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Science Response 2019/011

Pacific Region

BIOPHYSICAL AND ECOLOGICAL OVERVIEW OF THE OFFSHORE PACIFIC AREA OF INTEREST (AOI)

Context

Canada's Oceans Act states that "conservation, based on an ecosystem approach, is of fundamental importance to maintaining biological diversity and productivity in the marine environment". This act provides the legislative framework for an integrated ecosystem approach to management in Canadian oceans, particularly in areas considered ecologically or biologically significant. Ecologically or biologically significant areas (EBSAs) are areas in need of enhanced management that supercede the management needs of individual species. DFO has developed guidance for the identification of EBSAs (DFO 2004, 2011), and has endorsed the scientific criteria of the Convention on Biological Diversity (CBD) for identifying ecologically or biologically significant marine areas as defined in Annex I of Decision IX/20 of its 9th Conference of Parties (UNEP/CBD, 2008).

In 2015 Canada adopted complementary international and domestic 2020 Biodiversity Goals and Targets. Both targets (Aichi Target 11 and Canada's Target 1) call for the conservation of 10% of coastal and marine areas by 2020. The Government of Canada recently identified an interim target of 5% protection by 2017. Under the *Oceans Act*, Fisheries and Oceans Canada (DFO) is authorized to provide protection to areas of the oceans and coasts through the establishment of MPAs, where the identification of an Area of Interest (AOI) is the first step in this process. The designation of new Marine Protected Areas (MPAs) in Canadian waters has been identified as part of the national strategy to meet these targets.

The identification of EBSAs in the Canadian Pacific Region serves as a key component of the knowledge base for:

1. regional development activities and marine use planning;
2. the development of Canada's network of marine protected areas (MPAs) under the Oceans Act; and
3. facilitating the implementation of DFO's sustainable fisheries framework under the Fisheries Act.

On May 24, 2017, following the conclusion of a regional Area of Interest selection process, the southern portion of the Offshore Pacific Bioregion was announced as an Area of Interest (AOI) for potential MPA establishment. The area selection was informed by Identification of Ecologically and Biologically Significant Areas (EBSAs) in Canada's Offshore Pacific Bioregion (Ban et al., 2016; DFO 2016a). Currently seamounts and hydrothermal vents EBSAs, and their associated ecosystems, have been identified as an interim conservation objective for this area. To ensure consistency with other MPA planning processes in the Northern Shelf Bioregion, the continental slope is not considered within the boundary of the Offshore Pacific Bioregion and is instead considered part of the Northern and Southern Shelf Bioregions.

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This report provides detailed information on the key physical and biological oceanographic characteristics; predominant, unique habitat features; and significant species within the AOI, as they pertain to known EBSAs and their linkages to other key ecosystem components and processes. A review of this scientific knowledge may serve to highlight additional conservation priorities.

Furthermore, the biophysical and ecological overview may assist in formulating and/or refining conservation objectives, delineating the proposed MPA boundary (and zones if required), and contribute to completing an ecological risk analysis to inform the development of the regulatory approach for the MPA. The information contained within will also inform subsequent advice on monitoring protocols and strategies, identification of information gaps requiring further research, and the development of a management plan for the area.

Areas adjacent to the AOI may need to be considered to capture the necessary breadth and scope of the various components of the ecosystem. Therefore, given the geographic scale at which scientific information is currently collected and reported, the study area that has been deemed appropriate for the Offshore Area of Interest biophysical and ecological overview is displayed in Figure 1.

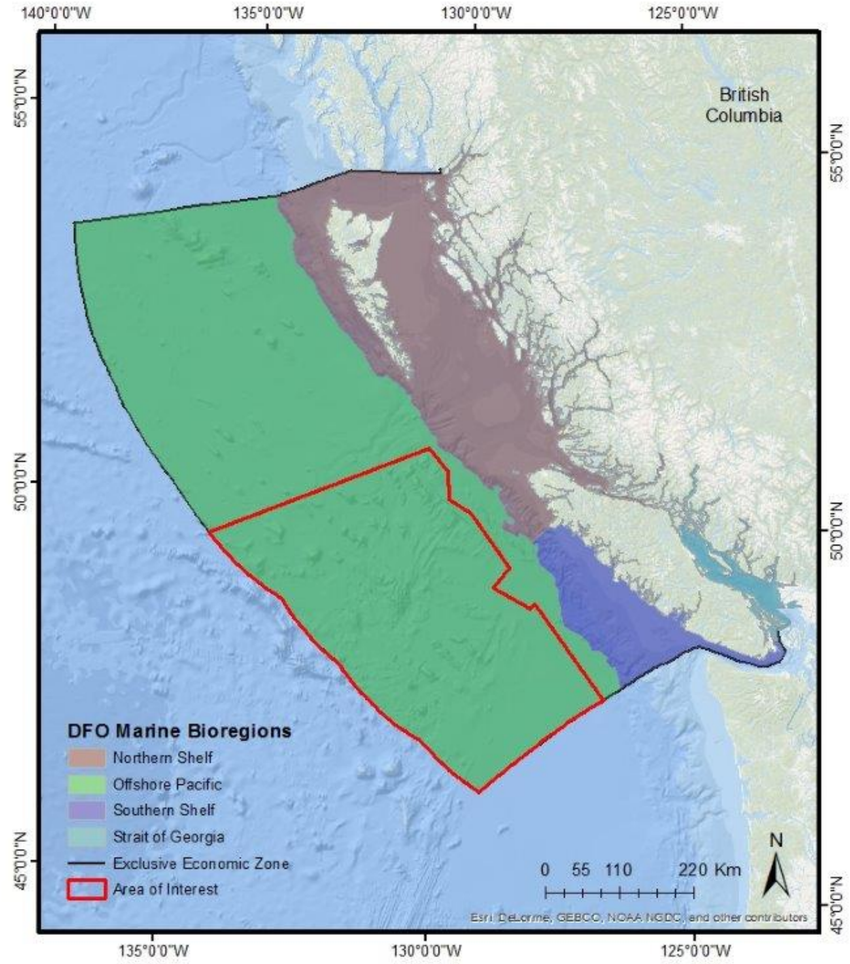


Figure 1. Offshore Area of Interest (AOI) in the Offshore Pacific Bioregion and the DFO marine bioregions.

The Oceans Management program of the Ecosystems Management Sector has requested DFO Science to provide advice and supporting documents to inform the Offshore Pacific AOI Marine Protected Area Process.

This Science Response results from the Science Response Process of October 2017 on the Biophysical and Ecological Overview of the Southern Portion of the Offshore Bioregion Area of Interest (AOI). It is based on the specific objectives outlined below:

1. Evaluate, describe and map, where possible the key biophysical and ecological features of the study area, including:
   a) predominant and/or unique physical and biological oceanographic characteristics;
   b) predominant, unique, and/or sensitive habitat features; and
   c) ecologically, socially/culturally and/or commercially significant species; depleted species; and marine mammals and birds

   Where appropriate, identify relevance of the study area to the life histories of species of interest, species distribution and abundance (and status and trends where available), and the local abiotic and biotic factors influencing these.
2. Identify known sensitivities, resilience and recoverability of habitats and species of interest within the study area.
3. Identify key uncertainties and knowledge gaps as it pertains to the current understanding of the existing environment and species of interest within the study area, and recommend measures to address these gaps, where possible.
4. Where appropriate, based on the best available science, describe the area that each ecosystem components/features covers.

Background

Key features in Canada's Offshore Pacific Bioregion were discussed in the Identification of Ecologically and Biologically Significant Areas (EBSAs) by Ban et al. (2016) (DFO 2016a). These features were evaluated against the seven criteria from the Convention on the Biological Diversity (CBD) and five DFO EBSA criteria. Specifically, hydrothermal vents, seamounts, the continental slope, bathyal and abyssal plains, and pelagic and surface waters were reviewed. For each of these features types the authors defined the known marine features and their associated fauna, they reviewed the processes that create or maintain these features, evaluated these features with respect to each of the EBSA criteria, and ranked each criterion in terms of importance (high, medium, low, or no information) (Ban et al. 2016; DFO 2016a).

This analysis and response includes the following features: hydrothermal vents, seamounts, bathyal plains, and pelagic and surface waters.

Terminology

The following terms used with in this document are defined below.

- **Predominant -** Refers to the most frequent or common oceanographic characteristics and/or habitat features. The best available science in the literature was used to determine this on a case by case basis.

- **Unique** - Following definitions in the DFO (2004) and CBD (2008) criteria for EBSAs, unique is defined as “the only one of its kind”. May be considered in regional, national and global context, with increased importance at each scale.
- **Rare** - Following definitions in the DFO (2004) and CBD (2008) criteria for EBSAs, rare is defined as “occurs only in few locations”. This definition is applicable at multiple scales.
- **Significant species** - Includes ecologically significant species, species of conservation concern, and socially, culturally, and commercially important species. Ecologically significant species are essential to maintaining ecosystem structure and function (e.g. foundation species, species providing structure for settlement and shelter, species with important trophic roles, and species that are extremely abundant) (DFO 2006).
- **Sensitive** - Following definitions in the DFO (2004) and CBD (2008) criteria for EBSAs, sensitive is defined as “highly susceptible to degradation or depletion by human activity or by natural events”. This definition may apply to species and/or habitat features.
- **Resilience** - For the purposes of this analysis, the O et al. 2015 definition of resilience is used, “The capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks, i.e., without changing self-organized processes and structures. Resilience can also be defined as the ability of an ecosystem to return to an equilibrium or steady-state following a perturbation”.
- **Recoverability** - Following the definition of recovery in O et al. 2015, recoverability is defined as the time required for a component to return to a pre-stress level once the stressor is removed. The best available science in the literature was used to make these determinations on a case by case basis.

Analysis and Response

Hydrothermal vents

Overview

Hydrothermal venting regions support chemosynthetically driven, high productivity ecosystems that contain a diverse array of unique organisms and supply energy to the surrounding pelagic and bathyal plain ecosystems (Levin et al. 2016). These geological features are associated with mid ocean ridge spreading centers, back-arc basins, volcanic arcs, and intraplate volcanoes. Hydrothermal fluids, which vent from cracks in the oceanic crust, are typically rich in hydrogen sulphide and a variety of metal oxides, allowing for multiple different pathways for primary production by chemosynthetic microbes. Sulphides and metals precipitating from the hydrothermal fluid accrete to create elaborate sulphide structures capable of supporting immense biomass. The organisms living in these environments are highly specialized to cope with physical, chemical, and thermal extremes. As a result, most species living within vent communities have been estimated to be endemic and limited in distribution (McArthur and Tunicliffe 1998).

In the assessment for designation as Ecologically and Biologically Significant Areas (EBSAs)(Ban et al. 2016; DFO 2016a), hydrothermal vents scored as “high” on all EBSA criteria except for importance for threatened or endangered species, for which there was insufficient information to evaluate the criterion. The identified EBSA includes all known active and inactive hydrothermal vents within Canada’s Offshore Pacific Bioregion (Figure 2), the hydrothermal plume above them, the substrate and hydrothermal cells beneath them, the rift valleys within which new vents may form with tectonic movement, and all fauna associated with these features. Inactive vent fields were included as part of the EBSA as they host novel assemblages and geomorphic features even though venting has ceased. The EBSA also includes two seamount systems that are influenced by hydrothermal activity. Hydrothermal vents are also recognized as vulnerable marine ecosystems (VME) by the United Nations General Assembly (UNGA) (DFO 2010). Here the hydrothermal vents in the southern Offshore Pacific Bioregion within the Offshore Pacific AOI are described.

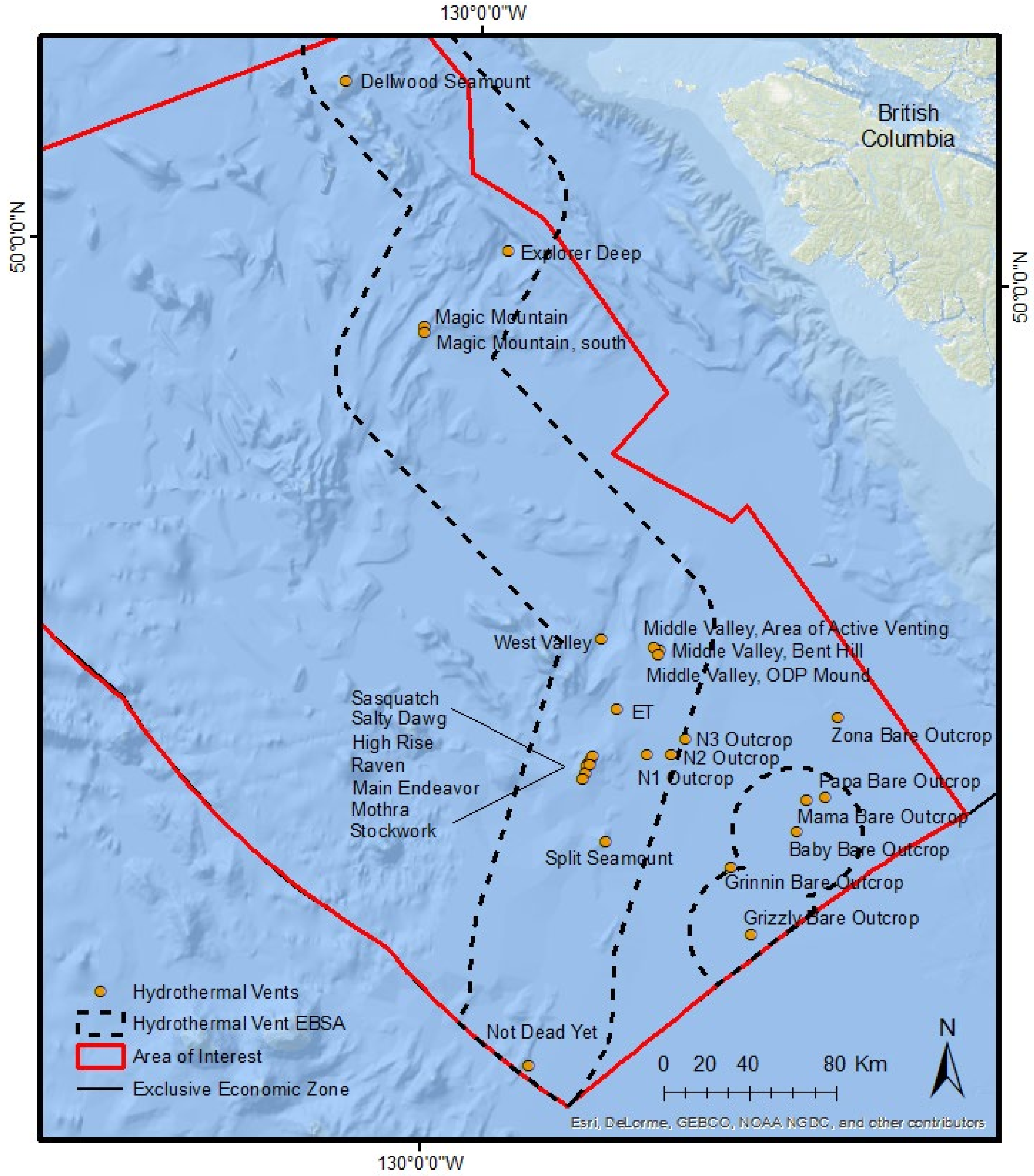


Figure 2. Known hydrothermal vents in the Pacific Offshore Region Ecological and biologically significant area boundaries (EBSAs). Boundaries were set to encompass furthest known ridge-associated vents and breadth of oceanographic influence for seamounts (DFO 2016a). Sources of vent location data are listed within Table 1.

Biophysical and Ecological Features

Physical and Biological Oceanographic Characteristics

The northeast Pacific ridge system ranges from 52-41°N latitude and from 185-280 km off the west coast of Vancouver Island. The system is made up of three ridge segments separated by two offset faults and is an intermediate spreading ridge that spreads an average of 56 mm yr[1]. The northernmost Explorer Ridge and a portion of the Juan de Fuca Ridge are located in Canadian waters, while the southernmost Gorda Ridge is located in U.S. waters. The vent fields are arranged mostly linearly along the ridge axes and are located within rift valleys (Tunnicliffe et al. 1998), with the exception of a series of outcrops on the eastern flank of the Juan de Fuca Ridge and Dellwood Seamount, all of which are off-axis volcanic structures.

Circulation at hydrothermal vents is achieved through downdrafting of seawater into the ridge flanks and transport through the crust near shallow magmatic intrusions, where the seawater is chemically altered by intense temperature and pressure, the dissolution of subsurface rocks, and the subsurface microbial community, before it vents out through cracks in the basalt of the ridge valley floor. Thus, while the ridge flanks and crests do not actively vent (with some exceptions), large portions of the ridge footprint (valley, crest, and flank) may be actively involved in hydrothermal circulation (Van Dover 2000). In the cases of Dellwood Seamount and the outcrops on the eastern flank of the Juan de Fuca Ridge, seawater is similarly drawn into the system at an area remote from the hydrothermal venting (Hutnak et al. 2006).

Sulphide structures, which form from a buildup of sulphides and metals precipitating from hydrothermal vent fluids and gases, vary in structure and composition within and among hydrothermal vent fields and ridges. These structures are also variable over time, with the genesis and growth of new structures, and the senescence and/or collapse of existing ones (Tunnicliffe and Juniper 1990a). Vigorously venting hydrothermal fields can produce large, steep-sided, free-standing deposits of sulphide-sulphate-silica (Delaney et al. 1992) that can reach diameters >30 m and heights >25 m (Tunnicliffe et al. 1986; Delaney et al. 1992) and structures found within sediments, such as those found at Middle Valley, can reach > 60 m in height and hundreds of meters in diameter (Goodfellow and Franklin 1993). High densities of active sulphide structures and associated fauna can occur on small scales (e.g., 200 m x 400 m) and be surrounded by many smaller inactive sulphide structures (Delaney et al. 1992).

Despite a common source of hydrothermal vent fluid, sulphide structures within a vent field can vary in fluid composition (Butterfield et al. 1994), flow (Delaney et al. 1992), and temperature (Delaney et al. 1992). Venting temperatures up to 400 °C are reported from black smoker chimneys (Butterfield et al. 1994), while temperatures from diffuse venting may be as low as 2°C; equal to the surrounding ambient seawater (Tunnicliffe et al. 2014). Fluid flow and temperature patterns show decimeter scale variability, creating patchiness in the resources available for chemosynthesis and ecological interactions within hydrothermal vent communities (Sarrazin and Juniper 1999a; Bates et al. 2005; Kelly et al. 2007).

The majority of hydrothermal vent fields in the Offshore Pacific AOI are unsedimented, with massive sulphide structures sitting atop a bare basalt crust (Table 1). Examples of this type of vent field include those within the Endeavour Hydrothermal Vents Marine Protected Area (EHV MPA) on the Endeavour Segment, as well as hydrothermal vent sites on Explorer Ridge. In the EHV MPA, sulphide structures can reach over 30 m in height, and range from heavily flanged (horizontal projections from the main structure; e.g., Main Endeavour Field structures), to unflanged (e.g. Mothra vent field structures)(Kelley et al. 2001). The increased complexity of the structures creates more surface area for colonization of hydrothermal vent fauna (Kelly and Metaxas 2006; Kelly and Metaxas 2008).

In contrast to the unsedimented fields, some hydrothermal vent fields within the Offshore Pacific AOI can be heavily sedimented. Middle Valley occurs roughly 60 km northeast of the EHV MPA, and is covered in 200 to over 1000 m of turbidite sediment from the continental shelf (Hannington et al. 2005). This sediment cover retains heat and precipitated metals and protects the sulphide deposits from seafloor weathering and oxidation, promoting the formation of some of the world's largest polymetallic sulphide (PMS) deposits (Hannington et al. 2005). Hydrothermal venting at sedimented sites occurs both from active sulphide structures projecting up through the sediment, and from focused areas where hydrothermal fluid upwells through the sediment. The hydrothermal sediment habitat hosts a unique infaunal assemblage not present on bare basalts and sulphide structures of the Juan de Fuca Ridge, and with different species than at other sedimented hydrothermal sites in the world (Juniper et al. 1992a).

While most vent fields in the Offshore Pacific AOI are located on or close to the ridge axes, there are a number of hydrothermally venting outcrops in an off-axis volcanic system located on the eastern flank of the Juan de Fuca Ridge, roughly 100 km east of the Endeavour Segment. Two of the most intensely studied of these outcrops, Baby Bare and Grizzly Bare, are connected through hydrothermal conduits in the oceanic crust. In this system, fluid input for hydrothermal venting at Baby Bare Outcrop comes from Grizzly Bare, a recharge outcrop; seawater is drawn down through Grizzly Bare into the igneous basement, and then travels 52 km north-northeast to Baby Bare, where it emanates as hydrothermal vent fluid (Wheat et al. 2000; Jungbluth et al. 2013). Fluid chemistry at this system differs from that of other hydrothermal systems in Canadian waters, which gives rise to a faunal assemblage of chemosynthetic organisms adapted for lower sulphide conditions. Two outcrops found in the same area as Baby Bare, Mama Bare and Papa Bare, have been moderately studied and also host diffuse hydrothermal venting (Thomson et al. 1995).

Despite differences in the physical and biological oceanographic characteristics between individual vent sites, the Canadian hydrothermal vents as a group contrast starkly with the surrounding bathyal plains, and were evaluated in Ban et al. (2016) as one large EBSA (DFO 2016a). The proposed Offshore Pacific AOI encompasses the full range of physical and biological oceanographic features characteristic of the Canadian hydrothermal vents.

Table 1. Hydrothermal vent field locations, depths and descriptions from the Offshore Pacific Area of Interest, ordered by latitude.

Site/Ridge	Hydrothermal vent field	Latitude	Longitude	Maximum or single reported depth (m)	Description
Northwestern Explorer Ridge Area	Dellwood Seamounts	50.8579	-129.3515	600-800 (dredge depth)	No active venting; hydrothermal deposit dredged from north slope of northernmost structure (Piper et al. 1975), which measures 915 m in elevation above a sedimented basement (Smoot 1985)
Northeastern Explorer Ridge Segment	Explorer Deep	50.0833	-129.7500	3200	No active venting; hydrothermal deposits collected by dredging median ridge that separates sedimented northeastern ridge segment into 2 ponds of sediment 100-200 m thick (Grill et al. 1981)
Southern Explorer Ridge Segment	Magic Mountain	49.7500	-130.2667	1850	Large active sulphide deposit measuring 250 x 200 x 50 m high topped with chimneys up to 10 m high and 2 m wide; metalliferous sediments (Tunnicliffe et al. 1986)
	Magic Mountain, 3 km south	49.7250	-130.2667	1850	Inferred active vent site; multiple simultaneous redox potential readings and temperature anomalies provide solid evidence of active venting; site remains unexplored (Yoerger et al. 2007); may be "Vent 1" in Tunnicliffe et al. (1986)

Site/Ridge	Hydrothermal vent field	Latitude	Longitude	Maximum or single reported depth (m)	Description
West Valley Segment, JdFR	West Valley Segment	48.4833	-129.0417	3000	Sulphide mounds and chimneys associated with moderately young pillow and lobate flows near base of small axial volcano; hydrothermal field tracked over a distance of 60 m; possible that some chimneys are active, as evidenced by slight shimmer in video (Leybourne and Van Wagoner 1992)
Middle Valley, JdFR	Area of Active Venting	48.4567	-128.7083	2450	Massive active sulphide deposits within deep (100-1500 m) turbiditic sediments in a buried rift; vent sites include Heineken Hollow, Inspired Mounds, Chowder Hill, Puppy Dog, East Hill, and Central Site (Ames et al. 1993)
	Bent Hill Massive Sulphide	48.4500	-128.6783	2400	Massive inactive sulphide deposits within deep (100-1500 m) turbiditic sediments in a buried rift (Ames et al. 1993)
	ODP Mound	48.4300	-128.6816	2440	Active sulphide deposit in deep (100-1500 m) turbiditic sediment topped with sulphide chimneys; located ~300 m south of Bent Hill MS deposit; vents include Lone Star, Shiner Bock, and Spire (Ames et al.1993)

Site/Ridge	Hydrothermal vent field	Latitude	Longitude	Maximum or single reported depth (m)	Description
Endeavour Offset, JdFR	ET	48.1993	-128.9257	2500	From InterRidge Database: inferred active; hydrothermal deposits; note: this location from the old InterRidge vents database does not appear to be in Crane et al. (1985) - their figure with all potential vent fields plotted only goes as far north as 48 deg.; this location appears to be in the Endeavour Offset; depth from GeoMapApp using position
Endeavour Segment, JdFR	Summit Volcano	NA	NA	NA	Located on north end of western flank of Endeavour Ridge; principal melt focusing and hottest (most MgO-rich) magmas occur at ~48°N, adjacent to Summit Volcano (Gill and Michael 2008).
	Sasquatch Field	47.9970	-129.0660	2200	Field is roughly 200 m in length; active venting limited to ~10, 1-10 m high fragile sulphide chimneys in a 20 x 20 m area in northern portion of field; vent fluids up to 287°C; a linear, N-S trending ridge of nearly continuous extinct sulphide chimney debris and thick deposits of oxidized hydrothermal sediment extends 200 m south; extinct chimneys are up to 20 m high and 2-4 m in diameter (Kelley et al. 2001; Glickson et al. 2006)

Site/Ridge	Hydrothermal vent field	Latitude	Longitude	Maximum or single reported depth (m)	Description
	Cirque	NA	NA	2130	Past site of black smoker activity now hosts 4-5 m high weakly venting chimneys which were venting 31°C fluids in 1995; located ~500 m southwest of Salty Dawg on western axial rift wall (Kelley et al. 2012)
	Dune	NA	NA	NA	Located ~500 m west of Salty Dawg on western axial rift wall and is one of several distal, diffusely venting fields (Kelley et al. 2012)
	Salty Dawg Field	47.9820	-129.0760	2200	Active vent field with > 25 sulphide structures; vent fluid temperatures up to 305°C with diffuse flow dominant and vigorous flow constrained to a few, multi-flanged structures up to 25 m in length and 25 m in height; fluid compositions and temperatures consistent with Salty Dawg being in a waning stage of evolution (Kelley et al. 2001)
	Vesta	NA	NA	NA	Smaller site of black smoker activity south of Salty Dawg (Kelley et al. 2012).

Site/Ridge	Hydrothermal vent field	Latitude	Longitude	Maximum or single reported depth (m)	Description
	High Rise Field	47.9667	-129.0900	2200	20-30 large active sulphide deposits near centre of rift valley on summit and sides of elongate horst; multi-flanged sulphide structures similar to Salty Dawg and Main Endeavour Field; current site of most intense hydrothermal and seismic activity (Kelley et al. 2012)
	Clam Bed	NA	NA	NA	Active vent field that hosts 1-2 small sulphide structures of focused fluid flow up to 262°C surrounded by widespread diffuse shimmering hydrothermal fluid flow; patches of sediment host dense clam beds (Stakes et al. 1992; Reyes 1995; Urcuyo et al. 2007)
	Raven	47.9583	-129.0833	2180	Active vent field roughly 95 x 30 m hosting only diffuse vents; located on western bounding fault of valley (Skeebo et al. 2006)
	Main Endeavour Field	47.9500	-129.1000	2220	Active vent field measuring 200 m wide x 300 m long along base of western axial valley wall; >17 large, multi-flanged edifices that up until ~2005 had >100 black smoker chimneys; proximal diffuse flow sites common; southern complex (Bastille) has been significantly waning since 1999 (Kelley et al. 2012)

Site/Ridge	Hydrothermal vent field	Latitude	Longitude	Maximum or single reported depth (m)	Description
	Quebec	NA	NA	NA	Diffusely venting field ~250 m south of Main Endeavour Field; roughly 40 m square; hosts abundant inactive sulfide structures and weathered sulphide talus; vents clear fluid ~12°C with no focused, high temperature hydrothermal activity as of 1999 (Veirs et al. 1999; Veirs 2003; Kelley et al. 2012;)
	Beach	NA	NA	NA	Diffusely venting field located within the axis ~300 m south of Main Endeavour Field (MEF); small sediment pond with diffuse hydrothermal fluid venting around and through sediments (Johnson et al. 2000; Kelley et al. 2012).
	Mothra Field	47.9230	-129.1090	2270	Active vent field with six clusters of chimneys reaching up to 24 m in height near western valley wall; clusters spaced 40 to 200 m apart with active and inactive chimneys that are typically tall, slender and lacking pronounced flanges; most of sulphide structures awash in diffusely venting fluids (30–200°C); isolated black smoker chimneys vent up to 320°C fluids (Kelley et al. 2001; Kelley et al. 2012)

Site/Ridge	Hydrothermal vent field	Latitude	Longitude	Maximum or single reported depth (m)	Description
	Stockwork	47.9000	-129.1292	NA	Inactive area hosting numerous exposures of upflow zones (stockworks); extinct sulphide chimneys adjacent to axial wall reach up to 14 m in height, and are reminiscent in morphology to those at Mothra; water column studies and high-resolution bathymetry suggest there is a weakly venting system 200 m north and northeast of Stockwork area (Karson et al. 2015)
Eastern Flank of JdFR	Zona Bare Outcrop	48.1922	-127.5467	70 (elevation)	Outcrop is 2 km x 1 km and elevation is 70 m above surrounding seafloor; southwestern edge of outcrop is steeper than other sides, whereas top is virtually flat; pattern of heat flux measurements generally consistent with Zona Bare outcrop being a site of hydrothermal discharge; fluids may recharge through Zona Bare or through other outcrops to the south (Hutnak 2006)

Site/Ridge	Hydrothermal vent field	Latitude	Longitude	Maximum or single reported depth (m)	Description
	N1 Outcrop	48.0101	-128.7309	100 (elevation)	Outcrop is 2.5 x 5 km and rises roughly 100 m above the surrounding seafloor; much of feature appears relatively flat, but there are two prominent high points along eastern edge where seafloor relief is greatest; may be a site of fluid recharge (Hutnak 2006)
	N2 Outcrop	48.0121	-128.5845	100 (elevation)	Outcrop is conical in shape with a diameter of 3-4 km and an elevation of roughly 100 m above surrounding seafloor; this feature is topped with three individual peaks; highest slope angles are found on northwestern peak, where seafloor elevation changes by roughly 110 m over a lateral distance of 200 m; may be a site of fluid recharge (Hutnak 2006)
	N3 Outcrop	48.0810	-128.4957	100 (elevation)	Outcrop covers an area of >20 km^2, and rises roughly 100 m above turbidite sediment plain; several prominent local peaks where igneous basement is likely exposed; may be a site of fluid recharge (Hutnak 2006)

Site/Ridge	Hydrothermal vent field	Latitude	Longitude	Maximum or single reported depth (m)	Description
	Papa Bare Outcrop	47.8567	-127.6204	240 (elevation)	Outcrop is built on buried basement ridge to the east of Mama Bare-Baby Bare buried basement ridge; covers an area of 2.6 km^2 and rises 240 m above surrounding seafloor; it is a site of hydrothermal discharge (Thomson et al. 1995; Hutnak 2006)
	Mama Bare Outcrop	47.8377	-127.7323	140 (elevation)	Outcrop located 14 km northeast of Baby Bare Outcrop on same basement ridge; covers an area of 0.9 km^2, and rises 140 m above surrounding seafloor; it is a site of hydrothermal discharge (Thomson et al. 1995; Hutnak 2006)
	Wuzza Bare Subcrop	NA	NA	NA	Subcrop is a shallowly buried basement high from which highly altered basement fluids seep; covered by a few 10s of meters of sediment (Zuhlsdorff et al. 2005)

Site/Ridge	Hydrothermal vent field	Latitude	Longitude	Maximum or single reported depth (m)	Description
	Baby Bare Outcrop	47.7092	-127.7870	70 (elevation)	Off-axis outcrop located on eastern flank of Juan de Fuca Ridge; hydrothermal fluid input from Grizzly Bare outcrop 52 km to southwest; low-temperature (25°C) hydrothermal vents near summit; clear shimmering water emanates through thin sediment and exposed basalt at three or more distinct sites along a fault that cuts across edifice; elevation is 70 m above surrounding seafloor (Thomson et al. 1995; Mottl et al. 1998; Fisher et al. 2003; Hutnak et al. 2006).
	Grinnin Bare Outcrop	47.5521	-128.1844	250 (elevation)	Outcrop appears to have been conical in form originally, but roughly 1/3 of its exposed mass has collapsed along a steeply dipping failure surface on its eastern side; exposed edifice rises 250 above surrounding seafloor, and was 2.5–3.0 km in diameter prior to collapse; heat flux data are most consistent with hypothesis that Grinnin' Bare Outcrop is a site of hydrothermal discharge, and possibly recharge; hydrothermal fluid may also come from Grizzly Bare Outcrop (Hutnak 2006)

Site/Ridge	Hydrothermal vent field	Latitude	Longitude	Maximum or single reported depth (m)	Description
	Grizzly Bare Outcrop	47.2738	-128.0511	450 (elevation)	Site of seawater recharge and source of hydrothermal fluid for Baby Bare outcrop 52 km to northeast; elevation is 450 m above surrounding seafloor; temperature of recharging fluid within Grizzly Bare edifice is 2-9°C to the depth of basement aquifer; heat flux patterns suggest that there may be an area of fluid discharge along northern edge of Grizzly Bare Outcrop (Hutnak 2006)
Northern Cobb Segment, JdFR	Split Seamount	47.6400	-128.9667	2350	Inactive deposits on rifted, conical, hill measuring 475 m in height and 7 km in diameter; located on northern end of Cobb segment of Juan de Fuca Ridge (Carbotte et al. 2006; NEMO 2007)
Southern Cobb Segment, JdFR	Not Dead Yet	46.6899	-129.3772	2419	Active vent about 20 m tall with 2 large spires and flanges located in a horizontal boundary between sedimented rocks; located on southern Cobb segment (NEMO 2007)

Predominant, Unique, and Sensitive Habitat Features

Hydrothermal vents in the Offshore Pacific AOI are areas of increased resource availability and habitat diversity, able to support unique assemblages of both vent obligate and non-obligate organisms and transfer energy to adjacent non-vent habitats. Habitat features at the northeast Pacific hydrothermal vents include: sulphide structures, unsedimented basalts, sedimented basalts, the hydrothermal plume, and the sub-seafloor. Each of these habitat features hosts distinct faunal communities specialized to the local conditions (Table 2). Each of the venting systems outlined in Table 1 is a complex mosaic of different habitat features.

Sulphide structure

One of the main habitat features at hydrothermal vents, sulphide structures are complex, three-dimensional sulphide deposits that can display large variations in the temperature and concentration of vent fluid over the same structure. Venting temperatures can range from near ambient to over 400°C, and this high variability leads to a mosaic of habitat types on each structure, which is also reflected in the faunal composition. On structures in the Offshore Pacific AOI, Sarrazin et al. (1997) described six recurring faunal assemblages which form a mosaic of decimeter to meter scale patches covering over 90% of the sulphide structure studied. Assemblages are comprised of various combinations of the sulphide edifice fauna listed in Table 2, and range from sulphide worm-dominated (*Paralvinella sulfincola*) early succession communities associated with higher flows, to tubeworm-dominated (*Ridgeia piscesae*) later succession communities associated with lower flows, to a final senescent community where flow has ceased and tubeworms have died (Sarrazin et al. 1997; Sarrazin and Juniper 1999a; Sarrazin et al. 2002).

On a larger scale, when flow ceases for an entire sulphide structure or vent field, the whole structure or field becomes senescent, and community changes are more extreme. While the communities colonizing inactive hydrothermal deposits have not been well studied, they tend to resemble seamount communities, with organisms typically being sessile, filter-feeding, long-lived and slow-growing (summarized in Boschen et al. 2013). These communities include fewer vent obligates, a more even representation of species, and the presence of typical deep-sea taxa such as isopods, tanaids, ophiuroids, hydrozoans, and sponges (Tsurumi and Tunicliffe 2003).

Basalt

Most of valley floor of the Juan de Fuca ridge system is exposed basalt. In hydrothermally active areas around sulphide structures, hydrothermal fluid vents through cracks in the basalt, creating a low complexity habitat, where fluid flow is diffuse with lower temperatures and sulphide concentrations. Species inhabiting basalt vents are similar to those on adjacent sulphide structures (Tsurumi and Tunnicliffe 2003), but are found in lower densities given the decreased chemical flux and surface area available for colonization.

Sediment

At sedimented hydrothermal vent sites in the Offshore Pacific AOI, basalt substrate is covered in 100 to over 1000 m of turbidite sediment from the continental shelf, with hydrothermal fluid percolating through the sediment in focused areas (Goodfellow and Franklin 1993). This creates a soft-bottom habitat with few hard surfaces for colonization. Sediment communities are dominated by bivalves, including species similar to *Calyptogena pacifica* from Axial Seamount (Juan de Fuca Ridge outside of the AOI) and *Calyptogena laubieri* from seep sites in Japan, and other infauna, which is rare for hydrothermal vent sites in the northeast Pacific (Juniper et al. 1992a). Non-vent species such as snails and squat lobsters are found among dead clam shells and rattail fish and octopus hover nearby (Juniper et al. 1992a).

Hydrothermal plume

Hydrothermal plumes are created when buoyant hydrothermal fluid rises to a point of neutral buoyancy. As it rises, the fluid entrains particulates, creating a nutrient-rich layer of water roughly 150-300 m above active vent fields and ridge flank outcrops (Thomson et al. 1992; 1995). Hydrothermal plumes support unique bacterial and viral communities (Juniper et al. 1998), zooplankton communities (Burd et al. 1992; Burd and Thomson 1994), and hydrothermal vent larvae (Mullineaux et al. 1995). In fact, these plumes play a significant role in larval dispersal at hydrothermal vents, carrying propagules to other vent fields several kilometers away (Marsh et al. 2001; Metaxas 2004). Plume transport may also be a mechanism for export of biological productivity, as entrained and settling hydrothermal vent larvae and particulates can be valuable food sources for both benthic and pelagic organisms in adjacent habitats (Levin et al. 2016).

Sub-seafloor

Beneath the seafloor at hydrothermal vent sites in the Offshore Pacific AOI, there are a number of habitat features in which communities of microorganisms thrive. In hydrothermal fluid cells, fractured basalt, porous mineral deposits, and sediment overlying hydrothermal vents, communities of microorganisms contribute to primary productivity and further alter hydrothermal fluids (e.g. Butterfield et al. 2004; Holland et al. 2004; Zierenberg and Holland 2004). Sub-seafloor microbial activity directly influences adjacent vent communities by altering the chemical composition of supplied hydrothermal fluids through processes such as oxidation, reduction, stripping of metallic compounds, and enrichment in methane, ammonia, and organic carbon, among others (Butterfield et al. 2004).

Outcrops and seamounts

There are a number of hydrothermally active outcrops and inactive seamounts hosting hydrothermal deposits in the Offshore Pacific AOI. One of the most intensely studied is Baby Bare Outcrop, where habitat features include sedimented habitat, found around the base and on portions of the seamount where up to 1 m of sediment has accumulated, basalt, found in areas where steeper slopes prevent sedimentation, hydrothermal plume, and the sub-seafloor. In contrast to these habitat features at on-axis hydrothermal vents, the hydrothermal fluid venting from Baby Bare is characterized by lower temperatures and chemical concentrations, and the fauna are not typical of hydrothermal vents. Bare basalt areas are dominated by sponges and ophiuroids, while bivalves are dominant in sediment (Oliver and Holmes 2007). While the bivalves here are not typical hydrothermal vent bivalve species, they do host chemosynthetic symbionts and display a limited capacity for chemosynthesis. Information about the inactive hydrothermal habitats on seamounts within the Offshore Pacific AOI is not available, but given their proximity to the on-axis hydrothermal vents, they may host faunal assemblages similar to senescent hydrothermal vents.

Habitat stability

While the tectonically influenced hydrothermal vent fields within the Offshore Pacific AOI are more stable than their volcanically influenced international counterparts, it is important to note that this is a highly variable environment, and hydrothermal vent habitats are continually changing. Levin et al. (2016) describe a potential pattern of community succession driven by changes in habitat, where hydrothermal vents may begin as high flux, toxic environments inhabited by only one to a few species, transition to more stable, moderate habitats with high biomass and numerous vent species, and then senesce into habitats with little to no hydrothermal fluid flow and a community of mainly non-vent species. In the northeast Pacific Ocean, this process happens on the order of one to two decades (Tunnicliffe and Juniper 1990a). Tectonic activity can cause similar changes in habitat, both increasing and strangling hydrothermal fluid flow, and these changes can happen much more rapidly (Tunnicliffe and Juniper 1990a; Sarrazin et al. 1997). The spatial extent and temporal persistence of fluctuations in fluid flow will play a role in the speed of community changes (Marcus et al. 2009; Kelly and Metaxas 2010). Regardless, the EBSA area identified was meant to capture the ephemeral nature of the hydrothermal vent environment by including areas of known active and inactive venting, as well as possible areas of future venting (DFO 2016a). The Offshore Pacific AOI, which includes all hydrothermal vent areas captured by the EBSA, will account for the initiation of new vent fields, as well as the collapse or senescence of existing fields, and encompass the full range of hydrothermal habitat features in the Canadian northeast Pacific.

Table 2. Species lists for various habitat features at the hydrothermal vents of the northeast Pacific Ocean. Asterisk (*) indicates taxa known to be present in the non-vent environment or, if the taxa are undescribed, higher order taxa that are common in the deep sea. X=present in samples. "-" indicates that the species was not present in the samples examined. For Middle Valley habitat features only, XX=abundant

		Habitat feature						
Group	**Species**	**Active Sulphide structure[1]**	**Basalt-hosted senescent vent[2]**	**Worm clump[3] Middle Valley**	**Sulphide and (or) sediment[3] Middle Valley**	**Sediment only[3] Middle Valley**	**Baby Bare Outcrop[4]**	**Non-vent obligate: Southern Juan de Fuca Ridge[2]**
Porifera	*Asbestopluma* n. Sp.	-	X	-	-	-	X	*
Cnidaria: Hydrozoa	Spp. Unknown	-	X	-	-	-	-	*
Cnidaria: Anthozoa: Actinostolidae	N.gen., n.sp.	-	-	X	-	-	-	-
Cnidaria: Anthozoa: Actinostolidae	Unknown genus	-	-	X	X	-	-	-
?	Acoelomates?	-	X	-	-	-	-	*
Nematoda	Unidentified	-	X	X	X	-	-	*
Annelida: Polychaeta: Alvinellidae	*Paralvinella dela*	-	-	X	-	-	-	-
Annelida: Polychaeta: Alvinellidae	*Paralvinella palmiformis*	X	-	X	-	-	-	-
Annelida: Polychaeta: Alvinellidae	*Paralvinella pandorae*	-	-	X	-	-	-	-
Annelida: Polychaeta: Alvinellidae	*Paralvinella sulfincola*	X	-	-	X	-	-	-
Annelida: Polychaeta: Ampharetidae	*Amphisamytha galapagensis*	X	-	X	X	X	-	-
Annelida: Polychaeta: Ampharetidae	Unknown polychaete	-	-	-	-	X	-	-

Group	Species	Habitat feature						
		Active Sulphide structure[1]	Basalt-hosted senescent vent[2]	Worm clump[3] Middle Valley	Sulphide and (or) sediment[3] Middle Valley	Sediment only[3] Middle Valley	Baby Bare Outcrop[4]	Non-vent obligate: Southern Juan de Fuca Ridge[2]
Annelida: Polychaeta: Capitellidae	*Capitella near capitata (n.sp.?)*	-	-	X	-	-	-	-
Annelida: Polychaeta: Cirratulidae	*Chaetozone n.sp. 1*	-	-	X	-	-	-	-
Annelida: Polychaeta: Cirratulidae	*Chaetozone n.sp. 2*	-	-	X	-	-	-	-
Annelida: Polychaeta: Dorvilleidae	*Ophryotrocha globopalpata*	-	-	X	-	-	-	-
Annelida: Polychaeta: Etioninae	*Protomystides verenae*	-	X	-	-	-	-	-
Annelida: Polychaeta: Hesioidae	*Amphiduros axialensis*	-	-	X	-	-	-	-
Annelida: Polychaeta: Hesioidae	*Hesiospina vestimentifera*	X	-	-	-	-	-	-
Annelida: Polychaeta: Hesioidae	*Orseis* near *grasslei*	-	-	X	-	-	-	-
Annelida: Polychaeta: Lacydoniidae	*Lacydonia n . sp .*	-	-	X	-	-	-	-
Annelida: Polychaeta: Maldanidae	*Nicomache venticola*	X	X	-	X	-	-	-

Group	Species	Habitat feature						
		Active Sulphide structure[1]	**Basalt-hosted senescent vent**[2]	**Worm clump**[3] **Middle Valley**	**Sulphide and (or) sediment**[3] **Middle Valley**	**Sediment only**[3] **Middle Valley**	**Baby Bare Outcrop**[4]	**Non-vent obligate: Southern Juan de Fuca Ridge**[2]
Annelida: Polychaeta: Nereidae	Nereis piscesae	-	-	-	-	X	-	-
Annelida: Polychaeta: Orbiniidae	*Leitoscoloplos pachybranchiatus*	-	-	X	X	X	-	-
Annelida: Polychaeta: Orbiniidae	*Orbiniella hobsonae*	-	-	X	-	-	-	-
Annelida: Polychaeta: Phylodocida	Polynoids	X	-	-	-	-	-	-
Annelida: Polychaeta: Phyllodocidae	Protomystides verenae	-	-	X	X	-	-	-
Annelida: Ploychaeta: Phyllodocidae	Mystides n . sp .	-	-	X	-	-	-	-
Annelida: Polychaeta: Polynoidae	Branchinotoglum grasslei	-	-	X	X	-	-	-
Annelida: Polychaeta: Polynoidae	Branchinotoglum sandersi	-	-	X	X	-	-	-
Annelida: Polychaeta: Polynoidae	*Harmothoe* sp.	-	X	-	-	-	-	*
Annelida: Polychaeta: Polynoidae	Lepidonotopodium piscesae	-	-	X	X	-	-	-

Group	Species	Habitat feature						
		Active Sulphide structure[1]	Basalt-hosted senescent vent[2]	Worm clump[3] Middle Valley	Sulphide and (or) sediment[3] Middle Valley	Sediment only[3] Middle Valley	Baby Bare Outcrop[4]	Non-vent obligate: Southern Juan de Fuca Ridge[2]
Annelida: Polychaeta: Polynoidae	Levensteiniella kincaidi	-	-	X	-	-	-	-
Annelida: Polychaeta: Polynoidae	Opisthotrochopodus tunnicliffeae	-	-	X	X	-	-	-
Annelida: Polychaeta: Siboglinidae	Ridgeia *piscesae*	X	-	XX	-	-	-	-
Annelida: Polychaeta: Spionidae	N. gen. 1, n.sp.	-	-	X	-	-	-	-
Annelida: Polychaeta: Spionidae	N. gen. 2, n.sp.	-	-	-	-	X	-	-
Annelida: Polychaeta: Spionidae	Prionospio (Munispio) sp.	-	-	X	-	-	-	-
Annelida: Polychaeta: Spionidae	*Prionospio* n. Sp.1	-	-	-	-	-	-	X
Annelida: Polychaeta: Syllidae	Sphaerosyllis ridgensis	-	X	X	X	X	-	*
Annelida: Polychaeta	*Neolira racemosa*	-	X	-	-	-	-	*
Arthropoda: Amphipoda	Unknown	-	X	X	-	-	-	*
Arthropoda: Amphipoda: Ischyroceridae	*Bonierella* nr. *linearis*	-	X	-	-	-	-	-

Group	Species	Habitat feature						
		Active Sulphide structure[1]	**Basalt-hosted senescent vent[2]**	**Worm clump[3] Middle Valley**	**Sulphide and (or) sediment[3] Middle Valley**	**Sediment only[3] Middle Valley**	**Baby Bare Outcrop[4]**	**Non-vent obligate: Southern Juan de Fuca Ridge[2]**
Arthropoda: Amphipoda: Pardaliscidae	*Pardalisca endeavouri*	-	X	-	-	-	-	X
Arthropoda: Copepoda	Copepods	X	-	-	-	-	-	-
Arthropoda: Copepoda	Calanoida; some are *Clausocalanus lividus*	-	X	-	-	-	-	X
Arthropoda: Copepoda	*Harpacticoida* spp. Unknown	-	X	-	-	-	-	X
Arthropoda: Copepoda: Dirivultidae	Unknown species	-	-	-	-	X	-	-
Arthropoda: Copepoda: Dirivultidae	*Benthoxynus spiculifer*	-	X	XX	X	X	-	-
Arthropoda: Copepoda: Dirivultidae	*Stygiopontius quadrispinosus*	-	-	-	X	-	-	-
Arthropoda: Copepoda: Erebonasteridae	*Amphicrossus n.sp.*	-	-	-	-	X	-	-
Arthropoda: Copepoda: Erebonasteridae	*Unknown siphonostome species*	-	-	X	-	-	-	-
Arthropoda: Copepoda: Mundiopsidae	*Munidopsis alvisca*	-	-	XX	-	-	-	-
Arthropoda: Copepoda: Tisbidae	Harpacticoida type 1	-	X	-	-	-	-	-
Arthropoda: Isopoda	Sp. Unknown	-	X	-	-	-	-	X

Group	Species	Habitat feature						
		Active Sulphide structure[1]	**Basalt-hosted senescent vent[2]**	**Worm clump[3] Middle Valley**	**Sulphide and (or) sediment[3] Middle Valley**	**Sediment only[3] Middle Valley**	**Baby Bare Outcrop[4]**	**Non-vent obligate: Southern Juan de Fuca Ridge[2]**
Arthropoda: Isopoda	Unknown species (cf. *Anthuridea*)	-	-	-	-	X	-	-
Arthropoda: Ostracoda	Ostracods	X	-	-	-	-	-	-
Arthropoda: Ostracoda	Spp. Unknown	-	X	-	-	-	-	X
Arthropoda: Ostracoda: Philomedidae	Euphilomedes n.sp	-	-	-	X	-	-	-
Arthropoda: Pycnogonida	Pycnogonids	X	-	-	-	-	-	-
Arthropoda: Pycnogonida: Ammotheidae	*Ammothea verenae*	-	X	X	-	-	-	-
Arthropoda: Tanaidacea	Sp. Unknown	-	X	-	-	X	-	X
Mollusca: Caenogastropoda: Buccinidae	*Buccinum sp.*	-	-	X	X	-	-	-
Mollusca: Caenogastropoda: Buccinidae	*Buccinum thermophilum*	-	X	-	-	-	-	-
Mollusca: Caenogastropoda: Buccinidae	*Buccinum cf viridum*	X	-	-	-	-	-	X
Mollusca: Caenogastropoda: Provannidae	*Provanna variabilis*	X	X	XX	X	X	-	-
Mollusca: Heterodonta: Thyasiridae	*Axinux cascadiensis*	-	-	-	-	-	X	-

Group	Species	Habitat feature						
		Active Sulphide structure[1]	Basalt-hosted senescent vent[2]	Worm clump[3] Middle Valley	Sulphide and (or) sediment[3] Middle Valley	Sediment only[3] Middle Valley	Baby Bare Outcrop[4]	Non-vent obligate: Southern Juan de Fuca Ridge[2]
Mollusca: Heterodonta: Vesicomyidae	Vesicomyid juvenile?	-	X	-	-	-	-	*
Mollusca: Heterodonta: Vesicomyidae	Calyptogena small (n.sp. 1)	-	-	-	-	X	-	-
Mollusca: Heterodonta: Vesicomyidae	Calyptogena large (n.sp. 2)	-	-	-	-	X	-	-
Mollusca: Neomphalina: Melanodrymiidae	*Melanodrymia brightae*	-	X	-	-	-	-	-
Mollusca: Neomphalina: Peltospiridae	*Depressigyra globulus*	X	-	XX	X	-	-	-
Mollusca: Protobranchia: Solemyidae	Solemya johnsoni	-	-	-	-	X	-	-
Mollusca: Pteriomorphia: Mytilidae	Adipicola sp. (n.sp.?)	-	-	-	X	-	-	-
Mollusca: Pteriomorphia: Mytilidae	Idasola washingtonia	-	-	X	X	-	-	-
Mollusca: Solenogastres: Simrothiellidae	*Helicoradomenia juani*	X	-	-	X	-	-	-
Mollusca: Trochidae	No gen., no sp.	-	-	X	-	-	-	-
Mollusca: Vetigastropoda: Lepetodrilidae	*Clypeosectus curvus*	-	-	-	X	-	-	-

Group	**Species**	**Habitat feature**						
		Active Sulphide structure[1]	**Basalt-hosted senescent vent**[2]	**Worm clump**[3] **Middle Valley**	**Sulphide and (or) sediment**[3] **Middle Valley**	**Sediment only**[3] **Middle Valley**	**Baby Bare Outcrop**[4]	**Non-vent obligate: Southern Juan de Fuca Ridge**[2]
Mollusca: Vetigastropoda: Lepetodrilidae	*Lepetodrilus* n.sp.	-	-	-	-	X	-	-
Mollusca: Vetigastropoda: Lepetodrilidae	*Lepetodrilus fucensis*	X	X	XX	XX	X	-	X
Mollusca: Vetigastropoda: Pyropeltidae	*Pyropelta musaica*	-	-	-	-	-	-	*
Echinodermata: Ophiuroidea	Sp. Unknown	-	X	-	-	-	X	X

[1] Sarrazin and Juniper 1999a
[2] Tsurumi and Tunnicliffe
[3] Juniper et al. 1992a
[4] Oliver and Holmes 2007

Significant Species

In relation to the surrounding bathyal plains, hydrothermal vents are well known oases of high animal density and biomass (e.g. Corliss et al. 1979; Grassle 1985). An estimate of biomass for one sulphide structure in the northeast Pacific Ocean found values comparable to those of the most productive marine environments, including photosynthetic environments, as well as other hydrothermal vents and cold seeps (Sarrazin et al. 1999b). All known hydrothermal vents in the Offshore Pacific AOI are located well below the photic zone and, as such, the food web structure and flow of energy depend mainly on chemosynthetic microorganisms and on symbioses with these microorganisms.

