2012 Expedition to Cobb Seamount: Survey Methods, Data Collections, and Species Observations

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2012 EXPEDITION TO COBB SEAMOUNT: SURVEY METHODS, DATA COLLECTIONS, AND SPECIES OBSERVATIONS

By

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Table of Contents

List of Tables

List of Figures

Abstract

Curtis, J.M.R., Du Preez, C., Davies, 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. 3124: xii + 145 p.

Cobb Seamount was discovered in 1950 and has been the site of biological, geological, and oceanographic research, as well as several commercial fisheries. This report reviews the history of Cobb Seamount and describes the methodology and data collected during a scientific survey of Cobb Seamount (46° 44′ 24″ N, 130° 48′ 0″ W) led jointly by Fisheries and Oceans Canada (DFO) and the United States National Oceanographic and Atmospheric Agency (NOAA) from 21-26 July 2012 (DFO Science Cruise Number PAC 2012-43). The survey objectives were to collect data to: (a) characterize the benthic community structure; (b) map the distribution of vulnerable marine ecosystem (VME) indicators taxa (e.g. corals, sponges, and other structure-forming species); and (c) document any evidence of lost fishing gear and its observable impacts. The survey involved use of two remotely operated vehicles (ROVs) capable of diving to 220 m and 550 m, respectively, and an autonomous underwater vehicle (AUV) capable of diving to 1400 m. Additionally, oceanographic and hydroacoustic data were collected to characterize the physical and biological attributes of the pelagic zone above Cobb Seamount, and the relative abundance and distribution of seabirds and marine mammals along the cruise track were documented. This report complements Du Preez et al. (2015) which provides a photo-documented checklist of species observed at Cobb Seamount in 2012. Included here are descriptions of the survey design and imagery annotation, and basic analyses of species, habitat, fishery, hydroacoustic, seabird, marine mammal, and oceanographic data. Overall 144 benthic taxa were observed from 19 ROV and AUV transects carried out from 34-1154 m in depth. Only five species of seabirds and one species of marine mammal were observed at Cobb Seamount. The avifaunal community was dominated by Leach's storm-petrels (*Hydrobates leucorhous*). The only marine mammal encountered over the seamount was one Dall's porpoise (*Phocoenoides dalli*). The taxa with the greatest densities on the Cobb Seamount plateau (<225 m depth) included Rosethorn Rockfish (*Sebastes helvomaculatus*), Puget Sound Rockfish (*S. emphaeus*) Pygmy Rockfish (*S. wilsoni*), the cup coral *Desmophyllum dianthus,* the brachiopod *Laqueus californianus,* colonies of *Stylaster* spp. and annelids. At greater depths on AUV transects, squat lobsters (Family Chirostylidae), an unidentified sponge (Demospongiae sp. 2, as described in Du Preez et al. 2015), the sea cucumbers *Pannychia* cf *moseleyi* and *Psolus squamatus*, thornyheads (*Sebastolobus* spp.), a bamboo coral *Lepidisis* sp., the antipatharian corals *Bathypathes* sp. and *Lillipathes* cf *lillei*, an unknown antipatharian species (Antipatharia sp. 1, as described in Du Preez et al. 2015), and the alcyonacean coral *Heteropolypus ritteri*. Seventeen coral taxa observed were on the North Pacific Fisheries Commission's list of indicators of potential vulnerable marine ecosystems (VMEs). Sand, boulders and creviced rock habitats were more prevalent on Cobb Seamount's plateau, but at greater depths (>435 m), creviced bedrock was more commonly observed. Fishing gear was documented at 13 of the 19 (68%) sites and included pieces of gillnet, trawl net, longlines, trap longlines, as well as anchors.

Observable impacts included ghost fishing, putative discards, drag marks, and entanglement in corals. We observed a strong backscatter in the hydroacoustics data likely associated with rockfish assemblages, particularly near the seamount’s summit. Various scattering layers were also observed near the surface (<50 m). Conductivity, temperature and depth (CTD) profiles included measures of salinity, temperature, depth and dissolved oxygen concentrations from 32 CTD cast locations. These data will provide a basis for characterizing the seamount’s community structure, mapping biodiversity and the location of potential VMEs, and carrying out more detailed ecological analyses.

RÉSUMÉ

Curtis, J.M.R., Du Preez, C., Davies, S.C., Pegg, J., Clarke, M.E., Fruh, E.L., Morgan, K., Gauthier, S., Gatien, G. et Carolsfield, W. 2015. Expédition au mont sous-marin Cobb en 2012: méthodes de relevé, collecte des données, et observations des espèces. Rapp. tech. can. sci. halieut. aquat. 3124 : xii + 145 p.

Le mont sous-marin Cobb a été découvert en 1950 et a fait l'objet de recherches biologiques, géologiques et océanographiques ainsi que de nombreuses pêches commerciales. Le présent rapport passe en revue l'historique du mont sous-marin Cobb et décrit la méthodologie et les données recueillies dans le cadre d'un relevé scientifique du mont sous-marin Cobb (46° 44′ 24″ N, 130° 48′ 0″ O) mené conjointement par Pêches et Océans Canada (MPO) et la National Oceanic and Atmospheric Administration (NOAA) des États-Unis du 21 au 26 juillet 2012 (croisière des Sciences du MPO n^{o} PAC 2012-43). Le relevé visait à recueillir des données pour : a) caractériser la structure de la communauté benthique; b) cartographier la répartition des taxons indicateurs de l'écosystème marin vulnérable (EMV) (p. ex., coraux, éponges, et autres espèces structurantes); c) rassembler des indices matériels de la présence d'engins de pêche perdus et de leurs impacts observables. Dans le cadre du relevé, on a utilisé deux véhicules sous-marins téléguidés (ROV) capables de plonger à des profondeurs de 220 m et à 550 m respectivement, ainsi qu'un véhicule sous-marin autonome (VSA) pouvant plonger à une profondeur 1400 m. De plus, des données océanographiques et hydroacoustiques ont été recueillies pour caractériser les paramètres physiques et biologiques de la zone pélagique au-dessus du mont sous-marin Cobb, et l'abondance relative et la répartition des oiseaux de mer et des mammifères marins le long de l'itinéraire du navire de recherche ont été documentées. Le présent rapport complète le document de Du Preez et al. (2015), qui fournit une liste avec photographies des espèces observées au mont sous-marin Cobb en 2012. Il comprend une description de la conception du relevé et des annotations des images, ainsi qu'une analyse de base des données sur les espèces, l'habitat, la pêche, l'hydroacoustique, les oiseaux de mer, les mammifères marins et l'océanographie. Un total de 144 taxons benthiques ont été observés lors de 19 transects par ROV et VSA à des profondeurs allant de 34 à 1 154 m. Seules cinq espèces d'oiseaux de mer et une espèce de mammifère marin ont été observées au mont sous-marin Cobb. La communauté avifaune était dominée par l'océanite cul-blanc (*Hydrobates leucorhous*). Le seul mammifère marin rencontré près du mont sous-marin était un marsouin de Dall (*Phocoenoides dalli*). Les taxons affichant la plus grande densité sur le plateau du mont sous-marin Cobb (< 225 m) comprenaient le sébaste rosacé (*Sebastes helvomaculatus*), le sébaste paradeur (*S. emphaeus*), le sébaste pygmée (*S. wilsoni*), le madréporaire *Desmophyllum dianthus*, le brachiopode *Laqueus californianus*, des colonies de *Stylaster* sp. et des annélides. Lors de transects du VSA à de plus grandes profondeurs, on a pu observer des galatées (famille des Chirostylidae), une éponge non identifiée (*Demospongiae* sp. 2, selon la description de Du Preez et al. 2015), des holothuries *Pannychia moseleyi* et *Psolus squamatus*, des sébastolobes (*Sebastolobus* sp.), des coraux bambous *Lepidisis* sp., des coraux antipathaires *Bathypathes* sp. et *Lillipathes lillei*, une espèce inconnue d'antipathaire (Antipatharia sp. 1, selon la description de Du Preez et al. 2015), et du corail alcyonaire *Heteropolypus* *ritteri*. Dix-sept taxons de coraux observés figurent sur la liste des indicateurs d'EMV potentiels de la Commission des pêches du Pacifique Nord. Les habitats de sable, de blocs et de crevasses rocheuses prédominaient sur le plateau du mont sous-marin Cobb, mais, à de plus grandes profondeurs (> 435 m), il y avait surtout des crevasses rocheuses. On a observé des engins de pêche à 13 des 19 sites (68 %); il s'agissait notamment d'ancres et de morceaux de filets maillant, de filets de fond, de palangres et de casiers. Les impacts observables comprenaient la pêche fantôme, des rejets présumés, des marques de dragage et des enchevêtrements parmi les coraux. Nous avons observé une forte rétrodiffusion dans les données acoustiques, vraisemblablement associée aux assemblages de sébastes, surtout près du sommet du mont sous-marin. Diverses couches de diffusion ont également été observées près de la surface (< 50 m) Les profils de conductivité, de température et de profondeur (CTP) comprenaient des mesures de la salinité, de la température, de la profondeur et des concentrations d’oxygène dissous pour 32 emplacements. Ces données serviront à caractériser la structure des communautés du mont sous-marin, à cartographier la biodiversité et l'emplacement des EMV potentiels, et à réaliser d'autres analyses écologiques détaillées.

Introduction

Seamounts support populations of isolated coldwater corals, sponges and other structural or functional components of vulnerable marine ecosystems (VMEs). Many seamounts are also fished commercially, which poses management challenges for ensuring the long-term persistence and integrity of VMEs. The North Pacific Fisheries Commission's Scientific Working Group is in the process of identifying VMEs on seamounts in the North Pacific Ocean. As a signatory to the Convention on the Conservation and Management of High Seas Fisheries Resources in the North Pacific Ocean, Canada is in the process of identifying the location of potential VMEs in international waters that are fished by Canadian vessels, and assessing potential impacts of fishing activities on those VMEs. Among the seamounts off the west coast of British Columbia (BC), Cobb Seamount is subject to a Canadian commercial fishery for Sablefish (*Anoplopoma fimbria*). In July 2012, Fisheries and Oceans Canada (DFO) and collaborators from National Oceanic and Atmospheric Administration (NOAA) Fisheries, University of Victoria (UVic), Memorial University of Newfoundland (MUN), Simon Fraser University (SFU) and Environment Canada (EC) undertook a survey of benthic communities on Cobb Seamount using video and still cameras mounted on remotely operated vehicles (ROVs) and an autonomous underwater vehicle (AUV). The survey aimed to identify the species and occurrences of coldwater corals and sponges, collect data to characterize the benthic community structure and habitat, and document any evidence of fishing gear or related impacts. Here, we provide descriptions of the survey design, imagery analysis, benthic species assemblages, fishery interactions, analyses of hydroacoustic, seabird and marine mammal surveys, and a summary of oceanographic data. A photo-documented species inventory list is included in a companion report by Du Preez et al. (2015).

Cobb seamount is located at 46° 44′ 24″ N, 130° 48′ 0″ W (Figure 1), approximately 500 km west of Gray's Harbour, Washington outside of Canadian and US exclusive economic zones (Birkeland 1971). The seamount was discovered by the crew aboard the research vessel *John N. Cobb* in 1950 and has been the site of biological, geological, and oceanographic research, as well as several commercial fisheries (Douglas 2011). Cobb Seamount stands out among approximately 100 seamounts in the northeast Pacific Ocean as an unusual and biologically significant feature because it extends from the abyssal plain at almost 3000 m depth to well into the photic zone and supports productive, diverse and unusual communities of organisms (Birkeland 1971; Dower et al. 1992; Parker and Tunnicliffe 1994).

Geology

Cobb Seamount is a 27 million year old symmetrical and terraced guyot with a centrally located pinnacle (Budinger 1967) that rises from a base of 2743 m to within 24 m of the surface (Parker and Tunnicliffe 1994), with an area of approximately 824 km^2 (Budinger 1967) (Figure 2). The seamount flanks average 12^o in slope, and are marked by four terraces (Budinger 1967) and a summit that is characterized by a steep-sided flat-topped plateau (Chaytor et al. 2007).

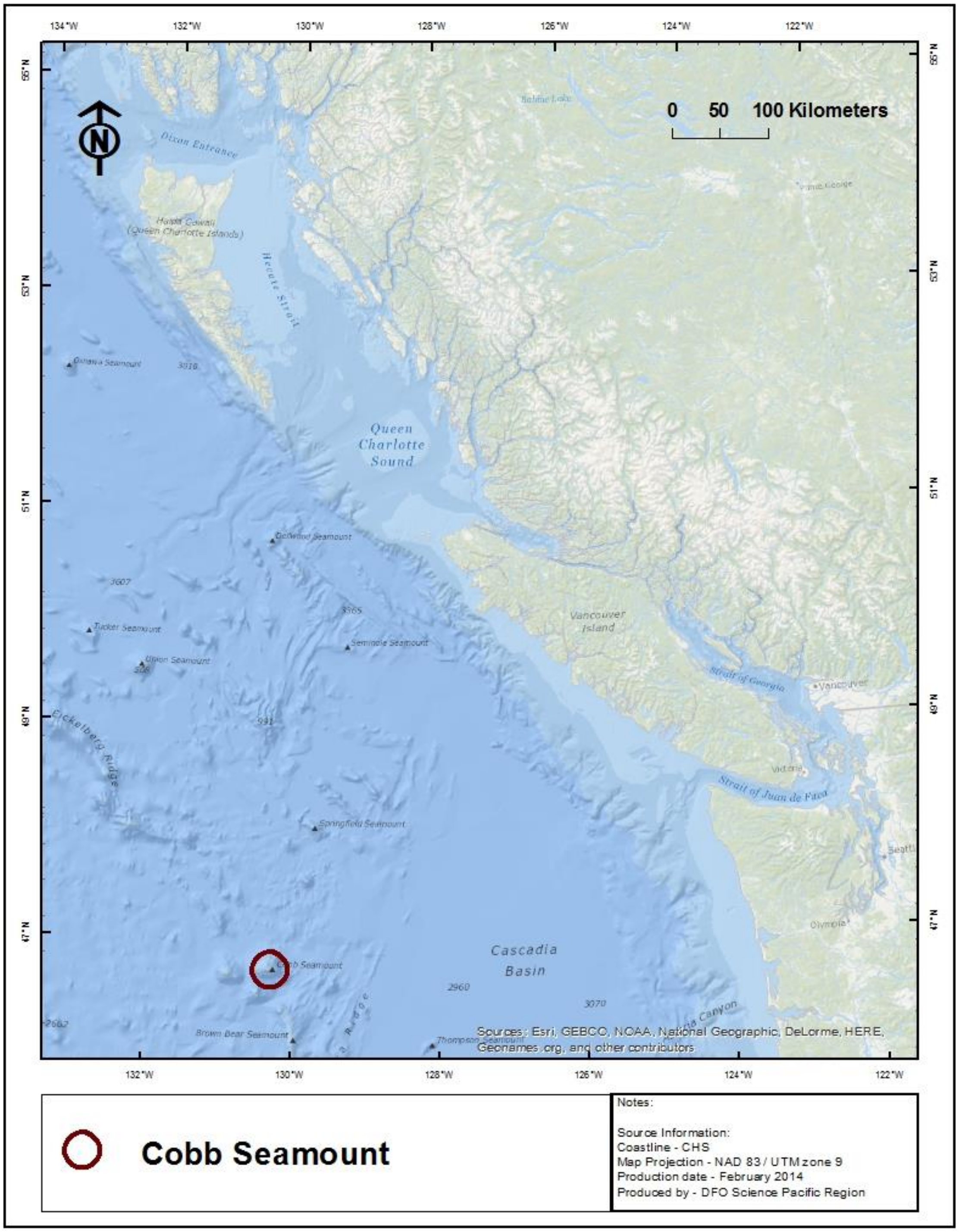

Figure 1. Location of Cobb Seamount off the west coast of North America.

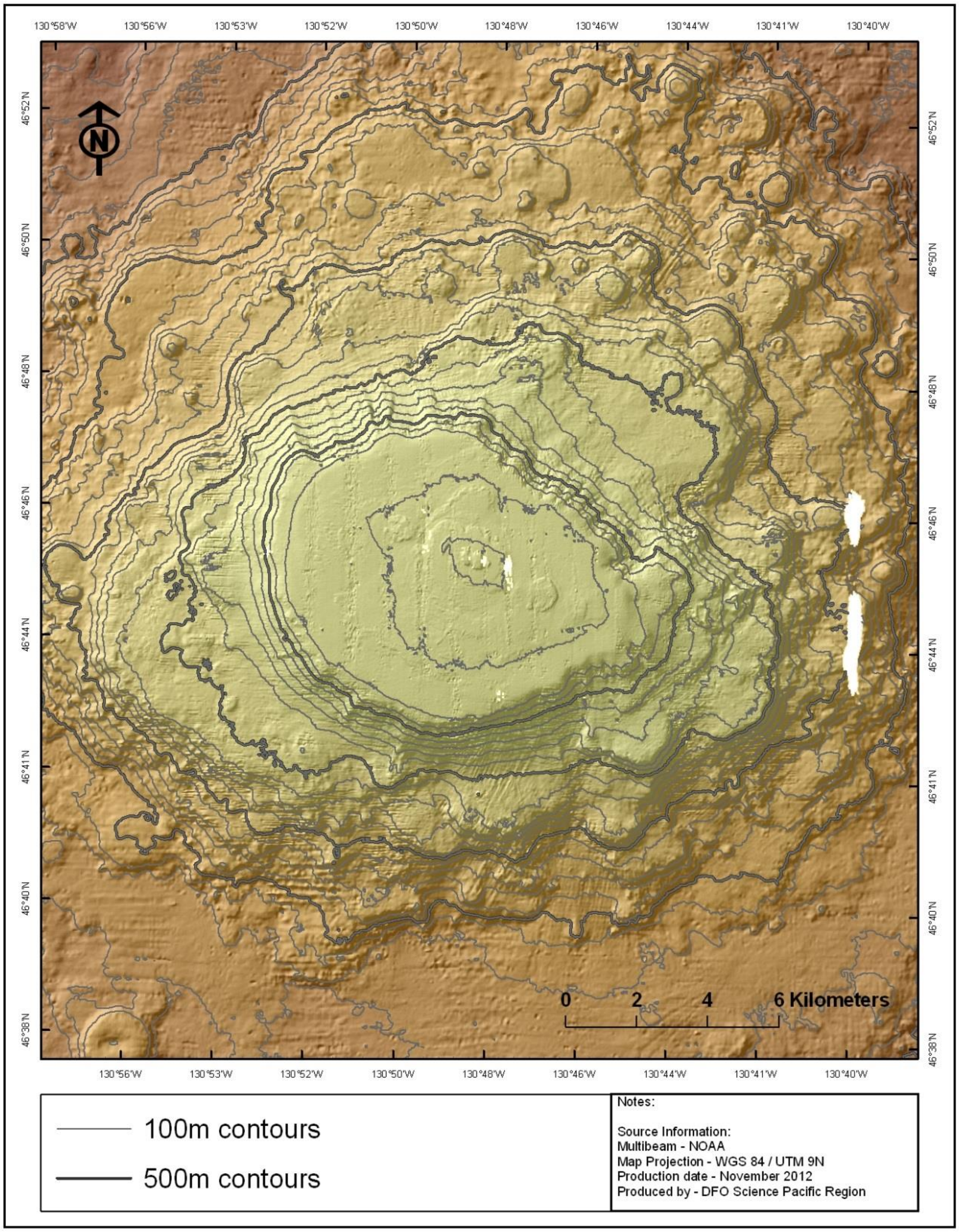

Figure 2. Bathymetric map of Cobb Seamount.

The seamount is part of the Cobb-Eickleberg seamount chain of underwater volcanoes in the northeast Pacific Ocean, and its wave-cut terraces and cobble and sand beaches suggest it was once above sea level (Chaytor et al. 2007). The first terrace varies from 82-

91 m and is notable for an abundance of shells and shell fragments and well-worn basalt pebbles and cobbles (Budinger 1967). Shells were identified as those of pelecypods, gastropods, brachiopods and polychaetes, but in particular, Budinger (1967) noted an abundance of intertidal mussel shells similar in appearance to *Mytilus californicus*. From the shallowest terrace, 45˚ slopes rise to a flat, fissured top which is approximately 200 m x 400 m (Budinger 1967) and composed of smooth basalt concavities. The second terrace is less prominent at approximately 146 m (Budinger 1967). Wave ripples have been observed down to 150 m (Farrow and Durant 1985). The third terrace varies from 155-238 m, with a slope that increases to 22˚ below. Samples collected by Budinger (1967) from the third terrace included subangular to well-rounded pebbles and cobbles and hydrocoral fragments. The photic zone lies above the third terrace to a depth of 180 m (Farrow and Durant 1985) as inferred by the disappearance of *Lithothamnium spp*. at 185 m (Farrow and Durant 1985). The fourth terrace ranges from 823-1189 m (Budinger 1967).

Oceanography

Seamounts are characterized by dynamic oceanographic conditions, including localized high energy currents and eddies. Strong eddies can become trapped over seamounts, potentially leading to larval retention (Huppert and Bryan 1976; Cheney 1980, as cited in Douglas 2011). Oceanographic studies in the vicinity of Cobb Seamount began in 1952 (Douglas 2011). The North Pacific Current flows predominantly eastward at approximately 10 cm/sec (Hickey 1989, as cited by Parker and Tunnicliffe 1994). Surface drifters released near Cobb Seamount moved from NW to SE linearly (Dower et al. 1992), but water in the area is also characterized by a a persistent clockwise (i.e. downwelling) eddy, consistent with a stratified Taylor cone (Dower and Perry 2001, but see Freeland 1994), and Freeland (1994) reported clear evidence of recirculation around Cobb Seamount. In addition to currents, Cobb Seamount is subject to diurnal and semidiurnal tides (Larsen and Irish 1975).

Plankton community

Recirculating flows may act to entrap or concentrate primary productivity and ichthyofauna above seamounts (Dower et al. 1992). There is a subtle effect of Cobb Seamount on plankton communities compared to surrounding (i.e. background) areas in the northeast Pacific Ocean (Dower et al. 1992; Sime-Ngando et al. 1992; Dower 1994; Comeau et al. 1995; Dower and Mackas 1996). Primary production above Cobb Seamount was patchy but production rates were as much as 10 times greater than background levels (Comeau et al. 1995). This is consistent with observations of Dower et al. (1992) who repeatedly observed regions of high chlorophyll concentrations (2-5 times above background levels) with persistence times of at least one month over the seamount from 1990-1992. Similarly, Sime-Ngando et al. (1992) observed greater biomass and small-scale patchiness of ciliates on Cobb Seamount. In contrast, zooplankton biomass within 5 km of the summit was almost 30% lower than background levels (Dower 1994) and mesoplankton community composition differed on and off the seamount, with an effect on community composition detected as far as 30 km away from the pinnacle

(Dower 1994). Mesoplankton community composition was weakly correlated with environmental variables, including water temperature at a depth of 50 m (Dower and Mackas 1996). Hypotheses to explain differences in mesoplankton abundance and community composition included differential predation pressure on and off the seamount (Dower and Mackas 1996).

Cobb Seamount was also associated with a greater abundance of juvenile rockfishes, which dominated the ichthyoplankton up to 30 km from the pinnacle but were rarely captured in samples collected greater than 30 km away (Dower and Perry 2001). These observations are consistent with a high abundance of adult rockfishes on Cobb Seamount (Parker and Tunnicliffe 1994) and the hypothesis that these rockfish populations are self-recruiting to the seamount. Self-recruitment would be facilitated in part by oceanographic features that partially recirculate water around Cobb Seamount (Freeland 1994) and larval behaviour.

Benthic community

A series of expeditions to collect biological samples and visual observations with submersible vehicles or SCUBA divers (e.g. Birkeland 1971, Farrow and Durant 1985, Parker and Tunnicliffe 1994) have formed the basis for developing an inventory of species on Cobb Seamount and documenting patterns in community structure at different depths.

Investigations of fish communities on Cobb Seamount began in 1950 with longline gear deployed from the *RV John N Cobb*, and the capture of several species of rockfish (*Sebastes* spp.) and Pacific Halibut (*Hippoglossus stenolepis*) (Douglas 2011). Large catches of Black Rockfish (*Sebastes melanops*) were reported by Chikuni (1971) and rockfish catches in 1978 and 1979 were dominated by Rougheye Rockfish (*S. aleutianus*), but also Shortraker Rockfish (*S. borealis*), Redstripe Rockfish (*S. proriger*), Harlequin Rockfish (*S. variegatus*), Rosethorn Rockfish (*S. helvomaculatus*), Black Rockfish (*S. melanops*), Pacific Ocean Perch (*S. alutus*) and Yelloweye Rockfish (*S. ruberrimus*). Widow Rockfish (*S. entomelas*) and Sablefish (*Anopoploma fimbria*) were landed in US fisheries from 1991 to 2003 (Douglas 2011). Other species captured incidentally during that time period included: Rosy Rockfish (*S. rosaceus*), Shortbelly Rockfish (*S. jordani*), Blue Rockfish (*S. mystinus*), Yellowtail Rockfish (*S. flavidus*), Bocaccio (*S. paucispinis*), Dover Sole (*Microstomus pacificus*), Rex Sole (*Glyptocephalus zachirus*), Rock Sole (*Lepidopsetta bilineata*), Blue Shark (*Prionace glauca*), Pelagic Armourhead (*Pseudopentaceros richardsoni*), Pacific Mackerel (*Scomber japonicas*), Skilfish (*Erilepis zonifer*), Salmon Shark (*Lamna ditropis*), Longnose Skate (*Raja binoculata*), and Brown Cat Shark (*Apristurus brunneus*) (Douglas 2011).

Submersible and SCUBA dives from 1965 to 1983 surrounding the pinnacle (35-110 m) revealed communities dominated by echinoids, encrusting coralline algae, turf algae (primarily *Desmarestia viridis*), giant rock scallops (*Crassadoma gigantea*) colonized by strawberry anemones (*Corynactis californica*), sponges, tunicates and bryozoans, aggregations of sea urchins (*Mesocentrotus franciscanus*) and rockfishes (Birkeland 1971; Schwartz and Lingbloom 1973; Farrow and Durant 1985; Parker and Tunnicliffe 1994). In particular, Parker and Tunnicliffe (1994) noted that pelagic juvenile rockfish formed large schools in the 1980s and unusual abundances of larval rockfish have been captured in zooplankton tows (Dower and Perry 2001). The gently sloping terrace from 125-300 m was dominated by echinoderms including crinoids (*Florometra serratissima*), brachiopods, and ophiuroids inhabited calcareous sediment and rock outcroppings, and the seastars *Pycnopodia helianthoides* and *Crossaster papposus* were noted as common predators (Farrow and Durant 1985; Parker and Tunnicliffe 1994). Farrow and Durant (1985) described small coral bioherms at 300 m, and the presence of hydrocoral, crinoids, ophiuroids, and gorgonians from 500-700 m. The assemblages observed in less than 180 m depth on Cobb Seamount appeared to be dominated by species with larvae that spend less than two weeks in the water column. This observation suggests that oceanographic processes around the seamount may influence colonization and recruitment dynamics (Parker and Tunnicliffe 1994). This conclusion is consistent with studies that suggest water is recirculated around Cobb Seamount but turns over every 17 days (Dower et al. 1992; Freeland 1994); species with larvae that spend longer times in the water column may be more likely to drift off the seamount than those with shorter larval periods (Birkeland 1971; Parker and Tunnicliffe 1994). Birkeland (1971) also proposed numerous hypotheses to explain notable differences between the benthic community of Cobb Seamount and those of adjacent coastal areas, including the paucity of macroalgal species diversity, unusual abundance of *Crassadoma gigantea*, small sizes of *Metridium senile*, presence of typically warm water species (e.g. *Corynactis californica*) and deeper depth ranges of many species (e.g. *Leptasterias hexactis*).

Seabird assemblage

There is little published information on the assemblages of vertebrate species that use surface and near-surface waters around Cobb Seamount, although anecdotal observations and data from surveys undertaken in the vicinity may exist in unpublished form. Available literature on seabird assemblages associated with seamounts provides useful context for developing predictions on patterns of distribution and abundance around Cobb Seamount.

The environment in which most seabirds forage is heterogeneous, and their prey is most often patchily distributed (e.g. Ashmole 1971; Weimerskirch 1997, 2007). The stochastic nature of prey availability within that environment has been suggested as one of the primary factors shaping seabird life history strategies (Lack 1968). The distribution of oceanic prey depends primarily upon physical processes that vary spatially and temporally (Hunt et al. 1999; Ainley et al. 2005). Large frontal zones may support concentrations of prey patches, and the locations of the frontal zones may be predictable over prolonged periods of time (Schneider 1993; Weimerskirch et al. 2005). For example, Ballance et al. (2006) wrote that there are many distinct macro- (1000-3000 km), and meso-scale (100-1000 km; after Haury 1978) features that are *"...relatively* *permanent and predictable*" and include: *"...major surface currents, the boundaries between them, larger gyres and eddies and surface waters downstream of islands...*".

At-sea surveys have shown that seabird densities respond to increased indices of prey abundance at macro- and meso-scales (e.g. Fauchald and Erikstad 2002; Ainley et al. 2005; Bost et al. 2008). However, at coarse- (1-100 km) and fine- (< 1 km) scales, the predictability of prey patches is much lower (Hunt and Schneider 1987); and the link between prey abundance and seabirds may be inconclusive or contradictory (e.g. Logerwell and Hargreaves 1996; van Franecker et al. 2002).

Rogers et al. (2007) noted that: "*Seamounts act as biological hotspots and often attract a high abundance and diversity of large predators such as sharks, tuna, billfish, turtles, seabirds and marine mammals...*"; and that: "*Rogers (1994) suggests two main explanations why seamounts host such diverse benthic and pelagic communities....increased productivity resulting from upwelling of nutrient-rich deep seawater around seamounts.....or the trapping of layers of diurnally migrating zooplankton, advected over seamount summits at night*". Although there is evidence of enhanced productivity at some seamounts, it is not a consistent feature and a wide range of spatial and temporal variability exists (White et al. 2007).

A number of authors have reported that seabirds aggregate at seamounts (e.g. Blaber 1986; Bourne 1992; Haney et al. 1995; Yen et al. 2004); however, few studies have been able to show the causal relationships between seabirds and seamounts (Thompson 2007). Variation between seamounts in seabird prey composition, abundance and availability, is undoubtedly related to differences in seamount locations, topographies, summit depths and how the seamounts interact with physical processes (e.g., flows, currents and tides). Compounding the differences is the fact that the physical processes occurring over individual seamounts operate at different time-scales (from daily to inter-annually, Thompson 2007); and as such, the prey distribution, abundance and availability and the predator community fluctuates accordingly.

Not all seamounts are of equal importance to seabirds. Morato et al. (2008) examined the influence of seamounts on the abundance of four species of seabirds (Cory's shearwater *Calonectris borealis*, yellow-legged gull *Larus michahellis*, common tern *Sterna hirundo*, and roseate tern *Sterna dougallii*) and several dolphin and fish species. The authors found that while some marine predators (Cory's shearwater, short-beaked common dolphin *Delphinus delphis*, Skipjack Tuna *Katsuwonus pelamis* and Bigeye Tuna *Thunnus obesus*) were significantly more abundant in the vicinity of the summits of some shallow-water seamounts; other species examined did not demonstrate any association with seamounts. Morato et al. (2008) suggested that while some may act as feeding stations, only those seamounts shallower than 400 m in depth appeared to have an aggregative effect.

Haney et al. (1995) studying the seabird community associated with a mid-ocean seamount in the eastern North Pacific (Fieberling Guyot, minimum depth 438 m below the surface), noted that the 'away seamount seabird community' (> 30 km from the seamount) was dominated by Leach's storm-petrels Hydrobates *leucorhous*; whereas, the 'near seamount seabird community' (< 30 km from the seamount) consisted primarily of members of the order Procellariiformes (predominantly black-footed albatrosses *Phoebastria nigripes*). The authors reported that total bird density near the seamount was > 2.4 times greater than the away seamount total bird density. Haney et al. (1995) speculated on possible mechanisms that would attract seabirds to the guyot but they were unable to identify a plausible explanation.

Fisheries

Commercial fishing activities on Cobb Seamount began in the 1970s with Japanese fleets using stern trawlers, bottom longline, and gillnet gear (Takahashi and Sasaki 1997; Douglas 2011). Japanese stern trawlers fished Cobb Seamount in 1978 and 1979 and captured 396 metric tons of rockfishes (*Sebastes* spp.), predominantly Rougheye Rockfish (*Sebastes aleutianus*). Japanese fishers returned from 1985 to 1989 to fish with bottom longline and gillnet gear, as well as heavy-duty tire trawl gear (Sasaki, pers. comm. as cited in Douglas 2011). Total removals in the 1970s and 1980s included almost 1000 mt of groundfish (88% red rockfish, 3% Sablefish, 9% other, primarily Jack Mackerel, *Trachurus symmetricus*).

Douglas (2011) reviewed fishing activities undertaken by the United States (US) on Cobb Seamount. In the 1980s and a large fishable widow rockfish population was discovered by the US and fished until 2003. From 1994-1996, fishery landings were lower because schools were difficult to find and catches were low-volume; trawl vessels used mid-water gear exclusively (the bottom was too rugged for trawl nets). During that time, bottom longline and fish pot gear were also used at Cobb Seamount to target Sablefish. From 1991-2003, 5739 mt of fish caught at Cobb Seamount were landed; the vast majority were Widow Rockfish captured by trawl nets. US fisheries on Cobb Seamount ceased because of concerns about the sustainability of the Widow Rockfish fishery. The US National Marine Fisheries Service stopped issuing high seas permits for net gear types in 2004. Evidence of overfishing was based on changes in the size structure and abundance of catch, and reductions in the size at maturity (Douglas 2011).

Canada also conducted exploratory longline and bottom trawl fisheries at Cobb Seamount in 1980. From 1983 to the present, there have been sporadic trips to the seamount, and the majority of these trips have fished Sablefish by trap. The Sablefish seamount fishery is managed separately from the coastal Sablefish fishery and includes all seamounts off the British Columbia coast. The seamount fishery is divided between 'North' and 'South' management areas; with one vessel per month from 1 April to 30 September permitted to participate in the 'South' management area (DFO 2014). A lottery draw is used to determine which vessel can participate in the seamount fishery. Fishers that are permitted to fish in the 'South' management area and wish to fish beyond the 200 nautical mile Exclusive Economic Zone must apply for a Section 68 Licence to fish in international waters (DFO 2014). There is a monthly vessel limit for Sablefish of 75000 lbs (34 mt) (DFO 2014).

Other countries than those mentioned above have likely fished Cobb Seamount, but no data are available.

Vulnerable Marine Ecosystems (VMEs)

The North Pacific Fisheries Commission (NPFC) is a new Regional Fisheries Management Organization (RFMO) that will manage fishing activities in the North Pacific Ocean according to the Convention on the Conservation and Management of High Seas Fisheries Resources in the North Pacific Ocean. The NPFCs' Scientific Working Group (SWG) was formed to provide science-based advice needed to implement the Convention. Key priorities for the SWG include the identification of VMEs and the development of encounter protocols to limit fishing-related impacts to VMEs. International guidelines for management of deepwater fisheries in the high seas define a VME as one likely to show a substantial negative response to disturbance (FAO 2008).VMEs include those dominated by long-lived and fragile taxa, including but not limited to, coldwater corals and sponges. Thus, Fisheries and Oceans Canada (DFO) and the National Oceanic and Atmospheric Administration (NOAA) undertook a joint survey of VME components on Cobb Seamount, where the Canadian Sablefish fishery has the potential to impact coral and sponge dominated communities as well as other types of VMEs.

Objectives

The research objectives for the 2012 Cobb Seamount survey included:

1. surveying benthic communities to depths of approximately 1300 m;
2. identifying the location of vulnerable marine ecosystem (VME) indicator species;
3. surveying seabird and marine mammal communities;
4. surveying pelagic communities;
5. collecting oceanographic data including temperature, salinity and oxygen;
6. and documenting observations of fishing gear and impacts to benthic communities.

In order to achieve these objectives, we collected video and still images from 19 sites using two remotely operated vehicles (ROVs) and an autonomous underwater vehicle (AUV). The two ROVs were similar models with different depth capacities, while the AUV was capable of completing deeper dives. The occurrences of seabirds and marine mammals were documented through visual surveys. Hydroacoustic and oceanographic data were also collected to characterize the biological and physical attributes of the pelagic zone above Cobb Seamount. In this report, we provide a detailed description of our sampling design and image analyses, summary statistics on the benthic community structure, habitat types, the distribution of corals and sponges, and the location and type of fishing gear and related impacts observed during surveys. We also compile lists of observed species in demersal and surface waters, and a summary of environmental data collected on the seamount (e.g. temperature, salinity, oxygen, hydroacoustic). More detailed characterization of benthic community structure will follow additional quantitative analysis of video and photographs. Data are available upon request from the authors.

Methods

Details from the Science Cruise Number PAC 2012-43 led jointly by Fisheries and Oceans Canada (DFO) and the United States National Oceanic and Atmospheric Agency (NOAA) are available in the cruise plan[1] and cruise report[2]. The survey was carried out aboard the *CCGS John P. Tully* which sailed from the Institute of Ocean Sciences (IOS) in Sidney, BC on 19 July 2012, was stationed at Cobb Seamount from 21-26 July 2012, and returned to Port Hardy, BC on 28 July 2012. Science crew included researchers from eight institutions, including the Pacific Biological Station (DFO), The Northwest Fisheries Science Center (NOAA), The Southwest Fisheries Science Center (NOAA), The Pacific Islands Fisheries Science Center (NOAA), Memorial University of Newfoundland, Simon Fraser University, University of Victoria, and Environment Canada (Appendix 1).

The Canada Coast Guard crew on the *CCGS John P. Tully* from 17-28 July 2012 were led by Captain Joanne McNish; they managed all operations aboard the ship and assisted with hydro-acoustic surveys, remotely operated vehicle (ROV), autonomous underwater vehicle (AUV), and conductivity/temperature/depth (CTD) probe deployment, as well as ROV operations and underwater navigation.

Of the 11 days allocated for the cruise, six were spent on Cobb Seamount collecting data and two and a half were spent en-route to and from the seamount. Tests with ROV and AUV submersibles were carried out in Patricia Bay, BC on 18 and 19 July 2012 to practice and optimize communications and operations during deployment, underwater navigation and data collection and retrieval. During the six days on station at Cobb Seamount, the science crew undertook 18 ROV dives and five AUV dives primarily during daylight hours. Hydro-acoustic surveys and CTD data were carried out opportunistically during daylight hours and routinely at night.

Sea and weather conditions were generally favourable for surveys with ROV, AUV, hydro-acoustic and CTD equipment, but less so for observing seabirds, marine mammals and other animals at the water's surface (Appendix 2). Wind speed ranged from 8-22 knots on Cobb Seamount (mean ± SD = 16.8 ± 14.4). Weather conditions were dominated by slight or moderate precipitation and fog patches.

Surveys of benthic communities

Our sampling design was influenced in part by the types of submersibles available; they differed in terms of depth capabilities, equipment for data collection, and navigational

[1] https://public.waterproperties.ca/cruiseplanview.php?cruiseid=2012-43
[2] https://public.waterproperties.ca/cruisereportview.php?cruiseid=2012-43

considerations. We begin with a description of the submersible vehicles followed by our sampling design.

Submersible set-up and deployment

Submersible work was carried out using three submersible vehicles which differed in depth range and photographic capabilities. Two ROVs operated by DFO and SFU were tethered and, at the time of the survey, were capable of diving to depths of approximately 220 m and 550 m, respectively. The NOAA-operated SeaBED-class AUV was programmed to dive to a depth of 1300 m and was equipped to collect digital still photographs.

Each of the three vehicles was equipped with different camera types. Depending on the nature and quality of images and the question of interest, data on particular habitat types or taxonomic groups obtained with the three vehicles may not be directly comparable. In this report, we summarize observations at the scale of transects and discuss general patterns in species diversity, distribution and abundance across transects when appropriate.

Phantom ROVs

The ROV operated by DFO (Figure 3) was a customized Deep Ocean Engineering Phantom HD2+2 (from here onward referred to as the DFO ROV). This vehicle is rated to 300 m depth, but during the cruise, its umbilical cord limited dive depth to a maximum of 220 m. In addition to the stock standard definition (SD) video camera, it had one 8 megapixel Cyclops digital still camera (C-Map Systems, Inc.) with a separately housed flash, and one high definition (HD) Mini Zeus video camera (1080i, Insite Pacific Inc.). The still camera and the HD video camera were on a tilt mechanism on a frame extension at the front of the DFO ROV and tilted together and pointed in approximately the same direction. Each was fitted with parallel lasers to aid in sizing organisms for identification. The HD video camera had two green lasers attached to the camera housing that provided a 10 cm reference scale horizontally across the field of view (FOV). Two underwater red lasers located within the still camera housing were set up to provide a 10 cm reference scale in the centre of each image vertically across the FOV, while a third red laser provided an indication of distance from the substrate (to indicate distances greater or less than approximately 1 m). The SD video camera was mounted on the stock tilt mechanism and provided additional field of view while navigating the DFO ROV underwater. The two tilt mechanisms were able to tilt independently and were both capable of pointing from slightly backward of straight down to well above horizontal forward. Camera angles were generally adjusted to give the best view of the bottom, often obliquely forward (around 45˚ up from straight down). At this angle, operators were able to more easily detect and avoid obstacles while navigating the DFO ROV along the transect path.

Figure 3. Remotely operated vehicle (ROV) operated by Fisheries and Oceans Canada (photo courtesy of Jonathan Martin).

Video from the HD and stock SD cameras was recorded continuously throughout the dive, from the time of deployment to retrieval. The Cyclops digital still-camera was configured to take still photos every 15 seconds while the DFO ROV was on the seafloor. Manual photographs were also taken to photo-document organisms or other features of interest. Some voucher specimens were collected with a simple rotatable manipulator and collection bag.

The ROV operated by SFU (Figure 4) (from here onward referred to as the SFU ROV) was also a customized Deep Ocean Engineering Phantom HD2+2. This vehicle is rated to 600 m depth, but during the cruise, its umbilical cord limited dive depth to a maximum of 550 m. The stock SD video camera had two lasers to provide a 10 cm reference scale, however, these were not used during transects due to technical difficulties. The SFU ROV was not equipped with a digital still camera or the means to collect samples.

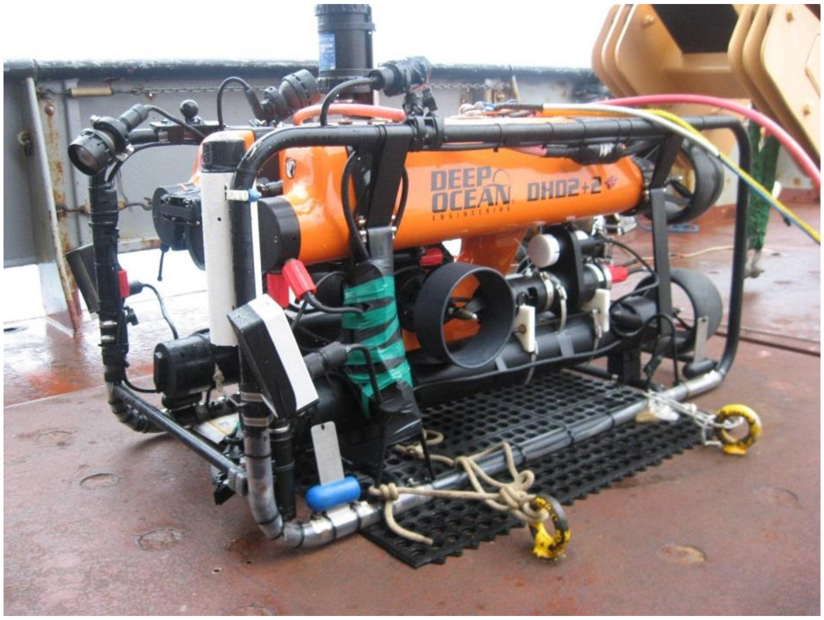

Figure 4. Remotely operated vehicle (ROV) operated by Simon Fraser University (Photo courtesy of Barbara de Moura Neves).

During dives the ROVs were piloted near the seafloor (0.5 to 1.5 m above) at a speed of approximately 0.1 to 0.25 m/s (0.2 to 0.5 knots). The umbilical cord of each ROV was attached to and deployed with a 218 kg (480 lb) clump weight mounted on a separate steel hydrographic cable. The ROVs free tether was 20-30 m, while the remainder of its umbilical cord was twinned with the steel cable supporting the clump weight. This configuration improved the pilot's navigational control during ROV operations by reducing the effects of drag caused by current acting on the umbilical cable between the surface and the working depth.

Hypack hydrographic software (Hypack, Inc.) and the ORE Trackpoint 3 (ORE Offshore) acoustic tracking system were used to navigate the ROVs during dives and record position information. On the HD video, the data, time (GMT), depth, and cruise number were recorded as an overlay using a combination of hardware (Sensoray 2246) and custom software (Cmap Systems, Inc.). On the SD video, the date, time (GMT), depth and magnetic compass heading (as well as umbilical turns) were recorded as an overlay using the DOE overlay. The time of all computers and video overlays was synchronized to GMT using a GPS. For still photographs, the camera was also synchronized to GMT time so that time recorded in the EXIF metadata could later be used to geotag the photos using the tracking data.

NOAA AUV

The NOAA SeaBED AUV (Figure 5) was designed by engineers at Woods Hole Oceanographic Institution and operated by the NOAA NWFSC and PIFSC. The AUV was a multi-hull, hover-capable vehicle that obtained data close to the seafloor while maintaining precise altitude and navigation control (Clarke et al. 2010). Survey imagery was collected using stereo still 5 megapixel, 12-bit dynamic range Prosilica GigE cameras mounted perpendicularly (downward-facing) and from a forward-angled 11 megapixel Prosilica CCD camera on the AUV (only used to aid in identification). The three still cameras (pointing downward and obliquely to the seafloor) were configured to produce orthogonal images of the seafloor. During surveying, the AUV was programmed to maintain a height of approximately 3 m above the seafloor and was programmed to take a photograph every 10 seconds. Cameras were synchronized with a camera strobe to light the images. During this survey, the SeaBED AUV dove to a maximum depth of 1,154 m. The SeaBED AUV's altitude control allowed it to remain at a relatively consistent altitude off the seafloor. The measured altitude off the bottom and specified camera field of view allowed the area captured in each photo to be easily determined (Clarke et. al. 2010). The AUV was not equipped with lasers or the means to collect samples.

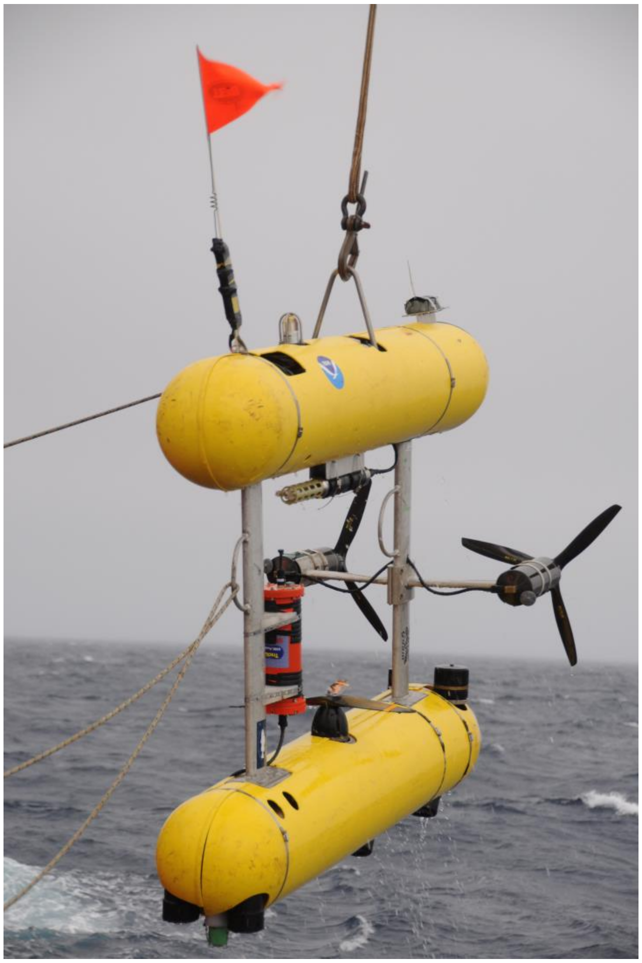

Figure 5. The National Oceanic and Atmospheric Administration's autonomous underwater vehicle (AUV) (Photo courtesy of Jonathan Martin).

