tadpole sculpin	*Psychrolutes paradoxus*	-	-	-	-	-	-	-	-	-	-	-	-	-
Big skate juvenile	*Raja binoculata*	-	-	-	-	-	-	-	-	-	-	-	-	-
Bay pipefish	*Syngnathus griseolineatus*	-	-	-	0.0054	0.0012	-	-	-	-	0.0086	0.0038	-	-
Tubesnout	*Aulorhynchus flavidus*	-	-	-	-	-	-	-	-	-	-	-	-	-
White spotted greenling	*Hexagrammos stelleri*	-	-	-	-	-	-	-	-	-	0.0003	0.0016	-	0.0003
Walleye pollock	*Theragra chalcogramma*	-	-	-	-	-	-	-	-	-	0.0003	-	-	-
Sturgeon poacher	*Agonus acipenserinus*	-	0.0014	0.0014	0.0006	-	-	-	0.0004	0.0003	-	-	-	-
Northern spearnose poacher	*Agonopsis vulsa*	-	-	-	0.0006	-	-	-	-	-	-	-	0.0004	-
Pygmy poacher	*Odontopyxis trispinosa*	-	0.0005	-	-	-	0.0008	0.0003	0.0016	0.0003	0.0010	0.0016	0.0004	-
Smooth alligator fish	*Anoplagonus inermis*	-	-	-	-	-	-	-	-	-	-	0.0005	-	-
Tubenose poacher	*Pallasina barbata*	-	-	-	-	-	-	-	-	-	-	-	0.0004	-
Saddleback gunnel	*Pholis ornata*	-	-	-	-	-	0.0004	-	-	-	-	-	0.0004	-
Cresent gunnel	*Pholis laeta*	-	-	-	-	-	-	-	-	-	-	0.0005	-	-
Long fin smelt	*Spirinchus thaleichthys*	-	-	-	-	-	-	-	-	-	-	-	-	-
Surf smelt	*Hypomesus pretiosus*	-	-	-	-	-	-	-	-	0.0003	-	-	-	-
Pacific sand lance	*Ammodytes hexapterus*	-	-	-	-	-	-	-	-	-	-	-	-	-
Plainfin midshipman	*Porichthys notatus*	-	-	-	-	-	-	-	-	0.0003	-	-	-	-
Total			**0.0333**	**0.0434**	**0.1286**	**0.0680**	**0.0152**	**0.0237**	**0.0452**	**0.0425**	**0.1017**	**0.0778**	**0.0211**	**0.0775**

Table 18. Fish density, species evenness, and species diversity linear mixed effects models with seasonal, depth, sediment type, sea pen distribution, tidal state, and individual site comparisons at all sites (excluding site T11) sampled by otter trawl in summer and fall 2012, and winter and spring 2013 during the Benthic Fish Trawl Survey. *df* is degrees of freedom.

	Model	df	χ2	*p* value
Fish density (transformed): without site				
A	$1/(density+1)^{12}$ = season + depth + sediment type + sea pen distribution + tide + (1| season)			
B	$1/(density+1)^{12}$ = season + depth + sediment type + sea pen distribution + (1| season)	2	0.92	0.631
C	$1/(density+1)^{12}$ = depth + sediment type + sea pen distribution + (1| season)	3	14.97	0.002*
D[1]	$1/(density+1)^{12}$ = season + depth + sediment type + (1| season)	2	7.11	0.029*
E[1]	$1/(density+1)^{12}$ = season + depth + sea pen distribution + (1| season)	4	19.39	0.001*
F[1]	$1/(density+1)^{12}$ = season + sediment type + sea pen distribution + (1| season)	2	19.27	<0.001*
Fish density (transformed): with site				
G	$1/(density+1)^{12}$ = season + tide + site + (1| season)			
H	$1/(density+1)^{12}$ = season + site + (1| season)	2	1.09	0.580
I	$1/(density+1)^{12}$ = season + (1| season)	9	37.67	<0.001*
J[2]	$1/(density+1)^{12}$ = site + (1| season)	3	14.98	0.002*
Fish species evenness (transformed): without site				
K	$Evenness^{2.5}$ = season + depth + sediment type + sea pen distribution + tide + (1| season)			
L	$Evenness^{2.5}$ = season + depth + sediment type + sea pen distribution + (1| season)	2	2.63	0.269
M	$Evenness^{2.5}$ = season + depth + sediment type + (1| season)	2	2.79	0.247
N	$Evenness^{2.5}$ = season + depth + (1| season)	4	6.51	0.164
O	$Evenness^{2.5}$ = season + (1| season)	2	5.36	0.069
P	$Evenness^{2.5}$ = 1 + (1| season)	3	8.32	0.040*
Fish species evenness (transformed): with site				
Q	$Evenness^{2.5}$ = season + site + tide + (1| season)			
R	$Evenness^{2.5}$ = season + site + (1| season)	2	2.43	0.296
S	$Evenness^{2.5}$ = season + (1| season)	9	15.47	0.079
T	$Evenness^{2.5}$ = 1 + (1| season)	3	8.32	0.040*
Fish species diversity: without site				
U	Diversity = season + depth + sediment type + sea pen distribution + tide + (1| season)			
V	Diversity = season + depth + sediment type + sea pen distribution + (1| season)	2	4.59	0.101
W	Diversity = season + depth + sediment type + (1| season)	2	3.01	0.222
X	Diversity = depth + sediment type + (1| season)	3	9.14	0.027*
Y[3]	Diversity = season + depth + (1| season)	4	14.44	0.006*
Z[3]	Diversity = season + sediment type + (1| season)	2	9.36	0.009*
Fish species diversity: with site				
A1	Diversity = season + tide + site + (1| season)			
B1	Diversity = season + site + (1| season)	2	4.69	0.096
C1	Diversity = season + (1| season)	9	25.80	0.002*
D1[4]	Diversity = site + (1| season)	3	10.04	0.018*

