POTENTIAL IMPACTS OF THE MONTEREY ACCELERATED RESEARCH SYSTEM (MARS) CABLE ON THE SEABED AND BENTHIC FAUNAL ASSEMBLAGES

2015

L.A. Kuhnz, K. Buck, C. Lovera, P.J. Whaling, J.P. Barry
Monterey Bay Aquarium Research Institute

SUMMARY

In addition to an initial biological assessment (2004) and an early 2007 Post-Lay Inspection and Burial Survey, a geological and biological sampling program to assess the condition of the MARS cable and its potential effects on seabed geology and biology was performed in late 2007 through 2008, in 2010, and again in late 2014 through 2015. The most recent study was conducted eight years after the cable was installed. The sampling program was designed to:

- Observe the condition of the cable or cable trench along the cable route (51 km),
- Assess the potential impacts of the MARS cable on geological characteristics and biological assemblages on a local scale (0–100 m from the cable) and at a regional scale (km), using remotely operated vehicle (ROV) video transects and sediment samples.

The major conclusion of the study is that the MARS cable has had little detectable impact on seabed geomorphology, sediment conditions, or biological assemblages. Specific conclusions include the following:

- Over most of its length, the cable remains buried, with little evidence of change since installation.
    - The cable remains buried along shallow areas of the cable route
    - Sediment has filled the cable trench in deeper areas, which is now nearly invisible in most locations
    - In the limited areas where the cable was not buried, only minor suspensions of the cable are present
- No differences in mean grain size were detected in relation to the MARS cable.
- The percent organic carbon content of sediments increased near the MARS cable at some depths, possibly due to natural variation or the effects of the cable or both.
- Local variation in benthic megafaunal communities near (within 50–100 m) the MARS cable is minor or undetectable.
    - The abundances of most animals observed did not differ between the area over the cable route and 50 m away.
    - In 2008, before the cable was powered, Longnose skates *(Raja rhina)* were significantly more abundant along a short section at ~300 m depth, near minor (2–10 cm) suspensions of the cable above the seabed. *R. rhina* may have responded to mild electromagnetic fields generated by components of the cable. In 2010, when the cable was powered, there was no significant difference in the abundance of skates near the cable compared to 50 m away. Normal abundances were observed again in 2015.

- The MARS cable has little or no detectable effect on the distribution and abundance of macrofaunal and megafaunal assemblages on a regional scale (i.e. kilometers).
    - Megafauna and macrofauna compared before and after cable installation among three control stations and one cable station at each of three depth zones (Shelf: <200 m, Neck: 200–500 m, Slope: >500 m) indicated very few potential changes in benthic biological patterns due to the MARS cable.
    - Natural spatial and temporal variation in the abundance and distribution of benthic macrofauna and megafauna appears to be greater than any detectable effects of the MARS cable.

INTRODUCTION

The Monterey Accelerated Research System (MARS) is an undersea cable spanning from the Monterey Bay Aquarium Research Institute (MBARI) in Moss Landing, California to a science node at a depth of 891 m on the continental slope just outside of Monterey Bay, California. The system provides power and high data bandwidth for science instruments connected to the node via thin extension cables deployed on the seabed by remotely operated vehicles (ROVs). MARS is one of a few cabled ocean-observing systems that enable continuous, long-term science capabilities for ocean science with real-time communication, control, and data capture from offshore subsea sensor systems.

The main MARS cable was installed in March 2007 from the cable-laying ship *Global Sentinel.* It stretches 51 km from shore to the science node, which is positioned in 891 m depth and roughly 35 km from shore. The cable was installed beneath the seabed for most of its length. Horizontal directional drilling (HDD) was used to install a conduit section from above the shoreline to 19 m water depth offshore. From this point, the cable was plowed into the seabed sediment to a depth of one meter for most of its length, and jetted into the sediment near the science node at the MARS site (Figure 1). Burial was not possible just below the continental shelf break (200–400 m depth) where authigenic carbonate crusts and rocky outcrops prevent complete burial of the cable. The MARS science node was installed and powered briefly in February 2008, but failed due to a subsea connector. The failed parts were recovered, repaired, and reinstalled in November 2008. MARS has been fully operational since that time.

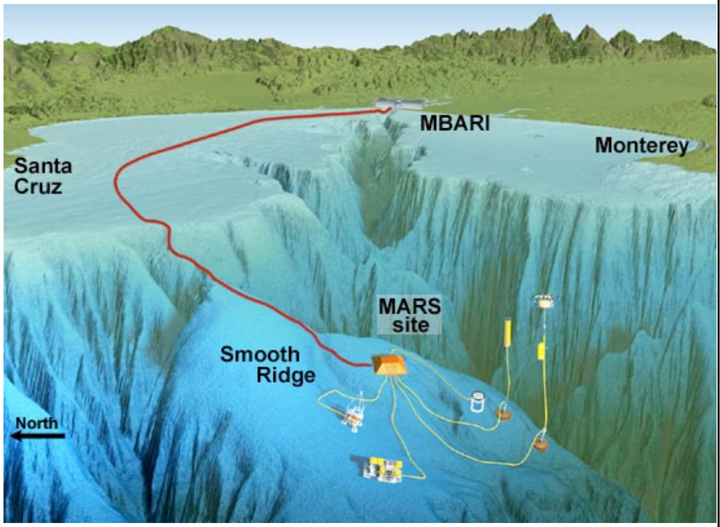

Figure 1. View of the MARS cable, node, and potential science instruments over exaggerated bathymetry of Monterey Bay, Monterey Canyon, and the continental slope. The science node is indicated as “MARS site”.

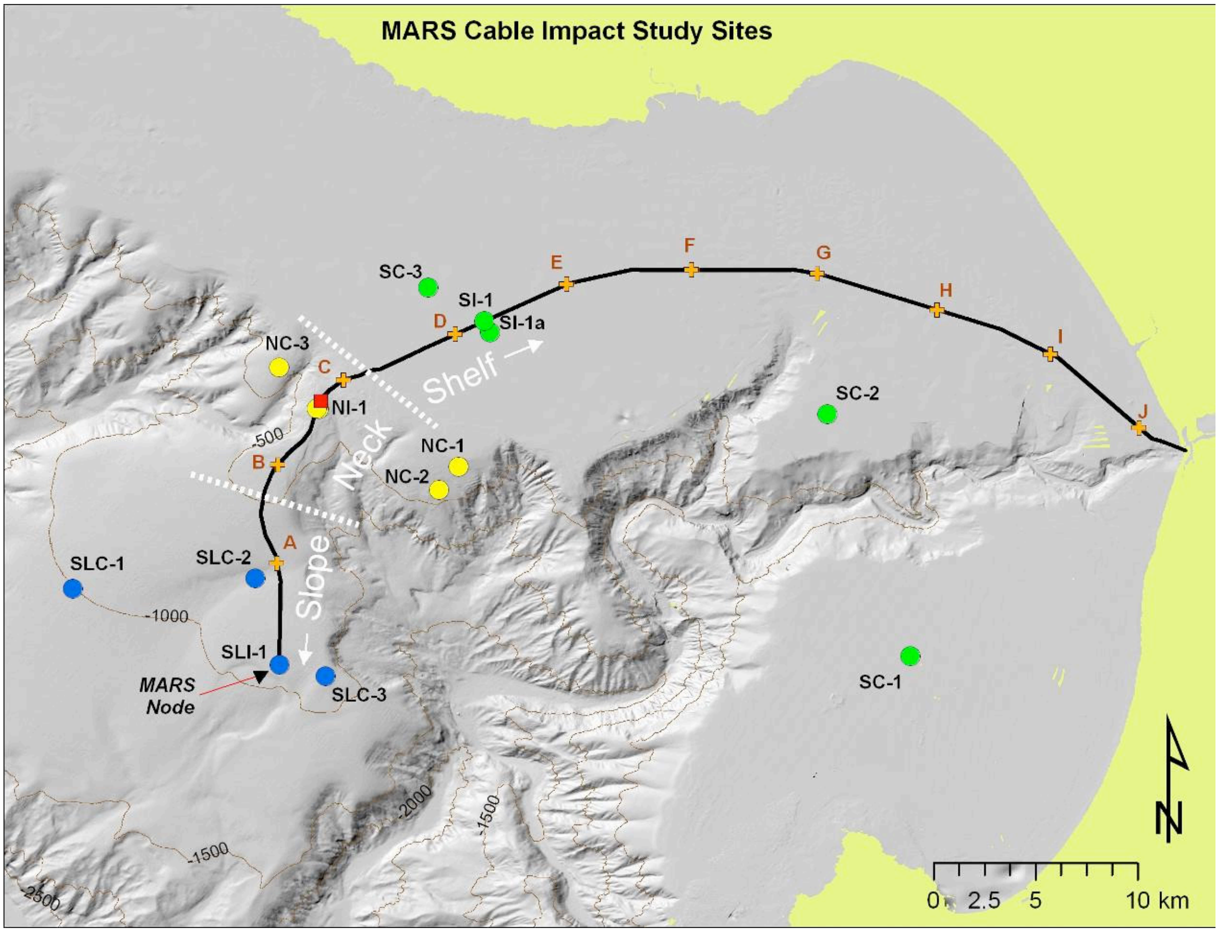

Figure 2. Map of MARS cable (black line) environmental studies sites. Colored circles represent regional sites for impact studies at Shelf (green), Neck (yellow), and Slope (blue) depths. The red box indicates the location of skate abundance transects. The brown plus symbols (A−-J) indicate transect locations for localized megafaunal studies. The end node is about 35 km from shore.

Prior to the MARS cable installation, an environmental impact report characterized seabed biological communities along the cable route and the initial sampling performed to support future environmental impact assessment (2004). This survey included characterization of megafaunal animals (organisms identifiable in video recordings) and macrofaunal organisms (worms, crustaceans, etc., captured from sieved sediment samples) along the cable route. Subsequent to the MARS cable installation, a Post-Lay Inspection and Burial (PLIB) survey of the entire route was conducted (March 16 – March 22, 2007 and June 7, 2007). Environmental impact assessments are required at 18-month to 5-year intervals, including observations of the condition of the cable and potential effects on biological communities. In this report, we present data from environmental impact assessment surveys performed prior to cable installation, 2007–2008 following cable installation (PLIB), 2010, and from the most recent 2015 study.

METHODS

Cable Condition Survey

The position and condition of the cable was assessed by a fly-over survey of the cable and cable route using the ROV *Ventana*. During the PLIB in 2007, the ROV was flown over the cable or cable route approximately 1–3 m above the seabed, using a cable-sensing system attached to the ROV to determine precisely the position of the cable along the buried portion of the cable route. In subsequent surveys, the cable tracking system was not used and sonar plus visual observations along most of the cable route were used to assess cable burial and condition. Low visibility near the seabed along the shallower portion of the cable route during 2010 prevented ROV observations along a portion of the cable route. The condition of the cable in low visibility sections was either determined by sonar (cable was evident if present on the seabed) or was not observed (~12 km long section). Annotations of video observations included:

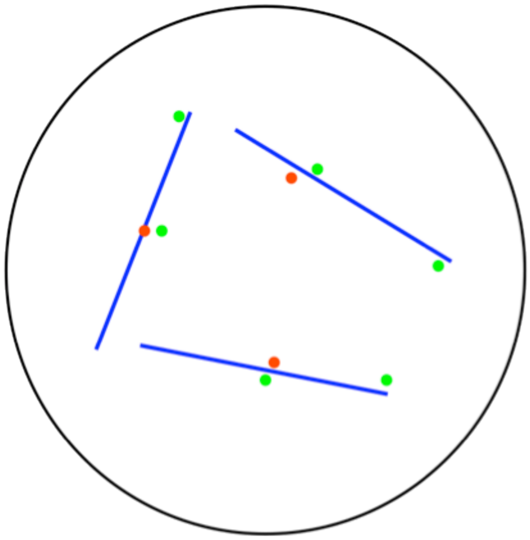

Figure 3. Sampling protocol for cable and control sites at each depth. Circle: 200 m-diameter station. Blue lines: 100 m- long video transects. Green circles: sediment core samples for macrofaunal assemblage characterization. Red circles: cores for sediment characteristic measurements.

- megafauna present
- superficial condition of the seabed
- damage to the seabed related to cable installation
- burial of the cable
- condition of the burial trench (i.e., exposed, filled with mud, etc.), and
- if not buried, the condition of the cable (lying on seabed or suspended between seabed objects

Seabed Observations and Sediment Sampling

Observations of the seabed and sample collections were performed using the ROV *Ventana* supported by R/Vs *Point Lobos*/*Rachel Carson* and ROV *Doc Ricketts*, supported by the R/V *Western Flyer*. The main camera on each of the ROVs is an Ikegama high definition camera with a HA10Xt2 Fujinon Lens mounted on a 3-axis pan and tilt capable of +/- 45^{o} of tilt. Two manipulator arms and a sample drawer provide space and manipulation capabilities for sediment sampling. All available recorded video was annotated using MBARI's computer annotation system, Video Information and Reference System (VARS).

Video Transects

Quantitative estimates of the densities of seabed organisms and objects were obtained from the analysis of video transects. For each video transect, the ROV camera was tilted toward the seabed

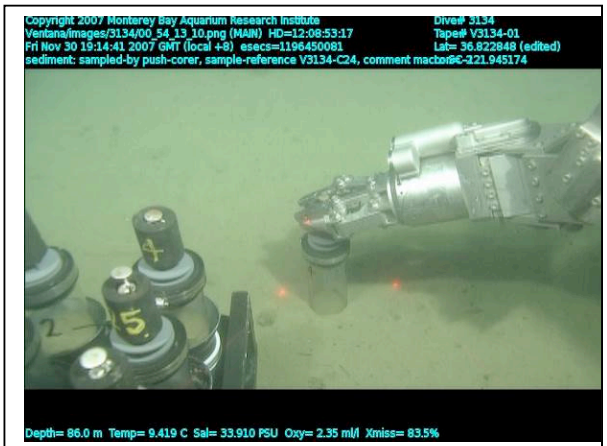

Figure 4. Collection of sediment core.

and zoomed to provide a 1-m-wide swath visible at the base of the image frame. Each transect was run at ~0.1–0.2 ms^{-1} over a distance of ~100 m. Paired parallel lasers (23 cm apart *Ventana*, 29 cm apart *Doc Ricketts*) provided a reference scale for estimating the spatial dimensions of the video image. Voucher specimens were collected as needed for additional taxonomic study.

Video transects were annotated using the VARS annotation system in a quantitative manner to provide estimates of the density (# 100 m^{-2}) of identifiable objects and organisms. Taxonomic identification of all megafauna was performed to the lowest practical taxonomic level. Because identification of organisms from video can be difficult, we were conservative in assignment of taxonomic names. All objects within a 1–1.5 m-wide swath were annotated along the length of each transect. To avoid bias in counts of the number of organisms due to field of view distortion, animals in the upper third of the image were not counted. Thus only those organisms passing through a 1-m-wide swath in the lower 2/3 of the image were used for counts. The density of objects and organisms over a single transect was used as a sample unit for further analyses.

Sediment Samples

Samples of seabed sediments for faunal and geologic characteristics were collected using 6.9 cm diameter tube cores (area = 37.39 cm^2), which penetrated the sediment to a depth of ~20 cm. The top 5 cm of each core sample was washed gently through a 0.3 mm sieve using cold seawater.

Collected organisms were relaxed using a 7% solution of magnesium chloride ($MgCl_2$), then preserved in a 4% formaldehyde (10% formalin) solution for several days. Samples were then rinsed with de-ionized water and stored in 70% ethanol for subsequent sorting and identification under a dissecting microscope.

Biological Communities

Local Effects of Cable Installation

Are there detectable differences in the abundances of animals living directly on or over the cable path compared to nearby areas not on the cable path? This was evaluated using video transects positioned at 5 km intervals along the entire cable route, comprising 10 cable sites (Figure 2). At each site, a 100-m-long video transect was run over the cable route (impact), and a second 100-m-long transect (control) was performed parallel to the cable, but 50 m away from it. For each transect, all identifiable organisms were identified and counted. Data from impact and control treatments were then compared to assess differences in megafaunal assemblages potentially caused by the cable.

Regional Effects of Cable Installation

Geological and biological impacts potentially associated with the installation and presence of the MARS cable were investigated at three depths selected within three major habitat types or "depth regions" occupied by the cable (Figure 2). These include 1) the continental shelf (Shelf: <200 m), 2) the continental shelf break and upper slope (Neck: 200–500 m) and 3) the continental slope region near the MARS benthic node (Slope: >500). These depths represent the principal habitat types along the cable path. Within each depth region, a single cable station was selected over the cable route, and three control stations were selected at distances of 1–16 km from the cable route.