The AUV was equipped with two navigational sensors: the RDI 1200 kHz Doppler Velocity Log as the primary navigational sensor and the iXSea OCTANS gyrocompass and inertial motion sensor. The AUV was tracked using a Link Quest TrackLink 1500 USBL navigation system. Subsurface communication was provided by the WHOI

256008 acoustic micromodem and surface communication used a FreeWave FGR-115 RCRF radio modem. Depth was determined using a Paroscientific depth sensor. Salinity, temperature, and pressure were collected using a Sea-Bird model 49 FastCat CTD mounted on the AUV. The SeaBED AUV's position was estimated using an ultra short base line (USBL) range and bearing measurement in relation to the ship, the coordinates of the vehicle position in relation to its dive origin, and the GPS coordinates of the dive launch point. For additional AUV information see Clarke et al. (2010).

Sampling design

Through our sampling design, we aimed to characterize the benthic community structure of Cobb Seamount at different depths and aspects, assess changes in community structure over time, and investigate features of the seamount that might support unique or diverse communities. The depth capabilities of the three submersibles allowed us to stratify their use according to three depth zones. In BC, the Sablefish trap fishery extends from approximately 180 to 1300 m; although approximately three quarters of the fishing effort occurs between 460 and 825 m (Haist 2005). On Cobb Seamount, fishing gear deployed from 1996 – 2010 was set between 102 m and 1591 m. However, 90% of gear sets occurred between 366 and 1088 m, and well within the AUV's depth range. Thus, we prioritized AUV transects in this deeper zone and deployed the ROVs in the shallower zones. The two shallower depth zones were defined based on the depth range capabilities of the ROVs. The shallowest zone ranged to a depth of 220 m, while the intermediate depth zone ranged from 220 m to 550 m.

Lack of information on the distribution of habitat type made it difficult to stratify sampling by variables other than depth and aspect. Prior to the survey, we obtained available data on the bathymetry (provided by NOAA), historical Canadian fishing effort, location of previous underwater visual surveys, and species lists to inform decisions on sampling design. The locations of previous underwater visual surveys carried out in the early 1980s were also plotted (Figure 6) and used to select one of the ROV haphazard dive sites. Information on the species previously observed on Cobb Seamount was collated from a number of sources including Birkeland (1971), Pearson et al. (1993), Parker and Tunnicliffe (1994), Dower and Perry (2001), and Douglas (2011).

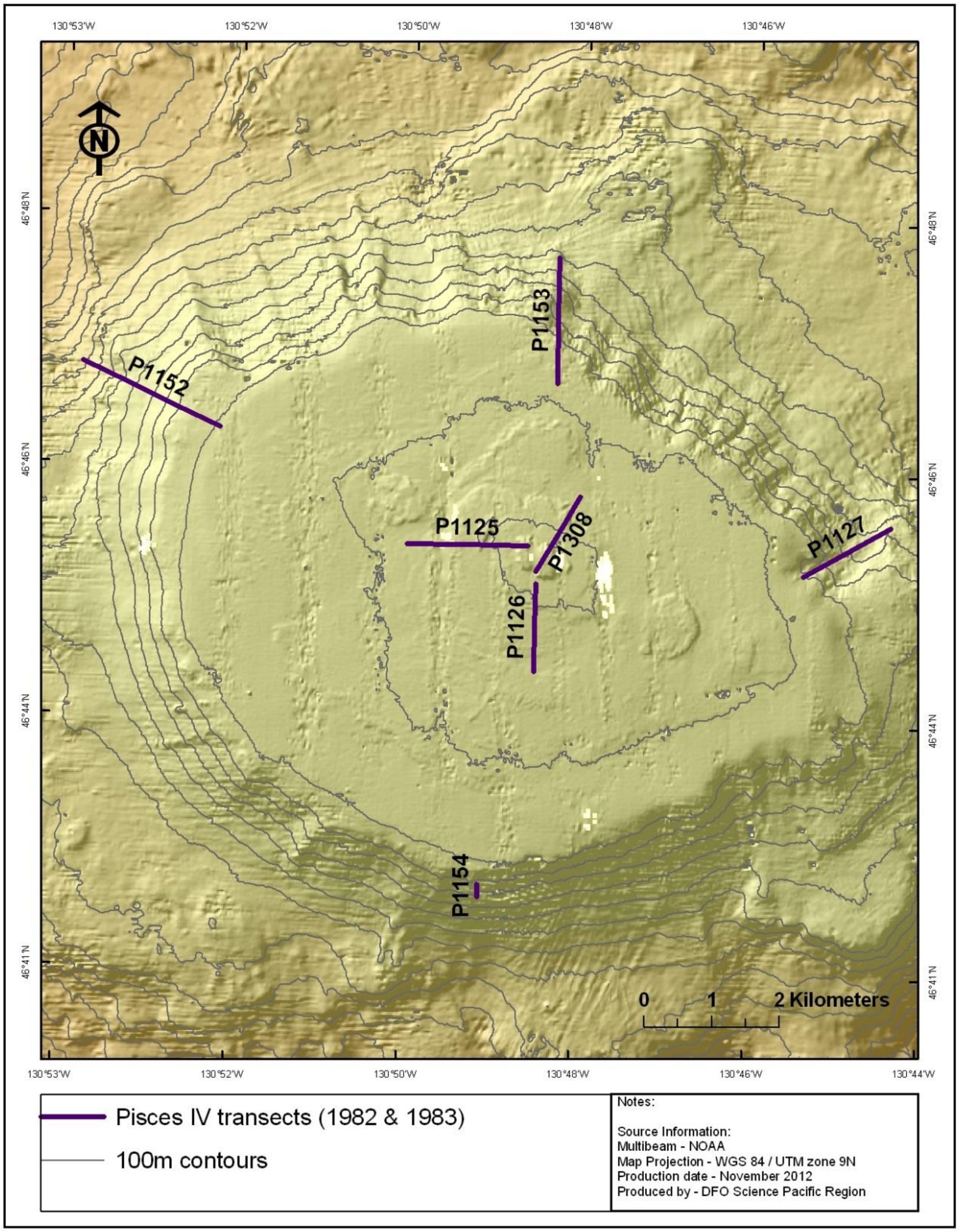

Figure 6. Location of transects surveyed during PISCES IV dives in 1982 and 1983 (coordinates courtesy of Verena Tunnicliffe).

The ROV strata were determined by the umbilical depth range of each vehicle (DFO to ~ 220 m; SFU 220 m to ~ 550 m). ROV dive sites were selected randomly within their depth range in order to encounter a variety of habitats using Hawth's Analysis Tools (Beyer 2004), specifically the Generate Random Points Tool and ArcMap 9.3 to create six random points within each stratum. The RANDBETWEEN function in Excel was used to determine the course bearing (between 1 - 360°) for each transect. Five hundred metre transects were plotted in ArcMap from the random points according to random bearings. The start position for each transect was assigned to the deeper end. ROVs travelled along the transect line from the deeper end to the shallower end for optimal image collection. During the survey, technical issues with the SFU ROV allowed time for six additional DFO transects. These transects were selected haphazardly using bathymetric data to survey features of interest, including the location of the pinnacle, terraces, areas of high rugosity (roughness) and areas proximate to historical dive locations.

AUV dive sites were selected to encounter areas that varied in the degree of Sablefish fishing effort. Data on the distribution of fishing effort associated with the Canadian Sablefish fishery for the period 1996-2010, were obtained from the DFO Groundfish Data Unit. Start and end positions were plotted in ArcMap 9.3 to represent the approximate location of each fishing event. Fishing events were buffered to account for trap and bridle length. Fishing events were spatially joined to a 500 m x 500 m grid layer (Figure 7). Final site selection took into consideration potential navigational hazards for the AUV, including areas of steep slopes (>30º), documented locations of lost fishing gear and the desire to obtain images of the seafloor within each quadrant of the seamount. The AUV was programmed to travel along the transect line from its shallower end to the deeper end for optimal image collection. Spatially-referenced data on the effort distribution associated with other fisheries reviewed in Douglas (2011) were not available.

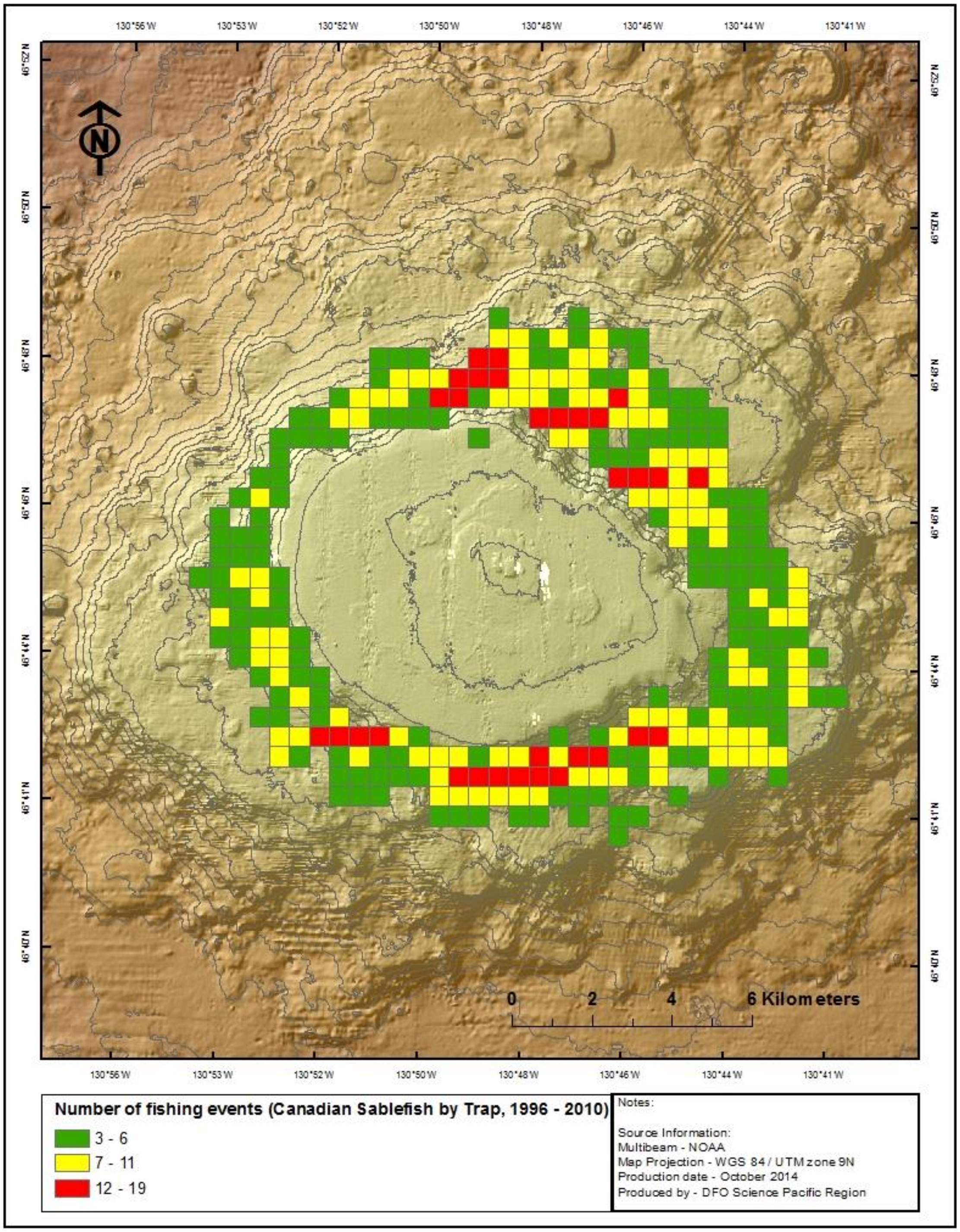

Figure 7. Map of the frequency of Canadian Sablefish fishing events from 1996 – 2010, modified to comply with the three party rule to respect privacy considerations for commercial fishing data.

Collection of imagery data

High definition video

High definition (HD) video was collected continuously from the time the DFO ROV was deployed from the ship until it was retrieved. For each dive, the HD video was archived as a series of shorter video clips (5 min 43 s each; file size limited to a manageable 2 GB). Prior to detailed annotation, each of these clips was viewed and classified according to the stage of the dive: deployment, pre-transect, transect, post-transect, retrieval. These clips were further classified as either ‘quantitative’ if they were of sufficient quality for characterizing habitat attributes and counting individuals, or ‘qualitative’ if the quality of the video clip was too poor for either. Approximately 23% of the HD video was collected during deployment to and retrieval from the seafloor. These images were collected in order to cross reference interpretation of the hydro-acoustic data with observations of zooplankton at different depths. Approximately 46% of the HD video collected during the cruise was obtained while in transect mode, during which time the DFO ROV generally flew in a continuous direction along the planned transect line. Most of the HD video clips collected along the transect line were classified as quantitative and were used as the basis for characterizing habitat and community structure in our study (methods described below). The rest of the video was collected either in pre-transect or post-transect mode.

Overall, we collected 20.25 hours of HD video from the 12 DFO ROV dives, of which approximately 9.5 hours were deemed of sufficient quality for further annotation of the identification, distribution, and habitat of benthic species. An additional 4.5 hours of video were collected from the seafloor pre- and post-transect and of sufficient quality for other purposes including verification of species identification, supplementing the list of observed species, and extracting close-up photos of habitat attributes, and marine flora and fauna (e.g. Du Preez et al. 2015).

Standard definition video

Standard definition (SD) video was collected with both ROVs during deployment, pre-transect, transect, post-transect and retrieval stages of most dives. Because the HD video is of superior quality, the 19 hours of SD video collected with the DFO ROV were not viewed or classified. Overall, we collected 4.8 hours of SD video during the six SFU ROV dives. This video included short clips collected during three aborted dives at site SFU_5, two completed transects at sites SFU_3 and SFU_5, and one incomplete transect at site SFU_2. However, none of the SFU ROV video was used for quantifying relative abundances because lasers could not be projected onto the seafloor while in transect mode. Thus, we did not quantitatively annotate any of the SD video from the three SFU ROV transects, nor did we include these data in our characterization of habitat and community structure. Nevertheless, approximately two hours of the SFU SD video was of sufficient quality and used for species identification and recording species occurrences and depth ranges (Du Preez et al. 2015) at three sites.

Photographs

High resolution photographs were collected from all 12 DFO ROV dives (3264 x 2448 pixels) and four AUV dives (2448 x 2050 pixels). During the DFO ROV dives, photographs were collected systematically every 15 seconds along each transect. Additional photos were also captured pre-, during, and post-transect to photo-document species, objects or features of interest. Overall, 3322 photos were collected during the DFO ROV dives. A subset of the photos captured while in transect mode was annotated in detail, as described below. However, all ROV photographs were viewed to develop a complete species inventory for Cobb Seamount (Du Preez et al. 2015).

High resolution AUV photographs were collected using three cameras mounted at different angles. Overall, 8321 photos were collected along the four AUV transects, most of which were of sufficient quality to quantitatively record species and habitat data. All photos from the AUV's port side camera were annotated to document the occurrences of discernable taxa, with the exception of brittle stars.

Collection of specimens

The DFO ROV was equipped with a rudimentary mechanical manipulator and collection bag while surveying three transects. However, samples were only collected from two transects. The organisms collected were identified to the lowest taxonomic level based on morphological characteristics and their known location, as of July 2014, noted.

Species identification

Species identification of small, cryptic, and rare taxa is challenging, particularly when observers must rely on images alone for identification. In this report we examined all images collected while on station at Cobb Seamount, to produce a species inventory list (Du Preez et al. 2015), and to aid with future species identifications. We identified species primarily on the basis of their appearance, depth range, and behaviour as documented in photographs and video. We were also able to collect a few specimens to confirm identity by examining morphology more closely (described below). We drew on a compilation of published species checklists from Cobb Seamount (Du Preez et al. 2015), expert knowledge, and a range of taxonomic references to identify organisms to the lowest taxonomic level given available evidence based on the phylogeny outlined in the World Register of Marine Species database (WoRMS 2015). Overall, 144 taxa were identified from the images, and a photo-documented inventory of species observed during the 2012 cruise is presented in Du Preez et al. (2015).

While we may be confident of the occurrence of particular taxa on Cobb Seamount, we were not always confident in identification of individuals encountered while annotating the video and photos (methods described below) because of such factors as image quality, distance from the camera, the lack of observable distinguishing features, individual size, and orientation to the camera. During annotation of video and photos, organisms were identified to the lowest taxonomic level given these factors. For example, if no distinguishing features of a rockfish were visible we recorded "*Sebastes* spp.".

Rules were developed to annotate the abundance of pairs of cryptic species. Hermit crabs habitually occupy the empty shells of *Fusitriton oregonensis*. While the shell is easy to identify, it is not always easy to determine whether the shell is occupied or not, and if so, whether it is occupied by a living *F. oregonensis* or a hermit crab. Moreover, multiple species of hermit crabs are present on Cobb Seamount. Thus, if the snail's foot or the hermit crab was visible, identification was simple. If not, the following points were considered:

- If a hermit crab was observed in the shell, and the bright purple claws of the purple hermit (*Elassochirus cavimanus*) were not visible, the individual was simply recorded as Paguridae (hermit crab).
- If the shell's opening was orientated any other way than downwards, and/or if the shell was broken, the shell was deemed empty and was not recorded.
- If the shell's opening was downward-facing, and the shell was flush against the substrate (usually a hard substrate), it was recorded as a living *F. oregonensis* snail.
- If a shell did not conform to the above points, and it was on sand surrounded by other identified hermit crabs, it was recorded as a Paguridae.

Another pair of species, Rosethorn and Rosy Rockfish, has very similar morphologies but differ slightly in colouration. Rosy rockfish contain more orange and purple than Rosethorn Rockfish (Love, Yoklavich and Thorsteinson, 2002). This subtle difference can be hard to observe in video and photographs. Thus, as a default, individuals were recorded as Rosethorn rockfish because Rosy Rockfish were deemed rare at Cobb Seamount by experts aboard the cruise.

Annotation of HD ROV video

DFO's custom image annotation software, Video Miner (versions 2.1.3 and 2.1.4, see Appendix 3), was used to annotate the video clips collected while the DFO ROV was in transect mode, as well as a subset of photographs collected from the DFO ROV and AUV transects. Video Miner displays (video or still) images in a player window and populates a Microsoft Access database with time-tagged entries. For still images the time is extracted from the EXIF metadata and for video the time is calculated from frame counts by the software after calibrating it with the time displayed in the video overlay. Because all ROV data is time synchronized, the time tagged data can be merged with the tracking data so that the coordinates and depth can be determined for any observation. Alternatively, for still images that have been geotagged, the software can extract the coordinates and depth directly from the images.

Video Miner has a flexible structure allowing for the addition of new fields and data types as needed for different projects. The software enters data into a single database table, however, most of the data are controlled by look-up tables that contain standard codes used across multiple DFO projects (species codes, substrate codes, etc.). A small number of fields in the table are uncontrolled, such as the project, transect, and comment fields, and the majority are either populated automatically by the software or by manually choosing from a look-up table. The software has three general areas for entering data. The first area refers to header information such as date, time, project, and transect are set, usually only at the beginning of a video/dive/transect and then written automatically in every subsequent record. The second section of the software window has programmable buttons that enter data into a database field from a look-up table. This area is referred to as the “habitat data” area and is often used for recording habitat characteristics such as substrate type and complexity, but can also be used for other data like image quality and survey mode. The thirst section contains what is referred to as the species button area. Each button in this area enters a species code from a very large look-up table. The user can also enter information about that observation such as counts, lengths, widths, and comments.

The video was viewed at a playback rate of 1.0 x. At 10 sec intervals, information on survey mode, video quality, habitat and species was annotated based on features of the seafloor and organisms that passed through the horizontal line transecting the projected lasers. Habitat and species data were annotated only when the image quality was sufficient and the DFO ROV was ‘On bottom’ and in ‘Transect’ survey mode.

Image quality depends mainly on water quality and often does not change during a dive, but factors such as camera angle, lighting changes, distance from the seafloor, fish behaviour (e.g. aggregating around the ROV or stiring up sediment), and technical difficulties can also change the quality of the video. The image quality categories and codes used to annotate the video are listed in Table 1.

Table 1. Categories used to describe image quality for each 10 second segment of video.

Code	Category	Description
1	Excellent	National Geographic quality, clear water, perfect lighting, good distance from bottom, camera steady or moving smoothly etc.
2	Good	Very good video, but not quite perfect.
3	Average	Water quality or lighting not good, but still able to see habitat and organisms clearly enough for classification and species identification.
4	Poor	Water quality or lighting not good, difficult to see habitat and organisms clearly enough for classification or species identification.
5	Very poor	Water quality and or lighting poor very. Difficult to identify even large objects unless they are very close.

During annotation, the ROV was considered ‘Off bottom’ if it was high enough that the field of view width was >550 cm; at that height it was difficult or impossible to see the seafloor and to identify animals. The ROV height resulting in ‘Off bottom’ may have been less if for other reasons the image quality was already poor (e.g. bad lighting or particulates in the water).

For each 10 sec of video, survey mode was classified according to whether the DFO ROV was following the transect line in a smooth and continuous manner (transect mode), stopped, slowed, or turned to investigate a feature or species of interest (investigation mode), or zoomed on a feature of interest (zoom mode). Only organisms visible on or near the seafloor that were large enough to be detected and resolved when the ROV was in ‘transecting’ mode were annotated. If animals were too small, or observed only when the ROV stopped in ‘investigating’ or ‘zoom’ mode, their presence was noted in the comments section and included in the species inventory of Du Preez et al. (2015).

Field of view width in video

For each 10 sec segment of video, we estimated the width of high definition video field of view (FOV), defined as the horizontal line transecting the green laser dots projected from the DFO ROV onto the seafloor. To calculate the approximate FOV width, we used the known distance (10 cm) between the projected dots (i.e. laser scale, Figure 8) and a simple scale equation (Eq. 1).

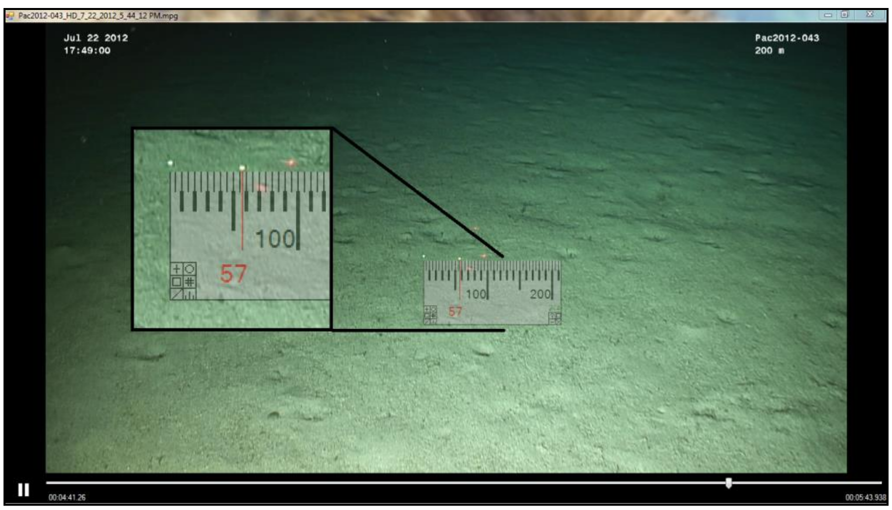

Figure 8. A screen shot of the Video Miner video player window with ruler overlay to measure the pixel distance between the horizontal 10 cm projected laser scale (green lasers; i.e. 57 pixels for this image) (photo credit: DFO PBS ROV team).

Because the actual distance of the laser-scale was 10 cm and the image’s FOV pixel width remains constant at 1242 pixels, the measured image distance between the lasers could be used to calculate the actual field of view width (in cm; Eq. 1):

$$\frac{D_a}{D_i} = \frac{W_a}{W_i} \qquad \text{(Eq. 1)}$$

where D_a is the actual laser scale distance in cm, D_i is the image laser-scale distance in pixels, W_a is the estimated FOV width (cm), and W_i is the image FOV width (pixels). For example, in Figure 8 the laser-scale distance is 57 pixels and so the approximate field of width is calculated as 218 cm:

$$W_a = \frac{10cm}{57\,pixels} \times 1242\,pixels = 218cm \qquad \text{(Eq. 2)}$$

This method is an approximation for the actual FOV width because an image scale changes with distance from the source of the scale measurement. Moreover, the refraction of light through water would also alter the scale. Estimates of the width of FOV were rounded to the nearest 10 cm.

The freely available program, 'A Ruler for Windows v 2.5' (www.arulerforwindows.com), a virtual ruler that enables users to accurately measure the pixel distance of objects on a computer screen, was used to calculate the number of pixels between the green dots. The ruler overlaid the Video Miner player while annotating the video, and was aligned with the projected laser-scale so that pixel measurement proceeded from the left laser to the location of the right laser. The pixel distance between the two points was input into an Excel worksheet to calculate the width of FOV, and the corresponding value was entered into the Field of View component of Video Miner.

Transect area

The width of the FOV and the length of the annotated vehicle track were used to estimate the area viewed and annotated for each transect. The length of the vehicle track was calculated with ArcGIS geometry calculator by connecting all of the way points on a given transect between the first and last record. The length of the annotated track excluded all sections of the vehicle track where video was not annotated (e.g. when the DFO ROV was being used to collect samples). The proportion of the annotated track that was viewed at a given FOV, ranging from 90 cm to 550 cm in 10 cm increments, was multiplied by that FOV to obtain the annotated area in m^2, and all areas were summed to determine the total area viewed and annotated for each transect.

Species abundance

The abundance of species and species groups was documented with estimates of relative abundance and, when feasible, counts of individuals or discrete colonies were obtained. The relative abundance of all taxa observed in video transects was categorized as rare, frequent, or abundant, according to Table 2. Organisms that were only viewed in the periphery of the video and did not pass through the horizontal line transecting the projected green lasers were not considered when annotating the video. Densities of counted taxa were obtained by dividing the counts summed within transects by the estimated area of annotated transect.

Table 2. Species relative abundance categories and definitions. Category definitions for colonial animals are based on Nelson et al. (2011).

Category	Non-colonial organisms	Colonial organisms
Abundant	>8 individuals	>25 % cover
Frequent	2-7 individuals	5-25 % cover
Rare	1 individual	<5 % cover

Habitat classification

Habitats observed in the DFO ROV video were classified according to substrate type and the degree of relief. For each 10 sec segment of transect video, the percent cover of the dominant and subdominant substrates were estimated and recorded. Fourteen codes were used to classify dominant and subdominant substrate types (Table 3), including coral rubble (Figure 9). Habitat codes used by DFO in a broad range of projects were adapted from the Wentworth Scale (Wentworth 1922). Percent cover of dominant and subdominant substrates was categorized according to five ranges specified in Table 4. Habitats were also classified according to the degree of relief, as defined by the four categories: (1) flat or rolling, (2) vertical relief between 0.5 and 2m, (3) vertical relief >2m, and (4), slope or wall.

Table 3. Substrate code, type and description used to classify dominant and subdominant substrate types on Cobb Seamount.

Substrate code	Substrate Type	Description
0	Wood	Wood, Bark, or Wood Debris
1	Bedrock, smooth	Bedrock, smooth, without crevices
2	Bedrock with crevices	Bedrock with crevices
3	Boulders	Boulders, bigger than a basketball
4	Cobble	Cobble, between 3 inches and a basketball
5	Gravel	Gravel, between ¾ inch and 3 inches
6	Pea gravel	Pea gravel, between 1/8 inch and ¾ inch
7	Sand	Sand
8	Shell	Shell
9	Mud	Mud
10	Crushed shell	Crushed shell
11	Whole Shell	Whole shell
12	Live sponge	Live sponge
13	Dead sponge	Dead sponge
14	Coral rubble	Dead coral debris

Table 4. Categories of percent cover used for estimating relative abundance of dominant and subdominant substrate types and the relative abundance of selected colonial or encrusting species.

%Cover Code	Range of Percent Cover	Mid-point of range
1	<5%	2.5
2	5-25%	15
3	26-50%	37.5
4	51-75%	62.5
5	>75%	87.5

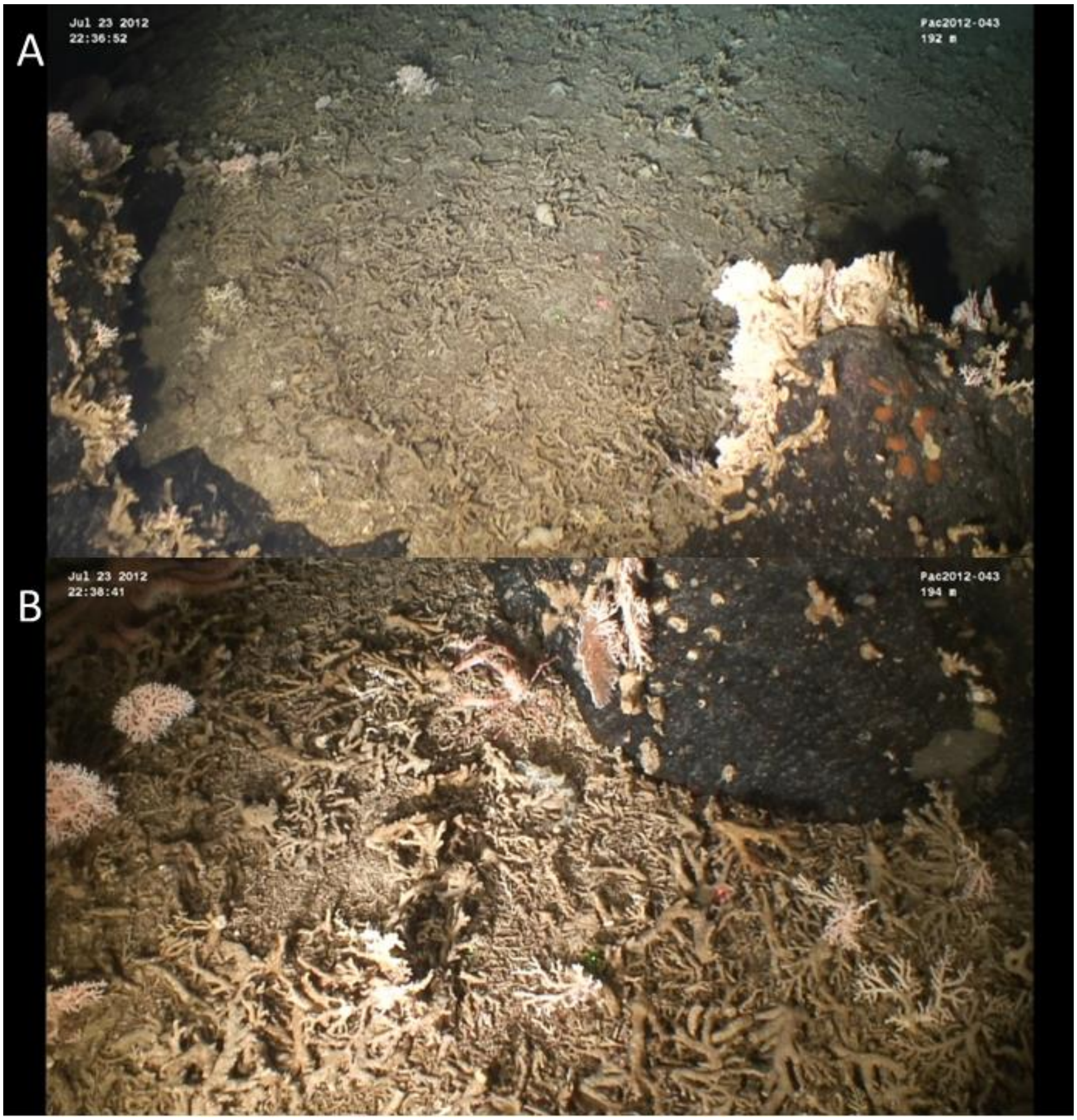

Figure 9. Any dense cover of dead coral debris (a) was annotated as "Coral rubble". A close-up of coral rubble (b) illustrates that it was composed primarily of variously sized fragments of *Stylaster* spp. Green laser scale is 10 cm horizontally and red laser scale is 10 cm vertically (photo credit: DFO PBS ROV team).

Seafloor features that were only viewed in the periphery of the video and did not pass through the horizontal line transecting the projected green lasers were not considered when annotating the video to estimate percent cover of substrate type or classifying the degree of relief.

Annotation of ROV photos

Photographs collected from the DFO ROV transects were used to count or estimate the percent cover of species for which counts of individuals were not feasible from the video imagery, including encrusting and colonial species. Between 102 and 430 photos were taken per DFO ROV dive, for a total of 3322 photos. Of these, a subset of 2057 photos corresponded to the quantitative transect video clips, which we refer to as the 'transect photos'. Every second photo within this subset (n = 1029) was annotated with Video Miner.

Area of ROV Photo quadrats

Calculating the area of FOV within each photo was challenging because the camera was pointed away from the seafloor and primarily at approximately 45˚. With two sets of parallel lasers projected onto perpendicular planes (one horizontally and one vertically across the image), we were able to overlay onto each photograph a small quadrat with dimensions corresponding to 40 cm x 40 cm. We used two virtual rulers (with the program 'A Ruler for Windows') to measure the relative or photo laser-scale, and with 10 cm between lasers, we calculated the photo's scale to determine the relative size of 40 cm within the photo in each perpendicular plane with Equation 3:

$$\frac{D_a}{D_i} = \frac{Q_a}{Q_i} \qquad \text{(Eq. 3)}$$

Where D_a was the actual laser scale distance in cm, D_i was the photo laser-scale distance in pixels, Q_a was the estimated length of the quadrat side (cm), and Q_i was the length of the photo quadrat side (pixels).

Once the photo quadrat length (horizontal) and height (vertical) were calculated, the rulers were oriented on the screen so they were perpendicular to each other, with the four projected lasers approximately in the center (the horizontal ruler creating the bottom-side of the quadrat and the vertical ruler creating the right-side of the quadrat; Figure 10). The two rulers were sufficient to visualize the 40 cm x 40 cm quadrat and more efficient in terms of time than adding two additional rulers to delineate the quadrat.

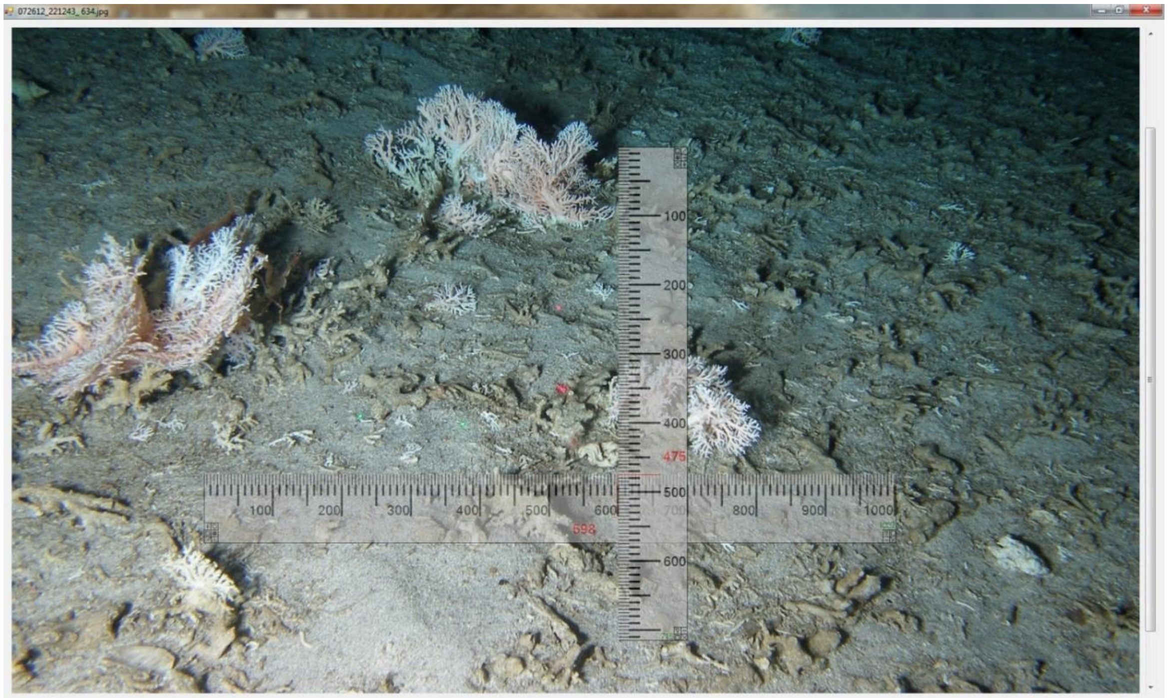

Figure 10. The Video Miner player window with two virtual rulers from the program 'A Ruler for Windows' used to define the bottom (horizontal ruler) and right-side (vertical ruler) of the overlaid 40 cm x 40 cm quadrat in each photo. In this example, the relative size of the green (10 cm horizontal) and red laser (10 cm vertical) scales resulted in the relative screen sizes of 40 cm equalling 698 and 475 for the length and height, respectively (photo credit: DFO PBS ROV team).

In a preliminary analysis, a square 40 cm x 40 cm quadrat was determined to most effectively and accurately utilize the ROV-collected photos. A square quadrat facilitates estimating percent cover (of species and substrate type) better than a recentangle quadrat and 40 cm lengths were easily calculated by multipling the projected scales (horizontal and vertical) by four. Selecting larger dimensions would have required larger extrapolation of the projected scales, introducing a higher the degree of error since a photogrammetric scale changes with distance from camera (i.e. a calculated scale is specific to a region of a photograph; Du Preez and Tunnicliffe 2012). Selecting for larger dimensions would have also reduced the number of usable photos (where the area within the photo < the quadrat dimensions). Selecting for smaller dimensions would have increased the bias against sparsely distributed species.

In photos where the quadrat could not be calculated from the projected lasers, the survey mode was recorded as 'Technical issues' and 'Could not calculate quadrat' was entered into the comment section. Reasons why the quadrat could not be calculated included: one or more of the lasers were not visible or were obscured; the DFO ROV was too far from the seafloor; the camera was too close to the seafloor or zoomed in too far; visibility in general was poor; the camera was out of focus; and the camera angle was too high. During DFO Dive 2, the substrate was often completely covered in red and green encrusting epifauna which made it very difficult to consistently locate the red and green projected lasers and the quadrats could not be calculated for many photos during this dive.

Species abundance

The 40 cm x 40 cm quadrats in the DFO ROV photos were used to quantify the relative abundance of species that were more difficult to count in the video because of their small size, cryptic nature, high density, or colonial growth form. These taxa included encrusting or colonial taxa (e.g. sponges) for which 'individuals' could not be discerned, and counts of those small taxa (e.g. polychaetes) that were not counted during DFO ROV video analyses. Quadrat area (0.16 m^2) was used to estimate densities of taxa that were counted in the ROV photos. The percent cover of colonial animals was quantified using the same five categories as percent cover for substrate types (Table 4).

Habitat classification and image quality

For every photo analyzed, metadata and habitat data were also recorded, including the photo filename, protocol, survey mode, photo quality, relief, disturbance, dominant and subdominant substrate types with percent cover estimates, and presence of anthropogenic objects.

Annotation of AUV photos

All non-overlapping colour-corrected AUV photos from the portside downward pointing camera were annotated by E. Fruh using methods outlined in Fruh et al. (2013), and data were entered into a spreadsheet. Photos taken at higher altitudes produced images with larger areas of view leading to difficulties in identifying organisms. Approximately 13.5% (409/3023) of photos were not annotated due to poor image quality. Discernable taxa, including corals, sponges, other invertebrates (but not brittle stars or snails) and fishes were identified and counted in the remainder. A subset of photos from the same port side camera were also annotated by C. Du Preez with Video Miner software to count all solitary and colonial corals and sponge taxa, identified to the lowest taxonomic level. Du Preez's annotations alternated between every second and then third photo, resulting in 1192 AUV photos analyzed. The angled camera photos were also used to help with taxonomic identification in some cases.

Area of AUV photo quadrats

The field of view area of each AUV photo was calculated based on the camera's recorded altitude above the seafloor. During cruise mobilization, the cameras were calibrated in their pressure housings following the procedures in Kunz and Singh (2008), and Jean-Yves Bouguet's Camera Calibration Toolbox for Matlab®. Calibrating cameras in this way serves to characterize the combined system of the camera lens and underwater housing, after which accurate measurements can be made of items of interest within the imagery.

One of the parameters resulting from the camera calibration procedure is the focal length of the combined camera lens-pressure housing lens system. Knowing that parameter along with the pixel dimensions of the image enables the calculation of the horizontal (H) and vertical (V) fields of view (FOV) angles according to the following equations:

$$HFOV = 2 \times \arctan\left(\frac{\frac{xdim}{2}}{fx}\right) \qquad \text{(Eq. 4)}$$

$$VFOV = 2 \times \arctan\left(\frac{\frac{ydim}{2}}{fy}\right) \qquad \text{(Eq. 5)}$$

where:

- *xdim* is the size, in pixels, of the horizontal dimension of the image
- *ydim* is the size, in pixels, of the vertical dimension of the image
- *fx* is the focal length, in pixels in the x dimension, of the combined lens system
- *fy* is the focal length, in pixels in the y dimension, of the combined lens system

With the combined lens system fields-of-views calculated, the actual area imaged by each photograph can be calculated if the distance from camera to the seafloor is known. Using data from the ADCP synchronized by time with the photographs, the area imaged by each photograph is calculated by the following equation:

$$image\ area = \left\{2 \times \left(alt \times \tan\left(\frac{HFOV}{2}\right)\right)\right\} \times \left\{2 \times \left(alt \times \tan\left(\frac{VFOV}{2}\right)\right)\right\} \qquad \text{(Eq. 6)}$$

where *alt* is the altitude of the AUV above the seafloor, as logged by the ADCP, at the time the photograph is taken.

Species abundance

All taxa within the camera's field of view of sampled photos were counted by E. Fruh and C. Du Preez; there was no sub-sectioning of the photo, overlay grid or quadrat. If a photo annotated by Du Preez contained no organisms, 'Nothing in photo' was recorded in the comment column of the database to denote that the photo was analysed. Other common entries in the comment section included: 'No image' if the photo was of insufficient quality to discern species or the seafloor; 'Camera against the sediment' if the AUV was on the substrate; 'Too high off seafloor' if the seafloor was visible but still too far to accurately analyse; and 'Anthropogenic object: ...' if fishing gear or trash was observed in the photo.

Habitat classification and image quality

In addition to species data, for every photo analyzed, metadata and habitat data were recorded, including the photo filename, time, latitude, longitude, altitude, seafloor depth, image width, height and area, survey protocol, survey mode, photo quality, relief, disturbance, dominant and subdominant substrate types with percent cover estimates, and presence of anthropogenic objects. The lack of scale projected onto photos made it challenging to determine the size of objects in the photos and classify substrate type. Thus, we used the known sizes of organisms that appeared in the photos to estimate the size of the sediment and annotate substrate type, including percent cover.

The primary and secondary habitat types were also annotated for each of the AUV photos taken from the port camera using NOAA's habitat classification system (Table 5), which was adapted from Stein et al. (1992). Primary habitat types were defined as those covering more than 50% of the area and secondary habitats covered 20-50% of the area.

Table 5. Habitat types defined by NOAA to characterize the substrata on the seafloor (adapted from Stein et al. 1992).

Habitat type	Description
Rock ridge	High to low relief
Boulder	> 25.5. cm
Cobble	> 6.5 cm, < 25.5 cm
Pebble	> 2 cm, < 6.5 cm
Gravel	> 0.4 cm, < 2 cm
Sand	Grains distinguishable
Mud	Noticeable organic particles

Species richness and diversity

Indices of benthic species richness, diversity, and evenness were calculated based on the count data obtained from all taxa identified to the lowest taxonomic unit on the DFO ROV transects. A species accumulation curve was created from all of the DFO ROV transects to determine the number of new species observations with each additional transect. Data analyses were carried out with Microsoft Access and the package vegan in R version 3.1.0 (R Development Core Team 2015).

Fishing gear and observable impacts

All of the ROV video, ROV photographs and AUV photographs were viewed to record observations of fishing gear and other anthropogenic objects, as well as any evidence of fishing-related impacts (e.g. drag marks, entangled nets, and toppled coral). Weights, line and nets were noted as "Fishing gear" in the Video Miner Comments section.

Surveys of seabirds and marine mammals

Sampling design

Seabird and marine mammal surveys were conducted en route to and from Cobb Seamount, as well as while the ship was on-station over the seamount. Two types of surveys were carried out: underway surveys were conducted while the ship was in transit and stationary surveys were conducted while the ship was on-station at the seamount. The stationary surveys were randomly distributed (spatially/temporally) over the seamount. In addition to seabirds, all identifiable marine mammals encountered were also recorded.

Data collection

There are limited quantitative data on seabirds and marine mammals over seamounts in the North Pacific Ocean, making it difficult to compare the results from Cobb Seamount with those from elsewhere. Consequently, we have also included in this report, observations made during underway surveys to and from Cobb Seamount, in July/August 1991 and June/July 1992.

Underway Surveys

Underway surveys in 2012 were conducted only during daylight hours while the vessel was in transit (minimum speed 4 knots [7.4 km/hr]), and followed a standardized protocol (Tasker et al. 1984; Gjerdrum et al. 2012). Depending on weather conditions, the observations were made from either the outside deck above the ship's bridge, or from inside the bridge. Observations were made by scanning ahead to a 90º angle from either the port or the starboard side of the vessel (depending on glare and/or wind direction); and for seabirds, observations were limited to a 300 m wide band, from the beam of the ship. All identifiable marine mammals seen within or beyond the 300 m band were recorded. Each survey lasted approximately 5 minutes in duration. Birds observed during each survey were counted and recorded as either in flight or on the water. Records were made continuously of all birds observed on the water throughout each survey and included an estimate of their perpendicular distance from the ship. Instantaneous ('snapshots') counts of flying birds were made at regular intervals throughout each survey, with the frequency determined by the speed of the vessel. Consecutive surveys were conducted as often as possible throughout the daylight hours, regardless of whether or not birds were present. Positions (latitude and longitude) and time were noted at approximately 5 minute intervals, as well as when the vessel altered speed, changed course or when surveys were terminated. A number of environmental variables (e.g. presence of precipitation, visibility, glare intensity and direction, sea state, swell height, wind speed, wind direction, etc.) were noted (minimum once per hour). Surveys were terminated during periods of reduced visibility (e.g. fog and/or heavy rain).

Underway surveys conducted in 1991 and 1992 differed from those done in 2012. In the early 1990s surveys, all seabirds seen on both sides of the vessel, out to a maximum distance (300 m), were recorded; the perpendicular distances of the birds from the ship were not recorded.

Stationary Surveys (2012 only)

While the ship was on-station, 'snapshot' counts of birds (in flight and on the water) within a set distance from the vessel (300 m) were conducted either from above or from within the ship's bridge, at random intervals and locations. We restricted this type of stationary surveys to locations within 8 km of the seamount pinnacle. Each stationary survey was conducted by scanning forward (or to one side depending on the glare) in a 180º arc; the semi-circle was visually swept only once per survey, and lasted approximately a minute.

Analysis of data

For each of the three survey years, underway surveys were categorized according to the distance from land and distance from Cobb Seamount. Underway surveys more than 50 km from the nearest land and more than 50 km from Cobb Seamount pinnacle were classified as distant underway surveys (from here onward distant surveys); and underway surveys less than 50 km from Cobb Seamount were identified as near seamount underway surveys (from here onward near surveys). The stationary survey data were assigned to four water-depth categories (< 200 m, 200-399 m, 400-799 m, ≥ 800 m), and four distance (from seamount pinnacle) categories (< 2.00 km, 2.00-3.99 km, 4.00-5.99 km, 6.00-7.99 km).

For each year and type of survey (distant, near, stationary), we summarized counts of all seabird and marine mammal species observed, and we calculated the density of seabird species within the 300 m boundaries of the search area. Counts and densities were also stratified by depth and distance from the seamount pinnacle. The common names, order, family, genus and species of all seabird and marine mammal species encountered during surveys, or mentioned in the text or tables are listed in Appendix 4.

Oceanographic surveys

Hydroacoustic data

Hydroacoustic data were collected while in transit to and from Cobb Seamount and over the seamount both opportunistically when neither ROV nor AUV were in operation, and also systematically along a set of defined parallel transects. Here we describe methods of system calibration, data collection, and the first stages of data processing and interpretation. Further analyses will be needed to fully interpret the data and relate signal attributes to specific organisms.