Hydrothermal vents in the Offshore Pacific AOI are noted for their exceptionally diverse microbial communities, which are unique in terms of physiologies, metabolism, thermal tolerance, and halotolerance, and play the ecologically significant role of primary producers in this habitat (Wang et al. 2009). At hydrothermal vents in the northeast Pacific Ocean, microbes are ubiquitous, being found in hydrothermal fluids, in mats covering vent substrates, on the tubes and bodies of vent organisms, and in elaborate symbioses with hydrothermal vent invertebrates. Microbes can be so dense that they form visible, thick mats that are grazed on by vent fauna, similar to grass in photosynthetic communities. The extreme temperatures of hydrothermal fluids support a variety of hyperthermophiles, and the hydrogen sulphide and reduced metal compounds support a diverse array of chemoautotrophs. Among the metabolic pathways supported are methanogenesis, aerobic and anaerobic methane oxidation, nitrification, denitrification, sulphide oxidation, sulphate reduction, and degradation of complex carbon substrates (Wang et al. 2009). Microbes are highly variable in density and composition among hydrothermal vent sites, which can support dense microbial communities of archaebacteria, Thiobacilli, and barophilic eubacteria (Hedrick et al. 1992). In a study by Zhou et al. (2009), high microbial diversity at one vent site in the Endeavour MPA included clones belonging to Thermococcales and deep-sea hydrothermal vent Euryarchaeota (DHVE). The associated microbes were characterized by thermophilic or hyperthermophilic physiologies, and sulphur-related metabolism by thermophilic archaea and mesophilic bacteria was common. Kaye and Baross (2000) found halotolerant bacteria from Endeavour (Juan de Fuca Ridge), and in the same area, De Angelis et al. (1993) found evidence that microbial methane oxidation can play an important role in productivity. The most notable metabolic pathway, due to its varied use by numerous taxa and its large contribution to the primary production of hydrothermal vents, is sulphide oxidation. In addition to being used by free-living bacteria, this chemosynthetic pathway is also used in complex symbioses between sulphide oxidizing bacteria and several hydrothermal vent macrofaunal species.

Macrofaunal groups typical of hydrothermal vents in the Offshore Pacific AOI include terebellids, vestimentiferans, phyllodocids, vetigastropods, caenogastropods, pycnogonids, capitellids, solenogasters, and crustaceans (Sarrazin and Juniper 1999a; Marcus et al. 2009). These groups perform a variety of ecologically significant functions, but a few species are particularly noteworthy in that they assist in primary productivity, are ecosystem engineers, and provide habitat and food for other vent and non-vent organisms. The polychaete tubeworm, *Ridgeia piscesae*, and vesicomyid clams, *Calyptogena* sp., participate in primary production through symbioses with sulphide oxidizing bacteria. In *R. piscesae*, the symbionts live in a highly-vascularized organ (the trophosome) inside the tubeworm's body and receive sulphide, oxygen, and carbon dioxide from the worm (Southward et al. 1995). In *Calyptogena*. sp., the symbionts live embedded in the clam's gills and benefit from increased delivery of sulphide, oxygen, and carbon dioxide facilitated by aeration of the clam's gills during respiration (Juniper et al. 1992a).

In both cases, the bacteria provide fixed carbon in return, either through translocation to the host, or by consumption of the bacteria by the host. In addition to assisting with primary production, both *R. piscesae* and *Calyptogena* sp. act as ecosystem engineers, providing settlement substrate, habitat, and a food source for other vent and non-vent organisms. *R. piscesae* colonizes hard substrates in areas of diffuse hydrothermal fluid flow (≤35-40°C), creating dense “forests” that greatly increase the surface area available for colonization, and host diverse communities of vent organisms (Tsurumi and Tunnicliffe 2003). Similarly, at sedimented sites, empty shells from *Calyptogena* sp. increase habitat complexity by providing hard substrate in an otherwise soft-bottomed area (Juniper et al. 1992a). Another ecosystem engineer present in the Offshore Pacific AOI is the sulphide worm, *Paralvinella sulfincola*. This pioneer species colonizes areas where hydrothermal fluid flow is too extreme for other vent macrofuna (60-90°C) and facilitates mineralization of the sulphide substrate, decreasing flow and temperature, and rendering the habitat suitable for colonization by other vent organisms (Tunnicliffe and Juniper 1990a; Juniper et al. 1992b). Also of note are gastropod species such as the limpet, *Lepetodrilus fucensis*, and the snail, *Depressigyra globulus*, and alvinellid polychaete worms such as *Paralvinella palmiformis.* Each of these species is numerically dominant at various community successional stages described for hydrothermal vents in the northeast Pacific Ocean (Sarrazin and Juniper 1999; Marcus et al. 2009).

Hydrothermal vents in the Offshore Pacific AOI also support a diverse array of organisms that are not obligate vent species, and are ecologically important in transferring chemoautotrophic production from hydrothermal vents to the surrounding deep sea. Zooplankton feeding on hydrothermally derived, particulate organic carbon entrained in the hydrothermal plume transfer this energy to adjacent pelagic food chains (Burd and Thomson 1994; Cowen et al. 2001; Bennett et al. 2011). Similarly, mobile benthic scavengers and predators, such as crabs, fish, sea stars, and octopus, export hydrothermal vent production to surrounding bathyal plain habitat (Tunnicliffe and Jensen 1987; Marques and Porteiro 2000; Voight 2000; MacAvoy et al. 2002, 2003, 2008). Non-obligate vent predators also play important roles in community structure through predation and other, more indirect effects (Micheli et al. 2002). Notable non-obligate vent species in the Offshore Pacific AOI include the Majid crab, *Macroregonia macrochira*, and the rattail fish, *Coryphaenoides acrolepi* (Tunnicliffe et al. 1990b), these species occur in greater densities around hydrothermal vent sites.

Within the Offshore Pacific AOI, no vent-obligate species are commercially fished or listed as species of conservation concern. There are records of midwater trawl fishing above the Endeavour Hydrothermal Vents MPA, and Dellwood Seamount is known to have been commercially fished for Sablefish, *Anoplopoma fimbria*, since 1983 using longlines and longline traps. However, the connection between these fish and the hydrothermal vents and deposits found within the MPA and on Dellwood Seamount is unclear. For a more complete list of commercial species and species of conservation concern that may be found on Dellwood and other seamounts in the Offshore Pacific AOI, refer to the Seamount section.

As noted in Ban et al. (2016), insufficient information exists to assess whether any of the hydrothermal vent species in the Offshore Pacific AOI are depleted (DFO 2016a). Source-sink dynamics act in these communities (e.g. Tunnicliffe et al. 2014), but have not been fully characterized, and baseline population levels have not been determined, so identifying depleted populations is problematic. However, there are several rare and unique species reliant on hydrothermal vent habitat that may become depleted if this habitat were to be altered by human activities. In a study of macrofaunal biogeography, Tunnicliffe (1988) estimated that 50% of the macrofaunal species observed at sampling sites on the Juan de Fuca Ridge were endemic to hydrothermal vents of the northeast Pacific Ocean. Globally rare or unique species at the northeast Pacific hydrothermal vents include *R. piscesae*, *Calyptogena sp., Paralvinella sulfincola, Paralvinella palmiformis, Lepetodrilus fucensis,* and *Depressigyra globulus*.

Barriers to dispersal causing isolation may result in different sets of rare or unique hydrothermal vent species that evolve separately, but fill the same niches (Tunnicliffe et al. 1996; Tunnicliffe et al. 1998). There appears to be significant larval retention on the scale of vent fields and ridge segments (Metaxas 2004) in the northeast Pacific Ocean, possibly because the location of hydrothermal vents within axial valleys of the mid-ocean ridge system shields them from stronger tidal and wind-driven currents in the water column above the ridge crest (Thomson et al. 2003; Metaxas 2004). Rising hydrothermal plumes also induce flow into the axial valley of the Endeavour Segment of Juan de Fuca Ridge that helps retain drifting larvae (Thomson et al., 2003; Thomson et al., 2005, 2009). Additionally, vestimentiferans are genetically structured within the northeast Pacific Ocean indicating limited gene flow over long distances (Southward et al. 1996). To illustrate distribution patterns at the global scale, species distribution models have been used to describe different sets of biogeographic provinces in the world's oceans (Tunnicliffe 1997; Mironov et al. 1998; Tunnicliffe et al. 1998; Tyler and Young 2003; Desbruyeres et al. 2006; and Bachraty et al. 2009). Interestingly, all but one of the proposed models designates the northeast Pacific as its own separate biogeographic province, indicating that this area is unique among the hydrothermal vents of the world (Figure 3).

In capturing the full range of hydrothermal vent habitat features present within Canadian waters, the Offshore Pacific AOI will serve to maintain the current biodiversity found at these vent sites and will protect several rare, unique, and ecologically important hydrothermal vent species.

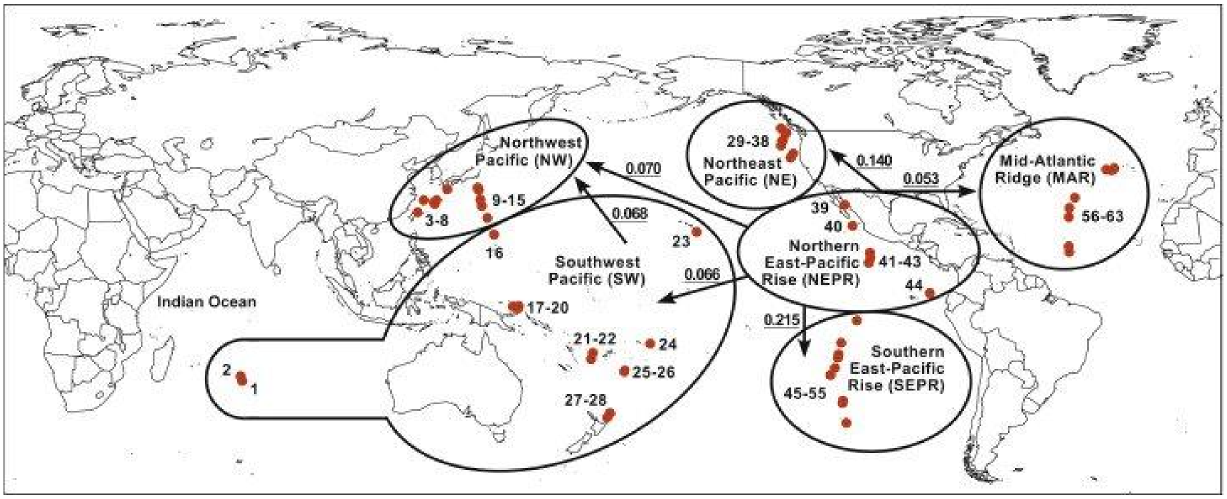


Figure 3. Global biogeographic model of the 6 hydrothermal vent provinces proposed by Bachraty et al. (2009). Arrows indicate significant coefficients of dispersal direction. Used with permission.

Sensitivities, Resilience, and Recoverability

Sensitivities

Hydrothermal communities are highly susceptible to frequent tectonic events (Tunnicliffe and Juniper 1990a), which can cause large fluctuations in hydrothermal fluid flow and alter habitat structure. Hydrothermal vent habitat in the northeast Pacific Ocean is deep and remote, and so is relatively inaccessible and has few anthropogenic threats other than scientific activities. It is thought that, even though human impacts, such as scientific activities, may have similar effects as natural disturbances, effects may be cumulative, and the increased frequency of disturbance may push communities past tipping points, making recovery difficult (Godet et al. 2011).

In a risk assessment for the Endeavour Hydrothermal Vents MPA, Thornborough et al. (2016) found that the main stressors at hydrothermal vents within the MPA were research activities, including vessel traffic and equipment installation and abandonment. Similarly, in an observational study conducted over 4 years at hydrothermal vents on the Juan de Fuca Ridge, Tunnicliffe and Juniper (1990) found that vents that had been sampled the most showed the greatest differences in visual changes to community structure. These authors listed excavation, removal of sulphides, animal sampling, and accidental damage by submersibles as common types of scientific sampling disturbances, but caution that this was not an experimental study, rather a series of incidental observations.

Commercial fishing for Sablefish, *Anoplopoma fimbria*, has occurred at Dellwood Seamount since 1983. This fishery uses longlines and longline traps, and benthic habitat destruction can occur through the use of anchors, weighted traps and kilometers of line, which may become ensnared in benthic habitat features (refer to the Seamount section).

The polymetallic sulphide (PMS) deposits that form hydrothermal vent structures contain metals such as copper, zinc, silver, and gold, that are of interest to the mining industry. Globally there are several mining companies investigating the possibilities of mining seafloor massive sulphides (Scott 2001). While there are currently no plans for exploration or mining within the Offshore Pacific AOI, this will be discussed as a potential threat given the serious implications if interests change. In 2011, Nautilus Minerals was granted the world’s first PMS deposit mining lease by the government of Papua New Guinea and mining operations will commence in 2018. The PMS deposits of the Solwara 1 project in Papua New Guinea contain much higher concentrations of gold and silver than do the PMS deposits in the northeast Pacific Ocean, but the PMS deposits at Middle Valley are some of the largest in the world (Hannington et al. 2011). Estimates of gold and silver content in 10 of the largest PMS deposits at Middle Valley range from 2.0-3.4 tonnes of gold, and 255-396 tonnes of silver (Hannington and Scott 1989). Several reviews (e.g. Van Dover 2007, 2011; Gwyther 2008) have outlined the potential impacts of PMS mining, which include alteration of seafloor structure and hydrothermal fluid flow and smothering of the surrounding communities by sediment plumes from mining operations, among others.

Other potential future threats to hydrothermal vents in the northeast Pacific Ocean include bioprospecting, geothermal exploitation, and eco-tourism. It is unknown if, or when, these may become threats and what the impacts might be.

Resilience and Recoverability

While hydrothermal vent fauna can be highly sensitive to both natural and human induced disturbances, vent communities can also adapt to this dynamic environment and can show resilience in the face of rapidly shifting conditions if they are exposed to high rates of natural disturbance. However, this resilience depends on the scale, magnitude and frequency of the disturbance, which if too high may push the assemblages past tipping points. At hydrothermal vents in the northeast Pacific Ocean, mobile species such as the polychaete *Paralvinella palmiformis*, the limpet, *Lepetodrilus fucensis*, and the two small snails, *Depressigyra globulus* and *Provanna variabilis*, have been shown to move into reinvigorated habitat after a disturbance (Sarrazin et al. 1997; Bates et al. 2005; Kelly et al. 2007; Kelly and Metaxas 2008). Snails can recover in less than 10 years from perturbations equivalent to a catastrophic eruption that removes 95% of the population (Kelly and Metaxas 2010). Sessile species take longer to recolonize, but display other adaptations that allow them to be resilient to disturbance as well

(Marcus et al. 2009). For example, *Ridgeia piscesae* is a phenotypically variable (likely phenotypically plastic) sessile species in which morphology appears to be modified for greater fitness in habitats of varying quality (Tunnicliffe et al. 2014). Phenotypic plasticity is common in sessile organisms inhabiting variable environments (Dudley 2004) and likely gives *R. piscesae* the ability to survive major disturbances where prime habitat is destroyed. Given that *R. piscesae* dominates the biomass, and is a foundation species providing habitat for nearly all vent assemblages (Tsurumi and Tunnicliffe 2003). After a 1993 eruption on the CoAxial segment of the Juan de Fuca Ridge (just outside the Offshore Pacific AOI), lava flows had covered all existing vent habitat, and there were no extant vents (seed populations) within 15 km. *R. piscesae* recolonized vents within 7 months, and one-third of the regional vent species pool had returned within 2 years (Tunnicliffe et al. 1997).

On March 4, 2003, the Endeavour Hydrothermal Vents Marine Protected Area (MPA) was identified as Canada's first MPA. This MPA falls within the Offshore Pacific AOI and is managed by DFO to conserve a highly productive and rare habitat. In the MPA, there are designated areas for scientific sampling as well as no-take, no-disturbance areas that remain relatively untouched. This area may act as a refuge for mobile vent obligate and non-obligate species, as well as a source of colonizers for disturbed hydrothermal vent sites. It is worth noting that this MPA does not include the heavily sedimented habitat type or hydrothermal venting seamounts.

While mobile species begin to move into denuded areas within minutes of a disturbance (Sarrazin et al. 1997), it can take much longer (5 to 10 years) for a community to recover to the late stages of succession (Tunnicliffe et al. 1997; Marcus and Tunnicliffe 2005; Kelly and Metaxas 2010). Furthermore, when a vent structure collapses, not only are most of the animals either crushed or starved, but the surface area that has developed over decades is not available for recolonization until a new structure can form. Also, the distance and connectivity with potential source populations of recruits will greatly influence the potential for recovery.

It is thought that fast-spreading ridges can recover more quickly than slow-speading ones following a major disturbance because they are able to rebuild sulphide deposits more quickly through hydrothermal activity, making suitable habitat for recolonization more readily available (Boschen et al. 2013). Given that the northeast Pacific ridge is an intermediate spreading ridge, hydrothermal vents within the Offshore Pacific AOI may have an intermediate rate of recovery to disturbance. That said, the compound effects of natural disturbance continuing alongside anthropogenic disturbance would likely increase recovery time for active deposit communities (Boschen et al. 2013).

Hydrothermal vents are highly variable areas that may experience frequent natural disturbance events and are also affected by human activities. Though primary succession can be is rapid for a given area, recovery from disturbance events is slow, and in many cases complete recovery may not be possible.

Uncertainties and Knowledge Gaps

Within the Offshore Pacific AOI, the major vent fields of the Endeavour Hydrothermal Vents MPA are the most extensively studied, and include Sasquatch, Salty Dawg, High Rise, Main Endeavour, and Mothra. Here, scientists have gathered a wealth of information such as bathymetry, geology, oceanography, water chemistry, species composition, food web structure, larval supply, successional patterns, colonization success, physiology, frequency and magnitude of natural disturbance, identification of threats, recovery potential, and connectivity among and between vents. Also in the MPA are many minor vent fields. One of these fields, Clam Bed, has been moderately studied, including experiments on physiology and population connectivity, but information for the other minor vent fields is limited to bathymetry, geology, and basic species lists from visual surveys.

Outside the MPA, Southern Explorer Ridge and Middle Valley have been moderately studied, but much of the higher-level information, such as community dynamics, recovery potential, and connectivity between vents is lacking. Other vent fields associated with the ridge axis are missing all but bathymetry, geology, water chemistry, and preliminary species lists (where present). For hydrothermal systems on the eastern ridge flank, Baby Bare outcrop has been moderately studied, but is missing all but the bathymetry, geology, water chemistry, and species distribution. The remaining outcrops in the region, such as Mama Bare and Papa Bare, have yet to be examined in any detail.

Given the sparse biological information for many vent fields in the Offshore Pacific AOI, future research efforts should focus on gathering species composition and abundance data for vent fields where this information is lacking so that monitoring baselines can be established. Colonization success, succession patterns, frequency and magnitude of natural disturbance, recovery potential, and connectivity among and between vents should also be investigated where this information is lacking, as it will be necessary in the development and implementation of management plans. Where possible, video imagery and non-invasive sampling techniques should be used to minimize anthropogenic impact in this vulnerable marine ecosystem.

In terms of connectivity between hydrothermal vents and surrounding ecosystems, a recent review (Levin et al. 2016) identified three major themes where scientific research could further knowledge on the interactions of vent and seep ecosystems with their surroundings:

- What is the influence of vent and seep plumes on local and global water column biogeochemical cycles, processes, microbiology, and biota?
- How do fauna use inactive chemosynthetic habitats, and how and over what time scales do they transition to background settings? What is the genetic connectivity between chemosynthetic and non-chemosynthetic ecosystems?
- What are the transfer mechanisms of chemosynthetic and photosynthetically-derived carbon, nitrogen, and sulphur into and out of vents and seeps and how does this vary with location and depth?

The authors suggest a number of ways to address these gaps, including: measurements of carbon, trace element, and nutrient export from vents to surrounding environments; molecular barcoding of fauna from chemosynthetic and background systems to investigate genetic exchange; and novel trophic approaches to evaluate nutritional subsidies.

Bachraty et al. (2009) also stressed the need for genetic analysis, in this case to support proposed biogeographic models.

Hydrothermal vents are unique environments that are vulnerable to long term impacts. Given the wide range of vent systems, habitat features, and communities present in the Offshore Pacific AOI, it is recommended that all hydrothermal vents known within the area be protected. The Offshore Pacific AOI boundaries are intended to capture potential emergence of new hydrothermal vents and the senescence of existing vents, as well as two off axis seamount systems.

Seamounts

Overview

Seamounts are seafloor features of considerable scientific and economic interest because of their distinct oceanography and ecology, and as sites for fisheries and potential seabed mining. In Canada's Offshore Pacific Bioregion, 19 well-known and named Canadian seamounts, including the seafloor, substrata, and associated water column, have been identified as EBSAs (DFO 2016a; Ban et al. 2016; summit information from BCMCA Project Team 2011). In the Canadian Science Advisory Secretariat (CSAS) assessment, seamounts ranked high in EBSA criteria on uniqueness, vulnerability, diversity, naturalness, and importance for species aggregation (DFO, 2016a).

Seamounts are designated as submarine mountains with summit elevations exceeding 1,000 m above the surrounding seafloor and are roughly circular or elliptical in shape (United States Board of Geographic Names 1981). While geologists and oceanographers define seamounts as extinct volcanoes, ecologists include any abrupt peak that exhibits similar biophysical properties (Pitcher et al. 2007). For decades, the Intergovernmental Oceanographic Commission (IOC), the International Hydrographic Organization (IHO), and the joint IOC/IHO Guiding Committee for the General Bathymetric Chart of the Oceans (GEBCO) have expressed concern about the indiscriminate and unregulated naming of undersea features (Bouma 1990). Even under their recommendation, a seamount is "a large, isolated elevation characteristically of conical form", with no explicit elevation provided (Bouma 1990). Since naming undersea features has historically occurred without scrutiny, it follows that there are features named "seamounts", that are technically "knolls" or "hills" (comparable features with summit elevations between 500 and 1,000 m, and under 500 m, respectively; United States Board of Geographic Names 1981). In Canada's Offshore Pacific Bioregion, there are at least four undersea features named as seamounts that would be more accurately defined as hills (or outcrops) or knolls; as well as dozens of unnamed features that could be potentially be seamounts (Table 3).

On a global scale, there is a need for accurate identification and information on the location and physical characteristics of undersea features (Clark et al. 2012), and within Canadian waters, a lack of full-coverage high-resolution bathymetry data means there are seamounts that have yet to be formally recognized and cataloged. Predictions based on satellite altimetry and available multibeam bathymetry provide the best science available for the location of additional, unnamed Canadian seamounts (models reviewed in this report include Kitchingman and Lai 2004; Manson 2009; Kim and Wessel 2011; and Yesson et al. 2011).

Although seamounts are globally distributed, there are currently no named seamounts within Canada's Atlantic and Arctic waters (NRC 2015; a few are predicted by Yesson et al. 2011). There are 24 named Canadian seamounts located in the Pacific Ocean (data from the BCMCA Project Team 2011; Canadian Undersea Gazetteer, NRC 2015; Ban et al. 2016; Figure 4). Near the northern edge of the Canadian Pacific Exclusive Economic Zone (EEZ), three named seamounts are within the already established SG̲aan K̲inghlas-Bowie Marine Protected Area (SK-B MPA; Figure 4): SG̲aan K̲inghlas-Bowie, Hodgkins, and Davidson (also known as Pierce) Seamounts. All three are part of the Kodiak-Bowie seamount complex. There are four other named seamounts in the northern half of the EEZ, outside the SK-B MPA: SAUP 5494, Graham, Oshawa, and Tuzo Wilson Seamounts (Figure 4). The other 17 named seamounts are located within the southern half of the EEZ, captured within the Offshore Pacific Area of Interest (AOI), but this includes the four knolls and hills that are called "seamounts" (Figure 4). The AOI also captures an additional 26 undersea features that are unnamed (or inconsistently named; NRC 2015), predicted or confirmed to meet the geomorphologic criteria of a seamount

(Kitchingman and Lai 2004; Manson 2009; Kim and Wessel 2011; Yesson et al. 2011; unpublished data from paritial or complete maping during Fisheries and Oceans Canada Offshore Expeditions PAC2017-036 and PAC2018-103), and have elevations >1000 m above the seafloor (BCMA Project Team 2011: 100 m resolution bathymetry; Yesson et al. 2011: 20 km pinnacle-to-base distance). Because unnamed seamount locations are based on four separate models, nearby summit locations from different studies are interpreted as predicting the same seamount (near: <20 km distance; pinnacle-to-base distance use by Yesson et al. 2011). In addition to those in the AOI, there are another six unnanmed (predicted or confirmed) seamounts located within the northern half of the EEZ.

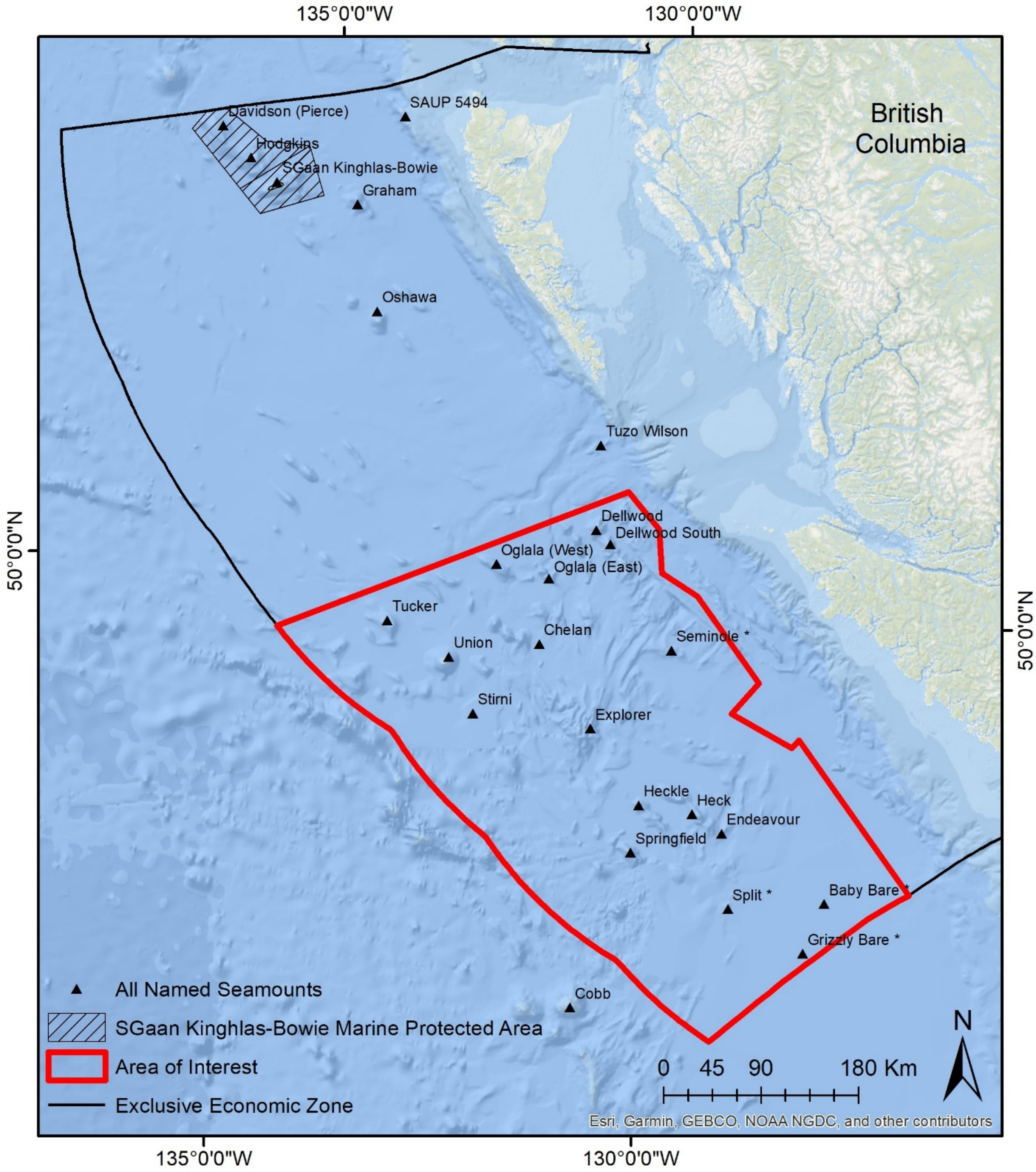


Figure 4. The 24 named seamounts within Canada's Pacific waters, as well as Cobb Seamount in international waters. The black line denotes the extent of Canada's Exclusive Economic Zone (EEZ); hatched polygon denotes the SGaan Kinghlas-Bowie Marine Protected Area (SK-B MPA); red polygon denotes the extent of the Offshore Pacific Area of Interest (AOI); and asterisks after the name denote knolls and hills that are commonly referred to as "seamounts" (i.e., Baby Bare, Grizzly Bare, Seminole, and Split Seamounts).

Although commercial fishery catch records and geological data exist from seamounts within the AOI, data regarding oceanography and ecology are relatively sparse (Ban et al. 2016). Fortunately, two nearby seamounts have been the subject of many scientific studies – SGaan Kinghlas-Bowie and Cobb Seamounts – and are ~380 km north and ~50 km south of the AOI respectively (Figure 4). These seamounts provide data for the northern and southern limits of the Offshore Pacific Bioregion's latitudinal gradients, and both seamounts are relatively tall, with depth ranges that overlap those of the AOI seamounts (~3 km water depth). In the following sections, the best available descriptions of seamounts in the Offshore Pacific AOI are provided, collectively drawing inferences from studies and surveys conducted on SGaan Kinghlas-Bowie and Cobb Seamount, as well as other seamounts in the northeast Pacific Ocean and abroad. Seamount visual surveying and mapping has been the focus of two recent Fisheries and Oceans Canada lead offshore expeditions in 2017 or 2018 but data collection and analyses are ongoing (PAC2017-036 and PAC2018-103; Table 3).

Biophysical and Ecological Features

Physical and Biological Oceanographic Characteristics

There are multiple lines of evidence indicating there are more seamounts within the Offshore Pacific Bioregion than those with official names. There are potentially 39 seamounts in the AOI (Figure 5): 13 named seamounts and 26 unnamed seamounts, as well as up to 258 knolls (data synthesis detailed in the previous section; Appendix A). While the majority of named seamounts overlap with predicted seamount locations (13 of 17), Grizzly Bare, Seminole, and Split Seamounts overlap with predicted knolls, and Baby Bare Seamount does not overlap with any predicted undersea feature (Table 3). The elevation of each of these four undersea features support the above non-seamount designations (Table 3). This report focuses on the 13 named seamounts with elevations >1000 m, but the information is applicable to any comparable features within the Offshore Pacific AOI that exhibit similar biophysical properties.

A mix of isolated seamounts and seamount complexes are distributed throughout the Offshore Pacific AOI, with higher frequency in the northwest corner than in the southeast. The Explorer Ridge complex includes Explorer, Union, and Heck Seamounts. Seamount chains include Dellwood, Heckle, Scott, and likely others that are not yet named (Table 3). Few of the Offshore Pacific AOI seamounts are truly remote. Instead, even the "isolated" seamounts are in close proximity to another seamount or close to the relatively broad continental slope (close proximity: <100 km distance, Clark et al. 2011) (Table 3) (base of continental slope inferred at ~2500 m depth, Ban et al. 2016). The distinction between clustered seamounts and remote seamounts has implications for ecological assumptions regarding species population connectivity, migration, endemism, refugia, habitat suitability for marine mammals, etc. (Kaschner 2008; Lundsten et al. 2009; Rowden et al. 2010).

Seamounts have varying effects on local circulation patterns, depending on their height, shape, and orientation (Ban et al. 2016). These effects include upwelling, the production of eddies and Taylor columns (Roden 1991), the formation of trapped waves (Eriksen 1991), and the amplification of tidal currents (Noble and Mullineaux 1989). At Cobb Seamount, a dome of cold, upwelled water is known to occur, as well as a persistent closed eddy (Dower and Fee 1999). The 30-km breadth of oceanographic influence associated with Cobb Seamount was used to mark the seamount EBSAs around each named seamount summit in the Offshore Pacific Bioregion by Ban et al. (2016) (i.e., the Taylor cone, Dower et al. 1992; Dower and Mackas 1996; Dower and Perry 2001). The authors note that this distance may overestimate the zone of influence for deep seamounts and underestimate it for shallow ones. While Cobb Seamount protrudes into the Epipelagic zone (<200 m depth), the AOI seamounts summit much deeper, within the Mesopelagic, but mainly the Bathypelagic zones (200-1000 m depth and 1000-4000 m depth, respectively; Table 3). The variable summit heights of the Offshore Pacific AOI seamounts suggest a range of circulation patterns are generated (290 to 2712 m depth; Table 3). Alterations in local currents, upwelling, and entrainment of eddies commonly enhance productivity over seamounts; however, this is not a universal feature due to wide variations in physical processes associated with differences in seamount topography (White et al. 2007). In general, seamounts are hotspots of biological productivity, in comparison to the surrounding bathyal waters and plains (White et al. 2007). Biological productivity may be generated locally or elsewhere, then advected and concentrated at the seamount (Boehlert and Genin 1987; Rowden et al. 2010).

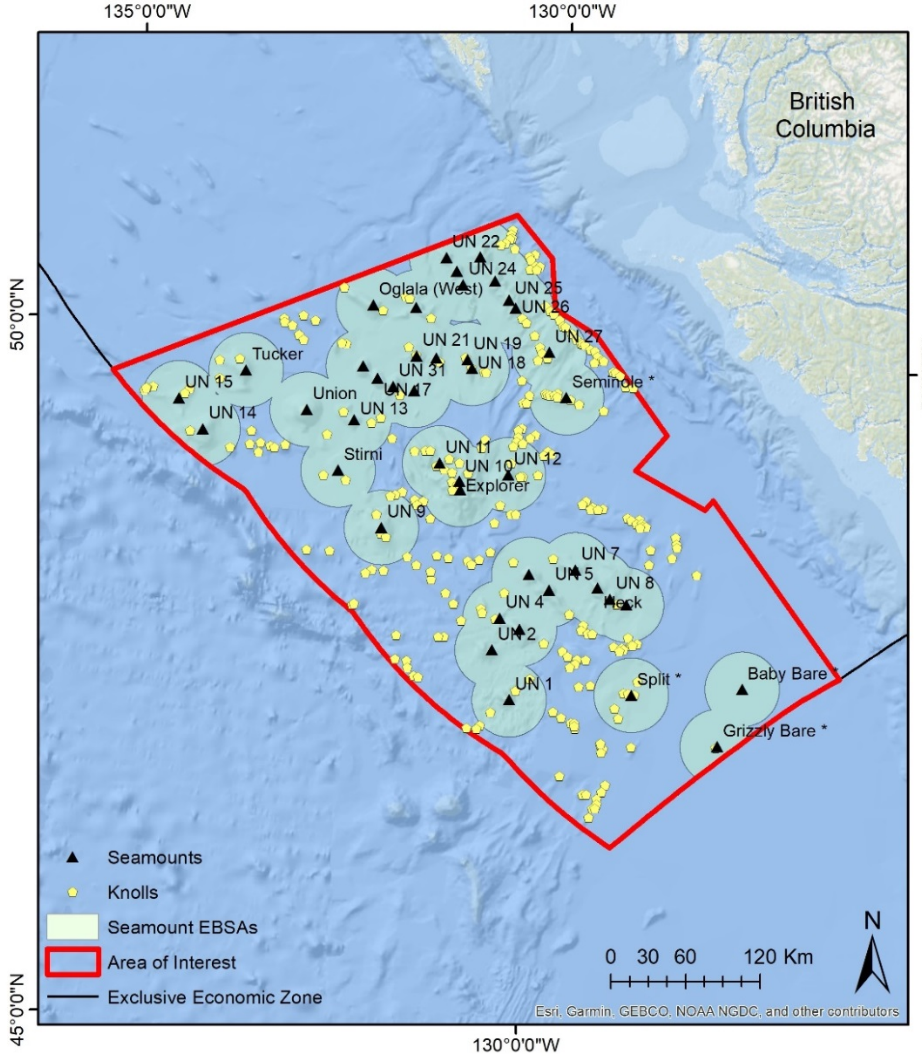


Figure 5. The 39 seamounts and 258 knolls within the Offshore Pacific Area of Interest (AOI), as well as the 30 km buffer used by Ban et al. (2016) to represent the oceanographic influence associated with each seamount (i.e., Ecologically or Biologically Significant Areas, EBSAs) (DFO 2016a). An asterisk denotes a knoll or hill that is commonly referred to as a "seamount"; the black lines denote the extent of Canada's Exclusive Economic Zone (EEZ); and the red lines denote the extent of the Offshore Pacific Area of Interest (AOI).

Table 3. Physical oceanographic data for 52 seamounts within Canada's Pacific Exclusive Economic Zone (EEZ), as well as Cobb Seamount in international waters (39 within the Offshore Pacific AOI, plus 13 outside). Seamounts are listed according to naming-status and location. Summit depths, base depths, elevations (i.e., summit - base), and locations from the British Columbia Marine Conservation Analysis (BCMCA) Project Team (2011) (from seamount data and derived from bathymetry), Canessa et al. (2003), and Barr (1974), with updates based on Fisheries and Oceans Canada Offshore Expeditions in 2017 and 2018. Base depth derived using Yesson et al. 2011 approach. Temperature and oxygen at-summit depth estimated from World Ocean Atlas 2013 data (Locarnini et al. 2013, Garcia et al. 2014). The base of continental slope inferred at ~2500 m depth (Ban et al. 2016). Seamount class based on Clark et al. (2011).

Named seamounts within the Offshore Pacific Area of Interest

#	Seamount	Feature class	In Ban et al. 2016	Summit depth (m)	Base depth (m)	Est. elevation (m)	Est. temp. (°C)	Est. [O2] (mL/L)	Lat.	Long.	To nearest seamount (km)	To continental slope (km)	Class	Predicted by:	Associated with:
1	Chelan	Seamount	Y	1459	3050	1591	2.40	0.60	49.75	-131.53	17.4	52.2	2	KL, M, KW, Y	na
2	Dellwood	Seamount	Y[5]	535	2659	2124	4.40	0.71	50.75	-130.90	22.23	on slope	3	KL, M, KW, Y	Dellwood Seamount Chain
3	Dellwood South	Seamount	Y[5]	821	2629	1808	3.65	0.36	50.58	-130.71	18.99	on slope	2	KL, M, KW, Y	Dellwood Seamount Chain
4	Endeavour	Seamount	Y	1703	2900	1197	2.15	1.08	48.29	-129.06	14.28	on slope	1	M, Y	na
5	Explorer	Seamount	Y[5]	814	3300	2486	3.67	0.40	49.06	-130.94	14	17	2	KL, M, KW, Y	Explorer Seamount (complex)
6	Heck Seamount	Seamount	Y	1039	2700	1661	3.2	0.4	48.41	-129.38	18	on slope	2	KL, M, KW, Y	Heck Seamount (chain)
7	Heckle Seamount	Seamount	N [2]	1400	2800	1400	2.5	0.6	48.48	-130.14	16	on slope	2	KL, M, KW, Y	Heckle Seamount Chain
8	Oglala Seamount (West)	Seamount	N [2]	1578	3069	1491	2.2	0.9	50.34	-132.07	41	91	2	KL, M, KW, Y	na
9	Oglala Seamount (East)	Seamount	Y	1600	3000	1400	2.6	0.5	50.35	-131.58	32	41	2	M, KW, Y	na
10	Springfield Seamount	Seamount	Y	938	3000	2062	3.5	0.4	48.08	-130.20	13	33	2	KL, M, KW, Y	Springfield Seamount (chain)
11	Stirni Seamount (East)	Seamount	Y	1710	3200	1490	2.4	0.7	49.13	-132.30	45	125	2	KW, Y	na

#	Seamount	Feature class	In Ban et al. 2016	Sum-mit depth (m)	Base depth (m)	Est. eleva-tion (m)	Est. temp. (°C)	Est. [O2] (mL/L)	Lat.	Long.	To nearest seamount (km)	To continen-tal slope (km)	Class	Predicted by:	Associated with:
12	Tucker Seamount	Seamount	Y	1242	3300	2058	2.6	0.5	49.77	-133.42	53	177	2	KL, M, KW, Y	na
13	Union Seamount	Seamount	Y	285	3239	2954	5.3	3	49.55	-132.70	27	128	4	KL, M, KW, Y	na

Knolls and hills that are named "seamounts" within the Offshore Pacific Area of Interest

#	Seamount	Feature class	In Ban et al. 2016	Sum-mit depth (m)	Base depth (m)	Est. eleva-tion (m)	Est. temp. (°C)	Est. [O2] (mL/L)	Lat.	Long.	To nearest seamount (km)	To continen-tal slope (km)	Class	Predicted by:	Associated with:
na	Baby Bare Seamount	Hill (outcrop)	Y[1]	2600	2691	91[4]	1.8	1.8	47.71	-127.79	51	61	1	no	Baby Bare-Grizzly Bare Complex
na	Grizzly Bare Seamount	Hill (outcrop)	N[1]	2712	2699	13[4]	1.9	1.8	47.29	-128.04	51	93	1	no (Y: knoll)	Baby Bare-Grizzly Bare Complex
na	Seminole Seamount	Knoll	Y[1]	1653	2400	747	2.2	1	49.77	-129.83	41	on slope	2	M (Y: knoll)	na
na	Split Seamount	Hill	Y[1]	2350	2600	250	1.8	1.9	47.64	-128.97	70	22	1	no (Y: knoll)	na

Unnamed (predicted) seamounts within the Offshore Pacific Area of Interest

#	Seamount	Feature class	In Ban et al. 2016	Sum-mit depth (m)	Base depth (m)	Est. eleva-tion (m)	Est. temp. (°C)	Est. [O2] (mL/L)	Lat.	Long.	To nearest seamount (km)	To continen-tal slope (km)	Class	Predicted by:	Associated with:
14	UN 1	Seamount	N[3]	2000	3000	1000	2	1.4	47.56	-130.27	39	58	1	KL, M, KW, Y	na
15	UN 2	Seamount	N[3]	2000	3000	1000	2	1.5	47.92	-130.48	28	61	1	M, KW, Y	na
16	UN 4	Seamount	N[3]	1610	2880	1270	2	1.4	48.15	-130.42	19	36	1	M, KW, Y	Springfield Seamount (chain)
17	UN 5	Seamount	N[3]	1572	2800	1228	2.27	0.85	48.37	-129.91	9.37	on slope	2	KL, M, KW, Y	Heckle Seamount Chain

#	Seamount	Feature class	In Ban et al. 2016	Sum-mit depth (m)	Base depth (m)	Est. eleva-tion (m)	Est. temp. (°C)	Est. [O2] (mL/L)	Lat.	Long.	To nearest seamount (km)	To continen-tal slope (km)	Class	Predicted by:	Associated with:
18	UN 7	Seamount	N [3]	1152	2700	1548	3.10	0.44	48.53	-129.63	22.98	on slope	2	KL, M, KW, Y	Heck Seamount Chain, West Peak
19	UN 8	Seamount	N [3]	1174	2900	1726	2.93	0.44	48.33	-129.24	13.28	on slope	1	KL, M, Y	Heck Seamount Chain, East Peak
20	UN 9	Seamount	N [3]	1000	3000	2000	3.20	0.39	48.74	-131.77	57.92	97.18	2	M, KW	na
21	UN 10	Seamount	N [3]	1124	3608	2484	3.03	0.48	49.12	-130.96	7.04	27.69	2	KL, M, Y	Explorer Seamount Complex
22	UN 11	Seamount	N [3]	1500	3147	1647	2.38	0.81	49.24	-131.19	21.47	45.75	2	M, Y	Explorer Seamount Complex
23	UN 12	Seamount	N [3,5]	1460	3046	1586	2.54	0.69	49.19	-130.43	39.62	on slope	2	KL, M, KW, Y	na
24	UN 13	Seamount	N [3]	2000	3157	1157	1.90	1.43	49.50	-132.17	38.42	102.42	1	KL, M, Y	na
25	UN 14	Seamount	N [3]	1600	3300	1700	2.18	0.79	49.33	-133.83	31.31	223.91	2	KL, M, KW, Y	Stirni; West
26	UN 15	Seamount	N [3]	2500	3635	1135	1.72	1.97	49.53	-134.13	31.31	233.6	1	M, KW, Y	na
27	UN 16 (Curtis)	Seamount	N [3,5]	1100	3150	2050	2.98	0.44	49.90	-132.12	15.29	95.28	2	KL, M, KW, Y	na
28	UN 17	Seamount	N [3]	1800	3138	1338	2.05	1.22	49.82	-131.95	13.98	82.57	1	KL, M, Y	na
29	UN 18	Seamount	N [3,5]	1555	2839	1284	2.28	0.77	49.94	-130.91	7.9	13.07	2	M, Y	na
30	UN 19	Seamount	N [3,5]	1765	2950	1185	2.11	1.22	50.00	-130.96	7.9	18.88	1	M, KW	na
31	UN 20	Seamount	N [3]	1711	2986	1275	2.12	1.07	49.99	-131.31	16.04	39.68	1	M, KW	na
32	UN 21	Seamount	N [3]	1963	3096	1133	1.96	1.38	50.00	-131.53	16.04	52.3	1	M, KW	na
33	UN 22	Seamount	N [3]	1170	2894	1724	2.93	0.49	50.73	-131.28	13.67	16.86	2	KL, M, Y	Scott Seamount Chain
34	UN 23	Seamount	N [3,5]	1541	2997	1456	2.30	0.65	50.63	-131.15	12.1	12.76	2	KL, M, KW, Y	Scott Seamount Chain
35	UN 24	Seamount	N [3]	1680	2950	1270	2.16	0.79	50.54	-131.07	12.1	15.44	2	M, Y	Scott Seamount Chain

#	Seamount	Feature class	In Ban et al. 2016	Sum-mit depth (m)	Base depth (m)	Est. eleva-tion (m)	Est. temp. (°C)	Est. [O2] (mL/L)	Lat.	Long.	To nearest seamount (km)	To continen-tal slope (km)	Class	Predicted by:	Associated with:
36	UN 25	Seamount	N[3,5]	1089	2601	1512	2.90	0.48	50.45	-130.54	8.54	on slope	2	KL, M, KW, Y	Dellwood Seamount Chain
37	UN 26	Seamount	N[3,5]	1140	2606	1466	2.90	0.48	50.39	-130.46	8.54	on slope	2	KL, M, Y	Dellwood Seamount Chain
38	UN 27	Seamount	N[3,5]	1689	2939	1250	2.14	1.09	50.09	-130.05	38.95	on slope	1	M, KW	na
39	UN 31	Seamount	N[3]	1500	3100	1176	1.74	1.79	49.77	-131.77	29.87	195.28	1	KL, M, KW, Y	na

Named seamounts within the SGaan Kinghlas-Bowie Marine Protected Area

#	Seamount	Feature class	In Ban et al. 2016	Sum-mit depth (m)	Base depth (m)	Est. eleva-tion (m)	Est. temp. (°C)	Est. [O2] (mL/L)	Lat.	Long.	To nearest seamount (km)	To continen-tal slope (km)	Class	Predicted by:	Associated with:
na	SGaan Kinghlas-Bowie	Seamount	Y[5]	24	3224	3200	10.26	6.69	53.30	-135.65	34.4	125.33	5	KL, M, KW, Y	Kodiak-Bowie Seamount Chain
na	Hodgkins	Seamount	Y[5]	611	3315	2704	4.02	0.57	53.51	-136.04	34.4	133.46	3	KL, M, KW, Y	Kodiak-Bowie Seamount Chain
na	Davidson (Pierce)	Seamount	Y[5]	1079	3310	2231	2.89	0.50	53.66	-136.59	40.55	159.45	2	KL, M, KW, Y	Kodiak-Bowie Seamount Chain

Other named seamounts in the Pacific Offshore Pacific Bioregion or Pacific continental slope

#	Seamount	Feature class	In Ban et al. 2016	Sum-mit depth (m)	Base depth (m)	Est. eleva-tion (m)	Est. temp. (°C)	Est. [O2] (mL/L)	Lat.	Long.	To nearest seamount (km)	To continen-tal slope (km)	Class	Predicted by:	Associated with:
na	Graham	Seamount	Y[5]	1201	2800	1599	2.81	0.62	53.26	-134.55	14.23	57.81	2	KL, M, KW, Y	na
na	Oshawa	Seamount	Y[5]	896	2940	2044	3.47	0.40	52.29	-134.03	30.95	96.61	2	KL, M, KW, Y	na
na	SAUP 5494	Seamount	Y	902	2778	1876	3.45	0.44	53.85	-133.78	83.07	on slope	2	KL, KW	na
na	Tuzo Wilson	Seamount	N[2]	1388	2550	1162	2.51	0.59	51.46	-130.85	79.07	on slope	2	M	na

Other unnamed (predicted) seamounts in the Pacific Offshore Pacific Bioregion

#	Seamount	Feature class	In Ban et al. 2016	Sum-mit depth (m)	Base depth (m)	Est. eleva-tion (m)	Est. temp. (°C)	Est. [O2] (mL/L)	Lat.	Long.	To nearest seamount (km)	To continen-tal slope (km)	Class	Predicted by:	Associated with:
na	UN 28	Seamount	N [3]	2282	3300	1018	1.76	1.88	50.33	-133.39	60.31	135.26	1	KW, M	na
na	UN 29	Seamount	N [3]	2374	3500	1126	1.71	1.92	50.72	-134.94	29.87	219.42	1	KL, M, KW, Y	na
na	UN 30	Seamount	N [3]	2264	3440	1176	1.74	1.79	50.95	-134.73	29.87	195.28	1	KL, M, KW, Y	na
na	UN 32	Seamount	N [3,5]	1878	3018	1140	1.97	1.16	52.43	-134.43	30.95	107.91	1	M, KW	na
na	UN 33	Seamount	N [3,5]	1799	3836	2037	2.02	1.07	53.19	-134.38	14.23	51.02	1	M, KW	na
na	UN 34	Seamount	N [3,5]	2103	3305	1202	1.90	1.56	52.90	-135.25	52.04	117.69	1	M	na

Named seamount outside Canadian Exclusive Economic Zone (EEZ)

#	Seamount	Feature class	In Ban et al. 2016	Sum-mit depth (m)	Base depth (m)	Est. eleva-tion (m)	Est. temp. (°C)	Est. [O2] (mL/L)	Lat.	Long.	To nearest seamount (km)	To continen-tal slope (km)	Class	Predicted by:	Associated with:
na	Cobb	Seamount	NA	24	3025	3001	11.40	6.43	46.75	-130.82	27.12	151.29	5	KL, KW, Y	Cobb-Eickelberg Seamount Chain

[1] Historically referred to as a "seamount" in the scientific literature.