Each sampling station was defined as a ~200-m-diameter circular area within which three replicate 100-m-long ROV video transects were performed along randomly selected compass headings (Figure 3). All animals were identified to the lowest possible taxon and counted. In addition, replicate sediment cores (6.9-cm-diameter) were collected (Figure 4) at random locations along video transects to characterize macrofauna (n= 6 cores per station) and sediment characteristics (n= 3 per station for % organic carbon, and grain size composition).

Skate Abundance at Neck Cable Region

An aggregation of Longnose skates (*Raja rhina*) observed during the 2008 cable survey suggested that they may associate with the cable, particularly in a localized area where small scarps and topographic depressions on the seafloor resulted in mild suspensions (2–10 cm) of the MARS cable. To test the hypothesis that this species (and perhaps others) were more (or less) abundant near suspended portions of the MARS cable, three replicate ROV video transects (100-m-long) were performed along a 300 m-long portion of the cable in the Neck cable region, and compared to three similar control transects performed ~50 m from the cable transects.

Analytical Methods

Differences in geologic and biologic parameters between cable and control sites with data available for both before and after cable installation were evaluated using a BACI (Before-After, Control-Impact) analytical design (Stewart-Oaten et al. 1986; Underwood et al. 1994; Hewitt et al. 2001). Using this design, individual 2-factor [Period (before, after), Treatment (cable, control)] comparisons were performed using permutation statistics available with *PRIMER-7* and *PERMANOVA+* (v.7.0.10; www.primer-e.com). This design was used for both multivariate and univariate data sets of biological and sediment parameters. Raw abundance of megafauna (# 100 m^{-2}) were square root transformed prior to analysis to increase homogeneity of variances among groups and to reduce the influence of very abundant species. Due to erratic (clumped) distributions, macrofauna counts (# $core^{-2}$) were first downweighted, then square root transformed. Similarity matrices for Permanova were calculated using Bray-Curtis for multivariate tests, univariate tests, and Multidimensional Scaling (MDS) analysis. Monte Carlo P-values (Anderson and Robinson 2003) were used to assess statistical significance.

Univariate tests were run for sediment characteristics (mean grain size and % organic carbon), with no transformation of raw data and Euclidean Distance as an overlap measure.

Faunal assemblage data were analyzed at the level of individual species and faunal groups (e.g. family, class). For multivariate tests, all species or all taxonomic groups were analyzed together. For univariate tests, only the most abundant species (~>1% of total faunal abundance) or faunal groups (~>3% of total faunal abundance) were analyzed.

For analyses using a large number of individual statistical tests, the likelihood of type I errors (i.e., finding a significant difference between groups when it truly does not exist) increases. While this level (α) is usually set at 0.05 (95% confidence of avoiding type 1 error), α is often adjusted downward based on the number of tests performed to reduce the likelihood of type I errors (Cabin and Mitchell 2000). While this method may be effective for correcting type 1 errors, its use is questionable (Perneger 1998; Cabin and Mitchell 2000) because it also increases the likelihood of type II errors (i.e., finding no difference between groups that truly differ). For this reason, α was maintained at 0.05 regardless of the number of tests used for analyses of cable impact data.

RESULTS & DISCUSSION

ROV Dive Series

ROV surveys, transects, and sediment collections (tube cores) were completed during these cable surveys. In addition to surveying the length (~51 km) of the cable route five times, the field and analysis team completed 180 quantitative video transects, and collected and analyzed 346 sediment cores (239 for macrofaunal analyses, 107 for sediment characteristics).

2008

A total of 16 days and 19 ROV dives using the R/V *Point Lobos* and ROV *Ventana* were used to complete the first MARS cable environmental studies from November 30, 2007 to April 1, 2008; (Appendix 1). Three additional sea days were cancelled or postponed due to weather or the presence of surface floats marking crab fishing gear, which interferes with ROV operations.

2010

The 2010 cable survey was performed between January 8, 2010 and April 9, 2010 during 11 sea days and 19 ROV dives. Shallow stations were sampled using the R/V *Point Lobos* and ROV *Ventana.* Deeper stations were surveyed using the R/V *Western Flyer* and the ROV *Doc Ricketts* (Appendix 1). Three sea days were aborted due to severe weather conditions and some dives were cancelled or aborted early due to poor visibility or the presence of crab pots. Low visibility near the seabed was frequently caused by suspended sediment from river outflow.

2015

The 2015 cable survey was performed between December 16, 2014 and December 18, 2015 during 10 sea days and 19 ROV dives. Shallow stations were sampled using the R/V *Rachel Carson* and ROV *Ventana.* Deeper stations were surveyed using the R/V *Western Flyer* and the ROV *Doc Ricketts* (Appendix 1). Low visibility near the seabed was cause by suspended sediment at the shallower end of the cable route.

Cable Route and Condition of the Cable

Seven general substrates, ranging from sand and mud to rocky habitat, were encountered. More than 70% of the route was composed of sand and sandy mud (Table 1). It was not possible to bury (jet-in) the cable during its installation along the neck of Smooth Ridge where rock and authigenic carbonate pavement is common.

Table 1. Composition of substrate on the MARS cable route, reported as total distance and as a percent of the total distance.

Substrate	Distance (km)	Percent of route
mixed substrate (mud interspersed with hard substrate)	0.67	1.3
Mud	3.37	6.6
mud over clay	7.60	15.0
rippled sand	0.64	1.3
rocky habitat	2.24	4.4
Sand	23.49	46.4
sandy mud	12.64	25.0
Total	50.65	100.0

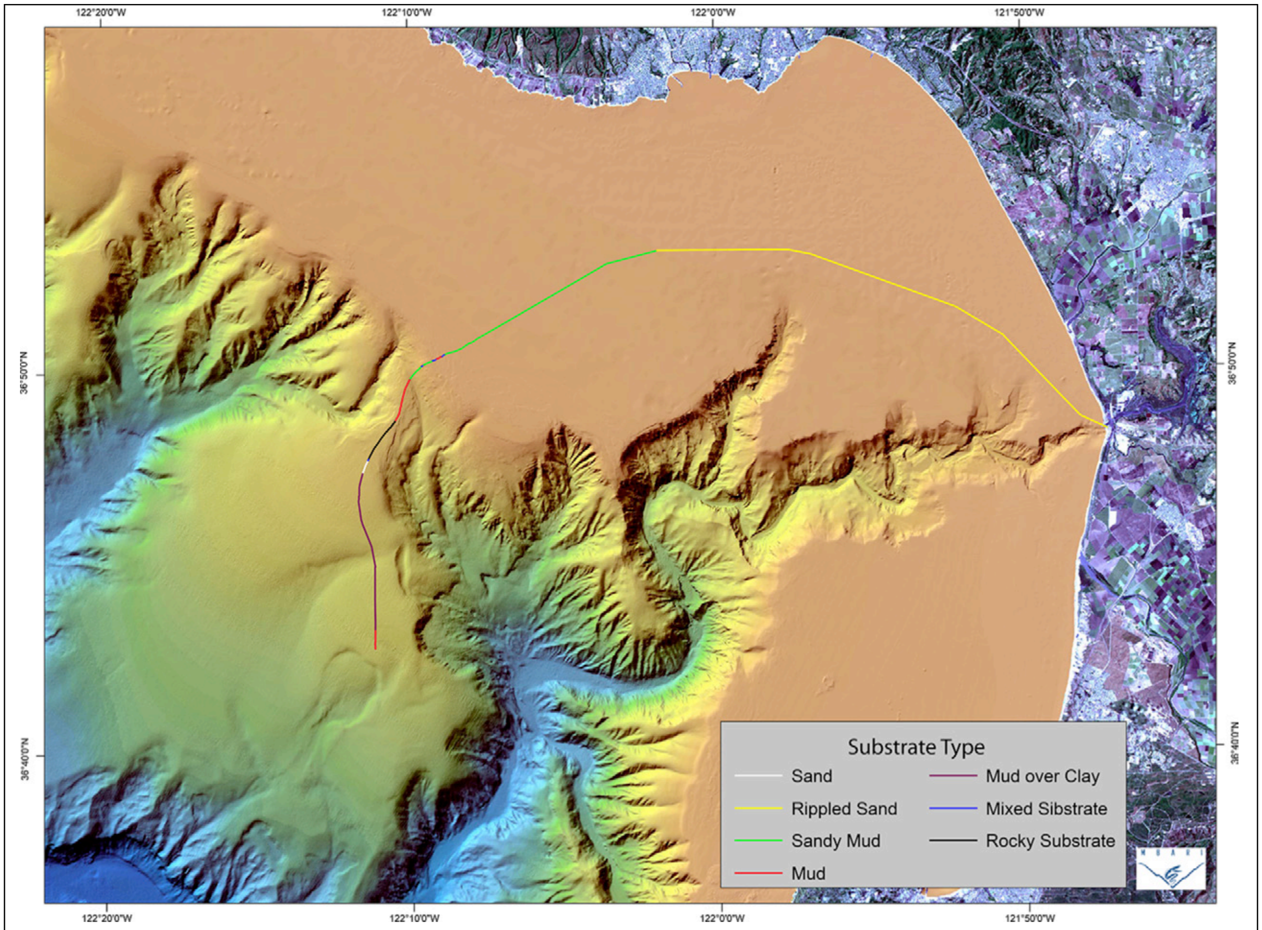

Figure 5. Substrates encountered along the MARS route.

Just weeks after it was installed in 2007, most of the cable (79%) was buried, 19% was exposed and 2% was partially buried (Figure 5, Table 1). At that time, the cable was covered in sand at the beginning of the route and was not visible for a distance of more than 27 km. The majority of the cable, where buried, was 0.6–1.0 m below the seabed. Mean burial depth for the entire route, excluding where the cable was surface laid, was 0.941 m.

The most recent survey verified that most of the cable remains buried beneath the surface of the seabed, as measured during the first post-installation survey (March–June 2007, Figure 6, Figure A in Appendix 2). Along the 6.9 km section between 116 and 453 m water depth, the cable is still exposed or intermittently exposed (Figure 6, Appendix 2 Figure B and C, Table 2). Over time, there appears to have been some minor relaxation in the tension of the cable, resulting in portions of previously exposed cable having settled into surficial sediments (Appendix 2 Figure D). Some sections of the cable that were exposed are now covered with ca. 5–60 cm of sediment. In 2015, the cable was not visible on the seafloor for a total of 34.45 km (86.4%, Table 2).

Table 2. Condition of the MARS cable along the route, reported as total distance and as a percent of the total distance. Comparison of the 2007 post-lay inspection and 2015 results are shown.

Cable Condition	Distance (km)	Percent of route
Cable buried		
2007	40.00	79.00
2015	43.75	86.40
Cable exposed, intermittently exposed, or shallowly buried		
2007	10.65	21.00
2015	6.90	13.60
Total	50.65	100.0

No evidence of trawling impact was observed, nor was any major change apparent along the exposed portions of the cable. There was no evidence of strumming or other movement of the cable. As observed in earlier surveys, there are no major spans or point suspensions in the MARS cable in the exposed area. In some short sections, the cable is still 1–6 cm above the seafloor, because the cable is being pulled taut where the seafloor is slightly irregular due to rocks or topographic changes in soft sediment (Appendix 2 Figure E). These irregularities also resulted in minor spans up to 41 m long (Appendix 2 Figure F, Appendix 2). One is 0.5 m above the seafloor for a distance of 20 m; the others are at a height of 0.3 m or less (Appendix 3). While there are some insignificant changes to the amount of sediment under the end points of the spans (build up or erosion), they look essentially the same in 2015 as they did in 2007, 2008, and 2010.

There are also minor point suspensions, caused by rocks and ledges in this region (Appendix 2 Figure G, Appendix 3). These are short sections of the cable (under ~ 3 m long) that are less than 15 cm above the seafloor.

Along some mid-depth sections, the cable was in the installation trench, but was not completely covered with sediment during installation, leaving the cable lying beneath the depth of the surrounding seafloor (Appendix 2 Figure H). Because the cable was visible within the trench it was categorized as exposed in 2007. Since installation, the trench has been filling with sediment and is full in most areas. Where not full, sediment infilling is estimated to be at least 90% with no sign of the cable near the surface (Appendix 2 Figure I).

The cable is buried along the final 9.3 km of its route, and emerges a few meters from its termination at the seaward MARS node (891 m). Mild sediment disturbance is the only remnant of the trench in this region (Appendix 2 Figure J).

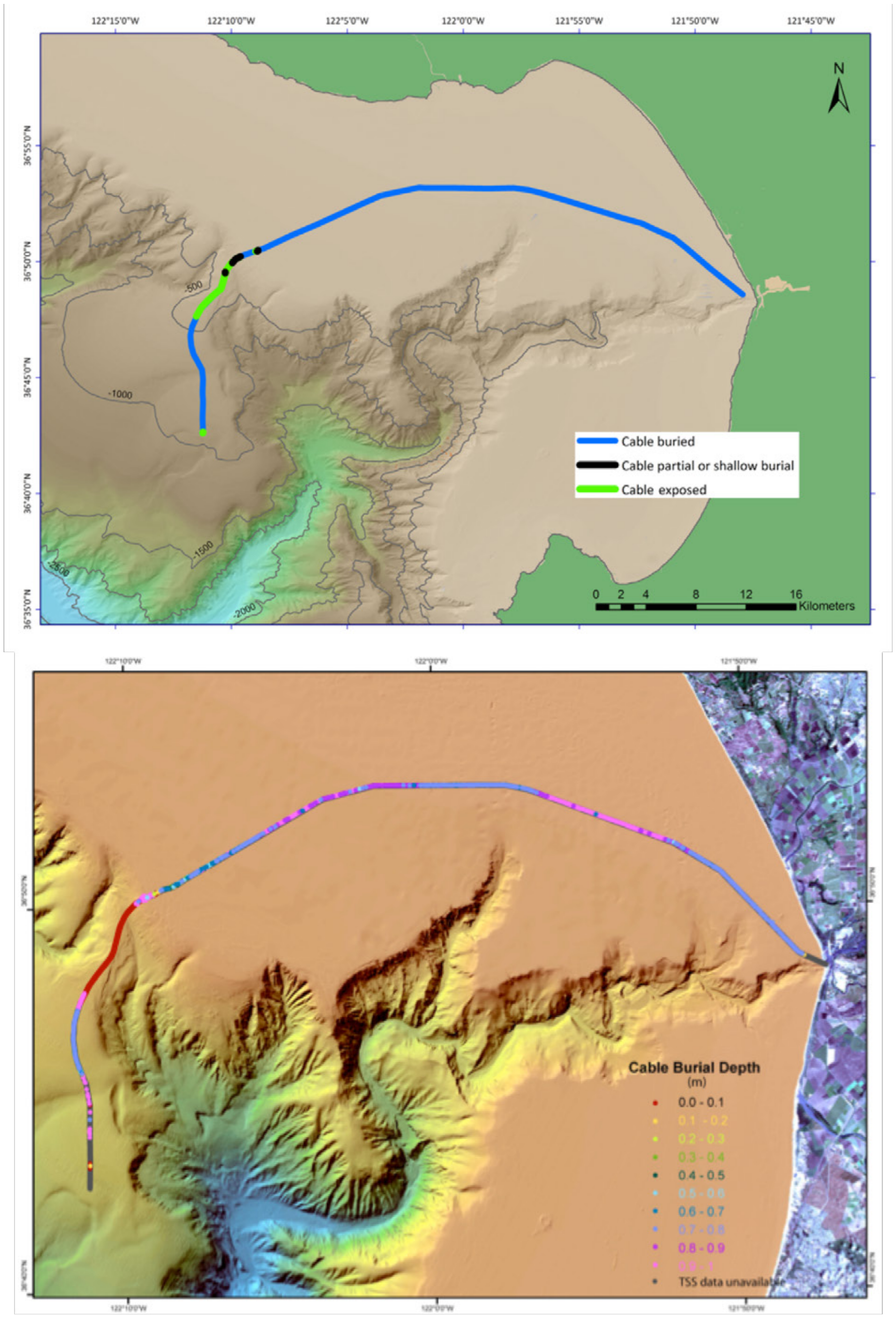

Figure 6. Exposure and depth of burial of the MARS cable. Upper: Current status of buried versus exposed condition of cable. In 2015, the cable was 86.4% buried with 13.6% either exposed, partially buried or shallowly buried. Lower: burial depth of the cable (2007 PLIB survey). Where buried, the average depth of burial was 0.941 m.

Sediment Characteristics

Sediment grain size and percent carbon content varied between treatments, sites, and sampling dates for all three cable depth regions. Because sediment samples were not collected before the cable was installed, variation in sediment characteristics among control and cable impact sites may represent natural variation or the effects of cable installation or both.

Sediment Grain Size

Mean sediment grain size ranged from 19 to 289 μm, with the coarsest sizes at Slope stations in 2010 (mean = 172 μm, Figure 7). Finer mean sizes characterized the Shelf (mean = 44 μm in 2008).