Sampling design

The Simrad EK60 multi-frequency scientific echosounder of the CCGS *J.P. Tully* was used to collect water column backscatter throughout the survey. This system consisted of five split-beam transducers operating at 18, 38, 70, 120, and 200 kHz mounted on the hull of the vessel. Calibration of this system was performed in Saanich Inlet on 11 May 2012. All frequencies were calibrated following recommended procedures using a 38.1 mm tungsten-carbide sphere with a 6% cobalt binder (Foote et al. 1987; Simmonds and MacLennan 2005). The vessel was anchored at a depth of 50 m and the sphere was suspended under the keel at a range of 22 m from the transducer's face for on-axis calibration and beam pattern mapping. A salinity and temperature profile from a CTD was taken to adjust the speed of sound in water and the sound absorption coefficients at the anchor site. The ER60 software (version 2.4.3) calibration utility was used to compute and adjust the transducers' peak gain and S_a corrections, along with the 3 dB beam widths and their offsets. Table 6 lists the values of the calibration parameters along with other relevant system settings used during the calibration and Cobb Seamount survey. A series of CTD profiles were collected around Cobb Seamount (see below) and were used to calculate the average sound speed and sound absorption coefficients for the survey area.

Table 6 EK60 calibration parameters and transceiver settings in effect during the survey.

Frequency (kHz)	18	38	70	120	200
SIMRAD transducer model	ES18-11	ES38B	ES70-7C	ES120-7C	ES200-7C
Transducer serial number	2064	30599	123	308	287
Transmit power (W)	2000	2000	750	250	110
Pulse duration (ms)	1.064	1.064	1.064	1.064	1.064
Transducer peak gain (dB)	22.05	21.06	27.06	27.43	25.53
S_a correction (dB)	-0.56	-0.39	-0.32	-0.28	-0.28
Bandwidth (Hz)	1570	2430	2860	3030	3090
Equivalent (two-way) beam angle (dB)	-17.0	-20.6	-21.0	-21.0	-20.7
Angle sensitivity (dB) alongship/athwartship	13.90	21.90	23.0	23.0	23.0
3 dB beamwidth (˚) alongship	11.27	7.12	6.32	6.40	6.60
3 dB beamwidth (˚) athwartship	13.34	7.24	6.37	6.38	6.85
Angle offset (˚) alongship	-0.16	0.04	-0.10	-0.16	-0.03
Angle offset (˚) athwartship	0.01	0.01	0.00	0.04	0.03

The EK60 recorded data almost continuously throughout the survey at a rate of one ping every one to two seconds down to a maximum recorded depth of 1500 m. This included data collection on the transit to and from Cobb Seamount, along with data collection during many of the on-site operations. The EK60 was turned off during some of the ROV deployments, while at other times data were recorded but the 18 kHz system was switched to passive mode (with no transmit) to avoid cross-talk with some of the other acoustic signals used for instrument communication and navigation. In addition to this opportunistic acoustic data collection, a number of dedicated parallel transects were carried out in an attempt to map the acoustic backscatter of the water column on and around the seamount (Figure 11, Figure 12). These parallel transects had a North-South orientation, were spaced by half a nautical mile and extended to a depth of at least 800 m on both their southern and northern limits. Vessel speed varied between 8 and 10 knots throughout the survey grids.

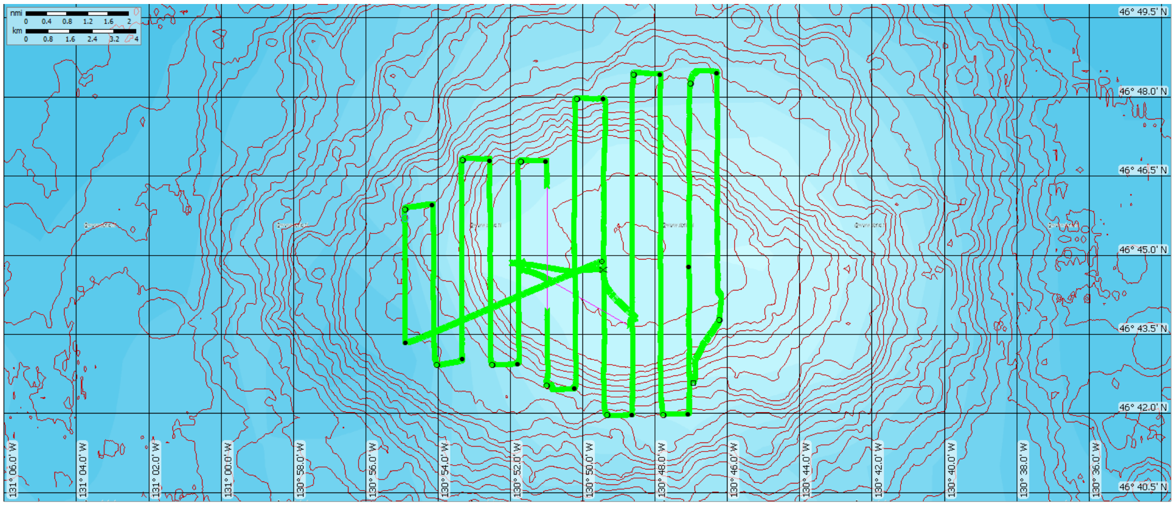

Figure 11. Vessel track (in green) showing the extent for the grid of parallel transects carried out on 22 July 2012 to map the water column acoustic backscatter on the western region of the Cobb Seamount.

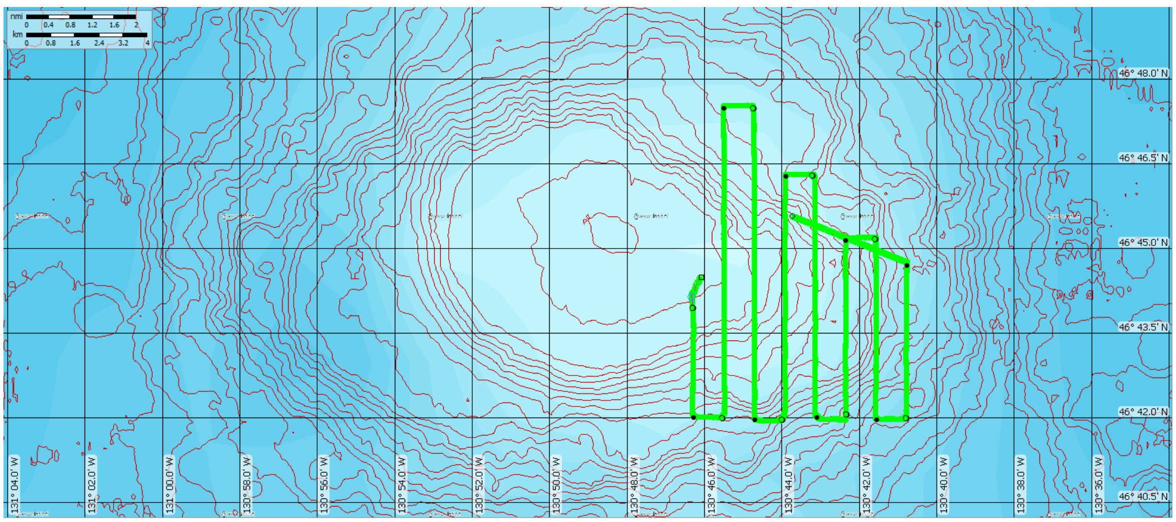

Figure 12. Vessel track (in green) showing the extent of the grid of parallel transects carried out on 23 and 24 July 2012 to map the water column acoustic backscatter on the eastern region of Cobb Seamount.

Data analysis

Acoustic data were analyzed using the Echoview© software (version 5.4, Myriax Ltd). Initial scrutiny of the data included removal of noise spikes and ping drop outs due to bubbles and cavitation. Drop outs were observed as low amplitude pings on the echogram that often extended to the bottom echoes (presenting a clean break point in the bottom echo return) and had values below typical background noise levels (< -90 dB). These pings were completely removed from all frequencies. Further background noise removal was performed following the approach described in De Robertis & Higginbottom (2007). Due to a weak signal of many scattering layers and aggregations, a signal-to-noise threshold of 3 dB was used throughout the study (whereas De Robertis and Higginbottom [2007] used 10 dB in their example). A lower signal-to-noise threshold was selected because of the nature of the pelagic aggregations in our study area, which often consisted of scattered layers or aggregations with low levels of volume backscattering. In these cases the signal of interest was what would be considered as background noise in many other studies dealing with denser and more discrete aggregations of fish. The signal-to-noise threshold was varied in the analyses from 3 to 10 dB to assess the effect this would have on the results. Increasing the threshold had little effect on the backscatter values of the densest aggregations, but would consistently remove echoes and layers that we believed were biological in nature. Reducing the signal-to-noise threshold to 3 dB did not appear to introduce noise in the data. To further limit the potential introduction of artificial noise in the results, the range of useable acoustic data were limited to 350 m for the 200 kHz, 500 m for the 120 kHz, 750 m for the 70 kHz, 1000 m for the 38 kHz, and 1500 m for the 18 kHz system. No Sv threshold was applied to the data during the noise removal process.

CTD casts

A Seabird 19 CTD (Model SEACATPLUS v1.6b, Serial number 5299) was used to collect oceanographic data while on station at Cobb Seamount. The CTD uses hydrostatic pressure to measure depth in m and electrical conductivity to measure salinity in PSU (practical salinity units). In addition, the CTD was equipped to measure water temperature in C° and dissolved oxygen (DO) in mL/L and µmol/kg with an SBE 43 DO sensor (#1483). Temperature and salinity instruments were calibrated prior to the cruise in January 2011, while the dissolved oxygen and pressure gauge were calibrated in December 2010. The sensors and housing on this CTD were rated for use to a depth of 600 m and was deployed from a wire cable (no rosette) to within 10-20 m of the estimated bottom depth (based on the ship's sounder) and up to a maximum of approximately 580 m. During deployment, the CTD was soaked below the surface (1-2 m depth) for approximately 1 min which was most likely adequate because the surface water temperature and air temperature were similar.

Sampling design

CTD profile data were obtained from a subset of ROV and AUV sites (n = 12) when time permitted prior to or following a dive. In some instances, the CTD instruments were cast at transect sites during the night to make the best use of daylight hours for ROV and AUV operations. In addition, 20 CTD profiles were obtained at night from a systematic grid to characterize the salinity and temperature profiles over most of the seamount (Figure 13).

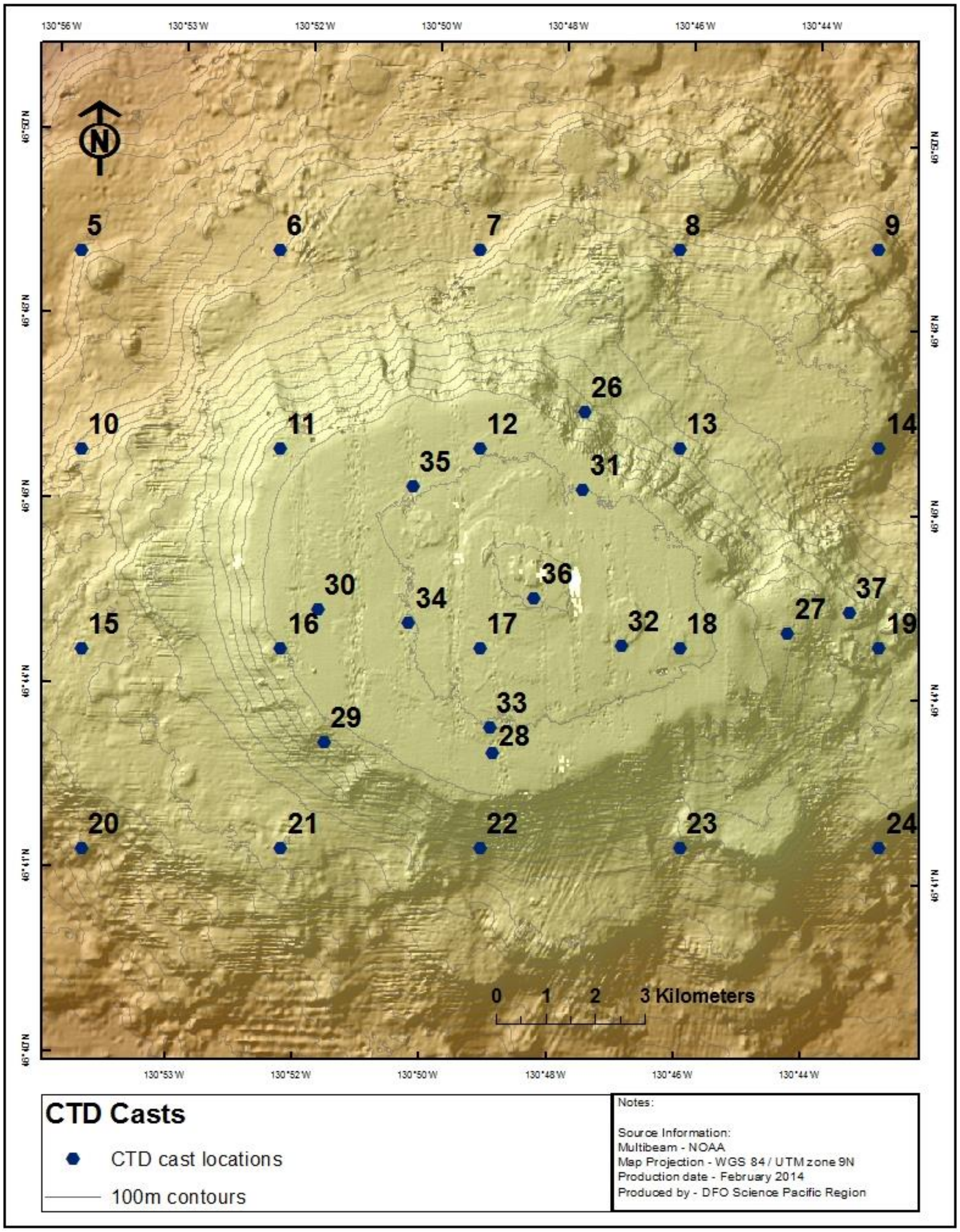

Figure 13. Map of CTD cast locations.

Data analysis

In this report, analyses of CTD data were generally limited to processing and aligning the raw data, and producing figures that summarize the temperature, salinity and dissolved oxygen profiles at the 32 cast locations (i.e. sites). Raw data downloaded from the CTD following the cruise were processed by G. Gatien (Institute of Ocean Sciences, DFO). Her detailed processing report is included as Appendix 5.

Processing of the data revealed some corruption due to a number of factors, and corrupted data were omitted from processed files. One factor associated with corruption was the descent rate, which often exceeded 2.5 $m \cdot s^{-1}$, or dropped suddenly to less than 1 $m \cdot s^{-1}$. These very high deceleration rates are assumed to be due to swell and are common in deep casts from the *CCGS J.P. Tully*. The first 250 records from each cast were also omitted to simplify editing by removing spikes before and during the soak period. Data may also have been subject to drift in the sensors which were not calibrated on board and had not been calibrated by the time of publication of this report. Other factors including download issues are discussed in detail in Appendix 5.

Data archiving

Data are archived according to type. ROV and AUV images are archived within the Shellfish Data Unit at PBS, Nanaimo, BC. Copies of the images are available upon request from the authors. A copy of AUV images may also be obtained from NOAA cruise participants. Seabird and marine mammal data may be obtained by contacting K. Morgan (see Appendix 1). Hydroacoustic data are archived as per standards recommended by the National Acoustic Data Archive initiative (NADA). Data are available by contacting S. Gauthier at IOS (Marine and Freshwater Acoustic Program, Ocean Sciences Division, P.O. Box 6000, 9860 West Saanich Road, Sidney, BC V8L 4B2 ; Stéphane.Gauthier@dfo-mpo.gc.ca). The CTD data may be obtained through the DFO Water Properties Profiles at: http://www.pac.dfo-mpo.gc.ca/science/oceans/data-donnees/search-recherche/profiles-eng.asp.

Results and Discussion

Surveys of benthic communities

A total of 23 dives were carried out at 20 sites ranging from 35 m to 1154 m depth while on station at Cobb seamount. Table 7 summarises information on the site name, vehicle, pilot, start and end times, start and end locations, transect length and depth range for each dive. Table 8 provides details on the sampling strategy, number of photos, and the amount and quality of video obtained from each site.

Table 9 provides estimates of the length, width and area of DFO ROV transects, and Table 10 provides the area of AUV photo analyzed on each AUV transect. Twelve transects were completed at each of 12 sites by the DFO ROV (Figure 14). Six dives were carried out with the SFU ROV (Figure 15). Due to technical difficulties, however, four of the SFU ROV dives were aborted; Dives 4, 11, and 12 at Site SFU_5 and Dive 16 at Site SFU_2. Only two transects with the SFU ROV were completed (SFU_3 and SFU_5). Photographs were obtained from four AUV transects (Figure 16), but the AUV was irreparably damaged during recovery at the end of its fifth dive (Dive 17) and all data collected from site AUV_3 were lost. In total 18 transects were completed and a small amount of video data were collected from site SFU_2.

Table 7. Summary of transects, including details related to time and location. Start and end times and locations, transect length and depth range correspond to the time stamp of the first and last records annotated for each transect. Site names correspond to locations depicted in Figure 14, Figure 15, and Figure 16. In terms of vehicle, DFO = DFO ROV, SFU = SFU ROV, and AUV = NOAA AUV. In terms of pilot, WC = Wolfgang Carolsfeld, JM = Jonathan Martin, JP = James Pegg, and P = Programmed. Start and end locations are given in decimal degrees. ROV transect lengths refer to the effective distance travelled between start and end locations (i.e. actual vehicle track) based on smoothed navigation data. The AUV transect lengths refer to the distance between the locations of the first and last photos taken from the seafloor.

Date	Dive	Site Name	Pilot	Start time, End time (GMT)	Start Location (latitude, longitude)	End Location (latitude, longitude)	Transect length (m)	Depth range (m)
21/07/2012	1	DFO_2	WC	21:04:07 21:32:46	46.743258, -130.780176	46.746271, -130.780037	351.7	114-138
21/07/2012	2	DFO_6	WC	22:43:42 23:56:27	46.750276, -130.805643	46.754819, -130.806748	671.1	35-95
21/07/2012	3	AUV_1	P	2:00:06 4:01:47	46.71864, -130.761418	46.708262, -130.779512	1807.5	618.5-817.5
22/07/2012	4	SFU_5	JM		Aborted	NA	NA	NA
22/07/2012	5	DFO_4	JP	17:38:25 18:52:08	46.745551, -130.838695	46.743888; -130.832066	1047.3	189-200
22/07/2012	6	AUV_5	P	22:26:15 23:31:15	46.73421, -130.889104	46.718112, -130.890025	1820.9	776.4-945.6
23/07/2012	7	DFO_3	JM	2:32:34 3:35:36	46.726947, -130.816328	46.728432, -130.810551	542.6	196-201
23/07/2012	8	AUV_2	P	16:14:26 17:22:07	46.749319, -30.724664	46.765483, -130.723441	1794.6	534.7-838
23/07/2012	9	DFO_1	WC	20:07:16 20:48:55	46.770321, -130.793186	46.765978, -130.793100	711.6	192-201
23/07/2012	10	DFO_5	WC	21:57:05 22:38:45	46.770074, -130.838251	46.766454, -130.841541	569.7	193-208
24/07/2012	11	SFU_5	JM		Aborted	NA	NA	NA
24/07/2012	12	SFU_5	JM		Aborted	NA	NA	NA
24/07/2012	13	AUV_4	P	16:54:48 17:53:38	46.790498, -130.840501	46.806368, -130.844997	1799.3	435.8-1154.1
24/07/2012	14	SFU_5	JM	20:32:12 21:21:30	46.747423, -130.862420	46.748174, -130.856015	519.5	241-255
24/07/2012	15	SFU_3	JM	22:53:50 23:39:59	46.722860, -130.822040	46.722357, -130.815794	517.0	248-260
24/07/2012	16*	SFU_2	JP	1:36:58 1:48:22	46.744686, -130.738920	46.744668, -130.739007	152.6	~364-373
25/07/2012	17	AUV_3	P		Data lost	NA	NA	NA
26 /07/2012	18	DFO_8	WC	1:34:00 2:23:11	46.776076, -130.796108	46.772184, -130.800429	598.9	202-211
26/07/2012	19	DFO_14	WC	14:50:09 15:44:07	46.767001, -130.839898	46.764392, -130.833560	719.8	147-197

Date	Dive	Site Name	Pilot	Start time, End time (GMT)	Start Location (latitude, longitude)	End Location (latitude, longitude)	Transect length (m)	Depth range (m)
26/07/2012	20	DFO_15	JM	17:08:31 18:09:32	46.764616, -130.824890	46.761241, -130.819729	636.9	123-183
26/07/2012	21	DFO_16	JP	19:33:23 20:30:40	46.751842, -130.759818	46.748965, -130.766488	719.4	184-221
26/07/2012	22	DFO_9	WC	21:41:11 22:15:27	46.735131, -130.760331	46.737265, -130.754496	624.8	215-216
27 /07/2012	23	DFO_17	JP	1:21:15 2:58:38	46.773731, -130.809795	46.769734, -130.815034	932.3	161-191

Table 8. Summary of dive sampling strategy, and the amount and description of images obtained. In terms of sampling strategy, 'random' refers to randomly drawn start location and orientation within ROV depth stratum, 'feature' refers to selection on the basis of features of interest likely to support diverse or unique assemblages of coral, sponge or rockfish taxa, and 'historic' refers to sites selected to revisit locations that were visually surveyed in the past. SD and HD video refer to the amount of standard definition and high definition video, respectively. Form ROV transects, image quality refers to the percentage of ROV video collected on the seafloor and suitable for qualitative (e.g. species identification) or quantitative (e.g. relative abundance estimation) analysis of benthic communities (seafloor) and the percentage of video collected while in transect mode (transect). For AUV transects, image quality refers to the percentage of AUV photos of sufficient quality for analysis of substrate type and species identification.

Dive Number	Site Name	Complete (Y/N)	Sampling strategy	Number of Photos*	SD video (hours: min)	HD video (hours: min)	Image quality (%)
1	DFO_2	Y	Random	102	1:51	2:00	Seafloor: 63 Transect: 21
2	DFO_6	Y	Random	169	1:26	1:41	Seafloor: 88 Transect: 71
3	AUV_1	Y	Selected on the basis of slope <30˚, aspect and fishing effort	A: 728 P: 733 S: 733	0	0	98.2% analyzed
4	SFU_5	N	Random	0	0	0	Seafloor: 0 Transect: 0
5	DFO_4	Y	Random	302	1:44	1:57	Seafloor: 73 Transect: 64
6	AUV_5	Y	Selected on the basis of slope <30˚, aspect and fishing effort	A: 734 P: 734 S: 734	0	0	99.3% analyzed
7	DFO_3	Y	Random	301	1:30	1:39	Seafloor: 58 Transect: 16
8	AUV_2	Y	Selected on the basis of slope <30˚, aspect and fishing effort	A: 808 P: 809 S: 808	0	0	71.0% analyzed

Dive Number	Site Name	Complete (Y/N)	Sampling strategy	Number of Photos*	SD video (hours: min)	HD video (hours: min)	Image quality (%)
9	DFO_1	Y	Random	169	0:57	1:09	Seafloor: 53 Transect: 47
10	DFO_5	Y	Random	343	1:56	2:02	Seafloor: 72 Transect: 32
11	SFU_5	N	Random	0	0:32	0	Seafloor: 0 Transect: 0
12	SFU_5	N	Random	0	0:35	0	Seafloor: 0 Transect: 0
13	AUV_4	Y	Selected on the basis of slope <30˚, aspect and fishing effort	A: 0ǂ P: 750 S: 750	0	0	79.1% analyzed
14	SFU_5	Y	Random	0	1:37	0	Seafloor: 58 Transect: 50†
15	SFU_3	Y	Random	0	1:19	0	Seafloor: 55 Transect: 55†
16	SFU_2	N	Random	0	0:46	0	Seafloor: 40 Transect: 0
17	AUV_3	N	Selected on the basis of slope <30˚, aspect and fishing effort	0	0	0	All images were lost
18	DFO_8	Y	Feature: structural complexity, coral and rockfish habitat	427	2:04	2:10	Seafloor: 83 Transect: 42
19	DFO_14	Y	Feature: structural complexity, coral and rockfish habitat	274	1:28	1:29	Seafloor: 74 Transect: 53
20	DFO_15	Y	Feature: structural complexity, coral and rockfish habitat	261	1:05	1:20	Seafloor: 75 Transect: 69
21	DFO_16	Y	Historic: previously sampled site with *Lophelia* sp. bioherms	286	1:14	1:33	Seafloor: 71 Transect: 59
22	DFO_9	Y	Feature: structural complexity,	258	1:52	2:11	Seafloor: 42 Transect: 25

Dive Number	Site Name	Complete (Y/N)	Sampling strategy	Number of Photos*	SD video (hours: min)	HD video (hours: min)	Image quality (%)
			coral and rockfish habitat				
23	DFO_17	Y	Feature: structural complexity, coral and rockfish habitat	430	1:59	2:12	Seafloor: 71 Transect: 42

*A = angled camera, P = port camera, S = starboard camera

ǂ No photos were obtained due to a camera malfunction.

†The SFU ROV collected SD video along the planned transect, however, lasers were not projected onto the seafloor due to technical difficulties.

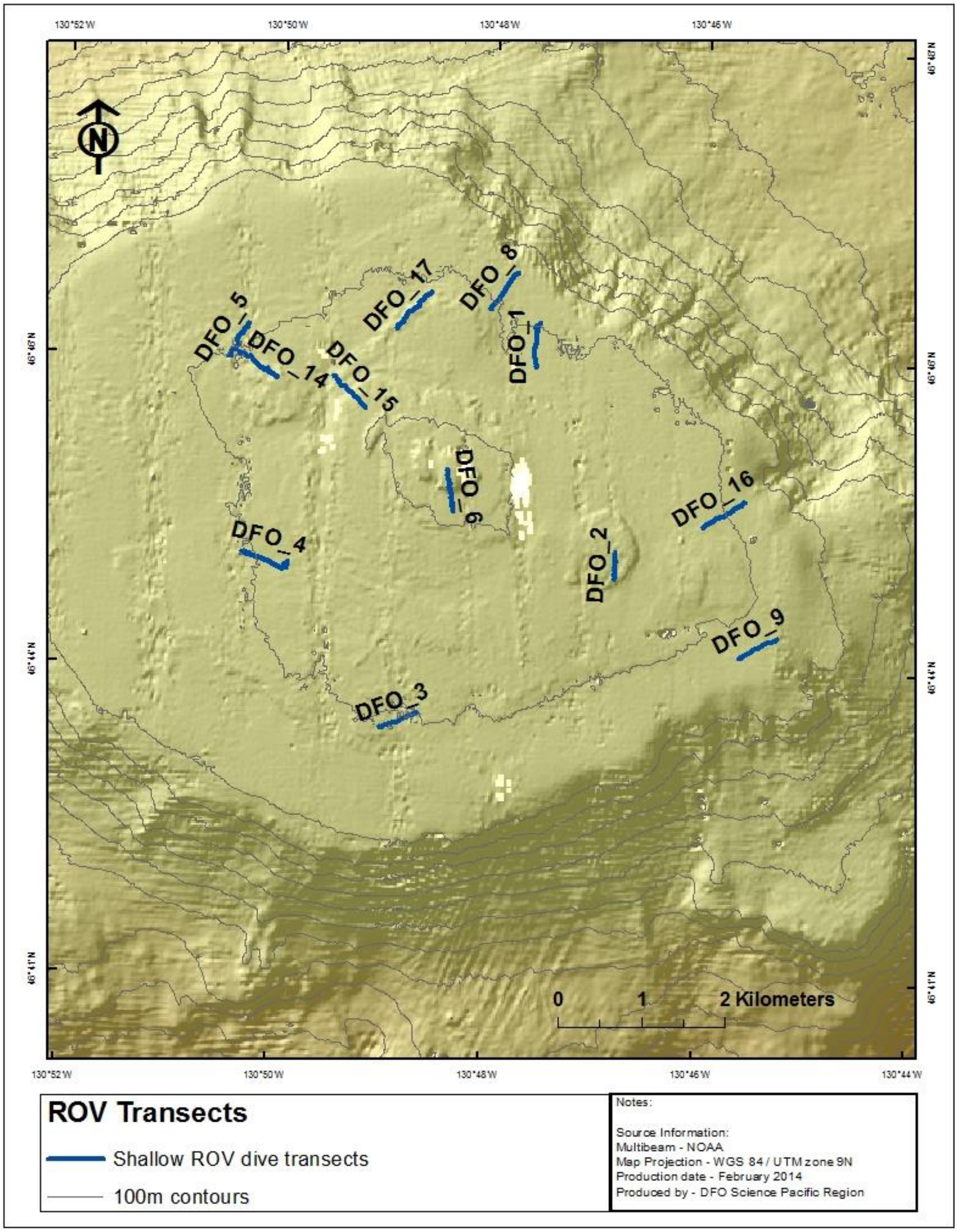

Figure 14. The Cobb Seamount 2012 DFO remotely operated vehicle (ROV) transects (n = 12).

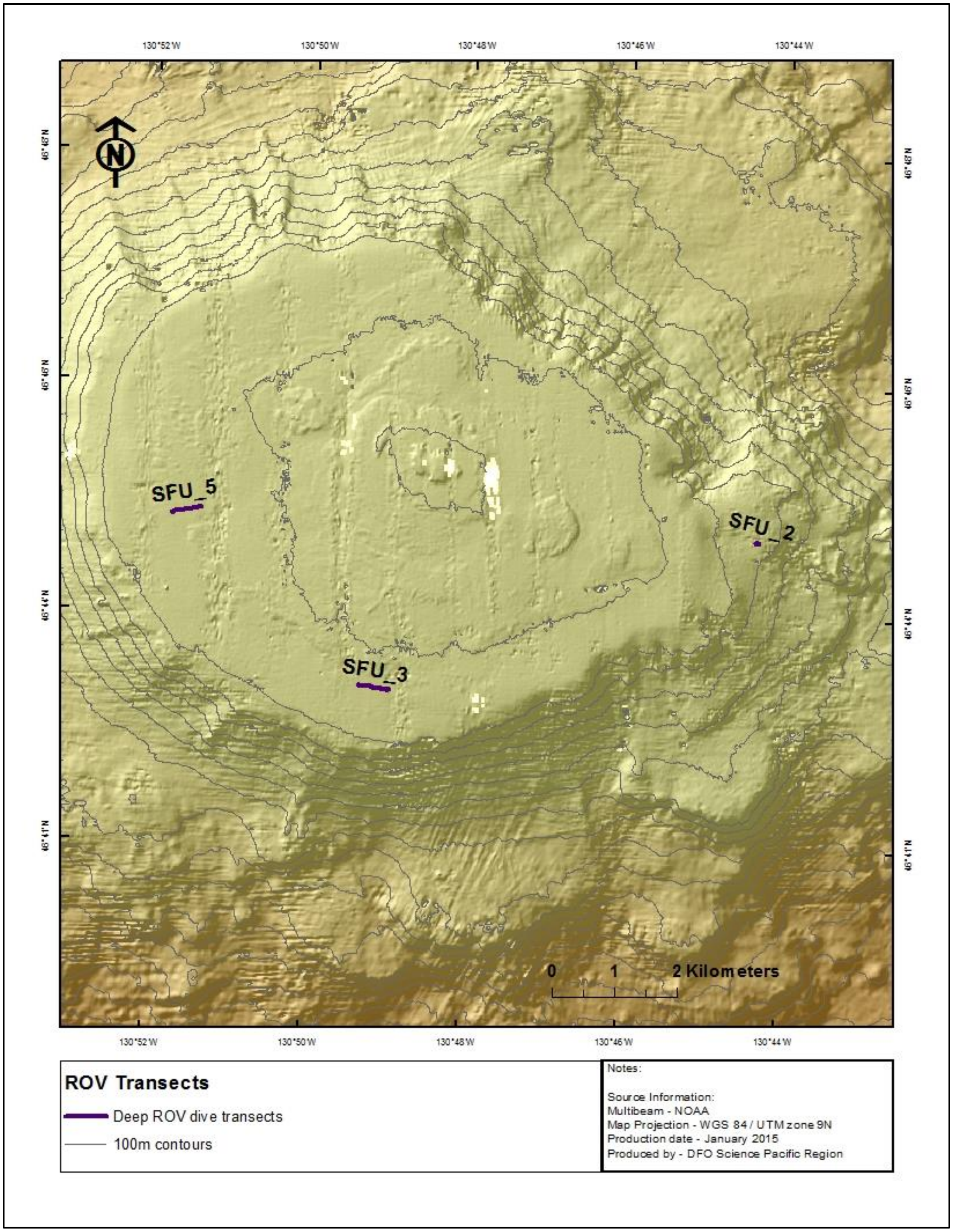

Figure 15. The Cobb Seamount 2012 SFU remotely operated vehicle (ROV) transects at SFU_3 and SFU_5 (n = 2) and the location of SFU_2 where a limited amount of imagery was collected.

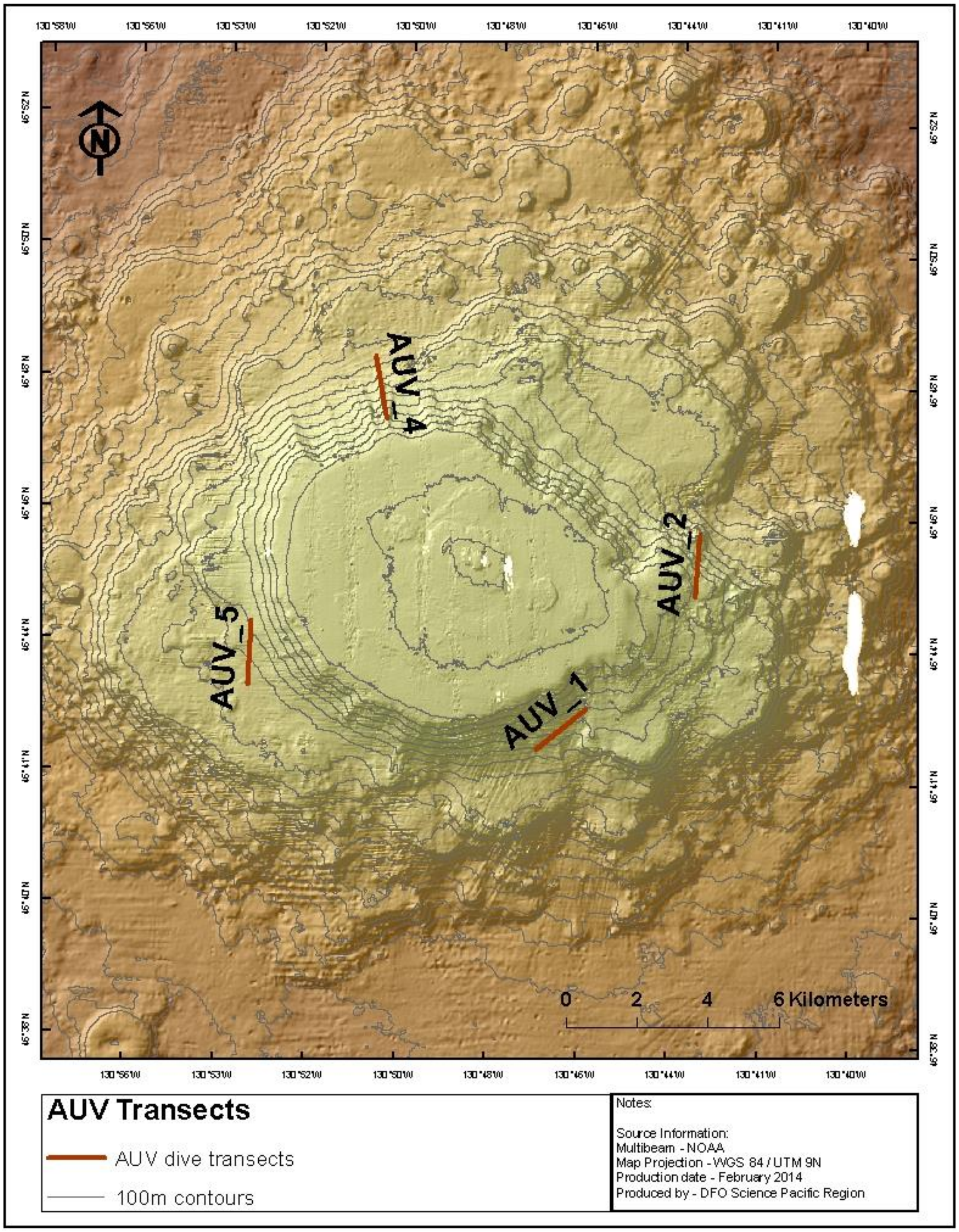

Figure 16. The Cobb Seamount 2012 NOAA AUV transects (n = 4).

Table 9. Length, width and area of DFO ROV transects. Transect length corresponds to the length of vehicle track between the first and last records annotated in the database while length of the annotated track excludes parts of the transect that were not suitable for obtaining counts and densities. Transect area refers to the area annotated using HD video. The sum of quadrat areas refers to the total area annotated using photos (0.16 m^2/photo) from the ROV's still camera. FOV refers to the width of field of view on the HD video.

Transect	Transect length (m)	Length of annotated track (m)	Transect area (m^2)	Mean (±SD) FOV (cm)	Number of FOV estimates	Number of photo quadrats	Sum of quadrat areas (m^2)
DFO_1	677	677	2127	297 (±127)	200	57	9.12
DFO_2	331	290	595	205 (±52)	140	37	5.92
DFO_3	504	381	1069	279 (±137)	237	64	10.24
DFO_4	1047	949	2778	290 (±143)	346	79	12.64
DFO_5	558	558	1852	329 (±118)	221	60	9.6
DFO_6	632	405	755	187 (±127)	158	23	3.68
DFO_8	502	502	1368	251 (±160)	234	33	5.28
DFO_9	505	503	1203	239 (±81)	173	47	7.52
DFO_14	651	570	1700	299 (±112)	253	71	11.36
DFO_15	567	382	1325	344 (±118	205	40	6.4
DFO_16	660	588	1551	264 (±159)	184	52	8.32
DFO_17	845	327	779	238 (±148)	205	23	3.68

Table 10. Total combined area of photos analyzed by E. Fruh and C. Du Preez for each of four AUV transects, and in total.

Expert	AUV_1 (m^2)	AUV_2 (m^2)	AUV_4 (m^2)	AUV_5 (m^2)	Total (m^2)
Fruh	3266	2647	3068	3282	12262
Du Preez	1387	1043	1255	1353	5038

Specimen collections

Most of the specimens collected were of the corals *Lophelia pertusa* (Figure 17) and *Stylaster* spp. (Figure 18). Descriptions and locations of these coral specimens at the time of publication are summarized in Table 11.

Table 11. List of specimens of *Lophelia* sp. and *Stylaster* spp. collected from Cobb Seamount on 26 July 2012 by at DFO_9 and DFO_16.

Species	Current location	Contact	Specimen Description	Comments
Lophelia sp.	PBS	Janelle Curtis	2 vials of colony fragments (15-20 mL); preserved in 95% ethanol	1vial for NWFSC 1 vial for Smithsonian Institute
Lophelia sp.	UVC	Cherisse Du Preez; Verena Tunnicliffe	1 vial of colony fragments; 15-20 mL; preserved in 95% ethanol and frozen at -80 C.	For genomics research
Lophelia sp.	UVic	Cherisse Du Preez; Verena Tunnicliffe	1 500 mL jar and 1 vial (15-20 mL), both frozen at -20 C.	Voucher specimen
Lophelia sp.	MUN	Barbara Neves	Colony fragments; 10-20 mL; frozen	Voucher specimen
Lophelia sp.	SWFSC	Mary Yoklavich	2 vials of colony fragments; 15-20 mL; 95% ethanol	
Stylaster sp.	PBS	Janelle Curtis	1 vial of colony fragments (1-2 mL); preserved in 95% ethanol	20 mL sample vial labelled for NWFSC
Stylaster sp.	PBS	Janelle Curtis	3 intact colonies (max dimension approximately 10cm); preserved in 95% ethanol	1 colony for Smithsonian Institute 2 colonies for PBS
Stylaster sp.	UVic	Cherisse Du Preez; Verena Tunnicliffe	1 vial of colony fragments; 15-20 mL; preserved in 95% ethanol and frozen at -80 C.	For genomics research
Stylaster sp.	MUN	Barbara Neves	Colony fragments (1-2mL); frozen	For species identification
Stylaster sp.	MUN	Barbara Neves	Dead base, maximum dimension 25 cm; frozen	For aging
Stylaster sp.	MUN	Barbara Neves	1 intact colony, maximum dimension 10 cm; frozen	Voucher specimen
Stylaster sp.	SWFSC	Mary Yoklavich	2 vials of colony fragments; 1-2 mL; 95% ethanol	1 vial for Peter Etnoyer.

Figure 17. A specimen of *Lophelia pertusa* collected on Cobb Seamount at site DFO_16 on 26 July 2014 (photo courtesy of Jonathan Martin).

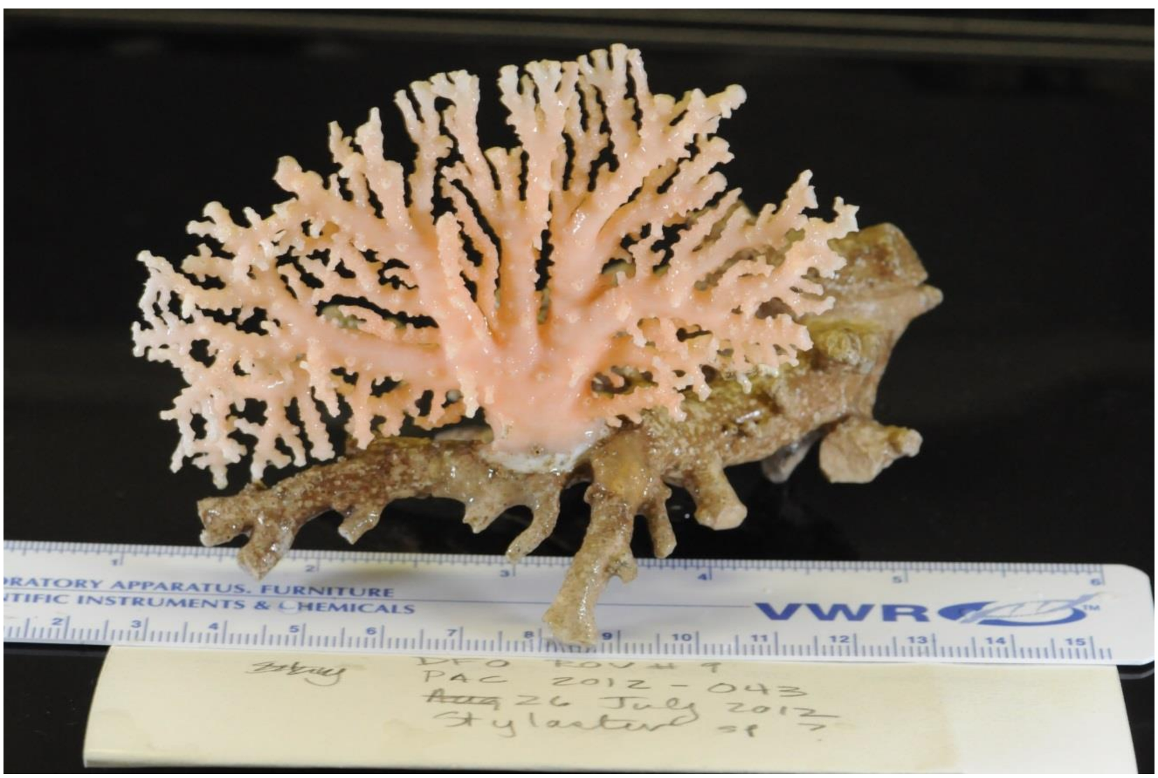

Figure 18. Specimen of *Stylaster* sp. collected from Cobb Seamount at site DFO_9 on 26 July 2014. (photo courtesy of Jonathan Martin).

Additional species collected from DFO_9 included the gastropod *Fusitriton oregonensis*, the polychaete *Nothria conchylega*, and two other unidentified polychaetes. Additional species collected from DFO_16 included the crinoid *Florometra serratissima*, two brittle stars *Asteronyx loveni* and *Ophiura sarsii*, as well as an unidentified crab and unidentified gastropod. All of these additional specimens were preserved in 95% ethanol and, at the time of publication, were stored at PBS.

Species distribution and abundance

We identified 144 taxa representing at least 120 genera, 90 families, 51 orders, 21 classes, and 11 phyla on the 15 ROV transects and four AUV transects, between 35 and 1154 m depth during the 2012 cruise. This brings the total number of taxa observed and/or collected from Cobb Seamount to 267 taxa from 14 phyla (Du Preez et al. 2015). The occurrence of the 144 taxa observed in 2012 is summarized by transect along with observed depth ranges in Table 12. Species previously observed on Cobb Seamount but not seen during the 2012 survey included small invertebrates such as polychaetes or small crustaceans that may have been difficult to identify or unlikely to be encountered with our ROV and AUV equipment. Many of the species we did not observe were previously collected with fishing gears or sediment grabs, are mid-water taxa, or were encountered by SCUBA divers who can more closely examine individual specimens. A number of factors may have influenced the species observed on Cobb Seamount with the ROV and AUV submersibles, including the time of day, time of year, vessel noise and lights (Stone et al. 2008).

Not all species were counted to estimated densities or characterize relative abundance. As examples, Bluntnose Sixgill Shark (*Hexanchus griseus*) and Grunt Sculpin (*Rhamphocottus richardsonii*) were only observed while the ROV was in investigation mode, making it difficult to quantify densities. The types of data collected are summarized by species in Appendix 6.

Each organism was identified to the lowest taxonomic level possible with confidence. If an organism could not be identified to species, the lowest taxonomic level was provided followed by “sp.”. If more than one taxon was observed and differentiated a number was assigned (e.g. “sp. 1”). If more than one taxon was observed but could not be differentiated, the lowest taxonomic level was followed by “spp.”. Photo-documentation of each taxon was collected during annotation of the videos and photos (Du Preez et al. 2015).

Frequency of occurrence

We used all the images and species observations to build a table of known occurrences at the 15 ROV sites and four AUV sites. In terms of the frequency of occurrence across sites, most taxa observed on Cobb Seamount in 2012 were relatively uncommon. The median frequency of occurrence was 0.16 and three quarters of taxa occurred at five or fewer sites. Only 13.7% of taxa were observed at half the sites or more, while 28.1% of taxa occurred at only one site (Table 13). The most frequent species observed across the 19 sites included the hermit crab *Pagurus kennerlyi*, rockfish species (*Sebastes* spp., in particular *Sebastes helvomaculatus*), the sea stars *Rathbunaster californicus* and *Henricia sanguinolenta*, the sea whip *Halipteris willemoesi*, and hydrocorals in the genus *Stylaster* (Table 13).

Abundance on ROV transects

In addition to noting species presence on the 12 DFO ROV transects (Table 13), counts or relative abundance measures (Appendix 7) and densities were obtained for the majority of organisms observed in the DFO ROV video (Table 14). Counts (Appendix 7), densities (Table 15), and the percent cover (Table 16) of organisms that were observed within 0.16 m^2 quadrats were also obtained from a subset of the ROV photos. Densities were calculated for most taxa on each transect using estimates of the total area surveyed on the ROV video, ROV photo quadrats (Table 9) and AUV photo quadrats (Table 10). Overall, 51 consistently identifiable taxa were counted in DFO ROV video, 20 were counted in the DFO ROV photo quadrats, and 57 identifiable taxa were counted in the AUV photo quadrats. The pecent cover of 15 taxa in the DFO ROV photo quadrats was also recorded.

Organisms counted on the DFO ROV video transects were generally large and conspicuous, including fishes, echinoderms, arthropods, cnidarians and molluscs. The most frequently counted organisms across all transects were the Rosethorn Rockfish *Sebastes helvomaculatus*, Puget Sound Rockfish *S. emphaeus*, and Pygmy Rockfish *S. wilsoni*, the cup coral *Desmophyllum dianthus*, and the sea cucumber *Apostichopus leukothele*. An unidentified sculpin (Cottidae sp.), the Sharpchin Rockfish *S. zacentrus*, and individuals from the complex of rougheye/blackspotted rockfish, *S. aleutianus/S. melanostictus*, were also locally abundant on some transects (Appendix 7 and Table 14).