[2] In the Canadian Undersea Gazetteer (NRC 2015).

[3] Unnamed but predicted as seamounts within the Offshore Pacific Area of Interest (AOI) by Kitchingman and Lai (2004), Manson (2009), Kim and Wessel (2011), and/or Yesson et al. (2011).

[4] Features are known to extend 100's of meters deeper, through the sediment seafloor, to a basaltic basement (Engelen et al. 2008)

[5] The unnamed (predicted) seamount was partially or completely mapped during Fisheries and Oceans Canada Offshore Expeditions in 2017 or 2018 (PAC2017-036 and PAC2018-103); details and location updated accordingly.

Note: Un 3 and 6 were determined to be extensions (part of) the seamounts Springfield and UN 5 respectively.

Seamount summits can trap prey near the surface, providing a source of food over the seamount, but this phenomenon depends on the depth of the seamount and the deep-scattering layer (vertical migration of a variety of marine animals). Seamount summits down to 1500 m depth may interact with the deep-scattering layer (Genin and Dower 2007). The community composition of some pelagic species tends to differ over seamounts, particularly that of nektonic and micronektonic organisms (Boehlert and Seki 1984). Seamounts are used as feeding grounds by many predators, including fish, seabirds, and marine mammals (Kaschner 2008; Santos et al. 2008; Thompson 2008). Studies have found higher diversity and abundance of demersal and benthopelagic fish species associated with seamounts (Parin and Prut'ko 1985; de Forges et al. 2000; Muhlia-Melo et al. 2003; Morato and Clark 2008). There is also accumulating evidence of high abundances of pelagic organisms (including tuna and sharks), as well as mammals and birds (Rowden et al. 2010). Although increased primary productivity and prey trapping are likely drivers, the oceanographic mechanisms of these aggregations are unclear and may still include less well-studied drivers, such as the locality of oceanic fronts.

Benthic fauna on seamounts are primarily distributed within depth-stratified bands which encircle the feature (Clark et al. 2010; as documented on Cobb Seamount, Du Preez et al. 2016). Although depth-distributed assemblages are not uncommon in other benthic ecosystems, bands may be more predominant on seamounts because of the particular assemblages present and because, in comparison to continental slopes, the steep flanks of a seamount produce narrow and distinct faunal zones. For example, with flanks averaging 12°, Cobb Seamount is seven times steeper than the adjacent North American continental slope within the same depth range (Du Preez et al. 2016).

In comparison to the surrounding bathyal waters and plains, seamounts are hotspots of biological diversity, with probable mechanisms including enhanced primary production and higher habitat heterogeneity (e.g., complex substrate including biogenic structures) (Rowden et al. 2010; Du Preez et al. 2016). The overall level of alpha biodiversity on seamounts is likely similar to that on the continental slope (O'Hara 2007; Lundsten et al. 2009; McClain et al. 2009; Howell et al. 2010), but the steep seamount flanks create narrowly banded communities, producing relatively high beta biodiversity (i.e., the high species turnover) (Du Preez et al. 2016).

The named Canadian seamounts are the result of volcanic activity along the Cascadia subduction zone (Desonie and Duncan 1990). Most coldwater coral and sponge species thrive on hard substrates, including bedrock and boulders. Because they usually originated as volcanoes, seamounts provide stable hard substratum on which corals, sponges, and other species settle and grow (Watling and Auster 2017). Surveys have confirmed hard substratum, as well as corals and sponges, are common on SG̱aan Ḵinghlas-Bowie and Cobb Seamounts (Canessa et al. 2003; Curtis et al. 2015). It is inferred that the same is true for the Offshore Pacific AOI seamounts, and that they represent unique hard substrata in the otherwise mud-dominated surrounding deep sea (Ban et al. 2016) and continental slope (Pearcy et al. 1982; Bornhold and Yorath 1984). The potential habitats for filter-feeders (such as corals and sponges) on seamounts would be enhanced by the rugose (rough) topography of the seamount and the increased bottom flow (Genin et al. 1986). On Cobb Seamount, rugosity was the second strongest environmental proxy of community-structuring processes (after depth, Du Preez et al. 2016).

The tectonic or volcanic settings of seamounts may also support hydrothermal vent activity, and the presence of hydrothermal vents is considered to be an important distinguishing feature among seamounts (Clark et al. 2010, 2011). That said, availability of data confirming active hydrothermal venting is a recognized issue (Clark et al. 2011). Within the Offshore Pacific AOI, Dellwood Seamount is unique for its associated hydrothermal vents, but these are presently considered inactive. Baby Bare, Grizzly Bare, and Split "Seamounts" have associated hydrothermal activities as well, but these underwater features are not designated as seamounts (i.e., <1000 m elevation) (Table 3). Since the shallowest of the Offshore Pacific AOI seamounts summit is well below the photic zone limits recorded for SGaan Kinghlas-Bowie and Cobb Seamount (Table 3) (e.g., 180 m depth, Du Preez et al. 2016), there is little chance of photosynthetic primary production on the seafloor (i.e., no sea grasses or algae). There would be, however, chemosynthetic primary production at seamount-associated hydrothermal vents. As a possible senescent vent site, Dellwood Seamount may hosts a relatively dense assemblage of background seamount-associated fauna (Levin et al. 2016). For details on hydrothermal vents, see the Hydrothermal vent section of this report.

Seamounts are sources of habitat heterogeneity within the deep sea (Rowden et al. 2010). Furthermore, seamounts differ among themselves in their physical and biological oceanographic characteristics (Table 3). Clark et al. (2011) identified five "biologically meaningful" physical variables to be considered in the scientific design of seamount MPA networks in data-limited situations, including the biogeographic province, export productivity, summit depth (<200, 200-800, >800 m depth), at-summit dissolved oxygen (above or below the hypoxia threshold of 1.0 O_2 ml/L), and proximity (distance between seamounts). The Offshore Pacific AOI seamounts are all within the same biogeographic province and estimates for the latter three factors are available from the World Atlas data (2013) and the BCMCA Project (2011), as well as Barr (1974) and Canessa et al. (2003). Using the classification splits of three factors (Clark et al. 2011; export productivity data not available), the 39 seamounts within the Offshore Pacific AOI fall within four different seamount classes (Table 3; Figure 6). The majority of seamounts fall within two classes (~25 % are "1" and 70 % are "2") as a result of their deep summits (>800 m depth), where the split between these two classes is oxygen concentration ($[O_2]$ > or < 1 ml/L, respectively). Hodgkins and Dellwood Seamounts make up another class ("3"; <800 m and $[O_2]$ < 1 ml/L), while Union Seamount alone makes up the last ("4"; <800 m and $[O_2]$ > 1 ml/L). The variability in at-summit oxygen concentration between seamounts is the result of the summit depth relative to the Northeast Pacific Oxygen Minimum Zone (OMZ; $[O_2]$ < 1 ml/L), which occurs naturally between approximately 1800 and 300-400 m depth (Whitney et al. 2007).

Of the 13 seamounts outside the Offshore Pacific AOI, only one falls within a novel seamount class, SGaan Kinghlas-Bowie Seamount, within the SK-B MPA ("5"; <200 m and $[O_2]$ > 1 ml/L) (Cobb Seamount in international waters is also a "5"). Therefore, not only does the combination of the SK-B MPA seamounts and the Offshore Pacific AOI seamounts capture the largest possible north-south geographic spread of Canadian Pacific seamounts, but it also represents the breadth of "biologically meaningful" physical seamount classes estimated to occur in Canadian waters.

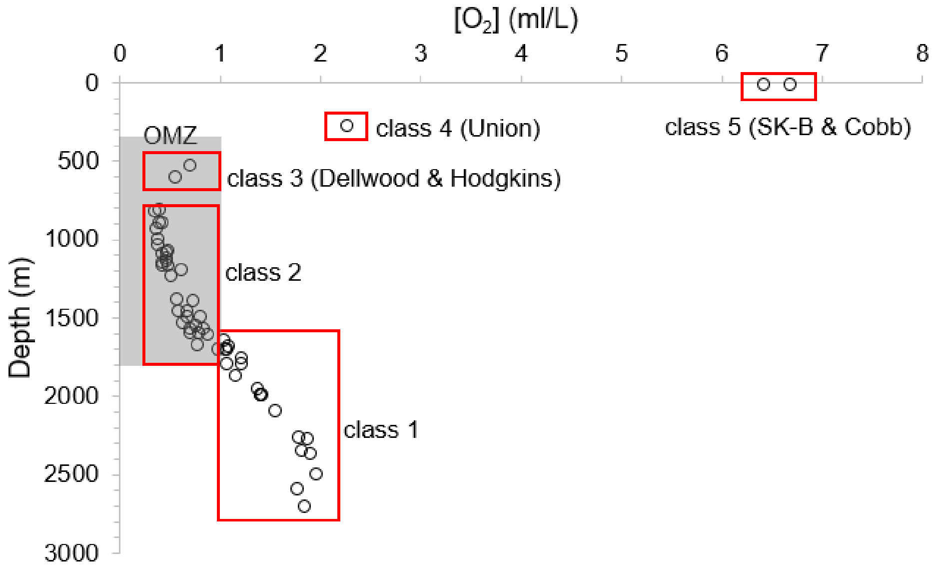


Figure 6. The five seamount classes as defined by depth and at-summit oxygen concentration (in the red boxes; based on Clark et al. 2011). Included are the 52 seamounts (circles) within Canada's Pacific Exclusive Economic Zone (EEZ), as well as Cobb Seamount in international waters. The 39 seamounts within the Offshore Pacific Offshore Pacific Area of Interest (AOI) fall within four different seamount classes, 1 to 4. Approximate 60% of summits fall within the Oxygen Minimum Zone (OMZ; shaded area; [O$_2$] < 1 ml/L).

Predominant, Unique, & Sensitive Habitat Features

Seamounts generally have a varied and complex topography of pinnacles, plateaus, terraced flanks, cones, and craters that create numerous habitat types (e.g., descriptions in Chaytor et al. 2007). The breadth of processes that shape a seamount's geomorphology (e.g., volcanic, erosion), along with the lack of high-resolution bathymetry and geological data for the Offshore Pacific AOI seamounts, limits what can be inferred about their physical habitat features, but inferences can be made about their biological habitat features. Within the Offshore Pacific AOI, the depth ranges of the eight shallowest seamounts partially overlap with the well-surveyed depths of SGaan Kinghlas-Bowie and Cobb Seamounts (<1250 m depth; Table 3). Although dependent on connectivity and currents, SGaan Kinghlas-Bowie and Cobb Seamounts are documented as sharing many of the same benthic fauna despite their differences in latitude; this suggests seamounts located between the two are likely to host similar faunal assemblages over similar depths. Surveys of Cobb Seamount have counted 269 taxa from 14 phyla and 27 orders (Budinger 1967; Birkeland 1971; Du Preez et al. 2015; Appendix B), while surveys of SGaan Kinghlas-Bowie Seamount have counted 341 taxa from 10 phyla and 30 orders (summarized in Gale et al. 2017; Appendix C). Limited groundfish surveys have also occurred on Dellwood and Union Seamounts (Appendices D and E), but these species lists are likely incomplete given the relatively low sampling effort. Common groups include crustacea, anthozoans, gastropods, bivalves, echinoids, ophiuroids, asteroids, polychaetes, hexactinellids, bony fishes, and elasmobranchs (Birkeland 1971; Morato and Pauly 2004; Du Preez et al. 2015). Although there is essentially a knowledge gap concerning the composition and abundance of benthic fauna on the AOI seamounts, patterns based on Cobb and SGaan Kinghlas-Bowie Seamounts can be used as a guide. The following are the key habitat features of the depth-stratified bands, and are either known foundation species (e.g., biogenic structures, such as coldwater corals and sponges), extremely abundant, and/or dominant predators.

Depending on the age of the seamount, subsidence history, and changes in sea-level, shallow summits may be encircled by patches of submarine ancient beaches and wave-cut terraces, potentially down to 900 m depth (Budinger 1967). Above 350 m depth, shallow, unconsolidated sediment would likely be typified by brittle stars, hermit crabs, and sea pens, while hard substrates would probably be colonized by stony corals, hydrocorals, and brachiopods. Shallow NE Pacific seamount summits often support dense assemblages of rockfishes, including high frequencies of large species (e.g., *Sebastes aleatianus*). The flanks below 350 m likely host patchy bands typified by anemones, soft corals and glass sponges, and black corals and sea pens. On Cobb Seamount, the lava cones and steep lava terrace edges host a soft coral-typified community while the well-developed, flat-topped lava terraces host an anemone-typified community (Chaytor et al. 2007; Du Preez et al. 2016). Mobile fauna within these deeper bands are likely to include thornyheads, sea cucumbers, squat lobsters, and crabs. 1250 m represents the current limit of our seamount surveys within or near to Canada's Pacific Offshore Bioregion. Some inferences are made concerning the deeper predominant species from Davidson Seamount (south of the Offshore Pacific AOI) and Alaskan Seamounts (north). Davidson was the first submarine feature to be named a “seamount” and is one of the most comprehensively studied seamounts in the world. Between its summit and base, at 1246 to 3656 m depth, Davidson transitions through faunal bands comprised of coldwater corals, sponges, and echinoderms (Lundsten et al. 2009; McClain et al. 2010). On Gulf of Alaska seamounts, soft corals and black corals are known to occur down to 4784 m (Greene et al. 1999). The extent and diversity of corals and sponges inhabiting AOI seamounts is unknown, but it is likely ecologically significant—in a review of deep corals, Stone and Shotwell (2007) documented the distribution of 141 coral taxa in Alaskan waters.

Seamounts were once thought to support highly endemic fauna that comprised unique communities distinct from other comparable environments (Rowden et al. 2010). However, in recent years, this paradigm in seamount ecology has been shown to be unsubstantiated (global trend summarized in Rowden et al. 2010). Instead, seamounts appear to offer suitable, alternative habitat for a subset of continental and deep sea species, especially near-slope seamounts (Howell et al. 2010), such as the Offshore Pacific AOI seamounts. Seamount isolation and hydrographic structure and dynamics are likely factors influencing the degree of endemism (e.g., proximity to other seamounts and continental slopes, large-scale currents and eddies) (Howell et al. 2010). In local examples, benthic surveys on Cobb Seamount and Davidson Seamount found the benthic assemblages were similar to those occurring on the adjacent continental slope and shelf (McClain et al. 2009; Du Preez et al. 2016). Although seamount assemblages are generally a subset of fauna found in other comparable habitats, it is possible that each location supports distinct and discrete biological communities, unique assemblages, and unusual patterns of distribution and abundance (Boehlert and Genin 1987; Tunnicliffe et al. 1998; McClain et al. 2009). For example, Cobb Seamount supports an unusually high abundance of rock scallop, which are otherwise scarce in the Pacific Ocean, and some species depth distributions on Cobb Seamount exceeded known limits based on continental slope observations (Curtis et al. 2015). Research from Cobb Seamount found that larval dispersal modes may strongly influence the seamount assemblage (e.g., the majority of invertebrate species there had direct or short larval dispersal modes, Parker and Tunnicliffe 1994).

Significant Species

Seamounts are known to provide important habitats for many species of conservation concern, as well as socially, culturally (e.g., for coastal First Nations, Weatherdon et al. 2016), and commercially valuable species (Ban et al. 2016). In particular, coldwater corals and sponges, rockfish species, Pacific Halibut, Sablefish, marine mammals, sea birds, and others are known to be associated with seamounts in Canada's Pacific waters (Ban et al. 2016). Surveys of the Kodiak-Bowie Seamount chain and Cobb Seamount have indicated that both deep water and coastal species can be found on the offshore seamounts (Canessa et al. 2003; Du Preez et al. 2015; Gale et al. 2017; Gauthier 2018a,b,c).

Coldwater corals and sponges

As biogenic structures, coldwater corals and sponges are ecologically significant species (ESS). These living structures provide a broad range of ecosystem functions including substrates for attachment, shelter, and feeding, and generally support higher levels of biodiversity and productivity than surrounding habitats (Buhl-Mortensen et al. 2010). As important fish habitat, they also have indirect commercial significance (e.g. important habitat for deep-sea northeast Pacific rockfish, Du Preez and Tunnicliffe 2011). Given the broad depth distribution and diversity of coldwater corals known and predicted to occur on northeast Pacific Ocean seamounts (see above sections), inferences are made that these habitat-forming species are likely to occur on all seamounts within Canadian waters (Canessa et al. 2003; Stone and Shotwell 2007; Lundsten et al. 2009; Du Preez et al. 2015). The majority of Offshore Pacific AOI seamounts are also within depths inhabited by bioherm- and reef-forming species of coldwater corals and sponges (Du Preez et al. 2015; Du Preez et al. 2016; Gauthier et al. 2018a), such as the stony coral *L. pertusa* and glass sponge *Ferrea* spp. These corals and sponges can create unusually large, complex, and fragile biogenic habitat features.

As part of the northeast Pacific Fisheries Commission (NPFC), Fisheries and Oceans Canada (DFO) recognizes seamounts and three orders of coldwater corals as Vulnerable Marine Ecosystem (VME) indicators (Alcyonacea, Antipatharia, and Scleractinia; Table 4). In response to the United Nations General Assembly (UNGA) Resolution 61/105 to protect VMEs from bottom-contact fishing gear, the presence of dense assemblages of coldwater corals on seamounts has significant management implications, as well as economic implications for offshore fisheries that target seamounts. The fragile, erect structures of coldwater corals, and their longevity and slow growth, make them particularly susceptible to physical damage and population depletion. Species within these three coral orders are also listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (Table 5: examples on SG̲aan K̲inghlas-Bowie and Cobb Seamounts). CITES Appendix II is used to manage the international trade of listed taxa to ensure sustainable use. The conservation status of these orders has not been assessed by the International Union for the Conservation of Nature (IUCN), nor by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

Table 4. Indicator species of vulnerable marine ecosystems (VMEs) observed on or collected from SGaan Kinghlas-Bowie and Cobb Seamounts (Du Preez et al. 2015, Gauthier et al. 2018c). Based on their observed depth ranges, these species may also occur on the AOI seamounts. Species are grouped according to the three orders of coral identified as VME indicators by the North Pacific Fisheries Commission (NPFC) in 2009.

SGaan Kinghlas-Bowie Seamount

Alcyonacea	Antipatharia	Scleractinia
Alcyonacea spp.	Antipatharia spp.	*Balanophyllia elegans*
Calcigorgia spiculifera	*Lillipathes* sp.	*Desmophyllum dianthus*
Anthomastus sp.		*Madrepora* sp.
Clavularia sp.		
Isidella sp.		
Lepidisis sp.		
Paragorgia sp.		
Paragorgia arborea		
Swiftia simplex		
Primnoa cf *pacifica*		
Primnoidea		

Cobb Seamount

Alcyonacea	Antipatharia	Scleractinia
Gersemia sp.	Antipatharia sp. (unidentified)	*Desmophyllum dianthus*
Heteropolypus ritteri	*Bathypathes* sp.	*Lophelia pertusa*
Isidella sp.	*Lillipathes* cf *lillei*	
Keratoisis sp.	*Parantipathes* sp.	
Lepidisis sp.	*Stichopathes* sp.	
Narella sp.		
Paragorgia sp.		
Plumarella superba		
Primnoa cf *pacifica*		
Swiftia simplex		

Rockfish

Rockfish and thornyheads (*Sebastes* and *Sebastolobus* spp.) are ecologically, culturally, and commercially significant species. Nearly every rockfish species listed within this section is a fish harvested for food, social, and ceremonial purposes by First Nations in coastal British Columbia (Weatherdon et al. 2016). Rockfish observation and landings on seamounts is common in the northeast Pacific (Appendices B, C, D, E). On Canadian fished seamounts, there have been indications that rockfish populations have been depleted due to overexploitation which may have altered ecosystem structure and function (e.g., Cobb Seamount, Curtis et al. 2015). The following information is from the Offshore Pacific Bioregion EBSA Research Document (Ban et al. 2016), updated with additional species observed on recent SK-B MPA survey (Gale et al. 2017).

Dellwood and Union Seamounts are known to provide suitable rockfish habitat. Individuals from the Rougheye/Blackspotted rockfish complex (*Sebastes aleutianus, S. melanostictus*), Redbanded Rockfish (*S. babcocki*), Silvergray Rockfish (*S. brevispinis*), and Yelloweye Rockfish (*S. ruberrimus*) were captured on Dellwood Seamount (Appendix D), while Aurora Rockfish (*S. aurora*), Canary Rockfish (*S. pinniger*), Chilipepper (*S. goodei*), Pacific Ocean Perch (*S. alutus*), Redbanded Rockfish, Rosethorn Rockfish (*S. helvomaculatus*), Rougheye/Blackspotted Rockfish complex, Shortraker Rockfish (*S. borealis*), Widow Rockfish (*S. entomelas*), Yelloweye Rockfish (*S. ruberrimus*) and Yellowmouth Rockfish (*S. reedi*) were reportedly captured on Union Seamount (Appendix E). At least 25 rockfish species have been observed at SGaan Kinghlas-Bowie Seamount (Appendix C), of which Rougheye Rockfish, Yelloweye Rockfish, and Widow Rockfish were the most abundant (Canessa et al. 2003; McDaniel et al. 2003; Yamanaka 2005). Of these species, Boccacio (*S. paucispinis*) is listed as Endangered by COSEWIC (and Critically Endangered by IUCN), three are listed as Threatened, and four are listed as Special Concern. SGaan Kinghlas-Bowie Seamount also likely supports a self-sustaining population of Widow Rockfish that may be prey for halibut, Sablefish, and other rockfish (Beamish and Neville 2003; Yamanaka 2005). In contrast, the observed age structure (Canessa et al. 2003) and lack of genetic differentiation from coastal populations (Siegle et al. 2013) of Yelloweye Rockfish at SGaan Kinghlas-Bowie Seamount suggests that they may be immigrating from elsewhere. In addition, the apparent lack of small pelagic fish and the presence of top predators suggests Rougheye Rockfish may be a keystone species at SGaan Kinghlas-Bowie Seamount; the loss of which was hypothesized to have the potential to lead to a decline or disappearance of Sablefish and Halibut (Beamish and Neville 2003). At least 21 rockfish species have been observed at Cobb Seamount. Due to conservation concerns, four species are listed by CITES, IUCN, or COSEWIC (Table 5). Shortspine Thornyhead (*Sebastolubus alascanus*), listed as Endangered by the IUCN (IUCN 2014), was captured annually in the Sablefish fishery on Cobb Seamount from 2007-2011 (Curtis et al. 2015). Longspine Thornyhead (*S. altevelis*), assessed as Special Concern by COSEWIC (COSEWIC 2015), are also captured by the fishery. Other species captured in the groundfish surveys for the Dellwood, and Union Seamounts are listed in (Appendices D & E).

Table 5. Taxa observed on SGaan Kinghlas-Bowie and Cobb Seamounts (summarized in Du Preez et al. 2015, Gauthier et al. 2017a,b,c) and included on CITES (Convention on International Trade of Endangered Species of Wild Fauna and Flora) Appendix II or the IUCN (International Union for the Conservation of Nature) Red List. Where relevant, the present status in Canada as assessed by COSEWIC (Committee on the Status of Wildlife in Canada) is also included (COSEWIC 2015). Based on their observed depth ranges, these species may also occur on the AOI seamounts.

Classification	**Scientific and Common Name**	Observed on SGaan Kinghlas-Bowie Seamount	**Observed on Cobb Seamount**	**CITES List**	**IUCN List**	**COSEWIC Assessment**
Class Actinopteri	*Mola mola* Sunfish	X	-	-	Vulnerable (A2cd)	-
Class Elasmobranchii	*Prionace glauca* Blue Shark	X	X	-	Near Threatened	Data Deficient
	Hexanchus griseus Bluntnose Sixgill Shark	-	X	-	Near Threatened	Special Concern
	Carcharodon carcharias Great White Shark	-	X	Appendix II	Vulnerable (A2cd+3cd)	Data Deficient
	Cetorhinus maximus Basking Shark	X	-	Appendix II	Vulnerable (A2cd+3cd)	Special Concern
	Apristurus brunneus Brown Catshark	X	-	-	Data Deficient	-
	Somniosus pacificus Pacific Sleeper Shark	X	-	-	Data Deficient	-
	Squalus acanthias Spiny Dogfish	X	-	-	Vulnerable (A2cd+3cd)	Special Concern
	Raja binoculata Big Skate	X	X		Near Threatened	Not at Risk
	Raja rhina Longnose Skate	X	-	-	Least Concern	Not at Risk
Class Holocephali	*Hydrolagus colliei* Spotted Ratfish	X	-	-	Least Concern	-
Class Actinopterygii	*Sebastes paucispinis* Bocaccio Rockfish	X	X	-	Critically Endangered (A1abd+2d)	Endangered
-	*Sebastes ruberrimus* Yelloweye Rockfish	X	X	-	-	Special Concern

Classification	**Scientific and Common Name**	Observed on SGaan Kinghlas-Bowie Seamount	**Observed on Cobb Seamount**	**CITES List**	**IUCN List**	**COSEWIC Assessment**
	Sebastolobus altivelis Longspine Thornyhead	X	X	-	-	Special Concern
	Sebastes crameri Darkblotched Rockfish	X	-	-	-	Special Concern
	Sebastes maliger Quillback Rockfish	X	-	-	-	Threatened
	Sebastes pinniger Canary Rockfish	X	-	-	-	Threatened
	Sebastes reedi Yellowmouth Rockfish	X	-	-	-	Threatened
	Sebastolobus alascanus Shortspine Thornyhead	X	X	-	Endangered (A2d)	-
	Sebastolobus altivelis Longspine Thornyhead	X	X	-	-	Special Concern
Class Anthozoa Order Antipatharia	Antipatharia sp.(unidentified)	X	X	Appendix II	-	-
Class Anthozoa Order Antipatharia	*Bathypathes* sp.	-	X	Appendix II	-	-
	Lillipathes cf *lillei*	X	X	Appendix II	-	-
	Parantipathes sp.	-	X	Appendix II	-	-
	Stichopathes sp.	-	X	Appendix II	-	-
Class Anthozoa Order Scleractinia	*Balanophyllia elegans*	X	-	Appendix II	-	-
	Desmophyllum dianthus	X	X	Appendix II	-	-
	Lophelia pertusa	-	X	Appendix II	-	-
Class Anthozoa Family Stylasteridae	*Stylaster verrillii* & *Stylaster campylecus*	X	X	Appendix II	-	-

Pacific Halibut

Pacific Halibut (*Hippoglossus stenolepis*), a culturally and commercially valuable species (Weatherdon et al. 2016), may be found at depths of up to 1200 m on various bottom types (Eschmeyer et al. 1983), and thus may be expected to occur on Hodgkins, Explorer, Springfield, Union, Dellwood, and possibly Tucker Seamounts (Ban et al. 2016).

Sablefish

Sablefish (*Anoploma fimbria*) is a demersal species endemic to the North Pacific Ocean targeted by coastal and offshore commercial and cultural fisheries (e.g., one of the largest First Nations' commercial fisheries, Weatherdon et al. 2016). From the Offshore Pacific Bioregion EBSA Research Document (Ban et al. 2016), updated with additional species observed on recent SK-B MPA survey (Gale et al. 2017):

Sablefish can be found from depths of 175 m to as much as 2700 m, and tend to favour muddy substrates (Eschmeyer et al. 1983). Thus, although all of the seamounts considered here are potential Sablefish habitat in terms of depth range, further benthic classification would be necessary to make a more definitive judgment. Catch data from groundfish surveys show that Sablefish are found at the SGaan Kinghlas-Bowie, Union, Heck, and Dellwood Seamounts (Lisa Lacko, DFO, Nanaimo, B.C., personal communication, 2015), and they were observed on Cobb Seamount at depths ranging from 903-927 m. While initially it was thought that Sablefish at SGaan Kinghlas-Bowie Seamount may be a distinct population from the coast, the weight of evidence suggests that there is continuous movement back and forth between the coast and the seamount (Kabata et al. 1988; Whitaker and McFarlane 1997; Kimura et al. 1998; Beamish and Neville 2003), and that Sablefish form a single biological population throughout their range in the northeast Pacific Ocean (DFO 2013). The age structure of Sablefish at SGaan Kinghlas-Bowie Seamount suggests that the population there is not self-sustaining, and it is unknown whether they spawn there (Canessa et al. 2003).

Marine Mammals and Birds

From the Offshore Pacific Bioregion EBSA report (Ban et al. 2016), updated with additional species observed on recent SK-B MPA survey (Gale et al. 2017):

Although quantitative data are lacking, the prey aggregation effect of seamounts is likely to attract both piscivorous and planktivorous marine mammals, but this association must be inferred on the basis of habitat suitability monitoring (Kaschner 2008). Seamount density also appears to be a better predictor of marine mammal habitat suitability than the presence of individual seamounts (Kaschner 2008). In the vicinity of SGaan Kinghlas-Bowie Seamount, observers have seen Steller Sea Lions (*Eumetopias jubatus*), Blue Whales (*Balaenoptera musculus*), Fin Whales (*Balaenoptera physalus*), Humpback Whales (*Megaptera novaeangliae*), Sperm Whales (*Physeter macrocephalus*), Orcas (*Orcinus orca*), Pacific White-sided Dolphin (*Lagenorhynchus obliquidens*), Northern Right Whale Dolphin (*Lissodelphis borealis*), Dall's Porpoises (*Phocoenoides dalli*), and possibly Striped Dolphins (*Stenella coeruleoabla*) (Canessa et al. 2003; Yamanaka 2005; Gale et al. 2017). Pacific White sided Dolphins, Dall's Porpoises, and Elephant Seals (*Mirounga angustirostris*) have also been seen in the vicinity of Cobb Seamount (Curtis et al. 2015: Ken Morgan, pers. Comm., Environment Canada, Institute for Ocean Sciences, Sidney BC).

Seamounts also act as aggregation points for seabirds (Thompson 2008). Bird species observed at or near SGaan Kinghlas-Bowie and Cobb Seamounts which may also be indicative of species likely to be found at shallower seamounts include: Black-footed Albatross (*Phoebastria nigripes*), Northern Fulmar (*Fulmarus glacialis*), Sooty Shearwater (*Puffinus griseus*), Buller's shearwater (*Puffinus bulleri*), Fork-tailed Storm Petrel (*Oceanodroma furcata*), Leach's Storm Petrel or Beal's Petrel (*Oceanodroma leucorhoa*), Murphy's Petrel (*Pterodroma ultima*), Sabine's Gull (*Xema sabini*), Western Gull (*Larus occidentalis*) or Herring Gull (*Larus argentatus smithsonianus*), Ancient Murrelet (*Synthliboramphus antiquus*), Red Phalarope (*Phalaropus fulicarius*), Long-tailed Jaeger (*Stercorarius longicaudus*), Parasitic Skua (*S. parasiticus*), South Polar Skua (*Catharacta maccormicki*), Horned Puffin (*Fratercula corniculata*), Tufted Puffin (*F. cirrhata*), Arctic tern (*Sterna paradisaea*), Cassin's Auklet (*Ptychoramphus aleuticus*), Rhinoceros Auklet (*Cerorhinca monocerata*), and unidentified Storm Petrels, Auklet, Gull, Shearwater, and Phalarope species (Thompson 2008; Curtis et al. 2015; Gale et al. 2017; Ken Morgan, pers. Comm, Environment Canada, Institute for Ocean Sciences, Sidney BC). Glaucous-winged Gull (*Larus glaucescens*) and Black-legged Kittiwake (*Rissa tridactyla*) were seen during winter (Gale et al. 2017).

Elsewhere, numerous Shearwater species have been found associated with seamounts in both Alaskan and British Columbian waters. The Canadian Wildlife Service has identified SG̲aan K̲inghlas-Bowie Seamount as an Area of Interest for Migratory Birds, and two SARA-listed species, the Black-footed Albatross (*Phoebastria nigripes*) and Ancient Murrelet (*Synthliboramphus antiquus*), which are known to occur in the SK-B MPA area (Yamanaka 2005). Black-footed Albatross, Sooty Shearwater, and Buller's Shearwater are also Red-Listed by the IUCN. However, the degree to which these seabird species aggregate around or depend on seamounts in Canadian Pacific waters is unknown.

Others

Seamounts may also be important habitat for sea turtles (Santos et al. 2008) and pelagic sharks (Litvinov 2008). Four Elasmobranchs documented at Cobb Seamount are listed by CITES, IUCN, or COSEWIC (Table 4).

Sensitivities, Resilience, and Recoverability

In response to growing concerns about the ecosystem-level impacts of bottom-contact fisheries, the United Nations General Assembly (UNGA), called upon States and Regional Fisheries Management Organizations (RFMOs) in Resolution 61/105 to protect vulnerable marine ecosystems (VMEs), including seamounts, hydrothermal vents, and corals. Following this resolution, the Food and Agriculture Organization (FAO) published its International Guidelines for the Management of Deepsea Fisheries in the High Seas (FAO 2008) in which it defined a VME as an ecosystem that is likely to show a substantial negative response to disturbance. Specifically, the FAO (2008) defined a serious adverse impact (SAI) as one that takes more than 5-20 years for recovery. To date, 16 coral species belonging to VME indicator taxa have been identified on SG̲aan K̲inghlas-Bowie Seamount (Gauthier et al. 2018a), and 17 species on Cobb Seamount (Du Preez et al. 2015). These species are vulnerable to SAIs by bottom-contact fishing gear (e.g., trawling and longlines). The remoteness (and in some cases, depth) of many seamounts in the Offshore Pacific AOI have meant that they are generally exposed to less human disturbance than inshore and coastal areas; however, seamounts are also specifically targeted by fisheries and may be the future targets of seabed mining operations. VMEs on seamounts may have already suffered some damage from trawling or other fishing activities that contact the seafloor. On Cobb Seamount, 95 incidences of abandoned gear or observable fishery impacts were documented (Curtis et al. 2015). Dellwood Seamount has known hydrothermal vent deposits, which are considered delicate, and could be easily damaged or destroyed by bottom-contact fishing gears (DFO 2016a) or other activities that contact the seafloor.

Other RFMOs have also adopted the use of VME indicators to inform decisions on spatial closures and development of encounter protocols (FAO 2008). In its implementation of UNGA Resolution 61/105, the Northwest Atlantic Fisheries Organization (NAFO) VME indicators included sponges, corals, sea pens, anemones, bryozoans, crinoids and sea squirts (NAFO 2014).

In general, seamount fauna may be vulnerable to human impact due to their longevity and slow growth, limited recruitment between seamounts, and localized distributions of many benthic seamount species (Samadi et al. 2007). Adjacent seamounts may be sensitive to impact on surrounding seamounts if those seamounts form "stepping stones" for source populations. Entrainment of prologues leading to low genetic diversity may reduce the resilience of individual populations. Fish species that aggregate at seamounts also tend to be K-selected species that are long-lived and slow growing, with low fecundity (Probert et al. 2007; Morato and Clark 2008).

Compared to inshore and coastal areas, seamounts are impacted by fewer human activities. However, they can be intensely fished at levels comparable to or exceeding nearshore areas. Relative to other surrounding deepwater environments, they could be more disturbed because of fishing and research activities. Shallow seamounts are also more likely to be disturbed by human activities than deeper seamounts because of their accessibility. Seamounts that are deeper and further offshore would tend to be less exposed to human impacts due to their inaccessibility. Offshore seamounts would have less cumulative impacts, potentially making them more resilient to individual impacts (e.g., less noise pollution, less land runoff). Although it is thought that offshore seamounts may provide some initial refugia (Tittensor et al. 2010), global climate change is a threat to all marine habitats, e.g., anoxia and ocean acidification. Ocean acidification is particularly harmful to aragonite and calcium carbonate shell- and skeleton-building organisms, such as corals and molluscs.

There is little quantified data on the recovery of most of the vulnerable habitat features and species of interest, with the exception of coldwater sponges and corals. Coldwater sponges and corals are known to be vulnerable, fragile, sensitive, and slow-growing, and thus will take considerable time to recover following disturbance. At the Darwin mounds, off the coast of Scotland, the *L. pertusa* reefs showed no signs of recovery 8 years after the fisheries closure (Huvenne et al. 2016). Even after fisheries closures, lost fishing gear can continue to impact the environment (as seen on Cobb Seamount, Curtis et al. 2015). Watling and Auster (2017) strongly suggest RFMC use the precautionary approach when managing seamounts, calling for all seamounts on the high seas to be managed as VMEs. The potential recovery of any non-VME indicator species likely increases with increasing proximity to other seamounts and the continental slope, especially concerning migrating populations.

Uncertainties and Knowledge Gaps

Baseline information is still lacking for the seamounts within the offshore Pacific AOI. This problem is not unique to these seamounts. At a global scale, scientists recognize the collection of baseline information is still a key area of research impeding the management and conservation of seamounts (Figure 7; Clark et al. 2012). Of the research priorities listed for seamounts over the next decade, Clark et al. (2012) specify the need for accurate information on the location and physical characteristics of seamounts, and complete documentation of seamount biota. Within the Offshore Pacific AOI, measures to address these knowledge gaps are likely to require confirming satellite-based predictions of raised topography (e.g., the Kitchingman and Lai 2004 data) with ship-based surveys (e.g., multibeam bathymetry), and biological surveys on unexplored seamounts (Clark et al. 2012) or unexplored regional seamount classes (Clark et al. 2011).

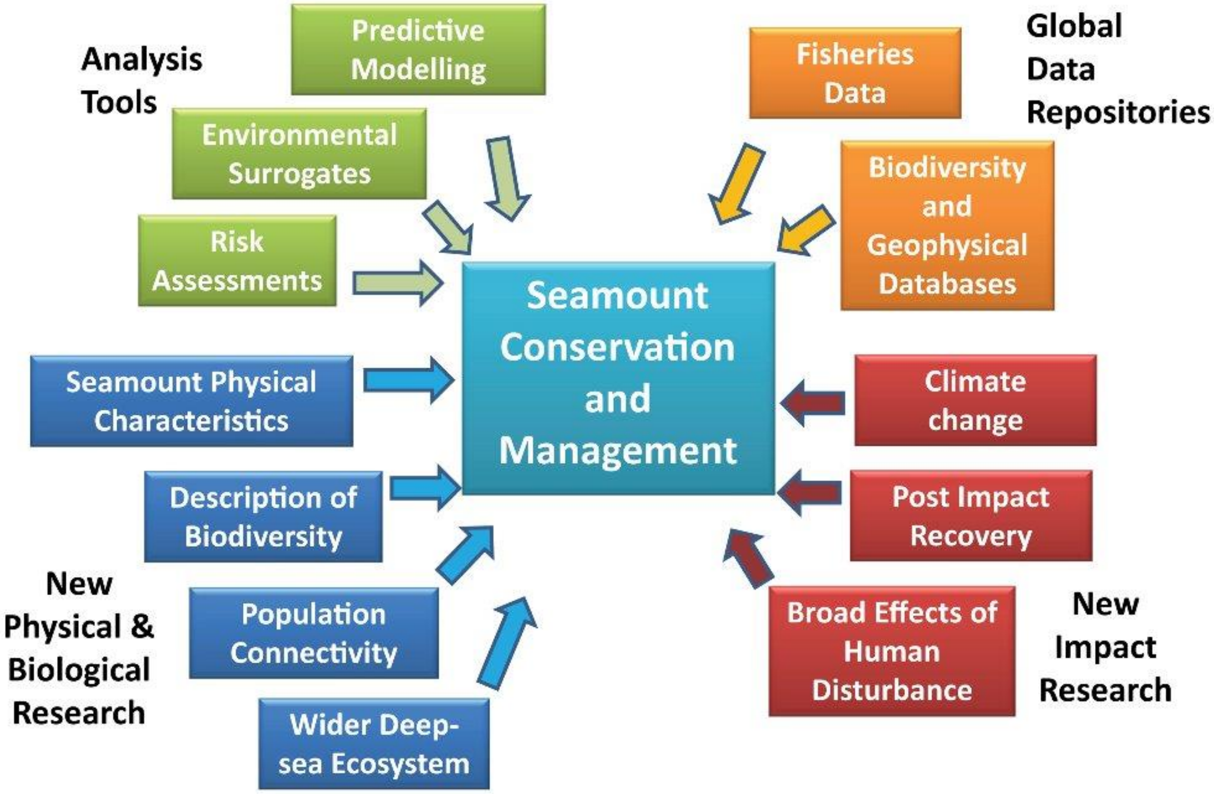


Figure 7. The key areas of research identified as requirements for improved management and conservation of seamounts over the next decade. Figure from Clark et al. (2012) (doi:10.1371/journal.pone.0029232.g001).

For the Offshore Pacific AOI, there is both a lack of detailed, high-resolution bathymetric data (Ban et al. 2016), and a lack of variety in the seamount classes that have been surveyed. The information summarized in the above section draws on physical and ecological surveys within, or adjacent to, the Canadian Pacific Bioregion. These surveys have focused on the two shallow seamounts, SGaan Kinghlas-Bowie and Cobb Seamounts, both of which are in the same seamount class (Table 3). Although these seamounts provide valuable information (e.g., extensive water depth range and latitudinal range), the extent to which the ecology and oceanography differ between the shallow and deep Canadian Pacific Bioregion seamounts is unknown.

To describe the biodiversity of a seamount's benthos, it is recommended that, when possible, seamount surveys include image-based techniques rather than relying on fisheries data or invasive sampling methods. In an example provided by Walting and Auster (2017), every camera tow of a seamount survey documented the occurrence of one or more VME indicator species whereas only 4 of 255 trawl tows (<2%) in the same region provided evidence of VMEs (Louisville Seamounts, New Zealand Ministry of Fisheries, 2008).

Clark et al. (2012) further suggest prioritizing research on population connectivity and the broader influence of seamounts. In the meantime, the application of analysis tools can help with management and conservation decisions for data-poor seamounts, such as predictive modeling and surrogacy (Clark et al. 2012) (e.g., community distribution mapping on Cobb Seamount, Du Preez et al. 2016). At the development stage of future surveys, planning to extrapolate limited transects for a larger area might include creating a nested survey design, where multiple modes of data collection are employed (e.g., a high-above-bottom, relatively fast overview of an area with nested near-bottom, slow, high-resolution surveying). Science effort will also be needed to improve our understanding and mitigation of human impacts (e.g., documenting lost fishing gear on Cobb Seamount, Curtis et al. 2016), and to effectively share information and data (Clark et al. 2012). The recommended measures to address uncertainties and knowledge gaps for seamounts are also applicable for other topographic features that exhibit similar biophysical properties, such as knolls, and possibly even hills.

Seamounts support productive and diverse ecosystems within the Offshore Pacific AOI. Named seamounts in the Offshore Pacific Bioregion have been identified as EBSAs (Ban et al. 2016; DFO 2016a). In addition to the named seamounts, there is compelling evidence of 27 more seamounts within the Offshore Pacific AOI. Hydroacoustic scans of four of these predicted seamounts, collected during the Pac2017-036 expedition, have provided corroborating evidence that these features have the geomorphological dimensions predicted (Table 3: UN 16, 18, 23, 27), and they are by definition “seamounts”. It is very likely that all 40 seamounts (named and unnamed) will have the geomorphological dimensions to be seamounts so all should be classified as EBSA’s Table 3).

Of the four knolls and hills previously assessed as seamounts, Baby Bare, Grizzly Bare, and Split, all have associated hydrothermal vent processes, and are ESBAs under the hydrothermal vent criteria (Ban et al. 2016; DFO 2016a). Although Seminole is a knoll, at 747 m elevation, it may exhibit similar biophysical properties to a seamount and could be considered functionally equivalent.

Bathyal plains

Overview

The vast majority of the ocean floor within the Offshore Pacific AOI falls within the bathyal zone (between 1000 and 4000 depth), with approximately 36% defined exclusively as bathyal plains (i.e., not hydrothermal vent or seamount EBSAs). Similarily, the majority of the global ocean floor falls within or beyond these depths (65.4%; Watling et al. 2013). The Offshore Pacific AOI does not into the abyssal or hadal zones within the Offshore Pacific AOI (>4000 m depth; Figure 8). There are two named plains within the Offshore Pacific AOI; the small central Juan de Fuca Plain and the larger Cascadia Plain, within the southern portion of the Offshore Pacific AOI (Figure 8). Two additional named plains, Tufts and Alaska Plains, are located to the west and north of the Offshore Pacific AOI respectively (Table 6, Figure 8; Ban et al. 2016). The Clarion-Clipperton Zone is a named abyssal plain with extensive scientific literature arising from an abyssal baseline project located in the central eastern Pacific Ocean (Abyssline 2017). Due to a lack of local data, research from other bathyal and abyssal plains will be referenced within this section.

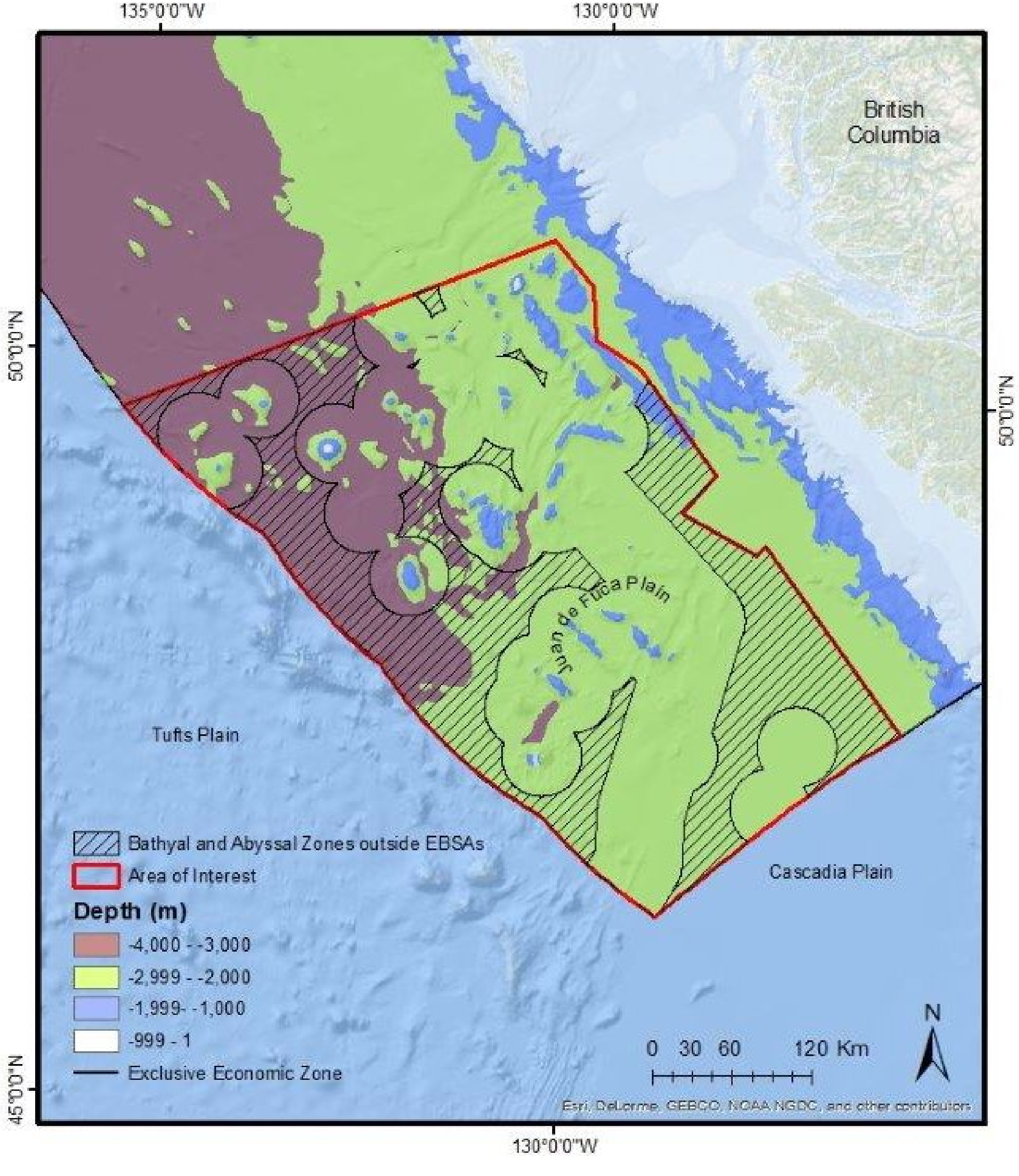


Figure 8. Bathymetry within the Offshore Pacific Area of Interest (AOI), excluding the hydrothermal vent and seamount ecological and biologically significant areas (EBSAs). Cascadia, Tufts and Juan de Fuca Plains are labelled. Alaska Plain is not labelled because it is not within the figure area. Bathymetry data from NOAA National Geophysical Data Center.

Table 6. Named bathyal and abyssal plains in the northeast Pacific Ocean. Modified from Ban et al. 2016. Area and depth of Juan de Fuca Plain calculated from Manson's (2009) shapefile and NOAA bathymetry data.

Name	Maximum Depth (m)	Area (km^2)
Juan de Fuca Plain	2610	5 925
Cascadia Plain	2800 to 3000	170 000
Tufts Plain	5300	36 260
Alaska Plain	~4500	?

Although the bathyal and abyssal plains are generally considered to be relatively flat, a number of topographical features, such as hills and knolls, channels and trenches, create structural complexity. Bathyal and abyssal habitats of the Offshore Pacific Bioregion were not classified as EBSAs by DFO 2016a, primarily because of insufficient information regarding special importance for life-history stages of species, importance for threatened, endangered or declining species and/or habitats, vulnerability, fragility, sensitivity, or slow recovery and importance for species aggregation. A reassessment of this area was recommended when more information becomes available (DFO 2016a, 2016b; Ban et al. 2016).