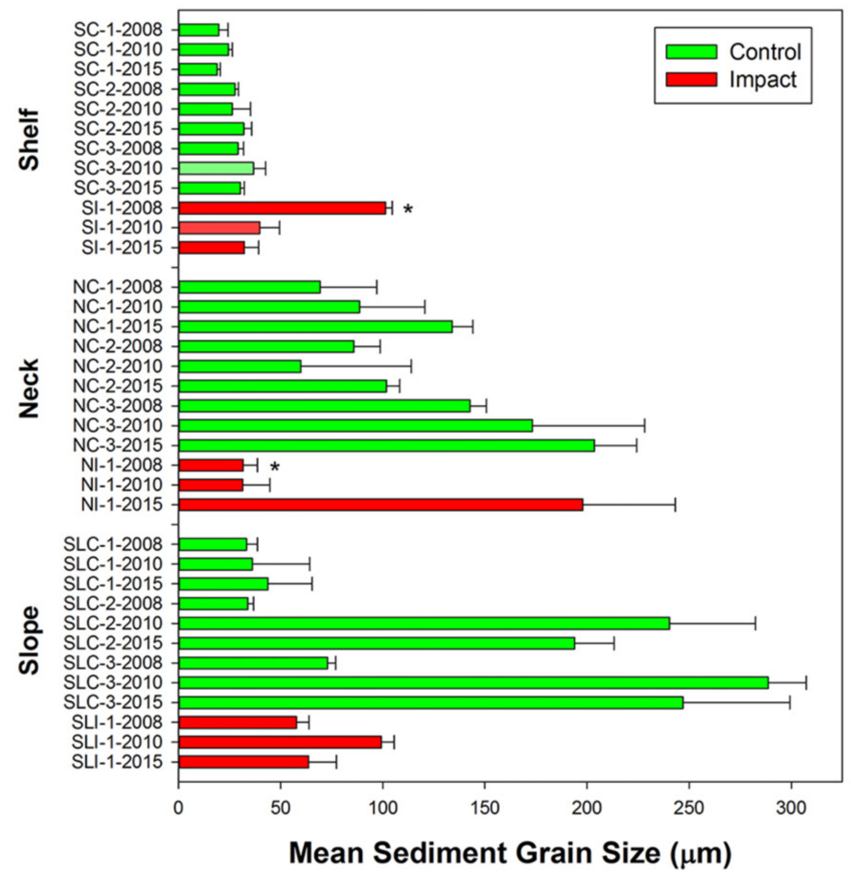

Figure 7. Mean sediment grain size (+/- SD) at control and cable (impact) stations for cable depth regions**.** Neck and Slope depths were nonsignificant ($p < 0.05$), but the difference was significant for the Shelf region ($p > 0.001$). * = significant difference between control and impact areas for the sampling period.

Grain sizes at Shelf sites varied significantly over the sampling periods ($p<0.001$) and between impact and control sites ($p<0.001$). In 2008, mean grain sizes were significantly smaller at the control station than at the impact station ($p<0.001$; Figure 7), which might be expected in association with the installation of the cable. But because grain size also varied significantly between sites, irrespective of treatment it is not possible to determine if the observed variation in grain size among stations is due to natural variability or any effects of the cable. In 2010 and again in 2015, mean grain size did not differ significantly between the impact and control sites.

Variation in sediment grain size in the Neck region was significant over sampling periods ($p<0.01$), but the variation in control vs. impact samples was nonsignificant. This region is subject to sediment winnowing due to currents and is visually variable on a small scale.

The interstation variation in grain size observed at shallower depths also occurred in the Slope depth zone. Overall there was no significant difference in mean grain size between control and impact treatments nor sampling dates.

Sediment Percent Carbon Content

The carbon content of sediments varied considerably, ranging from 0.35 to 1.33 percent, with highest organic-rich sediments generally found in the finer grain sizes on the Shelf, and had no detectable differences in control vs. impact stations or by sampling date (Figure 8).

Neck (p<0.01), and Slope (p = 0.02), regions each had detectably higher percentages of carbon content at impact stations. This could represent natural variation or potentially an enhancement of organic rich material near control stations, perhaps due to the aggregation of debris or organisms or both near the cable. Such aggregation could be related to the increase in habitat heterogeneity created in some sections of the cable during installation.

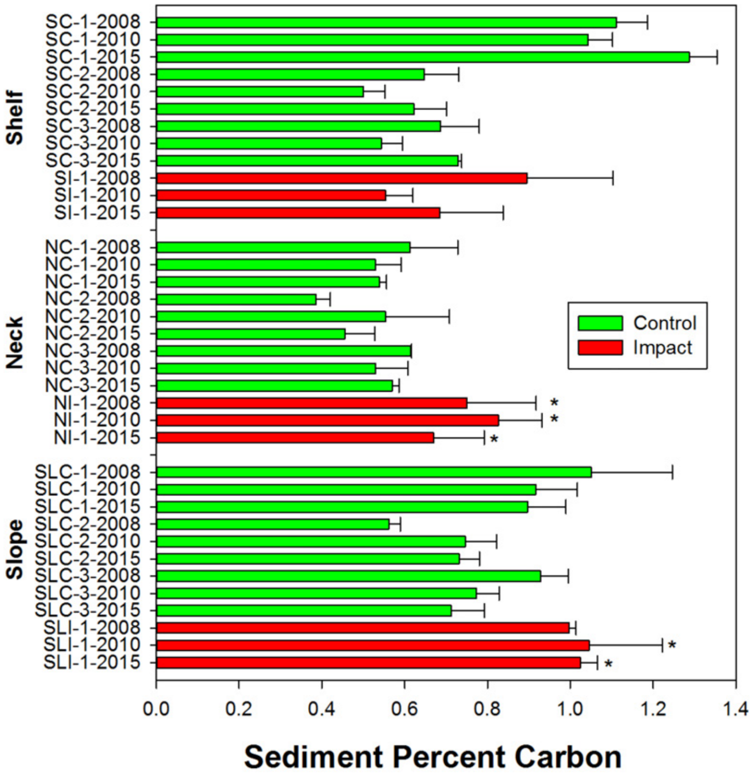

Figure 8. Mean percent organic carbon in surficial sediments for control and cable sites at the three cable depth regions (+/- SD). Comparisons of control vs. cable (impact) sites was nonsignificant for the Shelf region (p = 0.35). Differences were significant for Slope (p = 0.002) and Neck depths (p = 0.001).
* = significant difference between control and impact areas for the sampling period.

Biological Characteristics Megafaunal Assemblage

The seabed megafaunal assemblage along the cable route was characterized from counts of 29,956 individuals from 154 taxa observed in 212 ROV video transects (Figure 9, Appendix 1). The overall mean density of megafauna was 151 ind. 100 m^{-2} (Table 3). Cnidarians were the most abundant group, comprising over 47 percent of the total megafaunal abundance. They were represented mainly by sea pens (Pennatulacea) and anemones (Actinaria). Echinoderms ranked second among phyla with almost 42 percent of the total abundance, particularly seastars (Asteroidea) and urchins (Echinoidea), (Table 3). Fishes (Chordata) were the third most abundant phylum with nearly 14 percent of the total abundance. Flatfishes (Pleuronecitformes) and rockfishes (Sebastidae) had the highest densities.

The top eight ranking megafaunal species accounted for nearly 60 percent of the total abundance. Three common taxa (Appendix 4) comprised just over 35 percent of the total megafauna. *Funiculina* sp., a common sea pen at slope depths near 500–1000 m was the most abundant species (30 ind. 100 m^{-2}), at 20 percent of the total megafaunal abundance. Other sea pens (likely *Acanthoptilum* sp.), common on the continental shelf, and *Stronglylocentrotus fragilis,* a common urchin at upper slope depths, ranked second and third, with early 8 percent each.

Eighteen months after installation, 59 organisms were attached to the cable in the neck region where the cable is exposed on the seafloor (anemones *Liponema brevicornis,* 39 individuals, and *Metridium farcimen,* 13, and the crinoid *Florometra serratisima,*7). We also observed four sea slug egg cases (*Pleurobranchaea californica*) attached to the cable. After 36 months, there were 683 animals on the cable; 66 percent of them are semi-mobile and may be using the cable as temporary habitat (*L. brevicornis,* 345; *F. serratissima,* 108; actinostolid anemones, 189; *M. farcimen,* 37; hydroids, 4).

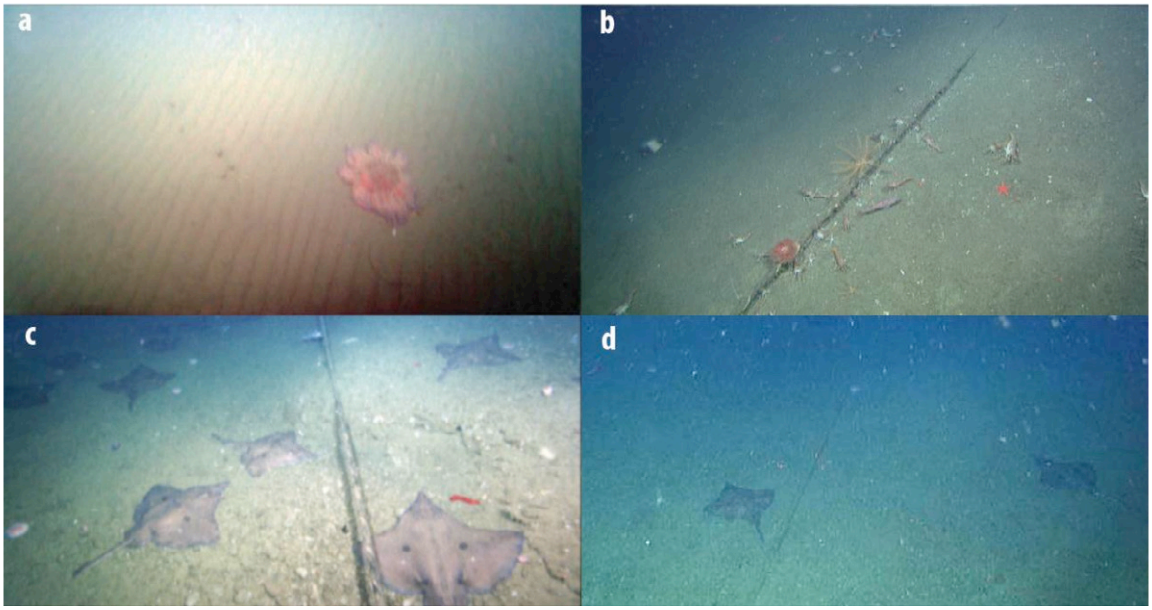

Figure 9. Megafauna along the cable route. A. Sand ripples and the seastar *Pycnopodia helanthoides* at 31 m depth, cable buried and not visible. B. Cable on seabed at 226 m depth with an anemone and crinoid attached. C. Skate (*Raja rhina*) aggregation at 303 m depth (2008). D. Far fewer skates were present in this area in 2010 and in 2015.

Table 3. Summary of megafaunal abundance by phyla and groups. Abundance is listed as a mean (# ind. 100 m^2, standard error of the mean (SE), and percent of total abundance (%) for all sampling periods combined (n= 212).

Phylum / Group	Mean	SE	%
Cnidaria	**71.56**	**10.46**	**47.52**
Pennatulacea	48.86	8.25	32.45
Actiniaria	19.17	2.94	12.73
Ceriantharia	2.98	0.41	1.98
Alcyonacea	0.35	0.10	0.23
Corallimorphidae	0.17	0.05	0.11
Anthozoa	0.02	0.01	0.01
Rhodaliidae	0.02	0.01	0.01
Echinodermata	**41.72**	**5.87**	**27.71**
Asteroidea	15.82	2.31	10.51
Echinoidea	12.02	2.59	7.98
Holothuroidea	6.62	2.70	4.40
Ophiuroidea	6.98	1.82	4.63
Crinoidea	0.28	0.12	0.19
Vertebrata	**13.90**	**1.09**	**9.23**
Pleuronectiformes	6.14	0.66	4.08
Sebastidae	3.26	0.67	2.16
Zoarcidae	1.52	0.26	1.01
Agonidae	0.51	0.10	0.34
Actinopteri	0.48	0.16	0.32
Hexagrammidae	0.43	0.07	0.28
Stichaeidae	0.24	0.11	0.16
Merlucciidae	0.24	0.08	0.16
Squalidae	0.23	0.06	0.15
Myxinidae	0.21	0.06	0.14
Rajiformes	0.19	0.04	0.12
Liparidae	0.16	0.04	0.11
Macrouridae	0.10	0.05	0.07
Scyliorhinidae	0.06	0.02	0.04
Moridae	0.04	0.02	0.03
Anoplopomatidae	0.04	0.02	0.02
Embiotocidae	0.04	0.02	0.02
Torpedinidae	0.01	0.01	0.01
Alepocephalidae	0.01	0.01	0.00
Chimaeridae	0.01	0.01	0.00
Mollusca	**10.60**	**1.69**	**7.04**
Gastropoda	8.53	1.68	5.66
Cephalopoda	1.67	0.30	1.11
Bivalvia	0.41	0.33	0.27
Annelida	**6.36**	**2.05**	**4.22**
Polychaeta	6.25	2.05	4.15
Echiura	0.11	0.06	0.07
Arthropoda	**4.16**	**0.80**	**2.76**
Decapoda	4.12	0.80	2.73
Mysidacea	0.04	0.02	0.03
Porifera	**2.14**	**0.46**	**1.42**
Tunicata	**0.10**	**0.04**	**0.06**
Brachipoda	**0.05**	**0.03**	**0.03**
Grand Total	**150.57**		

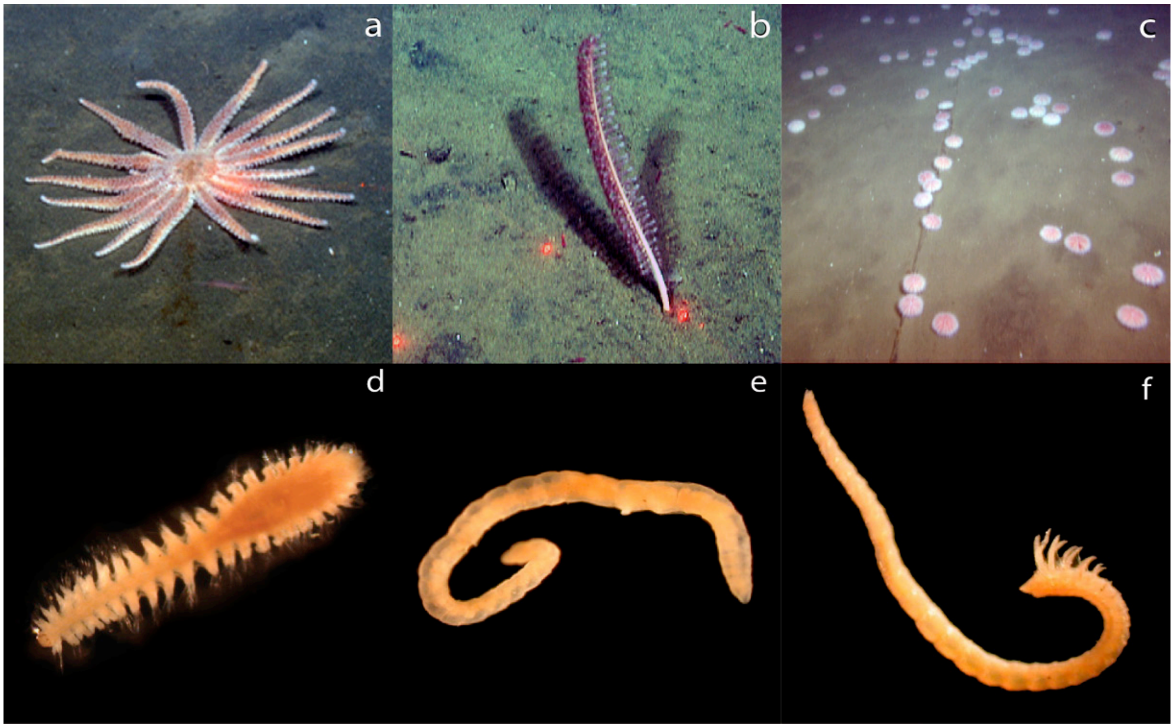

Figure 10. Common megafaunal and macrofaunal animals along the MARS cable route. A–C: Megafauna: A. *Rathbunaster californicus* (sea star). B. *Funiculina* sp. (sea pen). C. *Stronglylocentrotus fragilis*, (urchin). D–F: Macrofauna: D. *Cossura* sp. (polychaete). E. Oligochaeta. F. *Prionospio* sp. (polychaete). These taxa are some of the most abundant organisms observed in video (megafauna) or collected in sediment cores (macrofauna).