[1]Compared to Model B
[2]Compared to Model H
[3]Compared to Model W
[4]Compared to Model B1

Table 19. Species richness generalised mixed effects models (GLMM) with seasonal, depth, sediment type, sea pen distribution, tidal state, and individual site comparisons at all sites (excluding site T11) sampled by otter trawl in summer and fall 2012, and winter and spring 2013 during the Benthic Fish Trawl Survey. *df* is degrees of freedom.

Model		df	χ2	*p* value
Fish richness (Poisson distribution): without site				
A	Richness = season + depth + sediment type + sea pen distribution + tide + (1| season)			
B	Richness = season + depth + sediment type + tide + (1| season)	2	2.39	0.303
C	Richness = season + depth + sediment type + (1| season)	2	1.20	0.549
D	Richness = season + depth + (1| season)	4	1.66	0.797
E	Richness = season + (1| season)	2	16.32	<0.001*
F[1]	Richness = depth + (1| season)	3	8.81	0.032*
Fish richness (Poisson distribution): with site				
G	Richness = season + tide + site + (1| season)			
H	Richness = season + site + (1| season)	2	1.34	0.512
I	Richness = season + (1| season)	9	20.51	0.015*
J[2]	Richness = site + (1| season)	3	8.41	0.038*

[1] Compare to Model D

[2] Compare to Model H

Table 20. Species and average density for fish sampled in four sampling events between summer 2012 and spring 2013, by season, summarised from SIMPER.

Species		Average Density	Total Cumulative % Contribution to Grouping
Common name	**Latin name**		
Summer 2012			
English sole	*Parophrys vetulus*	7.04	> 80%
Sanddab species	*Citharichthys sordidus* and *Citharichthys stigmaeuss*	4.15	
Snake prickleback	*Lumpenus sagitta*	4.35	
Fall 2012			
English sole	*Parophrys vetulus*	6.55	> 80%
Sanddab species	*Citharichthys sordidus* and *Citharichthys stigmaeuss*	3.38	
Bay pipefish	*Syngnathus griseolineatus*	3.41	
Winter 2012/2013			
English sole	*Parophrys vetulus*	5.87	> 80%
Starry flounder	*Platichthys stellatus*	2.43	
Sanddab species	*Citharichthys sordidus* and *Citharichthys stigmaeuss*	2.47	
Spring 2013			
Sanddab species	*Citharichthys sordidus* and *Citharichthys stigmaeuss*	5.11	> 80%
English sole	*Parophrys vetulus*	3.08	
Snake prickleback	*Lumpenus sagitta*	3.27	
Rock sole	*Lepidopsetta* spp.	2.21	
Padded sculpin	*Artedius fenestralis*	2.23	

Table 21. Species and average density for fish sampled in four sampling events between summer 2012 and spring 2013, by depth strata, summarised from SIMPER.