This section will describe the biophysical and ecological characteristics of the seafloor and bottom waters within the bathyal of the Offshore Pacific AOI (>1000 m depth; Figure 8). Due to the lack of local, offshore, biological data, references and information from research from outside of the Offshore Pacific AOI will be included.

Biophysical and Ecological Features

Physical and Biological Oceanographic Characteristics

Bathyal benthic environments have no local primary production; therefore, they are energy or food limited. The ecosystem depends on the euphotic zone located in the top 200 m of the ocean (Carey 1981; Smith et al. 2006, 2008), except for organic falls (discussed as specific habitats later in this section). Surface photosynthetic primary production in the ocean is limited by light, nutrients, and temperature and influenced by large scale ocean circulation (Field et al. 1998). The major Pacific Ocean bottom water is from Atlantic Ocean bottom water flowing northwards after passing through the southern Pacific Ocean (Thomson et al. 1995), and causes upwelling in the North Pacific (Knauss 1962). This upwelling results in relatively high particulate organic carbon (POC) flux of 8.57 g m^{-2} yr^{-1} within the North Pacific Boreal province, which includes the lower bathyal zone of the Offshore Pacific AOI (Watling et al. 2013). The North Pacific abyssal province characterises a separate depth range within the Offshore Pacific AOI, and has a moderate POC flux of 2-3 g m^{-2} yr^{-1} (Watling et al. 2013). Organic flux also increases in close proximity to the bottom from 500 m to near bottom (Wishner 1980).

As described earlier, the Offshore Pacific AOI overlays a tectonically complex area. The Juan de Fuca and Explorer oceanic plates are moving under the North American continental plate at the Cascadia subduction zone that runs parallel to North America. An abundance of abyssal hills have formed through these tectonic processes (Han et al. 2016). Analysis of the undersea features within the Canadian Pacific Exclusive Economic Zone highlighted the heterogeneity of the Pacific offshore region, particularly in the southern half (Manson 2009). Submarine features within the Offshore AOI include seamounts, hills, ridges, troughs, valleys, basins, gaps and plains (Manson 2009). Recent technology allows the combination of ship sounding data and satellite imagery for more accurate global bathymetric maps (Smith and Sandwell 1997). Flat plains are a relatively small portion of the Offshore Pacific AOI (Figure 8).

Predominant, Unique, and Sensitive Habitat Features

Bathyal Plains

Bathyal plains are characterized by medium sand to clay sediments, well-oxygenated waters and low structural complexity (Smith et al. 2006, 2008). The temperatures range from -0.5 to 3.0 °C, averaging 1.8 °C, and low current velocities (Smith et al. 2008; Watling et al. 2013). Hydrostatic pressure increases with depth and salinity is fairly constant with 34.6 to 34.8 psu in much of the deep sea. Many animals within this environment have adapted to the lack of light and pressure with smaller eyes, less colour and gelatinous bodies (Robison 2004). There may be distinguishing habitat categories due to depth and bottom type, but this is largely unknown within the Offshore Pacific AOI.

The Juan de Fuca plain is a small region surrounding hydrothermal vent fields in the central Offshore Pacific AOI (Figure 8; Manson 2009). The Cascadia Plain is in the southern portion of the Offshore Pacific AOI and expands to the south, off Washington and Oregon, USA. Outside of the Offshore Pacific AOI, the Tufts Plain lies to the west and the Alaskan Plain to the north of the Exclusive Economic Zone (Carey 1981; Percy et al. 1982; DFO 2016a). Proximity to coastal upwelling and the continental run off increases the particulate input to the Cascadia plain over the adjacent Tufts plain located outside of the Offshore Pacific AOI. This results in more species, particularly arthropods, compared to the surrounding plain (Carey 1981).

Bathyal Bathymetric Features

Approximately 50% of the global abyssal zone is abyssal hills, defined as having elevations of 300-1000 m (Stefanoudis et al. 2016). These variable undersea structures are also known as peaks, knolls, caldera, cones, plateaus, or pinnacles, depending on their shape and size (Manson 2009). This heterogeneous bathymetry provides habitats within the abyssal region that support distinct species assemblages compared with the flat plains. For example, higher species densities and distinct fauna of Foraminfera were documented on hills compared to plains in the Porcupine Abyssal Plain in North East Atlantic (Stefanoudis et al. 2016).

Similarly, the Cascadia Deep-Sea Channel had more species compared to the surrounding plain, and comparable species to the continental slope base (Carey 1981). The Cascadia Deep-Sea Channel collects terrestrial sedimentary materials, increasing the particulate organic matter, and periodically distributes the sediments along the channel. On the continental slope to the east of the Offshore Pacific AOI, submarine canyons function as habitat refugia for rockfish (Yoklavich et al. 2000), and increase benthic production by accumulating organic debris (Vetter 1994; Vetter and Dayton 1999). Submarine canyons increase heterogeneity of the physical environment and organic matter enhancing diversity (Levin and Sibuet 2012).

Whale Falls

The food limited environment of the deep sea has allowed for the evolution of a unique community dependent on organic remains or falls, primarily whale carcasses. Whales have lipid-rich bones that provide large amounts of nutrients when a carcass sinks into the abyss. These transient sites provide “habitat islands” containing diverse and unique species (Smith et al. 2015). Even smaller cetaceans support enriched biodiversity in the deep-sea (Amon et al.

2017). Similar to hydrothermal vents or cold seeps, the basis of these communities are microorganisms: bacteria that breakdown sulphur and methanogenic archaea that release chemicals into organic carbon (Smith et al. 2015).

Species richness is comparable between whale falls and cold seeps, and is higher than species richness at hydrothermal vent communities (Baco and Smith 2003). Deep-sea background fauna likely make up the majority of species present at whale falls, with limited specialist species present (Lundsten et al. 2010a, 2010b). There is a temporal component to the increased biological diversity at whale falls, with succession stages including the mobile scavenger stage, enrichment-opportunist stage, and sulphilic stage (Smith and Baco 2003; Lundsten et al. 2010a, 2010b; Smith et al. 2015). The duration and persistence of successional stages depends on the size and age of organic remains, water depth and environmental conditions (temperature and oxygen), and may persist for years to decades (Smith and Baco 2003; Lundsten et al. 2010a, 2010b).

A late successional stage whale fall has been described near Vancouver Island in Barkley canyon on the continental slope estimated at <10 years old (Lundsten et al. 2010a). Whale fall sites are hypothesized to be abundant at a regional level, but the actual density and persistence in not well documented.

Due to the dependence on chemoautotrophic organisms, vent and seep fauna are closely related to whale fall fauna (Smith et al. 2015). There are hypotheses describing the ecological and evolutionary relationships between these related chemosynthesis-based ecosystems including “stepping stones” between isolated vent and seep sites and biodiversity “hot spots” allowing species radiations (Smith et al. 2015). Recent descriptions of whale fall fauna from the deep southwest Atlantic Ocean highlighted a 12% genera overlap with the northeast Pacific Ocean showing limited global distributions of these specialist species (Sumida et al. 2016).

Wood Falls

Another source of localized enrichment in the deep sea is sunken wood. Woods falls have been found up to 2250 km from the nearest coast (Amon et al. 2017). At this distance from shore, the abundance of wood falls was estimated at 4.29 wood falls per km^2 (Amon et al. 2017). The Offshore Pacific AOI, located as close as 80 km and averaging 100-150 km from Vancouver Island, likely has more abundant wood falls. Bacterial mats, indicating a sulphilic stage similar to whale falls, have been observed (Amon et al. 2017). Although there may be a critical size of wood fall needed to create a persistent and intense reducing environment for chemosynthetic organisms to colonize (Cunha et al. 2013), the degree to which wood falls function as stepping stones between cold seep or hydrothermal vent communities is being researched (Smith and Baco 2003; Cunha et al. 2013, Levin et al. 2016, Amon et al. 2017). Nevertheless, wood fall habitats offer substrate, food, and shelter in the deep sea, increasing localized species biodiversity (Cunha et al. 2013).

Connectivity of Habitats

The connectivity of the bathyal and abyssal plains with adjacent seamounts and hydrothermal vents is directly relevant in establishment of marine protected areas (Hilário et al. 2015; Baco et al. 2016). Transition zones may exist where particulate organic carbon, elements, gametes, mobile scavengers, and predators disperse from adjacent communities (Levin et al. 2016). A synthesis of genetic connectivity of deep-sea fauna estimated dispersal distances of 0.24 km to 2028 km, and averaged 33.2 km within deep-sea fauna, depending on the taxonomy and life history factors (Baco et al. 2016). Mollusca and other invertebrates were less dispersive than fishes. In addition, benthic species from soft-substrate habitats were less dispersive (Baco et al. 2016). Significant knowledge gaps from deep-sea environments and species limit the accuracy of population connectivity estimates (Hilário et al. 2015). There is some evidence that ocean currents limit gamete dispersal within hydrothermal vent field valleys (Thomson et al. 2003, 2005, 2009). Nevertheless, connectivity with hydrothermal vent fields increases in species with longer pelagic larval development (Boschen et al. 2013) and with mobile organisms, such as the vent-associated spider crab, *Macoregonia marcochira* (Tunnicliffe and Jensen 1987).

In contrast to this connectivity between bathyal and abyssal plains and seamounts and hydrothermal vents, examples of genetic isolation exist. In the North Atlantic, there is a strong genetic divergence above and below 3000 m showing a lack of connectivity across a depth boundary (Etter and Bower 2015). As another example, distinct genetic populations of the nematode species, *Halomonhystera disjuncta*, were observed in shallow and deep sea environments of the Barents Sea (Van Campenhout et al. 2014). The underlying causes, currents, larval behavior or mortality, or selective processes limiting recruitment to within a particular depth range, is still under investigation (Etter and Bower 2015). It is unclear if any genetic isolation occurs within the Offshore Pacific AOI and more information is needed.

Significant Species

Meiofauna (41-500 µm benthic animals) and bacteria dominate the abyss (Smith et al. 2013) and diversity is high (Snelgrove and Smith 2002). Growth, reproduction, and colonization rates of the abyss are typically low due the food limitations (Smith et al. 2006), and body size decreases with depth in many organisms (Rex et al. 2006). Deep-sea communities also show less dominance compared to shallow-water communities (Snelgrove and Smith 2002). Abyssal bacteria and archaea are largely unknown, but these groups potentially have numerous species (Snelgrove and Smith 2002). Up to 90% of invertebrates sampled from the abyss are new to science. And there are estimates of greater than 100 macrofaunal invertebrate species in a square meter of sediment (Danovaro et al. 2014). The peak in macrofauna and megafauna biodiversity in North Atlantic occurs at 3000 m (Smith et al. 2006), although the depth-diversity relationship may not be as simple is other regions (Snelgrove and Smith 2002). Hard substrate populations have distinct species compared with soft sediment populations sampled (Smith et al. 2006).

The equatorial Pacific abyssal region is considered to have the highest biodiversity while the North Atlantic abyssal region is considered to have lowest biodiversity (Smith et al. 2008). The Offshore Pacific AOI likely sits within in the middle range of global biodiversity. Deep-sea cosmopolitan species exist within the abyss, but endemic species are also common (Smith et al. 2008). The number of infauna species in the Tufts Plain and Cascadia Plain is similar, although there is less biomass in the Tufts Plain, likely due to fewer organic particulates (Carey 1981). The most abundant infauna invertebrates in the Cascadia and Tufts Plains were: polychaete annelids, arthropods (isopods and amphipods), pelecypods (bivalves), solenogasters (worm-like, shell-less molluscs), echinoderms (holothurians and sea stars), nemerteans (ribbon worms), brachiopods (lophotrochozoan animals with upper and lower valves), sipunculans (unsegmented marine worms) and echiuroids (spoon worms) (Carey 1981). Bottom up control is indicated in abyssal ecosystems with increases in fish abundance correlated with, but lagging behind increases in invertebrate abundance (Bailey et al. 2006).

It is difficult to identify the ecologically, socially/culturally and/or commercially significant species within the bathyal plains due to a lack of information and a bias against invertebrates, compared to mammals, birds, and commercial fishes. The bathyal plains contain biodiversity that has intrinsic value. Select Arthropoda, Chordata, Cnidaria, and Mollusca species were found in midwater trawls and traps > 2500 m from 1969 to 1980 within DFO Area 127 within the Offshore Pacific AOI (Ban et al. 2016). A range of benthic species (fish, echinoderms, mollusc, polychaetes, nematodes, microorganisms) are presented below with an emphasis on the unique species found within the Offshore Pacific abyss or comparable environments.

Fish

There are 104 benthic fish species known to inhabit the Cascadia and Tufts Plains (Percy et al. 1982). Bait traps, trawl nets and acoustic methods have been used to determine fish biodiversity (Carey 1981; Percy et al. 1982; Smith et al. 1992; Drazen et al. 2008), and some more recent studies incorporate *in situ* video (Priede et al. 1990; Bailey et al. 2006; Gerringer et al. 2017; Linely et al. 2017). In Cascadia and Tufts Abyssal Plains, benthic fish species richness decreased with increasing depth from the upper continental slope adjacent to the Cascadia Abyssal Plains to within the Tufts Abyssal Plain (Percy et al. 1982). In addition to depth, benthic fish communities also depend on surface productivity and temperature (Linely et al. 2017). Bathyal and abyssal benthic fish assemblages are dominated by scavengers (Linely et al. 2017).

Distinct fish community assemblages exist for bathyal and abyssal zones of the west Pacific Ocean (Linely et al. 2017). Bathyal fish communities are more diverse with species overlap with seamount and pelagic species. Abyssal fish communities are dominated by macrourids (rattails), except in one location where ophidiids (cusk-eels) occupied the same niche (Linely et al. 2017). The macrourids, or grenadiers, make up a major component of deep-sea benthic fish (Smith et al. 2006). In Cascadia and Tufts Plains, the most common benthic fish are Macrouridae (grenadiers or rattails), Liparididae (snailfish), and Zoarcidae (eelpouts) (Percy et al. 1982).

Macrourids are long-lived, survive for long periods without food, have a benthopelagic lifestyle, and planktonic larvae (Bailey et al. 2006; Smith et al. 2006). Macrourids have low to moderate species diversity and broad distributions (Smith et al. 2006). The number of species is highest in the Pacific Ocean compared other oceans globally (Gaither et al. 2016). The most recognizable genus is the genus *Corphaenoides* or grenadiers. *Corphaenoides* species have a global distribution with 66 species living from depths of 110 m to 7000 m; withpeak species diversity at 1000 m (Gaither et al. 2016). Molecular studies indicate a well-supported grouping of the abyssal species that live below 4000 m (Gaither et al. 2016).

In the Cascadia and Tufts Plains, *Corphaenoides* species are the most abundant benthic fish with 44-100% of captures at different locations (Percy et al. 1982). Furthermore, the abundance of grenadiers increased in abundance in the northeast Pacific abyss from 1989 to 2004 (Bailey et al. 2006). *Corphaenoides yaquinae* was caught extensively with baited trap and hook and line survey sampling methods in North Pacific abyss and up to 1000 m above bottom (Smith et al. 1992). The abundance of *Corphaenoides* was estimated to be 14 to 37 individuals per hectare (Percy et al. 1982) or 7.5 to 32.4 individuals per hectare in northeast Pacific (Bailey et al. 2006). *Corphaenoides armatus* and *C. yaquinae* move with currents in a nomadic lifestyle to increase their chances of finding organic falls (Priede et al. 1990). Grenadiers likely spend majority of their time near the bottom and only leave for ~5% of the time (Priede et al. 1990)

Results from stomach contents and isotopes examination indicate a generalist feeding approach; stomach contents included amphipods, fish remains, decapods, polychaetes, squid and a holothurian (Drazen 2008; Gerringer et al. 2017). The abundance of grenadiers was correlated to holothurian abundance, although it is likely more complicated than a direct predator-prey relationship (Bailey et al. 2006). Isotopic analysis suggested that carrion is the most important prey resource allowing grenadiers to bypass dependence on particulate matter (Drazen et al. 2008).

Liparidae, or snailfish, are distributed from the intertidal to the hadal zones of the ocean (Stein 1980). Liparids are also common at abyssal-hadal boundary. Hadal liparids have been found at the hypothetical lower depth limit (~8200 m) for teleosts due to pressure constraints (Gerringer et al. 2017). Snailfish are predatory fish that suction feed on benthic organisms (Gerringer et al. 2017). Amphipods composed 35.2% to 37.4% of the stomach contents of hadal snailfish (Gerringer et al. 2017). Minor prey items included decapods and polychaetes (Gerringer et al. 2017). Abyssal liparids spawn asynchronously, whereas some bathyal and all shallow water species reproduce periodically or seasonally (Stein 1980).

It is hypothesized that lower energy ophidiids (cusk-eels) replace macrourids as dominant benthic fish in regions in areas further from large land masses with lower particulate organic carbon flux such as in the southwest Pacific Ocean (Linely et al. 2017). Cusk-eels have been observed feeding on amphipods in the Kermadec Trench (Linley 2017). Isotopic studies indicated that ophidiids derive more food from benthic sources compared to macrourids (Gerringer et al. 2017). Ophidiidae species are also present at organic falls (Amon et al. 2017).

Additional fish species have been observed at organic falls in the northeast Pacific including: hagfish (*Eptatretus deani* and *Mixine circifrons*), Sleeper sharks *(Somniosus pacificus*) and macrourids (Smith and Baco 2003). Zoarcidae have been observed on the Cascadia Plain (Ban et al. 2016), and at organic falls in Clarion Clipperton Zone (Amon et al. 2017).

Echinoderms

The most common abyssal megafauna in the abyss are echinoderms, including holothurians (sea cucumbers) and ophiuroids (brittle stars). These echinoderm species are also associated with organic falls in the Clarion-Clipperton Zone (Amon et al. 2017). Trawl and photographic data indicate an adaptive radiation of holothurians within the abyss (Smith et al. 2006). The broad distributions of holothurians are facilitated by lecithotrophic larvae, swimming and sailing (Smith et al. 2006). Holothurian biomass remains constant from continental slope to depths of up to 3400 to 3600 m in the abyss (Carey 1981); furthermore, holothurian species grow larger in the deep-sea (Mauchline 1972). Holothurians species diversity is highest at 3000 m on Cascadia and Tufts Plains (Percy et al. 1982). Population levels remain constant across the Cascadia Plain; however, holothurian populations decrease below 3400 to 3600 m in the more oligotrophic regions of the Tufts Plain (Carey 1981).

Modification to ocean currents by climate scale process such as El Niño /La Niña events may alter the phytoplankton, which impacts echinoderm populations in the Pacific abyssal zones. For example, in the North Atlantic, *Amperima rosea*, an abyssal holothurian, increased in abundance dramatically between 1994 and 1996. Changes at surface due to the North Atlantic Oscillation influenced the particulate organic carbon reaching the abyss. The higher proportion of cyanobacteria favoured this species of holothurian causing an increase in abundance (Smith et al. 2008).

Molluscs

In the North Atlantic, bivalves and gastropods from the bathyal plains may disperse into the abyss, but it is hypothesized that the abyssal populations live at densities too low for successful reproduction (Rex et al. 2005). This would mean little risk of species extinctions from abyssal activities (Rex et al. 2005; Smith et al. 2006). Nevertheless, the source sink hypothesis is unlikely to be appropriate in the Pacific abyss that is dominated by other invertebrate species (crustaceans, polychaetes, echinoderms and nematodes) (Smith et al. 2006).

Abyssal vesicomyid clams (*Vesicomya gigas* and *Calyptogena pacifica*), mussels (*Idasola washingtonia*) and other bivalves (*Lucinoma annulata*) use sulphur-oxidizing, chemosynthetic, endosymbiotic bacteria to colonize whale remains (Smith et al. 1989, 2015; Smith and Baco 2003). *I. washingtonia* dominates the sulphophilic stage at whale falls, along with bacterial mats (Smith and Baco 2003). In addition, the gastropod genus *Rubyspira* feeds on bacterial mats at whale falls (Smith et al. 2015).

Molluscs are the most represented group on wood falls since they remain attached in trawls (Smith and Baco 2003). They were also abundant on artificially implanted wood falls (Cunha et al. 2013). *Xyloredo* bivalves are wood fall specialists that digest wood using symbiotic chemosynthetic bacteria (Amon et al. 2017).

Arthropods

Isopods and amphipods have high species diversity in the abyss (Smith et al. 2006). Isopods are known as “pouch shrimp” and brood their young, limiting dispersal (Smith et al. 2006). There are more than 500 species described from the deep-sea and every sample contains species new to science; therefore, there is evidence of adaptive radiation in this group (Smith et al. 2006). Amphipods and isopods are second only to the polychaete annelids for numerical species abundance in the northwest Pacific (Carey 1981). Benthic copepods have high local diversity in the deep-sea, but poor taxonomic resolution (Smith et al. 2006). Eusphausiids (krill) and mysids grow larger at depths of 1000 to 6000 m. Copepods grow larger until 2000 m, then potential size decreases. Larger body sizes are likely due to increased longevity at latitudes above 40°N. Females outnumber males in bathypelagic environments and may have lower fecundity. Longer lived species with low fecundity means these abyssal species are more vulnerable to disturbances (Mauchline 1972).

Galatheid crabs or squat lobsters (*Munidopsis species*), are found at whale falls (Smith et al. 2015; Amon et al. 2017). True crabs, or Brachyura, are poorly represented in the abyss, likely due to food-limitation. The vent-associated spider crab (*Macoregonia marcochira*) may range hundreds of meters from the vent fields into the abyssal zone (Tunnicliffe and Jensen 1987). This movement may allow trophic transfer of chemoautotrophically derived production (Levin et al. 2016).

Polychaetes

Marine annelid worms are the most abundant and diverse macrofaunal group in the abyss, comprising up to 40% of every core sample (Lambshead and Boucher 2003), and polychaete annelids are also the most abundanct macro-infaunal species in the Cascadia and Tufts Plains(Carey 1981). Life history and dispersal patterns indicates species variablity with more than 90% of polychaete species sampled new to science (Smith et al. 2006). For example, the specialist genus, *Osedax*, is a polychaete genus that has endosymbiotic bacteria and lives on whale bones. Molecular genetics have confirmed that this genus falls within Siboglinidae, thus is related to vestimentiferan tube worms from hydrothermal vents and cold seeps (Rouse et al. 2004; Smith et al. 2015). In addition, hesionid annelids may represent a link between whale falls and methane hydrate sites (Pleijel et al. 2008; Smith et al. 2015). Whale falls also host a diversity of dorvilleid polychaetes, including *Ophryotrocha*, which may also colonize organic rich anthropogenic sites such as fish farms and pulp mill outfalls (Wiklund et al. 2009; Smith et al. 2015).

Nematodes

Commonly known as parasites in the terrestrial environment, free living marine nematodes are another diverse abyssal taxonomic group. Numerical abundance in the abyss is estimated at 10^5 individuals per square meter in abyssal habitats. Abyssal nematodes have patchy distributions within an area (Lambshead and Boucher 2003). Well-studied regions in Northwest Europe have 450 known nematode species, but cores still find 30-40% of species new to science (Lambshead and Boucher 2003). High diversity has also been found in the equatorial Pacific region (Snelgrove and Smith 2002). Increased nematodes species abundance is correlated with organic flux gradients from the Clarion-Clipperton Zone in the central Pacific (Lambshead and Boucher 2003).

Microorganisms

Microorganisms, including bacteria, archaea, and foraminifera, are important within the benthic bathyal and abyssal environments. Abyssal sediments, polymetallic nodules and deep waters in the Clarion-Clipperton Zone had distinct microbial assemblages (Shulse et al. 2016).

Bacterial biomass and abundance show no decline with depth (Rex et al. 2006). Furthermore, sulphate-reducing bacteria and methanogenic archaea dominate communities at whale remains (Smith et al. 2015). Mats of filamentous chemolithoautotrophic bacteria form, and evidence of archaeal methanogenesis is present, in whale fall sediments (Smith et al. 2015). O*ceanospirillales* bacteria live in the trophosome of *Osedax* polychaetes that hydrolyze collagen and cholesterol from whale bones (Smith et al. 2015).

Foraminifera, single-celled eukaryotes or protists that produce shells or tests, are common in the benthic, marine environments. Their abundance is correlated with particulate organic matter and dissolved oxygen (Stefanoudis et al. 2016). This taxon has more than 1000 deep-sea species (Smith et al. 2006), and have been used by paleontologists to characterize ancient oceans (Stefanoudis et al. 2016). Despite this taxonomic knowledge, approximately 60% of the benthic foraminifera were still new to science in the northeast Atlantic (Stefanoudis et al. 2016). Foraminifera have high local diversity, low global diversity, and ranges of more than 5000 m (Smith et al. 2006).

Sensitivities, Resilience, and Recoverability

Until recently, the bathyal and abyssal plains have been considered pristine areas due to inaccessibility (Ban et al. 2016). The bathyal and abyssal plains are now facing risks from indirect stresses such as climate change, as well as direct physical stresses such as oil spills, submarine cables and scientific activities (Ramirez-Llodra et al. 2011; Sweetman et al. 2017). Although less relevant in Canada, mining plumes and bottom trawling are potential physical threats (Sweetman et al. 2017), if policies or technologies change.

Globally, the oceans function to buffer rising carbon dioxide in our atmosphere (Sweetman et al. 2017). Climate change and rising carbon dioxide increases ocean stratification and reduces the primary production of the upper regions, reducing the particulate organic carbons available to the abyssal species. Climate change may have already reduced primary ocean productivity by 6% (Smith et al. 2008). Projections indicate that global greenhouse gases will increase abyssal temperatures and decrease oxygen levels, pH, and particulate organic matter in the bathyal and abyssal plains (Sweetman et al. 2017). The reduction in particulate organic carbon may significantly reduce benthic species diversity (Sweetman et al. 2017).

Seafloor massive sulphides, also known as SMS, have been evaluated globally for potential mining sites including sites within the Canadian Pacific EEZ. Middle Valley had the highest deposits of these Canadian sites (Hannington et al. 2010). Abyssal benthic fauna would be at risk of smothering by potentially toxic sediment plumes because increased sedimentation has been measured up to 10 km from mine sites (Boschen et al. 2013). Recent recommendations to reduce mining impacts on the deep sea include spatial management to protect organisms for recolonization in marine protected areas, and environmental impact assessments (Boschen et al. 2013; Wedding et al. 2013, 2015).

There is slow recovery in the deep sea benthic environment. Trawl-doors marks can remain visible on the deep sea floor at depths 300-1400 m for at least 10 years on the continental slope (De Leo et al. 2017), or up to 37 years in the Clarion Clipperton Fracture Zone (Van Reusel et al. 2016). Deep-sea organisms have slow population growth rates and long generation times which limit their ability to adapt to stresses (Sweetman et al. 2017).

Uncertainties and Knowledge Gaps

Uncertainties and knowledge gaps regarding biophysical attributes of the abyssal zone environment include: accurate species composition, and thorough understanding of species' lifecycles, reproduction, dispersal, and resilience. In fact, scientists predict a large proportion of abyssal benthic species (60-90%) are unknown to science (Smith et al. 2006, 2008; Stefanoudis et al. 2016). Many species have not been described by taxonomists, making it difficult to compare between regions (Smith et al. 2006, 2008). Invertebrates and microorganisms may be overlooked in favour of more familiar taxa.

There is currently an abyssal baseline project being conducted in the Clarion-Clipperton Zone to document community structure and biodiversity, influence of environmental parameters, and connectivity of species and populations before deep-sea mining occurs there (Abyssline 2017).This baseline environmental assessment may help to increase biological information on background abyssal species (Abyssline 2017).

Biological research, integrated with physical data, may help to characterize abyssal ecosystems and species distributions. Technological advances have made abyssal environmental data available for research within the Offshore Pacific AOI (Oceans Network Canada 2017). For example the NEPTUNE observatory, with a node on the Cascadia Plain at 2660 m (Figure 9), collects data for research in a number of fields such as , plate tectonic processes and earthquake dynamics; dynamic processes of seabed fluid fluxes and gas hydrates; regional ocean/climate dynamics and effects on marine biota; deep-sea ecosystem dynamics; and engineering and computational research" (Barnes et al. 2013). Much of this data is not analyzed or reviwed so is not useable at the present time. Collaborations between physical scientists and biologists will be imperative to increase our knowledge of the bathyal plains.

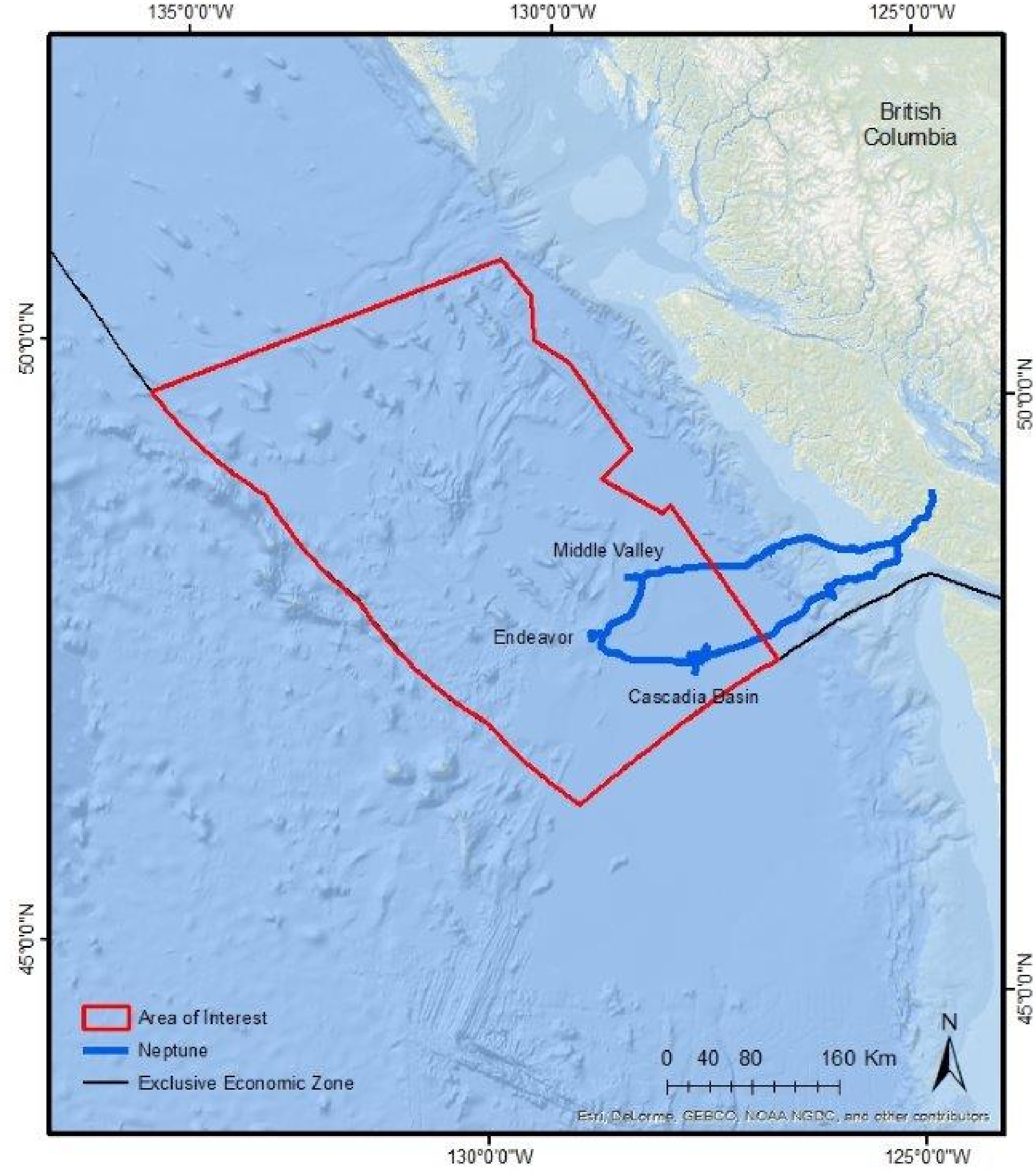


Figure 9. Location of North East Pacific Time-series Underwater Networked Experiments (NEPTUNE) within the Offshore Pacific Area of Interest. Neptune shapefile provided by Oceans Network Canada.

The population connectivity of abyssal species is largely unknown (Smith et al. 2006, 2015; Hilário et al. 2015; Baco et al. 2016), and hard to measure (Hilário et al. 2015; Levin et al. 2016). Global deep-sea monitoring programs are advocates for ecosystem-based management that include key physical and chemical variables (Danovaro et al. 2017).

The bathyal and abyssal plains have not been classified as EBSAs within the Pacific Offshore Bioregion, largely because four criteria had insufficient information (special importance for life history stages of species; importance for threatened, endangered or declining species and or habitats; vulnerability, fragility, sensitivity or slow recovery; and importance for species aggregation). Canada's *Oceans Act* promotes the wide application of the precautionary approach, whereby in the absence of scientific certainty, conservation measures can and should be taken when there is knowledge of a risk of serious or irreversible harm to the environment and/or resources using best available information" (DFO 2017). Re-evaluation of the status of the bathyal and abyssal plains was recommended as more information becomes available (DFO 2016a, 2016b); however, given the expense and technical difficulties of deep sea research, the collection of information is challenging. The potential importance of the bathyal and abyssal zones includes ecosystem services, geological complexity of the region, population connectivity between EBSAs, and biodiversity of the deep-sea species, specifically the benthic-associated fish, epibenthic fauna, and infauna.

Pelagic and surface waters

Overview

The pelagic waters within Canada's Offshore Pacific Bioregion extend from the edge of the shelf break westward to the EEZ boundary (Figure 1) and encompass the entire water column from the seafloor to the sea surface. The previous section described the ocean floor within the bathyal zone and this section will focus on the oceanography of the pelagic waters and surface waters within the AOI. The surface layer is broken into the euphotic (approx. 0-80 m) and disphoic zone (approx. 80-200 m), where the euphotic zone receives enough sunlight to permit photosynthesis. The aphotic zone generally lies below 200 m and is the area of the ocean that receives no sunlight and is perpetual darkness.

Important oceanographic features within the pelagic waters include oceanic fronts, current divergence areas, mesoscale eddies and seamount circulation patterns (Figure 10). Also upwelling and large-scale gyres are found these waters, within and adjacent to the AOI (Ban et al. 2016). Many of these oceanographic features create biological hotspots. Often these features are ephemeral and dynamic, making the drawing of static boundaries difficult.

The North Pacific Transition Zone (NPTZ) was recently classified as an Ecologically and Biologically Significant Area (EBSA) in Pacific International waters, and in the Canadian Pacific (CBD 2014; Ban et al. 2016; DFO 2016a). This 9,000 km wide, upper water column, oceanographic feature is bounded by thermohaline fronts; the Subarctic Frontal Zone in the north (40-43°N), and the Subtropical Frontal Zone in the south (28-34°N), thereby establishing a highly productive habitat that aggregates prey resources, attracts a number of pelagic predators, and serves as a migratory corridor (Ban et al. 2016 ; DFO 2016a). The North Pacific Transition Zone has been described in detail (Ban et al. 2016); this SR instead focusses on the Coastal Transition Zone (CTZ) and its importance to the AOI.

The CTZ is an area where two major currents (the Subarctic and North Pacific currents) bifurcate, causing an area of variable currents. This bifurcation area is farther north during summer months (likely on the northern edge of the AOI) and centered over the AOI during winter months (Figure 11). This zone is characterized by numerous eddies and meandering currents, embedded in an overall eastward drift, with spatial scales that range from tens to hundreds of kilometers . This zone is discussed in more detail below.

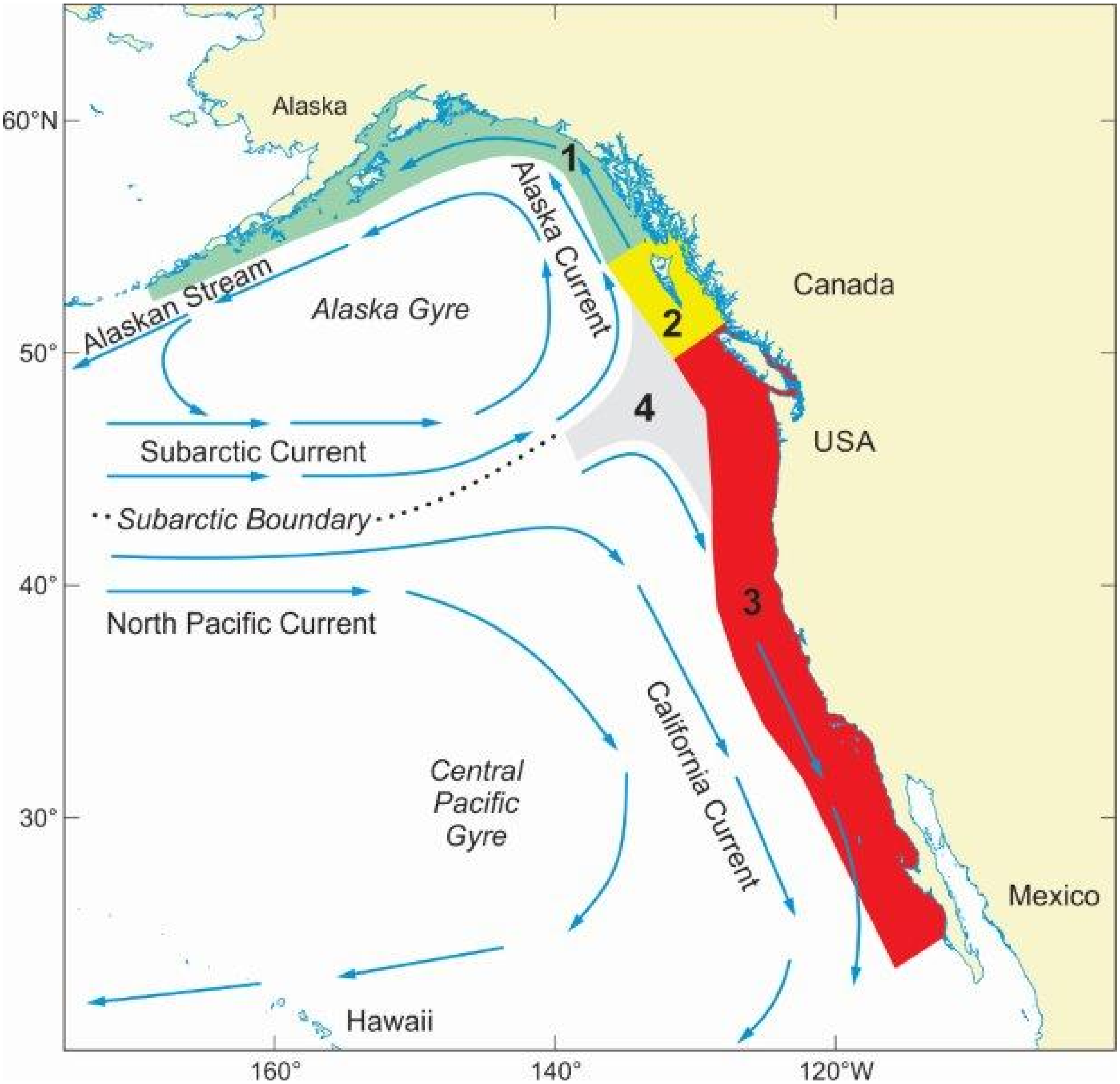
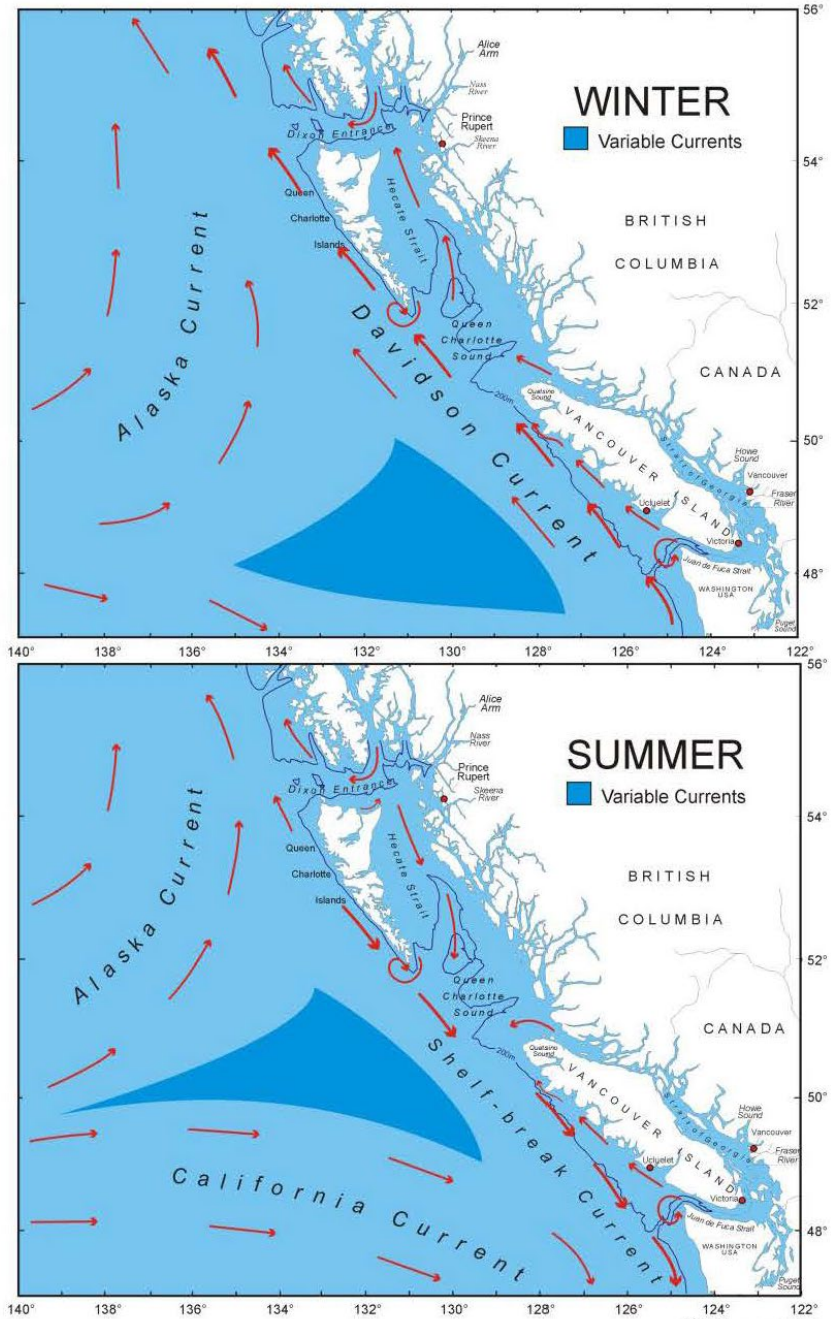


Figure 10. Ocean Circulation in the northeast Pacific. Area 1 Coastal Downwelling Zone, Area 2 Upwelling/Downwelling Transition Zone (transition in wind-generated currents), Area 3 Coastal Upwelling Zone, and Area 4 Bifurcation Zone.



R.E. Thomson, 2003

Figure 11. Ocean circulation with the variable current (Bifurcation Zone) shown as dots. (Modified from Thomson (1981).

A description of the pelagic and surface waters was conducted by Ban et al. (2016).

Biological and oceanographic information for the pelagic and surface waters within Canada's Offshore bioregion has come predominantly from fishing data and from ship oceanographic sampling of the Line P transect to Ocean Station Papa at 50°N and 145°W (Figure 12).

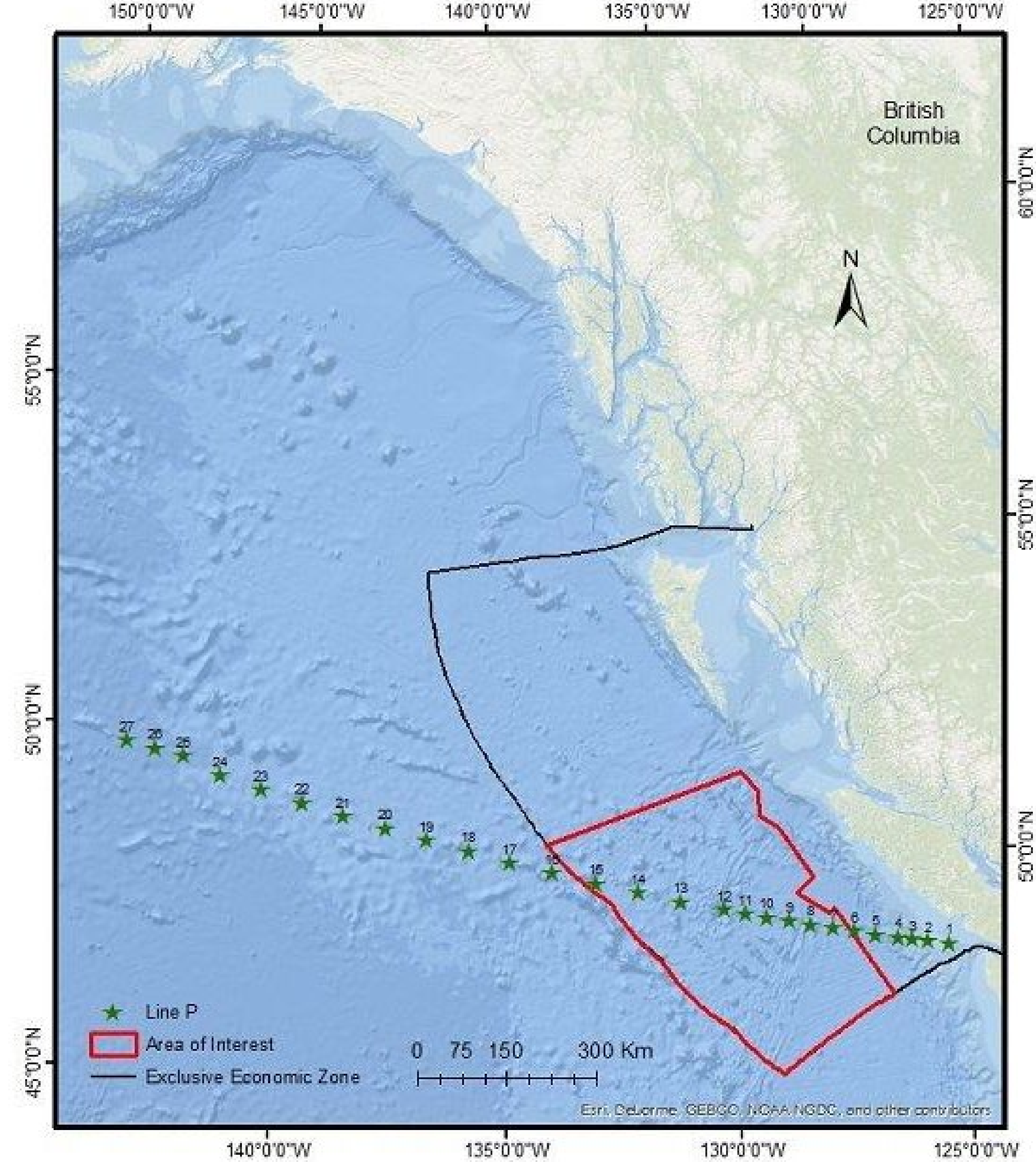


Figure 12. Line P sampling stations within the AOI.

Biophysical and Ecological Features

Physical and Biological Oceanographic Characteristics

In the offshore pelagic and surface waters, phytoplankton are the main primary producers, and are highly influenced by light, nutrients, and temperature. Ocean circulation patterns can also affect primary production by causing upwelling and downwelling regimes. Circulation patterns generated by the tides, winds, and buoyancy effects are influenced by the rotation of the earth (Coriolis effect), such that large-scale flow in the northern hemisphere, including tidal currents, are turned to the right. Wind-driven, northward flowing, currents are deflected towards the coast, creating a downwelling environment where low-nutrient surface waters build up against the coast, and denser, high-nutrient, intermediate depth waters are displaced to deeper depths. For this reason, wind-forced downwelling is often associated with reduced ocean productivity. Conversely, southward flowing, wind-driven, currents are deflected away from the coast, creating an upwelling environment, whereby intermediate depth ocean waters are brought close to the surface. In Figure 10, the area labelled as Zone 2 is an upwelling/downwelling transition zone associated with these wind driven currents. In upwelling areas, nutrients brought up from depth drive high rates of primary productivity (Thomson 1981; Ware and Thomson 2005; Jackson et al. 2015). Upwelling is a key ecosystem feature that can support primary production in areas that might otherwise be devoid of any biological productivity, since nutrients are normally in short supply in the open ocean. Phytoplankton blooms are common in upwelling areas when coupled with sufficient sunlight (McCabe et al. 2016). However, upwelling can also transport low-oxygen waters to the surface, which can have a negative effect on species in the vicinity. The Northeast Pacific Oxygen Minimum Zone (OMZ) is a naturally occurring layer of hypoxic water located throughout the Offshore Pacific AOI between approximately 1800 and 300-400 m depth ([O_2] < 1 ml/L; Whitney et al. 2007). Oxygen concentration influences aquatic species distributions.

Upwelling occurs on the continental slope and shelf, along the eastern edge of the AOI boundary. Coastal upwelling is typically associated with supporting productive fisheries (Ware and Thomson 2005; Figure 10). Upwelling also seems to be important in the formation of certain corals and sponges, including boot sponge communities. Additionally, upwelling regions have been identified as the preferred habitat of the short-tailed albatross and black-footed albatross. The black-footed albatross has been listed as a species of special concern by COSEWIC (COSEWIC 2015). These regions can create physical barriers that reduce flow between areas, which can limit the dispersal of species. Similarly, zooplankton communities within eddies have been observed to be distinct from the communities outside, which suggest that eddies are an important mechanism for dispersing plankton (Miller et al. 2005; Ban et al. 2016). Additionally, mesoscale eddies transport primary production from the more productive coastal areas into pelagic waters (Crawford et al. 2007).

Areas of high biological diversity in pelagic waters tend to be also associated with oceanographic fronts and boundary regions, to depths of around 1,000 m (Angel 1993). Oceanographic features such as fronts, eddies and gyres can create biological hotspots in the ocean (Palacios et al. 2006).

Features such as seamounts can also alter local circulation patterns in the pelagic, depending on their height, shape, and orientation (Ban et al. 2016). Effects of seamounts include upwelling, the production of eddies and Taylor columns (Roden 1991), the formation of trapped waves (Eriksen 1991), and the amplification of tidal currents (Noble and Mullineaux 1989). These effects are discussed further in the Seamount section.

Observations from the Line P oceanographic monitoring program are consistent with the oceanographic description of the AOI being at times in the Coastal Transition Zone and at times south or north of it. a review of the data from the August 2016 Line P survey has been used to complete this analysis. The temperature and salinity contours from August 2016 (Figure 13) generally show a flat profile which is indicative of weak CTZ currents; these contours, particularly temperature, are at times sloped down toward the coast, indicating gyre-like circulation. The zooplankton record along Line P also supports this picture with different crustacean assemblages associated with the CTZ, versus the Alaskan or California Current systems (e.g. Mackas and Galbraith 2002a). The smooth contours of temperature and salinity are at times punctuated by doming associated with passing eddies, which bring additional nutrients, productivity and different zooplankton species into the AOI (Whitney and Robert 2002; Mackas and Galbraith 2002b). Surface hydrographic properties, nutrients and primary productivity vary on seasonal (largely with the typical spring bloom cycle), and interannual scales, with the interannual variability closely linked to the Pacific Decadal Oscillation (PDO; Figure 14).