Organisms observed in the photo quadrats were generally small, colonial, or encrusting. The most commonly counted taxa within ROV photo quadrats were the brachiopod *Laqueus californianus*, colonies of the hydrocoral *Stylaster* spp., and the annelids *Nothria conchylega*, *Paradexiospira* sp. and *Spiochaetopterus* cf *costarum* (Appendix 7, Table 15). The encrusting or colonial taxa with the greatest overall percent cover were in the red algae *Lithophyllum* spp. and cf *Lithothamnion* spp., an unidentified hydroid (Hydroid sp. 1), the bryozoan cf *Reginella hippocrepsis*, and unidentified ascidian (Ascidiacea sp.), and the colonial anthozoan *Corynactis californica* (Table 16).

Table 12. List of taxa observed during the 2012 Cobb Seamount survey at 15 ROV and four AUV transects. Depth ranges are given for each taxon (see Du Preez et al. 2015).

Phylum	Class	Order	Family	Genus and species	Transects	Depths (m)
Ochrophyta	Phaeophyceae	Desmarestiales	Desmarestiaceae	*Desmarestia viridis*	DFO_6	34-49
Rhodophyta	Florideophyceae	Ceramiales	Rhodomelaceae	*Polysiphonia* spp.	DFO_6	40
Rhodophyta	Florideophyceae	Corallinales	Corallinaceae	cf *Lithophyllum* spp.[1]	DFO_2, 6, 14, 15, & 17	34-191
Rhodophyta	Florideophyceae	Corallinales	Hapalidiaceae	cf *Lithothamnion* spp.[1]	DFO_2, 6, 14, 15, & 17	34-191
Porifera	Hexactinellida	Hexactinosida	Euretidae	*Pinulasma fistulosom*	AUV_2, 4, & 5	635-934
Porifera	Hexactinellida	Hexactinosida	Farreidae	*Farrea omniclavata* sp. nov.	AUV_2, 4, & 5	681-1147
Porifera	Hexactinellida	Lyssacinosida	Rossellidae	*Acanthascus* spp.[2]	AUV_1, 2, 4, & 5	501-1147
Porifera	Hexactinellida	Lyssacinosida	Rossellidae	*Bathydorus* sp.	AUV_2, 4, & 5	567-887
Porifera	Hexactinellida	Lyssacinosida	Rossellidae	*Rhabdocalyptus* spp[2].	AUV_1, 2, 4, & 5	501-1147
Porifera	Hexactinellida	Lyssacinosida	Rossellidae	*Staurocalyptus* spp.[2]	AUV_1, 2, 4, & 5	501-1147
Porifera	Demospongiae			Demospongiae sp. 1	DFO_2, 3, 8, & 15; AUV_4	127-436
Porifera	Demospongiae			Demospongiae sp. 2	DFO_2, 3, 5, 14, & 15; AUV_1, 2, 4, & 5	124-1131
Porifera	Demospongiae			Demospongiae sp. 3	DFO_2; AUV_1, 2, & 4	123-998
Porifera	Demospongiae	Astrophorida	Vulcanellidae	*Poecillastra* sp.	AUV_4	772
Porifera	Demospongiae	Hadromerida	Polymastiidae	*Polymastia* sp.	DFO_2, & 6	94-141
Porifera	Demospongiae	Halichondria	Axinellidae	cf *Auletta* sp.	DFO_3, 4, 5, &14	183-210
Porifera	Demospongiae	Halichondria	Halichondriidae	*Halichondria panicea*	DFO_2, 3, 5, 6, 8, 14, 15, 16, & 17	63-212
Porifera	Demospongiae	Poecilosclerida	Acarnidae	cf *Acarnus erithacus*	DFO_6, & 15	35-127
Porifera	Demospongiae	Poecilosclerida	Latrunculiidae	*Latrunculia* (*Biannulata*) *oparinae*	DFO_15	122-126
Cnidaria	Anthozoa	Actiniaria		Actiniaria sp. 1	AUV_4	615
Cnidaria	Anthozoa	Actiniaria		Actiniaria sp. 2	AUV_2	785
Cnidaria	Anthozoa	Actiniaria		Actiniaria sp. 3	AUV_1 & 5	619-939
Cnidaria	Anthozoa	Actiniaria	Actiniidae	*Cribrinopsis fernaldi*	DFO_1 & 4; SFU 3 & 5	196-259
Cnidaria	Anthozoa	Actiniaria	Actiniidae	*Urticina crassicornis*	DFO_3; SFU_3 & 5	193-259
Cnidaria	Anthozoa	Actiniaria	Actinostolidae	*Stomphia didemon*	DFO_2, 4, & 15	121-187
Cnidaria	Anthozoa	Actiniaria	Hormathiidae	cf Hormathiidae sp.	AUV_2 & 4	527-1090
Cnidaria	Anthozoa	Actiniaria	Metridiidae	*Metridium senile*	DFO_2, 3, & 17	116-220

Phylum	Class	Order	Family	Genus and species	Transects	Depths (m)
Cnidaria	Anthozoa	Alcyonacea	Alcyoniidae	*Heteropolypus ritteri*	AUV_1, 2, 4, & 5	436-1036
Cnidaria	Anthozoa	Alcyonacea	Isididae	*Isidella* sp.	AUV_2, 4, & 5	495-875
Cnidaria	Anthozoa	Alcyonacea	Isididae	*Keratoisis* sp.	AUV_2, & 4	436-819
Cnidaria	Anthozoa	Alcyonacea	Isididae	*Lepidisis* sp.	AUV_2, & 4	488-1154
Cnidaria	Anthozoa	Alcyonacea	Nephtheidae	*Gersemia* sp.	AUV_2, & 4	800-885
Cnidaria	Anthozoa	Alcyonacea	Paragorgiidae	*Paragorgia* sp.	AUV_4	825
Cnidaria	Anthozoa	Alcyonacea	Plexauridae	*Swiftia simplex*	AUV_1, 2, 4, & 5	536-1083
Cnidaria	Anthozoa	Alcyonacea	Primnoidae	*Narella* sp.	DFO_4	198
Cnidaria	Anthozoa	Alcyonacea	Primnoidae	*Plumarella superba*	AUV_4	788-826
Cnidaria	Anthozoa	Alcyonacea	Primnoidae	*Primnoa cf pacifica*	DFO_3; SFU_2; AUV_2 & 4	198-888
Cnidaria	Anthozoa	Antipatharia		Antipatharia sp.	AUV_2, 4, & 5	524-1086
Cnidaria	Anthozoa	Antipatharia	Antipathidae	*Stichopathes* sp.	AUV_1, 2, 4, & 5	681-840
Cnidaria	Anthozoa	Antipatharia	Schizopathida	*Bathypathes* sp.	AUV_1, 2, 4, & 5	681-1153
Cnidaria	Anthozoa	Antipatharia	Schizopathida	*Lillipathes* cf *lillei*	AUV_1, 2, 4, & 5	436-1088
Cnidaria	Anthozoa	Antipatharia	Schizopathida	*Parantipathes* sp.	AUV_1, 2, 4, & 5	775-1003
Cnidaria	Anthozoa	Corallimorpharia	Corallimorphidae	*Corynactis californica*	DFO_6	34-95
Cnidaria	Anthozoa	Pennatulacea	Anthoptilidae	*Anthoptilum* spp.	AUV_1, 2, 4, & 5	723-1003
Cnidaria	Anthozoa	Pennatulacea	Halipteridae	*Halipteris willemoesi*	DFO_1, 3, 4, 5, 8, 9, 15, 16, & 17; SFU_5, AUV_1 & 2	99-807
Cnidaria	Anthozoa	Pennatulacea	Umbellulida	*Umbellula lindahli*	AUV_5	920
Cnidaria	Anthozoa	Scleractinia	Caryophylliidae	*Desmophyllum dianthus*	DFO_3, 4, 5, 8, 14, 15, 16, & 17; SFU_2 & 3; AUV_4	91-557
Cnidaria	Anthozoa	Scleractinia	Caryophylliidae	*Lophelia pertusa*	DFO_3, 16, & 17; SFU_3	162-254
Cnidaria	Anthozoa	Zoantharia	Epizoanthidae	*Epizoanthus* sp.	DFO_4	198
Cnidaria	Hydrozoa			Hydroid sp. 1	DFO_3, 5, 6, 8, 15, & 17	58-209
Cnidaria	Hydrozoa			Hydroid sp. 2	DFO_6	84
Cnidaria	Hydrozoa	Anthoathecata	Stylasteridae	*Stylaster* spp.[3]	DFO_3, 4, 5, 8, 9, 14, 15, 16, & 17; SFU_3; AUV_1 & 4	91-886
Cnidaria	Hydrozoa	Leptothecata	Campanulariidae	cf *Obelia* spp.	DFO_1, 6, 8, 9, 15, 16, & 17	40-220
Annelida	Polychaeta	Eunicida	Onuphidae	*Nothria conchylega*	DFO_2, 6, 8, & 9	89-191
Annelida	Polychaeta	Sabellida	Serpulidae	*Crucigera zygophora*	DFO_6	83
Annelida	Polychaeta	Sabellida	Serpulidae	*Paradexiospira* sp.	DFO_3, 4, 5, 6, 8, 14, 15, & 17	58-221
Annelida	Polychaeta	Sabellida	Serpulidae	*Protula pacifica*	DFO_2, 3, 4, 5, 6, 8, 14, 15, 16, & 17	84-224

Phylum	Class	Order	Family	Genus and species	Transects	Depths (m)
Annelida	Polychaeta	Spionida	Chaetopteridae	*Phyllochaetopterus prolifica*	DFO_6	34-69
Annelida	Polychaeta	Spionida	Chaetopteridae	*Spiochaetopterus* cf *costarum*	DFO_1, 2, 3, 4, 5, 6, 8, 9, 14, 15, 16, & 17	84-223
Anthropoda	Malacostraca	Amphipoda	Caprellidae	*Caprella* sp.	DFO_6	84
Anthropoda	Malacostraca	Decapoda	Chirostylidae	*Chirostylidae* sp.	AUV_1, 2, 4, & 5	562-1145
Anthropoda	Malacostraca	Decapoda	Epialtidae	*Chorilia longipes*	DFO_2, 3, 4, 5, 6, 9, 15, & 17; AUV_1, 4, & 5	40-1140
Anthropoda	Malacostraca	Decapoda	Lithodidae	*Lithodes couesi*	AUV_1, 2, & 4	623-1141
Anthropoda	Malacostraca	Decapoda	Majidae	*Chionoecetes tanneri*	AUV_1, 2, 4, & 5	619-1138
Anthropoda	Malacostraca	Decapoda	Paguridae	*Elassochirus cavimanus*	DFO_5	194
Anthropoda	Malacostraca	Decapoda	Paguridae	*Pagurus kennerlyi*	DFO_1, 2, 3, 4, 5, 6, 8, 9, 14, 15, 16, & 17; SFU_3, & 5	46-259
Anthropoda	Malacostraca	Decapoda	Oregoniidae	*Oregonia gracilis*	DFO_17	167
Mollusca	Bivalvia	Pectinoida	Pectinidae	*Crassadoma gigantea*	DFO_6	35-84
Mollusca	Cephalopoda	Octopoda	Octopodidae	Octopodidae sp.[4]	AUV_4	436
Mollusca	Cephalopoda	Octopoda	Octopodidae	*Graneledone boreopacifica*	AUV_4	1145
Mollusca	Gastropoda	Archaeogastropoda	Calliostomatidae	*Calliostoma annulatum*[5]	DFO_4, & 6	34-187
Mollusca	Gastropoda	Archaeogastropoda	Calliostomatidae	*Calliostoma ligatum*[5]	DFO_4, & 6	34-187
Mollusca	Gastropoda	Neogastropoda	Muricidae	*Ocinebrina lurida*	DFO_4, & 6	83-198
Mollusca	Gastropoda	Neogastropoda	Ranellidae	*Fusitriton oregonensis*	DFO_2, 3, 4, 5, 8, 9, 14, 15, 16, & 17	139-223
Mollusca	Gastropoda	Nudibranchia	Dorididae	*Doris montereyensis*	DFO_6	35
Mollusca	Gastropoda	Nudibranchia	Tritoniidae	Tritoniidae sp.	AUV_2, 4, & 5	485-1000
Mollusca	Polyplacophora	Lepidopleurida	Leptochitonidae	*Leptochiton rugatus*	DFO_6	34-84
Brachiopoda	Rhynchonellata	Terebratulida	Laqueidae	*Laqueus californianus*	DFO_2, 3, 4, 5, 6, 8, 9, 14, 15, 16, & 17	90-224
Bryozoa				Bryozoa sp.	DFO_2, 5 & 17	124-207
Bryozoa	Gymnolaemata	Cheilostomatida	Cribrilinidae	cf *Reginella hippocrepis*	DFO_2, 6	41-132
Bryozoa	Stenolaemata	Cyclostomatida	Lichenoporidae	*Disporella separata*	DFO_6	75-84
Echinodermata	Asteroidea			Asteroidea sp.	DFO_4; SFU_5	194-255
Echinodermata	Asteroidea	Brisingida	Brisingidae	Brisingidae sp.	AUV_1, 2, 4, & 5	536-1139
Echinodermata	Asteroidea	Forcipulatida	Asteriidae	*Leptasterias hexactis*	DFO_6, & 14	37-195

Phylum	Class	Order	Family	Genus and species	Transects	Depths (m)
Echinodermata	Asteroidea	Forcipulatida	Asteriidae	*Orthasterias koehleri*	DFO_4	196
Echinodermata	Asteroidea	Forcipulatida	Asteriidae	*Rathbunaster californicus*	DFO_1, 3, 4, 5, 8, 9, 14, 15, 16, & 17; SFU_3 & 5, AUV_4	102-617
Echinodermata	Asteroidea	Forcipulatida	Asteriidae	*Stylasterias forreri*	DFO_3, 4, & 14	180-202
Echinodermata	Asteroidea	Forcipulatida	Pedicellasteridae	*Ampheraster* sp.	AUV_1, 2, 4, & 5	544-944
Echinodermata	Asteroidea	Forcipulatida	Pycnopodiidae	*Pycnopodia helianthoides*	DFO_2, 6, 14, & 15	84-177
Echinodermata	Asteroidea	Paxillosida	Astropectinidae	*Thrissacanthias* sp.	AUV_4	436-562
Echinodermata	Asteroidea	Paxillosida	Pseudarchasteridae	*Pseudarchaster* sp.[6]	AUV_1, 2, 4, & 5	436-790
Echinodermata	Asteroidea	Spinulosida	Echinasteridae	*Henricia leviuscula*	DFO_6	37-91
Echinodermata	Asteroidea	Spinulosida	Echinasteridae	*Henricia sanguinolenta*	DFO_2, 3, 4, 5, 8, 9, 14, 15, & 17; SFU_3, & 5; AUV_1	111-726
Echinodermata	Asteroidea	Valvatida	Goniasteridae	*Ceramaster patagonicus*	DFO_2, 3, 4, 5, 8, 14, 15, & 17	110-217
Echinodermata	Asteroidea	Valvatida	Goniasteridae	*Ceramaster cf stellatus*	DFO_3, 4, 5, 8, 9, 14, & 16	172-218
Echinodermata	Asteroidea	Valvatida	Goniasteridae	*Hippasteria phrygiana*	DFO_3, 4, 9, & 17; AUV_1, 2, & 5	162-855
Echinodermata	Asteroidea	Valvatida	Solasteridae	*Crossaster papposus*	DFO_3, 5, 6, 8, & 17	84-220
Echinodermata	Asteroidea	Valvatida	Solasteridae	*Lophaster furcilliger*	DFO_6, & 15	95-154
Echinodermata	Asteroidea	Valvatida	Solasteridae	*Solaster cf endeca*	DFO_1, 2, 3, 5, 14, 15, & 17	123-255
Echinodermata	Asteroidea	Valvatida	Solasteridae	*Solaster stimpsoni*	DFO_6	91
Echinodermata	Asteroidea	Velatida	Pterasteridae	*Pteraster* sp.	AUV_1, 2, 4, & 5	539-930
Echinodermata	Crinoidae	Comatulida	Antedonidae	*Florometra serratissima*	DFO_2, 3, 4, 6, 8, 9, 15, 16, & 17; AUV_2 &4	84-749
Echinodermata	Echinoidea	Camarodonta	Strongylocentrotidae	*Mesocentrotus franciscanus*	DFO_6	35-95
Echinodermata	Echinoidea	Camarodonta	Strongylocentrotidae	*Strongylocentrotus pallidus*	DFO_3, 5, 14, 15, & 17	160-208
Echinodermata	Holothuroidea	Aspidochirotida	Molpadiidae	*Molpadia* sp.	AUV_1	678
Echinodermata	Holothuroidea	Aspidochirotida	Stichopodidae	*Apostichopus leukothele*	DFO_1, 2, 3, 4, 5, 8, 9, 14, 15, & 17; SFU_3	93-259
Echinodermata	Holothuroidea	Dendrochirotida	Psolidae	*Psolus squamatus*	AUV_2, 4, & 5	527-943
Echinodermata	Holothuroidea	Elasipodida	Laetmogonidae	*Pannychia* cf *moseleyi*	AUV_1, 2, 4, & 5	533-937
Echinodermata	Ophiuroidea	Euryalida	Asteronychidae	*Asteronyx loveni*	DFO_1, 3, 4, 5, 8, 15, & 16; SFU_3, & 5	165-259

Phylum	Class	Order	Family	Genus and species	Transects	Depths (m)
Echinodermata	Ophiuroidea	Ophiurida	Ophiacanthidae	*Ophiopholis bakeri*	DFO_2, 3, 4, 5, 8, 14, 15, 16, & 17; AUV_2, & 4	102-707
Echinodermata	Ophiuroidea	Ophiurida	Ophiuridae	*Ophiura sarsii*	DFO_1, 3, 4, 8, 9, 15, & 16; SFU_3, & 5	166-259
Chordata	Ascidiacea			Ascidiacea sp.	DFO_2, 4, 5, 6, 8, 14, 15, & 17	34-209
Chordata	Actinopterygii	Gadiformes	Macrouridae	cf *Coryphaenoides acrolepis*	AUV_1, 2, 4, & 5	608-1154
Chordata	Actinopterygii	Gadiformes	Moridae	*Antimora microlepis*	AUV_1, & 4	720-1118
Chordata	Actinopterygii	Perciformes	Stichaeidae	*Chirolophis decoratus*	DFO_2, 3, & 14	132-196
Chordata	Actinopterygii	Pleuronectiformes	Paralichthyidae	*Citharichthys sordidus*	DFO_1	194-198
Chordata	Actinopterygii	Pleuronectiformes	Pleuronectidae	*Embassichthys bathybius*	AUV_1, 2, 4, & 5	436-932
Chordata	Actinopterygii	Pleuronectiformes	Pleuronectidae	*Glyptocephalus zachirus*	DFO_1, 16; AUV_1	194-645
Chordata	Actinopterygii	Pleuronectiformes	Pleuronectidae	*Lepidopsetta bilineata*	DFO_1, 2, 3, 6, & 16	84-244
Chordata	Actinopterygii	Pleuronectiformes	Pleuronectidae	*Microstomus pacificus*	DFO_1; AUV_1	199-627
Chordata	Actinopterygii	Scorpaeniformes	Agonidae	*Agonopsis vulsa*	DFO_2	137
Chordata	Actinopterygii	Scorpaeniformes	Anoplopomatidae	*Anoplopoma fimbria*	AUV_5	903-937
Chordata	Actinopterygii	Scorpaeniformes	Cottidae	Cottidae sp.	DFO_1, 2, 3, 4, 5, 6, 8, 14, 15, 16, & 17	91-223
Chordata	Actinopterygii	Scorpaeniformes	Cottidae	*Hemilepidotus spinosus*	DFO_2, & 6	90-126
Chordata	Actinopterygii	Scorpaeniformes	Cottidae	*Paricelinus hopliticus*	DFO_1, 2, 3, 4, 5, 6, 8, 14, 15, 16, & 17	91-256
Chordata	Actinopterygii	Scorpaeniformes	Rhamphocottidae	*Rhamphocottus richardsonii*	DFO_16	184
Chordata	Actinopterygii	Scorpaeniformes	Scorpaenidae	*Sebastes* spp.	DFO_2, 3, 4, 5, 6, 8, 9, 14, 15, 16, & 17; SFU_3; AUV_4, & 5	84-555
Chordata	Actinopterygii	Scorpaeniformes	Scorpaenidae	*Sebastes aleutianus*[7]	DFO_2, 3, 4, 5, 8, 14, & 17; SFU_2	107-373
Chordata	Actinopterygii	Scorpaeniformes	Scorpaenidae	*Sebastes alutus*	DFO_3, 5, & 17; SFU_3	164-258
Chordata	Actinopterygii	Scorpaeniformes	Scorpaenidae	*Sebastes elongatus*	DFO_9	214-215
Chordata	Actinopterygii	Scorpaeniformes	Scorpaenidae	*Sebastes emphaeus*	DFO_2, 3, 4, 5, 8, 9, 14, 15, 16, & 17	93-222
Chordata	Actinopterygii	Scorpaeniformes	Scorpaenidae	*Sebastes entomelas*	DFO_2, 3, 6, & 15	37-198
Chordata	Actinopterygii	Scorpaeniformes	Scorpaenidae	*Sebastes helvomaculatus*	DFO_2, 3, 4, 5, 6, 8, 9, 14, 15, 16, & 17; SFU_3	84-259
Chordata	Actinopterygii	Scorpaeniformes	Scorpaenidae	*Sebastes melanostictus*[7]	DFO_2, 3, 4, 5, 8, 14, & 17;	107-373

Phylum	Class	Order	Family	Genus and species	Transects	Depths (m)
					SFU_2	
Chordata	Actinopterygii	Scorpaeniformes	Scorpaenidae	*Sebastes melanostomus*	AUV_2	556
Chordata	Actinopterygii	Scorpaeniformes	Scorpaenidae	*Sebastes mystinus*	DFO_6	84
Chordata	Actinopterygii	Scorpaeniformes	Scorpaenidae	*Sebastes rosaceus*	DFO_2, 3, 4, 5, 6, 8, 14, 16, & 17	35-219
Chordata	Actinopterygii	Scorpaeniformes	Scorpaenidae	*Sebastes ruberrimus*	DFO_2, 3, 4, 6, 8, 15, & 17	84-221
Chordata	Actinopterygii	Scorpaeniformes	Scorpaenidae	*Sebastes variegatus*	DFO_2, 3, 4, 5, 8, 14, & 17; SFU_3	91-258
Chordata	Actinopterygii	Scorpaeniformes	Scorpaenidae	*Sebastes wilsoni*	DFO_2, 3, 4, 5, 8, 14, 15, & 17	110-221
Chordata	Actinopterygii	Scorpaeniformes	Scorpaenidae	*Sebastes zacentrus*	DFO_2, 3, 4, 5, 8, 14, 15, 16, & 17; SFU_3	92-258
Chordata	Actinopterygii	Scorpaeniformes	Scorpaenidae	*Sebastolobus* spp.	AUV_1, 2, 4, & 5	436-1147
Chordata	Elasmobranchii	Carcharhiniformes	Scyliorhinidae	*Apristurus brunneus*	AUV_4	883
Chordata	Elasmobranchii	Hexachiformes	Hexanchidae	*Hexanchus griseus*	DFO_4	185
Chordata	Elasmobranchii	Rajiformes	Rajidae	*Raja rhina*	DFO_1 & 4; SFU_3	196-242

Table 13. Frequency of taxa observed at 12 DFO ROV sites, 3 SFU ROV sites and 4 AUV sites. The total number of species observed at the 19 sites – prior to, during and subsequent to transects – is also given. Taxa are listed in the same order as Du Preez et al. (2015) and Table 12. Presence is denoted by "1".

Phylum	Genus and species	DFO_1	DFO_2	DFO_3	DFO_4	DFO_5	DFO_6	DFO_8	DFO_9	DFO_14	DFO_15	DFO_16	DFO_17	AUV_1	AUV_2	AUV_4	AUV_5	SFU_2	SFU_3	SFU_5	Frequency
Ochrophyta	*Desmarestia viridis*						1														0.05
Rhodophyta	*Polysiphonia* spp.						1														0.05
Rhodophyta	cf *Lithophyllum* spp.[1]		1				1			1	1		1								0.26
Rhodophyta	cf *Lithothamnion* spp.[1]		1				1			1	1		1								0.26
Porifera	*Pinulasma fistulosom*														1	1	1				0.16
Porifera	*Farrea omniclavata* sp. nov.														1	1	1				0.16
Porifera	*Acanthascus* spp.[2]													1	1	1	1				0.21
Porifera	*Bathydorus* sp.														1	1	1				0.16
Porifera	*Rhabdocalyptus* spp[2].													1	1	1	1				0.21
Porifera	*Staurocalyptus* spp.[2]													1	1	1	1				0.21
Porifera	Demospongiae sp. 1		1	1				1			1					1					0.26
Porifera	Demospongiae sp. 2		1	1		1				1	1			1	1	1	1				0.47
Porifera	Demospongiae sp. 3		1											1	1	1					0.21
Porifera	*Poecillastra* sp.															1					0.05
Porifera	*Polymastia* sp.		1				1														0.11
Porifera	cf *Auletta* sp.			1	1	1				1											0.21
Porifera	*Halichondria panacea*		1	1		1	1	1		1	1	1	1								0.47
Porifera	*cf Acarnus erithacus*						1				1										0.11
Porifera	*Latrunculia oparinae*										1										0.05
Cnidaria	Actiniaria sp. 1															1					0.05
Cnidaria	Actiniaria sp. 2														1						0.05
Cnidaria	Actiniaria sp. 3													1			1				0.11
Cnidaria	*Cribrinopsis fernaldi*	1			1														1	1	0.21
Cnidaria	*Urticina crassicornis*			1															1	1	0.16
Cnidaria	*Stomphia didemon*		1		1						1										0.16

Phylum	Genus and species	DFO_1	DFO_2	DFO_3	DFO_4	DFO_5	DFO_6	DFO_8	DFO_9	DFO_14	DFO_15	DFO_16	DFO_17	AUV_1	AUV_2	AUV_4	AUV_5	SFU_2	SFU_3	SFU_5	Frequency
Cnidaria	cf Hormathiidae sp.														1	1					0.11
Cnidaria	*Metridium senile*		1	1									1								0.16
Cnidaria	*Heteropolypus ritteri*													1	1	1	1				0.21
Cnidaria	*Isidella* sp.														1	1	1				0.16
Cnidaria	*Keratoisis* sp.														1	1					0.11
Cnidaria	*Lepidisis* sp.														1	1					0.11
Cnidaria	*Gersemia* sp.														1	1					0.11
Cnidaria	*Paragorgia* sp.															1					0.05
Cnidaria	*Swiftia simplex*													1	1	1	1				0.21
Cnidaria	*Narella* sp.				1																0.05
Cnidaria	*Plumarella superba*															1					0.05
Cnidaria	*Primnoa cf pacifica*			1											1	1		1			0.21
Cnidaria	*Antipatharia* sp.														1	1	1				0.16
Cnidaria	*Stichopathes* sp.													1	1	1	1				0.21
Cnidaria	*Bathypathes* sp.													1	1	1	1				0.21
Cnidaria	*Lillipathes* cf *lillei*													1	1	1	1				0.21
Cnidaria	*Parantipathes* sp.													1	1	1	1				0.21
Cnidaria	*Corynactis californica*						1														0.05
Cnidaria	*Anthoptilum* spp.													1	1	1	1				0.21
Cnidaria	*Halipteris willemoesi*	1		1	1	1		1	1		1	1	1	1	1				1		0.63
Cnidaria	*Umbellula lindahli*																1				0.05
Cnidaria	*Desmophyllum dianthus*			1	1	1		1		1	1	1	1			1		1	1		0.58
Cnidaria	*Lophelia pertusa*			1								1	1						1		0.21
Cnidaria	*Epizoanthus* sp.				1																0.05
Cnidaria	Hydroid sp. 1			1		1	1	1			1		1								0.32
Cnidaria	Hydroid sp. 2						1														0.05
Cnidaria	*Stylaster* spp.[3]			1	1	1		1	1	1	1	1	1	1		1			1		0.63
Cnidaria	cf *Obelia* spp.	1					1	1	1		1	1	1								0.37

Phylum	Genus and species	DFO_1	DFO_2	DFO_3	DFO_4	DFO_5	DFO_6	DFO_8	DFO_9	DFO_14	DFO_15	DFO_16	DFO_17	AUV_1	AUV_2	AUV_4	AUV_5	SFU_2	SFU_3	SFU_5	Frequency
Annelida	*Nothria conchylega*		1				1	1	1												0.21
Annelida	*Crucigera zygophora*						1														0.05
Annelida	*Paradexiospira* sp.			1	1	1	1	1		1	1		1								0.42
Annelida	*Protula pacifica*		1	1	1	1	1	1		1	1	1	1								0.53
Annelida	*Phyllochaetopterus prolifica*						1														0.05
Annelida	*Spiochaetopterus* cf *costarum*	1	1	1	1	1	1	1	1	1	1	1	1								0.63
Anthropoda	*Caprella* sp.						1														0.05
Anthropoda	*Chirostylidae* sp.													1	1	1	1				0.21
Anthropoda	*Chorilia longipes*		1	1	1	1	1		1		1		1	1		1	1				0.58
Anthropoda	*Lithodes couesi*													1	1	1					0.16
Anthropoda	*Chionoecetes tanneri*													1	1	1	1				0.21
Anthropoda	*Elassochirus cavimanus*					1															0.05
Anthropoda	*Pagurus kennerlyi*	1	1	1	1	1	1	1	1	1	1	1	1						1	1	0.74
Anthropoda	*Oregonia gracilis*												1								0.05
Mollusca	*Crassadoma gigantean*						1														0.05
Mollusca	*Octopodidae* sp.[4]															1					0.05
Mollusca	*Graneledone boreopacifica*															1					0.05
Mollusca	*Calliostoma annulatum*[5]				1		1														0.11
Mollusca	*Calliostoma ligatum*[5]				1		1														0.11
Mollusca	*Ocinebrina lurida*				1		1														0.11
Mollusca	*Fusitriton oregonensis*		1	1	1	1		1	1	1	1	1	1								0.53
Mollusca	*Doris montereyensis*						1														0.05
Mollusca	Tritoniidae sp.														1	1	1				0.16
Mollusca	*Leptochiton rugatus*						1														0.05
Brachiopoda	*Laqueus californianus*		1	1	1		1	1	1	1	1	1	1								0.53
Bryozoa	Bryozoa sp.		1			1							1								0.16
Bryozoa	cf *Reginella hippocrepis*		1				1														0.11

Phylum	Genus and species	DFO_1	DFO_2	DFO_3	DFO_4	DFO_5	DFO_6	DFO_8	DFO_9	DFO_14	DFO_15	DFO_16	DFO_17	AUV_1	AUV_2	AUV_4	AUV_5	SFU_2	SFU_3	SFU_5	Frequency
Bryozoa	*Disporella separata*						1														0.05
Echinodermata	Asteroidea sp.				1															1	0.11
Echinodermata	Brisingidae sp.													1	1	1	1				0.21
Echinodermata	*Leptasterias hexactis*						1			1											0.11
Echinodermata	*Orthasterias koehleri*				1																0.05
Echinodermata	*Rathbunaster californicus*	1		1	1	1		1	1	1	1	1	1			1			1	1	0.68
Echinodermata	*Stylasterias forreri*			1	1					1											0.16
Echinodermata	*Ampheraster* sp.													1	1	1	1				0.21
Echinodermata	*Pycnopodia helianthoides*		1				1			1	1										0.21
Echinodermata	*Thrissacanthias* sp.															1					0.05
Echinodermata	*Pseudarchaster* sp.[6]													1	1	1	1				0.21
Echinodermata	*Henricia leviuscula*						1														0.05
Echinodermata	*Henricia sanguinolenta*		1	1	1	1		1	1	1	1		1	1					1	1	0.63
Echinodermata	*Ceramaster patagonicus*		1	1	1	1		1		1	1		1								0.42
Echinodermata	*Ceramaster cf stellatus*			1	1	1		1	1	1		1									0.37
Echinodermata	*Hippasteria phrygiana*			1	1				1				1								0.21
Echinodermata	*Crossaster papposus*			1		1	1	1					1								0.26
Echinodermata	*Lophaster furcilliger*						1				1										0.11
Echinodermata	*Solaster cf endeca*	1	1	1		1				1	1		1								0.37
Echinodermata	*Solaster stimpsoni*						1														0.05
Echinodermata	*Pteraster* sp.													1	1	1	1				0.21
Echinodermata	*Florometra serratissima*		1	1	1		1	1	1		1	1	1		1	1					0.58
Echinodermata	*Mesocentrotus franciscanus*						1														0.05
Echinodermata	*Strongylocentrotus pallidus*			1		1				1	1		1								0.26
Echinodermata	*Molpadia* sp.													1							0.05
Echinodermata	*Apostichopus leukothele*	1	1	1	1	1		1	1	1	1		1						1		0.58
Echinodermata	*Psolus squamatus*														1	1	1				0.16
Echinodermata	*Pannychia* cf *moseleyi*													1	1	1	1				0.21

Phylum	Genus and species	DFO_1	DFO_2	DFO_3	DFO_4	DFO_5	DFO_6	DFO_8	DFO_9	DFO_14	DFO_15	DFO_16	DFO_17	AUV_1	AUV_2	AUV_4	AUV_5	SFU_2	SFU_3	SFU_5	Frequency
Echinodermata	*Asteronyx loveni*	1		1	1	1		1			1	1							1	1	0.47
Echinodermata	*Ophiopholis bakeri*		1	1	1	1		1		1	1	1	1		1	1					0.58
Echinodermata	*Ophiura sarsii*	1		1	1			1	1		1	1							1	1	0.47
Chordata	Ascidiacea sp.		1		1	1	1	1		1	1		1								0.42
Chordata	cf *Coryphaenoides acrolepis*													1	1	1	1				0.21
Chordata	*Antimora microlepis*													1		1					0.11
Chordata	*Chirolophis decoratus*		1	1						1											0.16
Chordata	*Citharichthys sordidus*	1																			0.05
Chordata	*Embassichthys bathybius*													1	1	1	1				0.21
Chordata	*Glyptocephalus zachirus*	1										1		1							0.16
Chordata	*Lepidopsetta bilineata*	1	1	1			1					1									0.26
Chordata	*Microstomus pacificus*	1												1							0.11
Chordata	*Agonopsis vulsa*		1																		0.05
Chordata	*Anoplopoma fimbria*																1				0.05
Chordata	Cottidae sp.	1	1	1	1	1	1	1		1	1	1	1								0.58
Chordata	*Hemilepidotus spinosus*		1				1														0.11
Chordata	*Paricelinus hopliticus*	1	1	1	1	1	1	1		1	1	1	1								0.58
Chordata	*Rhamphocottus richardsonii*											1									0.05
Chordata	*Sebastes* spp.		1	1	1	1	1	1	1	1	1	1	1			1	1		1		0.74
Chordata	*Sebastes aleutianus*[7]		1	1	1	1		1		1			1					1			0.42
Chordata	*Sebastes alutus*			1		1							1						1		0.21
Chordata	*Sebastes elongatus*								1												0.05
Chordata	*Sebastes emphaeus*		1	1	1	1		1	1	1	1	1	1								0.53
Chordata	*Sebastes entomelas*		1	1			1				1										0.21
Chordata	*Sebastes helvomaculatus*		1	1	1	1	1	1	1	1	1	1	1						1		0.63
Chordata	*Sebastes melanostictus*[7]		1	1	1	1		1		1			1					1			0.42
Chordata	*Sebastes melanostomus*														1						0.05
Chordata	*Sebastes mystinus*						1														0.05

Phylum	Genus and species	DFO_1	DFO_2	DFO_3	DFO_4	DFO_5	DFO_6	DFO_8	DFO_9	DFO_14	DFO_15	DFO_16	DFO_17	AUV_1	AUV_2	AUV_4	AUV_5	SFU_2	SFU_3	SFU_5	Frequency
Chordata	*Sebastes rosaceus*		1	1	1	1	1	1		1		1	1								0.47
Chordata	*Sebastes ruberrimus*		1	1	1		1	1			1		1								0.37
Chordata	*Sebastes variegatus*		1	1	1	1		1		1			1						1		0.42
Chordata	*Sebastes wilsoni*		1	1	1	1		1		1	1		1								0.42
Chordata	*Sebastes zacentrus*		1	1	1	1		1		1	1	1	1						1		0.53
Chordata	*Sebastolobus* spp.													1	1	1	1				0.21
Chordata	*Apristurus brunneus*															1					0.05
Chordata	*Hexanchus griseus*				1																0.05
Chordata	*Raja rhina*	1			1														1		0.16

Table 14 Densities (individuals per m2) of taxa in annotated video on 12 DFO ROV transects, and the density (individuals per m2) calculated across all transects.

Phylum	Genus and species	DFO_1	DFO_2	DFO_3	DFO_4	DFO_5	DFO_6	DFO_8	DFO_9	DFO_14	DFO_15	DFO_16	DFO_17	Mean
Porifera	cf *Auletta* sp.	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0027
Porifera	*Latrunculia oparinae*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.0006
Cnidaria	*Cribrinopsis fernaldi*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0002
Cnidaria	*Stomphia didemon*	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.0087
Cnidaria	*Metridium senile*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0004
Cnidaria	*Narella* sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0001
Cnidaria	*Primnoa cf pacifica*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0001
Cnidaria	*Halipteris willemoesi*	0.01	0.00	0.01	0.01	0.00	0.00	0.02	0.00	0.00	0.00	0.01	0.00	0.0063
Cnidaria	*Desmophyllum dianthus*	0.00	0.00	0.08	0.09	0.15	0.00	0.08	0.00	0.06	0.02	0.01	0.33	0.0651
Anthropoda	*Chorilia longipes*	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.0013

Phylum	Genus and species	DFO_1	DFO_2	DFO_3	DFO_4	DFO_5	DFO_6	DFO_8	DFO_9	DFO_14	DFO_15	DFO_16	DFO_17	Mean
Anthropoda	*Elassochirus cavimanus*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0001
Mollusca	*Doris montereyensis*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0001
Bryozoa	Bryozoa sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0001
Echinodermata	Asteroidea sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0001
Echinodermata	*Leptasterias hexactis*	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.0004
Echinodermata	*Rathbunaster californicus*	0.01	0.00	0.02	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.01	0.0073
Echinodermata	*Stylasterias forreri*	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0009
Echinodermata	*Pycnopodia helianthoides*	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0008
Echinodermata	*Henricia leviuscula*	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.0002
Echinodermata	*Henricia sanguinolenta*	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.01	0.0051
Echinodermata	*Ceramaster patagonicus*	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0023
Echinodermata	*Ceramaster cf stellatus*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0005
Echinodermata	*Hippasteria phrygiana*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0003
Echinodermata	*Crossaster papposus*	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.01	0.0021
Echinodermata	*Lophaster furcilliger*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0002
Echinodermata	*Solaster cf endeca*	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.0018
Echinodermata	*Solaster stimpsoni*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0001
Echinodermata	*Strongylocentrotus pallidus*	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.0017
Echinodermata	*Apostichopus leukothele*	0.00	0.03	0.07	0.01	0.02	0.00	0.03	0.00	0.04	0.04	0.00	0.08	0.0231
Chordata	*Chirolophis decoratus*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0002
Chordata	*Citharichthys sordidus*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0001
Chordata	*Glyptocephalus zachirus*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0003
Chordata	*Lepidopsetta bilineata*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0005
Chordata	*Microstomus pacificus*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0002
Chordata	*Agonopsis vulsa*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0001
Chordata	Cottidae sp.	0.02	0.03	0.01	0.01	0.01	0.00	0.02	0.00	0.01	0.02	0.03	0.02	0.0149
Chordata	*Hemilepidotus spinosus*	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.0004
Chordata	*Sebastes* spp.	0.00	0.09	0.10	0.01	0.03	0.01	0.11	0.00	0.02	0.08	0.01	0.35	0.0482

Phylum	Genus and species	DFO_1	DFO_2	DFO_3	DFO_4	DFO_5	DFO_6	DFO_8	DFO_9	DFO_14	DFO_15	DFO_16	DFO_17	Mean
Chordata	*Sebastes aleutianus, S. melanostictus*[7]	0.00	0.00	0.02	0.01	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.06	0.0174
Chordata	*Sebastes alutus*	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.0026
Chordata	*Sebastes elongatus*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0003
Chordata	*Sebastes emphaeus*	0.00	0.35	0.06	0.03	0.02	0.00	0.08	0.00	0.01	0.03	0.01	0.23	0.0439
Chordata	*Sebastes entomelas*	0.00	0.01	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.0025
Chordata	*Sebastes helvomaculatus*	0.00	0.15	0.08	0.04	0.05	0.24	0.06	0.06	0.10	0.21	0.00	0.14	0.0741
Chordata	*Sebastes mystinus*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0001
Chordata	*Sebastes rosaceus*	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.0034
Chordata	*Sebastes ruberrimus*	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.0018
Chordata	*Sebastes variegatus*	0.00	0.01	0.03	0.00	0.02	0.00	0.06	0.00	0.00	0.00	0.00	0.07	0.0122
Chordata	*Sebastes wilsoni*	0.00	0.18	0.01	0.02	0.00	0.00	0.01	0.00	0.01	0.23	0.00	0.07	0.0329
Chordata	*Sebastes zacentrus*	0.00	0.22	0.07	0.00	0.02	0.00	0.02	0.00	0.01	0.03	0.00	0.07	0.0228
Chordata	*Raja rhina*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0002

Table 15. Densities (inidividuals per m^2) of taxa observed within photo quadrats on 12 DFO ROV transects, and the mean (±SD) across the 12 transects.

Phylum	Genus and species	DFO_1	DFO_2	DFO_3	DFO_4	DFO_5	DFO_6	DFO_8	DFO_9	DFO_14	DFO_15	DFO_16	DFO_17	Mean	SD
Porifera	cf *Auletta* sp.	0.00	0.00	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.14
Cnidaria	*Stylaster* spp.[3]	0.00	0.00	8.01	7.52	16.98	0.00	0.19	11.44	38.91	3.75	0.36	21.74	9.07	11.88
Cnidaria	cf *Obelia* spp.	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.72	0.00	0.09	0.22
Annelida	*Nothria conchylega*	0.00	0.00	0.00	0.00	0.00	130.43	0.00	0.00	0.00	0.00	0.00	0.00	10.87	37.65
Annelida	*Crucigera zygophora*	0.00	7.43	0.00	0.00	0.00	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.66	2.13

Phylum	Genus and species	DFO_1	DFO_2	DFO_3	DFO_4	DFO_5	DFO_6	DFO_8	DFO_9	DFO_14	DFO_15	DFO_16	DFO_17	Mean	SD
Annelida	*Paradexiospira* sp.	0.00	0.00	2.54	2.93	0.94	0.82	0.19	0.00	0.88	0.16	0.00	2.45	0.91	1.11
Annelida	*Protula pacifica*	0.00	1.01	0.88	0.08	0.00	0.00	0.00	0.00	1.23	1.56	0.24	2.99	0.67	0.93
Annelida	*Spiochaetopterus* cf *costarum*	13.82	3.89	10.84	6.57	0.31	0.00	44.70	0.13	13.82	3.44	9.01	7.88	9.53	12.14
Arthropoda	*Chorilia longipes*	0.00	0.17	0.00	0.08	0.00	0.82	0.00	0.13	0.00	0.00	0.00	0.00	0.10	0.23
Arthropoda	*Oregonia gracilis*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.02	0.08
Mollusca	*Crassadoma gigantea*	0.00	0.00	0.00	0.00	0.00	6.52	0.00	0.00	0.00	0.00	0.00	0.00	0.54	1.88
Mollusca	*Calliostoma annulatum,C. ligatum*[5]	0.00	0.00	0.00	0.08	0.00	22.01	0.00	0.00	0.00	0.00	0.00	0.00	1.84	6.35
Mollusca	*Ocinebrina lurida*	0.00	0.00	0.00	0.32	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.11
Mollusca	*Fusitriton oregonensis*	0.00	0.00	0.29	0.40	0.00	0.00	0.00	0.00	0.26	0.16	0.36	1.36	0.24	0.39
Mollusca	*Leptochiton rugatus*	0.00	0.00	0.00	0.00	0.00	10.33	0.00	0.00	0.00	0.00	0.00	0.00	0.86	2.98
Brachiopoda	*Laqueus californianus*	0.00	0.00	4.49	4.11	8.33	1.09	14.20	0.00	36.44	20.31	0.48	116.03	17.13	33.02
Bryozoa	Bryozoa sp.	0.00	0.17	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.06	0.12
Echinodermata	*Florometra serratissima*	0.00	31.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.50	1.56	0.00	3.4	9.19
Echinodermata	*Mesocentrotus franciscanus*	0.00	0.00	0.00	0.00	0.00	4.35	0.00	0.00	0.00	0.00	0.00	0.00	0.36	1.26

Table 16. Index of percent cover of colonial or encrusting taxa in annotated video on 12 DFO ROV transects, and an index of mean % cover across all transects. The index was calculated by taking the midpoint of values in each of the categorical ranges of % cover defined in Table 4. The five most abundant encrusting or small colonial taxa across all transects are highlighted in bold font.

Phylum	**Genus and species**	**DFO_1**	**DFO_2**	**DFO_3**	**DFO_4**	**DFO_5**	**DFO_6**	**DFO_8**	**DFO_9**	**DFO_14**	**DFO_15**	**DFO_16**	**DFO_17**	**All transects**
Ochrophyta	*Desmarestia viridis*	0.00	0.00	0.00	0.00	0.00	11.63	0.00	0.00	0.00	0.00	0.00	0.00	0.97
Rhodophyta	cf *Lithophyllum* spp., cf *Lithothamnion* spp.[1]	0.00	**63.04**	0.00	0.00	0.00	**32.07**	0.00	0.00	**14.79**	**41.00**	0.00	**11.74**	**13.55**
Porifera	Demospongiae sp. 1	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.69	0.00	0.00	0.73
Porifera	Demospongiae sp. 2	0.00	1.42	0.39	0.00	0.17	0.22	0.08	0.00	0.25	3.56	0.00	0.00	0.51
Porifera	*Polymastia* sp.	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Porifera	*Halichondria panicea*	0.00	2.84	0.08	0.06	0.38	3.91	0.00	**0.21**	0.74	1.31	0.05	0.98	0.88
Porifera	*cf Acarnus erithacus*	0.00	0.00	0.00	0.00	0.00	9.46	0.00	0.00	0.00	0.25	0.00	0.00	0.81
Cnidaria	*Corynactis californica*	0.00	0.00	0.00	0.00	0.00	11.96	0.00	0.00	0.00	0.00	0.00	0.00	**1.00**
Cnidaria	*Lophelia pertusa*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**2.88**	1.30	0.35
Cnidaria	*Epizoanthus* sp.	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cnidaria	Hydroid sp. 1	0.00	0.00	**4.02**	0.00	**1.79**	7.17	**4.24**	0.00	0.00	9.69	0.00	10.54	**3.12**
Annelida	*Phyllochaetopterus prolifica*	0.00	0.00	0.00	0.00	0.00	3.37	0.00	0.00	0.00	0.00	0.00	0.00	0.28
Byrozoa	cf *Reginella hippocrepis*	0.00	1.69	0.00	0.00	0.00	17.07	0.00	0.00	0.00	0.00	0.00	0.00	**1.56**
Byrozoa	*Disporella separata*	0.00	0.00	0.00	0.00	0.00	1.41	0.00	0.00	0.00	0.00	0.00	0.00	0.12
Chordata	Ascidiacea sp.	0.00	3.24	0.00	**1.65**	1.54	2.50	0.08	0.00	0.07	0.69	0.00	5.54	**1.28**

Abundance on AUV transects

Counts of organisms observed on the four AUV transects were obtained from two experts, E. Fruh and C. Du Preez. Fruh (EF) identified all taxa observed in all photos, while Du Preez (CD) identified and counted coral and sponge taxa from every 2-3 photos. Counts for each transect from both experts were converted to densities using estimates of the area of field of view in photos analyzed by each of the experts (Table 10). While the experts generally agreed on species identification, Du Preez identified more coral and sponge taxa to lower levels. Thus, we used the counts (and densities) of coral and sponge taxa obtained by Du Preez in further analyses of AUV data.