Species		Average Density	Total Cumulative % Contribution to Grouping
Common name	**Latin name**		
Shallow 0 – 5 m			
English sole	*Parophrys vetulus*	6.90	> 80%
Starry flounder	*Platichthys stellatus*	2.93	
Snake prickleback	*Lumpenus sagitta*	2.82	
Mid 5 – 10 m			
Sanddab species	*Citharichthys sordidus* and *Citharichthys stigmaeuss*	5.37	> 80%
English sole	*Parophrys vetulus*	4.10	
Rock sole	*Lepidopsetta* spp.	2.03	
Padded sculpin	*Artedius fenestralis*	2.41	
Deep 10 – 25 m			
Sanddab species	*Citharichthys sordidus* and *Citharichthys stigmaeuss*	4.99	> 80%
English sole	*Parophrys vetulus*	4.74	
Padded sculpin	*Artedius fenestralis*	3.03	
Rock sole	*Lepidopsetta* spp.	2.4	

Table 22. Species and average density for fish sampled in four sampling events between summer 2012 and spring 2013, by sediment type, summarised from SIMPER.

Species		Average Density	Total Cumulative % Contribution to Grouping
Common name	Latin name		
Sand			
English sole	*Parophrys vetulus*	6.61	> 80%
Snake prickleback	*Lumpenus sagitta*	3.15	
Starry flounder	*Platichthys stellatus*	2.34	
Muddy sand			
English sole	*Parophrys vetulus*	6.45	> 80%
Sanddab species	*Citharichthys sordidus* and *Citharichthys stigmaeuss*	2.43	
Snake prickleback	*Lumpenus sagitta*	2.47	
Slightly gravelly sand			
Sanddab species	*Citharichthys sordidus* and *Citharichthys stigmaeuss*	5.11	> 80%
Padded sculpin	*Artedius fenestralis*	3.71	
English sole	*Parophrys vetulus*	3.86	
Buffalo sculpin	*Enophrys bison*	2.13	
Slightly gravelly muddy sand			
Sanddab species	*Citharichthys sordidus* and *Citharichthys stigmaeuss*	5.35	> 80%
English sole	*Parophrys vetulus*	3.72	
Rock sole	*Lepidopsetta* spp.	2.65	
Padded sculpin	*Artedius fenestralis*	2.72	
Gravelly sand			
English sole	*Parophrys vetulus*	5.71	> 80%
Sanddab species	*Citharichthys sordidus* and *Citharichthys stigmaeuss*	4.79	
Padded sculpin	*Artedius fenestralis*	2.39	

Table 23. English sole (*Parophrys vetulus*) density linear mixed effects models with seasonal, depth, sediment type, sea pen distribution, tidal state, and individual site comparisons at all sites sampled by otter trawl in summer and fall 2012 and winter and spring 2013 during the Benthic Fish Trawl Survey. Separate analyses were conducted including and excluding site T11. *df* is degrees of freedom.

	Model	df	χ2	*p* value
English sole density (transformed): with site 11, and excluding site as factor				
A	$1/(density+1)^{28}$ = season + depth + sediment type + sea pen distribution + tide + (1| season)			
B	$1/(density+1)^{28}$ = season + depth + sediment type + sea pen distribution + (1| season)	2	1.10	0.576
C	$1/(density+1)^{28}$ = season + depth + sediment type + (1| season)	2	3.03	0.220
D	$1/(density+1)^{28}$ = season + depth + (1| season)	4	19.61	0.001*
E[1]	$1/(density+1)^{28}$ = season + sediment type + (1| season)	2	14.89	0.001*
F[1]	$1/(density+1)^{28}$ = depth + sediment type + (1| season)	3	14.30	0.003*
English sole density (transformed): with site 11, with site factor				
G	$1/(density+1)^{28}$ = season +site + tide + (1| season)			
H	$1/(density+1)^{28}$ = season +site + (1| season)	2	0.72	0.698
I	$1/(density+1)^{28}$ = season + (1| season)	10	27.43	0.002*
J[2]	$1/(density+1)^{28}$ = site + (1| season)	3	14.47	0.002*
English sole density (transformed): excluding site 11, and excluding site as factor				
K	$1/(density+1)^{30}$ = season + depth + sediment type + sea pen distribution + tide + (1| season)			
L	$1/(density+1)^{30}$ = season + depth + sediment type + sea pen distribution + (1| season)	2	0.57	0.752
M	$1/(density+1)^{30}$ = season + depth + sediment type + (1| season)	2	4.18	0.124
N	$1/(density+1)^{30}$ = season + depth + (1| season)	4	12.72	0.013*
O[3]	$1/(density+1)^{30}$ = season + sediment type + (1| season)	2	9.05	0.012*
P[3]	$1/(density+1)^{30}$ = depth + sediment type + (1| season)	3	15.83	0.001*
English sole density (transformed): excluding site 11, with site factor				
Q	$1/(density+1)^{30}$ = season +site + tide + (1| season)			
R	$1/(density+1)^{30}$ = season +site + (1| season)	2	0.53	0.769
S	$1/(density+1)^{30}$ = season + (1| season)	9	18.36	0.031*
T[4]	$1/(density+1)^{30}$ = site + (1| season)	3	16.06	0.001*