Local Effects of Cable Installation—Megafauna

Little variation in the megafaunal assemblage was detected between video transects directly over the cable route and parallel transects 50 m from the cable (Figure 11, 12). Multivariate tests comparing cable and control treatments for all species or all groups were non-significant ($p = 0.99$). Likewise, univariate tests evaluating the abundance of faunal groups or individual species indicated no significant variation in the megafaunal assemblage from directly over the cable to 50 m away. Thus, local variation in the megafaunal assemblage very near the cable was not detected.

One important exception to this pattern was observed near 300 m depth in 2008 in the Neck depth zone, where the cable is occasionally suspended 2–10 cm above the seabed between rocks for short distances. Within this 300 m-long segment of the cable route, the density of Longnose skates (*Raja rhina*) was anomalously high (Figure 9c) in 2008, before the cable was powered. The mean density of *R. rhina* was 33 100 m^{-2} over the cable, but only 0.3 100 m^{-2} at nearby control areas ($p = 0.027$).

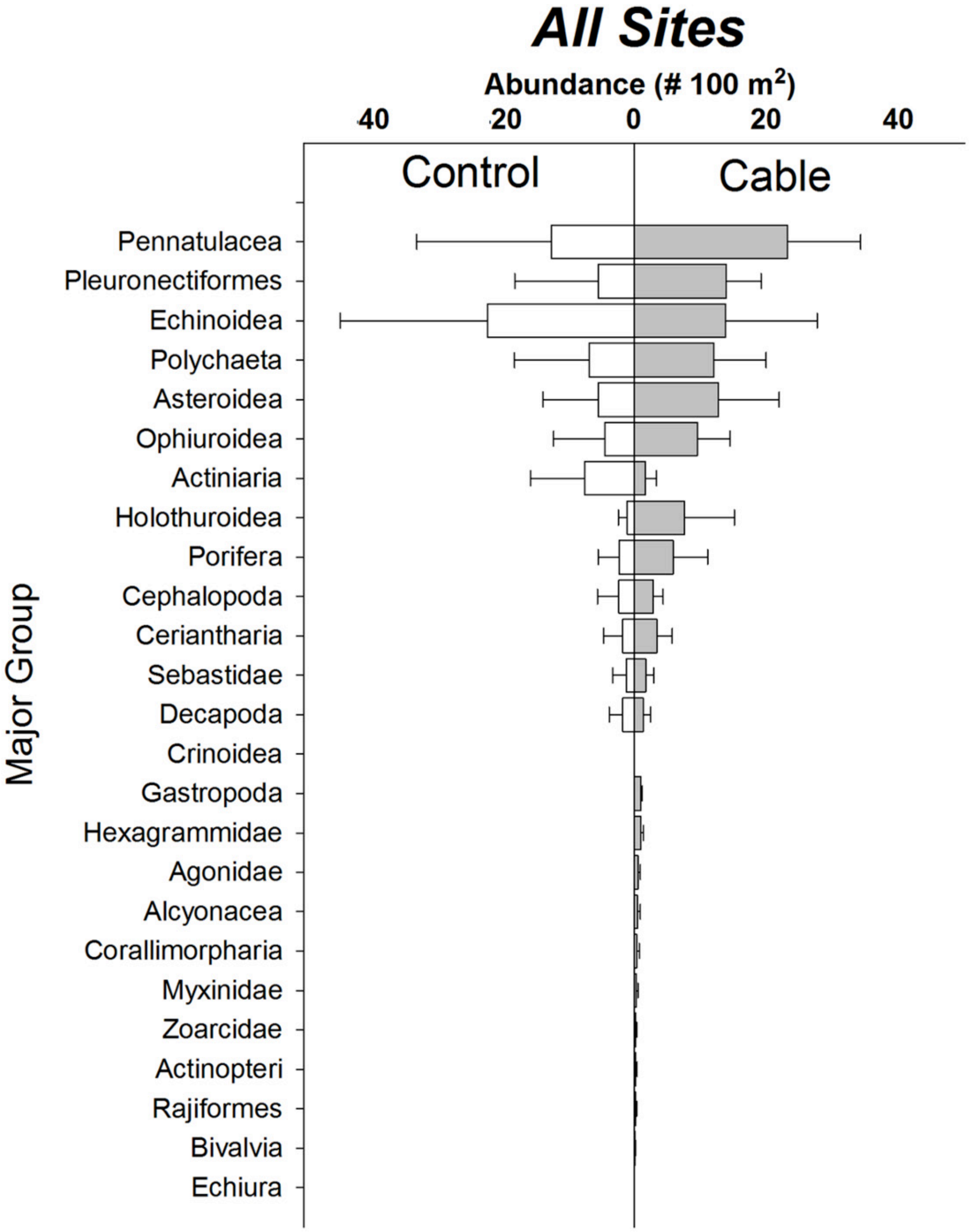

Figure 11. Variation in mean abundance (error bars = SEM) for megafaunal groups at stations along the cable route for the current sampling period.2015 survey. Paired transects for all sampling dates show little variation in the types and densities of megafaunal taxa over 10 sites along the cable (p = 0.99). Cable = directly over the cable route. Control = 50 m away from and parallel to the cable.

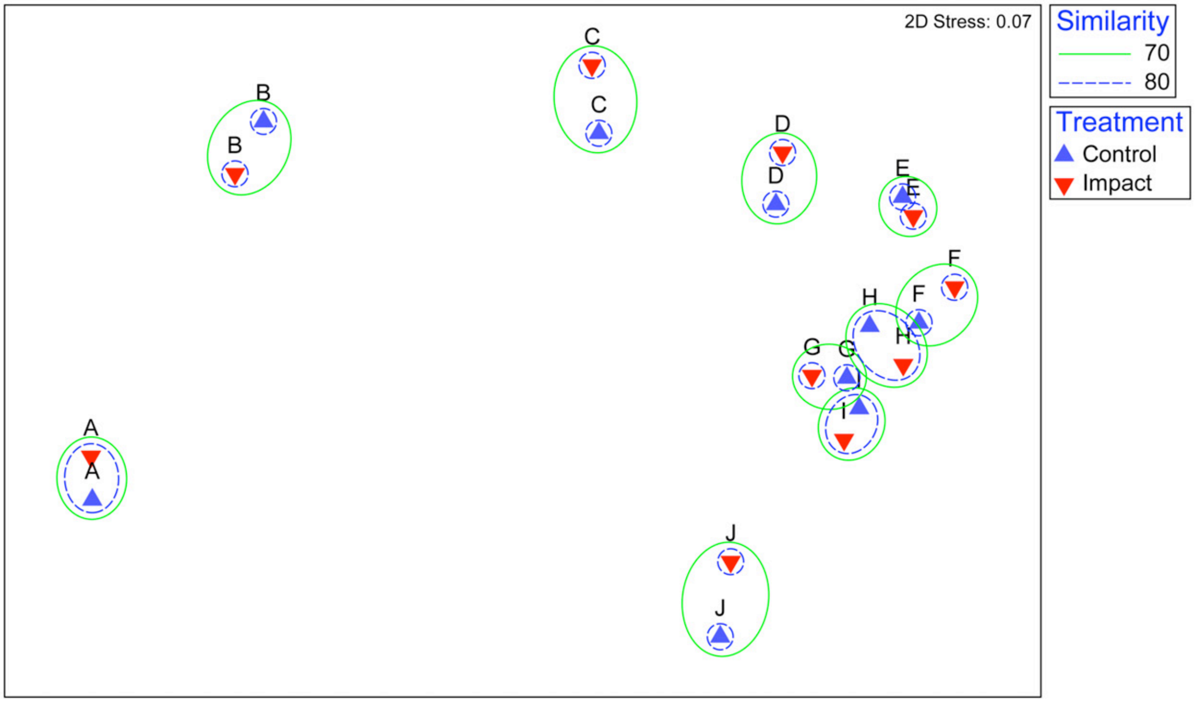

Figure 12. MDS plot based on Bray-Curtis Similarity Index for megafaunal assemblages at paired stations sampled through 2015, showing high similarity between biological communities at control and impact sites along the cable route and 50 m away. Letters refer to stations along the cable route (A = deepest station at 891 m, J = shallowest station at 19 m).

The densest aggregations were concentrated along a 75–100 m section, with the skates resting on the seafloor within 5–10 m of the unpowered cable. We also noted somewhat higher than normal numbers of the elasmobranchs *Parmaturus xaniurus* (catsharks) and *Hydrolagus colliei* (spotted ratfish) in this general area of the cable route, but off the transect. In 2010, when the cable was powered, no statistically significant difference in the number of skates present at the cable vs. distant from the cable was detected (Figure 9d); the mean number of *R. rhina* was 9.7 100 m^{-2}, vs. 6.3 100 m^{-2} at the nearby control transects ($p = 0.90$). The abundance of other elasmobranchs in the area appeared similar between the cable and nearby seabed. As in 2010, an overabundance of elasmobranchs was not observed near the powered cable in 2015.

A number of marine fishes, especially elasmobranchs are known to sense electromagnetic fields using electroreceptors as a method of prey detection (Bullock 1982). The suspended MARS cable very likely produced a weak electromagnetic field as local ocean currents flow through the Earth's magnetic field and around the cable (Sanford, 1971). This is possible even though the cable was not energized during the 2008 video survey. We noted that while the cable was taut and 2-10 cm off the seafloor in other areas with topographic highs and lows, no other skate aggregations were seen. The combination of topography (small scarps and sediment depressions unique to this area), natural distribution of the animals, and a mild electrical field may have contributed to the aggregation. This electric field may be detectable by *R. rhina*, which aggregated near the cable. Electric fields from seabed cables including telecommunications cables and power distribution cables (e.g. coastal windfarms) are expected to have ecological effects due to their effects on the behavior of various species capable of electroreception (Gill 2005).

Regional Effects of Cable Installation—Megafauna

The installation and presence of the MARS cable appears to have mild to benign effects on the structure of the megafaunal assemblages on the scale of kilometers, based on the results of samples from cable and control sites before and after cable installation (Figures 13–15). Using both multivariate and univariate analyses, few statistically significant differences in the densities of megafauna were detected in relation to the installation or presence of the cable.

For the BACI analyses used to evaluate changes related to the presence of the cable, a significant effect of cable installation would be indicated by a statistically significant Period x Treatment (PxT) interaction term for the abundance of a particular taxon (for univariate or multivariate tests). This result would indicate that the any change in the abundance of the taxon between periods (i.e., *Before* and *After* cable installation) at the cable stations was different than changes in abundance at control stations.

Few changes in the megafaunal community were attributable to the installation or presence of the cable at either the species/taxa level or group level (Table 4). At Shelf and Neck depths, multivariate comparisons (i.e., comparisons between the entire megafaunal assemblage) indicated no overall significant Period x Treatment interaction terms ($p = 0.11$, 0.15 respectively). While there were significant results for Ophiuroids (brittlestars) at the Shelf region, and for Pleuronectiformes (flatfishes) at the Neck region, we know that from our general benthic studies that both of these groups of animals are highly mobile and form ephemeral aggregations; these results may represent natural variability.

There was a significant effect of the cable in the Slope region at the higher taxon group level ($p = 0.03$), and the species/taxa level ($p = 0.01$). Holothurians (sea cucumbers) and marine snails (Gastropoda) may have been affected by the cable installation, as indicated by the significant PxT interactions (Table 4). The trench, before it was completely filled in, and the MARS node itself, may create habitat heterogeneity and organic enrichment in that region (Figure 7). Organic enrichment may have been due to the accumulation of *Phyllospadix* sp. (surf grass) strands and other detritus that was not observed at the Slope cable station during the pre-installation survey, but occurred there during the 2008–2015 surveys, resulting in the aggregation of *Pannychia moseleyi*, a holothurian that extracts nutrients from sediment. Gastropods (predators and omnivores) might be attracted because of increased habitat heterogeneity.

Multivariate tests also indicate that significant variation in megafaunal abundance is related to the main factors (Periods or Treatments, or both). Overall, these results indicate that most of the variation in the abundance and distribution of megafauna is due to natural variability between stations or periods – in other words, natural variation in megafaunal abundance among control stations was equal or greater than that measured between control and cable stations.

There were few other changes in the abundances of individual species in relation to the presence of the MARS cable, based on univariate tests to examine cable impacts. Even though the abundance of species or higher taxa frequently varied between Periods or Treatments (Table 4), very few significant PxT interaction terms were found, indicating little effect of the MARS cable. Univariate tests were conducted for the most abundant taxa representing the groups shown in Figure 13–15. Among these, the PxT interaction term was significant for only 3 of 13 tests. We have observed that the density of the sea pens (Pennatulacea) *Funiculina* sp. and *Umbellula lindahli* varies widely on a scale of only 10s of meters.

Although few effects of cable installation were detected, significant main effects (Treatment or Period) were found for some taxa and cable depth zones (Table 4). Closer examination of these frequently indicated that significant Treatment effects were related to statistically significant variation among control stations as well as differences between control and impact stations. Thus, natural variability in megafaunal abundance and distribution appears to be as large as differences in abundance related to the cable (Figure 16).

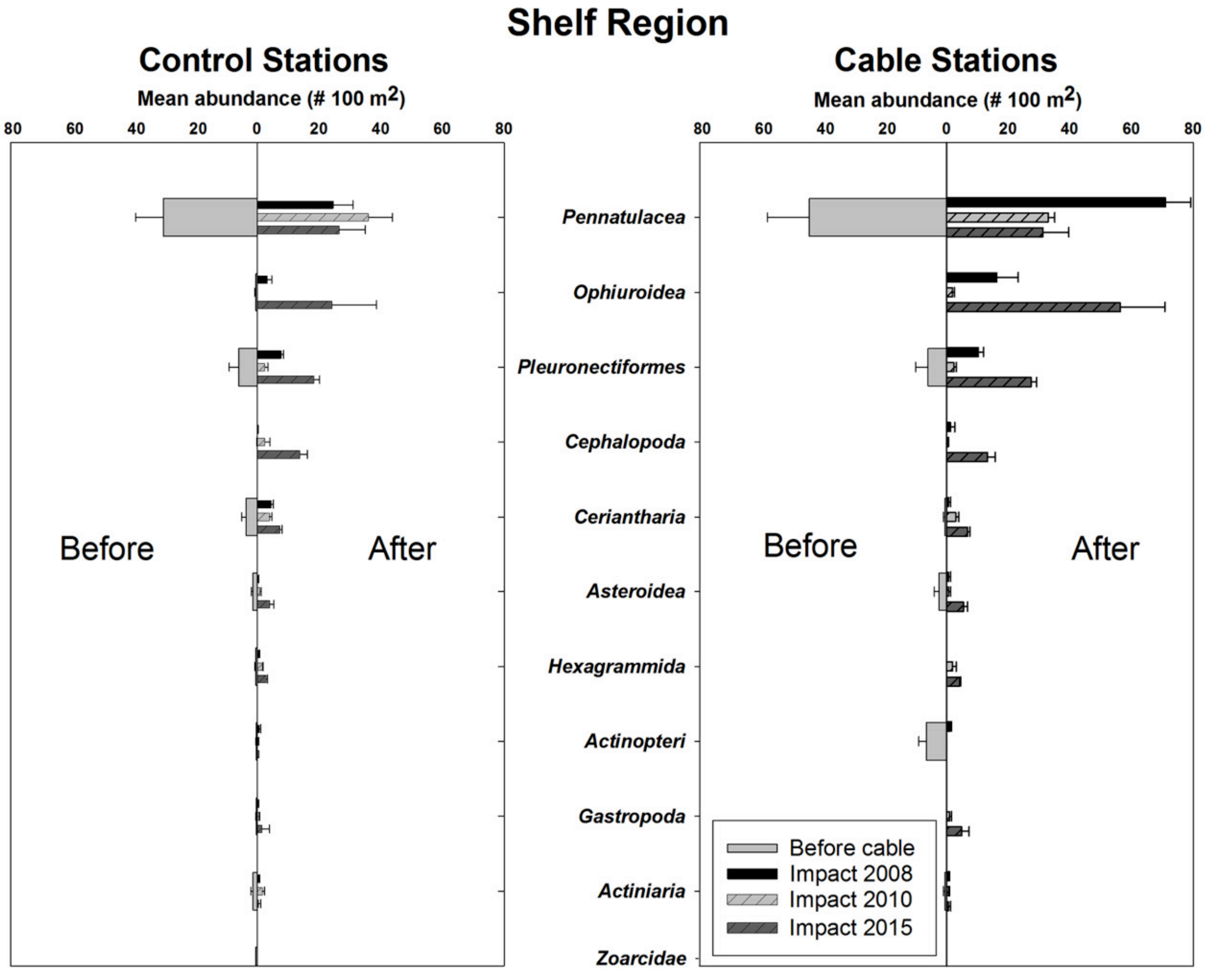

Figure 13. Variation in megafaunal abundance (by taxonomic groups) among treatments and periods at Shelf depth stations. BACI analysis indicated significant abundance changes over time ($p < 0.001$), but no overall significant effect of cable installation ($p > 0.05$) in this region for higher-level taxonomic groups. Error bars = stand error of the mean.