Overall, the most abundant taxa observed on all four AUV transects were squat lobsters (Family Chirostylidae), an unidentified encrusting sponge (Demospongiae sp. 2), the sea cucumbers *Pannychia cf moseleyi* and *Psolus squamatus,* a bamboo coral *Lepidisis* sp. two fishes in the genus *Sebastolobus*, the antipatharian corals *Bathypathes* sp. and *Lillipathes* cf *lillei*, an unknown antipatharian species (Antipatharia sp. 1), and the alcyonacean coral *Heteropolypus ritteri*. The least common taxa were the demosponge *Poecillastra* sp., the sea cucumber *Molpadia* sp., the Dover Sole (*Microstomus pacificus*) and the droopy sea pen *Umbellula lindhali* , which were each only observed once on AUV transects (Table 17).

Table 17. Counts and estimated densities of organisms observed in photographs obtained from the four AUV transects. E. Fruh (EF) identified and counted all taxa observed in all photos except brittle stars and snails (Neptunea), while C. Du Preez (CD) identified and counted coral and sponge taxa from every 2-3 photos. The 10 densest taxa in each transect and overall are highlighted in bold font.

Taxon	Expert	AUV_1 Count	AUV_1 Density (m^{-2})	AUV_5 Count	AUV_5 Density (m^{-2})	AUV_2 Count	AUV_2 Density (m^{-2})	AUV_4 Count	AUV_4 Density (m^{-2})	Total Count	Total Density (m^{-2})
Porifera											
Pinulasma fistulosom	CD	0	0.0000	2	0.0015	3	0.0029	4	0.0032	9	0.0018
Farrea omniclavata sp. nov	EF	0	0.0000	3	0.0022	3	0.0029	14	0.0112	20	0.0040
Farrea omniclavata sp. nov	CD	0	0.0000	5	0.0015	7	0.0026	27	0.0088	39	0.0032
Acanthascus spp. *Rhabdocalyptus* spp. *Staurocalyptus* spp.	CD	5	0.0036	4	0.0030	20	**0.0192**	18	0.0143	47	0.0093
Staurocalyptus sp.	EF	0	0.0000	2	0.0006	3	0.0011	3	0.0010	8	0.0007
Bathydorus sp.	CD	0	0.0000	1	0.0007	2	0.0019	4	0.0032	7	0.0014
Demospongiae sp. 1	CD	0	0.0000	0	0.0000	0	0.0000	7	0.0056	7	0.0014
Demospongiae sp. 2	CD	138	**0.0995**	142	**0.1049**	179	**0.1717**	77	**0.0614**	536	**0.1064**
Demospongiae sp. 3	CD	2	0.0014	0	0.0000	7	0.0067	10	0.0080	19	0.0038
Poecillastra sp.	CD	0	0.0000	0	0.0000	0	0.0000	1	0.0008	1	0.0002
Unidentified encrusting sponge	CD	1	0.0007	0	0.0000	0	0.0000	1	0.0008	2	0.0004
Unidentified ball sponges	EF	0	0.0000	0	0.0000	48	0.0181	19	0.0062	67	0.0055
Unidentified barrel sponges	EF	1	0.0003	1	0.0003	41	0.0155	22	0.0072	65	0.0053
Unidentified vase sponges	EF	0	0.0000	2	0.0006	12	0.0045	14	0.0046	28	0.0023
Unidentified sponges	CD	0	0.0000	0	0.0000	0	0.0000	2	0.0016	2	0.0004
Unidentified sponges	EF	24	0.0073	32	0.0098	49	0.0185	81	0.0264	186	0.0152
Cnidaria											
Actiniaria sp. 3	EF	295	**0.0903**	7	0.0021	0	0.0000	0	0.0000	302	0.0246
cf Hormathiidae sp.	EF	0	0.0000	0	0.0000	29	0.0110	6	0.0020	35	0.0029
Unidentified anemones	EF	36	0.0110	116	0.0353	99	0.0374	51	0.0166	302	0.0246

Taxon	Expert	AUV_1 Count	AUV_1 Density (m^{-2})	AUV_5 Count	AUV_5 Density (m^{-2})	AUV_2 Count	AUV_2 Density (m^{-2})	AUV_4 Count	AUV_4 Density (m^{-2})	Total Count	Total Density (m^{-2})
Gersemia sp.	EF	0	0.0000	0	0.0000	12	0.0045	34	0.0111	46	0.0038
Gersemia sp.	CD	0	0.0000	0	0.0000	3	0.0029	4	0.0032	7	0.0014
Heteropolypus ritteri	EF	15	0.0046	102	0.0311	60	0.0227	75	0.0244	252	0.0206
Heteropolypus ritteri	CD	8	**0.0058**	39	**0.0288**	16	**0.0153**	15	0.0120	78	**0.0155**
Isididae	EF	0	0.0000	0	0.0000	50	0.0189	613	0.1998	663	0.0541
Isidella sp.	CD	0	0.0000	5	0.0037	2	0.0019	13	0.0104	20	0.0040
Keratoisis sp.	CD	0	0.0000	0	0.0000	3	0.0029	23	**0.0183**	26	0.0052
Lepidisis sp.	CD	0	0.0000	0	0.0000	36	**0.0345**	215	**0.1714**	251	**0.0498**
Primnoidae	EF	0	0.0000	25	0.0076	109	0.0412	58	0.0189	192	0.0157
Plumarella superba	CD	0	0.0000	0	0.0000	0	0.0000	2	0.0016	2	0.0004
Primnoa cf pacifica	CD	0	0.0000	0	0.0000	2	0.0019	2	0.0016	4	0.0008
Swiftia simplex	EF	2	0.0006	2	0.0006	21	0.0079	4	0.0013	29	0.0024
Swiftia simplex	CD	2	0.0014	0	0.0000	2	0.0019	1	0.0008	5	0.0010
Antipatharia sp. 1	CD	0	0.0000	14	0.0103	47	**0.0451**	31	**0.0247**	92	**0.0183**
Bathypathes sp.	EF	30	0.0092	202	0.0616	37	0.0140	114	0.0372	383	0.0312
Bathypathes sp.	CD	11	**0.0079**	77	**0.0569**	12	0.0115	41	**0.0327**	141	**0.0280**
Lillipathes cf lillei	EF	11	0.0034	127	0.0387	71	0.0268	83	0.0271	292	0.0238
Lillipathes cf lillei	CD	5	0.0036	30	**0.0222**	23	**0.0221**	22	0.0175	80	**0.0159**
Parantipathes sp.	CD	4	0.0029	16	0.0118	2	0.0019	8	0.0064	30	0.0060
Stichopathes sp.	EF	0	0.0000	1	0.0003	55	0.0208	5	0.0016	61	0.0050
Stichopathes sp.	CD	1	0.0007	4	0.0030	29	**0.0278**	2	0.0016	36	0.0071
Anthoptilum spp.	EF	4	0.0012	44	0.0134	16	0.0060	32	0.0104	96	0.0078
Anthoptilum spp.	CD	6	0.0043	19	**0.0140**	6	0.0058	5	0.0040	36	0.0071
Halipteris willemoesi	EF	1	0.0003	0	0.0000	1	0.0004	0	0.0000	2	0.0002
Halipteris willemoesi	CD	8	**0.0058**	0	0.0000	6	0.0058	0	0.0000	14	0.0028

Taxon	Expert	AUV_1 Count	AUV_1 Density (m^{-2})	AUV_5 Count	AUV_5 Density (m^{-2})	AUV_2 Count	AUV_2 Density (m^{-2})	AUV_4 Count	AUV_4 Density (m^{-2})	Total Count	Total Density (m^{-2})
Umbellula lindhali	EF	0	0.0000	1	0.0003	0	0.0000	0	0.0000	1	0.0001
Unidentified sea pens	EF	13	0.0040	12	0.0037	8	0.0030	2	0.0007	35	0.0029
Desmophyllum dianthus	EF	0	0.0000	0	0.0000	0	0.0000	15	0.0049	15	0.0012
Desmophyllum dianthus	CD	0	0.0000	0	0.0000	0	0.0000	6	0.0048	6	0.0012
Stylaster spp.	EF	0	0.0000	0	0.0000	0	0.0000	18	0.0059	18	0.0015
Stylaster spp.	CD	2	0.0014	0	0.0000	0	0.0000	42	**0.0335**	44	0.0087
Unidentified corals	EF	18	0.0055	17	0.0052	157	0.0593	115	0.0375	307	0.0250
Unidentified coral	CD	1	0.0007	0	0.0000	0	0.0000	0	0.0000	1	0.0002
Arthropoda											
Chionocetes tanneri	EF	77	**0.0236**	73	**0.0222**	11	0.0042	23	0.0075	184	0.0150
Chirostylidae sp.	EF	47	**0.0144**	139	**0.0424**	404	**0.1526**	1039	**0.3387**	1629	**0.1328**
Chorilia longipes	EF	1	0.0003	2	0.0006	0	0.0000	10	0.0033	13	0.0011
Lithodes cousei	EF	6	0.0018	0	0.0000	3	0.0011	9	0.0029	18	0.0015
Unidentified Crabs	EF	0	0.0000	2	0.0006	0	0.0000	2	0.0007	4	0.0003
Mollusca											
Octopus spp.	EF	0	0.0000	0	0.0000	0	0.0000	2	0.0007	2	0.0002
Tritoniidae sp.	EF	0	0.0000	2	0.0006	2	0.0008	2	0.0007	6	0.0005
Echinodermata											
Brisingidae sp.	EF	3	0.0009	43	0.0131	2	0.0008	10	0.0033	58	0.0047
Ampheraster sp.	EF	8	0.0024	12	0.0037	5	0.0019	4	0.0013	29	0.0024
Rathbunaster californicus	EF	0	0.0000	0	0.0000	0	0.0000	12	0.0039	12	0.0010
Pseudarchaster sp.	EF	1	0.0003	1	0.0003	22	0.0083	18	0.0059	42	0.0034
Thrissacanthias sp.	EF	0	0.0000	0	0.0000	0	0.0000	13	0.0042	13	0.0011
Hippasteria phrygiana	EF	1	0.0003	1	0.0003	12	0.0045	0	0.0000	14	0.0011
Pteraster sp.	EF	1	0.0003	3	0.0009	2	0.0008	2	0.0007	8	0.0007

Taxon	**Expert**	**AUV_1 Count**	**AUV_1 Density (m^{-2})**	**AUV_5 Count**	**AUV_5 Density (m^{-2})**	**AUV_2 Count**	**AUV_2 Density (m^{-2})**	**AUV_4 Count**	**AUV_4 Density (m^{-2})**	**Total Count**	**Total Density (m^{-2})**
Unidentified sea stars	EF	39	0.0119	95	0.0289	138	0.0521	85	0.0277	357	0.0291
Florometra serratissima	EF	0	0.0000	0	0.0000	22	0.0083	4	0.0013	26	0.0021
Molpadia sp.	EF	1	0.0003	0	0.0000	0	0.0000	0	0.0000	1	0.0001
Psolus squamatus	EF	0	0.0000	117	**0.0357**	45	0.0170	78	**0.0254**	240	**0.0196**
Pannychia cf moseleyi	EF	104	**0.0318**	276	**0.0841**	454	**0.1715**	193	**0.0629**	1027	**0.0838**
Unidentified sea cucumbers	EF	2	0.0006	0	0.0000	0	0.0000	1	0.0003	3	0.0002
Unidentified invertebrates	EF	4	0.0012	10	0.0030	12	0.0045	3	0.0010	29	0.0024
Chordata											
Antimora microlepis	EF	2	0.0006	0	0.0000	0	0.0000	2	0.0007	4	0.0003
Coryphaenoides acrolepis	EF	31	**0.0095**	12	0.0037	11	0.0042	19	0.0062	73	0.0060
Embassichthys bathybius	EF	3	0.0009	3	0.0009	7	0.0026	4	0.0013	17	0.0014
Glyptocephalus zachirus	EF	2	0.0006	0	0.0000	0	0.0000	0	0.0000	2	0.0002
Microstomus pacificus	EF	1	0.0003	0	0.0000	0	0.0000	0	0.0000	1	0.0001
Anoplopoma fimbria	EF	0	0.0000	2	0.0006	0	0.0000	0	0.0000	2	0.0002
Sebastes spp.	EF	0	0.0000	0	0.0000	3	0.0011	14	0.0046	17	0.0014
Sebalastobus alascanus	EF	3	0.0009	1	0.0003	0	0.0000	2	0.0007	6	0.0005
Sebastolobus spp.	EF	202	**0.0619**	125	**0.0381**	148	**0.0559**	88	**0.0287**	563	**0.0459**
Scyliorhinidae spp.	EF	3	0.0009	0	0.0000	0	0.0000	2	0.0007	5	0.0004
Unidentified fishes	EF	11	0.0034	1	0.0003	10	0.0038	19	0.0062	41	0.0033

Species richness and diversity

Species richness and diversity varied among transects. The number of observed taxa on the plateau was greatest on DFO_3, DFO_6, and DFO_17. At greater depths, AUV_4 was the most speciose transect. Across all sites, individuals from 23 classes and 52 orders were observed. Anthozoa represented the most diverse class with 31 members, while Scorpaeniformes was the most diverse order with 22 members. Pelagic and mid-water species were underrepresented in the submersible surveys. Metrics of species diversity were used to further describe species assemblages and community structure. Table 18 summarizes the diversity indices calculated with the DFO ROV video transect counts.

Table 18. Measures of species diversity used to characterize communities observed within the DFO ROV video.

Name	Measurement	Formula	Properties	Reference
Species richness	Number of species	S = number of taxa	Species richness per site	Hill (1973)
Shannon index	Heterogeneity (number of species + evenness)	$H' = -\sum_{i=1}^{S} p_i ln\, p_i$	Species diversity index giving more weight to rare species	Hill (1973)
Pielou's index	Evenness	$J' = {H'}/{\log(S)}$	Distribution of individuals over species in the population	Pielou (1966)
Zipf-Mandelbrot model	Rank-abundance distribution model	$\hat{a}_r = N\, c(r + \beta)^{\gamma}$	Species distribution model fit using maximum likelihood estimation	Wilson (1991)
Sample-based species accumulation curve	Species richness across the study area	$S_n = \sum_{i=1}^{S}(1 - pi),$ where $p_i = (1 - {}^{N-f_i}_{n})/\binom{N}{n}$	Species richness across study area using comparable sample size from each site	Ugland et al. (2003)

List of symbols used:

- $\hat{a}_r$= the expected abundance of species at rank *r*
- f_i = frequency of species *i*
- *N* = the total number of individuals in the sample
- *n* = the number of individuals species *i*
- p_i = proportion of total sample belonging to *i* th species
- *r* = rank of species

Species richness observed on the DFO ROV transects with the HD video camera was greatest at DFO_3, DFO_4, and DFO_17 (Table 19). However species richness did not necessarily correspond with species diversity. For instance, we observed only 20 species on transect DFO_8, but this site had a relatively high Shannon index values of 2.30. This is likely due to the greater weight given to rare species by the Shannon index. DFO_3, DFO_8, and DFO_16 had the highest values for Pielou's index which indicates greater evenness. By contrast, DFO_9 and DFO_ 6 had the lowest values for Pielou's index suggesting that the assemblages on these sites were characterized by many uncommon species.

Table 19. Species diversity at 12 DFO ROV sites, based on counts from the DFO ROV video.

Site	Number of Species Observed (S)	Shannon-Wiener (H)	Pielou's (J)
DFO_1	12	1.69	0.68
DFO_2	23	2.09	0.67
DFO_3	32	2.65	0.76
DFO_4	27	2.14	0.65
DFO_5	25	2.18	0.68
DFO_6	18	1.60	0.55
DFO_8	20	2.30	0.77
DFO_9	11	1.16	0.48
DFO_14	24	2.26	0.71
DFO_15	22	2.14	0.69
DFO_16	13	1.96	0.77
DFO_17	26	2.24	0.69

Rank abundance plots (Whittaker 1965) display species abundance against species rank order using maximum likelihood estimation. To characterize the differences in species rank abundance at sites on Cobb Seamount, several models were fitted (broken stick, log normal, etc.) to the species counts from the DFO ROV video. The Zipf-Mandelbrot model produced the best fit to the data (lowest AIC values). Figure 19 illustrates the different abundance distributions at each site surveyed by the DFO ROV. Evenness was generally low at the DFO ROV sites: most sites had a high abundance of only a small number of species and a low abundance of many of the species observed. Many sites had several species with only one observation, producing skewed rank abundance distributions.

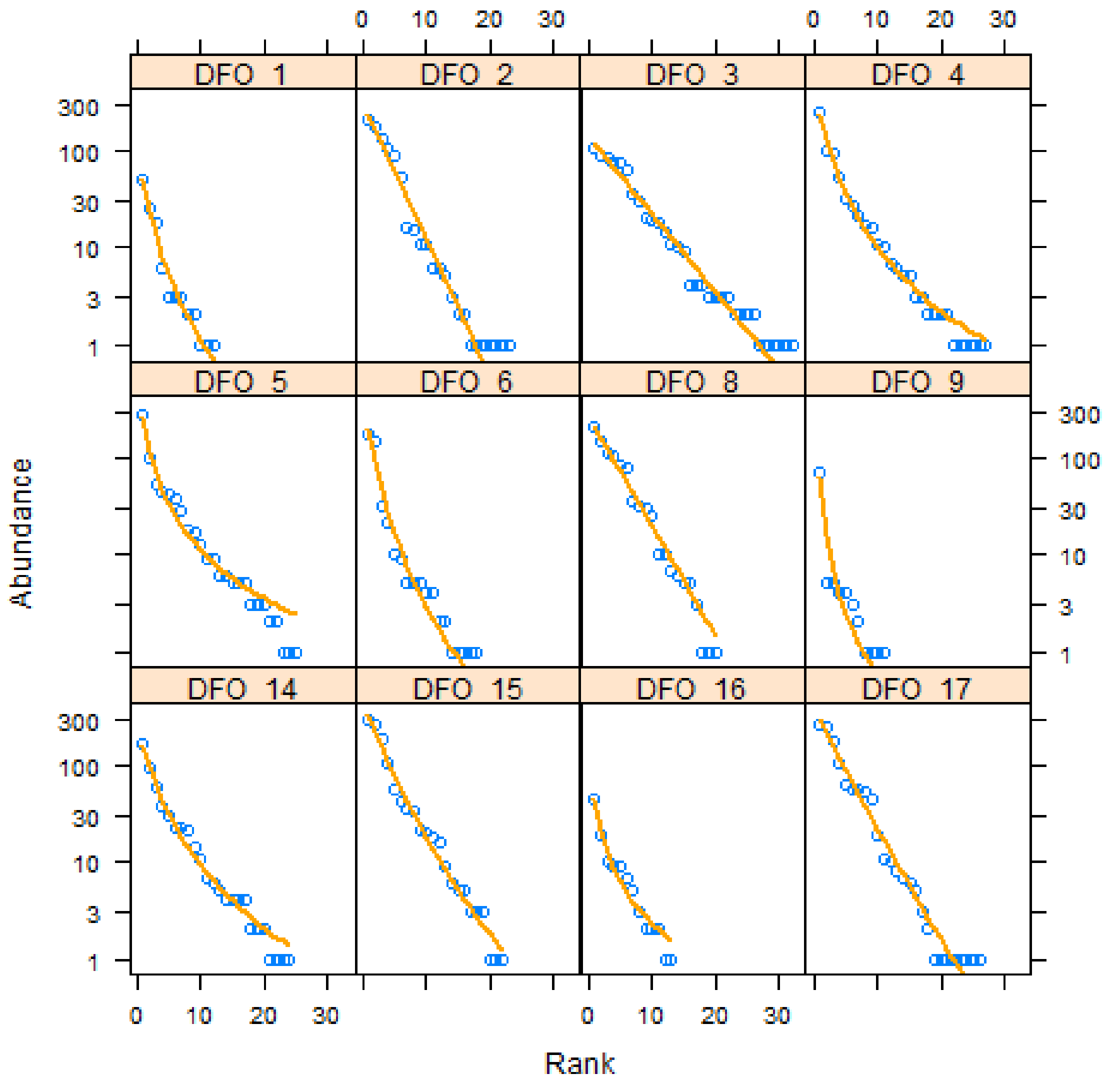

Figure 19. Rank abundance distributions for each DFO ROV site, based on counts from the DFO ROV video.

A sample-based species accumulation curve can be constructed using a species-by-sample matrix to illustrate the increase in the number of observed species as a function of the sampling effort (Colwell et al. 2004). To create this curve the sample size is set to the site with the least number of individuals. Sites are sampled in random order without replacement and the number of species observed within a sample is summed over 100 permutations to calculate the mean and standard deviation values for the accumulation curve. Theoretically when this curve reaches the asymptote the number of observations is adequate to describe the community. The curve in Figure 20 approaches the asymptote, but suggests other benthic species may remain undetected on the Cobb Seamount plateau.

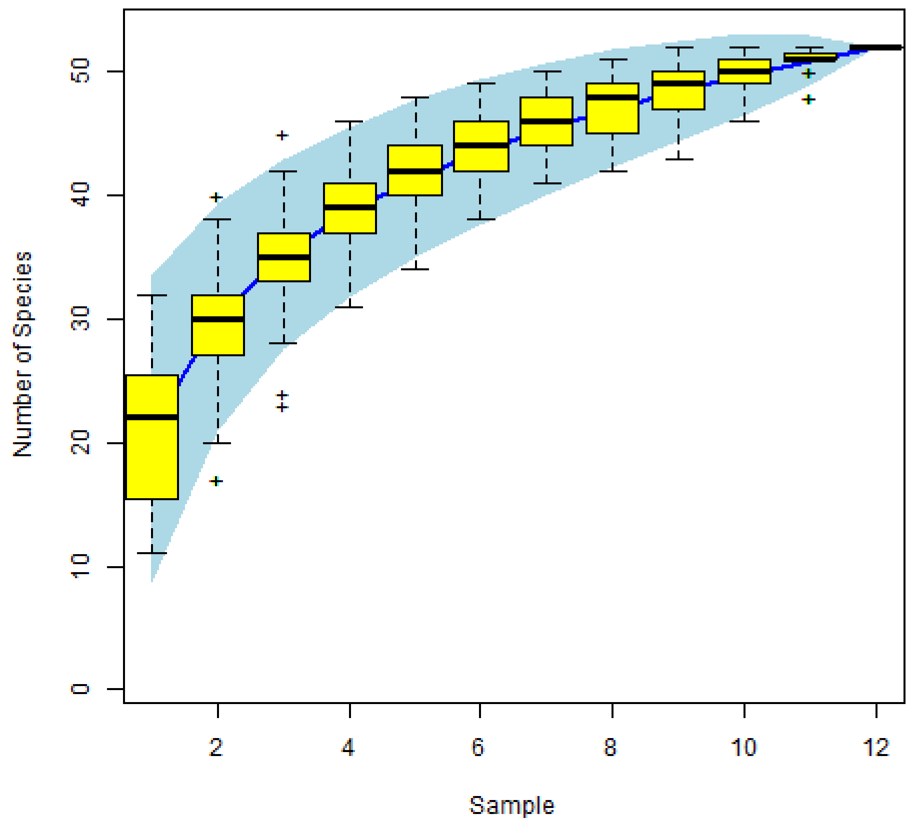

Figure 20. Species accumulation curve for DFO ROV transects at Cobb Seamount, based on counts from DFO ROV video.

Benthic habitat structure

Overall, 34443 records of dominant substrata type were extracted from DFO ROV video using DFO's habitat classification codes (Table 3) and 2614 records were obtained from AUV photos using NOAA's habitat classification system (Table 5). A variety of habitat types were encountered on Cobb Seamount, including bedrock (smooth or creviced), aggregates of various sizes from boulders and cobbles to gravel, crushed shell or coral and sand.

In terms of frequency of occurrence on transects, sand was the most prevalent dominant substrate observed at DFO ROV and AUV sites, followed by boulders and creviced bedrock (Table 20). The trend held when pooling observations across all ROV transects; sand was most frequently observed (38.1%), followed by boulders (28.7%) and creviced bedrock (24.0%). When pooling observations across all AUV transects (n = 2166), however, creviced bedrock was most frequently observed (36.9%) followed by sand (36.2%) and pea gravel (15.0%). Using NOAA's classification codes, the most frequently recorded primary habitat types observed across all four AUV transects were mud (26%), flat rock (24%) and sand (18%) (Table 21). However, because of the AUV camera angle (pointing straight down) it was difficult to distinguish lava flows forming contiguous flat rock from boulders and cobbles. Sites DFO_6, AUV_2, and AUV_5 had the greatest diversity of dominant substrata (6), while the substrata on DFO_1, DFO_9, and DFO_16 were predominantly sand (>80% of records). (Table 20).

Table 20. The proportion of 12 DFO ROV and four AUV transects dominated by different substrata using DFO's habitat classification codes (Table 3). For each transect, the sample size and number of dominant substrata observed are given, and the most frequently observed substratum is in bold. The frequency of occurrence across transects is given for each substratum. Data from SFU ROV transects are not given as habitat attributes were not quantitatively annotated at these sites.

Site	Number of observations	Number of substrata	Smooth bedrock	Bedrock with crevices	Boulders	Cobble	Gravel	Pea gravel	Sand	Crushed shell	Whole shell	Coral rubble
DFO_1	3517	1	0	0	0	0	0	0	**1**	0	0	0
DFO_2	1720	3	0	0.43	**0.49**	0	0	0	0.06	0	0	0
DFO_3	3060	5	0.04	0.33	0.20	0	0.02	0	**0.40**	0	0	0
DFO_4	4466	2	0	0	0.44	0	0	0	**0.56**	0	0	0
DFO_5	2266	4	0	0	**0.61**	0	0	0	0.26	0.05	0	0.13
DFO_6	2823	6	0.11	**0.58**	0.02	0.09	0	0	0.18	0	0.02	0
DFO_8	3114	3	0	0.08	**0.52**	0	0	0	0.40	0	0	0
DFO_9	2110	1	0	0	0	0	0	0	**1**	0	0	0
DFO_14	2811	5	0.21	0.08	0.19	0	0	0	0.03	0	0	**0.49**
DFO_15	2511	4	0.01	**0.61**	0.25	0	0	0	0.13	0	0	0
DFO_16	3454	2	0	0	0.19	0	0	0	**0.81**	0	0	0
DFO_17	2591	3	0	**0.58**	0.40	0	0	0	0.02	0	0	0
AUV_1	371	3	0	0.15	0	0	0	0.05	**0.8**	0	0	0
AUV_2	597	6	0.11	**0.57**	0.02	0	0.02	0.21	0.08	0	0	0
AUV_4	559	4	0	**0.65**	0.04	0.03	0	0	0.27	0	0	0
AUV_5	639	6	0.11	0.06	0	0.05	0.04	0.28	**0.46**	0	0	0
Frequency			6	11	12	3	3	3	16	1	1	2

Table 21. Frequency of primary habitat types on four AUV transects, classified according to habitat categories used by NOAA. Values in bold denote the most frequently observed primary habitat type on each AUV transect. N refers to the number of photos analyzed per transect.

Primary habitat	**AUV_1**	**AUV_2**	**AUV_4**	**AUV_5**
Boulder	0.07	0.11	0.27	0.01
Cobble	0	0.02	0.02	0.03
Flat rock	0.08	**0.52**	0.31	0.12
Gravel	0.01	0.26	0	0.35
Mud	0.2	0.05	**0.34**	**0.40**
Pebble	0	0.01	0	0.08
Rock ridge	0.01	0.02	0.06	0.01
Sand	**0.63**	0.01	0	0
N	718	574	593	729

Seafloor relief was classed into four categories representing a gradient from flat or rolling habitat to vertical wall. When pooling observations across all ROV transects (n = 34222); a flat or rolling seafloor was most frequently observed (37.2%), followed by a vertical relief of 0.5-2m (36.9%) and >2m (15.6%). At all sites except DFO_1 and DFO_9 more than one relief category was encountered; these two sites were characterized only by flat or rolling habitat (Table 22). When pooling observations across all AUV transects (n = 2178), flat or rolling seafloor was also most frequently recorded (78.5%) followed by a vertical relief of 0.5-2m (16.9%) and >2m (4.5%). The mean slopes on transects were similar on the seamount plateau where ROV transects were carried out and on the slopes of the seamount where the AUV transects were carried out (t = -1.845, df = 4.439, p-value = 0.1317). Even though the greatest slope was observed on AUV_4, no vertical walls were recorded on any of the AUV transects, which may be an artefact of the AUV's port camera angle (pointing straight down) and the small area captured by each photo (mean, SD).

Aspect of transects from shallow to deep included two cardinal directions (South, North), and three ordinal directions (Southwest, Northwest, Northeast).

Table 22. Seafloor relief categories, change in elevation, slope and aspect of 12 DFO ROV transects and four AUV transects. The habitats on SFU ROV transects were not quantitatively annotated and are therefore not included in this table.

Site	**N**	**Flat or rolling**	**Vertical relief 0.5 – 2m**	**Vertical relief >2m**	**Slope or Wall**	**Change in elevation (m)**	**Average slope (%)**	**Aspect**
DFO_1	3515	**1**	0	0	0	9	1.9	North
DFO_2	1709	0	**0.54**	0.32	0.13	24	7.2	South
DFO_3	3024	0.31	**0.51**	0.06	0.11	5	1.1	Southwest
DFO_4	4422	0.38	**0.49**	0.13	0	11	2.0	Northwest
DFO_5	2238	0.08	**0.83**	0.09	0	15	3.2	Northeast

DFO_6	2804	0.32	0.19	0.01	**0.48**	60	11.7	South
DFO_8	3086	0.27	0.25	**0.46**	0.01	9	1.7	Northeast
DFO_9	2110	**1**	0	0	0	0	0	Northeast
DFO_14	2785	0.43	**0.5**	0.01	0.05	50	8.8	Northwest
DFO_15	2499	0.12	**0.65**	0.11	0.11	60	11.0	Northwest
DFO_16	3449	**0.84**	0.16	0	0	37	6.1	Northeast
DFO_17	2581	0.05	0.34	**0.48**	0.13	30	5.0	Northeast
AUV_1	375	**0.94**	0.06	0	0	198	11.0	Southwest
AUV_2	641	**0.96**	0.03	0.01	0	153	8.5	North
AUV_4	603	**0.75**	0.21	0.04	0	285	15.9	North
AUV_5	559	**0.51**	0.36	0.12	0	78	4.3	South

Fishing gear and observable impacts

We noted 95 instances of fishing gear and/or their observable impacts at 13 (68%) of the dive sites during the 2012 Cobb Seamount survey (Figure 21, Table 23). The gear types we observed on the seafloor included pieces of gillnet, trawl net, longlines, trap longlines, as well as anchors and various pieces of rope. Trap or longline groundlines were most common (41%) followed by unidentifiable pieces of rope (23%), monofilament gillnet (15%) and unidentifiable pieces of netting (8%). Only one trawl net was identified. We also encountered several small pieces of rope (cut or snapped) and anchors.

There were pieces of fishing gear or observable impacts on 8 of 12 DFO ROV transects, at 1 of the 3 SFU sites and at each of the 4 AUV transects. Two-thirds (n=61) of those instances included images of fishing gear.

Impacts of the fishing gears observed or inferred during the Cobb Seamount cruise included: lost or abandoned pieces of fishing gear; entangled gear; damaged, toppled, or dead corals; ghost fishing; drag marks; and discards of fish. Of the images depicting fishing gear, 18% were of fishing gear entangled in damaged, toppled, or dead coral. Most instances of entangled fishing gear involved corals, including bamboo corals and *Stylaster* spp. On the plateau, most instances of entangled fishing gear involved *Stylaster* spp. In deeper waters surveyed with the AUV, only trap or longline groundlines were observed entangled in coral. In some cases, the groundlines appeared to have toppled or killed whole colonies (Figure 22). In other cases, entangled groundlines were associated with partial damage to coral colonies (Figure 23). Approximately one third (n=30) of the images depicted putative drag marks, and a few images depicted putative incidents of ghost fishing (Figure 24) and recently discarded fish (Figure 25).

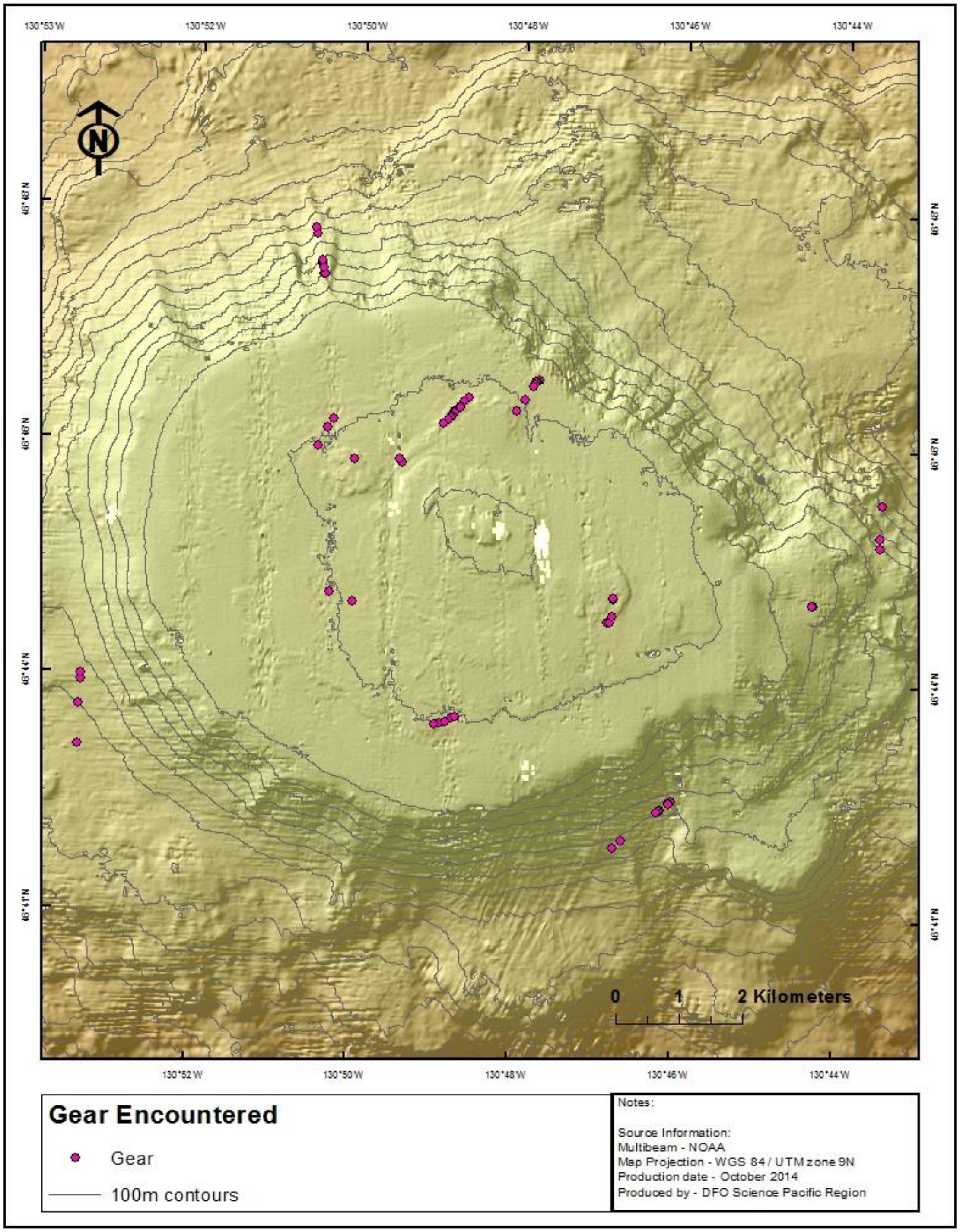

Figure 21. Location of fishing gear observed on Cobb Seamount in 2012.

Table 23 Dives sites where fishing gear and/or observable impacts were noted in ROV video and/or still photographs, or in AUV photos.

Dive number and site	Gear type	Observable Impact	Corresponding Image File [1]
1 DFO_2	netting		
1 DFO_2	trawl netting		
1 DFO_2	monofilament gill net	ghost fishing or discards	
1 DFO_2	monofilament gill net		
1 DFO_2	monofilament gill net		072112_212302_ 81.jpg
3 AUV_1	small piece of rope		20120722.021246.00157.jpg
3 AUV_1	small piece of rope		20120722.021536.00191.jpg
3 AUV_1	small piece of rope		20120722.021636.00203.jpg
3 AUV_1	snapped rope		20120722.022636.00323.jpg
3 AUV_1	small piece of rope		20120722.022826.00345.jpg
3 AUV_1	small piece of rope		20120722.031906.00953.jpg
3 AUV_1	rope		20120722.033156.01107.jpg
3 AUV_1		putative drag mark	20120722.022546.00313.jpg
3 AUV_1		putative drag mark	20120722.022556.00315.jpg
3 AUV_1		putative drag mark	20120722.022606.00317.jpg
3 AUV_1		putative drag mark	20120722.022616.00319.jpg
3 AUV_1		putative drag mark	20120722.022726.00333.jpg
3 AUV_1		putative drag mark	20120722.022736.00335.jpg
3 AUV_1		putative drag mark	20120722.022806.00341.jpg
3 AUV_1		putative drag mark	20120722.022826.00345.jpg
3 AUV_1		putative drag mark	20120722.023006.00365.jpg
3 AUV_1		putative drag mark	20120722.023016.00367.jpg
3 AUV_1		putative drag mark	20120722.023116.00379.jpg
3 AUV_1		putative drag mark	20120722.023126.00381.jpg
3 AUV_1		putative drag mark	20120722.023136.00383.jpg
3 AUV_1		putative drag mark	20120722.023156.00387.jpg
3 AUV_1		putative drag mark	20120722.023206.00389.jpg
3 AUV_1		putative drag mark	20120722.023216.00391.jpg
3 AUV_1		putative drag mark	20120722.023226.00393.jpg
3 AUV_1		putative drag mark	20120722.023236.00395.jpg
3 AUV_1		putative drag mark	20120722.023246.00397.jpg
3 AUV_1		putative drag mark	20120722.023316.00403.jpg
3 AUV_1		putative drag mark	20120722.023326.00405.jpg
3 AUV_1		putative drag mark	20120722.023336.00407.jpg
3 AUV_1		putative drag mark	20120722.023406.00413.jpg
3 AUV_1		putative drag mark	20120722.023526.00429.jpg
3 AUV_1		putative drag mark	20120722.023536.00431.jpg

Dive number and site	Gear type	Observable Impact	Corresponding Image File [1]
3 AUV_1		putative drag mark	20120722.023726.00453.jpg
3 AUV_1		putative drag mark	20120722.024826.00585.jpg
3 AUV_1		putative drag mark	20120722.025536.00671.jpg
3 AUV_1		putative drag mark	20120722.025716.00691.jpg
3 AUV_1		putative drag mark	20120722.035126.01341.jpg
5 DFO_4	trap or longline groundline	drag marks	
5 DFO_4	trap or longline groundline		072212_182626_ 150.jpg
5 DFO_4	netting		072212_183956_ 204.jpg
6 AUV_5	small piece of rope		20120722.221005.00493.jpg
6 AUV_5	rope		20120722.221555.00563.jpg
6 AUV_5	rope or monofilament line		20120722.224215.00879.jpg
7 DFO_3	monofilament gill net	entangled in coral	072312_030132_ 157.jpg
7 DFO_3	monofilament gill net	entangled in coral; ghost fishing	072312_032346_ 246.jpg; 072312_032401_ 247.jpg; 072312_032417_ 248.jpg
7 DFO_3	rope		072312_023616_ 56.jpg
7 DFO_3	rope		072312_031617_ 216.jpg
8 AUV_2	snapped rope		20120723.160756.00701.jpg
8 AUV_2	rope or monofilament line		20120723.164247.01119.jpg
10 DFO_5	netting	entangled in coral	072312_220123_ 208.jpg
10 DFO_5	monofilament gill net	entangled in coral	
10 DFO_5	monofilament gill net	entangled in dead coral	072312_230525_ 407.jpg (all photos from 402-409)
13 AUV_4	trap or longline groundline	entangled in toppled bamboo coral	20120724.155247.00013.jpg
13 AUV_4	trap or longline groundline		20120724.155347.00025.jpg
13 AUV_4	trap or longline groundline	entangled in dead coral	20120724.155357.00027.jpg
13 AUV_4	trap or longline groundline		20120724.155417.00031.jpg
13 AUV_4	trap or longline groundline	entangled in damaged coral	20120724.155537.00047.jpg
13 AUV_4	trap or longline groundline		20120724.155547.00049.jpg
13 AUV_4	trap or longline groundline	entangled in damaged coral	20120724.155557.00051.jpg
13 AUV_4	trap or longline groundline		20120724.160147.00121.jpg
13 AUV_4	trap or longline groundline		20120724.160447.00157.jpg
13 AUV_4	trap or longline groundline		20120724.160747.00193.jpg
13 AUV_4	trap or longline groundline		20120724.160757.00195.jpg
13 AUV_4	trap or longline groundline		20120724.163658.00543.jpg
13 AUV_4	snapped rope		20120724.164418.00631.jpg
13 AUV_4	trap or longline groundline		20120724.155527.00045.jpg
16 SFU_2	trap or longline groundline		

Dive number and site	Gear type	Observable Impact	Corresponding Image File [1]
16 SFU_2	trap or longline groundline		
16 SFU_2	trap or longline groundline	entangled in coral?	
18 DFO_8	trap or longline groundline		072612_013821_ 12.jpg
18 DFO_8	trap or longline groundline		072612_014036_ 21.jpg
18 DFO_8	trap or longline groundline		072612_014151_ 26.jpg
18 DFO_8	trap or longline groundline	drag marks	072612_014736_ 49.jpg; 072612_014751_ 50.jpg
18 DFO_8	trap or longline groundline		072612_015135_ 65.jpg
18 DFO_8	mass of rope or netting		072612_021106_ 143.jpg
18 DFO_8	piece of rope		072612_023306_ 231.jpg
19 DFO_14	monofilament line		
20 DFO_15	longline groundline		072612_171049_ 6.jpg
20 DFO_15	anchor		072612_171918_ 40.jpg
23 DFO_17	anchor		072712_013001_ 841.jpg
23 DFO_17	trap or longline groundline	coral damage?	072712_014446_ 900.jpg
23 DFO_17	float line		072712_014518_ 902.jpg
23 DFO_17	netting	entangled in coral?	072712_020001_ 961.jpg
23 DFO_17	netting	entangled in coral	
23 DFO_17	rope gill net	entangled in coral	
23 DFO_17	small piece of rope	entangled in coral?	
23 DFO_17	rope gill net	entangled in coral	072712_021116_ 1006.jpg
23 DFO_17	monofilament gill net	entangled in coral	072712_024446_ 1140.jpg
23 DFO_17	monofilament gill net		072712_025231_ 1171.jpg
23 DFO_17	mass of rope or netting		072712_030316_ 1214.jpg

[1]Not all fishing gears observed in the ROV video were purposefully photo-documented with the digital still camera.

Figure 22. Groundlines entangled in (A) a damaged and toppled bamboo coral, and (b) the remains of a dead unidentified coral colony. Both digital photos were captured on transect AUV_4 on 24 July 2012 (photo credit: NOAA NWFSC/PIFSC AUV team).

At least one possible example of ghost fishing was observed in DFO ROV HD video collected during the first Dive at DFO_2 (Figure 24). What appeared to be recently discarded fish were observed on transect DFO_2 on 21 July 2012, the day the *CCGS J.P. Tully* arrived at Cobb Seamount fish (Figure 25)

In addition to inferred impacts of fishing gear seen *in situ*, we observed evidence of fishing gear or other objects being dragged along the seafloor (Figure 26). Most of the images of drag marks were captured with the AUV's digital still cameras on transect AUV1.

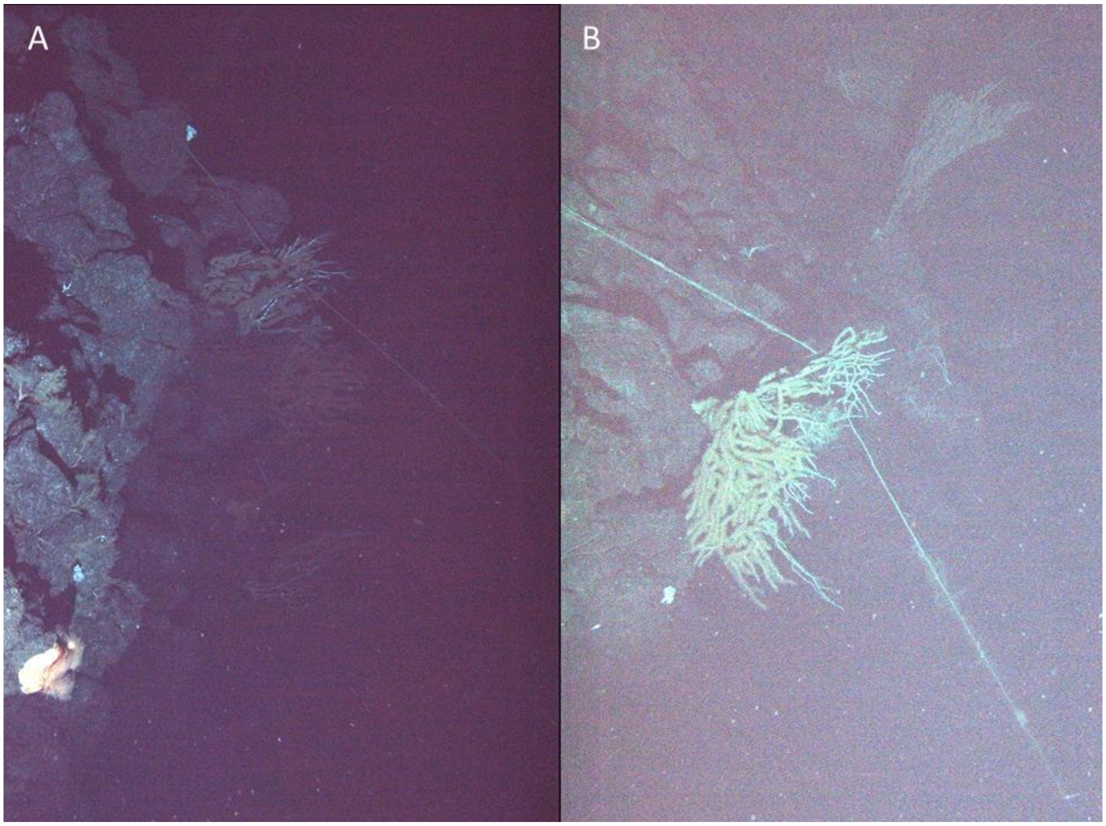

Figure 23. Two examples (A and B) of groundlines entangled in coral colonies, captured in digital still photographs on transect AUV_4 on 24 July 2012 (photo credit: NOAA NWFSC/PIFSC AUV team).

Figure 24. Four dead rockfish were observed in what appeared to be monofilament gillnet on transect DFO_2 surveyed 21 July 2012. This screen capture from the DFO ROV HD video shows that the gillnet is draped over boulders and growth on the netting indicates the net may have been *in situ* for some time (photo credit: DFO PBS ROV team).

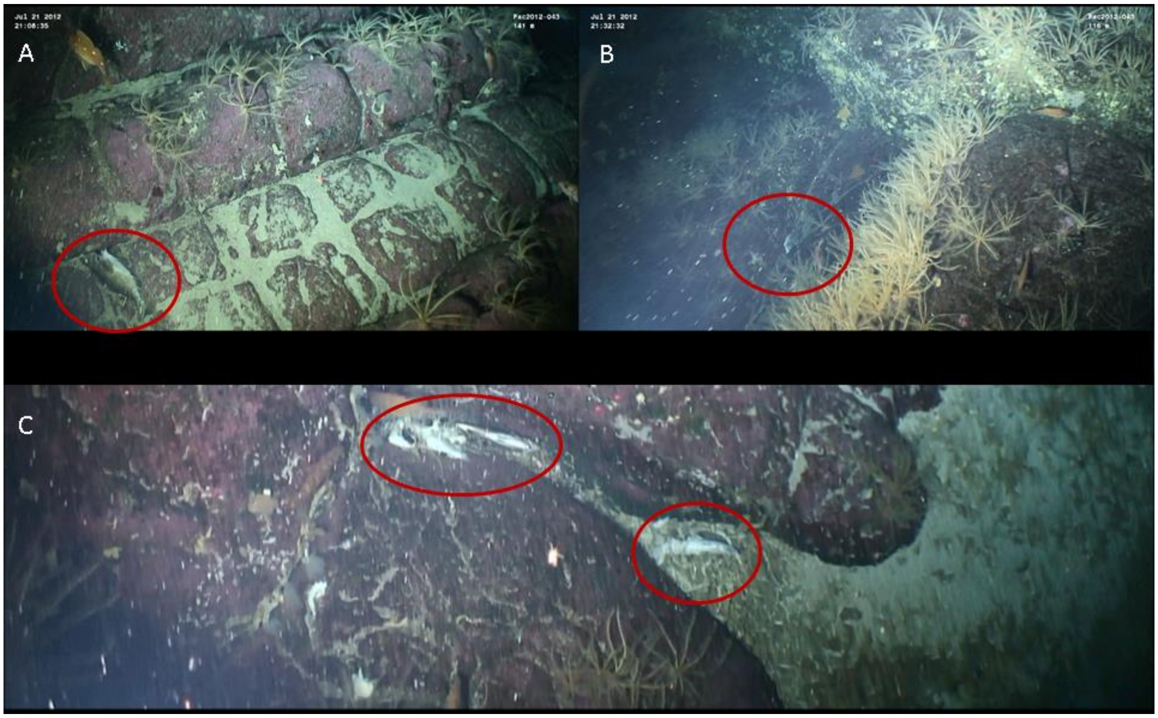

Figure 25. Examples (A, B, and C) of what appear to be recently discarded fish observed in ROV video images from Dive 1 (transect DFO_2) on 21 July 2012. None of these dead fish were associated with visible fishing gear (photo credit: DFO PBS ROV team).