[1]Compared to Model C

[2]Compared to Model H

[3]Compared to Model M

[4]Compared to Model R

Table 24. English sole (*Parophrys vetulus*) and rock sole (*Lepidopsetta* spp.) fork length Kruskal-Wallis non-parametric models with seasonal, depth, and sea pen distribution comparisons at all sites sampled by otter trawl in summer and fall 2012, and winter and spring 2013 during the Benthic Fish Trawl Survey. Kruskal-Wallis only allows comparisons of main factors and not interaction effects. *df* is degrees of freedom.

Model		df	χ2	*p* value
English sole length				
A	Length = season	3	24.51	<0.001*
B	Length = depth	2	95.79	<0.001*
C	Length = sea pen distribution	2	46.76	<0.001*
Rock sole length				
D	Length = season	3	26.60	<0.001*
E	Length = depth	2	20.78	<0.001*
F	Length = sea pen distribution	2	6.83	0.033*

Table 25. Sanddab species (*Citharichthys sordidus* and *Citharichthys stigmaeuss*) density linear mixed effects models with seasonal, depth, sediment type, sea pen distribution, tidal state, and individual site comparisons at all sites sampled by otter trawl in summer and fall 2012, and winter and spring 2013 during the Benthic Fish Trawl Survey. Separate analyses were conducted including and excluding site T11. *df* is degrees of freedom.

	Model	df	χ2	*p* value
Sanddab density (transformed): with site 11, and excluding site as factor				
A	$1/(density+1)^{32}$ = season + depth + sediment type + sea pen distribution + tide + (1| season)			
B	$1/(density+1)^{32}$ = season + depth + sediment type + sea pen distribution + (1| season)	2	3.34	0.188
C	$1/(density+1)^{32}$ = season + depth + sea pen distribution + (1| season)	4	38.64	<0.001*
D[1]	$1/(density+1)^{32}$ = season + depth + sediment type + (1| season)	2	7.46	0.024*
E[1]	$1/(density+1)^{32}$ = season + sediment type + sea pen distribution + (1| season)	2	59.55	<0.001*
F[1]	$1/(density+1)^{32}$ = depth + sediment type + +sea pen distribution (1| season)	3	14.96	0.002*
Sanddab density (transformed): with site 11, with site factor				
G	$1/(density+1)^{32}$ = season +site + tide + (1| season)			
H	$1/(density+1)^{32}$ = season + site + (1| season)	2	3.79	0.150
I	$1/(density+1)^{32}$ = season + (1| season)	10	88.15	<0.001*
J[2]	$1/(density+1)^{32}$ = site + (1| season)	3	14.99	0.002*
Sanddab density (transformed): excluding site 11, and excluding site as factor				
K	$1/(density+1)^{52}$ = season + depth + sediment type + sea pen distribution + tide + (1| season)			
L	$1/(density+1)^{52}$ = season + depth + sediment type + sea pen distribution + (1| season)	2	5.70	0.058
M	$1/(density+1)^{52}$ = season + depth + sediment type + (1| season)	2	5.71	0.058
N	$1/(density+1)^{52}$ = season + depth + (1| season)	4	8.79	0.067
O	$1/(density+1)^{52}$ = season + (1| season)	2	44.93	<0.001*
P[3]	$1/(density+1)^{52}$ = depth + (1| season)	3	15.65	0.001*
Sanddab density (transformed): excluding site 11, with site factor				
Q	$1/(density+1)^{52}$ = season +site + tide + (1| season)			
R	$1/(density+1)^{52}$ = season +site + (1| season)	2	5.56	0.062
S	$1/(density+1)^{52}$ = season + (1| season)	9	59.63	<0.001*
T[4]	$1/(density+1)^{52}$ = site + (1| season)	3	15.43	0.001*

[1]Compared to Model B

[2]Compared to Model H

[3]Compared to Model N

[4]Compare to Model R

Table 26. Sanddab species (*Citharichthys sordidus* and *Citharichthys stigmaeuss*) and starry flounder (*Platichthys stellatus*) fork length linear mixed effects models with seasonal, depth, and sea pen distribution comparisons at all sites sampled by otter trawl in summer and fall 2012, and winter and spring 2013 during the Benthic Fish Trawl Survey. *df* is degrees of freedom.