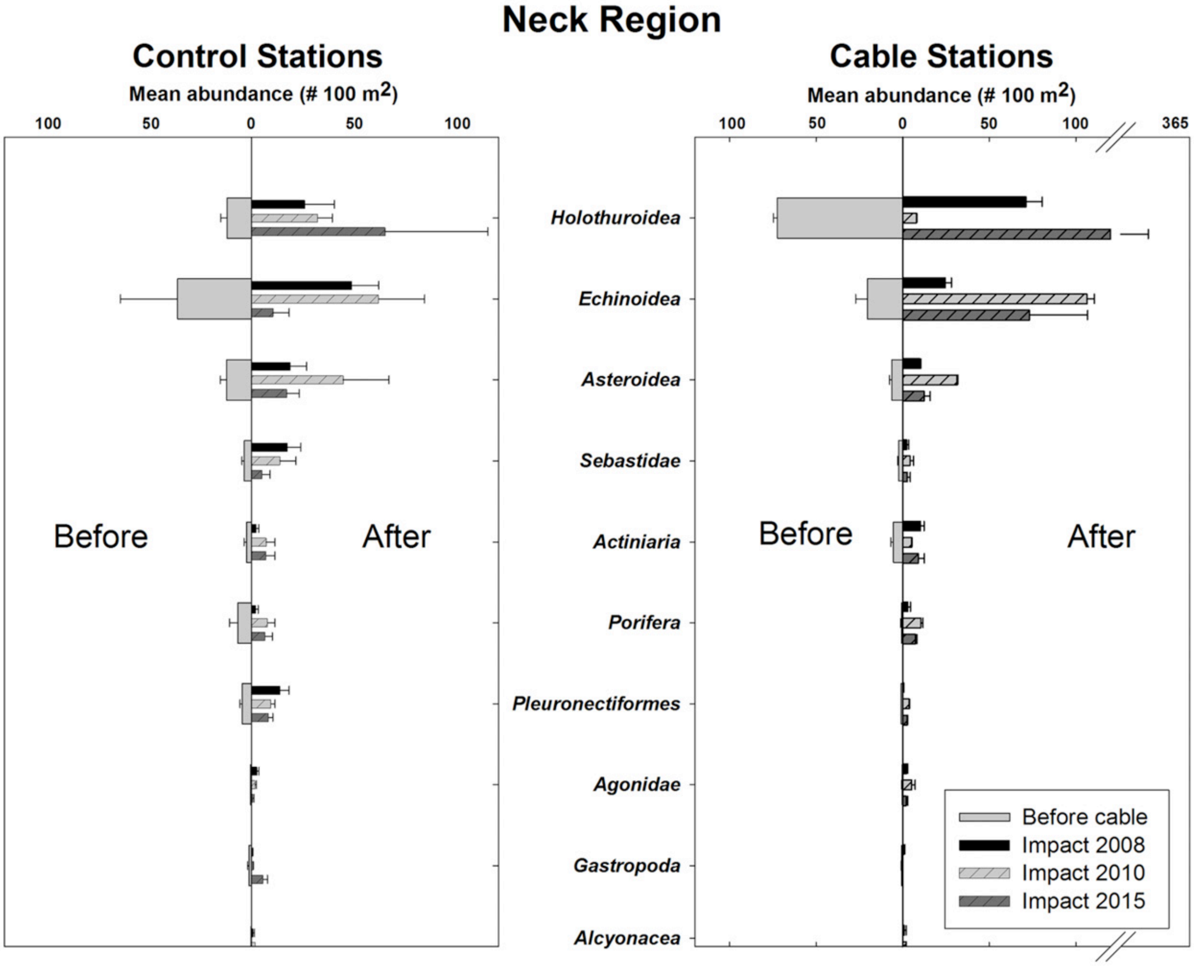

Figure 14. Variation in megafaunal assemblage among periods and treatments at Neck region stations. BACI analysis indicated no significant effect of cable installation ($p > 0.05$), nor abundance changes over time ($p > 0.05$), but an overall significant effect of cable installation ($p < 0.001$) in this region for higher-level taxonomic groups. Error bars = standard error of the mean.

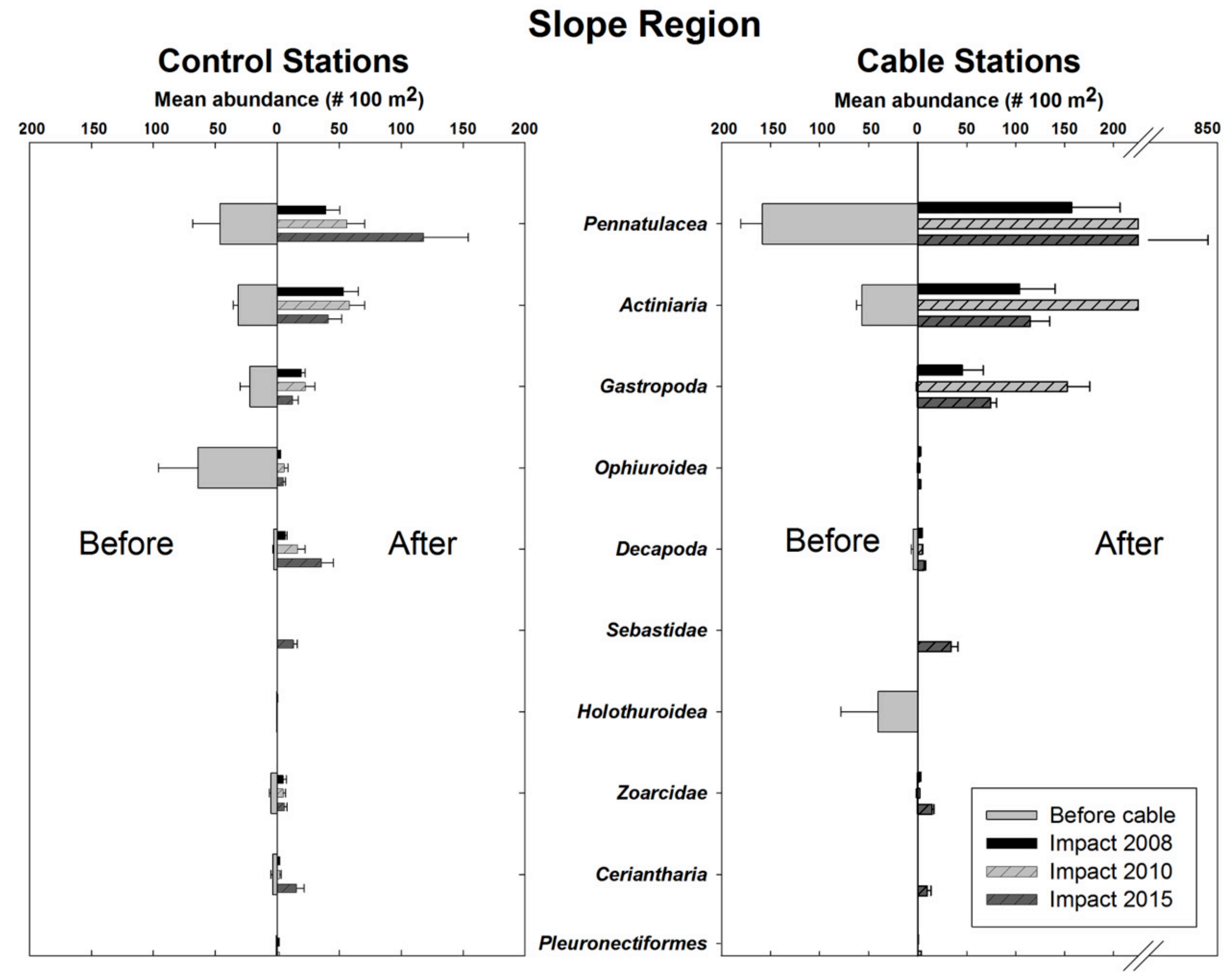

Figure 15. Variation in megafaunal abundance among treatments and periods at Slope region stations. BACI analysis indicated abundance changes over time ($p<0.001$), but and a significant effect of cable installation ($p<0.001$) in this region for higher-level taxonomic groups. Error bars = standard error of the mean.

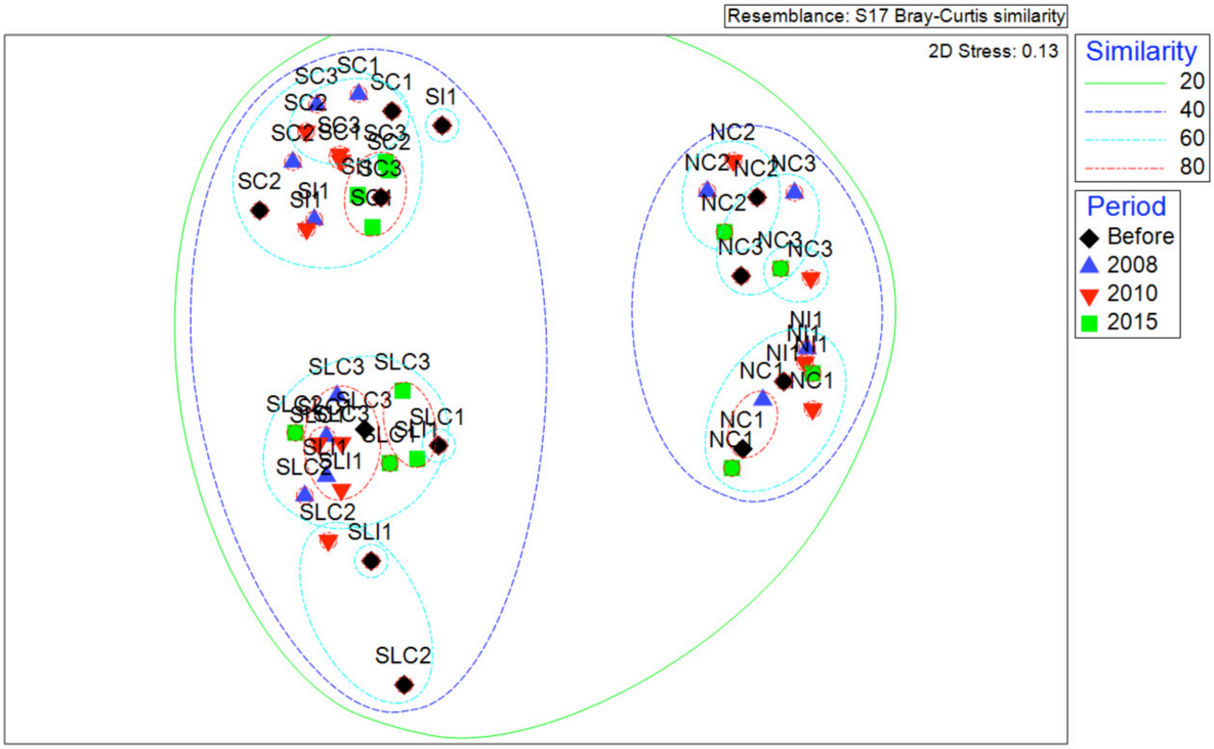

Figure 16. MDS plot based on Bray-Curtis Similarity Index. Regional megafaunal communities remained at least 60 percent similar in a comparison of community structure before the MARS cable was installed, and at 18 (2008), 36 months (2010) and 96 months (2015) post-installation. Stations clustered based on depth, with shelf, neck and slope stations most similar to each other.

Table 4. Summary of univariate BACI analysis for megafaunal taxa for all cable regions and periods. P= Period, T= Treatment, PxT = Period x Treatment interaction term. A significant PxT term suggests an effect of cable installation. Comments explain patterns of results or propose possible factors influencing differences detected among treatments. ** = sig. ≤0.001 * = sig. <0.05, - indicates absent from region. See Figures 13–15 for detail.

	SHELF			**NECK**			**SLOPE**			
Taxon	**P**	**T**	**PxT**	**P**	**T**	**PxT**	**P**	**T**	**PxT**	**Comment**
Higher Taxa										
Multivariate Tests										
All Groups	**	*	ns	ns	**	ns	**	**	*	
Univariate Tests										
Actinaria (anemones)	ns	ns	ns	ns	*	ns	*	**	ns	> After cable inst.
Ceriantharia (tube anemones)	*	ns	ns	ns	ns	ns	*	ns	ns	Natural variability
Pennatulacea (sea pens)	ns	ns	ns	ns	ns	ns	*	**	ns	Sig. station variab.
Asteroidea (sea stars)	**	ns	ns	ns	**	ns	ns	ns	ns	Natural variability
Echinoidea (sea urchins)	-	-	-	ns	*	ns	ns	ns	ns	Cable > Control
Holothuroidea (sea cucumbers)	*	ns	ns	ns	*	ns	**	**	**	Natural variability? Detritus?
Ophiuroidea (brittle stars)	**	**	*	ns	ns	ns	ns	ns	ns	Natural variability
Gastropoda (snails)	*	ns	ns	ns	ns	ns	**	ns	**	> After cable inst.
Pleuronectiformes (flatfishes)	**	ns	ns	*	**	*	**	ns	ns	Control > Cable and Natural variability
Sebastidae (rockfish)	ns	ns	ns	ns	ns	ns	ns	ns	ns	

	SHELF			**NECK**			**SLOPE**			
Taxon	**P**	**T**	**PxT**	**P**	**T**	**PxT**	**P**	**T**	**PxT**	**Comment**
Species										
Multivariate Tests										
All Species	**	*	ns	*	**	ns	**	**	*	
Univariate Tests										
Funiculina sp. (sea pen)	-	-	-	-	-	-	ns	**	ns	Sig. station variation
Rathbunaster californicus (sea star)	ns	ns	ns	ns	*	**	ns	ns	ns	Cable > Control
Stronglylocentrotus fragilis (urchin)	-	-	-	ns	*	ns	ns	ns	ns	Cable > Control
Psolus squamatus (sea cucumber)	-	-	-	ns	ns	ns	-	-	-	
Isoscyonis sp. (anemone)	-	-	-	-	-	-	*	**	ns	> After cable inst.
Umbellula lindahli (sea pen)	-	-	-	-	-	-	**	ns	ns	Natural variability
Actinostolidae (anemone)	-	-	-	ns	ns	ns	**	ns	**	Cable > Control
Florometra serratissima (crinoid)	-	-	-	ns	**	ns	-	-	-	> after cable inst.
Pannychia mosleyi (sea cucumber)	-	-	-	-	-	-	**	*	**	Cable > Control

Regional Effects of Cable Installation—Macrofauna

Macrofaunal assemblages (Table 5) along the cable route appear to be largely unaffected by the installation and presence of the cable.

Multivariate tests for the Shelf region indicates a significant PxT interaction term at the taxonomic group level (Table 6). There was no detectable cable effect in the Neck and Slope regions. Owing to the overwhelming dominance of polychaete worms in the macrofauna (Table 5, Figures 17–19), at the Shelf depth zone in particular, this group has a large influence on the outcome of this multivariate test.

In the Shelf depth zone, the cable is fully buried in this sandy region, and there has been no visible evidence of detrital accumulation or seabed alteration from within just weeks of the cable installation. The abundance of polychaetes, and thus the macrofauna in general, increased after cable installation, but increased far more at the Shelf cable station than at Shelf control stations (Figures 17–19). Simultaneously, the abundance of most other macrofaunal taxa at control stations decreased in 2010, then increased in 2015. While it is possible that the installation of the cable increased the suitability of the habitat for polychaetes in particular it seems equally or more likely that other factors (e.g., natural variability, sample method difference in "before" samples) had greater influence on polychaete abundance.

A large pulse of brittlestars (Ophiuroidea, Figure 17) was observed at the Shelf in 2010, particularly at the control station. High ophiuroid abundance also occurred in 2015 in the Neck region at both control and cable stations. Brittle star aggregations are a natural phenomenon and unrelated to the presence or absence of the cable. Amphipods are also dominant infauna in the Shelf and Neck depth zone. Before the cable was installed, they were far more abundant at the Shelf cable station compared to the control station. Abundance was even higher 18 months-post installation, but trended more toward the "before" numbers in 2010. In 2015 there were larger abundances of both Amphipods and Tanaids, which is likely a natural event.

All of these results, when taken together, indicate few detectable effects of the MARS cable on seabed biology, and are similar to results reported in other studies. Kogan et al. (2003) reported that few statistically significant effects of the ATOC submarine cable were detectable. They noted that the major effect of the cable was on organisms that attached to it, especially anemones, and also reported erosion of the seabed by strumming of the exposed cable at shallow depths.