Fish and fishing gear were not the only discards on Cobb Seamount: numerous pieces of trash, including fabric and cans (e.g. Figure 27) were observed on the seafloor on several transects.

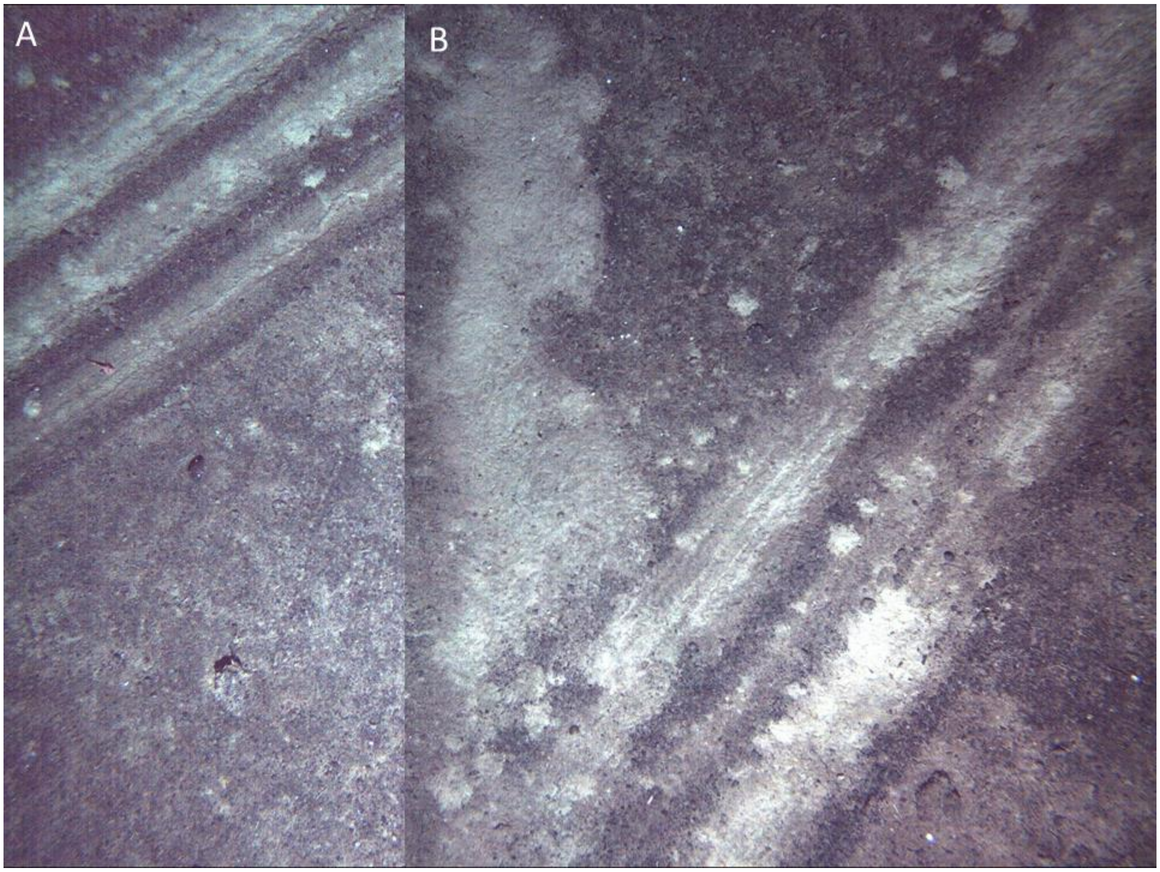

Figure 26. Photos of putative drag marks captured with the AUV digital still camera on transect AUV_1 on 21 July 2012 (photo credit: NOAA NWFSC/PIFSC AUV team).

Figure 27. An example of garbage (aluminum can) observed on the seafloor, in this case on transect AUV_5 on 22 July 2012 (photo credit: NOAA NWFSC/PIFSC AUV team).

Vulnerable marine ecosystem indicator species

International guidelines for management of deepwater fisheries in the high seas define a VME as one likely to show a substantial negative response to disturbance (FAO 2008). In practice, however, VME identification has proven challenging because of a dearth of data on the initial response of ecosystems to fishing and the trajectory of recovery. Many RFMOs have therefore identified a suite of taxa as indicators of the presence of VMEs. These suites of indicator species vary according to RFMO. VME indicator species adopted by the NPFC in 2009 include three orders of coldwater corals: Alcyonacea, Antipatharia, and Scleractinia.[3] To date, 17 taxa of the orders Alcyonacea, Antipatharia, and Scleractinia have been identified on Cobb Seamount (Table 24).

Table 24. Indicator species of vulnerable marine ecosystems (VMEs) observed on or collected from Cobb Seamount during the past five decades (see Du Preez et al. 2015). Species are grouped according to the three orders of coral identified as VME indicators by the North Pacific Fisheries Commission (NPFC 2009).

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		

Seabird and marine mammals

Counts and Densities

Underway Surveys

Figure 28 shows the locations of all 2012 underway surveys. Due to differences in survey methods (between 1991/1992 and 2012), the densities of seabirds presented in this report have not been adjusted to account for differences in species-specific detectability. Table 25 provides a summary of the species counts and densities of seabirds in each year during the distant surveys, as well as the number of marine mammals detected (no density estimates). Counts and densities of seabirds and counts of marine mammals encountered during the near surveys are summarized in Table 26.

[3]Gorgonacea was also adopted by NPFC (2009) as a VME indicator, but this order is synonymous with Alcyonacea (WoRMS 2015).

Distant Surveys

Compared with the 1991 and 1992 distant surveys, low numbers of birds were encountered in 2012; whereas, the number of species detected (i.e. species richness) was similar to the surveys conducted in the early 1990s (Table 25). The low number of birds observed in 2012 may in part have been due to the reduced survey effort (primarily due to adverse weather conditions). Comparing bird densities (numbers/km^2), 1992 stands out as being somewhat 'anomalous'; largely due to the high number of sooty shearwaters (*Ardenna grisea*) encountered that year. In contrast, few sooty shearwaters were seen in 2012. Differences in timing of the surveys (as well as the cruise tracks) contribute contribute to the variation in the number of shearwaters encountered between years. Kenyon et al. (2009) reported that sooty shearwaters are most numerous during June and July, especially along and over the shelfbreak along southwest Vancouver Island. Overall, the avifaunal community in 1991 and 2012 was dominated by the two storm-petrel species. The combined total count of storm-petrels encountered represented approximately 65% of the total number of birds seen in 1991 and 2012, and 50% of the combined three-year total number of birds observed. Procellariiform seabirds (albatrosses, fulmars and shearwaters) represented approximately 29%, 60% and 24% of all birds observed, respectively in 1991, 1992 and 2012; and approximately 42% of all birds seen during the three years of distant surveys.

Only three species of marine mammals were encountered during the 2012 distant surveys (humpback whale *Megaptera novaeangliae*, Dall's porpoise *Phocoenoides dalli* and northern fur seal *Callorhinus ursinus*). The number of individual marine mammals seen in 2012 was also lower than in previous surveys. The highest number of mammals and the highest species richness were found in the 1992 distant surveys (Table 25).

Near Surveys

Although far fewer birds and a reduced number of species were encountered in the 2012 near surveys (Table 26), the 2012 total average density was the highest of the three survey years. Leach's storm-petrel was the dominant species in the 1991 and 2012 surveys; whereas, in 1992 the fork-tailed storm-petrel (*Hydrobates furcatus*) was the most numerous species. The combined total combined number of storm-petrel seen over the three years dominated the avifauna; total numbers of fork-tailed and Leach's storm-petrels represented almost 75% of all birds encountered in the near surveys.

No marine mammals were encountered during near surveys in 1991 or 2012; whereas, 28 mammals (comprised of three species: Pacific white-sided dolphin (*Lagenorhynchus obliquidens*), Dall's porpoise and northern elephant seal (*Mirounga angustirostris*) were seen in the 1992 near surveys.

Stationary Surveys

A total of 27 stationary surveys were conducted in 2012 (Figure 29). Table 27 shows that the highest numbers and densities of black-footed albatrosses, fork-tailed and Leach's storm-petrels occurred over waters within the shallower depth categories (especially < 400 m). The only marine mammal encountered during stationary surveys was a group of Dall's porpoise; they also occurred at one of the shallow stations (Table 28).

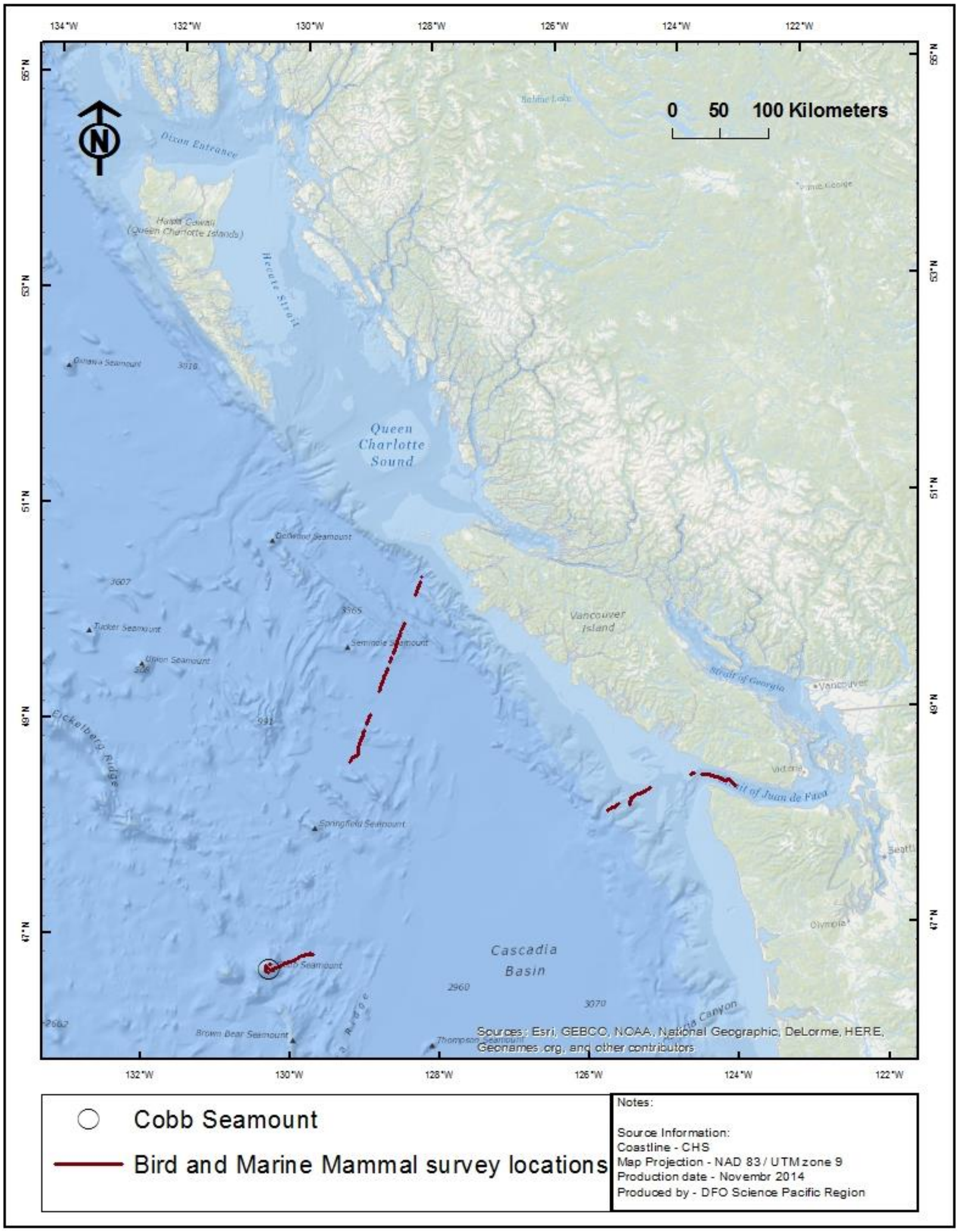

Figure 28 Locations of seabird and marine mammal surveys conducted in 2012. Distant surveys are those transects outside of the black circle; whereas near surveys are those within the 50 km circle.

Table 25. Counts and average densities (no/km^2) of seabirds, and counts of marine mammals observed during distant surveys conducted 28-30 July 28-30 and 7-8 August 1991, 22 June – 1 July 1992 and 20 and 28 July 2012.

	1991 Count - total birds	**1991** Average density (no/km^2)	**1992** Count - total birds	**1992** Average density (no/km^2)	**2012** Count - total birds	**2012** Average density (no/km^2)	**3-Year** Count - total birds	**3-Year** Average density (no/km^2)
Seabirds								
Pacific loon	0	-	1	0.01	0	-	1	0.003
Laysan albatross	0	-	0	-	1	0.02	1	0.003
Black-footed albatross	76	0.48	39	0.40	6	0.13	121	0.311
Northern fulmar	95	0.74	63	0.65	13	0.29	171	0.438
Pink-footed shearwater	21	0.16	74	0.76	43	0.95	138	0.354
Sooty shearwater	224	1.58	701	7.28	17	0.38	942	2.414
Buller’s shearwater	1	0.01	0	-	0	-	1	0.003
Fork-tailed storm-petrel	219	1.24	401	4.11	15	0.33	635	1.627
Leach’s storm-petrel	728	3.42	61	0.64	202	4.47	991	2.539
Red-necked phalarope	0	-	12	0.12	0	-	12	0.031
Red phalarope	7	0.03	1	0.01	6	0.13	14	0.036
Unidentified phalarope	5	0.02	0	-	4	0.09	9	0.023
South polar skua	2	0.01	0	-	3	0.07	5	0.013
Parasitic jaeger	6	0.02	0	-	1	0.02	7	0.018
Pomarine jaeger	1	0.01	0	-	0	-	1	0.003
Long-tailed jaeger	30	0.09	0	-	0	-	30	0.077
Unidentified jaeger	0	-	0	-	2	0.04	2	0.005
Herring gull	0	-	1	0.01	0	-	1	0.003
Glaucous-winged gull	0	-	6	0.06	0	-	6	0.015
Sabine’s gull	5	0.02	0	-	2	0.04	7	0.018
Arctic tern	7	0.04	0	-	3	0.07	10	0.026
Common murre	1	0.01	35	0.36	1	0.02	37	0.095
Ancient murrelet	0	-	7	0.07	0	-	7	0.018
Cassin’s auklet	5	0.02	36	0.37	14	0.31	55	0.141
Rhinoceros auklet	7	0.04	15	0.16	1	0.02	23	0.059
Tufted puffin	10	0.07	9	0.09	0	-	19	0.049
Unidentified alcid	3	0.02	3	0.03	0	-	6	0.015
Total Birds	**1453**	**8.03**	**1465**	**15.14**	**334**	**7.39**	**3252**	**8.334**
Number of Species	**18**		**16**		**15**		**24**	
Area surveyed (km^2)	**244.1**		**100.9**		**45.2**		**390.2**	

Marine Mammals	**1991 Count**	**1992 Count**	**2012 Count**	**3-Year Total**
Humpback whale	0	2	4	6
Fin whale	5	0	0	5
Killer whale	0	9	0	9
Pacific white-sided dolphin	5	66	0	71
Northern right whale dolphin	0	6	0	6
Dall’s porpoise	*59*	10	11	80
Northern fur seal	2	1	2	5
Northern elephant seal	3	0	0	3
Total Marine Mammals	**74**	**94**	**17**	**185**
Number of Species	**5**	**6**	**3**	**8**

Table 26. Counts and average densities (no/km^2) of seabirds, and counts of marine mammals observed during near surveys conducted 31 July – 7 August 1991, 22 June – 1 July 1992 and 21 July 2012.

	1991 Count - total birds	**1991** Average density (no/km^2)	**1992** Count - total birds	**1992** Average density (no/km^2)	**2012** Count - total birds	**2012** Average density (no/km^2)	**3-Year** Count - total birds	**3-Year** Average density (no/km^2)
Seabirds								
Black-footed albatross	58	0.76	58	0.37	10	0.57	126	0.468
Sooty shearwater	6	0.05	9	0.05	1	0.06	16	0.059
Buller's shearwater	2	0.02	0	-	0	-	2	0.007
Fork-tailed storm-petrel	56	0.83	78	0.46	4	0.23	138	0.513
Leach's storm-petrel	174	1.88	73	0.46	67	3.79	314	1.166
Unidentified storm-petrel	0	-	0	-	1	0.06	1	0.004
Red phalarope	4	0.05	8	0.06	1	0.06	13	0.048
Unidentified phalarope	2	0.04	0	-	0	-	2	0.007
Long-tailed jaeger	1	0.01	1	0.01	0	-	2	0.007
Arctic tern	5	0.09	0	-	0	-	5	0.019
Rhinoceros auklet	0	-	1	0.01	0	-	1	0.004
Total Birds	**308**	**3.71**	**228**	**1.41**	**84**	**4.75**	**620**	**2.303**
Number of Species	**8**		**7**		**5**		**9**	
Marine Mammals	**1991 Count**		**1992 Count**		**2012 Count**		**3-Year Total**	
Pacific white-sided dolphin	0		12		0		12	
Dall's porpoise	0		15		0		15	
Northern elephant seal	0		1		0		1	
Total Marine Mammals	**0**		**28**		**0**		**28**	

Table 27. Counts and average densities (no/km^2) of seabirds, and counts of marine mammals observed during 2012 stationary surveys by water depth.

Depth Category (m)	**No. of Stations**	**Total Area Surveyed (km^2)**		**Black-footed albatross**	**Sooty shearwater**	**Fork-tailed storm-petrel**	**Leach's storm-petrel**	**Total Birds**	**Marine Mammals**
< 200									
			Count	82	0	23	74	179	5 *
	6	0.848	**Density**	96.7	-	27.1	87.2	211.0	
200-399									
			Count	41	1	2	42	86	0
	8	1.131	**Density**	36.2	0.9	1.8	37.1	76.0	
400-799									
			Count	4	0	0	2	6	0
	6	0.848	**Density**	4.7	0	0	2.4	7.1	
> 800									
			Count	5	0	2	3	10	0
	7	0.990	**Density**	5.05	0	2.0	3.0	10.1	

* Dall's porpoise

Table 28. Counts and average densities (no/km^2) of seabirds, and counts of marine mammals observed during 2012 stationary surveys by distance.

Distance Category (km)	No. of Stations	Total Area Surveyed (km^2)		Black-footed albatross	Sooty shear-water	Fork-tailed storm-petrel	Leach's storm-petrel	Total Birds	Marine Mammals
< 2.0									
			Count	48	0	21	59	128	0
	2	0.283	**Density**	169.7	0	74.3	208.6	452.6	
2.0-3.9									
			Count	49	1	3	25	77	5 *
	10	1.414	**Density**	34.7	0.8	2.1	17.7	54.6	
4.0-5.9									
			Count	31	0	1	16	49	0
	9	1.273	**Density**	24.4	0	0.8	12.6	38.5	
>6.0-7.9									
			Count	4	0	1	3	8	0
	6	0.848	**Density**	4.71	0	1.18	3.5	9.4	

* Dall's porpoise

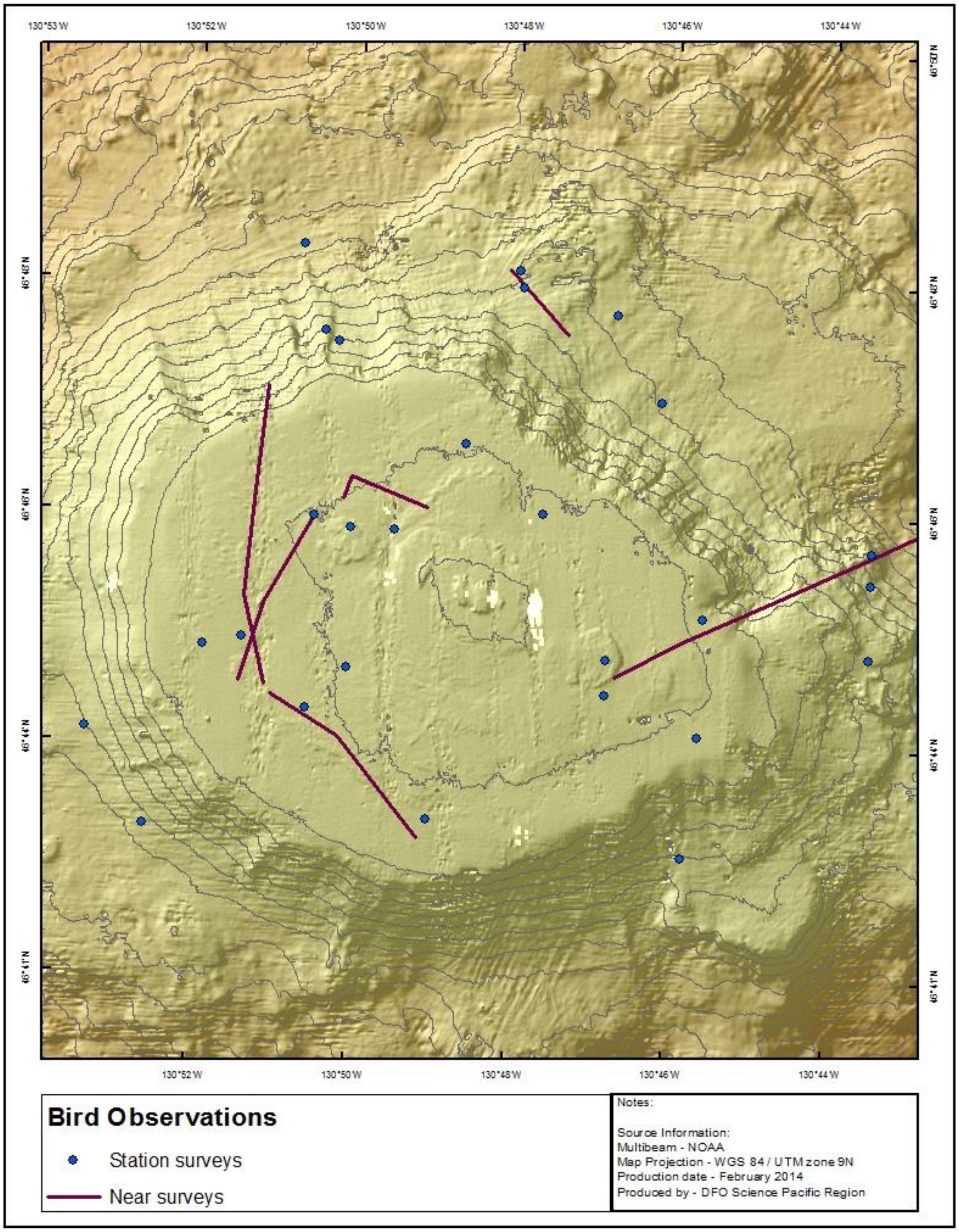

Figure 29. Locations of stationary surveys (blue dots) and near surveys (red lines) of seabirds and marine mammals conducted over Cobb Seamount in 2012.

When counts and densities were stratified by distance from the seamount pinnacle (Table 28), the highest density of black-footed albatrosses occurred in the inner-most distance band (< 2 km from the pinnacle). High numbers and densities of black-footed albatrosses were observed in the adjacent two distance bands (2.0–3.9 and 4.0–5.9 km from the pinnacle). Similarly, stationary surveys nearest to the pinnacle supported the highest counts and densities of storm-petrels; and consequently, the highest total bird density was found to be in the inner distance band. However, as only two stationary surveys were conducted in that distance band, one must interpret results with caution.

Powell et al. (1952, as cited in Thompson 2007) were likely the first to write about the seabirds at Cobb Seamount; they noted the occurrence of black-footed albatrosses, sooty shearwaters, and fork-tailed and Leach's storm-petrels. These four species are amongst the most common and wide-spread pelagic seabirds off the west coast of Canada (Kenyon et al. 2009); and, accounted for the highest three year near survey average densities (Table 26). The results of the stationary survey indicated that the highest number and densities of seabirds occurred primarily closest to the seamount pinnacle (i.e. the shallowest regions) (Table 27,
Table 28).

Dower and Mackas (1996) found that there was a "*seamount effect*" on zooplankton community composition that extended up to 30 km from the pinnacle. Further, they concluded that: "*....absence of an effective trapping mechanism and the fact that total zooplankton abundance does not increase near the seamount lead us to conclude that the bottom-up model of localized energy transfer proposed under the "classic hypothesis" is incorrect for Cobb Seamount: nektonic stocks.....are more likely supported by flow-through....rather than local production*."

Although the results from the three years of surveys suggest that Cobb Seamount had an aggregative effect on seabirds, it is beyond the scope of this report to identify the causal mechanisms. The three seabird species that were most abundant over the seamount (black-footed albatross, fork-tailed and Leach's storm-petrels) are unable to dive for prey and can only access food at or just below the sea-surface. Consequently, it is assumed that there was a 'surface signature' that the birds responded to; and although speculative, the following section might in part explain the results observed.

According to Dower and Mackas (1996) there is an extensive area (approximately 50 km^2) of waters shallower than 200 m. From personal observations, there was a notable shift in the colour and clarity of the water when the vessel was over the seamount pinnacle. As most seabirds rely primarily upon eyesight to find food (Shealer 2002), it is likely that they use cues such as differences in water colour/clarity, as potential indicators of prey concentrations. However, their ability to detect differences is most likely limited from hundreds to low thousands of metres in distance, depending on flight altitude, visual acuity and weather and ocean conditions.

What mechanism, acting at a coarser spatial scale could attract seabirds to remote prey concentrations, such as over shallow seamounts? A possible explanation is the ability of some seabirds to use olfaction to detect concentrations of prey. For nearly two decades, there has been compelling evidence that Procellariiform seabirds use differences in dimethyl sulfide (DMS) levels to locate prey (Nevitt et al. 1995). Procellariiform seabirds, which forage over hundreds to thousands of kilometres for food, have the largest olfactory bulbs amongst all birds; and the ability to detect DMS may play a crucial role in successful foraging (Nevitt and Haberman 2003; Nevitt 2008). In addition to foraging, olfaction has also been shown to be important to other avian behaviours, such as homing and individual recognition (Nevitt 2008).

DMS, which can also be detected by seaturtles and seals (Kowalewsky et al. 2006; Santos et al. 2007), is associated with areas of high productivity, such as occurring at shelfbreaks, frontal zones and seamounts (Berresheim 1987; Hay and Kubanek 2002; Nevitt 2011). According to Nevitt and Bonadonna (2005), this natural olfactory cue not only persists for days or weeks, but it can also be seasonally predictable, providing "*...cues for orientation...*". Further, Nevitt et al. (1995) suggested that changes in the 'olfactory landscape' are used by Procellariiform seabirds to recognize potentially productive foraging opportunities; and that "*....the odor landscape reflects bathymetric features, which tend to accumulate phytoplankton and therefore prey, and ..... birds build up a map of these features over time*" (Nevitt 2000).

There is one final comment that must be made; the results and discussion summarized here may be in part an artifact of the prolonged presence of the ship in proximity to the seamount. Many species of seabirds are attracted to vessels, inflating 'normal' background densities (Hyrenbach 2001). As well, many species are subsequently attracted to the presence of other foraging seabirds (detectable at considerable distances, Hunt 1990); again, further inflating background densities. Consequently, the numbers reported here may, to an unknown extent, reflect seabird attraction to the vessel and/or to other seabirds, rather than to the seamount itself. However, separating the influence of the vessel and/or the presence of other seabirds from the aggregative effect of the seamount is beyond the scope of this report.

Hydroacoustics

Preliminary observations

Initial scrutiny of the cleaned data collected on the parallel transects revealed a number of areas with strong backscatter associated with fish, particularly near the top of the seamount (Figure 30). The morphometric attributes of these schools (shape and amplitude characteristics) were typical of rockfish assemblages (*Sebastes* spp.). A number of various scattering layers, particularly near the surface (<50 m), were also observed. These upper layers displayed in some cases proeminent scattering at 18 kHz, which suggested the presence of resonant scattering from small air bubbles (e.g. juvenile and larval fish), while in other cases the layer exhibited resonant scattering at higher frequencies (120-200 kHz), consistent with zooplankton and other types of small fluid-like sound scatterers. The layers detected from the echosounder were consistent with greater concentration of zooplankton observed in underwater videos. Preliminary analyses of the acoustic data indicated that the presence and density of schools and backscattering layers were more prominent on the western side of the seamount.

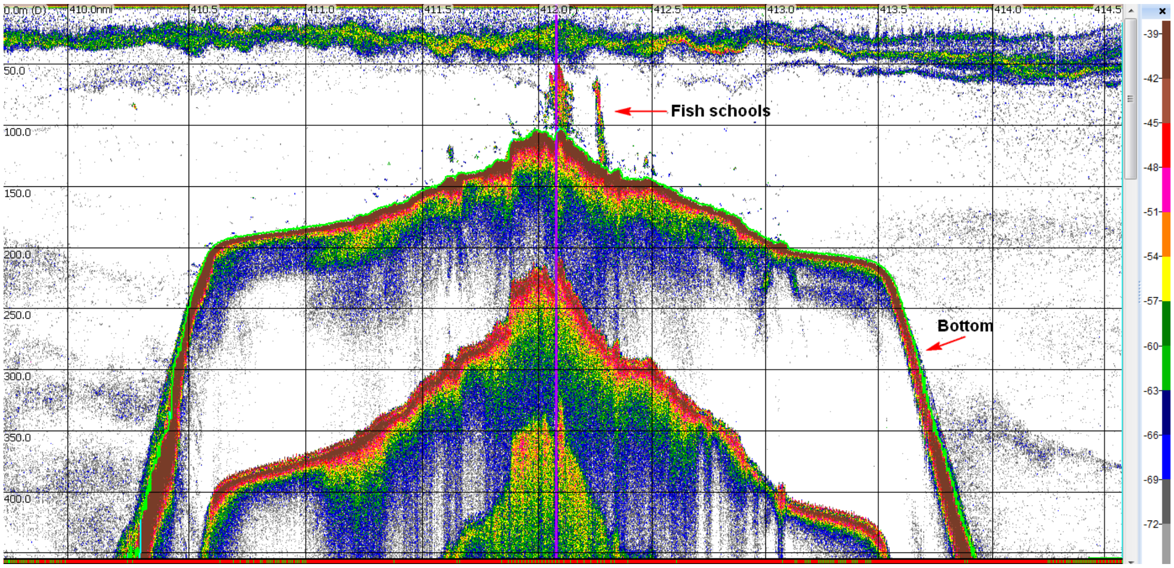

Figure 30 Example of an echogram displaying a north-south cross-section of Cobb Seamount from the 38 kHz EK60 echosounder. The vertical axis displays the depth range to 450 m while the horizontal axis displays a total distance of 5 nmi. A number of fish schools were observed near the top of the seamount, while a strong scattering layer was observed in the upper 50 m of the water column.

Multiple acoustic frequencies data collected as part of this study can be used to determine the frequency responses of the major backscattering aggregations (Figure 31 and Figure 32). Differences in frequency responses have been described for many aquatic organisms (Holliday et al. 1989; Stanton et al. 2000) and empirically used to classify acoustic backscatter produced by various species (Madureira et al. 1993; Korneliussen & Ona 2003; Benoit-Bird 2009; De Robertis et al. 2010). With these analysis techniques, we can isolate sources of scattering associated with fish with swimbladders (such as rockfish species) from the scattering more typically associated with planktonic animals such as euphausiids. To perform those analyses the data from each acoustic frequency need to be adjusted to account for the differences in transducer locations under the keel. The resolution of the adjusted data is then be reduced by applying a grid of 5 pings by 5 m depth over the entire echogram (a smoothing function) and generating an average Sv value in each cell. The difference (in dB) between these matching cells will be calculated at each unique frequency pairs as the difference between the volume backscattering coefficient (Sv) value of a cell (in dB re $1m^{-1}$) at one frequency (f2) to the Sv value of that corresponding cell (in dB re $1m^{-1}$) at another frequency (f1). This is equivalent to calculating the ratio of the backscatter amplitudes between the two frequencies in the linear domain.

$Sv_{f2} - Sv_{f1} = sv_{f2}/sv_{f1}$ where $Sv = 10 \log10 sv$ (Eq. 3)

The results of these analyses will be used to identify and map unique features of the backscatter in the water column based on these empirical frequency responses.

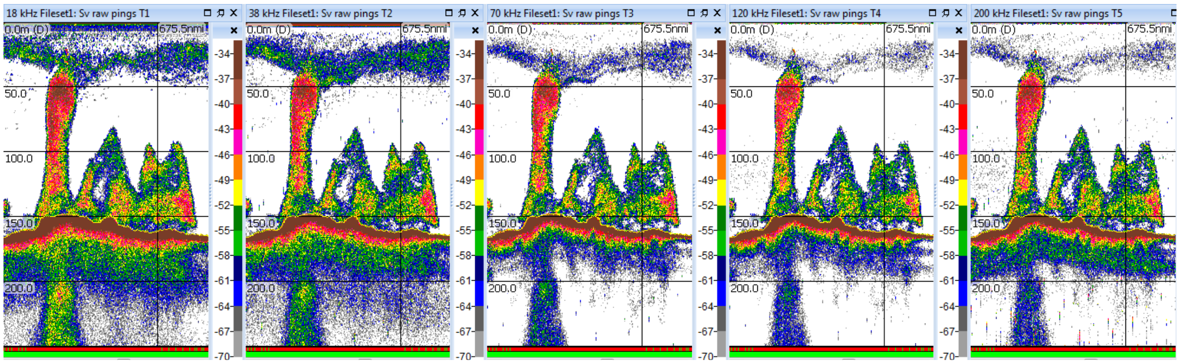

Figure 31. Example of the volume backscattering strength (Sv) associated with a large fish aggregation and upper scattering layer as observed with the 18, 38, 70, 120, and 200 kHz echosounder. Each frequency is displayed using a Sv threshold of -75 dB. The vertical axis represents a depth of 250 m (with the bottom roughly just below 150 m) and the horizontal range displays a distance of 0.5 nmi. Signal strength appears to decrease monotonically as frequency increases (particularly for the upper scattering later), suggesting the presence of gas-bearing animals (such as fish with gas filled swimbladders).

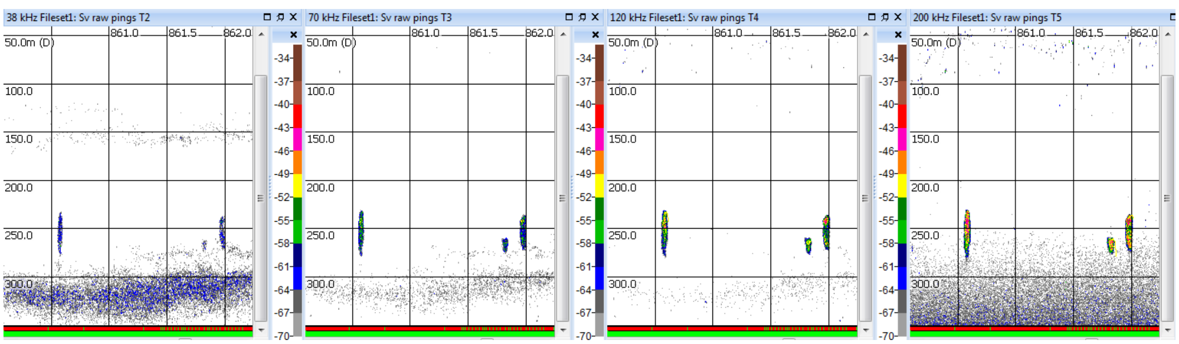

Figure 32. Example of the volume backscattering strength (Sv) associated with aggregations as observed with the 38, 70, 120, and 200 kHz echosounder (in this example the 18 kHz was in passive mode). Each frequency is displayed using a Sv threshold of -75 dB. The vertical axis represents a depth of 350 m and the horizontal range displays a total distance of 2.5 nmi. Signal strength at 250 m depth appears in this case to increase monotonically as frequency increases (the opposite of Figure 31), suggesting that they consist of zooplankton aggregations.

Analysis of CTD data

The CTD profiles were obtained from 32 sites on Cobb Seamount, down to a maximum depth of 580 m (Table 29). The processed temperature, salinity and dissolved oxygen concentrations are plotted against depth for each of the 32 CTD cast locations in Appendix 7.

Table 29. Sampling date, time, latitude, longitude and ID number assigned to 32 CTD profiles obtained from a subset of ROV and AUV transect sites and from a systematic grid over Cobb Seamount in 2012 (Figure 13). Missing are estimates of depth at seven CTD cast locations.

ID	Site	Date	Time (Pacific Time)	Latitude (Degrees, Decimal minutes)	Longitude (Degrees, Decimal minutes)	Bottom depth (m)	CTD cast depth (m)
5	Grid	25-Jul-12	0:15	46 42.20368	-130 55.37791	1400	580
6	Grid	25-Jul-12	1:05	46 44.36227	-130 55.45466	1367	580
7	Grid	25-Jul-12	1:49	46 46.52084	-130 55.53155	1098	580
8	Grid	25-Jul-12	2:40	46 46.57301	-130 52.38958	1094	580
9	Grid	25-Jul-12	3:15	46 46.62373	-130 49.24746	1027	580
10	Grid	25-Jul-12	3:45	46 46.67302	-130 46.10520	1135	580
11	Grid	25-Jul-12	4:15	46 46.72087	-130 42.96281	334	320
12	Grid	25-Jul-12	5:20	46 48.87968	-130 43.03148	207	190
13	Grid	25-Jul-12	6:06	46 48.83177	-130 46.17597	707	580
14	Grid	25-Jul-12	21:50	46 48.78242	-130 49.32032	1033	580
15	Grid	25-Jul-12	22:45	46 48.73163	-130 52.46453		~600
16	AUV_2	23-Jul-12	6:12	46 44.93652	-130 43.37409		530
17	Grid	23-Jul-12	20:55	46 44.41437	-130 52.31477		~550
18	DFO_3	22-Jul-12	21:24	46 43.60719	-130 49.00097		165
19	Grid	24-Jul-12	20:03	46 44.56204	-130 42.89427	670	580
20	Grid	25-Jul-12	23:40	46 48.67940	-130 55.60860	1400	580
21	Grid	24-Jul-12	20:53	46 42.40320	-130 42.82586	920	580
22	Grid	24-Jul-12	21:45	46 42.35547	-130 45.96408	860	580
23	Grid	24-Jul-12	22:35	46 42.30631	-130 49.10216	580	550
24	Grid	24-Jul-12	23:20	46 42.25571	-130 52.24011	780	580
26	DFO_5	26-Jul-12	0:55	46 46.20703	-130 50.29588	198	180
27	SFU_1	26-Jul-12	1:30	46 47.04481	-130 47.60935	515	490
28	DFO_1	26-Jul-12	2:05	46 46.20818	-130 47.61544	196	180
29	DFO_6	26-Jul-12	2:37	46 45.02610	-130 48.34181	88	70
30	SFU_5	22-Jul-12	6:15	46 44.84461	-130 51.74888		200
31	DFO_2	26-Jul-12	3:00	46 44.53075	-130 46.94791	130	110
32	SFU_2	26-Jul-12	3:30	46 44.70317	-130 44.34045	329	310
33	Grid	23-Jul-12	21:42	46 44.46503	-130 49.17474		~150
34	SFU_3	26-Jul-12	4:20	46 43.33956	-130 48.95229	238	220
35	SFU_4	26-Jul-12	4:45	46 43.41044	-130 51.60269	421	400
36	DFO_4	26-Jul-12	5:18	46 44.71790	-130 50.31166	200	190
37	Grid	23-Jul-12	22:19	46 44.51425	-130 46.03457		~140

Across all CTD cast locations and depths, temperature ranged from 4.2 ºC to 13.5 ºC, generally cooling with depth. However, for most casts, we observed a local minimum in temperature at roughly 100 m depth below which temperature increased slightly and then gradually declined with depth to the lowest values observed within a site. This pattern was not evident at ID 16, ID 21, ID 22, ID 28, ID 31, ID 33, and 36. The CTD deployed at ID 29 and ID 37 was only lowered to 70 m and 140 m depth, respectively. The temperature generally dropped from 13.5 ° C to approximately 7 °C in the top 100 m, and approached 4 °C at 600 m depth.

Dissolved oxygen concentration ranged from 0.52 $mL \cdot L^{-1}$ at 600 m depth to 6.39 $mL \cdot L^{-1}$ near the surface (22. 6 $umol \cdot kg^{-1}$ to 278.2 $umol \cdot kg^{-1}$) across all CTD cast locations and depths. Its profile generally increased to a local maximum in dissolved oxygen occurring at roughly between 50 m and 100 m depth. Below 100 m, dissolved oxygen generally decreased monotonically.

Salinity values range from 32.5 PSU to 34.1 PSU across all CTD cast locations and depths. Its profile was generally stepped and increased with depth. Salinity increased only slightly from approximately 32.5 PSU down to 100 m depth, and then increased rapidly between 100 and 200 m depth to roughly 33.75 PSU. Below 200 m depth, salinity increased gradually and monotonically to approximately 34 PSU at 600 m.

Acknowledgements

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Appendices

Appendix 1. Science crew

Names (in alphabetical order), affiliations and roles of scientific crew aboard the CCGS John P. Tully, 17-28 July 2012 (DFO = Fisheries and Oceans Canada; EC = Environment Canada; IOS = Institute for Ocean Sciences; MUN = Memorial University of Newfoundland; NOAA = National Oceanic and Atmospheric Administration; NWFSC = Northwest Fisheries Science Center; PBS = Pacific Biological Station; PIFSC = Pacific Islands Fisheries Science Center; SFU = Simon Fraser University; SWFSC = Southwest Fisheries Science Center, UVic = University of Victoria).

Participant	**Affiliation**	**Role(s)**
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Taylor, Jeremy	PIFSC, NOAA	AUV Project Manager; AUV operations, expert in deep sea research, and seabed mapping Address: NMFS/PIFSC/CRED 1845 Wasp Boulevard, Building 176, Honolulu, HI 96818 Email: Jeremy.taylor@noaa.gov
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Yoklavich, Mary	SWFSC, NOAA	Research Biologist; expert in rockfish biology, habitat ecology, and deep sea research. Address: Southwest Fisheries Science Center, NOAA, 110 Shaffer Road, Santa Cruz, CA 95060 Email: mary.yoklavich@noaa.gov

Appendix 2. Conditions at sea (from ship's log)

Prevalent wind and weather conditions on and off Cobb Seamount from 20-27 July 2012. Wind speeds were averaged across hourly observations recorded in the ship's log from 7am – 7pm inclusive. Given are the ranges, and mean and standard deviations in parentheses. Weather observations include all those recorded hourly during the same time period.

Date	**Wind speed (knots)**	**Weather observations**
20 July	7-16 (10.8 ± 3.3)	slight rain; slight or moderate thunderstorm with hail; heavy thunderstorm without hail; distant fog; fog patches
21 July	17-21 (18.9 ± 1.4)	Slight rain; rain showers; moderate drizzle; heavy thunderstorm without hail
22 July	14-20 (17.4 ± 1.6)	heavy thunderstorm without hail
23 July	15-20 (17.7 ± 1.7)	Clouds forming; slight or moderate thunderstorm with hail; heavy thunderstorm without hail
24 July	14-20 (17.7 ± 1.7)	Slight drizzle; drizzle; slight or moderate thunderstorm with hail; heavy thunderstorm without hail; fog patches
25 July	17-22 (20 ± 1.6)	slight or moderate thunderstorm with hail; heavy thunderstorm without hail; fog patches
26 July	8-13 (10.5 ± 1.6)	Slight or moderate rain or snow or hail; slight or moderate thunderstorm with hail; fog patches; thick fog
27 July	5-7 (5.7 ± 1.2)*	slight or moderate thunderstorm without and with hail; heavy thunderstorm without hail

*average of three recorded wind speeds, all other records on 27 July were for light airs.

Appendix 3. Video analysis protocol

Summary

Species relative abundance and habitat recorded every 10 seconds for the 10 seconds of video just viewed. Counts are recorded for fish and species of interest. The habitat variables recorded are: dominant substrate, dominant substrate percent cover, subdominant substrate, subdominant substrate percent cover, relief, image quality, survey mode, protocol, and field of view (cm).

This protocol is based on the "Qualitative (fast)" protocol used to analyse the video from Bowie Seamount with relative abundance added for all species observations, counts for species of interest and field of view added.

How to use Video Miner with this Protocol

Make a copy and rename the Video Miner 2.0 template database provided by DFO, not the template database installed with the software. The database installed with the software does not have the correct look-up tables. Make sure you have the latest version of Video Miner, ver. currently 2.1.3 (you may need to use an earlier version if you are using Win XP). Start the software then open the database and a video file.

In general with the software you work from left to right. At the start of each clip, fill in everything on the left side, especially the time; then, make sure the "Repeat Habitat Data" and "Record Every Second of Video" check boxes are both checked. Type 10 in the box beside the "play seconds". Click the "play seconds" button to watch the first 10 seconds of video. You can pause it if you want, and it should still stop after 10 seconds. At the end of 10 seconds you will record data for the video you just watched.

Next, click on each button in the Transect Data area and select a row from the table by clicking on the box on the left side of the row. Your selection will appear in green under the button. Then click on the "Define All" button which will bring up tables for every habitat button.

Field of view can be entered into Video Miner or using a separate software package, whichever is more effective in terms of efficiency and accuracy. If a separate software package is used, we will need a table with Time, Date, Dive, Cruise, Field of view (with any other relevant details, including units) so that field of view can be integrated into the database. The key challenge will be ensuring that the field of view records correspond to the appropriate section of video.

After everything else is filled out you can do the species observations. A relative abundance will be recorded for every species observed and counts of species of interest will also be recorded (list attached). You will need to use the "detailed entry" option in order to enter counts, but the "abundance entry" option should be faster for species where you are only entering abundance. Whether you want to switch back and forth between these two species entry modes or just use the "detailed entry" mode is personal preference.

The reason you do it in that order is that all the left side (time, date, etc.) and "Transect" fields are written for every record, but do not create a record on their own so you want them filled out before you create a record with the "Define All" button. And because we have the "Repeat Habitat Data" box checked you want to create a habitat record before you do species observations so the habitat data for the same period is written with the species observations.

Details

Date: [database field name = 'TransectDate'] Date is also from the video overlay, and since GMT time is used the date will sometimes change if a video spans midnight GMT.

Time: [database field name = 'Timecode'] Time is from the video overlay, in 24 hour format and should be GMT time.

Project Name: [database field name = 'ProjectName_'] Project name should be the DFO Water Properties cruise number (e.g. Pac2012-043).

Transect: [database field name = 'TransectName'] The dive number (number only) should be used for transect name.

On/off bottom: [database field name = 'OnBottom'] On bottom (1) is used when the bottom is visible and analysis is possible off bottom (0) is used when the bottom is not visible enough to distinguish at least substrate and large organisms.