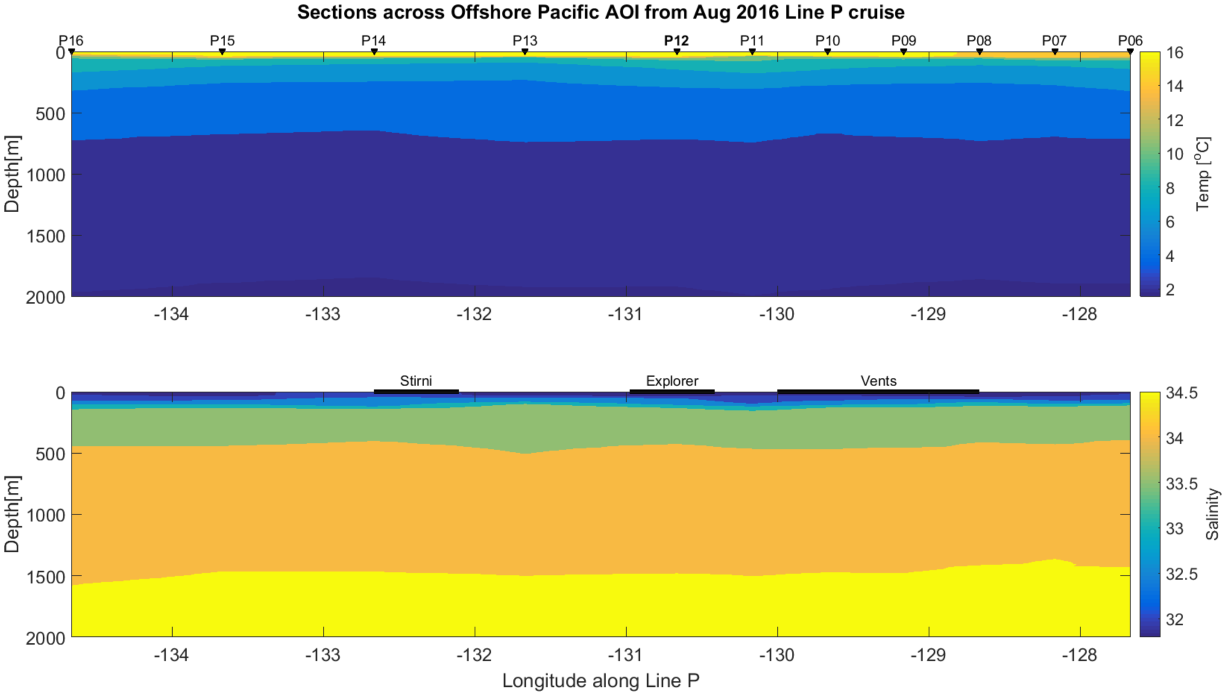


Figure 13. Continuous temperature and salinity measurements interpolated across 11 Line P sampling stations within the AOI from August 2016.

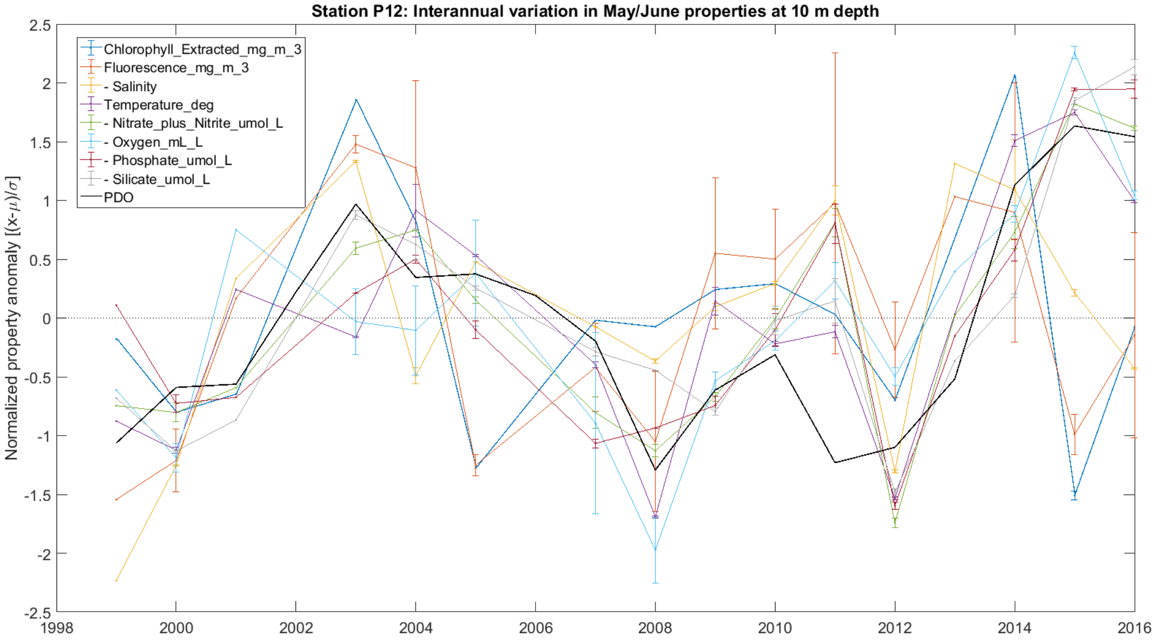


Figure 14. Measurements of 8 variables measured at station 12 on Line P from a depth of 10 m in May and June from 2000-2017. Data were normalized to facilitate comparisons of all variables over time and Pacific Decadal Oscillation data has been overlaid.

Predominant, Unique & Sensitive Habitat Features

Within the CTZ, the edges of two different water domains come together, creating a juxtaposition of two water masses, each containing different species. Because of this, the area contains high biological diversity. Further, it can have distinct endemic species of zooplankton and micronekton species (Pearcy 1991).

The location of the CTZ is affected by seasonal atmospheric conditions and its intersection near the coast of North America can vary from as far north as the Alaskan Panhandle in summer, to be centered over the AOI during winter months (Figure 10; Figure 11). It is created by the bifurcation of major, eastward flowing, cross-Pacific currents located between large-scale oceanic gyres. At the ocean basin scale, prevailing oceanic winds create these giant circular current systems, called gyres. The North Pacific Gyre comprises of the North Pacific Current, the Subarctic Current, the California Current, the North Equatorial Current, the Alaskan Stream, the Kuroshio and the Oyashio. The North Pacific Surface Current flows with prevailing westerly winds towards Vancouver Island. The Coastal Transition Zone is formed when these currents near the coast of North America and are divided into two branches by a change in the cyclonicity (direction of rotation) in the prevailing wind pattern. The northern branch curves northeastward into the Gulf of Alaska and becomes the Alaska Current, which flows northward off the BC coast, and the southern branch turns to the southeast as the California Current (Thomson 1981; Figure 10). The location of the bifurcation zone is significant because it affects where downwelling and upwelling processes occur.

To understand the currents within the AOI and the location of this bifurcation zone, an analysis was completed using Simple Ocean Data Assimilation (SODA) data, which includes a wide variety of observations including hydrographic profiles, ocean station data, moored temperature and salinity measurements, surface temperature and salinity observations from a variety of instruments (e.g., MBT, XBT, CTD), sea surface temperature (SST) from nighttime infrared observations from satellites, and satellite based sea level altimetry (SODA3 2017). The modeling methods used to analyze this dataset followed the methods of Carton and Giese (2008), but used the SODA3 dataset. Two time periods were modeled separately, 1980-1997 and 1998-2015, because it was determined that these time periods were different enough that much information would be lost in averaging all the data across all the years from 1980 to 2015. The bottom figure in each panel shows the differences between these time periods. Modeling of the ocean currents was completed at 5 m, 100 m, 300 m, 500 m 1000 m, 1500 m and 2000 m. The deeper depth zones were chosen to correspond with peaks of seamounts found within the AOI. Appendix F shows the results of this Ocean Current modeling.

Based on the model results, the bifurcation zone was evident to a depth of 300 m. In summer, the bifurcation zone is more to the north, above 50 degrees and in the winter the zone is more to the South, below 48 degrees. The California Undercurrent, which is a major ocean current that passes along the eastern edge of the AOI boundary (Thomson and Krassovski 2010, 2015), is evident until about 1000 m depth. The model did not indicate any dominate currents deeper than 1000 m, but some small scale eddies could be seen Appendix F.

Significant Species

Within the Pelagic and Surface water sections of Ban et al. 2016 a summary of some of the significant species found in the Offshore Pacific was found in the section call “Feature Description of the Evaluated Area. This summary focuses on Plankton, Other Invertebrates (such as squid), Fishes, Salmon, Marine Mammals, Seabirds and Top Predators (tuna, sharks, pinnipeds, cetaceans and marine turtles). In the section below, we expanded our knowledge of the plankton but not contributed any extra information to the other sections so please refer to Ban et al. (2016) for information on the other significant species.

Plankton

Plankton play a vital role in ocean ecosystems, and in the biosphere as a whole. Plankton, including phytoplankton and zooplankton, represent a key link between energy from the sun and fish, and forms the base of the oceanic food web. Copepods have been well-sampled in both the California Current and Gulf of Alaska ecosystems: Line P, Station P and La Perouse Oceanographic Monitoring Programs, by the Institute of Ocean Sciences; Newport Line developed by NOAA in Oregon; and the CalCOFi lines off California from Scripps (Batten and Walne 2011; Francis et al. 2012). The cold neritic, subarctic shelf and nearshore groups typical in northeastern Canada’s Pacific waters include species such as *Acartia hudsonica, A. longiremis, Calanus marshallae, Centropages abdominalis, Epilabidocera longipedata, Pseudocalanus mimus, Tortanus discaudatus,* (Hooff and Peterson 2006). Oceanic subarctic and boreal copepods include *Neocalanus cristatus*, *N. plumchrus, N. flemingeri, Metridia pacifica* and *Eucalanus bungii*; with *Scolecthricella minor, Microcalanus pygmaeus, Microcalanus puscillus* and *C. pacificus* found in both nearshore and oceanic areas. These coldwater species dominate during cool water periods.Appendix G list the calanoid copepod species collected on the west coast of Vancouver Island and generally where they have been found.

Euphausiids (krill) form an important part of the diet for many pelagic fishes, including hake and salmon, as well as sea birds and whales (Mackas et al. 1997). Adult euphausiids undergo diel migration and are usually only found in waters deeper than 125 m. *Euphausia pacifica* comprise the majority of the euphausiid community along the BC coast with a distribution stretching from the shelf break to offshore areas, and from California to Alaska. The second most common species, *Thysanoessa spinifera*, is found from nearshore areas to the shelf break after which it is replaced by the oceanic species, *T. inspinata*. Episodically abundant organisms (salps, doliolids, pteropods, medusa) can be found in large numbers along the shelf break, depending on the surface ocean and wind currents (Figure 16 & 16).

Some phytoplankton species produce harmful toxins that bioaccumulate in filter feeding organisms. These toxins are associated with Paralytic Shellfish Poisoning (PSP) and Amnesic Shellfish Poisoning (ASP). PSP is most often caused by blooms of a dinoflagellate species, *Alexandrium catenella*, while toxins causing ASP are produced by species in the genus *Pseudo-nitzschia* (Horner 2001; Taylor and Harrison 2002). *Pseudo-nitzschia* is usually most abundant over the outer continental shelf (on the eastern edge of the AOI) (Taylor and Harrison 2002). Recent years of anomalous warm sea surface temperature (2015-2016) resulting in algal blooms from California to Alaska have been implicated, directly or indirectly, with the death or impairment of forage fish, sea mammals and seabirds (Moira Galbraith, pers. comm. DFO, Institute of Ocean Sciences, Sidney, BC). Blooms of non-toxic algae can also have adverse effects on fish by depleting oxygen and causing gill damage (Mackas et al. 2007).

Seamounts are unique in combining the oceanic community, around the steep sides, and near shore or shelf zooplankton communities brought into the area via eddies and/or upwelling coastal currents. For more detail on Seamounts see the Seamount section.

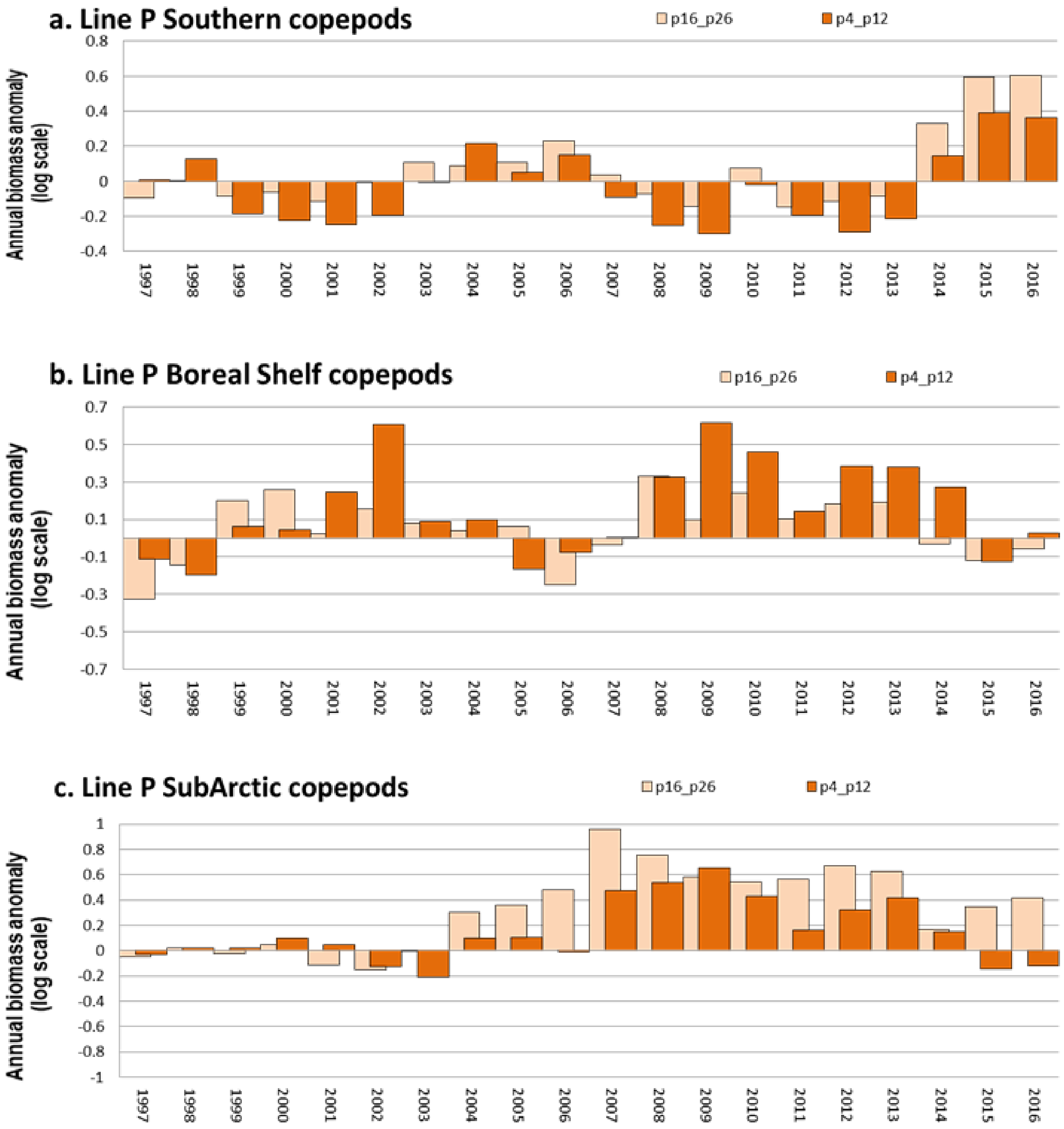


Figure 15. Calanoid copepod synopsis along Line P shown as log of annual biomass for inner (p4-p12) and outer (p16-26) sampling stations.

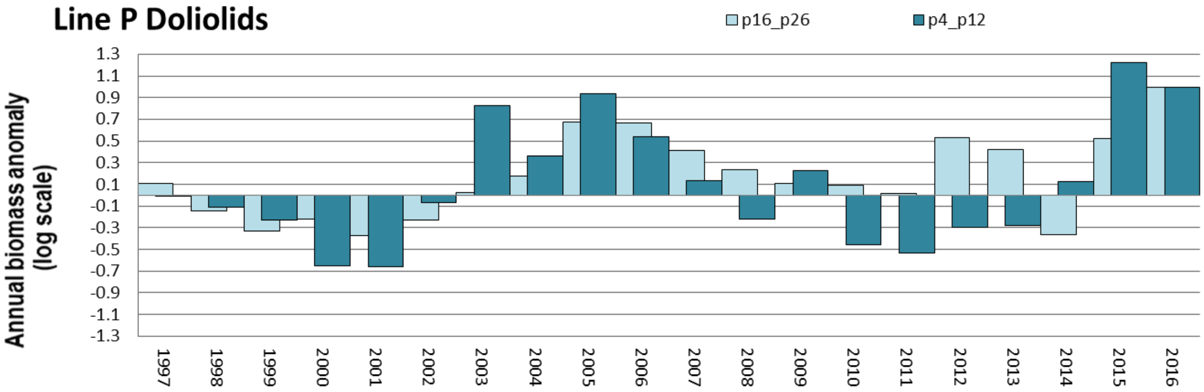


Figure 16. Synopsis of doliodid biomass anomaly (log transformed) along Line P for inner (p4-p12) and outer (p16-26) sampling stations.

Sensitivities, Resilience and Recoverability

Currently, offshore pelagic and surface waters experience fewer direct impacts from human activity than pelagic waters that are coastal and on-shelf because they are less accessible. However, increasing ship traffic and human use of the high seas and underlying seabed pose an emerging threat. Increased ship traffic can result in increased noise may affect marine mammal behavior and disrupt migration and feeding (Erbe 2002; Gordon et al. 2003; Weilgart 2007; Tyack 2008; Richardson et al. 2013). Undersea resource exploitation can result in metal contaminants from deep-sea mining that may affect plankton distribution (Omori et al. 1994). The effects of pollutants are most significant in areas of oceanic fronts and convergences such as the CTZ, where concentrations may be elevated by natural oceanographic processes. Marine platics and debris and oil spills also pose as potential threats.

The largest effects on pelagic waters are likely to be from two main stresses: climate change and fishing. Climate change may also interact with fishing and pollution to result in synergistic impacts, which are often unpredictable (Strömberg 1997; Winder and Schindler 2004; Schiedek et al. 2007).

Some of the predominant features of the pelagic waters, such as the CTZ and upwelling, may not be highly sensitive to small scale disturbances, but will be affected by large-scale changes in ocean winds and currents as a result of climate change. Approximately half of the Offshore Pacific Bioregion is in a global marine hotspot, which will warm faster than 90% of oceans (Okey et al. 2014), indicating that the region may be particularly vulnerable to oceanic warming. Ocean acidification may also impact the community composition of planktonic ecosystems, as well as levels of primary and secondary production in pelagic waters.

Fishing within the AOI

The widespread removal of predators from the oceans by fishing has resulted in changes in the structure and function of marine ecosystems; these changes include species replacements, changes in biomass at lower trophic levels, and reductions in nutrient cycling from the water column to the benthos (Pauly et al. 1998a; Verity et al. 2002; Myers and Worm 2003; Heithaus et al. 2008; Baum and Worm 2009). Small pelagic fish species are particularly vulnerable to overfishing due to their shoaling behavior, but are also quick to recover once fishing pressure is reduced (Beverton 1990; Hutchings 2000). Fishing activities that are conducted in the offshore AOI may pose a threat to many pelagic bird species, such as albatrosses (Cousins et al. 2000;

Bull 2007) and sea turtles (Kleiber 1998). These species are often killed incidentally as bycatch in some fisheries, and many are long-lived, thus likely slow to recover from population declines.

Seven different commercial licences have occurred within the AOI since 2006. These include Tuna Hook and Line, Groundfish Trawl, Halibut Hook and Line, Halibut and Sablefish Licence, Lingcod Hook and Line, Rockfish Outside Hook and Line and Sablefish by Trap. The Hook and Line Tuna fishery is the largest valued fishery within the AOI, focused mostly in pelagic waters. A total list of species caught by all the fisheries on and off the seamounts is provided in (Table 7).

The traditional territories of sixteen west coast Vancouver Island First Nations could overlap the eastern edge of the proposed AOI. The traditional territories of the Haida Nation overlap with the northern portion of the proposed AOI, as identified in the Haida Statement of Claim. Fishing effort by the First Nations in the AOI is largely unknown due to limited catch information.

There is no catch data available for recreational fisheries in the AOI at this time. Recreational fisheries are likely limited due to distance from shore and depths of catch. Recreational Tuna fishing is known to occur on the continental slope but it is unknown if it is occurring within the AOI.

Climate change

The ecology of the pelagic and surface waters is a function of local oceanographic conditions. These conditions are likely to be altered with climate change, resulting in significant ecosystem impacts. The most dramatic effects will likely be caused by increases in temperature, accompanied by increased stratification and reduced vertical mixing; followed by decreases in dissolved oxygen; and finally increases in carbon-dioxide, which causes ocean acidification (Gruber 2011). Decreased vertical mixing may reduce productivity through decreased delivery of limiting nutrients (Omori et al. 1994). Further still, these stressors may also act synergistically (e.g. Pörtner 2009; Haigh et al. 2015).

Regional sea surface temperature trends in the northeast Pacific Ocean have been variable over the period 1982-2006, with temperatures increasing 0.27°C in the Eastern Bering Sea, 0.37°C in the Gulf of Alaska, and decreasing 0.07°C in the California Current (Belkin 2009). Overall, sea surface temperatures are expected to increase by up to 1.5°C by 2050 (Overland and Wang 2007). Species distributions have already begun to shift polewards (or deeper) as waters warm, with phytoplankton, bony fish, and invertebrate zooplankton showing the greatest movement, ranging from 142 to 470 km per decade (Poloczanska et al. 2013). These shifts in zooplankton distribution may result in significant changes to community structure, which could cause profound changes to the base of pelagic food chains (Francis et al. 2012). Further, changes in species assemblages as warmer water species invade and expand (at a pace of 45.4 ± 6.33 km per decade), and potentially even local extinctions, have been predicted to occur in the North Pacific Ocean under the IPCC A2[1] emissions scenario (Cheung et al. 2015). Monitoring stations on the Pacific North Coast have observed a warming trend of 0.5-0.6°C over the past 80 years, with increases of up to 1°C in an El Niño year (Freeland 1990; Freeland et al. 1997; DFO 2012).

Another effect of climate change is an increase in hypoxic, or low oxygen regions, which will have negative impacts for many marine organisms (Hoffman et al. 2011; Vaquer-Sunyer and Duarte 2008). As larger regions become hypoxic or even anoxic, their species composition will

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[1] Intergovernmental Panel on Climate Change, emission scenario 2

alter and become limited to hypoxic-tolerant species such as squat lobster (e.g. Chu and Tunnicliffe 2015). A decrease in oxygen occurs in large part because oxygen solubility is strongly temperature dependent; warmer water holds less oxygen (Garcia and Gordon 1992). In addition, as the ocean becomes more stratified, less ventilation of the deep ocean will occur (Sarmiento et al. 1998; Keeling et al. 2010). Oxygen levels have been decreased in Pacific sub-surface Alaskan Gyre and continental shelf waters over the past few decades, with an expansion of the Northeast Pacific Oxygen Minimum Zone (OMZ), although there is large inter-decadal variability (Whitney et al. 2007; Crawford and Pena 2013; Crawford and Pena 2016).

Ocean acidification (OA) is caused by increases in ocean total dissolved carbon-dioxide as a consequence of human activities. It affects marine organisms in many ways, including behavioural changes and significant increases in juvenile mortality (Haigh et al. 2015). At a mechanistic level, the most compelling research to date shows that energetic costs increase when carbon dioxide levels increase. These higher costs apply to functions such as ion transport (due to decreased pH) and carbonate shell formation (due to decreased carbonate ion availability) (Haigh et al. 2015). Because many coral structures are composed of carbonates, some species have been a focus in OA research (e.g. Kleypas et al. 1999). However, none of the coral species found in the AOI region have been studied to date, although some local octocorals and stylasterids have been found to precipitate the more vulnerable crystal forms of carbonate (Haigh et al. 2015). In addition, pteropod concentrations are decreasing in the region (Mackas and Galbraith 2012) possibly due to OA (e.g. Bednarsek et al. 2014). Pteropods can be an important food source for pink salmon (Armstrong et al. 2005), although in general they make up a small portion of the local zooplankton biomass (Haigh et al. 2015). The Canadian Pacific coastal waters are naturally high in carbon dioxide, and thus relatively acidic (Feely et al. 2008; Ianson et al. 2009). Local pH is also highly variable, especially in the surface layer, due in large part to upwelling circulation on the outer coast (Haigh et al. 2015). Time series are not long enough to determine trends in pH on the coast (Ianson 2013), but increases in dissolved carbon-dioxide and decreases in pH are inevitable (Ianson et al. 2016).

Uncertainties and Knowledge Gaps

The pelagic and surface waters of the AOI is a very large and diverse area with many ecological and biological components. A compilation of data from all research activities that have occurred within the AOI is a gap that still needs be addressed. The data collected in this area are diverse and include hydrophone data on whale vocalization, zooplankton distribution data, fishing data, and modeling of currents using ARGO floats. A collation of all data sources within the AOI should be completed to serve as a baseline. These data will have to be considered when designing a monitoring plan for the pelagic waters within AOI.

Much of the survey work that has occurred within the AOI is mostly point in time sampling, and it is unclear how the results of many of these studies can be compared across the AOI and used in an overall analysis of present day conditions in the AOI. For example an excellent oceanographic data source from the AOI is the Line P research program, but there is uncertainty in whether this data can be extrapolated across the entire AOI.

Large Scale current modeling using the SODA3 dataset has been conducted within this area to determine the general direction of currents in different seasons, but actual physical measurements and ground truthing of these models is necessary to determine their accuracy.

Much of the information on fish species present in the AOI are from fisheries data, studies from seamounts not within the AOI, and from limited oceanographic sampling. Fishing data is very limited within the AOI because of the distance from market and low catches. Given this limited information, fisheries biomass estimates and species distribution information cannot be estimated.

Table 7. Presence (P) of species caught by each fishery in AOI either attributed or not attributed to a Seamount.

AOI Catch not attributed to Seamount

Fishery	Groundfish Trawl	Halibut	Halibut & Sablefish	Lingcod	Rockfish Outside	Sablefish
BOCACCIO	-	P	-	-	-	-
CHINA ROCKFISH	-	P	-	-	-	-
COPPER ROCKFISH	-	P	-	-	-	-
LINGCOD	-	P	-	P	P	-
LONGNOSE SKATE	-	P	-	-	-	-
PACIFIC COD	-	-	-	-	P	-
PACIFIC HAKE	P	-	-	-	-	-
PACIFIC HALIBUT	-	P	P	-	P	-
QUILLBACK ROCKFISH	-	P	-	-	-	-
REDBANDED ROCKFISH	-	P	P	-	P	-
ROUGHEYE ROCKFISH	-	P	P	-	P	P
SABLEFISH	-	P	P	-	P	P
SHORTRAKER ROCKFISH	-	-	P	-	-	-
SHORTSPINE THORNYHEAD	-	P	P	-	P	P
SILVERGRAY ROCKFISH	-	P	-	-	P	-
SPINY DOGFISH	-	P	-	-	-	-
WIDOW ROCKFISH	P	-	-	-	-	-
YELLOWEYE ROCKFISH	-	P	-	-	P	-
YELLOWMOUTH ROCKFISH	-	P	-	-	P	-
YELLOWTAIL ROCKFISH	P	-	-	-	-	-

AOI Catch attributed to Seamount

Fishery	Groundfish Trawl	Halibut	Halibut & Sablefish	Lingcod	Rockfish Outside	Sablefish
AURORA ROCKFISH	-	-	-	-	-	P
BIG SKATE	-	P	P	-	-	-
ENGLISH SOLE	P	-	-	-	-	-
LINGCOD	-	P	P	P	-	-
LONGNOSE SKATE	-	P	P	-	-	-
PACIFIC COD	-	-	P	-	-	-
PACIFIC HAKE	P	-	-	-	-	-
PACIFIC HALIBUT	-	P	P	-	P	P
PACIFIC OCEAN PERCH	P	-	-	-	-	-
QUILLBACK ROCKFISH	-	P	-	-	-	-
REDBANDED ROCKFISH	-	P	P	-	P	P
ROSETHORN ROCKFISH	-	-	-	-	-	P
ROUGHEYE ROCKFISH	-	P	P	-	P	P
SABLEFISH	-	P	P	-	P	P
SHORTRAKER ROCKFISH	-	-	P	-	P	P
SHORTSPINE THORNYHEAD	-	P	P	-	P	P
SILVERGRAY ROCKFISH	-	P	P	-	-	-
SKILFISH	-	-	-	-	-	P
SPINY DOGFISH	-	P	-	-	-	-
TIGER ROCKFISH	-	P	-	-	-	-
YELLOWEYE ROCKFISH	-	P	-	P	-	-
YELLOWMOUTH ROCKFISH	-	-	-	-	P	-

Summary of AOI ecosystem components

The known spatial locations of hydrothermal vents and seamounts with their associated EBSAs have been described, and are available in digital format (Figure 17). Seamounts and their EBSAs occupy approximately 50% of the Offshore Pacific AOI. The bathyal plains (not including EBSAs) are the next largest area making up approximately 36% of the Offshore Pacific AOI. Finally, hydrothermal vents and their associated EBSAs comprise approximately 28% of the

Offshore Pacific AOI. There is a 15% overlap between seamounts and hydrothermal vent EBSAs (Table 8).

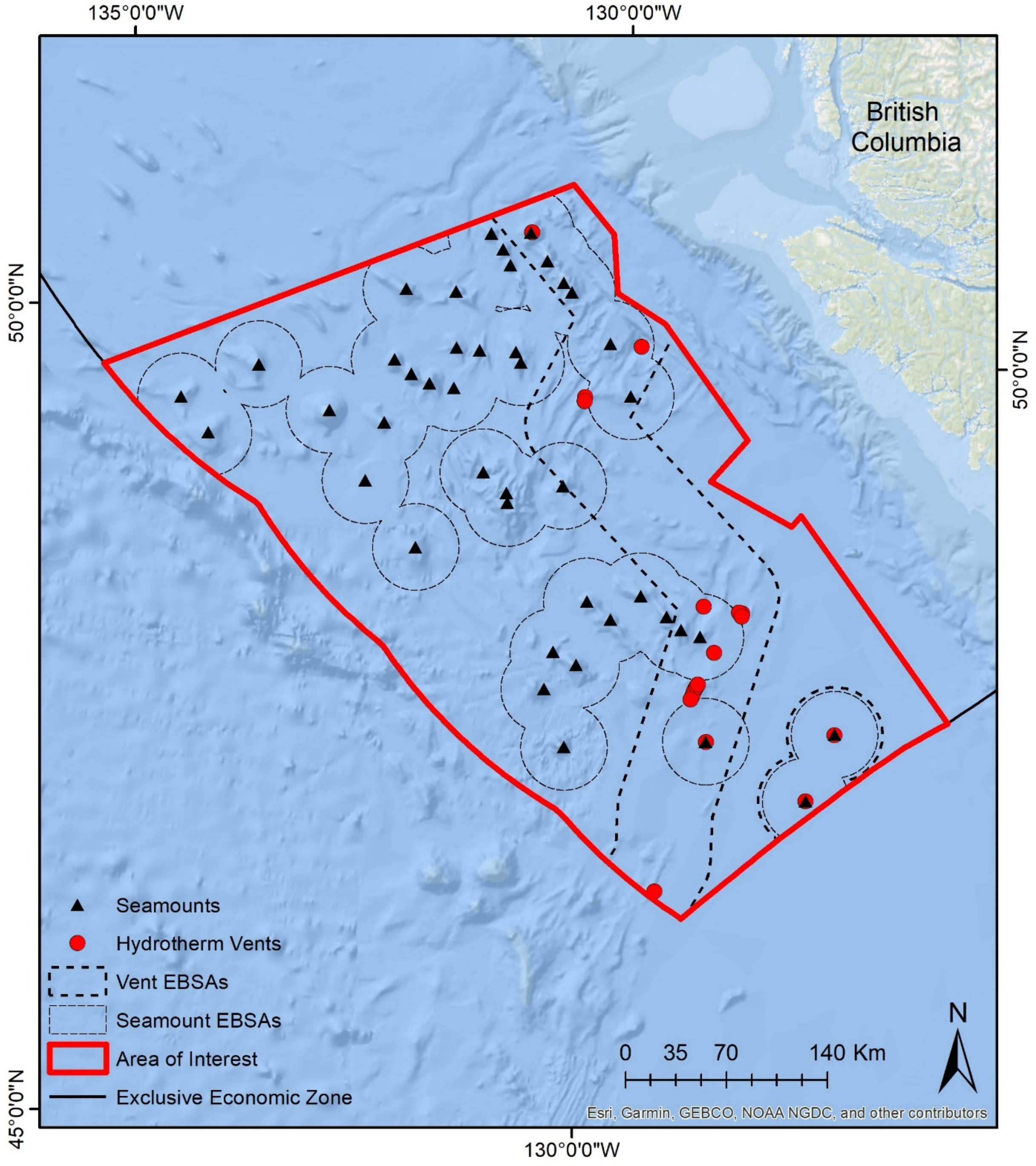

Figure 17. Ecosystem components, including seamounts, seamount EBSAs, hydrothermal vents, hydrothermal vent EBSAs, within the Offshore Pacific Area of Interest (AOI). EBSAs are clipped to within the AOI.

Table 8. Ecosystem components and their areas within the Offshore Pacific Area of Interest (AOI). Total percentage adds up to more than 100% because the hydrothermal vent and seamount EBSAs overlap in approximately 15 % of the AOI.

Features	Details	Approximate Area (km^2)	Percent of AOI
Hydrothermal Vents EBSAs	35 vent fields and associated EBSAs	39,655.76	28.4
Seamounts EBSAs	13 named seamounts, 26 unnamed seamounts, 4 named knolls/hills with their EBSAs	69,511.07	49.8
Bathyal Plains	Benthic regions excluding EBSAs	49,744.18	35.6
Pelagic and Surface Waters	Two-dimensional estimate from surface area of AOI	139,703.63	100%

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Sources of information

Abyssline. 2017. Abyssal Baseline Project. (Accessed January 21, 2019).

Ames, D.E., Franklin, J.M., and Hannington, M.D. 1993. Mineralogy and geochemistry of active and inactive chimneys and massive sulfide, Middle Valley, northern Juan de Fuca Ridge: an evolving hydrothermal system. Can. Mineral. **31**:997-1024.

Amon, D.J., Hilário, A., Arbizu, P.M., and Smith C.R. 2017. Observations of organic falls from the abyssal Clarion-Clipperton Zone in the tropical eastern Pacific Ocean. Mar. Biodiv. **47**(2): 311-321.

Angel, M.V. 1993. Biodiversity of the pelagic ocean. Conserv. Biol. **7**(4): 760-772.

Armstrong, J.L., Boldt, J.L., Cross, A.D., Moss, J.H., Davis, N.D., Myers, K.W., Walker, R.V., Beauchamp, D.A., and Haldorson, L.J. 2005. Distribution, size and interannual, seasonal and diel food habits of northern Gulf of Alaska juvenile pink salmon *Oncorhynchus gorbuscha*. Deep Sea Res II 52: 247–265.

Aron, W. 1962. The distribution of animals in the eastern North Pacific and its relationship to physical and chemical conditions. J. Fish. Res. Board Can. **19**(2): 271-314.

Austin, W.C. 1985. An annotated checklist of marine invertebrates in the cold temperate northeast Pacific. Khoyatan Marine Laboratory Cowichan Bay, British Columbia.

Bachraty, C., Legendre, P., and Desbruyeres, D. 2009. Biogeographic relationships among deep-sea hydrothermal vent faunas at global scale. Deep Sea Res. Pt I. **56**: 1371-1378.

Baco, A.R. and Smith, C.R. 2003. High species richness in deep-sea chemoautotrophic whale skeleton communities. Mar. Ecol. Progr. Ser. **260**: 109-114.

Baco, A.R., Etter, R.J., Ribeiro, P.A., Von Der Heyden, S., Beerli, P. and Kinlan, B.P. 2016. A synthesis of genetic connectivity in deep-sea fauna and implications for marine reserve design. Mol. Ecol. **25**: 3276-3298.

Bailey, D.M., Ruhl, H.A. and Smith, K.L., 2006. Long-term change in benthopelagic fish abundance in the abyssal northeast Pacific Ocean. Ecol. **87**(3): 549-555.

Ban, S., Curtis, J.M.R., St. Germain, C., Perry, R. I., and Therriault, T.W. 2016 Identification of Ecologically and Biologically Significant Areas (EBSAs) in Canada’s Offshore Pacific Bioregion. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/034. x + 152 p. (Accessed 20 March 2018)

Barnes, C.R., Best, M.M., Johnson, F.R., Pautet, L. and Pirenne, B., 2013. Challenges, benefits, and opportunities in installing and operating cabled ocean observatories: Perspectives from NEPTUNE Canada. IEEE J. Oceanic Eng. **38**(1):144-157.

Barr, S.M. 1974. Seamount chains formed near the crest of Juan de Fuca Ridge, northeast Pacific Ocean. Mar. Geol. **17**(2): 1-19.

Bates, A.E., Tunnicliffe, V., and Lee, R.W. 2005. Role of thermal conditions in habitat selection by hydrothermal vent gastropods. Mar. Ecol. Prog. Ser. **305**: 1-5.

Batten, S.D., and Walne, A.W. 2011. Variability in northwards extension of warm water copepods in the NE Pacific. J. Plankton Res. **33**(11): 1643-1653.

BCMCA Project Team. 2011. Marine Atlas of Pacific Canada: A Product of the British Columbia Marine Conservation Analysis. (Accessed March 20, 2018)

Beamish, R., and Neville, C. 2003. The importance of establishing Bowie Seamount as an experimental research area. Aquatic Protected Areas: What works best and how do we know: 652-663.

Beamish, R.J., Leask, K.D., Ivanov, O.A., Balanov, A.A., Orlov, A.M., and Sinclair, B. 1999. The ecology, distribution, and abundance of midwater fishes of the Subarctic Pacific gyres. Prog. Oceanogr. **43**(2–4): 399-442.

Beaulieu, S.E., 2015. InterRidge Global Database of Active Submarine Hydrothermal Vent Fields: prepared for InterRidge. World Wide Web Electronic Publication. Version 3.4 (Accessed March 20, 2018).

Bednarsek, N., Feely, R.A., Reum, J.C.P., Peterson, B., Menkel, J., Alin, S.R., and Hales, B. 2014. *Limacina helicina* shell dissolution as an indicator of declining habitat suitability owing to ocean acidification in the California Current Ecosystem. Proc. R. Soc. Lond., B., Biol. Sci. Vol 281.

Belkin, I.M. 2009. Rapid warming of large marine ecosystems. Prog. Oceanogr. **81**(1): 207-213.

Bennett, S.A., Statham, P.J., Green, D.R.H., Bris, N.L., McDermot, J.M., Prado, F. 2011. Dissolved and particulate organic carbon export from seafloor hydrothermal venting: East Pacific Rise, 9°50'N. *Deep Sea Res.* Pt I. **58**: 922-931.

Beverton, R. 1990. Small marine pelagic fish and the threat of fishing; are they endangered? J. Fish Biol. **37**(sA): 5-16.

Birkeland, C. 1971. Biological observations on Cobb Seamount. Northwest Sci. **45**(3): 193-199.

Block, B.A., Costa, D.P., Boehlert, G.W., and Kochevar, R.E. 2002. Revealing pelagic habitatuse: the tagging of Pacific pelagics program. Oceanol. Acta **25**(5): 255-266.

Block, B.A., Jonsen, I., Jorgensen, S., Winship, A., Shaffer, S.A., Bograd, S., Hazen, E., Foley, D., Breed, G., and Harrison, A. L. 2011. Tracking apex marine predator movements in a dynamic ocean. Nature **475**(7354): 86-90.

Bluhm, B., Coyle, K., Konar, B., and Highsmith, R. 2007. High gray whale relative abundances associated with an oceanographic front in the south-central Chukchi Sea. Deep Sea Res. Pt. II. **54**(23): 2919-2933.

Boehlert, G. W. and Genin, A. 1987. A Review of the Effects of Seamounts on Biological Processes. *In* Seamounts, Islands, and Atolls. Edited by B. H. Keating, P. Fryer, R. Batiza and G. W. Boehlert. American Geophysical Union, Washington, D. C. pp. 319-334.

Boehlert, G., and Seki, M. 1984. Enhanced micronekton abundance over mid-Pacific seamounts. T. Am. Geophys. Union **65**: 928.

Borstad, G., Crawford, W., Hipfner, M., Thomson, R., and Hyatt, K. 2011. Environmental control of the breeding success of rhinoceros auklets at Triangle Island, British Columbia. Mar. Ecol. Prog. Ser. **424**: 285-302, doi:10.3354/mps08950

Boschen, R.E., Rowden, A.A., Clark, M.R. and Gardner, J.P.A. 2013. Mining of deep-sea seafloor massive sulfides: A review of the deposits, their benthic communities, impacts from mining, regulatory frameworks and management strategies. Ocean Coastal. Manage. **84**: 54-67. (Accessed March 20, 2018)

Bost, C.A., Cotte, C., Bailleul, F., Cherel, Y., Charrissin, J.B., Guinet, C., Ainley, D.G., and Weimerskirch, H. 2009. The importance of oceanographic fronts to marine birds and mammals of the southern oceans. J. Mar. Systems. **bb**: 363-376.

Bouma, A.H. 1990. Naming of undersea features. Geo-Mar. Lett. **10**(3): 119-125.

Boustany, A.M., Matteson, R., Castleton, M., Farwell, C., and Block, B.A. 2010. Movements of pacific bluefin tuna (*Thunnus orientalis*) in the Eastern North Pacific revealed with archival tags. Prog. Oceanogr. **86**(1): 94-104.

Brodeur, R., McKinnell, S., Nagasawa, K., Pearcy, W., Radchenko, V., and Takagi, S. 1999. Epipelagic nekton of the North Pacific subarctic and transition zones. Prog. Oceanogr. **43**(2): 365-397.

Bucklin, A., and Wiebe, P. 1998. Low mitochondrial diversity and small effective population sizes of the copepods *Calanus finmarchicus* and *Nannocalanus minor*: possible impact of climatic variation during recent glaciation. J. Hered. **89**(5): 383-392.

Budinger, T.F. 1967. Cobb Seamount. Deep-Sea Res. **14**: 191-201.

Bull, L.S. 2007. Reducing seabird bycatch in longline, trawl and gillnet fisheries. Fish Fish. **8**(1): 31-56.

Burd, B.J., and Thomson, R.E. 1994. Hydrothermal venting at Endeavour Ridge: effect on zooplankton biomass throughout the water column. Deep Sea Res. Pt. I. **41**(9): 1407-1423.

Burd, B.J. and Thomson, R.E. 2000. Distribution and relative importance of jellyfish in a region of hydrothermal venting. Deep-Sea Res. I, **47:** 1703-1721.

Burd, B.J., Thomson, R.E. and Jamieson, G.S. 1992. Composition of a deep scattering layer overlying a mid-ocean ridge hydrothermal plume. Mar. Biol. **113**: 517-526.

Burd, B.J., Thomson, R.E., and Calvert, S.E. 2002. Isotopic composition of hydrothermal epiplume zooplankton: Evidence for mixed food resourses and implications for carbon recycling in the water column. Deep-Sea Res. **49:** 1877-1900.

Butterfield, D.A., McDuff, R.E., Mottl, M.J., Lilley, M.D., Lupton, J.E., and Massoth, G.J. 1994. Gradients in the composition of hydrothermal fluids from the Endeavour Segment vent field: phase separation and brine loss. J. Geophys. Res. **99**: 9561-9583.

Butterfield, D.A., Roe, K.K., Lilley, M.D., Huber, J.A., Baross, J.A., Embley, R.W., and Massoth, G.J. 2004. Mixing, reaction, and microbial activity in the sub-seafloor revealed by temporal and spatial variation in diffuse flow vents at Axial Volcano. *In* The subseafloor biosphere at mid-ocean ridges. Geophysical monograph ser. **144**: 269-289.

Calambokidis, J., Steiger, G., Ellifrit, D., Troutman, B., and Bowlby, C. 2006. Distribution and abundance of humpback whales *(Megaptera novaeangliae*) and other marine mammals off the northern Washington coast. Fish. Bull. **104**(1): 156-156.

Canessa, R., Conley, K., and Smiley, B. 2003. Bowie Seamount Pilot Marine Protected Area: an ecosystem overview. Can. Tech. Rep. Fish. Aquat. Sci. 2461: xi + 85p..

Carbotte, S.M., Detrick, R.S., Harding, A., Canales, J.P., Babcock, J., Kent, G., Van Ark, E., Nedimovic, M., and Diebold, J. 2006. Rift topography linked to magmatism at the intermediate spreading Juan de Fuca Ridge. Geol. Soc. Am. **34**(3): 209–212.

Carey, A.G., 1981. A comparison of benthic infaunal abundance on two abyssal plains in the northeast Pacific Ocean. Deep Sea Res. **28**(5): 467-479.

Carton, J.A. and Giese, B.S., 2008. A reanalysis of ocean climate using Simple Ocean Data Assimilation (SODA). Monthly Weather Review, **136**(8): 2999-3017.

CBD. 2008. Decision adopted by the conference of the parties to the convention on biological diversity at its ninth meeting. Decision IX/20, Sections 14 and 19. Convention on Biological Diversity. Ninth meeting. Bonn, May 19-30, 2008.

CBD. 2014. Report of the North Pacific regional workshop to facilitate the description of Ecologically or Biologically Significant Marine Areas. UNEP/CBD/RW/EBSA/NP/1/4. 187 pp.

Chaytor, J.D., Keller, R.A., Duncan, R.A. and Dziak, R.P. 2007. Seamount morphology in the Bowie and Cobb hot spot trails, Gulf of Alaska. Geochem. Geophy. Geosy. **8**(9).

Cheung, W.W., Brodeur, R.D., Okey, T.A., and Pauly, D. 2015. Projecting future changes in distributions of pelagic fish species of Northeast Pacific shelf seas. Prog. Oceanog. **130**: 19-31.

Chu, J.W. and Tunnicliffe, V., 2015. Oxygen limitations on marine animal distributions and the collapse of epibenthic community structure during shoaling hypoxia. Global change biology, **21**(8): 2989-3004.

Clark, M.R., Rowden, A.A., Schlacher, T., Williams, A., Consalvey, M., Stocks, K.I., Rogers, A.D., O'Hara, T.D., White, M., Shank, T.M., and Hall-Spencer, J.M. 2010. The ecology of seamounts: structure, function, and human impacts. Annu. Rev. Mar. Sci. **2**: 253-278.

Clark, M.R., Watling, L., Rowden, A.A., Guinotte, J.M., and Smith, C.R. 2011. A global seamount classification to aid the scientific design of marine protected area networks. Ocean Coast. Manage. **54**(1):19-36.

Clark, M.R., Schlacher, T.A., Rowden, A.A., Stocks, K.I., and Consalvey, M. 2012. Science priorities for seamounts: research links to conservation and management. PLoS One. **7**(1): p.e29232.

Corliss, J.B., Dymond, J., Gordon, L.I., Edmond, J.M., von Herzen, R.P., Ballard, R.D., Green, K., Williams, D., Bainbridge, A., Crane, K., and Andel, T.H. 1979. Submarine thermal springs on the Galapagos Rift. Science. **203**: 1073-1083.

COSEWIC. 2015. COSEWIC Wildlife Species Search. (Accessed January 21, 2019)

Cousins, K.L., Dalzell, P., and Gilman, E. 2000. Managing pelagic longline-albatross interactions in the North Pacific Ocean. Mar. Ornithol. **28**(2): 159-174.

Cowen, J.P., Bertram, M.A., Wakeham, S.G., Thomson, R.E., Lavelle, J.W., Baker, E.T. 2001. Ascending and descending particle flux from hydrothermal plumes at Endeavour Segment, Juan de Fuca Ridge. Deep Sea Res. Part I. **48**:1093-1120.

Crane, K., Aikman, F. III, Embley, R., Hammond, S., Malahoff, A., and Lupton, J. 1985. The Distribution of Geothermal Fields on the Juan de Fuca Ridge. J. Geophys. Res. **90**: 727-744.

Crawford, W.R., and Peña, M.A. 2013. Declining oxygen on the British Columbia continental shelf. Atmosphere- Ocean **51:** 88–103. doi:10.1080/07055900.2012.753028

Crawford, W.R., and Peña, M.A. 2016. Decadal trends in oxygen concentration in subsurface waters of the Northeast Pacific ocean. Atmosphere-Ocean. **54**: 171–192. doi:10.1080/07055900.2016.1158145

Crawford, W. R., Brickley, P. J., and Thomas, A. C. 2007. Mesoscale eddies dominate surface phytoplankton in northern Gulf of Alaska. Prog. in Oceanogr. **75**(2): 287-303.

Crocker, D.E., Simmons, S.E., Hassrick, J.L., Kuhn, C.E., Tremblay, Y., Costa, D.P., and Robinson, P.W. 2010. Climate-scale hydrographic features related to foraging success in a capital breeder, the northern elephant seal, *Mirounga angustirostris*. Endanger. Spec. Res. **10**:233-243.

Croom, M., Wolotira, R., and Henwood, W. 1995. Marine Region 15: Northeast Pacific. A global representative system of marine protected areas **4**: 55-106.

Cunha, M.R., Matos, F.L., Génio, L., Hilário, A., Moura, C.J., Ravara, A. and Rodrigues, C.F. 2013. Are organic falls bridging reduced environments in the deep sea? Results from colonization experiments in the Gulf of Cadiz. PLoS One. **8**(10): e76688.

Curtis, J.M., Du Preez, C., Davis, S.C., Pegg, J., Clarke, M.E., Fruh, E.L., Morgan, K., Gauthier, S., Gatien, G., and Carolsfield, W. 2015. 2012 Expedition to Cobb Seamount: Survey methods, data collections, and species observations. Can. Tech. Rep. Fish. Aquat. Sci. Report No. 3124: xii + 145.

de Angelis, M., Lilley, M., and Baross, J. 1993. Methane oxidation in deep-sea hydrothermal plumes of the Endeavour Segment of the Juan de Fuca Ridge. Deep Sea Res. Pt. I. **40**(6): 1169-1186.

de Forges, B.R., Koslow, J.A., and Poore, G. 2000. Diversity and endemism of the benthic seamount fauna in the southwest Pacific. Nature. **405**(6789): 944-947.

De Leo, F.C., Gauthier, M., Nephin, J., Mihaly, S. and Juniper, S. K. 2017.Bottom trawling and oxygen minimum zone influences on continental slope benthic community structure off Vancouver Island (NE Pacific). Deep-Sea Res. Part II **137**: 404-419.

Du Preez, C., and Tunnicliffe, V. 2011. Shortspine thornyhead and rockfish (Scorpaenidae) distribution in response to substratum, biogenic structures and trawling. Mar. Ecol. Prog. Ser. **425**: 217-231.