Table 5. Mean density of macrofaunal taxa, by group over all samples. Density is listed as number per core (area = 37.39 cm^2), with the standard error of the mean (SE). % indicates the percentage of total macrofaunal abundance.

Phylum	Group	Mean	SE	%
Annelida		**29.92**	**1.70**	**51.1**
	Polychaeta	26.71	1.28	45.6
	Oligochaeta	2.88	0.32	4.9
	Echiura	0.33	0.10	0.6
Arthropoda		**18.74**	**1.86**	**31.9**
	Amphipoda	11.26	0.86	19.2
	Tanaidacea	3.05	0.44	5.2
	Isopoda	1.50	0.16	2.6
	Ostracoda	1.47	0.23	2.5
	Cumacea	1.37	0.14	2.3
	Mysida	0.08	0.02	0.1
	Decapoda	0.01	0.01	0.0
Mollusca		**5.44**	**0.52**	**9.2**
	Bivalvia	3.93	0.30	6.7
	Gastropoda	0.91	0.12	1.5
	Scaphopoda	0.45	0.06	0.8
	Aplacophora	0.13	0.03	0.2
	Polyplacophora	0.02	0.01	0.0
Echinodermata		**2.44**	**0.40**	**4.2**
	Ophiuroidea	2.40	0.38	4.1
	Holothuroidea	0.03	0.01	0.1
	Echinoidea	0.01	0.01	0.0
Nemertea		**1.37**	**0.12**	**2.3**
Cnidaria		**0.37**	**0.08**	**0.7**
Platyhelminthes		**0.13**	**0.04**	**0.2**
Enteropneusta		**0.08**	**0.03**	**0.1**
Sipuncula		**0.07**	**0.02**	**0.1**
Kinorhyncha		**0.04**	**0.02**	**0.1**
Phoronida		**0.03**	**0.01**	**0.1**
Grand Total		**58.63**		

Table 6. Summary of BACI analysis for macrofaunal taxa. P = Period, T= Treatment, PxT = Period x Treatment interaction term. A significant PxT term suggests an effect of cable installation. Comments explain patterns of results or propose possible factors influencing differences detected among treatments. * = p<0.05, ** = p≤0.001. See Figures 17–19 for detail.

	SHELF			**NECK**			**SLOPE**			
Taxon	**P**	**T**	**PxT**	**P**	**T**	**PxT**	**P**	**T**	**PxT**	**Comment**
Higher Taxa										
Multivariate Tests										
All Groups	**	*	**	*	**	ns	*	**	ns	
Univariate Tests										
Polychaeta (worms)	**	ns	*	ns	ns	ns	ns	ns	ns	Sampling difference before vs. after?
Amphipoda (crustacea)	*	ns	ns	ns	*	ns	ns	*	ns	Natural variation over time at shelf region, higher abund. at cable in Neck region, lower at Slope region
Bivalvia (clams)	**	ns	ns	ns	**	ns	ns	**	ns	Natural variation over time at Shelf region, lower abundance at cable in Neck and Slope regions
Oligochaeta (worms)	**	ns	ns	ns	**	ns	**	*	ns	Natural variation over time at shelf region, higher abund. at cable in Neck region and Slope regions.
Tanaidacea (crustacea)	**	ns	*	ns	**	ns	ns	ns	ns	Natural variation over time at shelf region, higher abund. at cable in Neck region
Isopoda (crustacea)	ns	ns	ns	ns	ns	ns	ns	ns	ns	
Ostracoda (crustacea)	ns	ns	ns	ns	**	ns	ns	ns	ns	Impact>control at neck region
Ophiuroidea (brittle stars)	**	ns	ns	**	ns	ns	ns	ns	ns	Natural variation

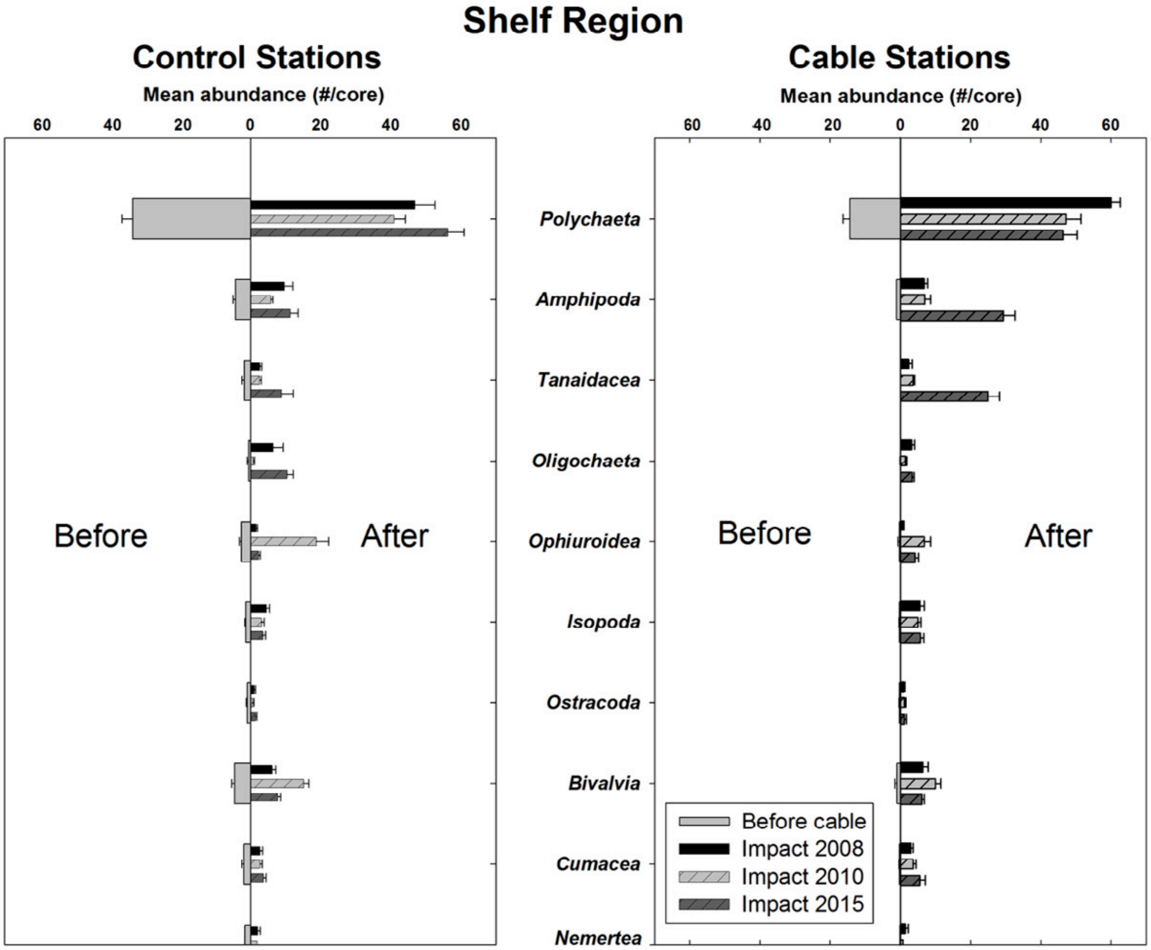

Figure 17. Variation in the abundance of major groups of macrofaunal taxa at the Shelf cable region among treatments and periods. Error bars = standard error of the mean.

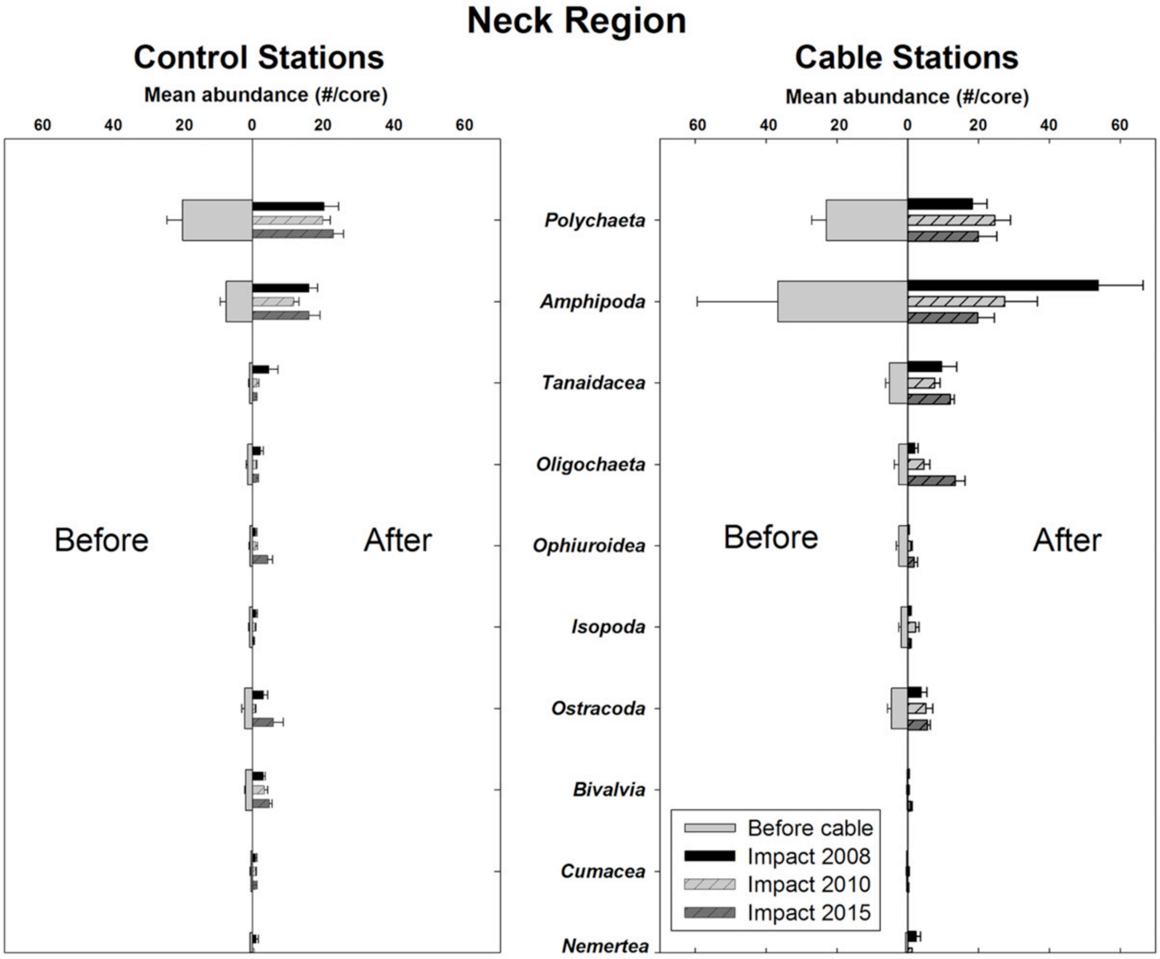

Figure 18. Variation in the abundance of major groups of macrofaunal taxa at the Neck cable region among treatments and periods. Error bars = standard error of the mean.

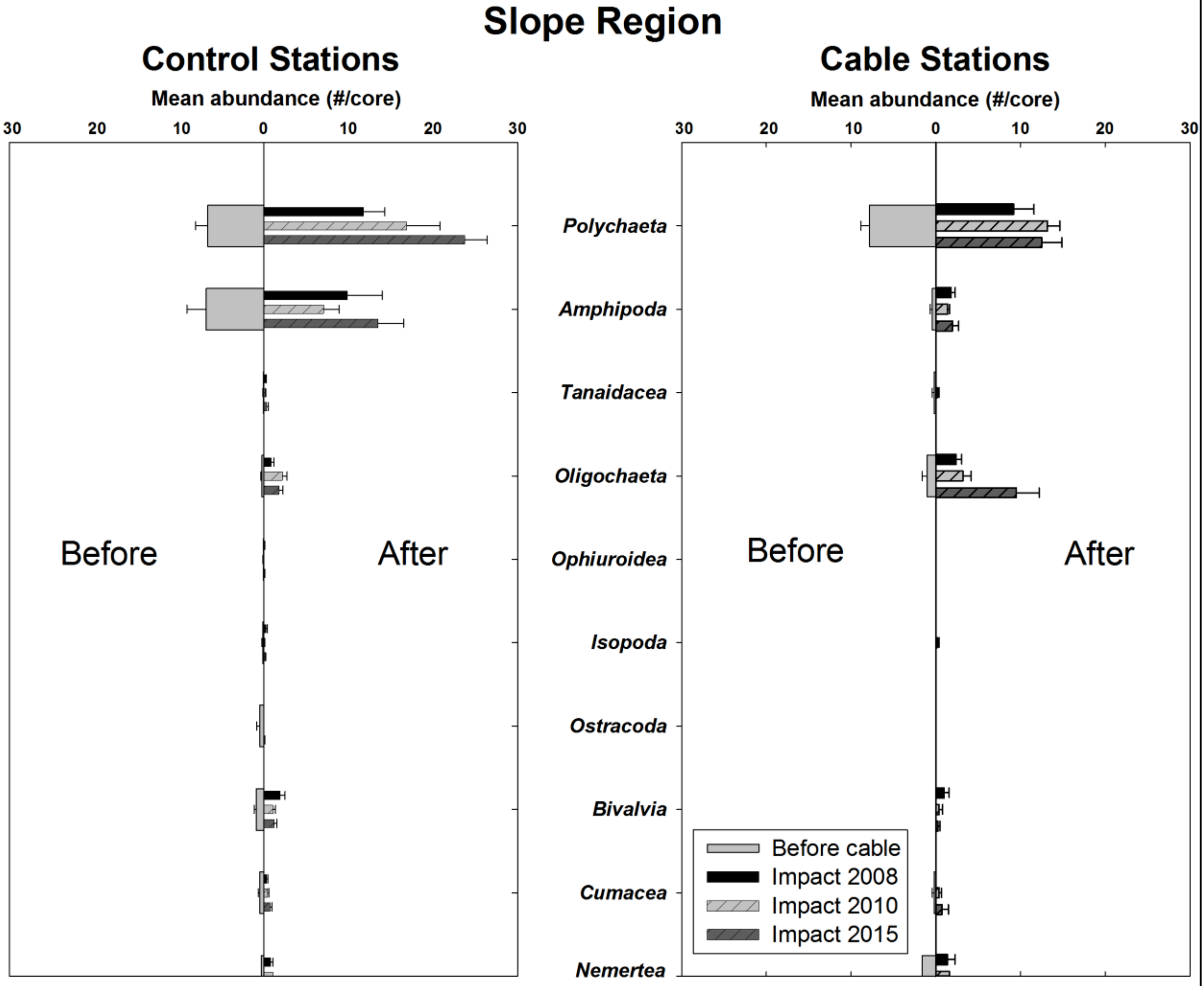

Figure 19. Variation in the abundance of major groups of macrofaunal taxa at the Slope cable region among treatments and periods. Error bars = standard error of the mean.

Other factors influencing faunal patterns

Several other factors may have influenced the variability observed in the abundance and distribution of benthic megafauna and macrofauna in relation to the installation of the MARS cable. First, the geological and biological sampling program included a few samples collected as early as 1999 and 2001, which were included in the "before" samples collected principally during 2008. Therefore, estimates of faunal abundance during this extended "before" sampling period reflect the natural variability of local benthic communities. Considering that the 2007–2008 and 2010 samples were collected over only a few months, they reflect a short-term "snap shot" of the benthic faunal communities.

Second, although the vast majority of sediment samples were collected using the same method (6.9 inch diameter tube core), 4 samples (from 1999) were collected using a Smith-MacIntyre Grab (0.1 x 0.1 m). The abundances of macrofauna derived from these samples were adjusted to 37.39 cm^2 (the area of a tube core), but differences in the collection efficiency of the two devices is likely to affect the results.

Third, there were no adjustments of probability levels to account for the large number of statistical tests. Over 100 statistical tests were performed, using an α of 0.05—that is the probability of a type 1 error (rejecting a true null hypothesis) is 1 in 20. Thus, for 100 statistical tests, one would by chance detect a significant effect (e.g. Period x Treatment interaction term indicating an effect of the MARS cable) approximately 5 times. There are methods of reducing α to further reduce the probability of a type 1 error, but this is generally avoided, since it also increases type II errors (the acceptance of a false null hypothesis) (Cabin and Mitchell 2000).