Model		df	χ2	*p* value
Sanddab spp. length				
A	Length = season + depth + sea pen distribution + (1|season)			
B	Length = season + depth + (1|season)	2	5.46	0.065
C	Length = season + (1|season)	2	76.25	<0.001*
D	Length = depth + (1|season)	3	18.27	<0.001*
Starry flounder length				
E	Length = season + depth + sea pen distribution + (1|season)			
F	Length = season + depth + (1|season)	2	1.61	0.446
G	Length = season + (1|season)	2	0.68	0.713
H	Length = 1 + (1|season)	3	12.64	0.005*

Table 27. Rock sole (*Lepidopsetta* spp.) density Kruskal-Wallis non-parametric models with seasonal, depth, and sea pen distribution comparisons at all sites sampled by otter trawl in summer and fall 2012, and winter and spring 2013 during the Benthic Fish Trawl Survey. Separate analyses were conducted including and excluding site T11. Kruskal-Wallis only allows comparisons of main factors and not interaction effects. *df* is degrees of freedom.

Model		df	χ2	*p* value
Rock sole density: with site 11				
A	Density = season	3	3.80	0.284
B	Density = site	10	39.69	<0.001*
C	Density = sediment	4	4.63	0.328
D	Density = depth	2	18.20	<0.001*
E	Density = tide	2	0.92	0.632
F	Density = sea pen distribution	2	6.93	0.031*
Rock sole density: without site 11				
G	Density = season	3	1.62	0.654
H	Density = site	9	25.34	0.003*
I	Density = sediment	4	5.90	0.207
J	Density = depth	2	10.41	0.005*
K	Density = tide	2	1.79	0.409
L	Density = sea pen distribution	2	8.65	0.013*

APPENDIX A
Photographs

Photo 1. Deploying the otter trawl.

Photo 2. Retrieving the otter trawl.

Photo 3. Retrieving the otter trawl.

Photo 4. Processing fish after trawl.

Photo 5. Juvenile English sole (*Parophrys vetulus*) at T1 – Fall 2012.

Photo 6. Adult English sole (*P. vetulus*) at T2 – Summer 2012.

Photo 7. Speckled sanddab (*Citharichthys stigmaeus*) at T1 – Summer 2012.

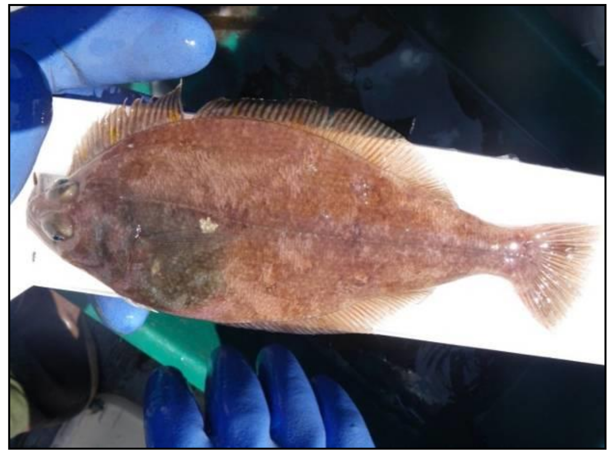

Photo 8. Pacific sanddab (*C. sordidus*) at T1 – Summer 2012.

Photo 9. Sand sole (*Psettichthys melanostictus*) caught at T7 – Spring 2013.

Photo 10. Rock sole (*Lepidopsetta* spp.) at T6 – Spring 2013.

Photo 11. Butter sole (*Pleuronectes isolepis*) at T5 – Spring 2013.

Photo 12. Starry flounder (*Platichthys stellatus*) at T1 – Fall 2012.

Photo 13. Padded sculpin (*Artedius fenestralis*) at T5 – Spring 2013.