Du Preez, C., Curtis, J.M.R., Davies, S.C., Clarke, M.E., and Fruh, E.L. 2015. Cobb Seamount species inventory. Can. Tech. Rep. Fish. Aquat. Sci. **3122**: viii + 108 p.

Du Preez, C., Curtis, J.M., and Clarke, M.E. 2016. The structure and distribution of benthic communities on a shallow seamount (Cobb Seamount, northeast Pacific Ocean). PloS one **11**(10): p.e0165513.

Dalla Rosa, L., Ford, J.K., and Trites, A.W. 2012. Distribution and relative abundance of humpback whales in relation to environmental variables in coastal British Columbia and adjacent waters. Cont. Shelf Res. **36**: 89-104.

Danovaro, R., Snelgrove, P., and Tyler, P. 2014. Challenging the paradigms of deep-sea ecology. Trends in Ecol. Evol. 29(8): 465-475.

Danovaro, R., Aguzzi, J., Fanelli, E., Billett, D., Gjerde, K., Jamieson, A., Ramirez-Llodra, E., Smith, C.R., Snelgrove, P.V.R., Thomsen, L., and Van Dover, C.L. 2017. An ecosystem-based deep-ocean strategy. Science. **355**(6324): 452-454.

Delaney, J.R., Robigou, V., McDuff, R.E., and Tivey, M.K. 1992. Geology of a vigorous hydrothermal system on the Endeavour Segment, Juan de Fuca Ridge. J. Geophys. Res. **97**: 19,663-619,682.

Desbruyeres, D., Segonzac, M., and Bright, M. 2006. Handbook of deep-sea hydrothermal vent fauna. 2nd edn. Linz, Austria: *Biologiezentrum*.

Desonie, D.L., and Duncan, R.A. 1990. The Cobb-Eickelberg Seamount Chain: Hotspot volcanism with mid-ocean ridge basalt affinity. J. Geophys. Res. Sol. Ea. (1978–2012) **95**(B8): 12697-12711.

DFO. 1999. Neon flying squid. DFO Science Stock Status Report C6-12 (1999). (Accessed January 21, 2019)

DFO. 2004. Identification of Ecologically and Biologically Significant Areas. DFO Can. Sci. Advis. Sec. Ecosystem Status Rep. 2004/006. (Accessed January 21, 2019)

DFO. 2006. Identification of Ecologically Significant Species and Community Properties. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2006/041. (Accessed January 21, 2019)

DFO. 2010. Occurrence, susceptibility to fishing, and ecological function of corals, sponges, and hydrothermal vents in Canadian waters. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2010/041. (Accessed January 21, 2019)

DFO. 2013. A review of sablefish population structure in the northeast Pacific Ocean and implications for Canadian seamount fisheries. DFO Can. Sci. Advis. Sec. Sci. Resp. 2013/017. (Accessed January 21, 2019)

DFO. 2016a. Identification of ecologically and biologically significant areas (ESBAs) in the offshore Pacific bioregion. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2016/011. (Accessed January 21, 2019)

DFO. 2016b. Proceedings of the Pacific regional peer review of the identification of ecologically and biologically significant areas (EBSAs) in the Offshore Pacific Bioregion February 11-12, 2015. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2016/020. (Accessed January 21, 2019)

DFO. 2017. Guiding Principles. (Accessed January 21, 2019).

Dower, J., and Fee, F.J. 1999. Oceans background report – the Bowie Seamount area pilot marine protected area in Canada's Pacific Ocean. Prepared for DFO.

Dower, J.F., and Mackas, D.L. 1996. "Seamount effects" in the zooplankton community near Cobb Seamount. Deep-Sea Res. Pt I. **43**(6): 837-858.

Dower, J.F., and Perry, R.I. 2001. High abundance of larval rockfish over Cobb Seamount, an isolated seamount in the Northeast Pacific. Fish. Oceanogr. **10**(3): 268-274.

Dower, J., Freeland, H., and Juniper, K. 1992. A strong biological response to oceanic flow past Cobb Seamount. Deep-Sea Res. **39**(7): 1139-1145.

Drazen, J.C., Popp, B.N., Choy, C.A., Clemente, T., Forest, L.D. and Smith, K.L. 2008. Bypassing the abyssal benthic food web: Macrourid diet in the eastern North Pacific inferred from stomach content and stable isotopes analyses. Limnol. Oceanogr. **53**(6): 2644-2654.

Dudley, S. 2004. The functional ecology of phenotypic plasticity in plants. *In*: DeWitt, T.J., Scheiner, S., editors. Phenotypic Plasticity: Functional and Conceptual Approaches. Oxford: Oxford University Press. pp. 151–172.

Dulvy, N.K., Baum, J.K., Clarke, S., Compagno, L.J., Cortes, E., Domingo, A., Fordham, S., Fowler, S., Francis, M.P., and Gibson, C. 2008. You can swim but you can't hide: the global status and conservation of oceanic pelagic sharks and rays. Aquat. Conserv.: Mar. Freshwat. Ecosyst. **18**(5): 459-482.

Engelen, B., Ziegelmüller, K., Wolf, L., Köpke, B., Gittel, A., Cypionka, H., Treude, T., Nakagawa, S., Inagaki, F., Lever, M.A., and Steinsbu, B.R.O. 2008. Fluids from the oceanic crust support microbial activities within the deep biosphere. Geomicrobiology J. **25**(1): 56-66.

Erbe, C. 2002. Underwater noise of whale-watching boats and potential effects on killer whales (*Orcinus orca*), based on an acoustic impact model. Mar. Mamm. Sci. **18**(2): 394-418.

Eriksen, C.C. 1991. Observations of amplified flows atop a large seamount. J. Geophys. Res-Oceans. **96**(C8): 15227-15236.

Eschmeyer, W.N., Herald, E.S., and Hammann, H. 1983. A field guide to Pacific coast fishes of North America. Houghton Mifflin Company, Boston, U.S.A.

Etter, R.J. and Bower, A.S. 2015. Dispersal and population connectivity in the deep North Atlantic estimated from physical transport processes. Deep Sea Res. Part I.**104**: 159-172.

Feely, R.A., Sabine, C.L., Hernandez-Ayon, J.M., Ianson, D., and Hales, B. 2008. Evidence for upwelling of corrosive ‘acidified’ water onto the continental shelf. Science. **320**: 1490–1492. doi: 10.1126/science. 1155676 PMID: 18497259

Field, C.B., Behrenfeld, M.J., Randerson, J.T. and Falkowski, P. 1998. Primary production of the biosphere: integrating terrestrial and oceanic components. Science. **281**(5374): 237-240.

Francis, T.B., Scheuerell, M.D., Brodeur, R.D., Levin, P.S., Ruzicka, J.J., Tolimieri, N., and Peterson, W.T. 2012. Climate shifts the interaction web of a marine plankton community. Global Change Biol. **18**(8): 2498-2508.

Freeland, H.J. 1990. Sea surface temperatures along the coast of British Columbia: regional evidence for a warming trend. Can. J. Fish. Aquat. Sci. **47**(2): 346-350.

Freeland, H., Denman, K., Wong, C., Whitney, F., and Jacques, R. 1997. Evidence of change in the winter mixed layer in the Northeast Pacific Ocean. Deep Sea Research Part I: Oceanographic Research Papers. **44**(12): 2117-2129.

Gaither, M.R., Violi, B., Gray, H.W., Neat, F., Drazen, J.C., Grubbs, R.D., Roa-Varón, A., Sutton, T., and Hoelzel, A.R. 2016. Depth as a driver of evolution in the deep sea: Insights from grenadiers (Gadiformes: Macrouridae) of the genus Coryphaenoides. Mol. Phylogenet. Evol. **104**:73-82.

Gale, K.S.P., Curtis, J.M.R., Morgan, K.H., Stanley, C., Szaniszlo, W., Burke, L.A., Davidson, L.N.K., Doherty, B., Gatien, G., Gauthier, M., Gauthier, S., Haggarty, D.R., Ianson, D., Neill, A., Pegg, J., Wallace, K., and Zand, J.D.M. 2017. Survey Methods, Data Collections, and Species Observations from the 2015 Survey to SGaan Kinghlas-Bowie Marine Protected Area. Can. Tech. Rep. Fish. Aquat. Sci. 3206: vii + 94 p.

Garcia, H. E., and Gordon, L. I. 1992. Oxygen solubility in seawater: Better fitting equations, Limnol. Oceanog., 37(6): 1307–1312.

Garcia, H.E., Locarnini, R.A., Boyer, T.P., Antonov, J.I., Baranova, O.K., Zweng, M.M., Reagan, J.R., and Johnson, D.R. 2014. World Ocean Atlas 2013, Volume 3: Dissolved Oxygen, Apparent Oxygen Utilization, and Oxygen Saturation. Edited by S. Levitus, and A. Mishonov. Technical Ed. 27 p.

Gauthier, M., Curtis, J.M.R., Gale, K.S.P., Archer, S.K., and Haggarty, D.R. 2018a. SGaan Kinghlas-Bowie Seamount Marine Protected Area Species Inventory: Algae, Cnidaria, Bryozoa and Porifera. Can. Tech. Rep. Fish. Aquat. Sci. 3196: vi + 56 p.

Gauthier, M., Curtis, J.M.R., Gale, K.S.P., and Haggarty, D.R. 2018b. SGaan Kinghlas-Bowie Seamount Marine Protected Area Species Inventory: Chordata. Can. Tech. Rep. Fish. Aquat. Sci. 3197: vi + 48 p.

Gauthier, M., Curtis, J.M.R., Gale, K.S.P., and Haggarty, D.R. 2018c. SGaan Kinghlas-Bowie Seamount Marine Protected Area Species Inventory: Invertebrates (Annelida, Arthropoda, Brachiopoda, Ctenophora, Echinodermata and Mollusca). Can. Tech. Rep. Fish. Aquat. Sci. 3198: vi + 67 p.

Genin, A., and Dower, J.F. 2007. Seamount plankton dynamics. *In* Seamounts: Ecology, Fisheries & Conservation. Edited by T.J. Pitcher, T. Morato, P.J.B. Hart, M.R. Clark, N. Haggan, and R.S. Santos. Blackwell Publishing , Oxford, UK. pp. 85-100.

Genin, A., Dayton, P.K., Lonsdale, P.F., and Spiess, F.N. 1986. Corals on seamount peaks provide evidence of current acceleration over deep-sea topography. Nature. **322**(6074): 59-61.

Gerringer, M.E., Popp, B.N., Linley, T.D., Jamieson, A.J., and Drazen, J.C. 2017. Comparative feeding ecology of abyssal and hadal fishes through stomach content and amino acid isotope analysis. Deep Sea Res. Part I. **121**:110-120.

Gill, J., and Michael, P. 2008. Open magmatic systems at ocean ridges. Am. Geophys. Union, Fall Meeting, abstract #V51F-2115.

Gillespie, G.E. 1997. Review of biology, fisheries and assessment of oceanic squids, particularly *Ommastrephes bartrami, Onychoteuthis borealijaponica*, *Gonatopsis borealis* and *Berrryteuthis magister*. DFO Can. Sci. Advis. Sec. Res. Doc. 1997/143. 45 p.

Gilly, W., and Field, J. 2012. Ecology and trophic interactions of jumbo squid (*Dosidicus gigas*) in the California Current Ecosystem. California Sea Grant College Program, Research Final Reports. Project No. R/OPCFISH-06.

Glickson, D.A., Kelley, D.S., and Delaney, J.R. 2006. The Sasquatch hydrothermal field: linkages between seismic activity, hydrothermal flow, and geology. Eos Trans. AGU. **87**(52), Fall Meet. Suppl., Abstract V23B-0614.

Godet, L., Zelnio, K.A., and Van Dover, C.L. 2011. Scientists as stakeholders in conservation of hydrothermal vents. Conserv. Biol. **25**: 214–222.

Goodfellow, W.D., and Franklin, J.M. 1993. Geology, mineralogy, and chemistry of sediment-hosted clastic massive sulfides in shallow cores, Middle Valley, northern Juan de Fuca Ridge. Economic Geology. **88**(8) 2037-2068.

Gordon, J., Gillespie, D., Potter, J., Frantzis, A., Simmonds, M.P., Swift, R., and Thompson, D. 2003. A review of the effects of seismic surveys on marine mammals. Mar. Technol. Soc. J. **37**(4): 16-34.

Gould, P., Ostrom, P., and Walker, W. 1997. Trophic relationships of albatrosses associated with squid and large-mesh drift-net fisheries in the North Pacific Ocean. Can. J. Zool. **75**: 549–562.

Grassle, J.F. 1985. Hydrothermal vent animals: distribution and biology. Science. **229**: 713-717.

Greene, H.G., Yoklavich, M.M., Starr, R.M., O'Connell, V.M., Wakefield, W.W., Sullivan, D.E., McRea, J.E., and Cailliet, G.M. 1999. A classification scheme for deep seafloor habitats. Oceanol. Acta **22**(6): 663-678.

Gregr, E.J., and Trites, A.W. 2001. Predictions of critical habitat for five whale species in the waters of coastal British Columbia. Can. J. Fish. Aquat. Sci. **58**(7): 1265-1285.

Grill, E.V., Chase, R.L., MacDonald, R.D., and Murray, J.W. 1981. A hydrothermal deposit from Explorer Ridge in the northeast Pacific Ocean. Earth Planet. Sci. Lett. **52**: 142-150.

Gruber, N. 2011. Warming up, turning sour, losing breath: Ocean biogeochemistry under global change. Philos. Trans. R. Soc. A. **369**(1943): 1980–1996. doi:10.1098/rsta.2011.0003.

Haigh, R., Ianson, D., Holt, C.A., Neate, H.E., Edwards, A.M. 2015. Effects of ocean acidification on temperate coastal marine ecosystems and fisheries in the northeast Pacific. PLoS ONE **10**(2): e0117533. doi:10.1371/journal.pone.0117533

Han, S., Carbotte, S.M., Canales, J.P., Nedimović, M.R., Carton, H., Gibson, J.C., and Horning, G.W. 2016. Seismic reflection imaging of the Juan de Fuca plate from ridge to trench: New constraints on the distribution of faulting and evolution of the crust prior to subduction. J Geophys Res: Solid Earth. **121**: 1849-1872.

Hannington, M., and Scott, S. 1989. Gold mineralization in volcanogenic massive sulfides: implications of data from active hydrothermal vents on the modern seafloor. Econ. Geol. Monogr. **6**: 491-507.

Hannington, M.D., de Ronde, C.D., and Petersen, S. 2005. Sea-floor tectonics and submarine hydrothermal systems. 100th Anniversary Volume of Economic Geology. **100**(6): 111-142.

Hannington, M., Jamieson, J., Monecke, T. and Petersen, S. 2010. Modern sea-floor massive sulfides and base metal resources: Toward an estimate of global sea-floor massive sulfide potential. Soc. Econ. Geol. Special Publication. **15**: 317-338.

Hannington, M., Jamieson, J., Monecke, T., Petersen, S., and Beaulieu, S. 2011. The abundance of seafloor massive sulfide deposits. Geology. **39**(12): 1155-1158.

Harrison, A.L. 2012. A synthesis of marine predator migrations, distribution, species overlap, and use of Pacific Ocean Exclusive Economic Zones. Thesis (PhD). University of California, Santa Cruz, Santa Cruz, California.

Hatch, S.A. 2013. Kittiwake diets and chick production signal a 2008 regime shift in the Northeast Pacific. Mar. Ecol. Prog. Ser. **477**: 271-284.

Hedrick, D.B., Pledger, R.D., White, D.C., and Baross, J.A. 1992. *In-situ* microbial ecology of hydrothermal vent sediments. FEMS Microbiol. Ecol. **10**(1): 1-10.

Heithaus, M.R., Frid, A., Wirsing, A.J., and Worm, B. 2008. Predicting ecological consequences of marine top predator declines. Trends Ecol. Evol. **23**(4): 202-210.

Hilário, A., Metaxas, A., Gaugron, S.M., Howell, K.L., Mercier, A., Mestre, N.C., Ross, R.E., Thurnherr, A.M., and Young, C. 2015. Estimating dispersal distance in the deep sea: challenges and applications to marine reserves. Front. Mar. Sci. **2**: 1-14. doi.org/10.3389/fmars.2015.00006.

Hodgson, S., Quinn, T.P., Hilborn, R., Francis, R.C., and Rogers, D.E. 2006. Marine and freshwater climatic factors affecting interannual variation in the timing of return migration to fresh water of sockeye salmon (*Oncorhynchus nerka*). Fish. Oceanogr. **15**(1): 1-24.

Holland, M.E., Baross, J.A., and Holden, J.F. 2004. Illuminating subseafloor ecosystems using microbial tracers. *In* The subseafloor biosphere at mid-ocean ridges. Geophysical monograph ser. **144**: 291-303.

Holmes, J. 2014. National report of Canada (Canadian tuna and tuna-like fisheries in the North Pacific Ocean in 2013). *In* Fourteenth Meeting of the International Scientific committee on Tuna and Tuna-like Species in the North Pacific Ocean, Taipei, China.

Hooff, R.C., and Peterson, W.T. 2006. Copepod biodiversity as an indicator of changes in ocean and climate conditions of the northern California current ecosystem. Limnol. Oceanogr. **51**(6): 2607-2620.

Horner, R.A. 2001. *Alexandrium* and *Pseudo-nitzschia*: Two of the genera responsible for toxic algal blooms on the US west coast. *In* Harmful algal blooms on the North American west coast. Edited by R. RaLonde. AK-SG-01-05. University of Alaska Sea Grant, Fairbanks, Alaska. 5-10p.

Howell, K.L., Mowles, S.L., and Foggo, A. 2010. Mounting evidence: near-slope seamounts are faunally indistinct from an adjacent bank. Mar. Ecol. **31**(s1): 52-62.

Hunt, G.L., Katō, H., and McKinnell, S.M. 2000. Predation by marine birds and mammals in the subarctic North Pacific Ocean. PICES Scientific Report No. 14.

Hutchings, J.A. 2000. Collapse and recovery of marine fishes. Nature **406**(6798): 882-885.

Hutnak, N., Fisher, A.T., Zuhlsdorff, L., Spiess, V., Stauffer, P.H., and Gable, C.W. 2006. Hydrothermal recharge and discharge guided by basement outcrops on 0.7–3.6 Ma seafloor east of the Juan de Fuca Ridge: Observations and numerical models. Geoch. Geoph. Geosys. **7**(7): 36 p.

Hyrenbach, D., Fernández, P., and Anderson, D.J. 2002. Oceanographic habitats of two sympatric North Pacific albatrosses during breeding season. Mar. Ecol. Prog. Ser. **233**: 283-301.

Ianson, D. 2013. The increase in carbon along the Canadian Pacific coast. *In*: Climate Trends and Projections for the Pacific Large Area Basin. Edited by J.R. Christian, M.G.G. Foreman Can. Tech. Rep. Fish. Aquat. Sci. 2013/3032 pp. xi + 113p.

Ianson, D., Feely, R.A., Sabine, C.L., and Juranek, L. 2009. Features of coastal upwelling regions that determine net air-sea CO_2 flux. J. Oceanogr. **65**: 677–687. doi: 10.1007/s10872-009-0059-z

Ianson, D., Allen, S.E., Moore-Maley, B.L., Johannessen, S.C., and Macdonald, R.W. 2016 Vulnerability of a semienclosed estuarine sea to ocean acidification in contrast with hypoxia. Geophys. Res. Lett. **43:** 5793–580. doi:10.1002/2016GL068996, 2016.

Ichii, T., Mahapatra, K., Sakai, M., Wakabayashi, T., Okamura, H., Igarashi, H., Inagake, D., and Okada, Y. 2011. Changes in abundance of the neon flying squid *Ommastrephes bartramii* in relation to climate change in the central North Pacific Ocean. Mar. Ecol. Prog. Ser. **441**: 151-164.

IUCN. 2014. The IUCN Red List of Threatened Species. (Accessed January 21, 2019).

Jackson, J.M., Thomson, R.E., Brown, L.N, Willis, P.G., and Borstad, G.A. 2015. Satellite chlorophyll off the British Columbia coast, 1997-2010. J. Geophysical Res. **120**(7):4709-4728.

Johnson, H.P., Hutnak, M., Dzlak, R.P., Fox, C.G., and Urcuyo, I. 2000. Earthquake induced changes in a hydrothermal system on the Juan de Fuca mid-ocean ridge. Nature **407**: 174-177.

Jungbluth, S.P., Johnson, L.G.H., Cowen, J.P., and Rappé, M.S. 2013. Data report: microbial diversity in sediment near Grizzly Bare Seamount in Holes U1363B and U1363G. *In* Proceedings of the Integrated Ocean Drilling Program. Edited by A.T. Fisher, T. Tsuji, K. Petronotis and Expedition 327 Scientists.

Juniper, S.K., Bird, D.F., Summit, M., Vong, M.P., and Baker, E.T. 1998. Bacterial and viral abundances in hydrothermal vent plumes over northern Gorda Ridge. Deep Sea Res. Part II. **45**: 2739–2749.

Juniper, S.K., Tunnicliffe, V., and Southward, C. 1992a. Hydrothermal vents in turbidite sediments on a Northeast Pacific spreading centre: organisms and substratum at an ocean drilling site. Can. J. Zool. **70**: 1792 – 1809.

Juniper, S.K., Jonasson, I.R., Tunnicliffe, V., and Southward, A.J. 1992b. Influence of a tube-building polychaete on hydrothermal chimney mineralization. Geology. **20**: 895-898.

Kabata, Z., McFarlane, G., and Whitaker, D. 1988. Trematoda of sablefish, *Anoplopoma fimbria* (Pallas, 1811), as possible biological tags for stock identification. Can. J. Zool. **66**(1): 195-200.

Karson, J.A., Kelley, D.S., Fornari, D.J., Perfit, M.R., and Shank, T.M. 2015. Discovering the deep: A photographic atlas of the seafloor and ocean crust. Cambridge University Press, Cambridge, United Kingdom. pp. 168-170.

Kaschner, K. 2008. Air-breathing visitors to seamounts: marine mammals. *In* Seamounts: Ecology, Fisheries and Conservation. Edited by T.J. Pitcher. Blackwell Publishing, Ames, Iowa. pp. 230-238.

Kaschner, K., Tittensor, D.P., Ready, J., Gerrodette, T., and Worm, B. 2011. Current and future patterns of global marine mammal biodiversity. PLos ONE **6**(5): e19653.

Kaschner, K., Rius-Barile, J., Kesner-Reyes, K., Garilao, C., Kullander, S.O., Rees, T., and Froese, R. 2013. AquaMaps: Predicted range maps for aquatic species (Accessed January 21, 2019)

Kaye, J.Z., and Baross, J.A. 2000. High incidence of halotolerant bacteria in Pacific hydrothermal-vent and pelagic environments. FEMS Microbiol. Ecol. **32**(3): 249-260.

Keeling, R.F., Körtzinger, A., and Gruber, N. 2010. Ocean deoxygenation in a warming world. *Annu. Rev. Mar. Sci.* **2**:199–229.

Kelley, D.S., Delaney, J.R., Lilley, M.D., and Butterfield, D.A. 2001. Vent field distribution and evolution along the Endeavour Segment, Juan de Fuca Ridge. EOS Trans. AGU 82 **47**: F612.

Kelley, D.S., Carbotte, S.M., Caress, D.W., Clague, D.A., Delaney, J.R., Gill, J.B., Hadaway, H., Holden, J.F., Hooft, E.E.E., Kellogg, J.P., Lilley, M.D., Stoermer, M., Toomey, D., Weekly, R., and Wilcock, W.S.D. 2012. Endeavour Segment of the Juan de Fuca Ridge: one of the most remarkable places on Earth. Oceanography **25**(1):44–61.

Kelly N.E., and Metaxas, A. 2006. Recruitment patterns of hydrothermal vent invertebrates in anhydrite-based habitats on the Juan de Fuca Ridge, NE Pacific. Cah. Biol. Mar. **47**: 435-441.

Kelly N.E., and Metaxas, A. 2008. Diversity of invertebrate colonists on simple and complex substrates at hydrothermal vents on the Juan de Fuca ridge. Aquatic Biol. **3**: 271-281.

Kelly N.E., and Metaxas, A. 2010. Understanding population dynamics of a numerically dominant species at hydrothermal vents: a matrix modeling approach. Mar. Eco. Prog. Ser. **403**: 113-128.

Kelly, N.E., Metaxas, A., and Butterfield, D. 2007. Spatial and temporal patterns in colonization of deep-sea hydrothermal vent invertebrates on the Juan de Fuca Ridge, NE Pacific. Aquatic Biol. **1**: 1-16.

Kenyon, J.K., Morgan, K.H., Bentley, M.D., MacFarlane, L.A., and Moore, K.E. 2009. Atlas of pelagic seabirds off the west coast of Canada and adjacent areas. Tech. Rep.Ser. No. 499. Canadian Wildlife Service, Pacific and Yukon Region, Delta.

Kim, S.S., and Wessel, P. 2011. New global seamount census from altimetry-derived gravity data. Geophys. J. Int. **186**(2): 615-631.

Kimura, D.K., Shimada, A.M., and Shaw, F.R. 1998. Stock structure and movement of tagged sablefish, Anoplopoma fimbria, in offshore northeast Pacific waters and the effects of El Niño-Southern Oscillation on migration and growth. Fish. Bull. 96(3): 462-481. (Accessed 20 March 2018).

Kitagawa, T., Boustany, A.M., Farwell, C.J., Williams, T.D., Castleton, M.R., and Block, B.A. 2007. Horizontal and vertical movements of juvenile bluefin tuna (*Thunnus orientalis*) in relation to seasons and oceanographic conditions in the eastern Pacific Ocean. Fish. Oceanogr. **16**(5): 409-421.

Kitchingman, A., and Lai, S. 2004. Inferences on potential seamount locations from mid-resolution bathymetric data. Seamounts: Biodiversity and Fisheries. UBC Fisheries Centre Report. (Accessed January 21, 2019)

Kleiber, P. 1998. Estimating annual takes and kills of sea turtles by the Hawaii longline fishery, 1994-1997, from observer program and logbook data. NMFS Honolulu Laboratory Administrative Report H-98-08.

Kleypas, J., Buddemeier, R.W., Archer, D., Gattuso, J.P., Langdon, C., and Opdyke, B.N. 1999. Geochemical consequences of increased atmospheric carbon dioxide on coral reefs. Science **284**: 118–120. doi: 10. 1126/science.284.5411.118 PMID: 10102806

Knauss, J.A., 1962. On some aspects of the deep circulation of the Pacific. J. Geophys. Res. **67**(10): 3943-3954.

Lambshead, P.J.D. and Boucher, G., 2003. Marine nematode deep-sea biodiversity–hyperdiverse or hype? J. Biogeography. **30**(4): 475-485.

LeBrasseur, R. 1964. Stomach contents of blue shark (*Prionace glauca* L.) taken in the Gulf of Alaska. J. Fish. Board Can. **21**(4): 861-862.

Levin, L.A. and Sibuet, M., 2012. Understanding continental margin biodiversity: a new imperative. Ann. Rev. Mar. Sci. **4**: 79-112.

Levin, L.A., Baco, A.R., Bowden, D.A., Colaco, A., Cordes, E.E., Cunha, M.R., Demopoulos, A. W.J., Gobin, J., Grupe, B.M., Le, J., Metaxas, A., Netburn, A.N., Rouse, G.W., Thurber, A. R., Tunnicliffe, V., Van Dover, C.L., Vanreusel, A. and Watling, L. 2016. Hydrothermal Vents and Methane Seeps: Rethinking the Sphere of Influence. Front. Mar. Sci. **3**:72.

Leybourne, M.I., and Van Wagoner, N.A., 1992. Volcanism, age, and hydrothermal deposits of the West Valley Segment, Juan de Fuca Ridge. Can. J. Earth Sci. **29**: 2346-2352.

Litz, M.N.C., Phillips, A.J., Brodeur, R.D., and Emmett, R.L. 2011. Seasonal occurrences of Humboldt squid (*Dosidicus gigas*) in the northern California Current System. CalCOFI Rep 52: 97-108.

Linley, T.D., Stewart, A.L., McMillan, P.J., Clark, M.R., Gerringer, M.E., Drazen, J.C., Fujii, T., and Jamieson, A.J. 2017. Bait attending fishes of the abyssal zone and hadal boundary: Community structure, functional groups and species distribution in the Kermadec, New Hebrides and Mariana trenches. Deep Sea Res Part I. **121**: 38-53.

Locarnini, R.A., Mishonov, A.V., Antonov, J.I., Boyer, T.P., Garcia, H.E., Baranova, O.K., Zweng, M.M., Paver, C.R., Reagan, J.R., Johnson, D.R., Hamilton, M., and D. Seidov. 2013. World Ocean Atlas 2013, Volume 1: Temperature. Edited by E.S. Levitus, and A. Mishonov. Technical Ed. 40 p.

Lundsten, L., Barry, J.P., Cailliet, G.M., Clague, D.A., DeVogelaere, A.P., and Geller, J.B. 2009. Benthic invertebrate communities on three seamounts off southern and central California, USA. Mar. Ecol. Prog. Ser. **374**: 23-32.

Lundsten, L., Paull, C.K., Schlining, K.L., McGann, M., and Ussler, W. 2010a. Biological characterization of a whale-fall near Vancouver Island, British Columbia, Canada. Deep Sea Res Part I. **57**(7): 918-922.

Lundsten, L., Schlining, K.L., Frasier, K., Johnson, S.B., Kuhnz, L.A., Harvey, J.B., Clague, G. and Vrijenhoek, R.C. 2010b. Time-series analysis of six whale-fall communities in Monterey Canyon, California, USA. Deep Sea Res. Part I: **57**(12):1573-1584.

MacAvoy, S.E., Carney, R.S., Fisher, C.R., and Macko, S.A. 2002. Use of chemosynthetic biomass by large, mobile, benthic predators in the Gulf of Mexico. Mar. Ecol. Prog. Ser. **225**: 65–78.

MacAvoy, S.E., Macko, S.A., and Carney, R.S. 2003. Links between chemosynthetic production and mobile predators on the Louisiana continental slope: stable carbon isotopes of specific fatty acids. *Chem.Geol.* **201**: 229–237.

MacAvoy, S.E., Carney, R.S., Morgan, E., and Macko, S.A. 2008. Stable isotope variation among the mussel *Bathymodiolus childressi* and associated heterotrophic fauna at four cold-seep communities in the Gulf of Mexico. J. Shellfish Res. **27**:147–151.

Mackas, D., and Coyle, K. 2005. Shelf–offshore exchange processes, and their effects on mesozooplankton biomass and community composition patterns in the northeast Pacific. Deep Sea Res.Pt. II. **52**(5): 707-725.

Mackas, D.L., and Galbraith, M. 2002a. Zooplankton community composition along the inner portion of Line P during the 1997–1998 El Nino event. Progress in Oceanography. **54**(1): 423-437.

Mackas, D.L., and Galbraith, M. 2002b. Zooplankton distribution and dynamics in a North Pacific eddy of coastal origin: I. Transport and loss of continental margin species. J. of oceanography. **58**(5): 725-738.

Mackas, D.L., and Galbraith, M.D. 2012. Pteropod time-series from the NE Pacific. ICES J. Mar. Sci. **69**: 448– 459. doi: 10.1093/icesjms/fsr163

Mackas, D.L., Kieser, R., Saunders, M., Yelland, D.R., Brown, R.M., and Moore, D.F. 1997. Aggregation of euphausiids and Pacific hake (*Merluccius productus*) along the outer continental shelf off Vancouver Island. Can. J. Fish. Aquat. Sci. **54**(9): 2080-2096.

Mackas, D.L., Thomson, R.E, Galbraith, M. 2001. Changes in the zooplankton community of the British Columbia continental margin, and covariation with oceanographic conditions, 1985-1998. Can. J. Fish. Aquat. Sci. **58**: 685-702

Mackas, D.L., Pena, A., Johannessen, D. Birch, R., Borg, K., and Fissel, D. 2007. Ecosystem overview: Pacific north coast integrated management area (PNCIMA). Appendix D: Plankton. DFO Can. Tech. Rep. Fish. Aquat. Sci 2667.

Manson, M.M. 2009. Small scale delineation of northeast Pacific Ocean undersea features using benthic position index. Can. Manu. Rep. Fish. Aquat. Sci. 2864: 16 p.

Marcus, J., Tunnicliffe, V., and Butterfield, D. 2009. Post-eruption succession of macrofaunal communities at diffuse flow hydrothermal vents on Axial Volcano, Juan de Fuca Ridge, Northeast Pacific. Deep-Sea Res. II **56**: 1586-98.

Marques, A. and Porteiro, F. 2000. Hydrothermal vent mussel *Bathymodiolus* sp. (Mollusca: Mytilidae): diet item of *Hydrolagus affinis* (Pisces: Chimaeridae). *Copeia* **2000**: 806–807.

Marsh, A.G., Mullineaux, L.S., Young, C.M., Manahan, D.T. 2001. Larval dispersal potential of the tubeworm *Riftia pachyptila* at deep-sea hydrothermal vents. Nature. **411**(6833): 77-80.

Matabos, M., Hoeberechts, M., Doya, C., Aguzzi, J., Nephin, J., Reimchen, T.E., Leaver, S., Marx, R.M., Branzan Albu, A., Fier, R., and Fernandez-Arcaya, U. 2017. Expert, crowd, students or algorithm: who holds the key to deep-sea imagery ‘big data’ processing? Methods Ecol. Evol. (Mar) 1-9.

Mauchline, J., 1972. The biology of bathypelagic organisms, especially Crustacea. Deep-Sea Res. Oceanogr. Abstr. **19**(11): 753-780.

McArthur, A., and Tunnicliffe, V. 1998. Relics and antiquity revisited in the modern vent fauna. Geological Society, London, Special Publications **148**: 271-291.

McCabe, R.M., Hickey, B.M., Kudela, R.M., Lefebvre, K.A., Adams, N.G., Bill, B.D., Gulland, F.M.D., Thomson, R.E., Cochlan, W.P., and Trainer, V.L. 2016. An unprecedented coastwide toxic algal bloom linked to anomalous ocean conditions. *Geophys. Res. Lett*. **43**(19): 10,021-10,552. doi:10.1002/2016GL070023.

McClain, C.R., Lundsten, L., Ream, M., Barry, J., and DeVogelaere, A. 2009. Endemicity, biogeography, composition, and community structure on a Northeast Pacific seamount. PLoS One **4**(1): p.e4141.

McClain, C.R., Lundsten, L., Barry, J., and DeVogelaere, A. 2010. Assemblage structure, but not diversity or density, change with depth on a northeast Pacific seamount. Mar. Ecol. 31(s1): 14-25.

McDaniel, N., Swanston, D., Haight, R., Reid, D., and Grant, G. 2003. Biological Observations at Bowie Seamount. Preliminary report prepared for Fisheries and Oceans Canada.

McGowan, J. 1990. Species dominance-diversity patterns in oceanic communities. Cambridge University Press. pp. 395-421.

Metaxas, A. 2004. Spatial and temporal patterns in larval supply at hydrothermal vents in the northeast Pacific Ocean. Limnol. Oceanogr. **49**(6): 1949-1956.

Micheli, F., Peterson, C.H., Mullineaux, L.S., Fisher, C.R., Mills, S.W., Sancho, G. 2002. Predation structures communities at deep-sea hydrothermal vents. Ecol.Monogr. **72**: 365-382.

Miller, L.A., Robert, M., and Crawford, W.R. 2005. The large, westward-propagating Haida eddies of the Pacific eastern boundary. Deep Sea Res. Pt. II. **52**(7): 845-851.

Mironov, A.N., Gebruk, A.V., and Mosjalev, L.I. 1998. Biogeography patterns of the hydrothermal vent fields: a comparison with non-vent biogeography. Cah. Biol. Mar. **39**: 367-368.

Monnahan, C.C., Branch, T.A., and Punt, A.E. 2015. Do ship strikes threaten the recovery of endangered eastern North Pacific blue whales? Mar. Mamm. Sci. **31**(1): 279-297.

Mottl, M.J., Wheat, G., Baker, E., Becker, N., Davis, E., Feely, R., Grehan, A., Kadko, D., Lilley, M., Massoth, G., Moyer, C., and Sansone, F. 1998. Warm springs discovered on 3.5 Ma oceanic crust, eastern flank of the Juan de Fuca Ridge. Geology. **26**: 51–54.

Morato, T., and Clark, M. 2008. Seamount fishes: ecology and life histories. *In* Seamounts: Ecology, Fisheries and Conservation. Edited by T.J. Pitcher. Blackwell Publishing, Ames, Iowa.

Morato, T., and Pauly, D. 2004. Seamounts: Biodiversity and fisheries. Fisheries Centre, University of British Columbia.

Muhlia-Melo, A., Klimley, P., Gonzalez-Armas, R., Jorgensen, S., Trasvina-Castro, A., Rodriguez-Romero, J., and Buenrostro, A.A. 2003. Pelagic fish assemblages at the Espíritu Santo seamount in the Gulf of California during El Niño 1997-1998 and non-El Niño conditions. Geofisica Internacional-Mexico. **42**(3): 473-482.

Mullineaux, L.S., Wiebe, P.H., and Baker, E.T. 1995. Larvae of benthic invertebrates in hydrothermal vent plumes over Juan de Fuca Ridge. *Mar. Biol.* **122**: 585-596.

Murase, H., Hakamada, T., Matsuoka, K., Nishiwaki, S., Inagake, D., Okazaki, M., Tojo, N., and Kitakado, T. 2014. Distribution of sei whales (*Balaenoptera borealis*) in the subarctic-subtropical transition area of the western north pacific in relation to oceanic fronts. Deep Sea Res. Pt II. **107**: 22-28.

Myers, R.A., and Worm, B. 2003. Rapid worldwide depletion of predatory fish communities. Nature. **423**(6937): 280-283.

Myers, K.W., Klovach, N.V., Gritsenko, O.F., Urawa, S., and Royer, T.C. 2007. Stock-specific distributions of Asian and North American salmon in the open ocean, interannual changes, and oceanographic conditions. North Pac. Anadromous Fish Comm. Bull. **4**: 159-177.

NEMO. 2007. NeMO 2007 Cruise Report: Axial Volcano, Endeavour Segment, and Cobb Segment Juan de Fuca Ridge. R/V Atlantis Cruise AT 15-21. August 3-20, 2007, Astoria, Oregon to Astoria Oregon. Jason dives J2-286 to J2-295. *Prepared by* Bobbitt, A. (Accessed January 21, 2019).

Noble, M., and Mullineaux, L.S. 1989. Internal tidal currents over the summit of Cross Seamount. Deep-Sea Res. **36**(12): 1791-1802.

Norris, R.D. 2000. Pelagic species diversity, biogeography, and evolution. Paleobiology **26**(sp4): 236-258.

NRC. 2015. Natural Resources Canada Gazetteer Service. (Accessed January 21, 2019).

Nur, N., Jahncke, J., Herzog, M.P., Howar, J., Hyrenbach, K.D., Zamon, J.E., Ainley, D.G., Wiens, J.A., Morgan, K., and Ballance, L.T. 2011. Where the wild things are: predicting hotspots of seabird aggregations in the California Current System. Ecol. Appl. **21**(6): 2241-2257.

O, M., Martone, R., Hannah, L., Greig, L., Boutillier, J. and Patton, S. 2015. An Ecological Risk Assessment Framework (ERAF) for ecosystem-based oceans management in the Pacific Region. DFO Can. Sci. Advis. Sec. Res. Doc. 2014/072.vii + 59 p.

Oceans Network Canada. 2017. Oceans Network Canada Observatories. (Accessed March 21, 2018).

O'Hara, T.D. 2007. Seamounts: centres of endemism or species richness for ophiuroids? Global Ecol. Biogeogr. **16**(6): 720-732.

Okey, T.A., Alidina, H., Lo, V.B., and Jessen, S. 2014. Effects of climate change on Canada's Pacific marine ecosystems: a summary of scientific knowledge. Rev Fish Biol Fisheries. **24**(2): 519-559.

Oliver, P.G. and Holmes, A.M. 2007. A new species of *Axinus* (Bivalvia: Thyasiroidea) from the Baby Bare Seamount, Cascadia Basin, NE Pacific with a description of the anatomy. J. Conchology. **39**: 363-375.

Omori, M., Van der Spoel, S., and Norman, C. 1994. Impact of human activities on pelagic biogeography. Prog. Oceanogr. **34**(2): 211-219.

Overland, J.E., and Wang, M. 2007. Future climate of the north Pacific Ocean. T. Am. Geophys. Union. **88**(16): 178-182.

Palacios, D.M., Bograd, S.J., Foley, D.G., and Schwing, F.B. 2006. Oceanographic characteristics of biological hot spots in the North Pacific: a remote sensing perspective. Deep Sea Res. Pt. **53**(3): 250-269.

Parin, N., and Prut'ko, V. 1985. The thalassial mesobenthopelagic ichthyocoene above the Equator Seamount in the western tropical Indian Ocean. Oceanology. **25**(6): 781-783.

Parker, T., and Tunnicliffe, V. 1994. Dispersal strategies of the biota on an oceanic seamount: Implications for ecology and biogeography. Biol. Bull. **187**(3): 336-345.

Pauly, D., Christensen, V., Dalsgaard, J., Froese, R., and Torres, F. 1998a. Fishing down marine food webs. Science. **279**(5352): 860-863.

Pauly, D., Trites, A., Capuli, E., and Christensen, V. 1998b. Diet composition and trophic levels of marine mammals. ICES J. Mar. Sci. **55**(3): 467-481.

Pearcy, W.G. 1991. Biology of the transition region. Biology, Oceanography, and Fisheries of the North Pacific transition zone and subarctic frontal zone. Edited by J.A. Wetherall. NOAA Tech. Rep. NMFS **105**: 39-55.

Pearcy, W.G., Stein, D.L. and Carney, R.S., 1982. The deep-sea benthic fish fauna of the northeastern Pacific Ocean on Cascadia and Tufts Abyssal Plains and adjoining continental slopes. Biol. Oceanogr. **1**(4): 375-428.

Pearcy, W., Nishiyama, T., Fujii, T., and Masuda, K. 1984. Diel variations in the feeding habits of Pacific salmon caught in gill nets during a 24-hour period in the Gulf of Alaska. Fish. Bull. **82**: 391-399.

Peterson, W.T., and Keister, J.E. 2003. Interannual variability in copepod community composition at a coastal station in the northern California Current: a multivariate approach. Deep Sea Res. Pt. II. **50**(14): 2499-2517.

Piper, D.Z., Veeh, H.H., Bertrand, W.G., and Chase, R.L. 1975. An iron-rich deposit from the northeast Pacific. Earth Planet. Sci. Lett. **26**: 114-120.

Pitcher, T.J., Morato, T., Hart, P.J.B., Clark, M.R., Haggan, N., and Santos, R.S. (eds.). 2007. Seamounts: ecology, fisheries and conservation. Fish and Aquatic Resources Series 12. Blackwell Publishing, Oxford, U.K. 527 p.

Pleijel, F., Rouse, G.W., Ruta, C., Wiklund, H. and Nygren, A., 2008. *Vrijenhoekia balaenophila*, a new hesionid polychaete from a whale fall off California. J. Linn. Soc. Zool. **152**(4): 625-634.

Poloczanska, E.S., Brown, C.J., Sydeman, W.J., Kiessling, W., Schoeman, D.S., Moore, P.J., Brander, K., Bruno, J.F., Buckley, L.B., and Burrows, M.T. 2013. Global imprint of climate change on marine life. Nature Climate Change. **3**(10): 919-925.

Pörtner, H.O. 2009. Ecosystem effects of ocean acidification in times of ocean warming: a physiologist's view. Mar. Ecol. Prog. Ser. **373**: 203–217.

Priede, I.G., Smith, K.L. and Armstrong, J.D., 1990. Foraging behavior of abyssal grenadier fish: inferences from acoustic tagging and tracking in the North Pacific Ocean. Deep Sea Res. Part A. **37**(1): 81-101.

Probert, P.K., Christiansen, S., Gjerde, K.M., Gubbay, S., and Santos, R.S. 2007. Management and conservation of seamounts. *In* Seamounts: Ecology, Fisheries & Conservation. Edited by T.J. Pitcher, T. Morato, P.J.B. Hart, M.R. Clark, N. Haggan, and R.S. Santos. Blackwell Publishing , Oxford, UK. pp. 442-475.

Ramirez-Llodra, E., Tyler, P.A., Baker, M.C., Bergstad, O.A., Clark, M.R., Escobar, E., Levin, L. A., Menot, L., Rowden, A.A., Smith, C.R., and Van Dover, C.L. 2011. Man and the last great wilderness: human impact on the deep sea. PLoS ONE. **6**(7): e22588.

Rex, M.A., McClain, C.R., Johnson, N.A., Etter, R.J., Allen, J.A., Bouchet, P. and Warén, A., 2005. A source-sink hypothesis for abyssal biodiversity. The American Naturalist. **165**(2): 163-178.

Rex, M.A., Etter, R.J., Morris, J.S., Crouse, J., McClain, C.R., Johnson, N.A., Stuart, C.T., Deming, J.W., Thies, R. and Avery, R., 2006. Global bathymetric patterns of standing stock and body size in the deep-sea benthos. Mar. Ecol. Prog. Ser. **317**: 1-8.

Reyes, A.O., Moore, W.S., and Stakes, D.S. 1995. ^{228}Th/^{228}Ra ages of a barite-rich chimney from the Endeavour Segment of the Juan de Fuca Ridge. Earth Planet. Sci. Lett. **131**(1): 99-113.

Richardson, W.J., Greene Jr, C.R., Malme, C.I., and Thomson, D.H. 2013. Marine mammals and noise. Academic Press.

Robinson, P.W., Costa, D.P., Crocker, D.E., Gallo-Reynoso, J.P., Champagne, C.D., Fowler, M.A., Goetsch, C., Goetz, K.T., Hassrick, J.L., and Hückstädt, L.A. 2012. Foraging behavior and success of a mesopelagic predator in the northeast Pacific Ocean: insights from a data-rich species, the northern elephant seal. PLos ONE **7**(5): e36728.

Robison, B.H., 2004. Deep pelagic biology. J. Exper. Mar. Biol. Ecol. **300**(1): 253-272.

Roden, G.I. 1991. Mesoscale flow and thermohaline structure around Fieberling seamount. J. Geophys. Res-Oceans. **96**(C9): 16653-16672.

Rouse, G.W., Goffredi, S.K. and Vrijenhoek, R.C., 2004. Osedax: bone-eating marine worms with dwarf males. Science. **305**(5684): 668-671.

Rowden, A.A., Dower, J.F., Schlacher, T.A., Consalvey, M., and Clark, M.R. 2010. Paradigms in seamount ecology: fact, fiction and future. Mar. Ecol. **31**(s1): 226-241.

Ruiz-Cooley, R.I., Ballance, L.T., and McCarthy, M.D. 2013. Range expansion of the jumbo squid in the NE Pacific: δ15N decrypts multiple origins, migration and habitat use. PLos ONE **8**(3): e59651.

Santos, M., Bolten, A.B., Martins, H.R., Riewald, B., and Bjorndal, K.A. 2008. Air-breathing visitors to seamounts: Sea turtles. *In* Seamounts: Ecology, Fisheries and Conservation. Edited by T.J. Pitcher. Blackwell Publishing, Ames, Iowa. pp. 239-244.

Sarmiento, J.L., Hughes, T.M.C., Stouffer, R.J. and Manabe, S. 1998. Simulated response of the ocean carbon cycle to anthropogenic climate warming. Nature. **393**: 245–249.

Sarrazin, J., Juniper, S.K. 1999a. Biological characteristics of a hydrothermal edifice mosaic community. Mar. Ecol. Prog. Ser. **185**: 1–19.

Sarrazin, J., Robigou, V., Juniper, S.K., Delaney, J. 1997. Biological and geological dynamics over four years on a high-temperature sulfide structure at the Juan de Fuca Ridge hydrothermal observatory. Mar. Ecol. Prog. Ser. **153**: 5-24.

Sarrazin, J., Juniper, S.K., Massoth, G., and Legendre, P. 1999b. Physical and chemical factors influencing species distributions on hydrothermal sulfide edifices of the Juan De Fuca Ridge, Northeast Pacific. Mar. Ecol. Prog. Ser. **190**: 89-112.

Sarrazin, J., Levesque, C., Juniper, S.K., and Tivey, M.K. 2002. Mosaic community dynamics on Juan De Fuca Ridge sulfide edifices: Substratum, temperature and implications for trophic structure. Cah. Biol. Mar. **43**: 275-279.

Schiedek, D., Sundelin, B., Readman, J.W., and Macdonald, R.W. 2007. Interactions between climate change and contaminants. Mar. Pollut. Bull. **54**(12): 1845-1856.

Scott, S. 2001. Deep ocean mining. Geoscience Canada. **28**(2): 87-96.

Shank, T.M., Fornari, D.J., Von Damm, K.L., Lilley, M.D., Haymon, R.M., and Lutz, R.A. 1998. Temporal and spatial patterns of biological community development at nascent deep-sea hydrothermal vents (9°50'N, East Pacific Rise). Deep Sea Res. Pt II. **45**: 465-515.

Shulse, C.N., Maillot, B., Smith, C.R. and Church, M.J., 2016. Polymetallic nodules, sediments, and deep waters in the equatorial North Pacific exhibit highly diverse and distinct bacterial, archaeal, and microeukaryotic communities. MicrobiologyOpen. **6**:e428: 1-16.

Siegle, M.R., Taylor, E.B., Miller, K.M., Withler, R.E., and Yamanaka, K.L. 2013. Subtle population genetic structure in Yelloweye Rockfish (*Sebastes ruberrimus)* is consistent with a major oceanographic division in British Columbia, Canada. PLoS ONE **8**(8): e71083.

Sinclair, E.H., and Zeppelin, T.K. 2002. Seasonal and spatial differences in diet in the western stock of Steller sea lions (*Eumetopias jubatus*). J. Mammal. **83**(4): 973-990.

Skeebo, S., Tunnicliffe, V., Garcia Berdeal, I., and Johnson, H.P. 2006. Spatial patterns of zooplankton and nekton in a hydrothermally active axial valley on Juan de Fuca Ridge. Deep-Sea Res. I. **53**: 1044–1060.

Smith, C.R. and Baco, A.R., 2003. Ecology of whale falls at the deep-sea floor. Oceanogr. Mar. Biol. **41**: 311-354.

Smith, C.R. and Kukert, H., 1989. Vent fauna on whale remains. Nature. **341**: 27-28.

Smith, C.R., Drazen, J. and Mincks, S.L. 2006. Deep-sea biodiversity and biogeography: Perspectives from the abyss. International Seabed Authority Seamount Biodiversity Symposium, pg.1-13.

Smith, C.R., De Leo, F.C., Bernardino, A.F., Sweetman, A.K., and Arbizu, P.M. 2008. Abyssal food limitation, ecosystem structure and climate change. Trends Ecol. Evol. **23**: 518-528.

Smith, C.R., Glover, A.G., Treude, T., Higgs, N.D. and Amon, D.J., 2015. Whale-fall ecosystems: recent insights into ecology, paleoecology, and evolution. Ann. Rev. Mar. Sci. **7**: 571-596.

Smith, K.L., Kaufmann, R.S., Edelman, J.L., and Baldwin, R.J. 1992. Abyssopelagic fauna in the central North Pacific: comparison of acoustic detection and trawl and baited trap collections to 5800 m. Deep Sea Res. Part A. **39**(3-4): 659-685.