CONCLUSIONS

Inspection of the MARS cable, coupled with a sampling program to evaluate changes in geological and biological conditions on local and regional scales with respect to the installation of the cable indicate little detectable influence of the cable. The most conspicuous evidence of cable installation is the cable exposed on the seabed for a short distance where it could not be buried. Analyses of the geological and biological sampling program indicate the following:

- Over most of its length, the cable remains buried, with little evidence of change since installation
- Changes in mean grain size were undetectable in relation to the MARS cable.
- The percent organic carbon content of sediments increased near the MARS cable at some depths, possibly due to natural variation or the effects of the cable or both.
- Local variation in benthic megafaunal communities within 50–100 m of the MARS cable is minor or undetectable.
    - The abundances of most animals observed did not differ between the area over the cable route and 50 m away

  - Longnose skates *(Raja rhina*) were significantly more abundant in one area where the MARS cable is suspended over topography (~300 m depth) in 2008. These animals may have responded to weak electromagnetic fields generated by the cable. After 2010, when the cable was energized, the numbers of *R. rhina* were near background levels near and distant from the cable.
- The MARS cable has little effect on the distribution and abundance of macrofaunal and megafaunal assemblages on a regional scale (e.g. kilometers).
  - Megafauna and macrofauna compared before and after cable installation among three control stations and one cable station at each of three depth zones (Shelf: <200 m, Neck: 200-500 m, Slope: >500 m) indicated relatively few potential changes in benthic biological patterns due to the MARS cable.
  - Natural spatial and temporal variation in the abundance and distribution of benthic macrofauna and megafauna appears to be greater than any detectable effects of the MARS cable.

Video of the entire cable route has been copied to DVDs or hard drives and provided to agencies with each successive report.

ACKNOWLEDGEMENTS

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Appendix 1. ROV video transect information. Transect Code (Tr. Code), Site/Station (Loc.), Cable depth region (Region), Treatment (control or cable location), Period (before or after (date) cable installation), depth in meters, Date, Dive number.

Tr. Code	**Loc.**	**Region**	**Treatment**	**Period**	**Latitude**	**Longitude**	**Depth (m)**	**Date**	**Dive #**
A-A-2008	A	All	Cable	2008	36.756899	-122.188391	710	12/12/07	V3139
A-B-2008	A	All	Control	2008	36.756899	-122.18771	724	12/12/07	V3139
A-A-2010	A	All	Cable	2010	36.756645	-122.188324	720	1/27/10	V3500
A-B-2010	A	All	Control	2010	36.757187	-122.18779	713	1/27/10	V3500
A-A-2015	A	All	Cable	2015	36.756645	-122.188324	720	12/17/14	D703
A-B-2015	A	All	Control	2015	36.757187	-122.18779	713	12/17/14	D703
B-A-2008	B	All	Cable	2008	36.79973	-122.186883	435	1/29/08	V3164
B-B-2008	B	All	Control	2008	36.799712	-122.18629	431	1/29/08	V3164
B-A-2010	B	All	Cable	2010	36.800182	-122.18656	431	1/29/10	V3506
B-B-2010	B	All	Control	2010	36.799267	-122.18654	436	1/29/10	V3506
B-A-2015	B	All	Cable	2015	36.800182	-122.18656	431	12/18/14	D705
B-B-2015	B	All	Control	2015	36.799267	-122.18654	436	12/18/14	D705
C-A-2008	C	All	Cable	2008	36.836974	-122.158251	172	1/31/08	V3167
C-B-2008	C	All	Control	2008	36.83734	-122.158864	162	1/31/08	V3167
C-A-2010	C	All	Cable	2010	36.836964	-122.15846	168	1/13/10	V3488
C-B-2010	C	All	Control	2010	36.836964	-122.15717	153	1/13/10	V3488
C-A-2015	C	All	Cable	2015	36.836964	-122.15846	168	12/18/15	V3893
C-B-2015	C	All	Control	2015	36.836964	-122.15717	153	12/18/15	V3893
D-A-2008	D	All	Cable	2008	36.857358	-122.10881	95	2/8/08	V3169
D-B-2008	D	All	Control	2008	36.856905	-122.108491	94	2/8/08	V3169
D-A-2010	D	All	Cable	2010	36.857227	-122.109116	92	1/28/10	V3503
D-B-2010	D	All	Control	2010	36.857254	-122.107834	92	1/28/10	V3503
D-A-2015	D	All	Cable	2015	36.857227	-122.109116	92	7/9/15	V3842
D-B-2015	D	All	Control	2015	36.857254	-122.107834	92	7/9/15	V3842
E-A-2008	E	All	Cable	2008	36.879787	-122.059782	72	4/1/08	V3186
E-B-2008	E	All	Control	2008	36.880117	-122.060248	71	4/1/08	V3186
E-A-2010	E	All	Cable	2010	36.879307	-122.06125	73	2/25/10	V3526
E-B-2010	E	All	Control	2010	36.88006	-122.060875	72	2/25/10	V3526
E-A-2015	E	All	Cable	2015	36.879307	-122.06125	73	12/18/15	V3895
E-B-2015	E	All	Control	2015	36.88006	-122.060875	72	12/18/15	V3895
F-A-2008	F	All	Cable	2008	36.885715	-122.00602	48	4/1/08	V3186
F-B-2008	F	All	Control	2008	36.885231	-122.006393	49	4/1/08	V3186
F-A-2010	F	All	Cable	2010	36.885746	-122.00542	48	4/9/10	V3551

Tr. Code	Loc.	Region	Treatment	Period	Latitude	Longitude	Depth (m)	Date	Dive #
F-B-2010	F	All	Control	2010	36.88624	-122.00661	48	4/9/10	V3551
F-A-2015	F	All	Cable	2015	36.885746	-122.00542	48	7/14/15	V3844
F-B-2015	F	All	Control	2015	36.88624	-122.00661	48	7/14/15	V3844
G-A-2008	G	All	Cable	2008	36.883813	-121.949321	39	1/8/08	V3149
G-B-2008	G	All	Control	2008	36.883895	-121.949741	40	1/8/08	V3149
G-A-2010	G	All	Cable	2010	36.883705	-121.94973	39	4/9/10	V3552
G-B-2010	G	All	Control	2010	36.884678	-121.950645	37	4/9/10	V3552
G-A-2015	G	All	Cable	2015	36.883705	-121.94973	39	7/14/15	V3845
G-B-2015	G	All	Control	2015	36.884678	-121.950645	37	7/14/15	V3845
H-A-2008	H	All	Cable	2008	36.868305	-121.895886	44	1/28/08	V3163
H-B-2008	H	All	Control	2008	36.867867	-121.896324	44	1/28/08	V3163
H-A-2010	H	All	Cable	2010	36.86803	-121.896835	46	4/9/10	V3553
H-B-2010	H	All	Control	2010	36.86886	-121.89786	44	4/9/10	V3553
H-A-2015	H	All	Cable	2015	36.86803	-121.896835	46	7/14/15	V3845
H-B-2015	H	All	Control	2015	36.86886	-121.89786	44	7/14/15	V3845
I-A-2008	I	All	Cable	2008	36.848015	-121.845586	26	1/22/10	V3173
I-B-2008	I	All	Control	2008	36.847485	-121.84478	26	1/22/10	V3173
I-A-2010	I	All	Cable	2010	36.848717	-121.8471	26	4/9/10	V3554
I-B-2010	I	All	Control	2010	36.849445	-121.84756	26	4/9/10	V3554
I-A-2015	I	All	Cable	2015	36.848717	-121.8471	26	7/15/15	V3846
I-B-2015	I	All	Control	2015	36.849445	-121.84756	26	7/15/15	V3846
J-A-2008	J	All	Cable	2008	36.815585	-121.807344	20	3/31/08	V3184
J-B-2008	J	All	Control	2008	36.816038	-121.806923	20	3/31/08	V3184
J-A-2010	J	All	Cable	2010	36.81612	-121.80773	20	4/9/10	V3555
J-B-2010	J	All	Control	2010	36.817257	-121.80802	19	4/9/10	V3555
J-A-2015	J	All	Cable	2015	36.81612	-121.80773	20	7/15/15	V3846
J-B-2015	J	All	Control	2015	36.817257	-121.80802	19	7/15/15	V3846
NC1-A-2008	NC-1	Neck	Control	2008	36.788543	-122.117341	399	1/30/08	V3165
NC1-B-2008	NC-1	Neck	Control	2008	36.789039	-122.117852	394	1/30/08	V3165
NC1-C-2008	NC-1	Neck	Control	2008	36.789491	-122.116151	386	1/30/08	V3165
NC1-A-2010	NC-1	Neck	Control	2010	36.788597	-122.11637	402	1/8/10	V3483
NC1-B-2010	NC-1	Neck	Control	2010	36.78881	-122.11577	401	1/8/10	V3483
NC1-C-2010	NC-1	Neck	Control	2010	36.789043	-122.116936	392	1/8/10	V3483
NC1-A-2005	NC-1	Neck	Control	Before	36.789158	-122.12428	401	7/13/05	V2687
NC1-B-2005	NC-1	Neck	Control	Before	36.789383	-122.12514	400	7/13/05	V2687
NC1-C-2005	NC-1	Neck	Control	Before	36.788088	-122.121619	400	7/13/05	V2687

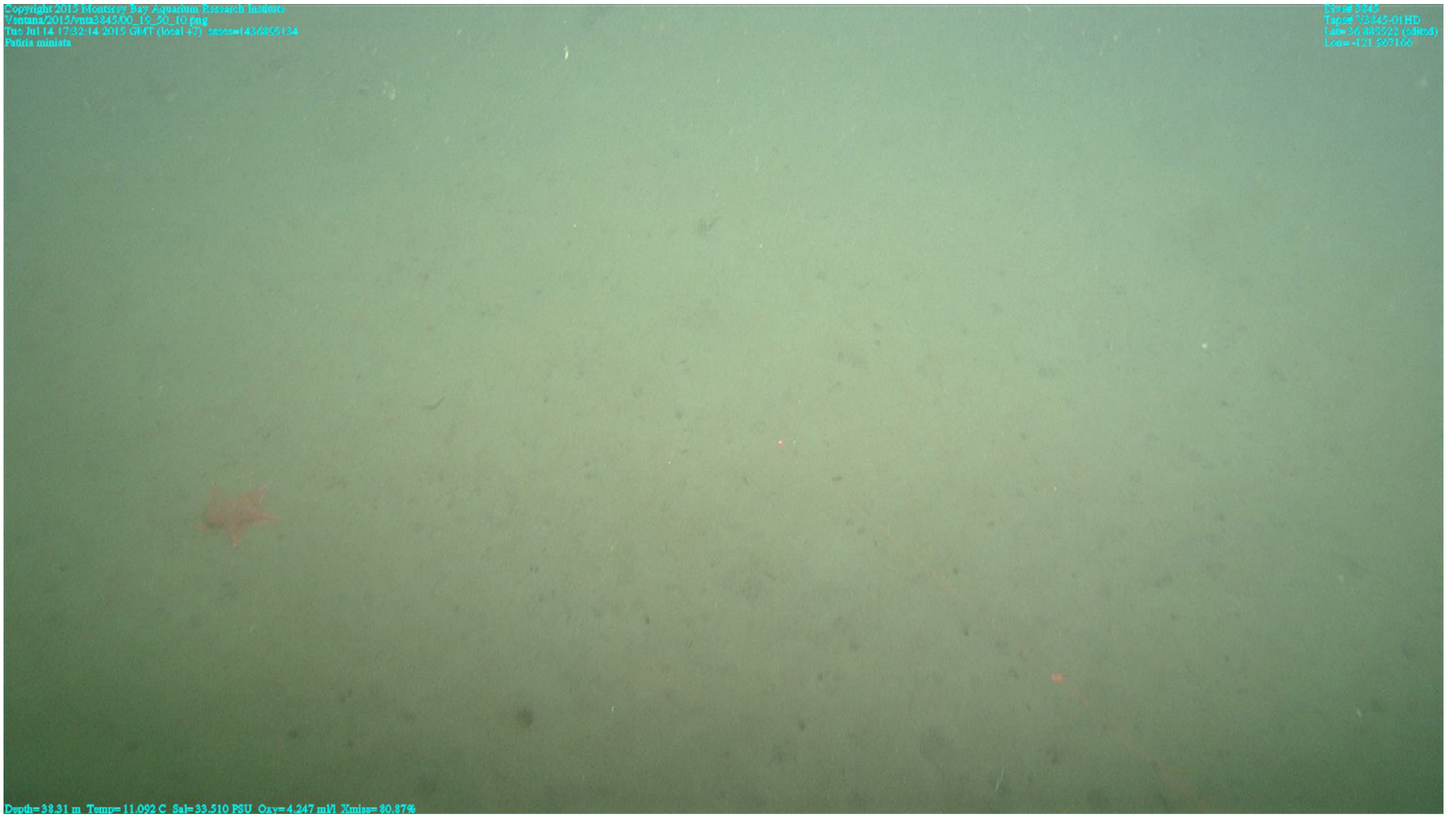
Tr. Code	Loc.	Region	Treatment	Period	Latitude	Longitude	Depth (m)	Date	Dive #
NC1-A-2015	NC-1	Neck	Control	2015	36.788597	-122.11637	402	12/19/14	D706
NC1-B-2015	NC-1	Neck	Control	2015	36.78881	-122.11577	401	12/19/14	D706
NC1-C-2015	NC-1	Neck	Control	2015	36.789043	-122.116936	392	12/19/14	D706
NC2-A-2008	NC-2	Neck	Control	2008	36.799381	-122.107564	207	1/30/08	V3165
NC2-B-2008	NC-2	Neck	Control	2008	36.799928	-122.108486	189	1/30/08	V3165
NC2-C-2008	NC-2	Neck	Control	2008	36.799216	-122.108455	195	1/30/08	V3165
NC2-A-2010	NC-2	Neck	Control	2010	36.79893	-122.1077	205	1/8/10	V3483
NC2-B-2010	NC-2	Neck	Control	2010	36.798664	-122.10672	208	1/8/10	V3483
NC2-C-2010	NC-2	Neck	Control	2010	36.798023	-122.10778	222	1/8/10	V3483
NC2-A-2005	NC-2	Neck	Control	Before	36.803011	-122.122515	196	8/1/05	V2696
NC2-B-2005	NC-2	Neck	Control	Before	36.803356	-122.123501	197	8/1/05	V2696
NC2-C-2005	NC-2	Neck	Control	Before	36.803646	-122.124485	198	8/1/05	V2696
NC2-A-2015	NC-2	Neck	Control	2015	36.79893	-122.1077	205	12/16/14	D701
NC2-B-2015	NC-2	Neck	Control	2015	36.798664	-122.10672	208	12/16/14	D701
NC2-C-2015	NC-2	Neck	Control	2015	36.798023	-122.10778	222	12/16/14	D701
NC3-A-2008	NC-3	Neck	Control	2008	36.842894	-122.187867	361	1/24/08	V3162
NC3-B-2008	NC-3	Neck	Control	2008	36.842918	-122.187669	352	1/24/08	V3162
NC3-C-2008	NC-3	Neck	Control	2008	36.842812	-122.186766	356	1/24/08	V3162
NC3-A-2010	NC-3	Neck	Control	2010	36.842316	-122.18726	358	1/14/10	V3490
NC3-B-2010	NC-3	Neck	Control	2010	36.84169	-122.186264	360	1/14/10	V3490
NC3-C-2010	NC-3	Neck	Control	2010	36.842228	-122.18566	349	1/14/10	V3490
NC3-A-2006	NC-3	Neck	Control	Before	36.842645	-122.189108	361	10/3/06	V2899
NC3-B-2006	NC-3	Neck	Control	Before	36.84212	-122.189979	368	10/3/06	V2899
NC3-A-2015	NC-3	Neck	Control	2015	36.842316	-122.18726	358	12/19/14	D707
NC3-B-2015	NC-3	Neck	Control	2015	36.84169	-122.186264	360	12/19/14	D707
NC3-C-2015	NC-3	Neck	Control	2015	36.842228	-122.18566	349	12/19/14	D707
NI1-A-2008	NI-1	Neck	Cable	2008	36.824453	-122.169606	321	1/31/08	V3167
NI1-B-2008	NI-1	Neck	Cable	2008	36.824886	-122.170095	318	1/31/08	V3167
NI1-C-2008	NI-1	Neck	Cable	2008	36.824287	-122.170539	323	1/31/08	V3167
NI1-A-2010	NI-1	Neck	Cable	2010	36.82433	-122.170204	323	1/13/10	V3488
NI1-B-2010	NI-1	Neck	Cable	2010	36.82388	-122.17008	324	1/13/10	V3488
NI1-C-2010	NI-1	Neck	Cable	2010	36.824795	-122.16919	321	1/13/10	V3488
NI1-A-1999	NI-1	Neck	Cable	Before	36.824453	-122.169606	325	1999	MCI-Pref325
NI1-B-1999	NI-1	Neck	Cable	Before	36.824886	-122.170095	325	1999	MCI-Pref325
NI1-C-1999	NI-1	Neck	Cable	Before	36.824287	-122.170539	325	1999	MCI-ACA325
NI1-A-2015	NI-1	Neck	Cable	2015	36.82433	-122.170204	323	12/19/14	D708