Protocol: [database field name = 'ProtocolID'] Protocol is usually the same for the whole project. There are currently three protocols in use.

lu_protocol		
ProtocolId	**ProtocolName**	**Description**
1	Qualitative (fast, Bowie)	Species presence and habitat recorded at 10 sec intervals, dominant substrate, %, subdominant substrate, %, relief, disturbance, video quality, survey mode, protocol
2	BCTC Sponge Reef (Quantitative)	Every species counted with range (to nearest 5 cm), habitat recorded at every change, dominant substrate, %, subdominant substrate, %, relief, disturbance, video quality, survey mode, protocol
3	Semi-Quantitative (Cobb)	Species relative abundance and habitat recorded at 10sec intervals, counts for fish and species of interest, dominant substrate, %, subdominant substrate, %, relief, disturbance, video quality, survey mode, protocol, field of view (cm)

Survey Mode: [database field name = 'SurveyModeID'] Survey mode is what the ROV is doing. Ideally the ROV is doing a transect (1) for most video being analysed, but in some cases the ROV will being doing other things. The categories and codes are in the table below.

lu_survey_mode			
SurveyModeId	**Entry**	**Description**	**DataCollecting**
1	Transect	Transecting e.g. moving video survey of area. Video must be suitable for quantitative analysis.	Y
2	Investigation (moving)	In-depth exploration of an area/subject. This is non-transect mode but the survey instrument is still in motion. Good video of the bottom is being collected but the video is not suitable for quantitative analysis	Y
3	Investigation (still)	In-depth exploration of an area/subject. This is non-transect mode and the survey instrument is usually relatively stationary (e.g. examining an organism, bedform, etc.). Direct sampling.	Y
4	Sampling	Taking/removing a physical sample from the environment. Equipment is typically stationary. Direct sampling.	Y
5	Transiting	Moving between sampling sites sometimes too fast or too far off the bottom to see clearly. Not in survey mode. Non-directed sampling. Substrate is usually visible.	Y
6	Technical issue	Due to ROV issue not transecting correctly & cannot be annotated	N
7	Not viewed	Have not yet viewed this video (not priority survey mode conducted)	N
8	Zoom	Camera has zoomed in significantly, usually, but not always when the ROV has stopped.	Y

Image Quality: [database field name = 'ImageQualityID'] Image (video) quality depends mainly on water quality and often does not change during a dive, but things like camera angle, lighting changes, distance off bottom, etc. can also change the quality of the video. The categories and codes are in the table below.

lu_image_quality		
ImageQualityId	**Label**	**ImageQualityDescription**
1	Excellent	National Geographic quality, clear water, perfect lighting, good distance to bottom, camera steady or moving smoothly etc.
2	Good	very good video, but not quite perfect.
3	Average	water quality or lighting not good, but still able to see habitat and organisms clearly enough for ID
4	Poor	water quality or lighting not good, difficult to see habitat and organisms clearly enough for ID
5	Very Poor	water quality and or lighting poor very hard to identify even a big object unless it almost hits camera

Dominant Substrate: [database field name = 'DominantSubstrate'] The dominant substrate is the most common substrate. The substrate codes in the table below will be used.

lu_substrate		
SubstrateId	**SubstrateType**	**SubstrateDescription**
0	Wood	Wood, Bark, or Wood Debris
1	Bedrock, smooth	Bedrock, smooth without crevices
2	Bedrock with crevices	Bedrock with crevices
3	Boulders	Boulders, bigger than a basketball
4	Cobble	Cobble, between 3 inches and basketball size
5	Gravel	Gravel, between 3/4 inch and 3 inch
6	Pea Gravel	Pea Gravel, between 1/8 inch and 3/4 inch
7	Sand	Sand
8	Shell	Shell
9	Mud	Mud
10	Crushed Shell	Crushed Shell (new code 2006)
11	Whole Shell	Whole Shell (new code 2006)
12	Live Sponge	For use in sponge reefs
13	Dead Sponge	For use in sponge reefs

Dominant Substrate Percent Cover: [database field name = 'DominantPercent'] Dominant substrate percent cover is estimated to be within one of five categories in the table below.

lu_percent	
Percent	**PercentDescription**
1	<5%
2	5-25%
3	26-50%
4	51-75%
5	>75%

Subdominant Substrate: [database field name = 'SubdominantSubstrate'] The second most common substrate. Same codes used as for dominant substrate.

Subdominant Substrate Percent Cover: [database field name = 'SubdominantPercent'] Same codes used as for dominant substrate.

Species Observations: [database field name = 'SpeciesID'] At the end of each ten seconds of video a species record will be created for every microorganism observed in the past ten seconds with a relative abundance.

Species Observations Reference Line: Species observations are made when an organism passes the reference line or comes closest to it. The reference line is a horizontal line across the field of view that passes through the 10 cm scaling lasers. If there are no lasers in the field of view the reference line should be in approximately the center of the field of view. If the camera angle is such that the center of the field of view does not give a clear view of organisms (tilted up so only water is visible in the middle) then the reference line will be in the middle of the area where the bottom and organisms are visible.

Species Count: [database field name = 'SpeciesCount'] Since a record is created for every organism species count should be 1 in most cases. This is true even for organisms that do not necessarily exist as individuals such as sponges or zooanthids. You should not have a species count if you have an abundance since for this protocol abundance is only used in situations where a count is not practical.

Taxonomic Level and Identification Confidence: [database field name = 'IDConfidence'] Each organism should be identified to the lowest taxonomic level at which you are confident of the identification (low = species, high = kingdom). So if you are not confident of the species, use genus. If you are not confident of the genus use family, etc. If you think you know a lower level taxonomic group, but are not confident, you can write it in the comment field.

Detailed Data specifications

Format

The preferred format for providing the data is a Microsoft Access database, however, a spreadsheet or comma delimited text file are also acceptable as long as the same column/field names are used.

Notes on using Video Miner to collect data for this protocol

If the Video Miner software (version 2.1 or later) and your computer are set up correctly, the following information will be collected automatically:

1. video or photo file name, field name = 'FileName'
2. video elapsed time, field name = 'ElapsedTime"
3. reviewed date, field name = 'ReviewedDate' (if your computer date is correct)
4. reviewed time, field name = 'ReviewedTime' (if your computer time is correct)

Appendix 4. Seabird and marine mammal species

Common names, orders, families, genera and species of all bird and mammal species mentioned in text or tables (*not encountered during three Cobb Seamount surveys).

Seabirds			
Common name	**Order**	**Family**	**Genus and Species**
Pacific loon	Gaviiformes	Gaviidae	*Gavia pacifica*
Laysan albatross	Procellariiformes	Diomedeidae	*Phoebastria immutabilis*
Black-footed albatross	Procellariiformes	Diomedeidae	*Phoebastria nigripes*
Northern fulmar	Procellariiformes	Procellariidae	*Fulmarus glacialis*
Cory's shearwater *	Procellariiformes	Procellariidae	*Calonectris borealis*
Pink-footed shearwater	Procellariiformes	Procellariidae	*Ardenna creatopus*
Sooty shearwater	Procellariiformes	Procellariidae	*Ardenna grisea*
Buller's shearwater	Procellariiformes	Procellariidae	*Ardenna bulleri*
Fork-tailed storm-petrel	Procellariiformes	Hydrobatidae	*Hydrobates furcatus*
Leach's storm-petrel	Procellariiformes	Hydrobatidae	*Hydrobates leucorhous*
Red-necked phalarope	Charadriiformes	Scolopacidae	*Phalaropus lobatus*
Red phalarope	Charadriiformes	Scolopacidae	*Phalaropus fulicarius*
South polar skua	Charadriiformes	Stercorariidae	*Catharacta maccormicki*
Parasitic jaeger	Charadriiformes	Stercorariidae	*Stercorarius parasiticus*
Pomarine jaeger	Charadriiformes	Stercorariidae	*Stercorarius pomarinus*
Long-tailed jaeger	Charadriiformes	Stercorariidae	*Stercorarius longicaudus*
Herring gull	Charadriiformes	Laridae	*Larus smithsonianus*
Glaucous-winged gull	Charadriiformes	Laridae	*Larus glaucescens*
Yellow-legged gull *	Charadriiformes	Laridae	*Larus michahellis*
Sabine's gull	Charadriiformes	Laridae	*Xema sabini*
Arctic tern	Charadriiformes	Laridae	*Sterna paradisaea*
Common tern *	Charadriiformes	Laridae	*Sterna hirundo*
Roseate tern *	Charadriiformes	Laridae	*Sterna dougallii*
Common murre	Charadriiformes	Alcidae	*Uria aalge*
Ancient murrelet	Charadriiformes	Alcidae	*Synthliboramphus antiquus*
Cassin's auklet	Charadriiformes	Alcidae	*Ptychoramphus aleuticus*
Rhinoceros auklet	Charadriiformes	Alcidae	*Cerorhinca monocerata*
Tufted puffin	Charadriiformes	Alcidae	*Fratercula cirrhata*
Marine Mammals			
Common name	**Order**	**Family**	**Genus and Species**
Humpback whale	Cetacea	Balaenopteridae	*Megaptera novaeangliae*
Fin whale	Cetacea	Balaenopteridae	*Balaenoptera physalus*
Killer whale	Cetacea	Delphinidae	*Orcinus orca*
Pacific white-sided dolphin	Cetacea	Delphinidae	*Lagenorhynchus obliquidens*
Northern right whale dolphin	Cetacea	Delphinidae	*Lissodelphis borealis*
Short-beaked common dolphin*	Cetacea	Delphinidae	*Delphinus delphis*
Dall's porpoise	Cetacea	Phocoenidae	*Phocoenoides dalli*
Northern fur seal	Carnivora	Otariidae	*Callorhinus ursinus*
Northern elephant seal	Carnivora	Phocidae	*Mirounga angustirostris*

Appendix 5. CTD data processing report

Raw CTD data downloaded from the Seabird 19 were kindly processed by Germaine Gatien (IOS, DFO) and archived in a data library at IOS, Sidney, BC. Included here is the report she drafted following initial processing of the CTD data.

PROCESSING NOTES

Cruises: 2012-43
Agency: Ocean Sciences Division, Sidney, BC
Project: Cobb Seamount ROV/AUV Survey
Area: North-East Pacific
Chief Scientist: Curtis J.
Platform: *CCGS John .P. Tully*
Date: 17 July 2012 – 28 July 2012

Processed by: Germaine Gatien
Date of Processing: 17 January 2014 – 4 February 2014
Number of original CTD casts: 37 (1 missing, 4 aborted and restarted)
Number of casts processed: 32

INSTRUMENT SUMMARY

A Sea Bird Model SBE 19+ SEACAT CTD (S/N#5299) was mounted with an SBE 43 DO sensor (# 1483).

SUMMARY OF QUALITY AND CONCERNS

No log was available. There was a spreadsheet with positions and times but there was some ambiguity about matching cast files to those entries. With help from the chief scientist these were resolved. The event numbers do represent the order in which casts occurred, but do not match the ID entries in the spreadsheet, which are entered in the CTD file headers as station names.
Times in the raw CTD files were in PST, while in the spreadsheet they were in PDT. The final files have time in UTC.

The manufacturer recommends that this type of CTD be soaked at 10 m for a few minutes. During this cruise there was a soak of about 1 minute at the 1 to 2 m level, which was probably adequate since there was not a large difference in temperature between air and water.

The descent rate of the CTD frequently exceeded 2.5 m/s, and often dropped suddenly to speeds of -1m/s. Descent rates below about 0.5m/s usually result in data corruption when shed wakes carrying water dragged by the CTD and cable overwhelm the CTD sensors. This is not as big a problem as when there is a rosette, but there was some such corruption of these data. Even before reaching that low a speed, noise is often found in the salinity data that may be due to the effect of rapid deceleration on alignment. These very high deceleration rates are assumed to be due to swell and are common in deep casts from the *CCGS John .P. Tully*.

The high descent rate also leads to a reduction in data available; this CTD collects four records per second, so when the descent rate is >2m/s, there are less than two records per metre. There are more records when the CTD is slowing, but those records are often corrupted.

There was no DO calibration sampling during this cruise, but there was for cruise 2011-08 when the same sensor was used. The 2011-08 results were used to update parameters SOC and Voffset in the configuration file used to process these data. Any drift in calibration is expected to produce dissolved oxygen concentration values that are too low.

Salinity for this cruise has been edited but large errors likely remain especially near the surface where gradients are large. Seabird 19+ salinity is prone to error due to mismatch of conductivity and temperature response times, especially when the descent rate is non-uniform. These errors are likely to be much larger than calibration errors. A rough estimate of salinity errors for this cruise is ~0.02 units in the thermocline and <0.005 below 100 m errors. Errors in the mixed layer will be chiefly due to calibration drift for which there is no estimate since there was no salinity calibration sampling during this cruise or any other cruise since the last factory calibration.

PROCESSING SUMMARY

1. **Seasave -** This step was completed at sea; the raw data files are *.hex.

2. Preliminary Steps
There was no log available. There was a spreadsheet which has id numbers that do not match the cast names in the files. This will be investigated later.

Conversion of Raw Data
The parameters in the configuration file used at sea were correct and were saved as 2012-43-ctd.xmlcon. There was no calibration sampling, so the results of 2011-08 were used to update the Soc/Voffset values for the dissolved oxygen sensor and the updated file was saved as 2011-77-ctd-new.xmlcon.

The raw data were converted using conversion file 2012-43-ctd-new.con.

After conversion the file names were changed to standard format assuming the cast numbers in the original file names are event numbers. The standard format will enable conversion to IOS SHELL, at which point investigations can be made to ensure casts are in time order.

Examination of a few plots suggests that the surface was close to 0db both for the downcast and upcast judging by the conductivity, with the maximum error ~0.2 db. There were soaks of at least 1 minute at about 1db. A two minute soak at 10 m is recommended for this instrument because the pumps don’t come on for 30 s and there is some equilibration after that. However, the air and surface water temperatures were probably close which reduces the time needed to warm the CTD and there is no evidence of significant problems with the downcast temperature and salinity for these data. So the shorter soak was ok.

A few problems were found:

- Cast #3 contains only a few surface records.
- An initial attempt at converting files turned up a problem with cast #15. The pressure channel is heavily corrupted on the upcast, so a text editor was used to remove records after #5460.

- Cast #19 was converted successfully, but the data are full of spikes, so a return was made to the beginning to investigate this. There are large sections of bad data – this looks like a dump of data from some other cast. One section of bad data looks like data from the end of the previous cast. Records 1092 to 1771 and 2525 to the end of the file were removed. Pad values were entered for some other bad data points. Occasionally there is an erroneous pad value of 99.000 which was replaced with -99.000.

3. FILTER

The temperature and conductivity channels were low-pass filtered with a time constant of 0.5 seconds to smooth high frequency data.

4. Align CTD

Tests were run to find appropriate advancements for T and DO. The results are not easy to interpret, but a value of +0.5s for temperature looks reasonable and is recommended by SeaBird. The dissolved oxygen has been advanced by 4.4s in previous uses. The DO data are too noisy to make a clear judgment on the best setting.
The temperature data were advanced relative to pressure by 0.5s.
The dissolved oxygen data were advanced relative to pressure by 4.4s.

5. CELLTM

Tests were run on three casts using a variety of settings to see which made the upcast look most like the downcast.
CELLTM was run on all casts using ($\alpha = 0.02$, $\beta=7$) for the conductivity channel.

6. DERIVE

Program DERIVE was run to calculate salinity and dissolved oxygen concentration.

7. Conversion to IOS Headers

The IOSSHELL routine for Sea Bird ASCII files was used to convert the Sea-Bird data to IOS Headers.

The station names, bottom depths and positions are missing from the headers. Positions and some station names are provided in the spreadsheet, “2012-43 CTD_cast_locations_with_time.xlsx.”

Spreadsheet 2012-43-hdr_merge.csv was prepared by matching information from the spreadsheet with that from the cast files. Later some logic checks such as ship speed and ship tracks can be used to see if there are any obvious errors. A few items that had to be kept in mind were:

- There is no file named cast #1 and too little data in casts #3, 17, 31 and 33 to be worth processing. So there are 32 files that need identification.
- The spreadsheet list contains 33 events, of which one has a time well before any of the cast file times. This could be due to an error in either the CTD file or spreadsheet file, or the first cast file might either have not been recorded or been overwritten.
- Large gaps in time between CTD casts were useful in relating the two lists.
- The start times in the files appear to be in PST while the spreadsheet has PDT, so adding one hour to the file times should lead to a match. Times likely don’t match exactly as the entry might have been taken using slightly different stages of operation or clocks might not be in exact agreement.
- Cast files #6 to #37 match times with the events of 24 July onwards in the spreadsheet. There are three other casts in each list, so it is assumed they match.
- Cast #2 differs by just 15 minutes, so that is likely a good match.

- Casts # 4 – 6 were confusing with four not matching anything well and the others appearing offset from their best matches. The chief scientist checked and found the date was wrong for one spreadsheet entry. When that was fixed and the entries reordered on time, the matches were fine except that no match was found for the first item in the spreadsheet.

From this point on casts #3, 17, 31, 33 will not be processed.

The positions were converted to standard IOS SHELL style. This requires considerable manipulation to get results that look like:

```
   LATITUDE            :  48  24.06000 N  ! (deg min)
   LONGITUDE           : 125  53.82000 W  ! (deg min)
```

The station names were changed to format ID ** with the ID numbers taken from the spreadsheet.

Program MERGE CSV FILE TO HEADERS was run to add the headers to the IOS files. CLEAN was run to reset the header values and to replace pad values in the pressure channel with interpolated values based on record number.

ADD TIME CHANNEL was run to convert the file times to UTC by adding 8 hours.

8. Checking Headers

ADD TIME CHANNEL was used to add 8 hours to each header time.

Header Check was run and showed some large negative pressures in cast #19. Plots of pressure versus scan number were made to see if there were other problem casts, but no others were found. A return was made to edit the original CNV file and run it through the steps described in §3 to §8. A plot was made of the result and the pressure spikes are gone, but there are some bad salinity and dissolved oxygen concentration values that will be addressed at the CTDEDIT stage.

A cross-reference list was produced and no problems were found.

The surface check was run. The average surface pressure is-0.08db. The pressure calibration looks appropriate and no correction is indicated.

9. SHIFT

Tests were run to see if a shift in conductivity might improve the salinity, which tends to overshoot when temperature changes suddenly. But small shifts in either direction produced worse results, so SHIFT was not run.

10. Test Plots

Profiles were plotted for all casts and no serious problems were noted other than the cast #19 spikes.

11. DELETE

CLIP was run to remove 250 initial records to simplify editing by removing spikes before and during the soak period.

Then DELETE was run on the CLIP files using the following parameters:

Surface Record Removal: Last Press Min   Maximum Surface Pressure (relative): 10.00
Surface Swell Pressure Tolerance: 1.0   Pressure was filtered, width = 5
Swells deleted. Warning message if pressure difference of 2.00

Minimum Drop Rate 0.5 m/s over five records between 10db and 10db above maximum pressure

The only warnings in the Delete log came from cast #19 which led to finding another bad pressure value that was replaced with a pad value.

12. CTDEDIT

An initial attempt to edit showed more variability in the salinity data than expected, so more tests on the ideal settings for the adjustments made in processing. However, no settings could be found that made things better. The cause is likely the very noisy descent rate leading to corruption and misalignment, but we also have to expect errors due to inexact alignment in the presence of a large temperature gradient, which is always a problem with this type of CTD. Typically the SBE 19+ has a problem at the top and bottom of the thermocline and when the gradients are very high, these have been estimated to be as high as 0.05. For these data there is usually a well-mixed layer to about 25 m, then a drop in temperature by ~4C° between 25 and 60 m, followed by a lower temperature gradient. This is not an extreme gradient, so we might expect a salinity error of <0.05.

Shed wake corruption and/or noise due to sudden large changes in descent rate will confuse the analysis of alignment errors. But a few casts were found where the descent rate was relatively steady in the top 100 m. At the base of the mixed layer the salinity for two casts looked fine, but for another it moved too high and then too low. At the bottom of the thermocline there was no notable error. In the high gradient zone the salinity was highly variable with swings on the order of 0.03 for one cast, but quite smooth traces for others. These swings are rarely unstable in T-S space. So we might estimate a maximum error in salinity due to misalignment of ~0.03. Metre-averaging will reduce this slightly, but there are few data points in a metre when the descent rate is very high. Editing will also reduce the errors. So, as a rough estimate, the salinity in the thermocline is ±0.02.

CTDEDIT was used to remove records near the top (likely taken during the soak) and records corrupted by shed wakes and to smooth salinity, as required. All casts required some editing. For cast #19 some data were removed due to corruption due to pressure channel spikes. Notes were entered in the headers about editing applied.

13. Study of negative DO values

Header Check was run and the only problem found was some negative DO values. Each of casts #22, 23 and 36 had just a single negative value, so those were replaced with pad values.

The dissolved oxygen concentration channel is not normally edited, because corrupted points are removed in the editing of temperature and salinity. However, there can be residual problems in the DO data due to temperature spikes that get spread in filtering. Plots were made of the full DO profiles and large spikes were found in a few casts: 10, 21, 22, 23, 25, 26, 28, 36. These were removed using CTDEDIT.

CLEAN was run to update the header limits. Header Check was rerun on those files and no further negative DO values were found.

14. BIN AVERAGE

The following Bin Average values were used:

Bin channel = pressure

Averaging interval = 1.000	Minimum bin value = .000
Average value will be used.	Interpolated values are NOT used for empty bins

Page plots were examined and no further editing was needed.

15. Inter-comparisons

Previous Use of CTD – This CTD has been used on one other cruise that has been processed at IOS since it was last checked at the factory. During 2013-77 which followed this cruise there was no calibration sampling for salinity. The SBE dissolved oxygen sensor was used three times in 2011 and during 2013-77 with DO calibration sampling available only from 2011-08. Pressure and salinity were not recalibrated for 2013-77 and the 2011-08 data were used to recalibrate DO for that cruise.

Repeat casts – There were no repeat casts, but T-S plots of nearby casts are reasonably close given differences in time and position.

Historic ranges –All data fell within local climatology.

16. REMOVE and HEADEDIT

The following channels were removed from all casts: Scan_Number, Conductivity, Oxygen:Voltage:SBE, Descent_Rate and Flag.

The HEADEDIT routine was used to fix channel names, units and formats and to add the following comment to the headers:

****

Salinity data are given with 3 decimal places due to concerns over data quality.

The descent rate of the CTD was extremely noisy with very high deceleration rates which appear to affect the alignment of temperature and conductivity channels. SeaCat salinity is always prone to error due to a mismatch of conductivity and temperature response times, especially when the descent rate is non-uniform. Such errors are likely to be larger than calibration errors. There was no salinity calibration sampling during this cruise.

SeaCat salinity errors are expected to be as high as 0.05 units in areas of high gradients. For these data temperature and salinity gradients were not extreme; so the error due to mismatch in T and C is estimated to be up to 0.02 in the top 100 m and 0.005 below that, though editing and metre-averaging should reduce the errors somewhat.

The dissolved oxygen parameters in the configuration file were updated by using the values for SOC and Voffset that were determined by calibration sampling during cruise 2011-08 in April 2011. There was no calibration sampling during this cruise. Values are apt to be a little low due to drift in sensors.

Oxygen:Dissolved:SBE data are unedited except that some records were removed in editing temperature and salinity, and a few large spikes were removed.

****

The standards check routine was run and no further problems found.

17. Producing final files

a.) The final files were renamed *.ctd.
b.) A cross-reference listing was produced.
c.) A header check was run and no problems were found.
d.) The sensor histories were updated.

Institute of Ocean Sciences
CRUISE SUMMARY

Cruise ID#: 2012-43

Dates: Start: 17 July 2012 End: 28 July 2012

Location: North-East Pacific Vessel: *CCGS John P.Tully*

Party Chief: Curtis J.

CTD #	Make	Model	Serial #	Used with Rosette?	CTD Calibration Sheet Competed?
1	SEABIRD	SeacatPlus	5299	No	Yes

CTD Calibration Information

Make/Model/Serial#: SEABIRD/SEACATPLUS v1.6b / 5299

Cruise ID#: 2012-43

Calibration Information					
Sensor		**Pre-Cruise**		**Post Cruise**	
Name	**S/N**	**Date**	**Location**	**Date**	**Location**
Temperature	**5299**	**12Jan11**	**Factory**		
Conductivity	**5299**	**12Jan11**	**Factory**		
SBE 43 DO	**1483**	**24Dec10**	**Factory**		
Pressure Sensor	**5299**	**29Dec10**	**Factory**		

Appendix 6. Image data collections.

Types of data collected for each taxon observed on Cobb Seamount in 2012:
For each taxon, the table indicates whether it was observed at the DFO ROV, SFU ROV or AUV sites. For those observed at DFO ROV or AUV sites, the table indicates whether or not the taxon was viewed on the annotated transect, and if so, counted or categorized according to relative abundance with the video, or counted or categorized according to percent cover with the photos. Taxa observed on AUV transects were counted by Erica Fruh or Cherisse Du Preez, or both. Taxa are listed in the same order as Du Preez et al. (2015).

Phylum	**Genus and species**	**DFO ROV sites**	**SFU ROV sites**	**NOAA AUV sites**	**ROV or AUV transect**	**ROV Video counts and densities**	**ROV Video relative abundance**	**ROV Photo counts and densities**	**ROVphoto % cover**	**AUV photo counts and densities (EF)**	**AUV photo counts and densities (CD)**
Ochrophyta	*Desmarestia viridis*	Yes	No	No	Yes	No	Yes	No	Yes	No	No
Rhodophyta	*Polysiphonia* spp.	Yes	No	No	No	No	No	No	No	No	No
Rhodophyta	cf *Lithophyllum* spp.[1]	Yes	No	No	Yes	No	yes	No	Yes	No	No
Rhodophyta	cf *Lithothamnion* spp.[1]	Yes	No	No	Yes	No	yes	No	Yes	No	No
Porifera	*Pinulasma fistulosom*	No	No	Yes	Yes	No	No	No	No	Yes	Yes
Porifera	*Farrea omniclavata* sp. nov.	No	No	Yes	Yes	No	No	No	No	Yes	Yes
Porifera	*Acanthascus* spp.[2]	No	No	Yes	Yes	No	No	No	No	Yes	Yes
Porifera	*Bathydorus* sp.	No	No	Yes	Yes	No	No	No	No	Yes	Yes
Porifera	*Rhabdocalyptus* spp[2].	No	No	Yes	Yes	No	No	No	No	Yes	Yes
Porifera	*Staurocalyptus* spp.[2]	No	No	Yes	Yes	No	No	No	No	Yes	Yes
Porifera	Demospongiae sp. 1	Yes	No	Yes	Yes	No	Yes	No	Yes	Yes	Yes
Porifera	Demospongiae sp. 2	Yes	No	Yes	Yes	No	Yes	No	Yes	Yes	Yes
Porifera	Demospongiae sp. 3	Yes	No	Yes	Yes	No	Yes	No	No	Yes	Yes
Porifera	*Poecillastra* sp.	No	No	Yes	Yes	No	No	No	No	Yes	Yes
Porifera	*Polymastia* sp.	Yes	No	No	Yes	No	Yes	No	Yes	No	No
Porifera	cf *Auletta* sp.	Yes	No	No	Yes	Yes	No	Yes	No	No	No
Porifera	*Halichondria panicea*	Yes	No	No	Yes	No	Yes	No	Yes	No	No
Porifera	*cf Acarnus erithacus*	Yes	No	No	Yes	No	Yes	No	Yes	No	No
Porifera	*Latrunculia* (*Biannulata*) *oparinae*	Yes	No	No	Yes	Yes	No	No	No	No	No

Phylum	Genus and species	DFO ROV sites	SFU ROV sites	NOAA AUV sites	ROV or AUV transect	ROV Video counts and densities	ROV Video relative abundance	ROV Photo counts and densities	ROVphoto % cover	AUV photo counts and densities (EF)	AUV photo counts and densities (CD)
Cnidaria	Actiniaria sp. 1	No	No	Yes	Yes	No	No	No	No	Yes	No
Cnidaria	Actiniaria sp. 2	No	No	Yes	Yes	No	No	No	No	Yes	No
Cnidaria	Actiniaria sp. 3	No	No	Yes	Yes	No	No	No	No	Yes	No
Cnidaria	*Cribrinopsis fernaldi*	Yes	Yes	No	Yes	Yes	No	No	No	No	No
Cnidaria	*Urticina crassicornis*	Yes	Yes	No	No	No	No	No	No	No	No
Cnidaria	*Stomphia didemon*	Yes	No	No	Yes	Yes	No	No	No	No	No
Cnidaria	cf Hormathiidae sp.	No	No	Yes	Yes	No	No	No	No	Yes	No
Cnidaria	*Metridium senile*	Yes	No	No	Yes	Yes	No	No	No	No	No
Cnidaria	*Heteropolypus ritteri*	No	No	Yes	Yes	No	No	No	No	Yes	Yes
Cnidaria	*Isidella* sp.	No	No	Yes	Yes	No	No	No	No	Yes	Yes
Cnidaria	*Keratoisis* sp.	No	No	Yes	Yes	No	No	No	No	Yes	Yes
Cnidaria	*Lepidisis* sp.	No	No	Yes	Yes	No	No	No	No	Yes	Yes
Cnidaria	*Gersemia* sp.	No	No	Yes	Yes	No	No	No	No	Yes	Yes
Cnidaria	*Paragorgia* sp.	No	No	Yes	Yes	No	No	No	No	Yes	Yes
Cnidaria	*Swiftia simplex*	No	No	Yes	Yes	No	No	No	No	Yes	Yes
Cnidaria	*Narella* sp.	Yes	No	No	Yes	Yes	No	No	No	No	No
Cnidaria	*Plumarella superba*	No	No	Yes	Yes	No	No	No	No	Yes	Yes
Cnidaria	*Primnoa cf pacifica*	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes
Cnidaria	*Antipatharia* sp.	No	No	Yes	Yes	No	No	No	No	Yes	Yes
Cnidaria	*Stichopathes* sp.	No	No	Yes	Yes	No	No	No	No	Yes	Yes
Cnidaria	*Bathypathes* sp.	No	No	Yes	Yes	No	No	No	No	Yes	Yes
Cnidaria	*Lillipathes* cf *lillei*	No	No	Yes	Yes	No	No	No	No	Yes	Yes
Cnidaria	*Parantipathes* sp.	No	No	Yes	Yes	No	No	No	No	Yes	Yes
Cnidaria	*Corynactis californica*	Yes	No	No	Yes	No	Yes	No	Yes	No	No
Cnidaria	*Anthoptilum* spp.	No	No	Yes	Yes	No	No	No	No	Yes	Yes
Cnidaria	*Halipteris willemoesi*	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes
Cnidaria	*Umbellula lindahli*	No	No	Yes	Yes	No	No	No	No	Yes	Yes
Cnidaria	*Desmophyllum dianthus*	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes
Cnidaria	*Lophelia pertusa*	Yes	Yes	No	Yes	No	Yes	No	Yes	No	No
Cnidaria	*Epizoanthus* sp.	Yes	No	No	Yes	No	Yes	No	Yes	No	No
Cnidaria	Hydroid sp. 1	Yes	No	No	Yes	No	No	Yes	Yes	No	No
Cnidaria	Hydroid sp. 2	Yes	No	No	No	No	No	No	No	No	No
Cnidaria	*Stylaster* spp.[3]	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Cnidaria	cf *Obelia* spp.	Yes	No	No	Yes	No	Yes	Yes	No	No	No
Annelida	*Nothria conchylega*	Yes	No	No	Yes	No	No	Yes	No	No	No
Annelida	*Crucigera*	Yes	No	No	Yes	No	No	Yes	No	No	No

Phylum	Genus and species	DFO ROV sites	SFU ROV sites	NOAA AUV sites	ROV or AUV transect	ROV Video counts and densities	ROV Video relative abundance	ROV Photo counts and densities	ROVphoto % cover	AUV photo counts and densities (EF)	AUV photo counts and densities (CD)
	zygophora										
Annelida	*Paradexiospira* sp.	Yes	No	No	Yes	No	yes	Yes	No	No	No
Annelida	*Protula pacifica*	Yes	No	No	Yes	No	yes	Yes	No	No	No
Annelida	*Phyllochaetopterus prolifica*	Yes	No	No	Yes	No	No	No	Yes	No	No
Annelida	*Spiochaetopterus* cf *costarum*	Yes	No	No	Yes	No	yes	Yes	No	No	No
Anthropoda	*Caprella* sp.	Yes	No	No	No	No	No	No	No	No	No
Anthropoda	*Chirostylidae* sp.	No	No	Yes	Yes	No	No	No	No	Yes	No
Anthropoda	*Chorilia longipes*	Yes	No	Yes	Yes	Yes	No	Yes	No	Yes	No
Anthropoda	*Lithodes couesi*	No	No	Yes	Yes	No	No	No	No	Yes	No
Anthropoda	*Chionoecetes tanneri*	No	No	Yes	Yes	No	No	No	No	Yes	No
Anthropoda	*Elassochirus cavimanus*	Yes	No	No	Yes	Yes	No	No	No	No	No
Anthropoda	*Pagurus kennerlyi*	Yes	Yes	No	Yes	No	Yes	No	No	No	No
Anthropoda	*Oregonia gracilis*	Yes	No	No	Yes	No	No	Yes	No	No	No
Mollusca	*Crassadoma gigantea*	Yes	No	No	Yes	No	Yes	Yes	No	No	No
Mollusca	*Octopodidae* sp.[4]	No	No	Yes	Yes	No	No	No	No	Yes	No
Mollusca	*Graneledone boreopacifica*	No	No	Yes	Yes	No	No	No	No	Yes	No
Mollusca	*Calliostoma annulatum*[5]	Yes	No	No	Yes	No	Yes	Yes	No	No	No
Mollusca	*Calliostoma ligatum*[5]	Yes	No	No	Yes	No	Yes	Yes	No	No	No
Mollusca	*Ocinebrina lurida*	Yes	No	No	Yes	No	No	Yes	No	No	No
Mollusca	*Fusitriton oregonensis*	Yes	No	No	Yes	No	Yes	Yes	No	No	No
Mollusca	*Doris montereyensis*	Yes	No	No	Yes	Yes	Yes	No	No	No	No
Mollusca	Tritoniidae sp.	No	No	Yes	Yes	No	No	No	No	Yes	No
Mollusca	*Leptochiton rugatus*	Yes	No	No	Yes	No	yes	Yes	No	No	No
Brachiopoda	*Laqueus californianus*	Yes	No	No	Yes	No	Yes	Yes	No	No	No
Bryozoa	Bryozoa sp.	Yes	No	No	Yes	Yes	No	Yes	No	No	No
Bryozoa	cf *Reginella hippocrepis*	Yes	No	No	Yes	No	yes	No	Yes	No	No
Bryozoa	*Disporella separata*	Yes	No	No	Yes	No	Yes	No	Yes	No	No
Echinodermata	Asteroidea sp.	Yes	Yes	No	Yes	Yes	No	No	No	No	No
Echinodermata	Brisingidae sp.	No	No	Yes	Yes	No	No	No	No	Yes	No
Echinodermata	*Leptasterias hexactis*	Yes	No	No	Yes	Yes	No	No	No	No	No
Echinodermata	*Orthasterias*	Yes	No	No	No	No	No	No	No	No	No

Phylum	Genus and species	DFO ROV sites	SFU ROV sites	NOAA AUV sites	ROV or AUV transect	ROV Video counts and densities	ROV Video relative abundance	ROV Photo counts and densities	ROVphoto % cover	AUV photo counts and densities (EF)	AUV photo counts and densities (CD)
	koehleri										
Echinodermata	*Rathbunaster californicus*	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes	No
Echinodermata	*Stylasterias forreri*	Yes	No	No	Yes	Yes	No	No	No	No	No
Echinodermata	*Ampheraster* sp.	No	No	Yes	Yes	No	No	No	No	Yes	No
Echinodermata	*Pycnopodia helianthoides*	Yes	No	No	Yes	Yes	No	No	No	No	No
Echinodermata	*Thrissacanthias* sp.	No	No	Yes	Yes	No	No	No	No	Yes	No
Echinodermata	*Pseudarchaster* sp.[6]	No	No	Yes	Yes	No	No	No	No	Yes	No
Echinodermata	*Henricia leviuscula*	Yes	No	No	Yes	Yes	No	No	No	No	No
Echinodermata	*Henricia sanguinolenta*	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes	No
Echinodermata	*Ceramaster patagonicus*	Yes	No	No	Yes	Yes	No	No	No	No	No
Echinodermata	*Ceramaster cf stellatus*	Yes	No	No	Yes	Yes	No	No	No	No	No
Echinodermata	*Hippasteria phrygiana*	Yes	No	No	Yes	Yes	No	No	No	No	No
Echinodermata	*Crossaster papposus*	Yes	No	No	Yes	Yes	No	No	No	No	No
Echinodermata	*Lophaster furcilliger*	Yes	No	No	Yes	Yes	No	No	No	No	No
Echinodermata	*Solaster cf endeca*	Yes	No	No	Yes	Yes	No	No	No	No	No
Echinodermata	*Solaster stimpsoni*	Yes	No	No	Yes	Yes	Yes	No	No	No	No
Echinodermata	*Pteraster* sp.	No	No	Yes	Yes	No	No	No	No	Yes	No
Echinodermata	*Florometra serratissima*	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	No
Echinodermata	*Mesocentrotus franciscanus*	Yes	No	No	yes	No	Yes	Yes	No	No	No
Echinodermata	*Strongylocentrotus pallidus*	Yes	No	No	Yes	Yes	No	No	No	No	No
Echinodermata	*Molpadia* sp.	No	No	Yes	Yes	No	No	No	No	Yes	No
Echinodermata	*Apostichopus leukothele*	Yes	Yes	No	Yes	Yes	No	No	No	No	No
Echinodermata	*Psolus squamatus*	No	No	Yes	Yes	No	No	No	No	Yes	No
Echinodermata	*Pannychia* cf *moseleyi*	No	No	Yes	Yes	No	No	No	No	Yes	No
Echinodermata	*Asteronyx loveni*	Yes	Yes	No	Yes	No	Yes	No	No	No	No
Echinodermata	*Ophiopholis bakeri*	Yes	No	Yes	Yes	No	Yes	No	No	Yes	No
Echinodermata	*Ophiura sarsii*	Yes	Yes	No	Yes	No	Yes	No	No	No	No
Chordata	Ascidiacea sp.	Yes	No	No	Yes	No	No	No	Yes	No	No
Chordata	cf *Coryphaenoides acrolepis*	No	No	Yes	Yes	No	No	No	No	Yes	No
Chordata	*Antimora*	No	No	Yes	Yes	No	No	No	No	Yes	No

Phylum	Genus and species	DFO ROV sites	SFU ROV sites	NOAA AUV sites	ROV or AUV transect	ROV Video counts and densities	ROV Video relative abundance	ROV Photo counts and densities	ROVphoto % cover	AUV photo counts and densities (EF)	AUV photo counts and densities (CD)
	microlepis										
Chordata	*Chirolophis decoratus*	Yes	No	No	Yes	Yes	No	No	No	No	No
Chordata	*Citharichthys sordidus*	Yes	No	No	Yes	yes	No	No	No	No	No
Chordata	*Embassichthys bathybius*	No	No	Yes	Yes	No	No	No	No	Yes	No
Chordata	*Glyptocephalus zachirus*	Yes	No	Yes	Yes	Yes	No	No	No	Yes	No
Chordata	*Lepidopsetta bilineata*	Yes	No	No	Yes	Yes	No	No	No	No	No
Chordata	*Microstomus pacificus*	Yes	No	Yes	Yes	Yes	No	No	No	Yes	No
Chordata	*Agonopsis vulsa*	Yes	No	No	Yes	Yes	No	No	No	No	No
Chordata	*Anoplopoma fimbria*	No	No	Yes	Yes	No	No	No	No	Yes	No
Chordata	Cottidae sp.	Yes	No	No	Yes	Yes	No	No	No	No	No
Chordata	*Hemilepidotus spinosus*	Yes	No	No	Yes	Yes	Yes	No	No	No	No
Chordata	*Paricelinus hopliticus*	Yes	No	No	Yes	No	No	No	No	No	No
Chordata	*Rhamphocottus richardsonii*	Yes	No	No	No	No	No	No	No	No	No
Chordata	*Sebastes* spp.	Yes	Yes	Yes	Yes	yes	No	No	No	Yes	No
Chordata	*Sebastes aleutianus*[7]	Yes	Yes	No	Yes	Yes	No	No	No	No	No
Chordata	*Sebastes alutus*	Yes	Yes	No	Yes	Yes	No	No	No	No	No
Chordata	*Sebastes elongatus*	Yes	No	No	Yes	Yes	No	No	No	No	No
Chordata	*Sebastes emphaeus*	Yes	No	No	Yes	Yes	No	No	No	No	No
Chordata	*Sebastes entomelas*	Yes	No	No	Yes	Yes	No	No	No	No	No
Chordata	*Sebastes helvomaculatus*	Yes	Yes	No	Yes	Yes	No	No	No	No	No
Chordata	*Sebastes melanostictus*[7]	Yes	Yes	No	Yes	Yes	No	No	No	No	No
Chordata	*Sebastes melanostomus*	No	No	Yes	Yes	No	No	No	No	Yes	No
Chordata	*Sebastes mystinus*	Yes	No	No	Yes	Yes	No	No	No	No	No
Chordata	*Sebastes rosaceus*	Yes	No	No	Yes	Yes	No	No	No	No	No
Chordata	*Sebastes ruberrimus*	Yes	No	No	Yes	Yes	No	No	No	No	No
Chordata	*Sebastes variegatus*	Yes	Yes	No	Yes	Yes	No	No	No	No	No
Chordata	*Sebastes wilsoni*	Yes	No	No	Yes	Yes	No	No	No	No	No
Chordata	*Sebastes zacentrus*	Yes	Yes	No	Yes	Yes	No	No	No	No	No
Chordata	*Sebastolobus* spp.	No	No	Yes	Yes	No	No	No	No	Yes	No
Chordata	*Apristurus*	No	No	Yes	Yes	No	No	No	No	Yes	No

Phylum	Genus and species	DFO ROV sites	SFU ROV sites	NOAA AUV sites	ROV or AUV transect	ROV Video counts and densities	ROV Video relative abundance	ROV Photo counts and densities	ROVphoto % cover	AUV photo counts and densities (EF)	AUV photo counts and densities (CD)
	brunneus										
Chordata	*Hexanchus griseus*	Yes	No	No	No	No	No	No	No	No	No
Chordata	*Raja rhina*	Yes	Yes	No	Yes	Yes	No	No	No	No	No

Appendix 7. Counts from ROV video and photos.

Counts of taxa on 12 DFO ROV transects, and the sum of counts across all transects. The most commonly counted taxon on each transect is highlighted in bold. The five most commonly counted taxa across all transects are highlighted in bold. Taxa are listed in the same order as Du Preez et al. (2015).

Phylum	Genus and species	DFO_1	DFO_2	DFO_3	DFO_4	DFO_5	DFO_6	DFO_8	DFO_9	DFO_14	DFO_15	DFO_16	DFO_17	Total
Porifera	cf *Auletta* sp.	0	0	37	5	3	0	0	0	2	0	0	0	47
Porifera	*Latrunculia* (*Biannulata*) *oparinae*	0	0	0	0	0	0	0	0	0	10	0	0	10
Cnidaria	*Cribrinopsis fernaldi*	1	0	0	2	0	0	0	0	0	0	0	0	3
Cnidaria	*Stomphia didemon*	0	72	0	1	0	0	0	0	0	76	0	0	149
Cnidaria	*Metridium senile*	0	2	3	0	0	0	0	0	0	0	0	1	6
Cnidaria	*Narella* sp.	0	0	0	1	0	0	0	0	0	0	0	0	1
Cnidaria	*Primnoa cf pacifica*	0	0	1	0	0	0	0	0	0	0	0	0	1
Cnidaria	*Halipteris willemoesi*	23	0	10	24	1	0	23	3	0	4	18	1	107
Cnidaria	*Desmophyllum dianthus*	0	0	**89**	**257**	**278**	0	104	0	96	21	10	**259**	**1114**
Arthropoda	*Chorilia longipes*	0	1	2	1	3	10	0	0	0	5	0	1	23
Arthropoda	*Elassochirus cavimanus*	0	0	0	0	1	0	0	0	0	0	0	0	1
Mollusca	*Doris montereyensis*	0	0	0	0	0	1	0	0	0	0	0	0	1
Bryozoa	Bryozoa sp.	0	0	0	0	0	0	0	0	0	0	0	1	1
Echinodermata	Asteroidea sp.	0	0	0	1	0	0	0	0	0	0	0	0	1
Echinodermata	*Leptasterias hexactis*	0	0	0	0	0	5	0	0	1	0	0	0	6
Echinodermata	*Rathbunaster californicus*	18	0	18	11	9	0	7	4	23	18	5	11	124
Echinodermata	*Stylasterias forreri*	0	0	9	2	0	0	0	0	4	0	0	0	15
Echinodermata	*Pycnopodia helianthoides*	0	6	0	0	0	2	0	0	2	3	0	0	13
Echinodermata	*Henricia leviuscula*	0	0	0	0	0	4	0	0	0	0	0	0	4
Echinodermata	*Henricia sanguinolenta*	0	11	4	3	9	0	5	1	31	16	0	8	88
Echinoder	*Ceramaster*	0	3	3	10	6	0	5	0	5	6	0	2	40

Phylum	Genus and species	DFO_1	DFO_2	DFO_3	DFO_4	DFO_5	DFO_6	DFO_8	DFO_9	DFO_14	DFO_15	DFO_16	DFO_17	Total
mata	*patagonicus*													
Echinodermata	*Ceramaster cf stellatus*	0	0	1	1	1	0	1	1	1	0	3	0	9
Echinodermata	*Hippasteria phrygiana*	0	0	1	2	0	0	0	1	0	0	0	1	5
Echinodermata	*Crossaster papposus*	0	0	2	0	5	21	1	0	0	0	0	7	36
Echinodermata	*Lophaster furcilliger*	0	0	0	0	0	1	0	0	0	3	0	0	4
Echinodermata	*Solaster cf endeca*	1	11	2	0	2	0	0	0	2	9	0	3	30
Echinodermata	*Solaster stimpsoni*	0	0	0	0	0	1	0	0	0	0	0	0	1
Echinodermata	*Strongylocentrotus pallidus*	0	0	4	0	13	0	0	0	6	1	0	5	29
Echinodermata	*Apostichopus leukothele*	6	16	75	32	45	0	35	3	61	58	0	64	**395**
Chordata	*Chirolophis decoratus*	0	1	2	0	0	0	0	0	1	0	0	0	4
Chordata	*Citharichthys sordidus*	2	0	0	0	0	0	0	0	0	0	0	0	2
Chordata	*Glyptocephalus zachirus*	3	0	0	0	0	0	0	0	0	0	2	0	5
Chordata	*Lepidopsetta bilineata*	3	1	1	0	0	2	0	0	0	0	1	0	8
Chordata	*Microstomus pacificus*	3	0	0	0	0	0	0	0	0	0	0	0	3
Chordata	*Agonopsis vulsa*	0	1	0	0	0	0	0	0	0	0	0	0	1
Chordata	Cottidae sp.	**50**	15	14	16	17	1	33	0	23	20	**46**	19	254
Chordata	*Hemilepidotus spinosus*	0	1	0	0	0	5	0	0	0	0	0	0	6
Chordata	*Sebastes* spp.	0	53	107	21	54	9	155	2	38	106	9	270	824
Chordata	*Sebastes aleutianus, S. melanostictus*[7]	0	1	19	17	3	0	**208**	0	4	0	0	45	297
Chordata	*Sebastes alutus*	0	0	20	0	18	0	0	0	0	0	0	6	44
Chordata	*Sebastes elongatus*	0	0	0	0	0	0	0	5	0	0	0	0	5
Chordata	*Sebastes emphaeus*	0	**208**	63	97	38	0	113	1	11	34	9	177	**751**
Chordata	*Sebastes*	0	5	4	0	0	32	0	0	0	1	0	0	42

Phylum	Genus and species	DFO_1	DFO_2	DFO_3	DFO_4	DFO_5	DFO_6	DFO_8	DFO_9	DFO_14	DFO_15	DFO_16	DFO_17	Total
	entomelas													
Chordata	*Sebastes helvomaculatus*	0	91	86	99	99	**179**	84	**72**	**169**	274	7	107	**1267**
Chordata	*Sebastes mystinus*	0	0	0	0	0	1	0	0	0	0	0	0	1
Chordata	*Sebastes rosaceus*	0	2	1	4	2	43	3	0	1	0	1	1	58
Chordata	*Sebastes ruberrimus*	0	1	1	3	0	4	10	0	0	1	0	10	30
Chordata	*Sebastes variegatus*	0	6	30	6	28	0	82	0	4	0	0	53	209
Chordata	*Sebastes wilsoni*	0	105	10	53	5	0	10	0	21	**302**	0	57	**563**
Chordata	*Sebastes zacentrus*	0	131	75	1	43	0	31	0	14	37	2	56	390
Chordata	*Raja rhina*	2	0	0	1	0	0	0	0	0	0	0	0	3

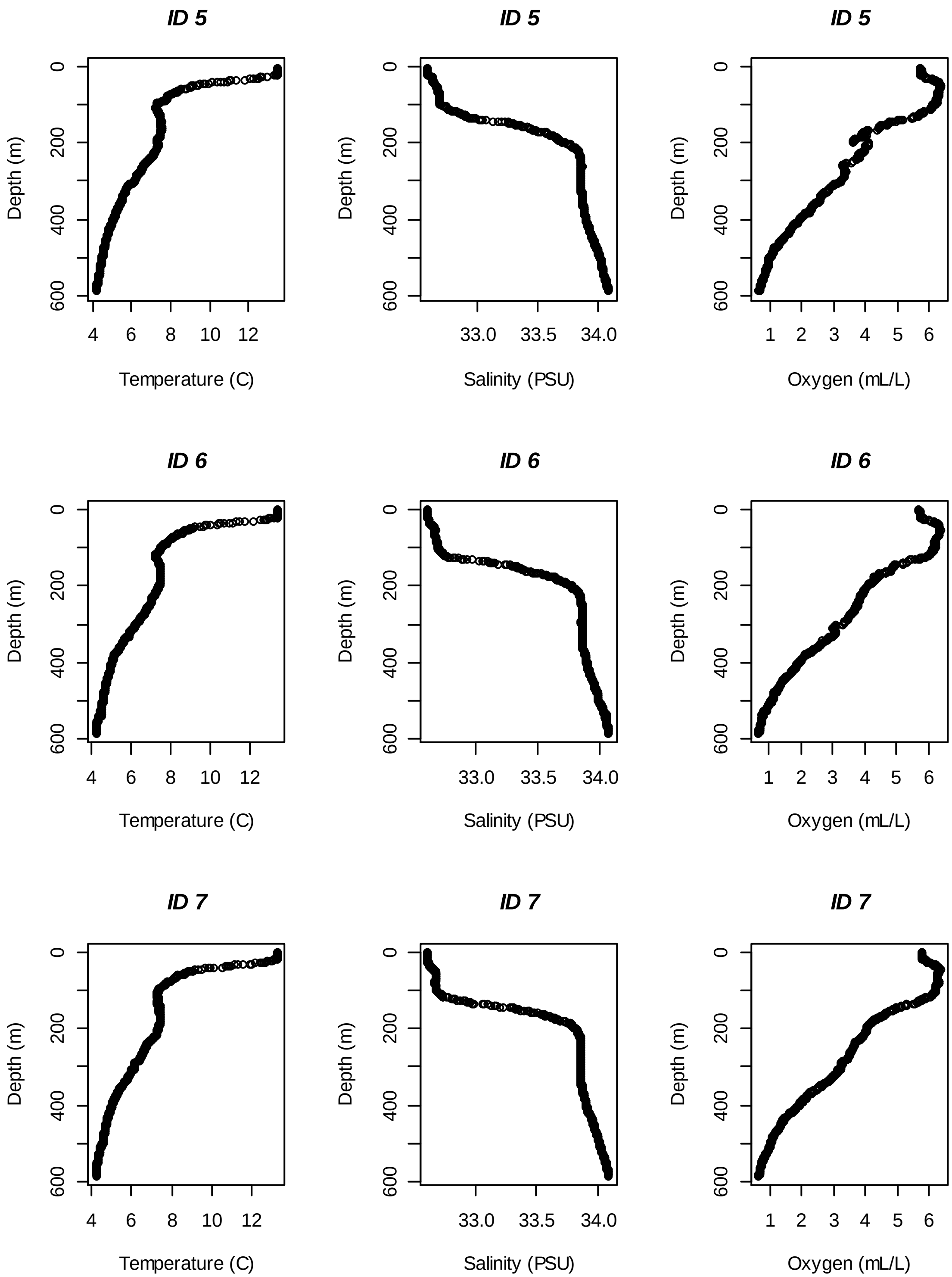
Counts of taxa observed in photo quadrats on 12 DFO ROV transects, and summed across all transects. The five most commonly counted taxa in photo quadrats are highlighted in bold.