Smith, W.H., and Sandwell, D.T. 1997. Global sea floor topography from satellite altimetry and ship depth soundings. Science. **277**(5334): 1956-1962.

Snelgrove, P.V.R. and Smith, C.R. 2002. A riot of species in an environmental calm: the paradox of the species-rich deep-sea floor. Ocean Mar Biol: Ann. Rev. **40:** 311-342.

SODA3. 2017. SODA3 (Accessed January 21, 2019).

Southward, E.C., Tunnicliffe, V., Black, M. 1995. Revision of the species of *Ridgeia* from northeast Pacific hydrothermal vents, with a redescription of *Ridgeia piscesae* Jones (Pogonophora: Obturata = Vestimentifera). Can. J. Zoo. **73**: 282–295.

Southward, E.C., Tunnicliffe, V., Black, M.B., Dixon, D.R., Dixon, L.R.J. 1996. Oceanridge segmentation and vent tubeworms (Vestimentifera) in the NE Pacific. *In*: Tectonic, Magmatic, Hydrothermal and Biological Segmentation of Mid-Ocean Ridges. Edited by C.J. MacLeod, P.A.Tyler, C.L. Walker. Geol. Soc. Spec. Pub. pp. 211–224.

Stakes, D.S., Moore, W.S., Redding, S., Smoak, J., Minnich, J., Tivey, M., Hannington, M., Edmond, J., Edmonds, H., Todd, J.F., Cychosz, J., Hussain, N., Mandernack, K., and Bollinger, M. 1992. Cores drilled into active smokers on Juan de Fuca Ridge. Eos **73**(26): 273-288.

Stefanoudis, P.V., Bett, B.J. and Gooday, A.J. 2016. Abyssal hills: Influence of topography on benthic foraminiferal assemblages. Progr. Oceanogr. **148**: 44-55.

Stein, D.L. 1980. Aspects of reproduction of liparid fishes from the continental slope and abyssal plain off Oregon, with notes on growth. Copeia. **4**: 687-699.

Stewart, J., Hazen, E., Foley, D., Bograd, S., and Gilly, W. 2012. Marine predator migration during range expansion: Humboldt squid *Dosidicus gigas* in the northern California Current System. Mar. Ecol. Prog. Ser. **471**: 135-150.

Stone, R.P., and Shotwell, S.K. 2007. State of deep coral ecosystems in the Alaska Region: Gulf of Alaska, Bering Sea and the Aleutian Islands. The State of Deep Coral Ecosystems of the United States. NOAA Technical Memorandum CRCP-3, Silver Spring, Maryland: 65-108.

Strömberg, J.O. 1997. Human influence or natural perturbation in oceanic and coastal waters—can we distinguish between them? Hydrobiologia. **352**(1): 181-192.

Sumida, P.Y., Alfaro-Lucas, J.M., Shimabukuro, M., Kitazato, H., Perez, J.A., Soares-Gomes, A., Toyofuku, T., Lima, A.O., Ara, K. and Fujiwara, Y., 2016. Deep-sea whale fall fauna from the Atlantic resembles that of the Pacific Ocean. Sci. Rep. **6**: 1-9.

Sweetman, A.K., Thurber, A.R., Smith, C.R., Levin, L.A., Mora, C., Wei, C.L., Gooday, A.J., Jones, D.O., Rex, M., Yasuhara, M. and Ingels, J. 2017. Major impacts of climate change on deep-sea benthic ecosystems. Elem. Sci. Anth. **5**: 1-23.

Sydeman, W.J., Losekoot, M., Santora, J.A., Thompson, S.A., Distler, T., Weinstein, A., Smith, M.A., Walker, N., Audubon, A., and Morgan, K.H. 2012. Hotspots of seabird abundance in the California current: Implications for important bird areas.

Tabata, S., and Pearl, J.L. 1985, Statistics of oceanographic data based on hydrographic/STD casts made at Station 1 through 6 along Line P during January 1959 through June 1981. Can. Data. Rep. Hydrogr. Ocean Sci., 38, 447p.

Tabata, S., and Pearl, J.L. 1986, Statistics of oceanographic data based on hydrographic/STD casts made at Station 7 through 12 along Line P during January 1959 through June 1981. Can. Data. Rep. Hydrogr. Ocean Sci., 43, 402p.

Taylor, F.J.R., and Harrison, P.J. 2002. Harmful algal blooms in western Canadian waters. *In* Harmful algal blooms in the PICES region of the North Pacific. Edited by F.J.R Taylor and v. Trainer. PICES Scientific Report No. 23. North Pacific Marine Science Organization (PICES), Sidney, BC.

Thomson, R.E. 1981, Oceanography of the British Columbia Coast. Can. Special Pub. Fish. Aquat. Sci., **56**. Ottawa, 291p.

Thompson, D.R. 2008. Importance of seamounts to seabirds. *In* Seamounts: Ecology, Fisheries and Conservation. Edited by T.J. Pitcher. Blackwell Publishing, Ames, Iowa. pp. 245-251.

Thomson, R.E., Delaney, J.R., McDuff, R.E., Janecky, D.R., and McClain, J.S. 1992. Physical characteristics of the Endeavour Ridge hydrothermal plume during July 1988. Earth Planet. Sci. Lett. **111**(1): 141-154.

Thomson, R.E., Davis, E.E., and Burd, B.J. 1995. Hydrothermal venting and geothermal heating in Cascadia Basin. J. Geophys. Res. (Solid Earth). **100**: 6121-6141.

Thomson, R. E., and M. V. Krassovski (2010), Poleward reach of the California Undercurrent extension, J. Geophys. Res., 115, C09027.

Thomson, R. E., and M. V. Krassovski (2015), Remote alongshore winds drive variability of the California Undercurrent off the British Columbia-Washington coast, J. Geophys. Res. Oceans, 120, 8151–8176.

Thomson, R.E., Mihály, S.F., Rabinovich, A.B., McDuff, R.E., Veirs, S.R., and Stahr, F.R. 2003. Constrained circulation at Endeavour ridge facilitates colonization by vent larvae. Nature. **424**(6948): 545-549.

Thomson, R.E., Subbotina, M. M., and Anisimov, M. V. 2005. Numerical simulation of hydrothermal vent-induced circulation at Endeavour Ridge. J. Geophys Res.Oceans. **110:** C01004 1-14. doi:10.1029/2004JC002337

Thomson, R.E., Subbotina, M.M. and Anisimov, M.V. 2009. Numerical simulation of mean currents and water property anomalies at Endeavour Ridge: Hydrothermal versus topographic forcing. J. Geophys Res. Ocean **114:** C09020. doi:10.1029/2008JC005249.

Thornborough, K., Dunham, J., and O, M. 2016 Development of risk-based indicators for the Endeavour Hydrotherma Vents Marine Protected Area.. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/028. vii + 124 p (Accessed January 21, 2019).

Tittensor, D.P., Baco, A.R., Hall-Spencer, J.M., Orr, J.C., and Rogers, A.D. 2010. Seamounts as refugia from ocean acidification for cold-water stony corals. Mar. Ecol. **31**: 212-225.

Tsurumi, M. and Tunnicliffe, V. 2003. Tubeworm-associated communities at hydrothermal vents on the Juan de Fuca Ridge, northeast Pacific. Deep-Sea Res. Pt. I. **50**: 611–629.

Tunnicliffe, V. 1997. Hydrothermal vents: a global system. In JAMSTEC Technical Reports. Deep Sea Research in subduction zones, spreading centers and back arc basins. 105–114.

Tunnicliffe, V. and Jensen, R.G. 1987. Distribution and behaviour of the spider crab *Macroregonia macrochira* Sakai (Brachyura) around the hydrothermal vents of the northeast Pacific. *Can. J. Zoo.* **65**: 2443–2449.

Tunnicliffe, V., and Juniper, S.K. 1990a. Dynamic character of the hydrothermal vent habitat and the nature of sulphide chimney fauna. Prog. Oceanogr. **24**: 1-14.

Tunnicliffe, V., Botros, M., de Burgh, M.E., Dinet, A., Johnson, H.P., Juniper, S.K., and McDuff, R.E. 1986. Hydrothermal vents of Explorer Ridge, northeast Pacific. Deep Sea Res. Pt I. **33**(3): 401-412.

Tunnicliffe, V., Garrett, J.F., and Johnson, H.P. 1990b. Physical and biological factors affecting the behaviour and mortality of hydrothermal vent tubeworms (vestimentiferans). Deep-Sea Res. Pt. I. **37**: 103–125.

Tunnicliffe, V., Fowler, C.M.R., and McArthur, A.G. 1996. Plate tectonic history and hot vent biogeography. *In*: Tectonic, Magmatic, Hydrothermal and Biological Segmentation of Mid-Ocean Ridges. Editors C.J. MacLeod, P.A. Tyler, C.L. Walker. Geological Society Special Publication, pp. 225-238.

Tunnicliffe, V., Embley, R.W., Holden, J.F., Butterfield, D.A., and Massoth, G.J. 1997. Biological colonization of new hydrothermal vents following an eruption on Juan de Fuca Ridge. Deep-Sea Res. Pt. I. **44**: 1627–1644.

Tunnicliffe, V., McArthur, A.G., and McHugh, D. 1998. A biogeographical perspective of the deep-sea hydrothermal vent fauna. *In* Adv. Mar. Biol. Edited by J.H.S. Blaxter, A.J. Southward and P.A. Tyler. Academic Press. pp. 353-442.

Tunnicliffe, V., St. Germain, C., and Hilário, A. 2014. Phenotypic Variation and Fitness in a Metapopulation of Tubeworms (*Ridgeia piscesae* Jones) at Hydrothermal Vents. PLoS ONE **9**(10): e110578.

Tyack, P.L. 2008. Implications for marine mammals of large-scale changes in the marine acoustic environment. J. Mammal. **89**(3): 549-558.

Tyler, P.A. and Young, C.M. 2003. Dispersal at hydrothermal vents: a summary of recent progress. Hydrobiologia. **503**(1-3): 9-19.

United States Board of Geographic Names. 1981. Gazetteer of Undersea Features. Defense Mapping Agency, Washington, DC.

Urcuyo, I.A., Bergquist, D., MacDonald, I., VanHorn, M., and Fisher, C. 2007. Growth and longevity of the tubeworm *Ridgeia piscesae* in the variable diffuse flow habitats of the Juan de Fuca Ridge. Mar. Ecol. Prog. Ser. **344**: 143–157.

Van Campenhout, J., Derycke, S., Tchesunov, A., Portnova, D., and Vanreusel, A. 2014. The *Halomonhystera disjuncta* population is homogeneous across the Håkon Mosby mud volcano (Barents Sea) but is genetically differentiated from its shallow-water relatives. J. Zoolog. Syst. Evol. Res. **52**(3): 203-216.

Van der Spoel, S. 1994. The basis for boundaries in pelagic biogeography. Prog. Oceanogr. **34**(2): 121-133.

Van Dover, C.L. 2000. The ecology of deep-sea hydrothermal vents. Princeton University Press, Princeton, New Jersey. 424 p.

Van Dover, C. L. 2007. The biological environment of polymetallic sulphides deposits, the potential impact of exploration and mining on this environment, and data required to establish environmental baselines in exploration areas. *In* Polymetallic sulphides and cobalt-rich ferromanganese crusts deposits: establishment of environmental baselines and an associated monitoring programme during exploration. Proceedings of the International Seabed Authority's Workshop held in Kingston, Jamaica, 6–10 September 2004. Prepared by Offices of Resources and Environmental Monitoring (OREM), pp. 169–190. International Seabed Authority, Kingston, Jamaica.

Van Dover, C. L. 2011. Mining seafloor massive sulphides and biodiversity: what is at risk? ICES J. Mar. Sci. **68**: 341-348.

Van Reusel, A.; Hilário, A.; Ribeiro, P.A.; Menot, L.; Martinez Arbizu, P. (2016). Threatened by mining, polymetallic nodules are required to preserve abyssal epifauna. NPG Scientific Reports **6**(26808): 6 pp. hdl.handle.net/10.1038/srep26808

Veirs, S.R. 2003. Heat flux and hydrography at a submarine volcano: Observations and models of the Main Endeavour vent field in the northeast Pacific. Doctoral Dissertation, University of Washington. ProQuest Dissertations Publishing.

Veirs, S.R., McDuff, R.E., Lilley, M.D., and Delaney, J.R. 1999. Locating hydrothermal vents by detecting buoyant, advected plumes. J. Geophys. Res. **104**(B12): 29,239-29,247.

Verity, P.G., Smetacek, V., and Smayda, T.J. 2002. Status, trends and the future of the marine pelagic ecosystem. Environ. Conserv. **29**(02): 207-237.

Vermeer, K., and Devito, K. 1988. The importance of *Paracallisoma coecus* and myctophid fishes to nesting fork-tailed and Leach's storm-petrels in the Queen Charlotte Islands, British Columbia. J. Plankton Res. **10**(1): 63-75.

Vetter, E.W. 1994. Hotspots of benthic production. Nature. **372**: 47.

Vetter, E.W. and Dayton, P.K., 1999. Organic enrichment by macrophyte detritus, and abundance patterns of megafaunal populations in submarine canyons. Mar. Ecol. Prog. Ser. **186**:137-148.

Vaquer-Sunyer, R., anf Duarte, C.M. 2008. Thresholds of hypoxia for marine biodiversity. Proc. Natl. Acad. Sci. U.S.A. **105:** 15452–15457. doi:10.1073/pnas.0803833105

Voight, J.R. 2000. A deep-sea octopus (*Graneledone* cf. *boreopacifica*) as a shell-crushing hydrothermal vent predator. *J. Zoo.* **252**: 335–341.

Wang, F., Zhou, H., Meng, J., Peng, X., Jiang, L., Sun, P., Zhang, C., Van Nostrand, J.D., Deng, Y., He, Z., Wu, L., Zhou, J., and Xiao, X. 2009. GeoChip-based analysis of metabolic diversity of microbial communities at the Juan de Fuca Ridge hydrothermal vent. P. Natl. Acad. Sci. USA. **106**(12): 4840-4845.

Ware, D.M., and Thomson, R.E. 2005. Bottom-up ecosystem trophic dynamics determine fish production in the northeast Pacific. *Science*. **308**: 1280-1284.

Watling, L., and Auster, P.J. 2017. Seamounts on the high seas should be managed as vulnerable marine ecosystems. Front. Mar. Sci. **4**(14).

Watling, L., Guinotte, J., Clark, M.R. and Smith, C.R., 2013. A proposed biogeography of the deep ocean floor. Prog. Oceanogr. **111**: 91-112.

Weatherdon, L.V., Ota, Y., Jones, M.C., Close, D.A., and Cheung, W.W. 2016. Projected scenarios for coastal First Nations' fisheries catch potential under climate change: management challenges and opportunities. PloS one **11**(1): p.e0145285.

Wedding, L.M., Friedlander, A.M., Kittinger, J.N., Watling, L., Gaines, S.D., Bennett, M., Hardy, S.M., and Smith, C.R. 2013. From principles to practice: a spatial approach to systematic conservation planning in the deep sea. Proc. R. Soc. Lond. (Biol.) **280**(1773): 20131684.

Wedding, L.M., Reiter, S.M., Smith, C.R., Gjerde, K.M., Kittinger, J.N., Friedlander, A.M., Gaines, S.D., Clark, M.R., Thurnherr, A.M., Hardy, S.M., and Crowder, L.B., 2015. Managing mining of the deep seabed. Science. **349**(6244): 144-145.

Weilgart, L.S. 2007. A brief review of known effects of noise on marine mammals. International J. Comp. Psychol. **20**(2): 159-168.

Welch, D.W., Ward, B.R., Smith, B.D., and Eveson, J. 2000. Temporal and spatial responses of British Columbia steelhead (*Oncorhynchus mykiss*) populations to ocean climate shifts. Fish. Oceanogr. **9**(1): 17-32.

Welch, D.W., Boehlert, G.W., and Ward, B.R. 2002. POST–the Pacific Ocean salmon tracking project. Oceanol. Acta. **25**(5): 243-253.

Weng, K.C., Castilho, P.C., Morrissette, J.M., Landeira-Fernandez, A.M., Holts, D.B., Schallert, R.J., Goldman, K.J., and Block, B.A. 2005. Satellite tagging and cardiac physiology reveal niche expansion in salmon sharks. Science. **310**(5745): 104-106.

Wheat, C.G., Elderfield, H., Mottl, M.J., and Monnin, C. 2000. Chemical composition of basement fluids within an oceanic ridge flank: Implications for along-strike and across-strike hydrothermal circulation. J. Geophys. Res-Sol. Ea. **105**(B6): 13437-13447.

Whitaker, D., and McFarlane, G. 1997. Identification of sablefish, *Anoplopoma fimbria* (Pallas, 1811), stocks from seamounts off the Canadian Pacific Coast using parasites as biological tags. Biology and management of sablefish, *Anoplopoma fimbria*. NOAA Tech. Rep. NMFS 130: 131-136.

White, M., Bashmachnikov, I., Arístegui, J., and Martins, A. 2007. Physical processes and seamount productivity. *In* Seamounts: Ecology, Fisheries & Conservation. Edited by T.J. Pitcher, T. Morato, P.J.B. Hart, M.R. Clark, N. Haggan, and R.S. Santos. Blackwell Publishing , Oxford, UK. pp. 65-84.

Whitney, F., and Freeland, H. 1999. Variability in upper-ocean water properties in the NE Pacific Ocean. Deep Sea Res. Pt. II. **46**(11): 2351-2370.

Whitney, F., and Robert, M. 2002. Structure of Haida eddies and their transport of nutrient from coastal margins into the NE Pacific Ocean. J. Oceanography. **58**(5): 715-723.

Whitney, F.A., Crawford, D.W., and Yoshimura, T. 2005. The uptake and export of silicon and nitrogen in HNLC waters of the NE Pacific Ocean. Deep Sea Res. Pt. II. **52**(7): 1055-1067.

Whitney, F.A., Freeland, H.J., and Robert, M. 2007. Persistently declining oxygen levels in the interior waters of the eastern subarctic Pacific. Prog. Oceanog. **75**(2): 179-199.

Wiklund, H., Glover, A.G. and Dahlgren, T.G., 2009. Three new species of *Ophryotrocha* (Annelida: Dorvilleidae) from a whale-fall in the North-East Atlantic. Zootaxa. **2228**: 43-56.

Winder, M., and Schindler, D.E. 2004. Climate change uncouples trophic interactions in an aquatic ecosystem. Ecology **85**(8): 2100-2106.

Wishner, K.F. 1980. The biomass of the deep-sea benthopelagic plankton. Deep Sea Res. **27**(3-4): 203-216.

Yamanaka, K.L. 2005. Data report for the research cruise onboard the CCGS John P. Tully and the F/V Double Decker to Bowie Seamount and Queen Charlotte Islands, July 31st to August 14th 2000. Can. Data. Rep. Fish. Aquat. Sci. 1163: vii + 46 p.

Yesson, C., Clark, M.R., Taylor, M.L., and Rogers, A.D. 2011. The global distribution of seamounts based on 30 arc seconds bathymetry data. Deep-Sea Res. PT I. **58**(4): 442-453.

Yoerger, D.R., Bradley, A.M., Jakuba, M., Tivey, M.A., German, C.R., Shank, T.M., and Embley, R.W. 2007. Mid-ocean ridge exploration with an autonomous underwater vehicle. Oceanog. **20**(4): 52-61.

Yoklavich, M.M., Greene, H.G., Cailliet, G.M., Sullivan, D.E., Lea, R.N. and Love, M.S. 2000. Habitat associations of deep-water rockfishes in a submarine canyon: an example of a natural refuge. Fish. B. NOAA. **98**(3): 625-641.

Yonezaki, S., Kiyota, M., and Baba, N. 2008. Decadal changes in the diet of northern fur seal (*Callorhinus ursinus*) migrating off the Pacific coast of northeastern Japan. Fish. Oceanogr. **17**(3): 231-238.

Zhou, H., Li, J., Peng, X., Meng, J., Wang, F., and Ai, Y. 2009. Microbial diversity of a sulfide black smoker in main endeavour hydrothermal vent field, Juan de Fuca Ridge. J. Microbiol. **47**(3): 235-247.

Zierenberg, R.A., and Holland, M.E. 2004. Sedimented ridges as a laboratory for exploring the subsurface biosphere. *In* The subseafloor biosphere at mid-ocean ridges. Geophysical monograph series **144**: 305-323.

Zuhlsdorff, L., Hutnak, M., Fisher, A., Speiss, V., Davis, E., Nedimovic, M., Carbotte, S., Villinger, H., and Becker, K. 2005. Site surveys related to IODP Expedition 301: Image- Flux (SO149) and RetroFlux (TN116) expeditions and earlier studies, Proc. Ocean Drill. Program Sci., 301.

Appendix A

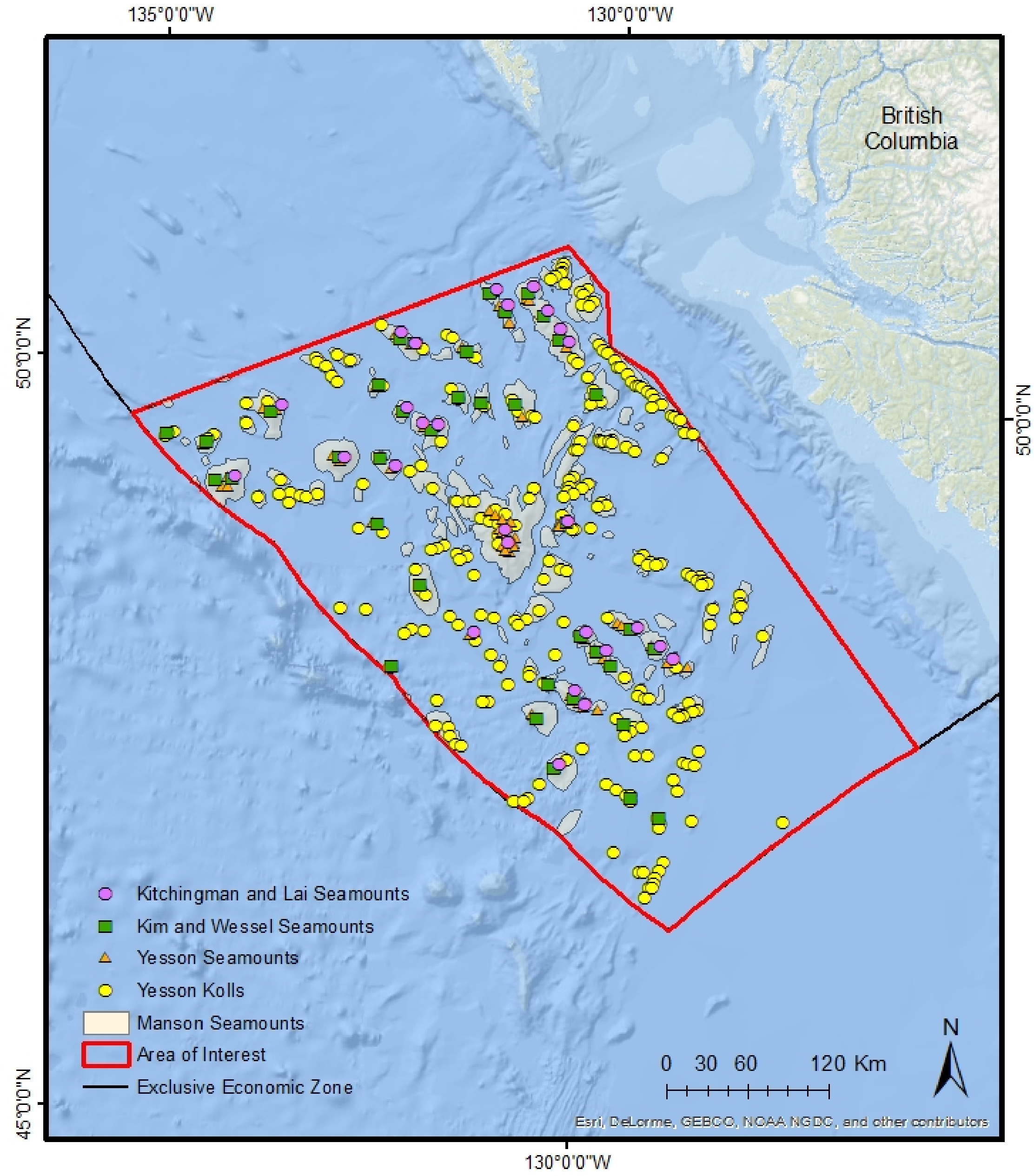


Figure A-1. The predicted locations of seamounts and knoll, made by Kitchingman and Lai (2004) (purple circles), Manson (2009) (beige polygons]), Kim and Wessel (2011) (green squares), and Yesson et al. (2011) (orange triangles for seamounts and yellow circles for knolls]). Manson (2009) generated polygons of seamounts, whereas the other three research groups generated the point location of the seamount summit. Red line denotes the extent of the Offshore Area of Interest (AOI).

Appendix B

Table B- 1. List of taxa observed during the 2012 Cobb Seamount survey at 15 ROV and four AUV transects. Depth ranges are given for each taxon (Du Preez et al. 2015).

Phylum	Class	Order	Genus and species	Depths (m)
Ochrophyta	Phaeophyceae	Desmarestiales	*Desmarestia viridis*	34-49
Rhodophyta	Florideophyceae	Ceramiales	*Polysiphonia* spp.	40
Rhodophyta	Florideophyceae	Corallinales	cf *Lithophyllum* spp.	34-191
Rhodophyta	Florideophyceae	Corallinales	cf *Lithothamnion* spp.	34-191
Porifera	Hexactinellida	Hexactinosida	*Pinulasma fistulosom*	635-934
Porifera	Hexactinellida	Hexactinosida	*Farrea omniclavata* sp. nov.	681-1147
Porifera	Hexactinellida	Lyssacinosida	*Acanthascus* spp.	501-1147
Porifera	Hexactinellida	Lyssacinosida	*Bathydorus* sp.	567-887
Porifera	Hexactinellida	Lyssacinosida	*Rhabdocalyptus* spp.	501-1147
Porifera	Hexactinellida	Lyssacinosida	*Staurocalyptus* spp.	501-1147
Porifera	Demospongiae	-	Demospongiae sp. 1	127-436
Porifera	Demospongiae	-	Demospongiae sp. 2	124-210
Porifera	Demospongiae	-	Demospongiae sp. 3	123-138
Porifera	Demospongiae	Astrophorida	*Poecillastra* sp.	772
Porifera	Demospongiae	Hadromerida	*Polymastia* sp.	94-141
Porifera	Demospongiae	Halichondria	cf *Auletta* sp.	183-210
Porifera	Demospongiae	Halichondria	*Halichondria panicea*	63-212
Porifera	Demospongiae	Poecilosclerida	cf *Acarnus erithacus*	35-127
Porifera	Demospongiae	Poecilosclerida	*Latrunculia* (*Biannulata*) *oparinae*	122-126
Cnidaria	Anthozoa	Actiniaria	Actiniaria sp. 1	615
Cnidaria	Anthozoa	Actiniaria	Actiniaria sp. 2	785
Cnidaria	Anthozoa	Actiniaria	Actiniaria sp. 3	619-939
Cnidaria	Anthozoa	Actiniaria	*Cribrinopsis fernaldi*	196-259
Cnidaria	Anthozoa	Actiniaria	cf Hormathiidae sp.	527-1090
Cnidaria	Anthozoa	Actiniaria	*Metridium senile*	116-220
Cnidaria	Anthozoa	Actiniaria	*Stomphia didemon*	121-187
Cnidaria	Anthozoa	Actiniaria	*Urticina crassicornis*	193-259
Cnidaria	Anthozoa	Alcyonacea	*Gersemia* sp.	800-885
Cnidaria	Anthozoa	Alcyonacea	*Heteropolypus ritteri*	436-1036
Cnidaria	Anthozoa	Alcyonacea	*Isidella* sp.	495-875
Cnidaria	Anthozoa	Alcyonacea	*Keratoisis* sp.	436-819
Cnidaria	Anthozoa	Alcyonacea	*Lepidisis* sp.	488-1154
Cnidaria	Anthozoa	Alcyonacea	*Narella* sp.	198
Cnidaria	Anthozoa	Alcyonacea	*Paragorgia* sp.	825
Cnidaria	Anthozoa	Alcyonacea	*Plumarella superba*	788-826
Cnidaria	Anthozoa	Alcyonacea	*Primnoa* cf *pacifica*	198-888
Cnidaria	Anthozoa	Alcyonacea	*Swiftia simplex*	536-1083
Cnidaria	Anthozoa	Antipatharia	*Antipatharia* sp.	524-1086
Cnidaria	Anthozoa	Antipatharia	*Bathypathes* sp.	681-1153
Cnidaria	Anthozoa	Antipatharia	*Lillipathes* cf *lillei*	436-1088
Cnidaria	Anthozoa	Antipatharia	*Parantipathes* sp.	775-1003
Cnidaria	Anthozoa	Antipatharia	*Stichopathes* sp.	681-840
Cnidaria	Anthozoa	Corallimorpharia	*Corynactis californica*	34-95
Cnidaria	Anthozoa	Pennatulacea	*Anthoptilum* spp.	723-1003
Cnidaria	Anthozoa	Pennatulacea	*Halipteris willemoesi*	99-807
Cnidaria	Anthozoa	Pennatulacea	*Umbellula lindahli*	920

Phylum	Class	Order	Genus and species	Depths (m)
Cnidaria	Anthozoa	Scleractinia	*Desmophyllum dianthus*	91-557
Cnidaria	Anthozoa	Scleractinia	*Lophelia pertusa*	162-254
Cnidaria	Anthozoa	Zoantharia	*Epizoanthus* sp.	198
Cnidaria	Hydrozoa	-	Hydroid sp. 1	58-209
Cnidaria	Hydrozoa	-	Hydroid sp. 2	84
Cnidaria	Hydrozoa	Anthoathecata	*Stylaster* spp.	91-886
Cnidaria	Hydrozoa	Leptothecata	cf *Obelia* spp.	40-220
Annelida	Polychaeta	Eunicida	*Nothria conchylega*	89-191
Annelida	Polychaeta	Sabellida	*Crucigera zygophora*	83
Annelida	Polychaeta	Sabellida	*Paradexiospira* sp.	58-221
Annelida	Polychaeta	Sabellida	*Protula pacifica*	84-224
Annelida	Polychaeta	Spionida	*Phyllochaetopterus prolifica*	34-69
Annelida	Polychaeta	Spionida	*Spiochaetopterus* cf *costarum*	84-223
Anthropoda	Malacostraca	Amphipoda	*Caprella* sp.	84
Anthropoda	Malacostraca	Decapoda	*Chionoecetes tanneri*	619-1138
Anthropoda	Malacostraca	Decapoda	*Chirostylidae* sp.	562-1145
Anthropoda	Malacostraca	Decapoda	*Chorilia longipes*	40-1140
Anthropoda	Malacostraca	Decapoda	*Elassochirus cavimanus*	194
Anthropoda	Malacostraca	Decapoda	*Lithodes couesi*	623-1141
Anthropoda	Malacostraca	Decapoda	*Oregonia gracilis*	167
Anthropoda	Malacostraca	Decapoda	*Pagurus kennerlyi*	46-259
Mollusca	Bivalvia	Pectinoida	*Crassadoma gigantea*	35-84
Mollusca	Cephalopoda	Octopoda	*Graneledone pacifica* (*boreopacifica*)	1145
Mollusca	Cephalopoda	Octopoda	*Octopus* sp.	436
Mollusca	Gastropoda	Archaeogastropoda	*Calliostoma annulatum*	34-187
Mollusca	Gastropoda	Archaeogastropoda	*Calliostoma ligatum*	34-187
Mollusca	Gastropoda	Neogastropoda	*Fusitriton oregonensis*	139-223
Mollusca	Gastropoda	Neogastropoda	*Ocinebrina lurida*	83-198
Mollusca	Gastropoda	Nudibranchia	*Doris montereyensis*	35
Mollusca	Gastropoda	Nudibranchia	Tritoniidae sp.	485-1000
Mollusca	Polyplacophora	Lepidopleurida	*Leptochiton rugatus*	34-84
Brachiopoda	Rhynchonellata	Terebratulida	*Laqueus californianus*	90-224
Bryozoa	-	-	Bryozoa sp.	180-207
Bryozoa	Gymnolaemata	Cheilostomatida	cf *Reginella hippocrepis*	41-84
Bryozoa	Stenolaemata	Cyclostomatida	*Disporella separata*	75-84
Echinodermata	Asteroidea	Brisingida	Brisingidae sp.	536-1139
Echinodermata	Asteroidea	Forcipulatida	*Ampheraster* sp.	544-944
Echinodermata	Asteroidea	Forcipulatida	*Leptasterias hexactis*	37-195
Echinodermata	Asteroidea	Forcipulatida	*Orthasterias koehleri*	196
Echinodermata	Asteroidea	Forcipulatida	*Pycnopodia helianthoides*	84-177
Echinodermata	Asteroidea	Forcipulatida	*Rathbunaster californicus*	102-617
Echinodermata	Asteroidea	Forcipulatida	*Stylasterias forreri*	180-202
Echinodermata	Asteroidea	Paxillosida	*Asteroidea* sp.	194-255
Echinodermata	Asteroidea	Paxillosida	*Pseudarchaster* sp.	436-790
Echinodermata	Asteroidea	Paxillosida	*Thrissacanthias* sp.	436-562

Phylum	Class	Order	Genus and species	Depths (m)
Echinodermata	Asteroidea	Spinulosida	*Henricia leviuscula*	37-91
Echinodermata	Asteroidea	Spinulosida	*Henricia sanguinolenta*	111-726
Echinodermata	Asteroidea	Valvatida	*Ceramaster patagonicus*	110-217
Echinodermata	Asteroidea	Valvatida	*Ceramaster* cf *stellatus*	172-218
Echinodermata	Asteroidea	Valvatida	*Crossaster papposus*	84-220
Echinodermata	Asteroidea	Valvatida	*Hippasteria phrygiana*	162-855
Echinodermata	Asteroidea	Valvatida	*Lophaster furcilliger*	95-154
Echinodermata	Asteroidea	Valvatida	*Solaster* cf *endeca*	123-255
Echinodermata	Asteroidea	Valvatida	*Solaster stimpsoni*	91
Echinodermata	Asteroidea	Velatida	*Pteraster* sp.	539-930
Echinodermata	Crinoidae	Comatulida	*Florometra serratissima*	84-749
Echinodermata	Echinoidea	Camarodonta	*Mesocentrotus franciscanus*	35-95
Echinodermata	Echinoidea	Camarodonta	*Strongylocentrotus pallidus*	160-208
Echinodermata	Holothuroidea	Aspidochirotida	*Apostichopus leukothele*	93-259
Echinodermata	Holothuroidea	Aspidochirotida	*Molpadia* sp.	678
Echinodermata	Holothuroidea	Dendrochirotida	*Psolus squamatus*	527-943
Echinodermata	Holothuroidea	Elasipodida	*Pannychia* cf *moseleyi*	533-937
Echinodermata	Ophiuroidea	Euryalida	*Asteronyx loveni*	165-259
Echinodermata	Ophiuroidea	Ophiurida	*Ophiopholis bakeri*	102-707
Echinodermata	Ophiuroidea	Ophiurida	*Ophiura sarsii*	166-259
Chordata	Ascidiacea		Ascidiacea sp.	34-209
Chordata	Actinopterygii	Gadiformes	*Antimora microlepis*	720-1118
Chordata	Actinopterygii	Gadiformes	cf *Coryphaenoides acrolepis*	608-1154
Chordata	Actinopterygii	Perciformes	*Chirolophis decoratus*	132-196
Chordata	Actinopterygii	Pleuronectiformes	*Citharichthys sordidus*	194-198
Chordata	Actinopterygii	Pleuronectiformes	*Embassichthys bathybius*	436-932
Chordata	Actinopterygii	Pleuronectiformes	*Glyptocephalus zachirus*	194-645
Chordata	Actinopterygii	Pleuronectiformes	*Lepidopsetta bilineata*	84-244
Chordata	Actinopterygii	Pleuronectiformes	*Microstomus pacificus*	199-627
Chordata	Actinopterygii	Scorpaeniformes	*Agonopsis vulsa*	137
Chordata	Actinopterygii	Scorpaeniformes	*Anoplopoma fimbria*	903-937
Chordata	Actinopterygii	Scorpaeniformes	Cottidae sp.	91-223
Chordata	Actinopterygii	Scorpaeniformes	*Hemilepidotus spinosus*	90-126
Chordata	Actinopterygii	Scorpaeniformes	*Paricelinus hopliticus*	91-256
Chordata	Actinopterygii	Scorpaeniformes	*Rhamphocottus richardsonii*	184
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes* spp.	84-555
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes aleutianus*	107-373
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes alutus*	164-258
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes elongatus*	214-215
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes emphaeus*	93-222
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes entomelas*	37-198
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes helvomaculatus*	84-259

Phylum	Class	Order	Genus and species	Depths (m)
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes melanostictus*	107-373
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes melanostomus*	556
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes mystinus*	84
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes rosaceus*	35-219
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes ruberrimus*	84-221
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes variegatus*	91-258
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes wilsoni*	110-221
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes zacentrus*	92-258
Chordata	Actinopterygii	Scorpaeniformes	*Sebastolobus* spp.	436-1147
Chordata	Elasmobranchii	Carcharhiniformes	*Apristurus brunneus*	883
Chordata	Elasmobranchii	Hexachiformes	*Hexanchus griseus*	185
Chordata	Elasmobranchii	Rajiformes	*Raja rhina*	196-242

Appendix C

Table C- 1. List of taxa observed during the 2000, 2011, and 2015 SGaan Kinghlas-Bowie Seamount surveys at 15 ROV and four AUV transects. Depth ranges are given for each taxon (Gauthier et al. 2017a,b,c).

Phylum	Class	Order	Genus and Species	Depth (m)
Ochrophyta	Phaeophyceae	-	Phaeophycea spp.	50
Rhodophyta	Florideophyceae	Corallinales	*Corallinaceae* spp.	29-92
Porifera	Demospongiae	-	Demospongiae sp. 1	635-1094
Porifera	Demospongiae	-	Demospongiae sp. 2	1058-1156
Porifera	Demospongiae	Axinellida	*Axinellidae* sp.	237
Porifera	Demospongiae	Desmacellid	*Desmacella* spp.	95-249
Porifera	Demospongiae	Poecilosclerida	*Asbestopluma* spp.	197-247
Porifera	Demospongiae	Poecilosclerida	*Esperiopsis* spp.	331-938
Porifera	Demospongiae	Poecilosclerida	*Hamigera* spp.	67-76
Porifera	Demospongiae	Poecilosclerida	*Isodictya* sp.	76-251
Porifera	Demospongiae	Polymastiida	*Polymastia* sp.	84-164
Porifera	Demospongiae	Tetractinellida	*Penares cortius*	29-951
Porifera	Demospongiae	Tetractinellida	*Poecillastra* sp.	591-918
Porifera	Hexactinellida	Hexactinosida	*Aphrocallistes vastus*	329-858
Porifera	Hexactinellida	Hexactinosida	*Heterochone calyx*	329-858
Porifera	Hexactinellida	Hexactinosida	*Chonelasma* spp. *(incl. Chonelasma oreia)*	602-773
Porifera	Hexactinellida	Hexactinosida	*Pinulasma* spp.	634-957
Porifera	Hexactinellida	Hexactinosida	*Farrea* spp.	634-966
Porifera	Hexactinellida	Hexactinosida	*Acanthascus* spp.*, Rhabdocalyptus* spp.*, & Staurocalyptus* spp.	97-1233
Porifera	Homoscleromorpha	-	Homoscleromorpha sp.	591-956
Cnidaria	Anthozoa	Actiniaria	Actiniaria sp. 1	NA
Cnidaria	Anthozoa	Actiniaria	Actiniaria sp. 2	NA
Cnidaria	Anthozoa	Actiniaria	*Cribrinopsis fernaldi*	48-565
Cnidaria	Anthozoa	Actiniaria	*Stomphia didemon*	69-219
Cnidaria	Anthozoa	Actiniaria	cf *Hormathiidae* sp.	335-435
Cnidaria	Anthozoa	Actiniaria	*Metridium* sp.	34-217
Cnidaria	Anthozoa	Actiniaria	*Liponema brevicorne*	330-413
Cnidaria	Anthozoa	Alcyonacea	Alcyonacea sp.	1211-1237
Cnidaria	Anthozoa	Alcyonacea	*Calcigorgia spiculifera*	201-261
Cnidaria	Anthozoa	Alcyonacea	*Anthomastus* sp.	738-1200
Cnidaria	Anthozoa	Alcyonacea	*Clavularia* sp.	428-483
Cnidaria	Anthozoa	Alcyonacea	*Isidella* sp.	330-1239
Cnidaria	Anthozoa	Alcyonacea	*Lepidisis* sp.	816-1169
Cnidaria	Anthozoa	Alcyonacea	*Paragorgia* sp.	241-960

Phylum	**Class**	**Order**	**Genus and Species**	**Depth (m)**
Cnidaria	Anthozoa	Alcyonacea	*Paragorgia arborea*	241-960
Cnidaria	Anthozoa	Alcyonacea	*Swiftia simplex*	781-809
Cnidaria	Anthozoa	Alcyonacea	*Swiftia* sp.	781-809
Cnidaria	Anthozoa	Alcyonacea	Primnoidae sp.	328-1173
Cnidaria	Anthozoa	Alcyonacea	*Primnoa* cf *pacifica*	242-731
Cnidaria	Anthozoa	Alcyonacea	Primnoidae sp. (yellow)	752-960
Cnidaria	Anthozoa	Antipatharia	Antipatharia sp.	738-966
Cnidaria	Anthozoa	Antipatharia	*Lillipathes* sp.	775-942
Cnidaria	Anthozoa	Pennatulacea	*Anthoptilum grandiflorum*	591-1096
Cnidaria	Anthozoa	Pennatulacea	*Halipteris willemoesi*	176-1047
Cnidaria	Anthozoa	Pennatulacea	*Ptilosarcus gurneyi*	76-170
Cnidaria	Anthozoa	Pennatulacea	*Umbellula* cf *lindahli*	704-1035
Cnidaria	Anthozoa	Pennatulacea	*Virgularia* sp.	420-930
Cnidaria	Anthozoa	Scleractinia	*Desmophyllum dianthus*	238-249
Cnidaria	Anthozoa	Scleractinia	*Balanophyllia elegans*	248
Cnidaria	Anthozoa	Zoantharia	Zoantharia sp.	29-183
Cnidaria	Hydrozoa	Leptothecata	*Abietinaria* sp.	67-248
Cnidaria	Hydrozoa	Anthoathecata	*Plumularia* spp.	29-33
Cnidaria	Hydrozoa	Anthoathecata	*Stylaster* spp.	45-251
Cnidaria	Hydrozoa	Anthoathecata	*Stylaster* sp. 1 (pink)	45-251
Cnidaria	Hydrozoa	Anthoathecata	Hydrocoral sp.1	NA
Cnidaria	Hydrozoa	Anthoathecata	Tubularia	78-173
Cnidaria	Hydrozoa	Anthoathecata	Hydroiza sp. 1	NA
Cnidaria	Hydrozoa	Anthoathecata	Hydroiza sp. 2	NA
Cnidaria	Hydrozoa	Anthoathecata	Bryozoan/Hydroid Morphotype	316-1196
Cnidaria	Schyphozoa	Coronatae	*Periphylla* sp.	449
Ctenophora	-	-	Ctenophora sp. 1	909-917
Annelida	Polychaeta	Sabellida	Serpulidae spp.	82-126
Annelida	Polychaeta	Terebellida	Terebellidae spp.	75-158
Arthropoda	Cirripedia	Sessilia	*Balanus nubilus*	29-40
Arthropoda	Malacostraca	Decapoda	*Glebocarcinus oregonensis*	85
Arthropoda	Malacostraca	Decapoda	*Romaleon branneri*	75-86
Arthropoda	Malacostraca	Decapoda	*Munida quadrispina*	54-728
Arthropoda	Malacostraca	Decapoda	Chirostylidae spp.	657-958
Arthropoda	Malacostraca	Decapoda	*Chorilia longipes*	194-236
Arthropoda	Malacostraca	Decapoda	*Acantholithodes hispidus*	246-251
Arthropoda	Malacostraca	Decapoda	*Lithodes aequispinus* & *Paralithodes camtschaticus*	251-770
Arthropoda	Malacostraca	Decapoda	*Lithodes aequispinus*	251
Arthropoda	Malacostraca	Decapoda	*Lopholithodes foraminatus*	236
Arthropoda	Malacostraca	Decapoda	*Majidae* spp.	67-232

Phylum	Class	Order	Genus and Species	Depth (m)
Arthropoda	Malacostraca	Decapoda	*Chionoecetes* (*Chionoecetes tanneri, Chionoecetes bairdi*)	309-1133
Arthropoda	Malacostraca	Decapoda	Paguridae sp.	36-220
Arthropoda	Malacostraca	Decapoda	Pandalidae spp.	87-1123
Arthropoda	Malacostraca	Decapoda	*Munidopsis quadrata*	339-1100
Mollusca	Bivalvia	Pectinoida	*Chlamys hastata*	83-97
Mollusca	Cephalopoda	Octopoda	*Graneledone boreopacifica*	833-934
Mollusca	Cephalopoda	Octopoda	Octopus sp.	420-930
Mollusca	Gastropoda	-	Gastropoda sp. 1	73-1220
Mollusca	Gastropoda	-	Gastropoda sp. 2	99
Mollusca	Gastropoda	Littorinimorpha	*Fusitriton oregonensis*	75-248
Mollusca	Gastropoda	Neogastropoda	*Muricidae* sp.	239-240
Mollusca	Gastropoda	Nudibranchia	*Dendronotus* sp.	105
Mollusca	Gastropoda	Nudibranchia	Dorididae sp.	92
Mollusca	Gastropoda	Nudibranchia	*Flabellina verrucosa*	84
Mollusca	Gastropoda	Nudibranchia	*Tritonia tetraquetra*	206-251
Mollusca	Polyplacophora	Chitonida	*Cryptochiton stelleri*	30
Mollusca	Polyplacophora	Chitonida	*Neoloricata* sp.	75
Brachiopoda	-	-	Brachiopoda sp.	157-248
Brachiopoda	Rhynchonellata	Terebratulida	*Laqueus californianus*	NA
Brachiopoda	Rhynchonellata	Terebratulida	Terebratalia sp.	NA
Bryozoa	Gymnolaemata	Cheilostomatida	*Bugulina californica*	38-222
Bryozoa	Gymnolaemata	Cheilostomatida	*Cellaria diffusa*	NA
Bryozoa	Gymnolaemata	Cheilostomatida	*Leieschara* sp.	NA
Bryozoa	Gymnolaemata	Cheilostomatida	*Phidolopora* sp.	NA
Bryozoa	Stenolaemata	Cyclostomatida	*Crisia* sp.	NA
Bryozoa	Stenolaemata	Cyclostomatida	*Heteropora* sp.	NA
Echinodermata	Asteroidea	Brisingida	Brisingidae sp.	443-1139
Echinodermata	Asteroidea	Forcipulatida	*Rathbunaster californicus*	65-227
Echinodermata	Asteroidea	Forcipulatida	*Stylasterias forreri*	69-410
Echinodermata	Asteroidea	Forcipulatida	*Ampheraster* sp.	69-410
Echinodermata	Asteroidea	Forcipulatida	*Pycnopodia helianthoides*	72-98
Echinodermata	Asteroidea	Notomyotida	*Cheiraster* (*Luidiaster*) *dawsoni* or *Nearchaster* sp.	408-912
Echinodermata	Asteroidea	Paxillosida	*Gephyreaster swifti*	145-153
Echinodermata	Asteroidea	Spinulosida	*Henricia leviuscula*	53-306
Echinodermata	Asteroidea	Spinulosida	*Henricia* sp.	29-1236
Echinodermata	Asteroidea	Valvatida	*Dermasterias imbricata*	29-177
Echinodermata	Asteroidea	Valvatida	*Goniasteridae* spp.	206-731
Echinodermata	Asteroidea	Valvatida	*Ceramaster patagonicus*	206-731
Echinodermata	Asteroidea	Valvatida	*Ceramaster* sp. or *Goniasteridae*	206-731

Phylum	Class	Order	Genus and Species	Depth (m)
Echinodermata	Asteroidea	Valvatida	*Hippasteria* sp.	145-958
Echinodermata	Asteroidea	Valvatida	*Hippasteria phrygiana*	145-237
Echinodermata	Asteroidea	Valvatida	*Mediaster aequalis*	54-172
Echinodermata	Asteroidea	Valvatida	*Poraniopsis* sp.	204-334
Echinodermata	Asteroidea	Valvatida	*Crossaster* sp.	406-427
Echinodermata	Asteroidea	Valvatida	*Crossaster papposus*	76-235
Echinodermata	Asteroidea	Valvatida	*Solaster* spp.	69-1123
Echinodermata	Asteroidea	Velatida	*Pteraster* sp.	341-1140
Echinodermata	Asteroidea	Velatida	*Pteraster* cf *militaris*	417-665
Echinodermata	Asteroidea	Velatida	*Pteraster tesselatus*	45-248
Echinodermata	Crinoidae	Comatulida	*Florometra serratissima*	116-1172
Echinodermata	Crinoidae	Comatulida	Crinoidea sp.	870-1093
Echinodermata	Echinoidea	Camarodonta	*Strongylocentrotus fragilis*	215-570
Echinodermata	Echinoidea	Camarodonta	*Strongylocentrotus pallidus*	79-163
Echinodermata	Holothuroidea	spidochirotida	*Apostichopus californicus*	69-101
Echinodermata	Holothuroidea	spidochirotida	*Apostichopus leukothele*	162-219
Echinodermata	Holothuroidea	Dendrochirotida	*Cucumaria* sp.	416
Echinodermata	Holothuroidea	Dendrochirotida	*Psolus* spp. or *P. squamatus*	97-1158
Echinodermata	Holothuroidea	Dendrochirotida	*Psolus chitonoides*	79-95
Echinodermata	Holothuroidea	Elasipodida	*Pannychia* cf *moseleyi*	310-1236
Echinodermata	Ophiuroidea	-	Ophiuroidea sp.	33-1233
Echinodermata	Ophiuroidea	Ophiurida	*Ophiacantha* sp.	176-498
Chordata	Ascidiacea	Aplousobranchia	*Distaplia occidentalis*	33-66
Chordata	Ascidiacea	Phlebobranchia	*Ciona savignyi*	186-236
Chordata	Ascidiacea	Stolidobranchia	*Cnemidocarpa finmarkiensis*	52-250
Chordata	Elasmobranchii	Rajiformes	*Raja binoculata*	92-236
Chordata	Elasmobranchii	Rajiformes	*Raja rhina*	76-242
Chordata	Holocephali	Chimaeriformes	*Hydrolagus colliei*	NA
Chordata	Actinopterygii	Gadiformes	*Gadus macrocephalus*	53-306
Chordata	Actinopterygii	Gadiformes	*Gadus chalcogrammus*	53-306
Chordata	Actinopterygii	Gadiformes	*Coryphaenoides acrolepis* & *Coryphaenoides armatus*	665-1224
Chordata	Actinopterygii	Perciformes	*Anarrhichthys ocellatus*	35
Chordata	Actinopterygii	Perciformes	*Bathymaster caeruleofasciatus*	29-218
Chordata	Actinopterygii	Perciformes	*Ronquilus jordani*	71-156
Chordata	Actinopterygii	Perciformes	*Pholis* sp.	222
Chordata	Actinopterygii	Perciformes	*Chirolophis decoratus*	240
Chordata	Actinopterygii	Perciformes	*Zaprora silenus*	42-177
Chordata	Actinopterygii	Perciformes	*Eelpout* spp.	580-805
Chordata	Actinopterygii	Pleuronectiformes	*Embassichthys bathybius*	327-1094
Chordata	Actinopterygii	Pleuronectiformes	*Lepidopsetta bilineata*	327-1094
Chordata	Actinopterygii	Pleuronectiformes	*Microstomus pacificus*	226-1094

Phylum	Class	Order	Genus and Species	Depth (m)
Chordata	Actinopterygii	Pleuronectiformes	*Hippoglossus stenolepis*	72-243
Chordata	Actinopterygii	Scorpaeniformes	*Agonidae* spp.	122-238
Chordata	Actinopterygii	Pleuronectiformes	*Xeneretumus latifrons*	273-324
Chordata	Actinopterygii	Scorpaeniformes	*Anoplopoma fimbria*	233-906
Chordata	Actinopterygii	Scorpaeniformes	*Cottidae* sp.	75-247
Chordata	Actinopterygii	Scorpaeniformes	*Hexagrammos decagrammus*	53-306
Chordata	Actinopterygii	Scorpaeniformes	*Ophiodon elongatus*	53-306
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes* spp.	325-458
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes babcocki*	259
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes borealis*	248
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes brevispinis*	33-221
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes crameri*	71-235
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes diploproa*	53-306
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes elongatus*	29-250
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes flavidus*	72-198
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes helvomaculatus*	59-298
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes melanostictus* & *Sebastes aleutianus*	60-449
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes nebulosus*	29
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes nigrocinctus*	38-257
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes paucispinis*	53-306
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes proriger*	34-256
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes reedi*	193-239
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes ruberrimus*	29-326
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes rufus*	186-483
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes variegatus*	35-327
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes zacentrus*	85-204
Chordata	Actinopterygii	Scorpaeniformes	*Sebastolobus* spp.	306-1173

Appendix D

Table D- 1. Species captured at Dellwood Seamount during groundfish surveys, 1991-2014 (summary of catch data courtesy of Lisa Lacko).