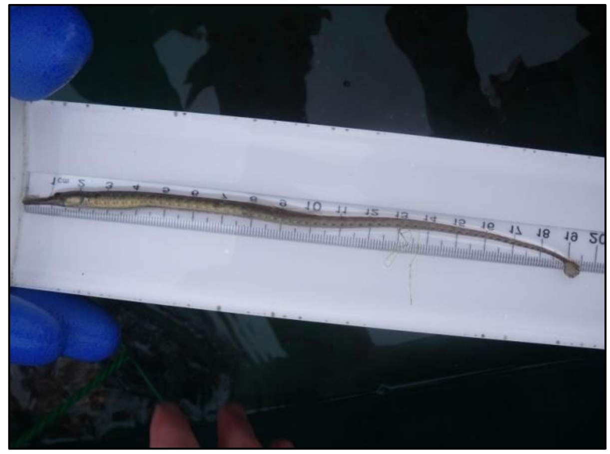

Photo 14. Bay pipefish (*Syngnathus griseolineatus*) at T-1 – Winter 2012/2013.

Photo 15. Pacific sand lance (*Ammodytes hexapterus*) at T4 – Winter 2012/2013.

Photo 16. Snake prickleback (*Lumpenus sagitta*) at T1 – Spring 2013.

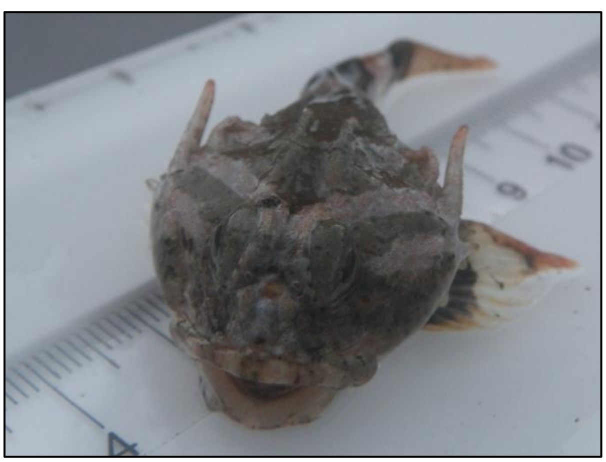

Photo 17. Buffalo sculpin (*Enophrys bison*) at T8 – Winter 2012/2013.

Photo 18. White spotted greenling (*Hexagrammos stelleri*) at T11 – Fall 2012.

Photo 19. Pygmy poachers (*Odontopyxis trispinosa*) at T10 – Spring 2013.

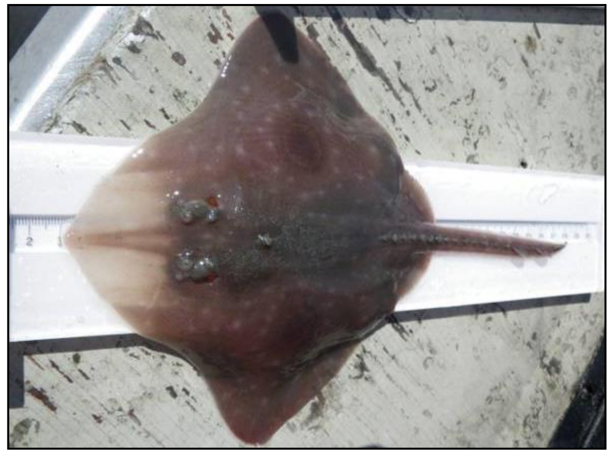

Photo 20. Big skate (*Raja binoculata*) at T2 – Summer 2012.

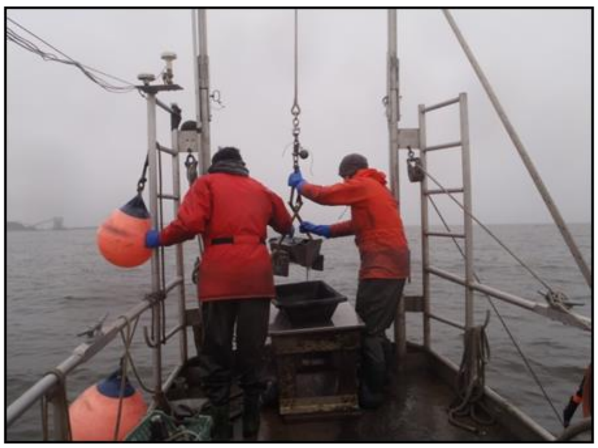

Photo 21. Sediment sampling with ponar grab.

Photo 22. Bagging sediment sample for lab processing.

Photo 23. Growth on English sole (*P. vetulus*) – Fall 2012.

Photo 24. Growth on English sole (*P. vetulus*) – Fall 2012.

Photo 25. Growth on English sole (*P. vetulus*) – Fall 2012.

Photo 26. Growth on English sole (*P. vetulus*) – Fall 2012.