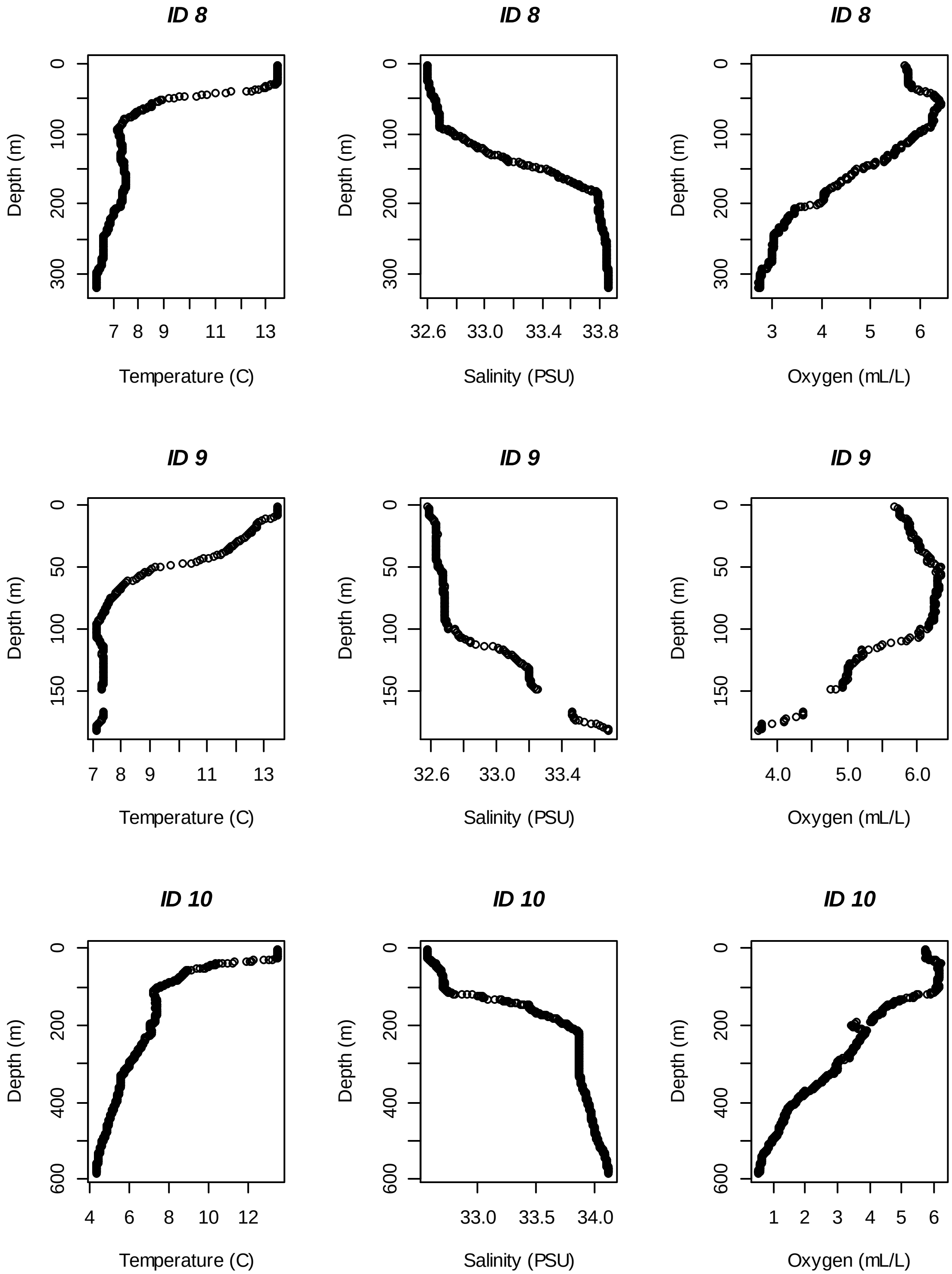
Phylum	Genus and species	DFO_1	DFO_2	DFO_3	DFO_4	DFO_5	DFO_6	DFO_8	DFO_9	DFO_14	DFO_15	DFO_16	DFO_17	All transects
Porifera	cf *Auletta* sp.			5										5
Cnidaria	*Stylaster* spp.[3]			82	95	163		1	86	442	24	3	80	**976**
Cnidaria	cf *Obelia* spp.	3										6		9
Annelida	*Nothria conchylega*						480							**480**
Annelida	*Crucigera zygophora*		44				2							2
Annelida	*Paradexiospira* sp.			26	37	9	3	1		10	1		9	**96**
Annelida	*Protula pacifica*		6	9	1					14	10	2	11	47
Annelida	*Spiochaetopterus* cf *costarum*	126	23	111	83	3		236	1	157	22	75	29	**843**

Arthropoda	*Chorilia longipes*		1		1		3		1					5
Arthropoda	*Oregonia gracilis*												1	1
Mollusca	*Crassadoma gigantea*						24							24
Mollusca	*Calliostoma annulatum, C. ligatum*[5]				1		81							82
Mollusca	*Ocinebrina lurida*				4		1							5
Mollusca	*Fusitriton oregonensis*			3	5					3	1	3	5	20
Mollusca	*Leptochiton rugatus*						38							38
Brachiopoda	*Laqueus californianus*			46	52	80	4	75		414	130	4	427	**1232**
Bryozoa	Bryozoa sp.		1			3							1	4
Echinodermata	*Florometra serratissima*		188								48	13		61
Echinodermata	*Mesocentrotus franciscanus*						16							16

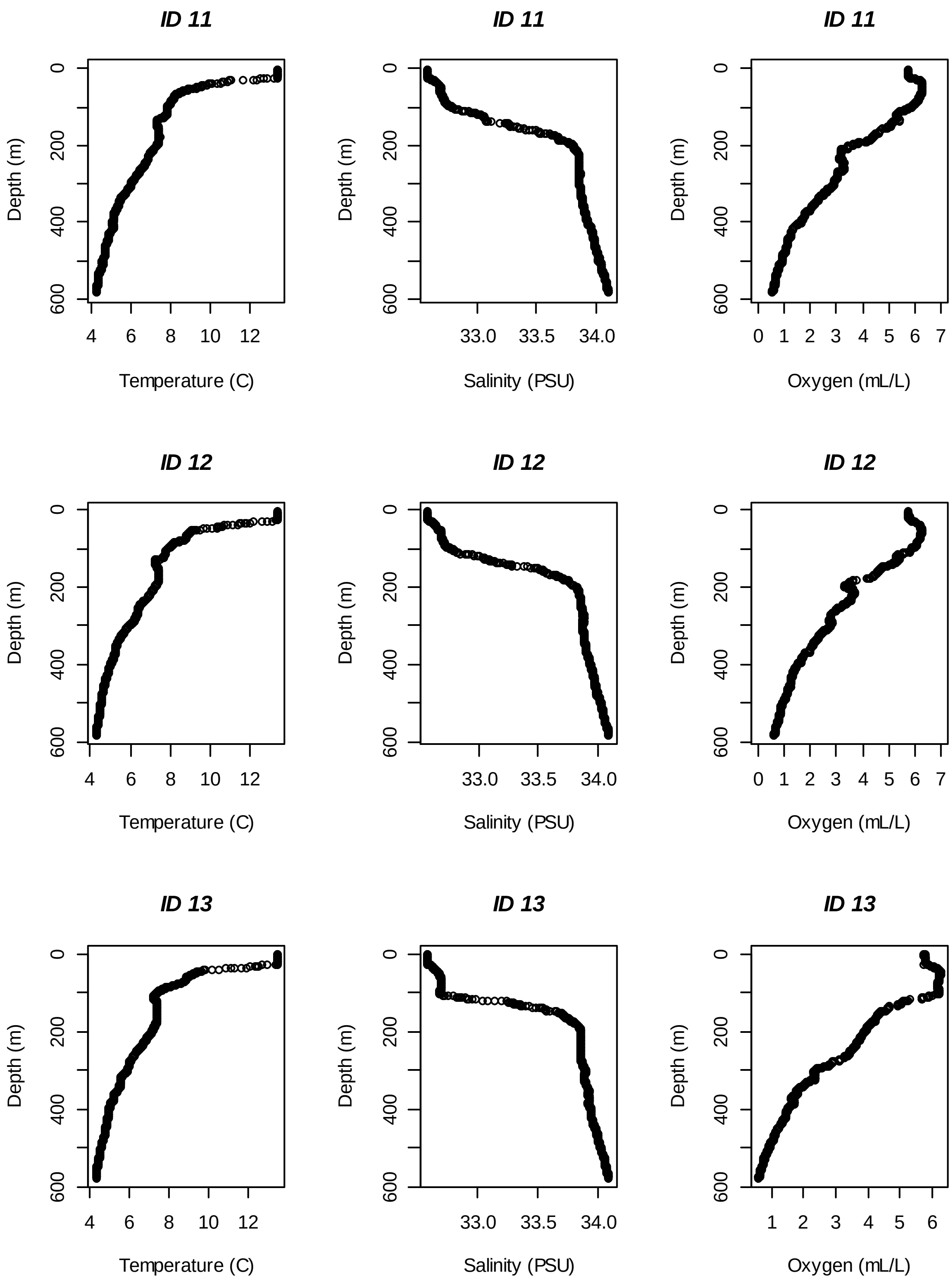
Appendix 8. CTD Profiles

Temperature, salinity and oxygen concentration are plotted as a function of depth at 32 sites. ID numbers correspond to site identification codes listed in Table 29 and Figure 13.





ID 8
Depth (m)
Temperature (C)
ID 8
Salinity (PSU)
ID 8
Oxygen (mL/L)
ID 9
Temperature (C)
ID 9
Salinity (PSU)
ID 9
Oxygen (mL/L)
ID 10
Temperature (C)
ID 10
Salinity (PSU)
ID 10
Oxygen (mL/L)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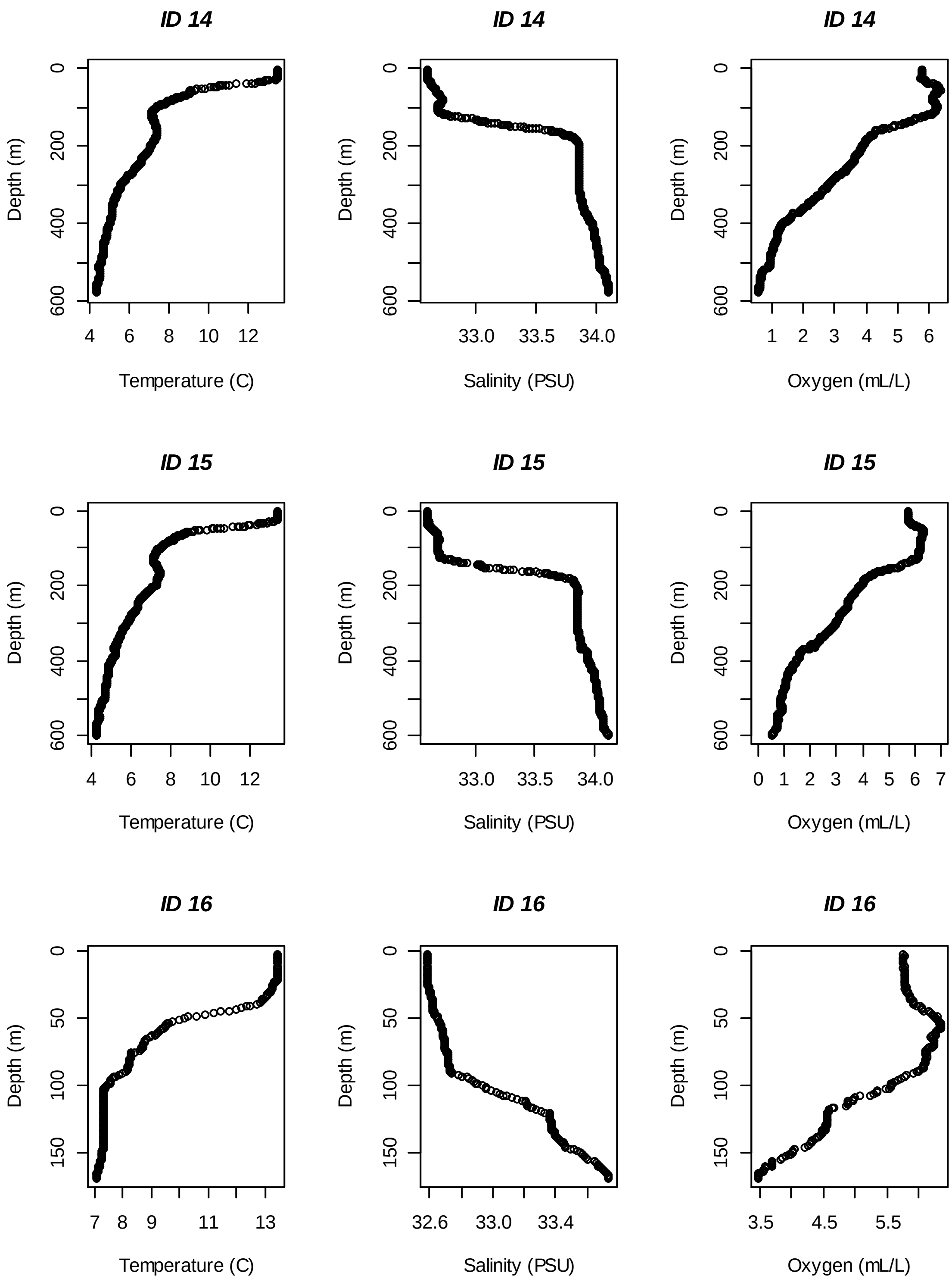
ID 11
ID 11
Depth (m)
Temperature (C)
Salinity (PSU)
Oxygen (mL/L)
ID 12
ID 12
ID 12
Depth (m)
Temperature (C)
Salinity (PSU)
Oxygen (mL/L)
ID 13
ID 13
ID 13
Depth (m)
Temperature (C)
Salinity (PSU)
Oxygen (mL/L)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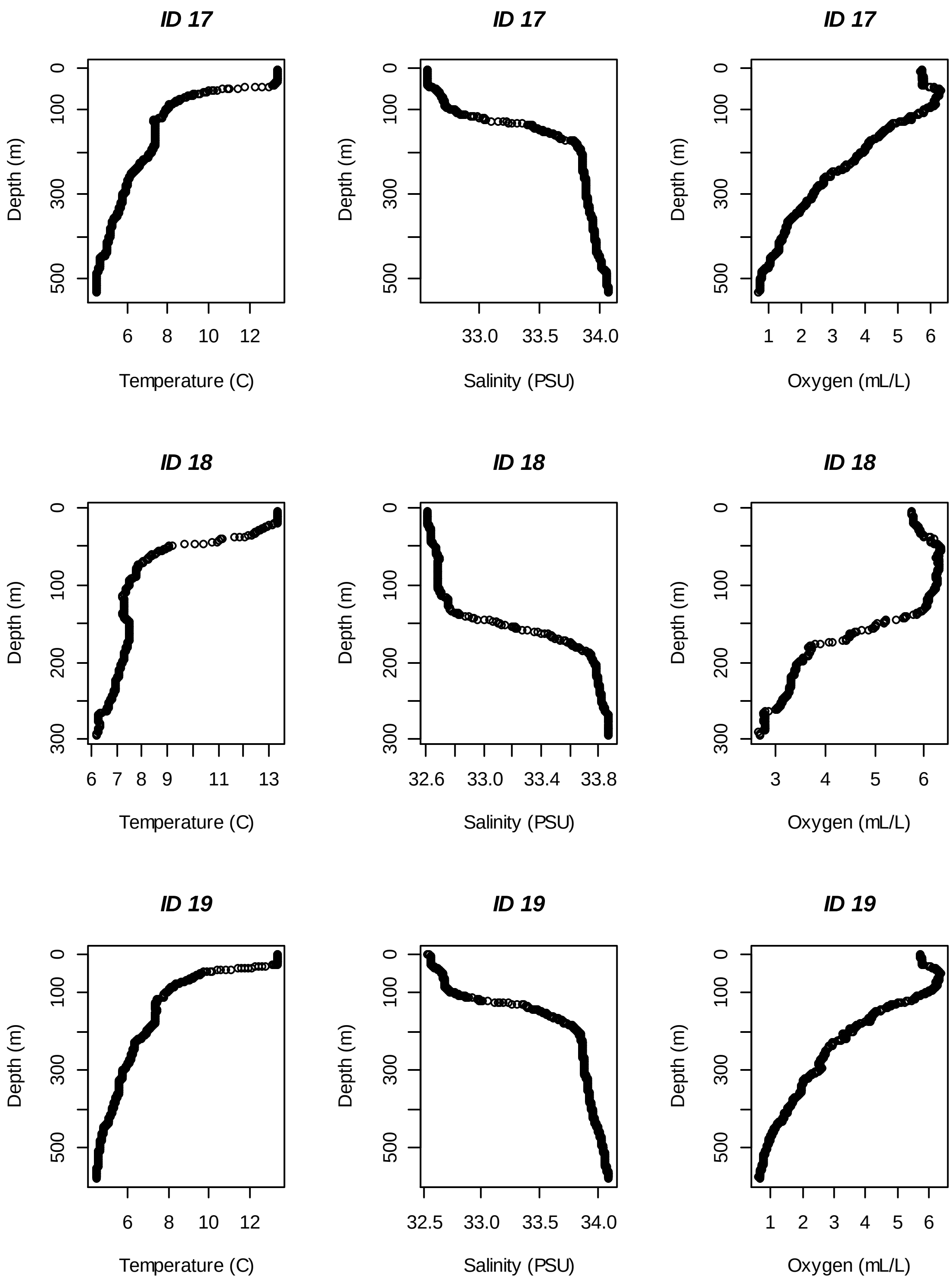
ID 14
ID 14
ID 15
ID 15
ID 15
ID 16
ID 16
ID 16
Depth (m)
Temperature (C)
Salinity (PSU)
Oxygen (mL/L)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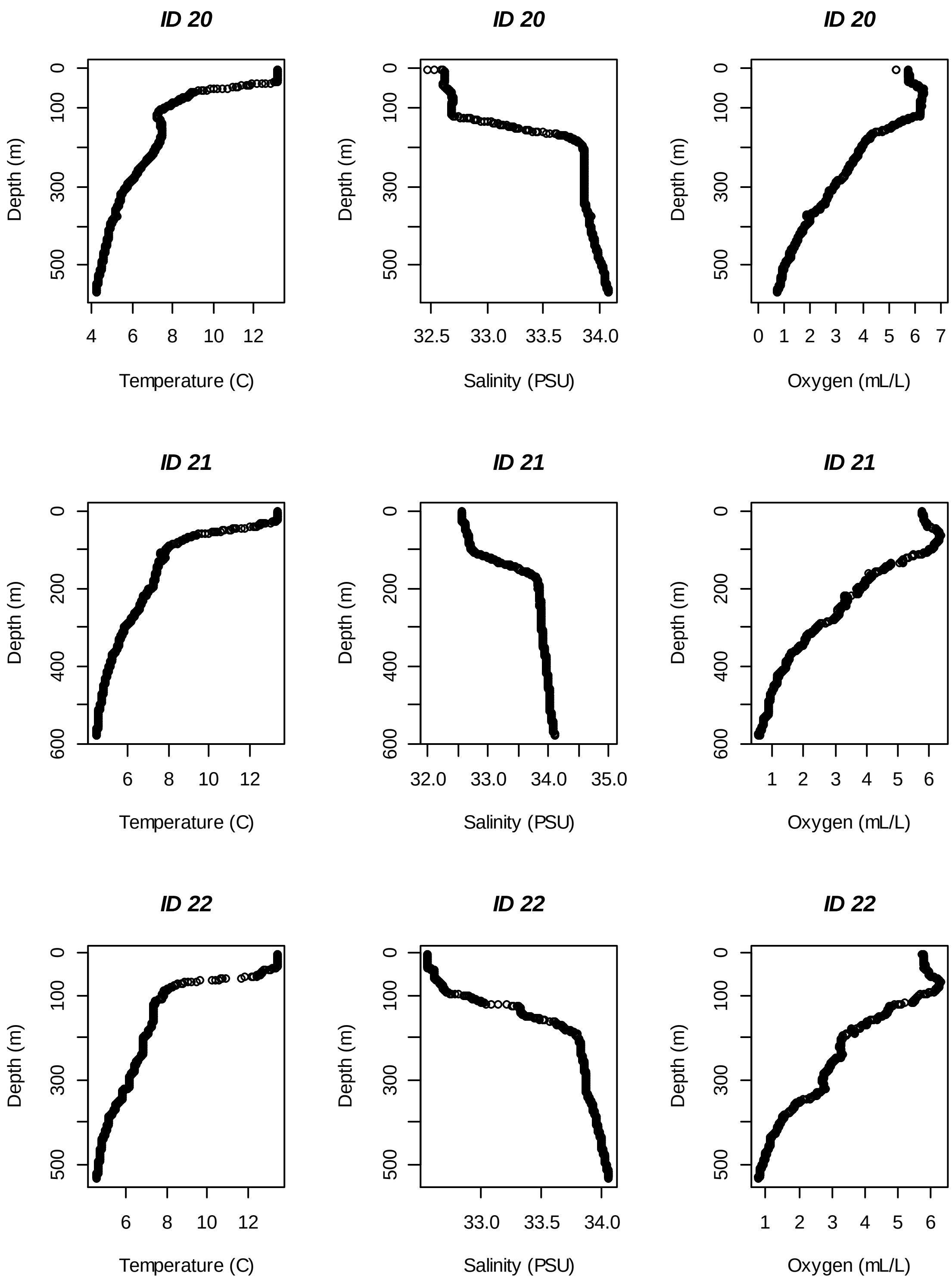
Depth (m)
Temperature (C)
Salinity (PSU)
Oxygen (mL/L)
ID 18
Depth (m)
Temperature (C)
Salinity (PSU)
Oxygen (mL/L)
ID 19
Depth (m)
Temperature (C)
Salinity (PSU)
Oxygen (mL/L)


ID 20
Depth (m)
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100
300
500
4
6
8
10
12
Temperature (C)
ID 20
Depth (m)
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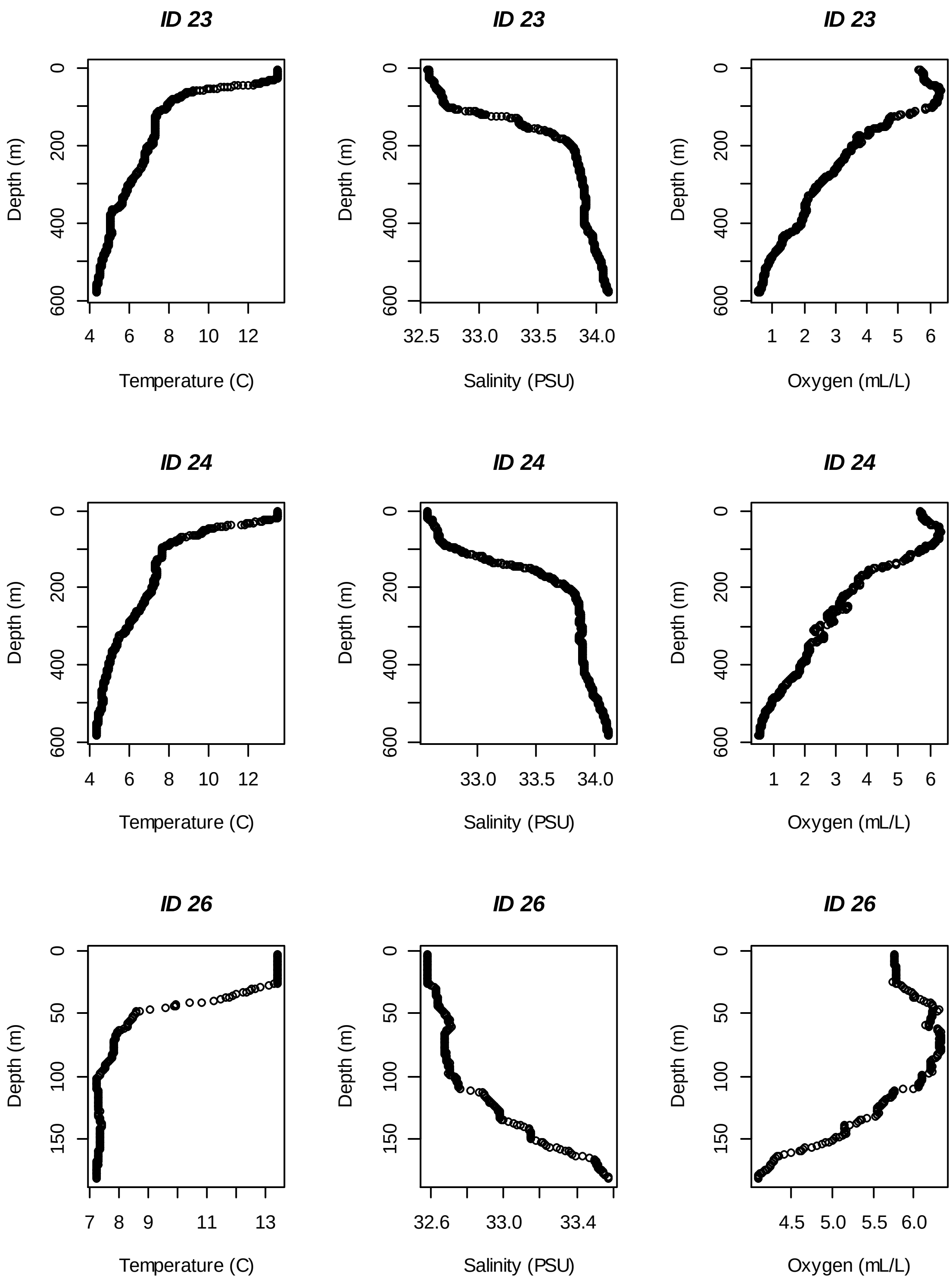
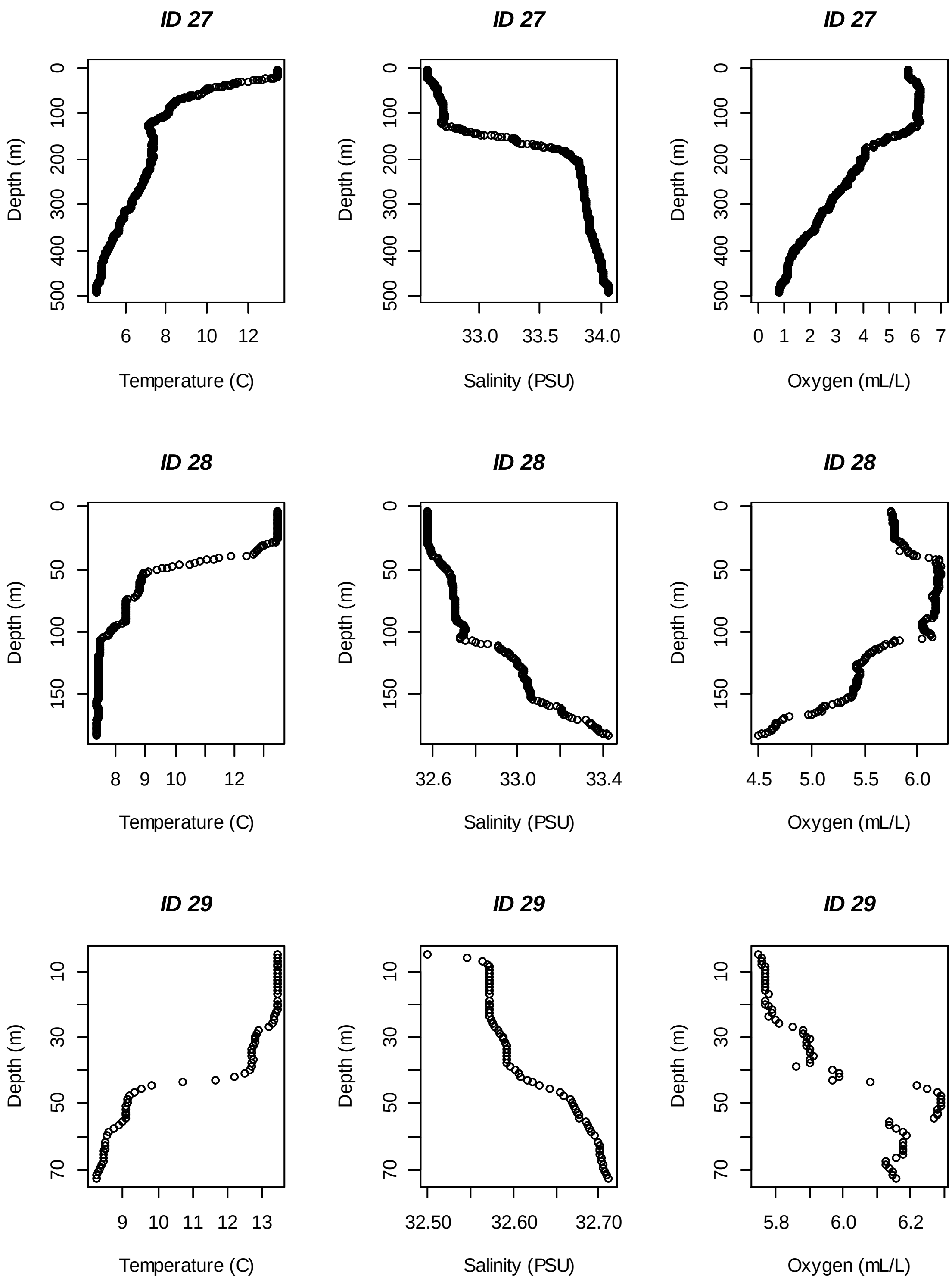
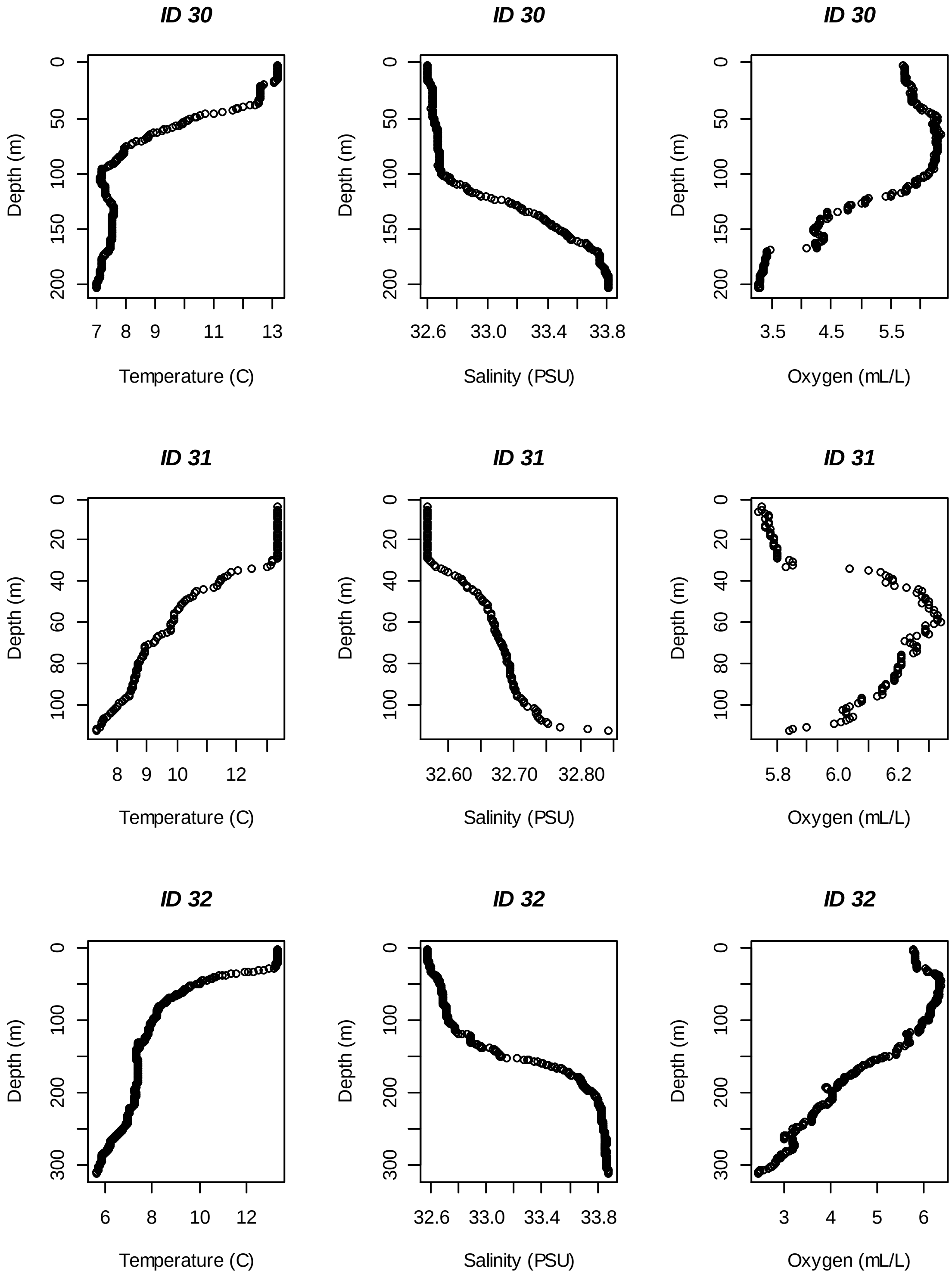
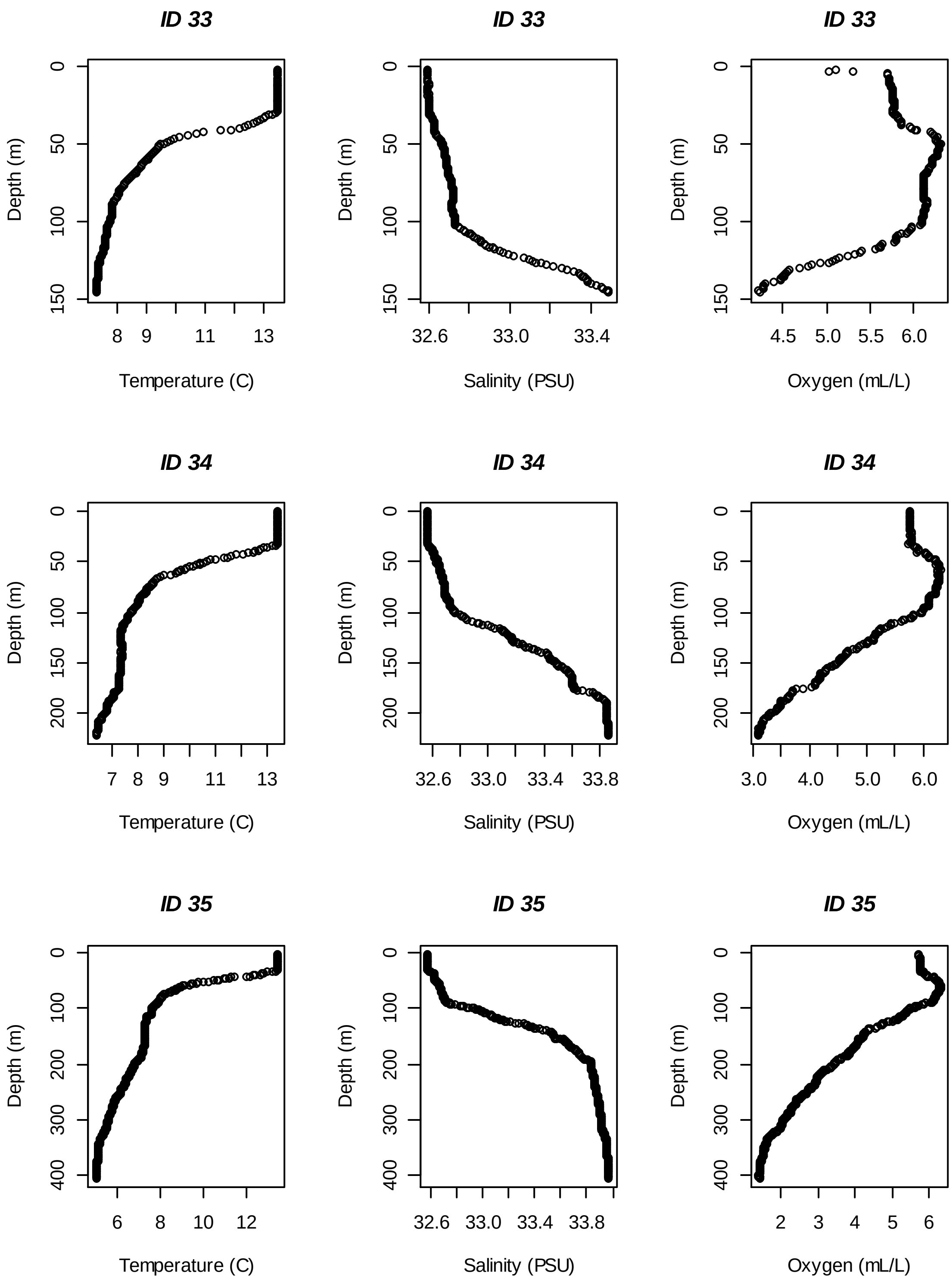
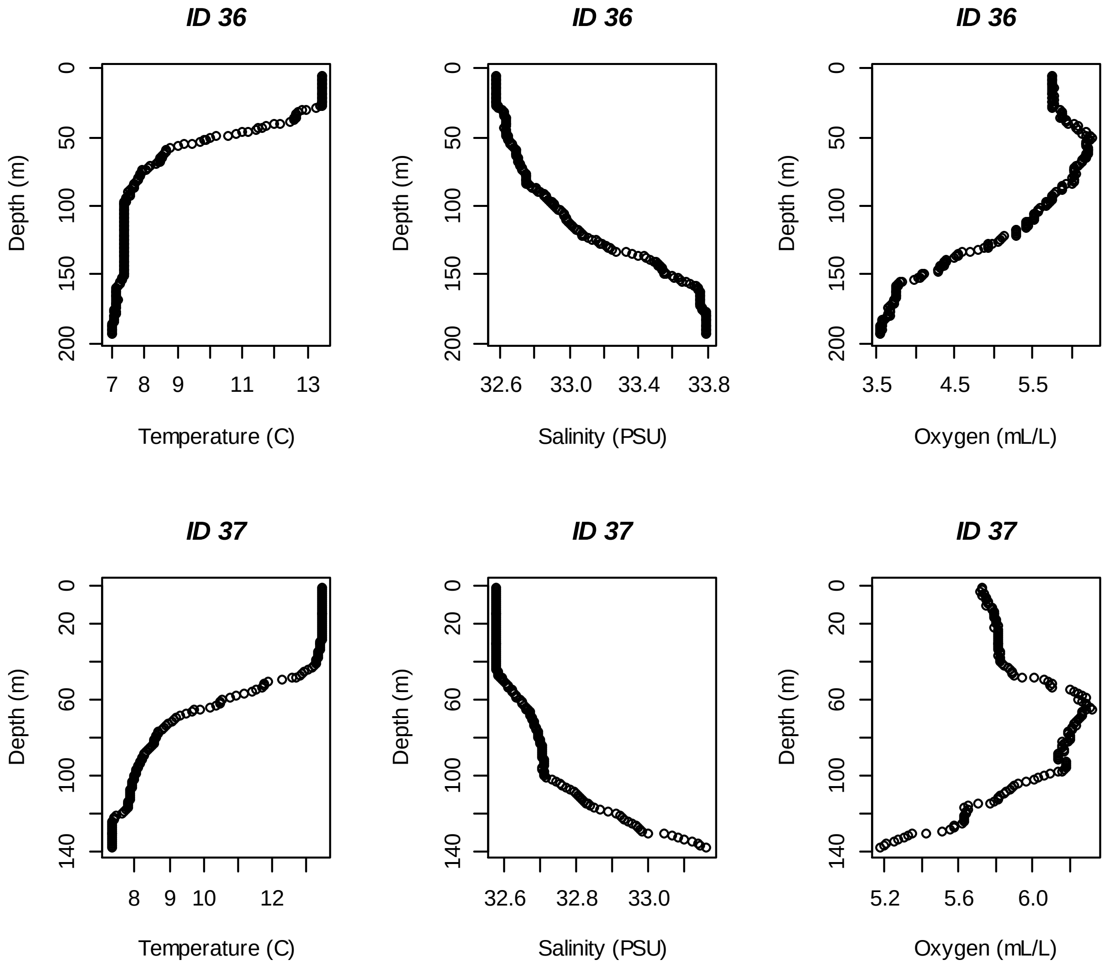
100
300
500
32.5
33.0
33.5
34.0
Salinity (PSU)
ID 20
Depth (m)
0
100
300
500
0
1
2
3
4
5
6
7
Oxygen (mL/L)
ID 21
Depth (m)
0
200
400
600
6
8
10
12
Temperature (C)
ID 21
Depth (m)
0
200
400
600
32.0
33.0
34.0
35.0
Salinity (PSU)
ID 21
Depth (m)
0
200
400
600
1
2
3
4
5
6
Oxygen (mL/L)
ID 22
Depth (m)
0
100
300
500
6
8
10
12
Temperature (C)
ID 22
Depth (m)
0
100
300
500
33.0
33.5
34.0
Salinity (PSU)
ID 22
Depth (m)
0
100
300
500
1
2
3
4
5
6
Oxygen (mL/L)


ID 23
ID 23
ID 23
Depth (m)
0
200
400
600
4
6
8
10
12
Temperature (C)
32.5
33.0
33.5
34.0
Salinity (PSU)
1
2
3
4
5
6
Oxygen (mL/L)
ID 24
ID 24
ID 24
Temperature (C)
Salinity (PSU)
Oxygen (mL/L)
ID 26
ID 26
ID 26
0
50
100
150
7
8
9
11
13
Temperature (C)
32.6
33.0
33.4
Salinity (PSU)
4.5
5.0
5.5
6.0
Oxygen (mL/L)


ID 27
Depth (m)
0
100
200
300
400
500
6
8
10
12
Temperature (C)
ID 27
Depth (m)
33.0
33.5
34.0
Salinity (PSU)
ID 27
Depth (m)
0 1 2 3 4 5 6 7
Oxygen (mL/L)
ID 28
Depth (m)
0
50
100
150
8 9 10 12
Temperature (C)
ID 28
Depth (m)
32.6
33.0
33.4
Salinity (PSU)
ID 28
Depth (m)
4.5
5.0
5.5
6.0
Oxygen (mL/L)
ID 29
Depth (m)
10
30
50
70
9 10 11 12 13
Temperature (C)
ID 29
Depth (m)
32.50
32.60
32.70
Salinity (PSU)
ID 29
Depth (m)
5.8
6.0
6.2
Oxygen (mL/L)


ID 30
Depth (m)
Temperature (C)
ID 30
Depth (m)
Salinity (PSU)
ID 30
Depth (m)
Oxygen (mL/L)
ID 31
Depth (m)
Temperature (C)
ID 31
Depth (m)
Salinity (PSU)
ID 31
Depth (m)
Oxygen (mL/L)
ID 32
Depth (m)
Temperature (C)
ID 32
Depth (m)
Salinity (PSU)
ID 32
Depth (m)
Oxygen (mL/L)


ID 33
Depth (m)
0
50
100
150
8
9
11
13
Temperature (C)
ID 33
Depth (m)
0
50
100
150
32.6
33.0
33.4
Salinity (PSU)
ID 33
Depth (m)
0
50
100
150
4.5
5.0
5.5
6.0
Oxygen (mL/L)
ID 34
Depth (m)
0
50
100
150
200
7
8
9
11
13
Temperature (C)
ID 34
Depth (m)
0
50
100
150
200
32.6
33.0
33.4
33.8
Salinity (PSU)
ID 34
Depth (m)
0
50
100
150
200
3.0
4.0
5.0
6.0
Oxygen (mL/L)
ID 35
Depth (m)
0
100
200
300
400
6
8
10
12
Temperature (C)
ID 35
Depth (m)
0
100
200
300
400
32.6
33.0
33.4
33.8
Salinity (PSU)
ID 35
Depth (m)
0
100
200
300
400
2
3
4
5
6
Oxygen (mL/L)


ID 36
Depth (m)
Temperature (C)
ID 36
Salinity (PSU)
ID 36
Oxygen (mL/L)
ID 37
Temperature (C)
ID 37
Salinity (PSU)
ID 37
Oxygen (mL/L)