Phylum	Class	Order	Scientific name	Species	Caught weight (kg)	Number caught	COSEWIC Status	SARA Status	IUCN Status
Chordata	Actinopterygii	n/a	n/a	Unknown Fish	-	29	n/a	n/a	n/a
Chordata	Actinopterygii	Pleuronectiformes	*Atheresthes stomias*	Arrowtooth Flounder	-	790	n/a	n/a	n/a
Chordata	Actinopterygii	Pleuronectiformes	*Hippoglossus stenolepis*	Pacific Halibut	21054.2	-	n/a	n/a	n/a
Chordata	Actinopterygii	Scorpaeniformes	*Ophiodon elongatus*	Lingcod	139	-	n/a	n/a	n/a
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes babcocki*	Redbanded Rockfish	467.1	-	n/a	n/a	n/a
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes aleutianus*	Rougheye Rockfish	265	-	Special Concern	Special Concern	n/a
Chordata	Actinopterygii	Scorpaeniformes	*Anoplopoma fimbria*	Sablefish	24764.4	-	n/a	n/a	n/a
Chordata	Actinopterygii	Scorpaeniformes	*Sebastolobus alascanus*	Shortspine Thornyhead	76.1	-	n/a	n/a	Endangered
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes brevispinis*	Silvergray Rockfish	28.6	-	n/a	n/a	n/a
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes ruberrimus*	Yelloweye Rockfish	373.1	-	Special Concern	Special Concern	n/a
Chordata	Elasmobranchii	Rajiformes	*Raja binoculata*	Big Skate	79.9	7	Not at Risk	n/a	Near Threatened
Chordata	Elasmobranchii	Rajiformes	*Raja rhina*	Longnose Skate	806.8	-	Not at Risk	n/a	Least Concern
Chordata	Elasmobranchii	Rajiformes	-	Sandpaper Skate	-	2	Not at Risk	n/a	Data Deficient
Chordata	Elasmobranchii	Squaliformes	*Squalus acanthias*	Spiny Dogfish	534.1	415	Special Concern	n/a	n/a

Appendix E

Table E 1. Species captured at Union Seamount during groundfish surveys, 1991-2014 (summary of catch data courtesy of Lisa Lacko).

Phylum	Class	Order	Scientific Name	Species	Caught weight (kg)	Number caught	COSEWIC Status	SARA Status	IUCN Status
Actinopterygii	Pleuronectiformes	Pleuronectidae	*Hippoglossus stenolepis*	Pacific Halibut	112.1	2	n/a	n/a	n/a
Actinopterygii	Scorpaeniformes	Sebastidae	*Sebastes alutus*	Pacific Ocean Perch	-	1	n/a	n/a	n/a
Arthropoda	Malacostraca	Decapoda	*Paralithodes sp./Lithodes sp.*	Alaskan King Crabs	2316	-	n/a	n/a	n/a
Arthropoda	Malacostraca	Decapoda	-	Crabs	369.6	248	n/a	n/a	n/a
Arthropoda	Malacostraca	Decapoda	-	Red Queen Crab	257.5	402	n/a	n/a	n/a
Arthropoda	Malacostraca	Decapoda	-	Tanner Crabs	188.1	638	n/a	n/a	n/a
Arthropoda	Malacostraca	Decapoda	-	True Crabs	3454.4	-	n/a	n/a	n/a
Chordata	Actinopterygii	-	-	Unknown Fish	108.3	2	n/a	n/a	n/a
Chordata	Actinopterygii	Gadiformes	*Albatrossia pectoralis*	Giant Grenadier	10	-	n/a	n/a	n/a
Chordata	Actinopterygii	Gadiformes	*Macrouridae* spp.	Grenadiers	64	260	n/a	n/a	n/a
Chordata	Actinopterygii	Gadiformes	*Gadus microcephalus*	Pacific Cod	-	1	n/a	n/a	n/a
Chordata	Actinopterygii	Perciformes	*Zaprora silenus*	Prowfish	-	1	n/a	n/a	n/a
Chordata	Actinopterygii	Pleuronectiformes	*Embassichthys bathybius*	Deepsea Sole	1	-	n/a	n/a	n/a
Chordata	Actinopterygii	Pleuronectiformes	*Microstomus pacificus*	Dover Sole	2.8	1	n/a	n/a	n/a
Chordata	Actinopterygii	Pleuronectiformes	*Pleuronectiformes* sp.	Flatfishes	4.1	1	n/a	n/a	n/a
Chordata	Actinopterygii	Pleuronectiformes	*Lepidopsetta bilineata*	Rock Sole	21	-	n/a	n/a	n/a
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes aurora*	Aurora Rockfish	0.3	-	n/a	n/a	n/a
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes pinniger*	Canary Rockfish	-	2	Threatened	n/a	n/a
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes goodei*	Chilipepper Rockfish	-	2	n/a	n/a	n/a
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes babcocki*	Redbanded Rockfish	173.5	-	n/a	n/a	n/a
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes helvomaculatus*	Rosethorn Rockfish	175.2	-	n/a	n/a	n/a
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes aleutianus*	Rougheye Rockfish	879780.7	-	Special Concern	Special Concern	n/a
Chordata	Actinopterygii	Scorpaeniformes	*Anoplopoma fimbria*	Sablefish	219788.9	-	n/a	n/a	n/a
Chordata	Actinopterygii	Scorpaeniformes	*Scorpaenidae* spp.	Scorpionfishes	10333.8	-	n/a	n/a	n/a
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes borealis*	Shortraker Rockfish	533.5	1	n/a	n/a	n/a
Chordata	Actinopterygii	Scorpaeniformes	*Sebastolobus alascanus*	Shortspine Thornyhead	193.4	-	n/a	n/a	Endangered
Chordata	Actinopterygii	Scorpaeniformes	*Erilepis zonifer*	Skilfish	1.3	-	n/a	n/a	n/a
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes entomelas*	Widow Rockfish	19.5	-	n/a	n/a	n/a
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes ruberrimus*	Yelloweye Rockfish	185.1	-	Special Concern	Special Concern	n/a
Chordata	Actinopterygii	Scorpaeniformes	*Sebastes reedi*	Yellowmouth Rockfish	1.8	-	Threatened	n/a	n/a
Chordata	Elasmobranchii	Carcharhiniformes	*Prionace glauca*	Blue Shark	-	1	Special Concern	n/a	Near Threatened
Chordata	Elasmobranchii	Squaliformes	*Somniosus pacificus*	Pacific Sleeper Shark	50	1	n/a	n/a	Data Deficient
Cnidaria	-	-	-	Jellyfish	44	-	n/a	n/a	n/a
Cnidaria	Anthozoa	Scleratinia	-	Stony Corals	1	-	n/a	n/a	n/a

Phylum	Class	Order	Scientific Name	Species	Caught weight (kg)	Number caught	COSEWIC Status	SARA Status	IUCN Status
Echinodermata	Asteroidea	-	-	Starfish	-	20	n/a	n/a	n/a
Echinodermata	Ophiuroidea	-	-	Ophiurae	6	-	n/a	n/a	n/a
Mollusca	Cephalopoda	Octopoda	*Enteroctopus dofleini*	Giant Pacific Octopus	6.3	-	n/a	n/a	n/a
Mollusca	Cephalopoda	Octopoda	-	Octopus	3	13	n/a	n/a	n/a
Mollusca	Gastropoda	-	-	Gastropods	11.9	2	n/a	n/a	n/a
Porifera	-	-	-	Sponges	-	1	n/a	n/a	n/a

Appendix F

5 meter models (scale 0 to 0.3 m/s current velocity)

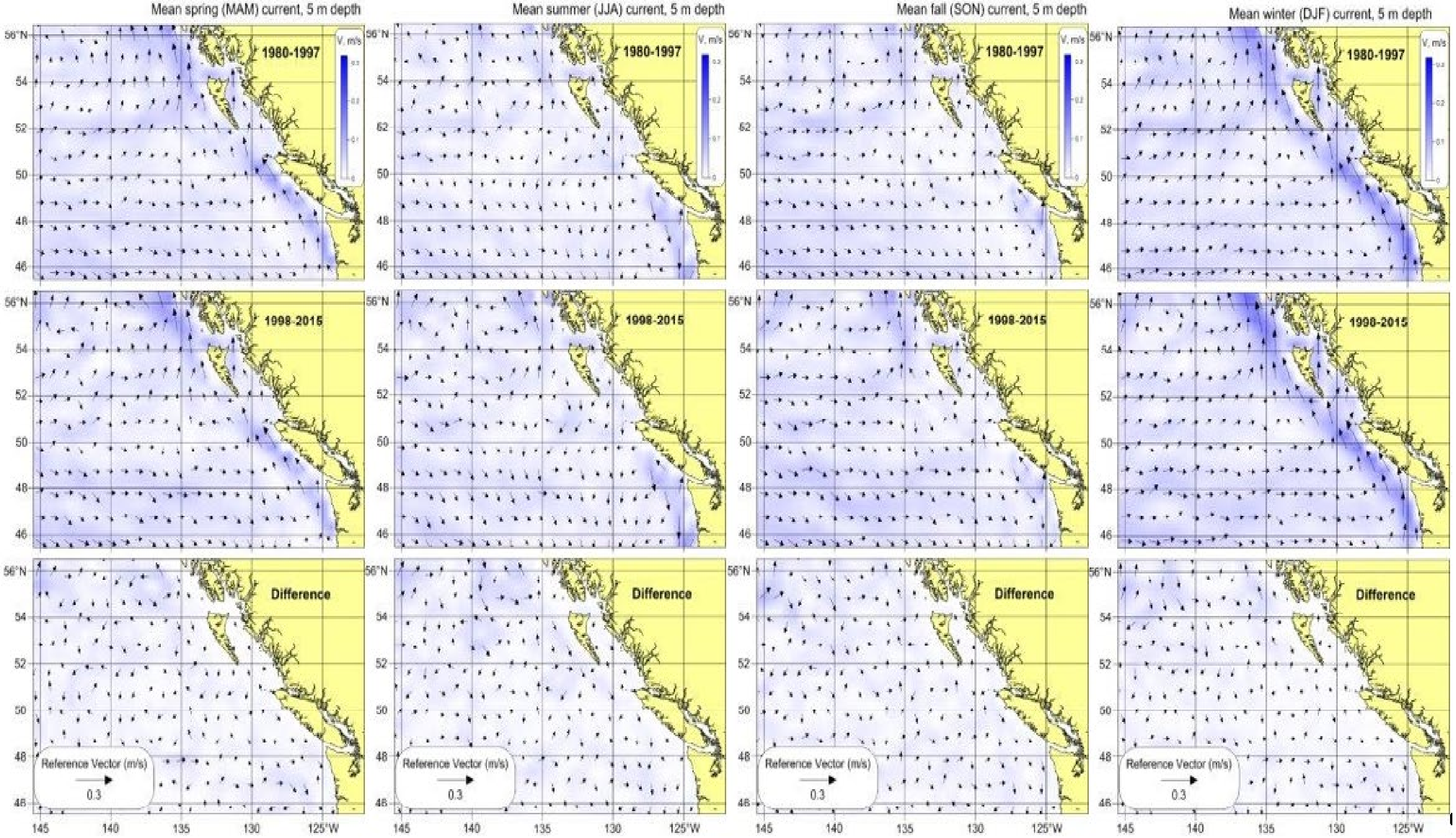


Figure F 1. Horizontal maps of currents at 5 m, 100 m, 300 m, 500 m, 1000 m, 1500 m and 2000 m for four seasons (1980-1997,1998-2015, difference between the two time periods)100 meter models (scale 0 to 0.2 m/s current velocity)

100 meter models (scale 0 to 0.2 m/s current velocity)

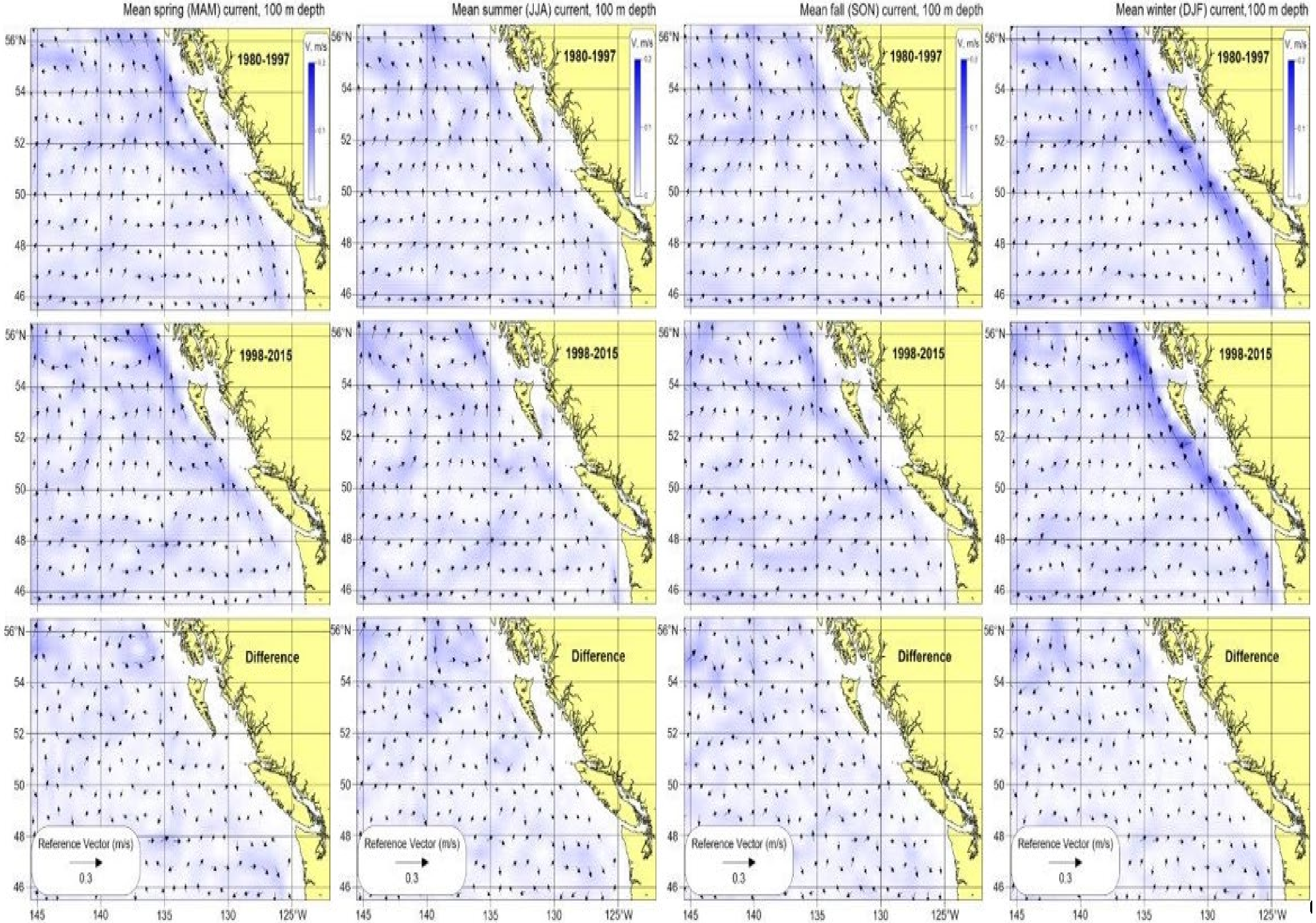


Figure F.1 continued

300 meter models (scale 0 to 0.2 m/s current velocity)

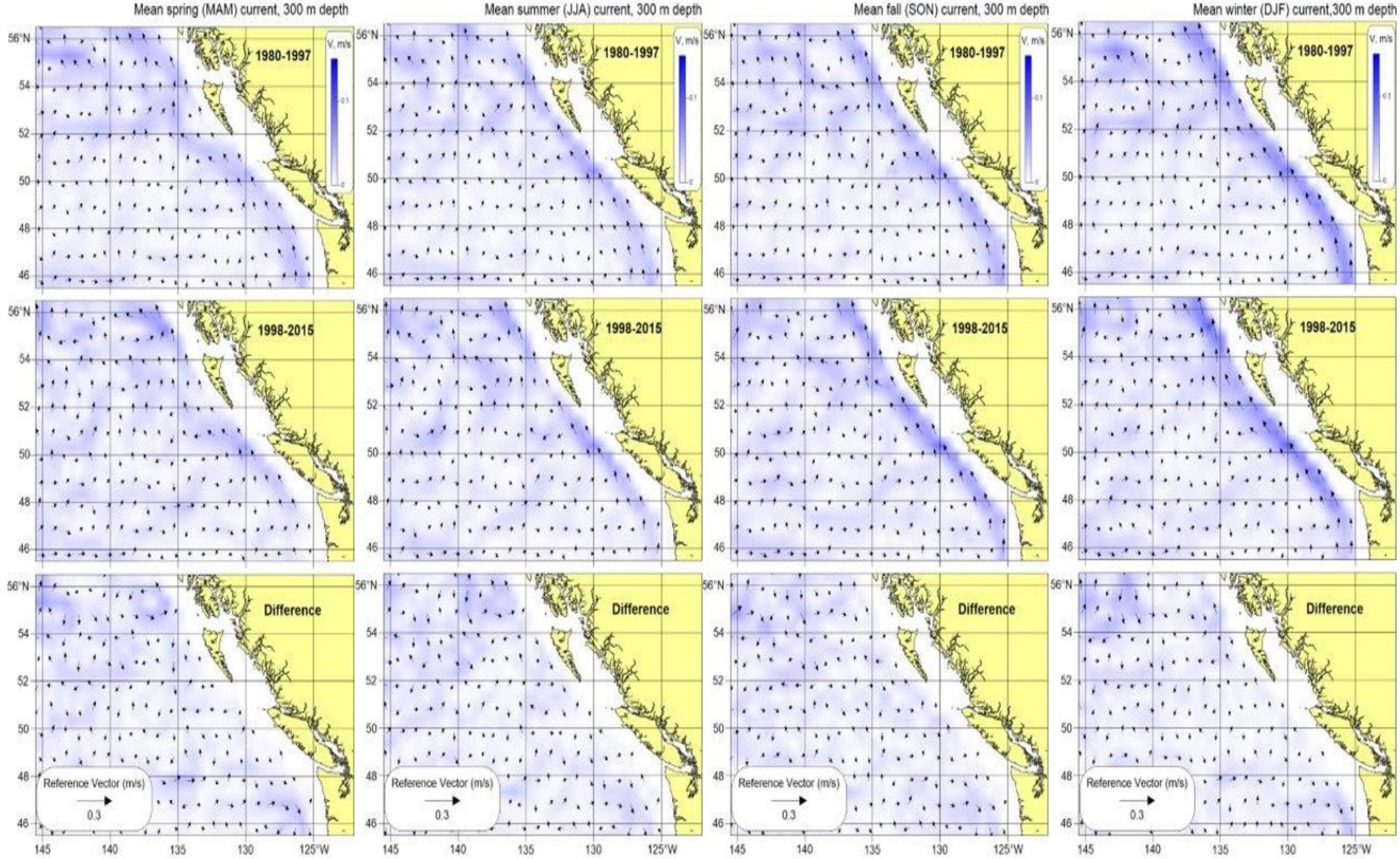
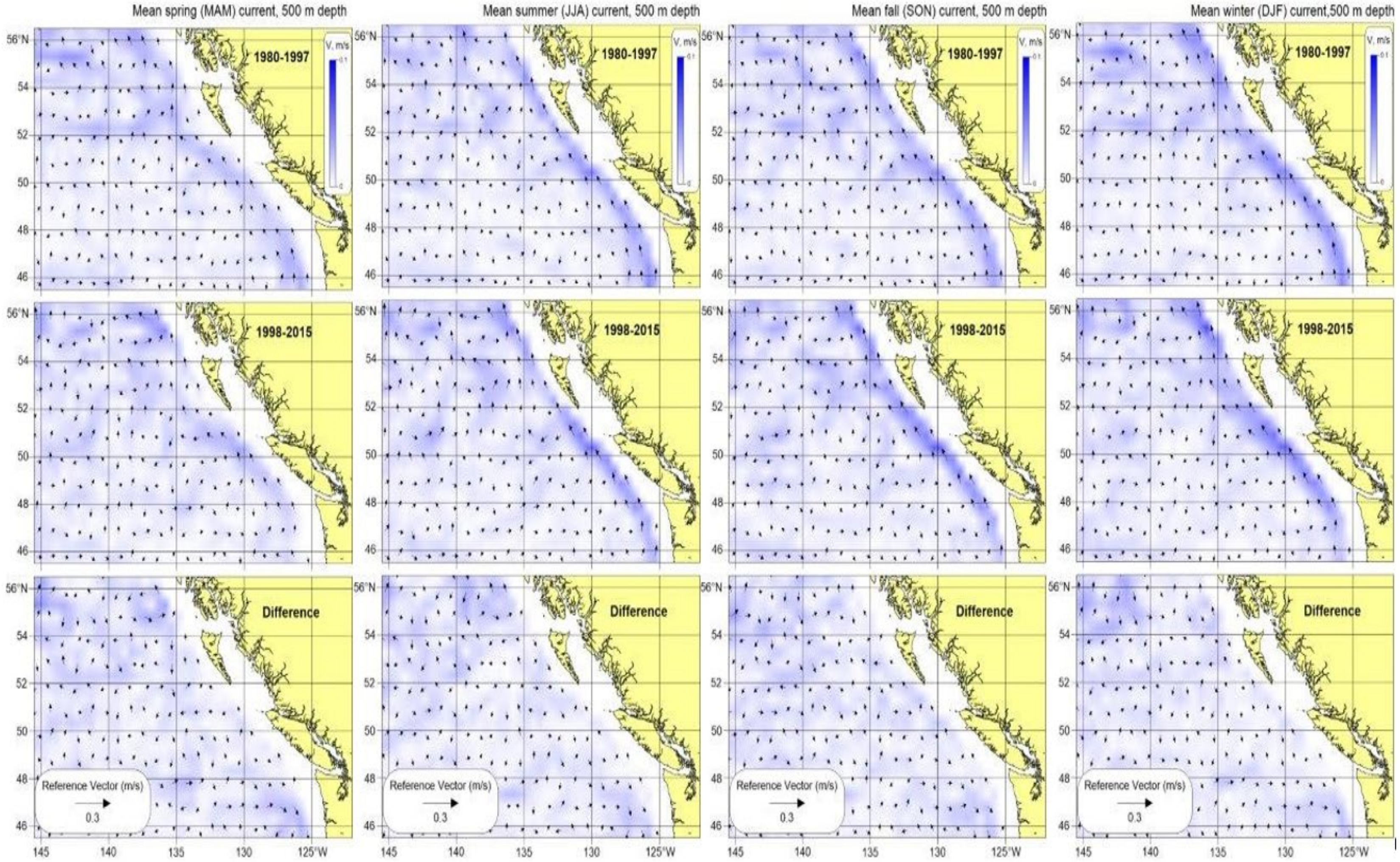


Figure F.1 continued

500 meter models (scale 0 to 0.1 m/s current velocity)


Mean spring (MAM) current, 500 m depth

Mean summer (JJA) current, 500 m depth

Mean fall (SON) current, 500 m depth

Mean winter (DJF) current,500 m depth

Figure F.1 continued

5 meter models (scale 0 to 0.05 m/s current velocity)

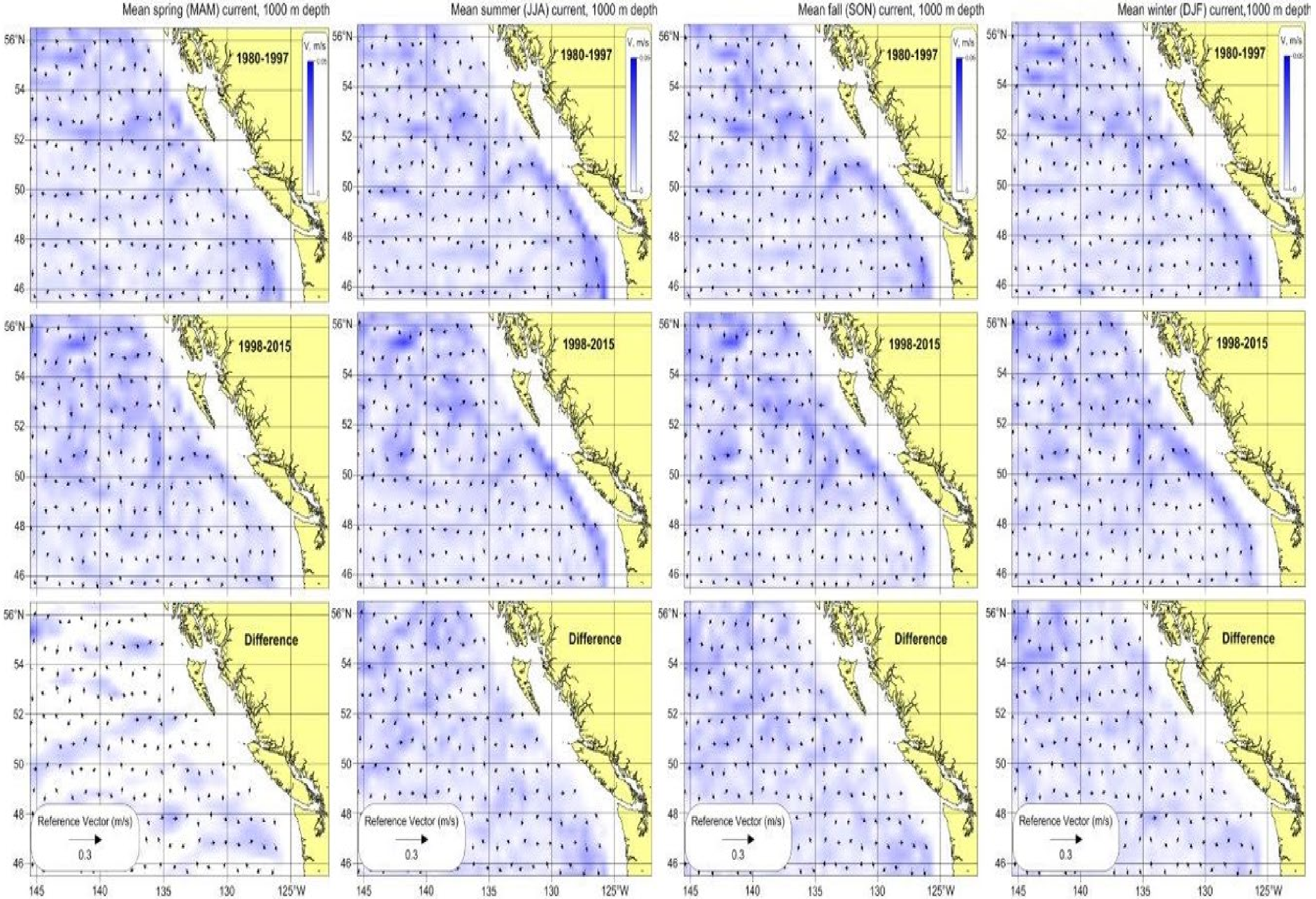


Figure F.1 continued

5 meter models (scale 0 to 0.03 m/s current velocity)

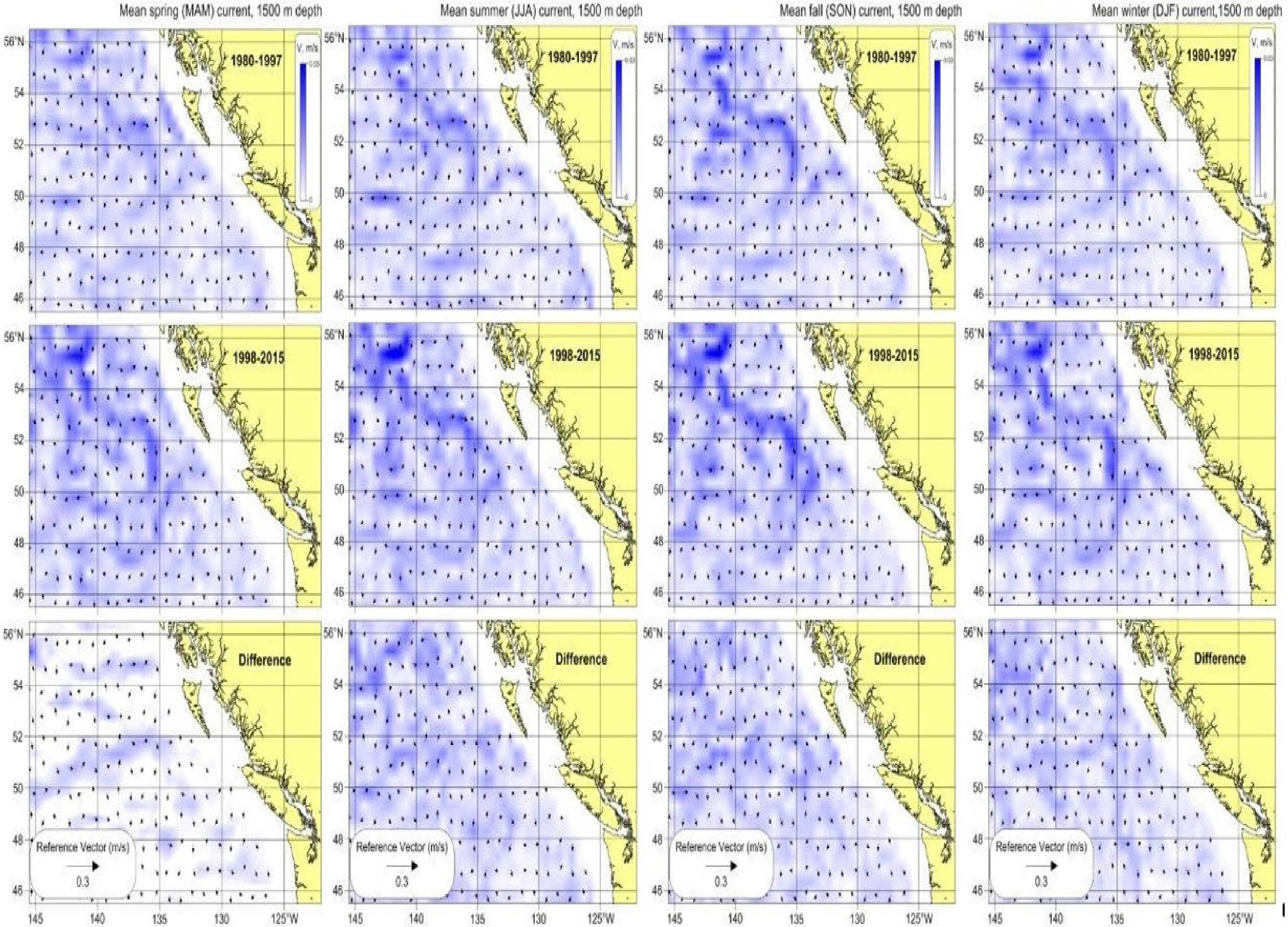


Figure F.1 continued

5 meter models (scale 0 to 0.02 m/s current velocity)

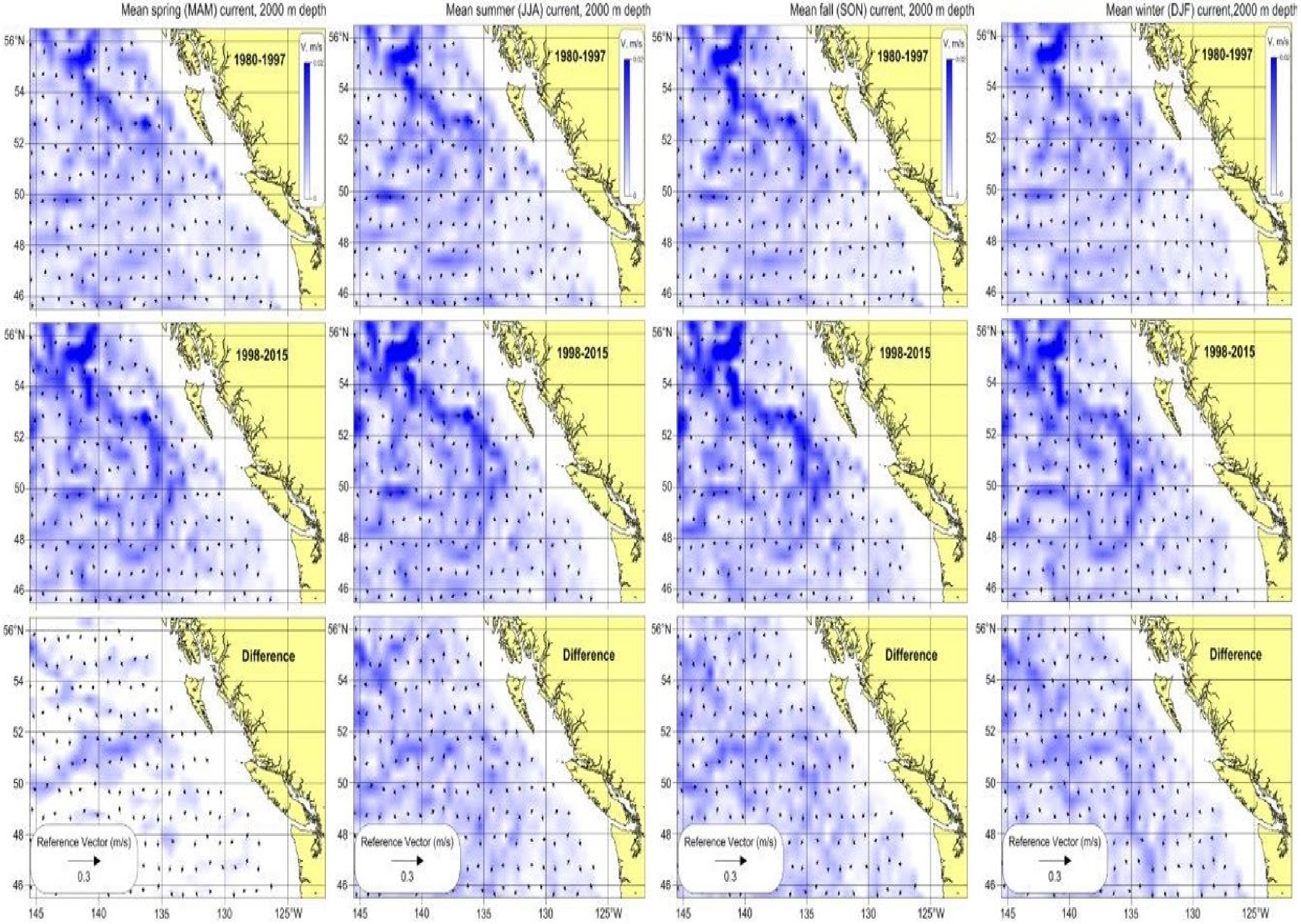


Figure F.1 continued

Appendix G

Table G.1. This table list the Calanoid copepods that were found in the West Coast Vancouver Island (WCVI) samples collected by the Department of Fisheries Ocean Surveys (Moira Galbraith, pers. comm. DFO, Institute of Ocean Sciences, Sidney, BC)

Genus	Species	Shelf	Shelf Break	Slope	Oceanic	Inlet & Straits	Abundance
Acartia	californiensis	x	-	-	-	-	rare
Acartia	danae	-	-	x	x	-	rare
Acartia	hudsonica	x	-	-	-	x	common
Acartia	longiremis	x	x	-	-	x	common
Acartia	tonsa	x	x	-	-	-	can be common, usually rare
Acartia	tumida	x	-	-	-	-	rare
Aetideopsis	multiserrata	-	-	x	x	-	rare
Aetideopsis	rostrata	-	-	x	x	-	rare
Aetideus	arcuatus	-	-	x	x	-	rare
Aetideus	armatus	x	-	-	-	-	-
Aetideus	bradyi	x	-	-	-	-	-
Aetideus	divergens	-	-	-	-	x	always in low numbers
Aetideus	pacificus	-	x	x	x	-	always in low numbers
Azygokeras	columbiae	-	-	-	-	x	rare
Bradyidius	saanichi	-	-	-	-	x	always in low numbers
Bradyidius	similis	-	-	x	x	x	always in low numbers
Chiridiella	pacifica	-	-	x	x	-	always in low numbers
Chiridiella	reducta	-	-	x	x	-	rare
Chiridius	gracilis	-	-	-	x	x	always in low numbers
Chiridius	obtusifrons	-	-	x	X	-	rare
Chiridius	pacificus	-	-	x	x	-	rare
Chirundina	alaskaensis	-	x	x	x	-	rare
Chirundina	streetsii	-	x	x	x	-	always in low numbers
Euchirella	bitumida	-	-	x	x	-	rare
Euchirella	curticauda	-	-	x	x	-	rare
Euchirella	formosa	-	-	x	x	-	rare
Euchirella	grandicornis	-	-	x	x	-	rare
Euchirella	maxima	-	-	x	x	-	rare
Euchirella	pseudopulchra	-	x	x	-	-	always in low numbers
Euchirella	rostrata	-	x	x	-	-	rare
Gaetanus	antarcticus	-	-	-	x	-	rare
Gaetanus	armiger	-	-	-	x	-	rare
Gaetanus	brevicornis	-	-	X	x	-	rare
Gaetanus	brevirostris	-	-	X	x	-	rare
Gaetanus	brevispinus	-	-	-	x	-	rare
Gaetanus	kruppii	-	-	x	x	-	rare
Gaetanus	miles	-	-	x	x	-	rare
Gaetanus	minor	-	-	x	x	-	Rare

Genus	Species	Shelf	Shelf Break	Slope	Oceanic	Inlet & Straits	Abundance
Gaetanus	minutus	-	x	-	-	x	common
Gaetanus	pileatus	-	-	x	x	-	rare
Gaetanus	pungens	-	-	x	x	-	rare
Gaetanus	robustus	-	-	x	x	-	rare
Gaetanus	secundus	-	-	x	x	x	rare
Gaetanus	simplex	-	x	x	-	-	common
Gaetanus	tenuispinus	-	x	x	-	x	always in low numbers
Pseudochirella	obtusa	-	-	-	x	-	rare
Pseudochirella	pacifica	-	-	-	x	-	rare
Pseudochirella	tanakai	-	-	-	x	-	rare
Undeuchaeta	intermedia	-	-	x	x	-	rare
Undeuchaeta	major	-	-	x	x	-	rare
Undeuchaeta	plumosa	-	-	-	x	-	rare
Valdiviella	brevicornis	-	-	-	x	-	rare
Valdiviella	imperfecta	-	-	-	x	-	rare
Arietellus	giesbrechti	-	-	-	x	-	rare
Arietellus	pacificus	-	-	-	x	-	rare
Arietellus	plumifer	-	-	x	x	-	always in low numbers
Arietellus	setosus	-	-	x	x	-	rare
Arietellus	simplex	-	-	x	x	-	rare
Augaptilus	cornutus	-	-	x	x	-	rare
Augaptilus	glacialis	-	x	x	x	-	always in low numbers
Augaptilus	longicaudatus	-	-	-	x	-	rare
Centraugaptilus	macrodus	-	-	-	x	-	rare
Centraugaptilus	porcellus	-	-	-	x	-	rare
Centraugaptilus	horridus	-	-	-	x	-	rare
Euaugaptilus	angustus	-	-	-	x	-	rare
Euaugaptilus	filigerus	-	-	-	x	-	rare
Euaugaptilus	graciloides	-	-	-	x	-	rare
Euaugaptilus	laticeps	-	-	-	x	-	rare
Euaugaptilus	mixtus	-	-	-	x	-	rare
Euaugaptilus	nodifrons	-	x	x	x	-	always in low numbers
Euaugaptilus	oblongus	-	-	x	x	-	rare
Euaugaptilus	rigidus	-	-	x	x	-	rare
Euaugaptilus	rostratus	-	-	x	x	-	rare
Haloptilus	acutifrons	-	-	x	x	-	rare
Haloptilus	longiceps	-	-	x	x	-	rare
Haloptilus	longicirrus	-	-	x	x	-	rare
Haloptilus	longicornis	-	-	x	x	-	rare
Haloptilus	oxycephalus	-	-	x	x	-	always in low numbers
Haloptilus	pseudooxycephalus	-	-	x	x	-	always in low numbers
Haloptilus	validus	-	-	-	x	-	rare
Pseudhaptilus	abbreviatus	-	-	-	x	-	rare
Pseudhaptilus	eurygnathus	-	-	-	x	-	rare

Genus	Species	Shelf	Shelf Break	Slope	Oceanic	Inlet & Straits	Abundance
Pseudhaptilus	pacificus	-	-	-	x	-	rare
Temorites	brevis	-	-	-	x	-	rare
Calanus	marshallae	x	x	-	-	x	common
Calanus	pacificus	-	x	x	x	x	common
Mesocalanus	tenuicornis	-	x	x	-	-	common
Neocalanus	cristatus	-	x	x	x	x	common
Neocalanus	flemingeri	-	x	x	x	-	common
Neocalanus	plumchrus	-	x	x	x	x	common
Candacia	bipinnata	-	x	x	x	-	always in low numbers
Candacia	columbiae	-	x	x	x	x	always in low numbers
Centropages	abdominalis	x	x	-	-	x	common
Centropages	bradyi	x	x	-	-	-	rare
Phaenna	spinifera	-	-	x	x	-	rare
Clausocalanus	arcuicornis	x	x	x	-	-	common
Clausocalanus	dubius	x	x	x	-	-	rare
Clausocalanus	furcatus	x	x	x	-	-	rare
Clausocalanus	lividus	-	x	x	x	-	common
Clausocalanus	parapergens	x	x	x	-	-	common
Clausocalanus	paululus	x	x	x	-	-	rare
Clausocalanus	pergens	x	x	x	-	-	common
Ctenocalanus	vanus	x	x	x	-	-	common
Microcalanus	pusillus	-	-	x	x	x	common
Microcalanus	pygmaeus	-	-	x	x	x	common
Pseudocalanus	major	x	-	-	-	-	rare
Pseudocalanus	mimus	x	x	-	-	-	common
Pseudocalanus	minutus	x	-	-	x	x	common
Pseudocalanus	moultoni	x	-	-	-	x	common
Pseudocalanus	newmani	x	-	-	-	x	common
Eucalanus	bungii	-	x	x	x	x	common
Eucalanus	californicus	-	x	x	x	-	common
Eucalanus	hyalinus	-	-	x	x	-	rare
Pareucalanus	parki	-	-	-	x	-	rare
Euchaeta	media	-	x	x	-	-	rare
Euchaeta	spinosa	-	x	x	-	-	rare
Paraeuchaeta	antarctica	-	-	x	x	-	rare
Paraeuchaeta	barbata	-	-	x	x	-	rare
Paraeuchaeta	birostrata	-	-	x	x	-	always in low numbers
Paraeuchaeta	californica	-	-	x	x	-	always in low numbers
Paraeuchaeta	elongata	-	x	x	x	x	common
Paraeuchaeta	pavlovskii	-	-	-	x	-	rare
Paraeuchaeta	rubra	-	-	-	x	-	always in low numbers
Paraeuchaeta	tuberculata	-	-	-	x	-	rare
Paraeuchaeta	spinosa	-	-	-	x	-	rare
Paraeuchaeta	tonsa	-	-	-	x	-	rare

Genus	Species	Shelf	Shelf Break	Slope	Oceanic	Inlet & Straits	Abundance
Disseta	grandis	-	-	-	x	-	rare
Disseta	maxima	-	-	-	x	-	rare
Disseta	palumboi	-	-	-	x	-	rare
Disseta	scopularis	-	-	-	x	-	always in low numbers
Heterorhabdus	abyssalis	-	-	-	x	-	rare
Heterorhabdus	clausi	-	-	-	x	-	rare
Heterorhabdus	compactus	-	-	-	x	-	rare
Heterorhabdus	pacificus	-	-	x	x	-	rare
Heterorhabdus	papilliger	-	x	x	x	-	always in low numbers
Paraheterorhabdus	robustus	-	-	x	x	-	always in low numbers
Heterorhabdus	spinifrons	-	-	x	x	-	always in low numbers
Heterorhabdus	tanneri	-	x	x	x	x	common
Heterostylites	longicornis	-	-	x	x	-	always in low numbers
Heterostylites	major	-	-	x	x	-	always in low numbers
Lucicutia	anomala	-	-	-	x	-	rare
Lucicutia	bicornuta	-	-	x	x	-	always in low numbers
Lucicutia	curta	-	-	-	x	-	rare
Lucicutia	flavicornis	-	x	x	x	-	always in low numbers
Lucicutia	grandis	-	-	-	x	-	rare
Lucicutia	lucida	-	-	-	x	-	rare
Lucicutia	magna	-	-	-	x	-	rare
Lucicutia	ovalis	-	-	x	x	-	always in low numbers
Lucicutia	pacifica	-	-	-	x	-	always in low numbers
Bathycalanus	bradyi	-	-	-	x	-	rare
Megacalanus	longicornis	-	-	-	x	-	rare
Gaussia	intermedia	-	-	-	x	-	always in low numbers
Gaussia	princeps	-	-	-	x	-	rare
Metridia	assymetrica	-	-	-	x	-	always in low numbers
Metridia	brevicauda	-	-	x	x	-	rare
Metridia	curticauda	-	-	x	x	-	always in low numbers
Metridia	longa	-	-	x	x	-	rare
Metridia	okhotensis	-	-	-	-	x	can be common
Metridia	ornata	-	-	x	x		rare
Metridia	pacifica	-	x	x	x	x	common
Metridia	princeps	-	-	-	x	-	always in low numbers
Metridia	similis	-	-	x	x	-	rare
Pleuromamma	abdominalis	-	x	x	x	-	always in low numbers
Pleuromamma	borealis	-	x	x	x	-	rare
Pleuromamma	gracilis	-	-	x	x	-	rare
Pleuromamma	quadrungulata	-	x	x	x	-	always in low numbers
Pleuromamma	robusta	-	-	x	x	-	always in low numbers
Pleuromamma	scutullata	-	x	x	x	-	common
Pleuromamma	xiphias	-	-	-	x	-	always in low numbers
Nullosetigera	bidentatus	-	-	-	x	-	always in low numbers

Genus	Species	Shelf	Shelf Break	Slope	Oceanic	Inlet & Straits	Abundance
Nullosetigera	integer	-	-	-	x	-	rare
Nullosetigera	impar	-	-	-	x	-	rare
Nullosetigera	helgae	-	-	-	x	-	rare
Calocalanus	pavoninus	-	x	x	x	-	rare
Calocalanus	styliremis	-	x	x	x	-	rare
Calocalanus	tenuis	-	x	x	x	-	rare
Paracalanus	indicans	x	x	-	-	x	common
Paracalanus	parvus	x	x	-	-	x	common
Paracalanus	quasimodo	x	x	-	-	-	rare
Cornucalanus	chelifer	-	-	-	x	-	rare
Cornucalanus	indicus	-	-	-	x	-	rare
Onchocalanus	cristatus	-	-	-	x	-	rare
Onchocalanus	magnus	-	-	-	x	-	rare
Xanthocalanus	borealis	-	-	-	x	-	rare
Xanthocalanus	maximus	-	-	-	x	-	rare
Epilabidocera	longipedata	x	x	-	-	x	common
Rhinocalanus	nasuta	-	-	x	x	-	rare
Lophothrix	frontalis	-	-	x	x	-	always in low numbers
Racovitzanus	antarcticus	-	-	x	x	x	common
Scaphocalanus	affinis	-	-	x	x	-	rare
Scaphocalanus	brevicornis	-	-	x	x	x	common
Scaphocalanus	echinatus	-	-	x	x	x	common
Scaphocalanus	insignis	-	-	x	x	-	rare
Scaphocalanus	magnus	-	-	x	x	-	always in low numbers
Scaphocalanus	major	-	-	x	x	-	rare
Scaphocalanus	subbrevicornis	-	-	x	x	-	always in low numbers
Scolecithricella	auropecten	-	-	-	x	-	rare
Scolecithricella	dentata	-	-	-	x	-	rare
Scolecithricella	emarginata	-	-	x	x	-	always in low numbers
Scolecithricella	globulosa	-	-	x	x	-	always in low numbers
Scolecithricella	minor	x	x	x	x	x	common
Scolecithricella	ovata	-	-	-	x	-	always in low numbers
Scolecithricella	valida	-	-	-	x	-	rare
Scolecithrix	danae	-	-	-	x	-	rare
Scottocalanus	persecans	-	-	-	x	-	rare
Scottocalanus	securifrons	-	-	-	x	-	rare
Spinocalanus	abyssalis	-	-	x	x	x	always in low numbers
Spinocalanus	brevicaudatus	-	-	x	x	x	common
Spinocalanus	horridus	-	-	x	x	-	always in low numbers
Spinocalanus	longicornis	-	-	x	x	x	common
Spinocalanus	longispinus	-	-	x	x	-	rare
Spinocalanus	magnus	-	-	x	x	-	always in low numbers
Spinocalanus	similis	-	-	x	x	-	rare
Spinocalanus	stellatus	-	-	x	x	-	rare

Genus	Species	Shelf	Shelf Break	Slope	Oceanic	Inlet & Straits	Abundance
Tharybis	fultoni	-	-	-	-	x	common
Undinella	acuta	-	-	-	x	-	always in low numbers
Tortanus	discaudatus	x	x	-	-	x	common

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