Tr. Code	Loc.	Region	Treatment	Period	Latitude	Longitude	Depth (m)	Date	Dive #
NI1-B-2015	NI-1	Neck	Cable	2015	36.82388	-122.17008	324	12/19/14	D708
NI1-C-2015	NI-1	Neck	Cable	2015	36.824795	-122.16919	321	12/19/14	D708
SC1-A-2008	SC-1	Shelf	Control	2008	36.714458	-121.909033	89	11/30/07	V3135
SC1-B-2008	SC-1	Shelf	Control	2008	36.714299	-121.908597	90	11/30/07	V3135
SC1-C-2008	SC-1	Shelf	Control	2008	36.713548	-121.907717	89	11/30/07	V3135
SC1-A-2010	SC-1	Shelf	Control	2010	36.715485	-121.90863	88	2/18/10	V3518
SC1-B-2010	SC-1	Shelf	Control	2010	36.714436	-121.90862	88	2/18/10	V3518
SC1-C-2010	SC-1	Shelf	Control	2010	36.71479	-121.90738	88	2/18/10	V3518
SC1-A-2006	SC-1	Shelf	Control	Before	36.714458	-121.909033	90	9/25/06	V2891
SC1-B-2006	SC-1	Shelf	Control	Before	36.714299	-121.908597	90	9/25/06	V2891
SC1-C-2006	SC-1	Shelf	Control	Before	36.713548	-121.907717	90	9/25/06	V2891
SC1-A-2015	SC-1	Shelf	Control	2015	36.715485	-121.90863	88	9/1/14	V3797
SC1-B-2015	SC-1	Shelf	Control	2015	36.714436	-121.90862	88	9/1/14	V3797
SC1-C-2015	SC-1	Shelf	Control	2015	36.71479	-121.90738	88	9/1/14	V3797
SC2-A-2008	SC-2	Shelf	Control	2008	36.822428	-121.945564	87	11/30/07	V3134
SC2-B-2008	SC-2	Shelf	Control	2008	36.822978	-121.944894	86	11/30/07	V3134
SC2-C-2008	SC-2	Shelf	Control	2008	36.823517	-121.944924	86	11/30/07	V3134
SC2-A-2010	SC-2	Shelf	Control	2010	36.821888	-121.94553	88	1/29/10	V3504
SC2-B-2010	SC-2	Shelf	Control	2010	36.822903	-121.94554	87	1/29/10	V3504
SC2-C-2010	SC-2	Shelf	Control	2010	36.82335	-121.946236	88	1/29/10	V3504
SC2-A-2006	SC-2	Shelf	Control	Before	36.821804	-121.9445	87	10/5/06	V2905
SC2-B-2006	SC-2	Shelf	Control	Before	36.822571	-121.94354	86	10/5/06	V2905
SC2-A-2015	SC-2	Shelf	Control	2015	36.821888	-121.94553	88	9/18/14	V3801
SC2-B-2015	SC-2	Shelf	Control	2015	36.822903	-121.94554	87	9/18/14	V3801
SC2-C-2015	SC-2	Shelf	Control	2015	36.82335	-121.946236	88	9/18/14	V3801
SC3-A-2008	SC-3	Shelf	Control	2008	36.877177	-122.120826	90	1/30/08	V3166
SC3-B-2008	SC-3	Shelf	Control	2008	36.877639	-122.121503	91	1/30/08	V3166
SC3-C-2008	SC-3	Shelf	Control	2008	36.877494	-122.120593	91	1/30/08	V3166
SC3-A-2010	SC-3	Shelf	Control	2010	36.87826	-122.12123	90	1/28/10	V3502
SC3-B-2010	SC-3	Shelf	Control	2010	36.878094	-122.1199	90	1/28/10	V3502
SC3-C-2010	SC-3	Shelf	Control	2010	36.876762	-122.119804	90	1/28/10	V3502
SC3-A-2006	SC-3	Shelf	Control	Before	36.878461	-122.121178	89	10/5/06	V2904
SC3-B-2006	SC-3	Shelf	Control	Before	36.878765	-122.120205	89	10/5/06	V2904
SC3-A-2015	SC-3	Shelf	Control	2015	36.87826	-122.12123	90	9/1/14	V3800
SC3-B-2015	SC-3	Shelf	Control	2015	36.878094	-122.1199	90	9/1/14	V3800
SC3-C-2015	SC-3	Shelf	Control	2015	36.876762	-122.119804	90	9/1/14	V3800

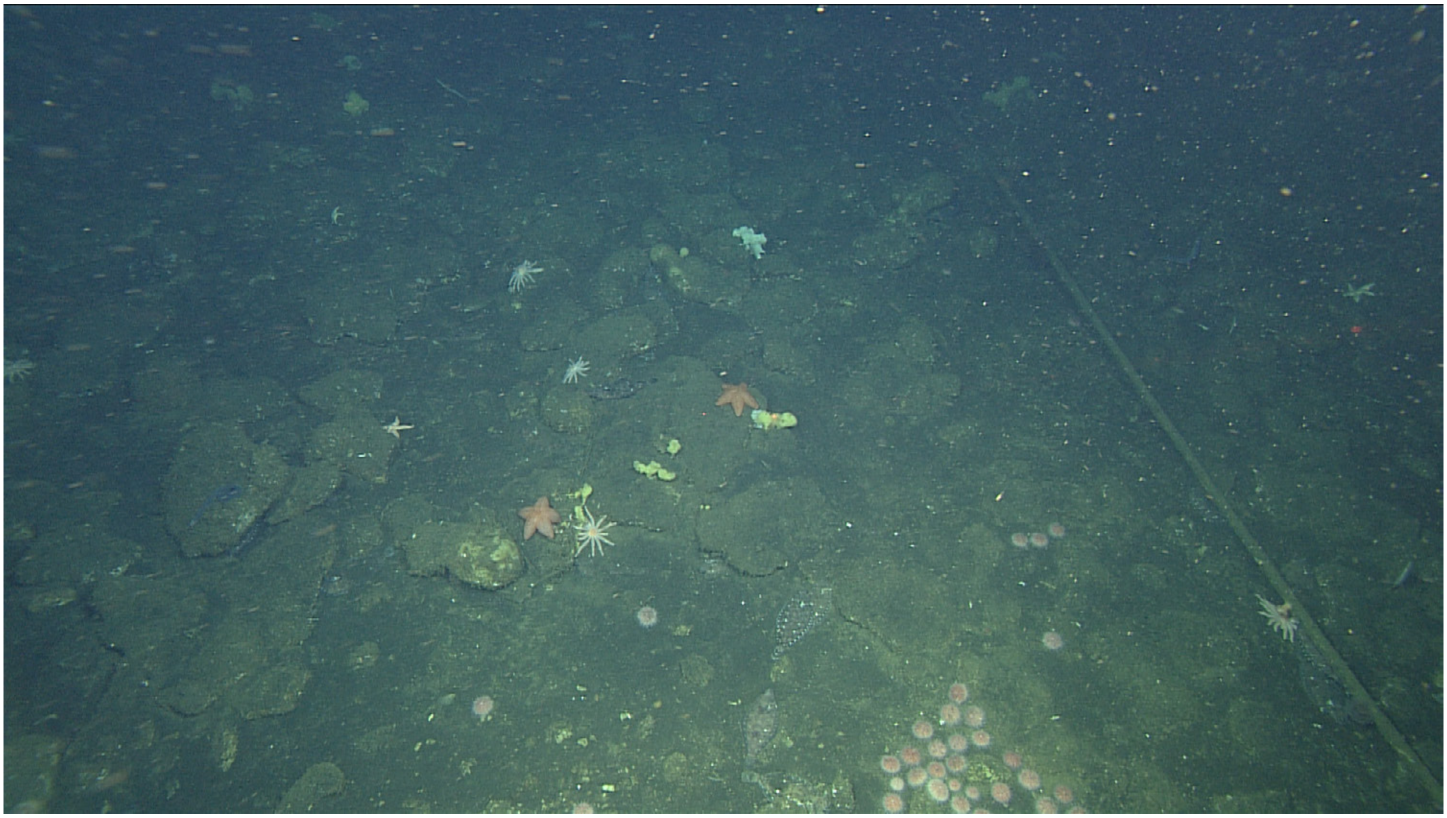
Tr. Code	Loc.	Region	Treatment	Period	Latitude	Longitude	Depth (m)	Date	Dive #
SI1-A-2008	SI-1	Shelf	Cable	2008	36.863391	-122.0969	91	1/23/08	V3161
SI1-B-2008	SI-1	Shelf	Cable	2008	36.863186	-122.096707	92	1/23/08	V3161
SI1-C-2008	SI-1	Shelf	Cable	2008	36.863471	-122.096143	92	1/23/08	V3161
SI1-A-2010	SI-1	Shelf	Cable	2010	36.863014	-122.09654	89	1/28/10	V3503
SI1-B-2010	SI-1	Shelf	Cable	2010	36.86213	-122.09633	89	1/28/10	V3503
SI1-C-2010	SI-1	Shelf	Cable	2010	36.862755	-122.09486	89	1/28/10	V3503
SI1-A-1999	SI-1	Shelf	Cable	Before	36.863391	-122.0969	90	1999	MCI-ACAD90
SI1-B-1999	SI-1	Shelf	Cable	Before	36.863186	-122.096707	90	1999	MCI-ACAD90
SI1-A-2015	SI-1	Shelf	Cable	2015	36.863014	-122.09654	89	9/18/14	V3802
SI1-B-2015	SI-1	Shelf	Cable	2015	36.86213	-122.09633	89	9/18/14	V3802
SI1-C-2015	SI-1	Shelf	Cable	2015	36.862755	-122.09486	89	9/18/14	V3802
Skate1-A-2008	Skate	Skate	Control	2008	36.82574	-122.168653	313	1/31/08	V3167
Skate1-B-2008	Skate	Skate	Control	2008	36.826303	-122.168202	310	1/31/08	V3167
Skate1-C-2008	Skate	Skate	Control	2008	36.827346	-122.167738	309	1/31/08	V3167
Skate2-A-2008	Skate	Skate	Cable	2008	36.826029	-122.169319	317	1/31/08	V3167
Skate2-B-2008	Skate	Skate	Cable	2008	36.826903	-122.168852	311	1/31/08	V3167
Skate2-C-2008	Skate	Skate	Cable	2008	36.82757	-122.168474	306	1/31/08	V3167
Skate1-A-2010	Skate	Skate	Control	2010	36.82574	-122.168653	313	1/13/10	V3488
Skate1-B-2010	Skate	Skate	Control	2010	36.826303	-122.168202	310	1/13/10	V3488
Skate1-C-2010	Skate	Skate	Control	2010	36.827346	-122.167738	309	1/13/10	V3488
Skate2-A-2010	Skate	Skate	Cable	2010	36.826029	-122.169319	317	1/13/10	V3488
Skate2-B-2010	Skate	Skate	Cable	2010	36.826903	-122.168852	311	1/13/10	V3488
Skate2-C-2010	Skate	Skate	Cable	2010	36.82757	-122.168474	306	1/13/10	V3488
SLC1-A-2008	SLC-1	Slope	Control	2008	36.74579	-122.277049	992	1/7/08	V3147
SLC1-B-2008	SLC-1	Slope	Control	2008	36.745207	-122.277572	1001	1/7/08	V3147
SLC1-C-2008	SLC-1	Slope	Control	2008	36.745351	-122.278318	1007	1/7/08	V3147
SLC1-A-2010	SLC-1	Slope	Control	2010	36.744267	-122.27703	1001	3/8/10	D115
SLC1-B-2010	SLC-1	Slope	Control	2010	36.7452	-122.277725	1002	3/8/10	D115
SLC1-C-2010	SLC-1	Slope	Control	2010	36.74442	-122.27807	1006	3/8/10	D115
SLC1-A-2001	SLC-1	Slope	Control	Before	36.743379	-122.275459	1000	10/12/01	V2083
SLC1-B-2001	SLC-1	Slope	Control	Before	36.742199	-122.274547	1000	10/12/01	V2083
SLC1-C-2001	SLC-1	Slope	Control	Before	36.741165	-122.27301	999	10/12/01	V2083
SLC1-A-2015	SLC-1	Slope	Control	2015	36.744267	-122.27703	1001	12/17/14	D702
SLC1-B-2015	SLC-1	Slope	Control	2015	36.7452	-122.277725	1002	12/17/14	D702
SLC1-C-2015	SLC-1	Slope	Control	2015	36.74442	-122.27807	1006	12/17/14	D702
SLC2-A-2008	SLC-2	Slope	Control	2008	36.748745	-122.197382	820	1/23/08	V3160

Tr. Code	Loc.	Region	Treatment	Period	Latitude	Longitude	Depth (m)	Date	Dive #
SLC2-B-2008	SLC-2	Slope	Control	2008	36.74858	-122.197578	817	1/23/08	V3160
SLC2-C-2008	SLC-2	Slope	Control	2008	36.748988	-122.198433	827	1/23/08	V3160
SLC2-A-2010	SLC-2	Slope	Control	2010	36.749023	-122.19783	821	1/27/10	V3500
SLC2-B-2010	SLC-2	Slope	Control	2010	36.74834	-122.19758	820	1/27/10	V3500
SLC2-C-2010	SLC-2	Slope	Control	2010	36.74918	-122.19624	813	1/27/10	V3500
SLC2-A-2005	SLC-2	Slope	Control	Before	36.752527	-122.20002	801	6/8/05	V2674
SLC2-B-2005	SLC-2	Slope	Control	Before	36.75264	-122.200906	800	6/8/05	V2674
SLC2-C-2005	SLC-2	Slope	Control	Before	36.752558	-122.202336	801	6/8/05	V2674
SLC2-A-2015	SLC-2	Slope	Control	2015	36.749023	-122.19783	821	12/18/14	D705
SLC2-B-2015	SLC-2	Slope	Control	2015	36.74834	-122.19758	820	12/18/14	D705
SLC2-C-2015	SLC-2	Slope	Control	2015	36.74918	-122.19624	813	12/18/14	D705
SLC3-A-2008	SLC-3	Slope	Control	2008	36.705268	-122.166423	895	1/8/08	V3148
SLC3-B-2008	SLC-3	Slope	Control	2008	36.706463	-122.165729	884	1/8/08	V3148
SLC3-C-2008	SLC-3	Slope	Control	2008	36.705928	-122.164967	887	1/8/08	V3148
SLC3-A-2010	SLC-3	Slope	Control	2010	36.706226	-122.1662	885	3/9/10	D116
SLC3-B-2010	SLC-3	Slope	Control	2010	36.70553	-122.16609	892	3/9/10	D116
SLC3-C-2010	SLC-3	Slope	Control	2010	36.706146	-122.1672	885	3/9/10	D116
SLC3-A-2006	SLC-3	Slope	Control	Before	36.707094	-122.167266	881	10/3/06	V2898
SLC3-B-2006	SLC-3	Slope	Control	Before	36.707753	-122.166954	877	10/3/06	V2898
SLC3-C-2006	SLC-3	Slope	Control	Before	36.70771	-122.16586	874	10/3/06	V2898
SLC3-A-2015	SLC-3	Slope	Control	2015	36.706226	-122.1662	885	12/18/14	D704
SLC3-B-2015	SLC-3	Slope	Control	2015	36.70553	-122.16609	892	12/18/14	D704
SLC3-C-2015	SLC-3	Slope	Control	2015	36.706146	-122.1672	885	12/18/14	D704
SLI1-A-2008	SLI-1	Slope	Cable	2008	36.712528	-122.18707	877	12/6/07	V3136
SLI1-B-2008	SLI-1	Slope	Cable	2008	36.71302	-122.186753	877	12/6/07	V3136
SLI1-C-2008	SLI-1	Slope	Cable	2008	36.712683	-122.186665	874	12/6/07	V3136
SLI1-A-2010	SLI-1	Slope	Cable	2010	36.71275	-122.187164	877	3/8/10	D114
SLI1-B-2010	SLI-1	Slope	Cable	2010	36.713116	-122.1869	875	3/8/10	D114
SLI1-C-2010	SLI-1	Slope	Cable	2010	36.71259	-122.18689	877	3/8/10	D114
SLI1-A-2003	SLI-1	Slope	Cable	Before	36.711241	-122.186781	885	10/13/03	V2439
SLI1-B-2003	SLI-1	Slope	Cable	Before	36.711353	-122.186449	883	10/13/03	V2439
SLI1-C-2003	SLI-1	Slope	Cable	Before	36.711883	-122.186523	882	10/13/03	V2439
SLI1-A-2015	SLI-1	Slope	Cable	2015	36.71275	-122.187164	877	12/17/14	D703
SLI1-B-2015	SLI-1	Slope	Cable	2015	36.713116	-122.1869	875	12/17/14	D703
SLI1-C-2015	SLI-1	Slope	Cable	2015	36.71259	-122.18689	877	12/17/14	D703

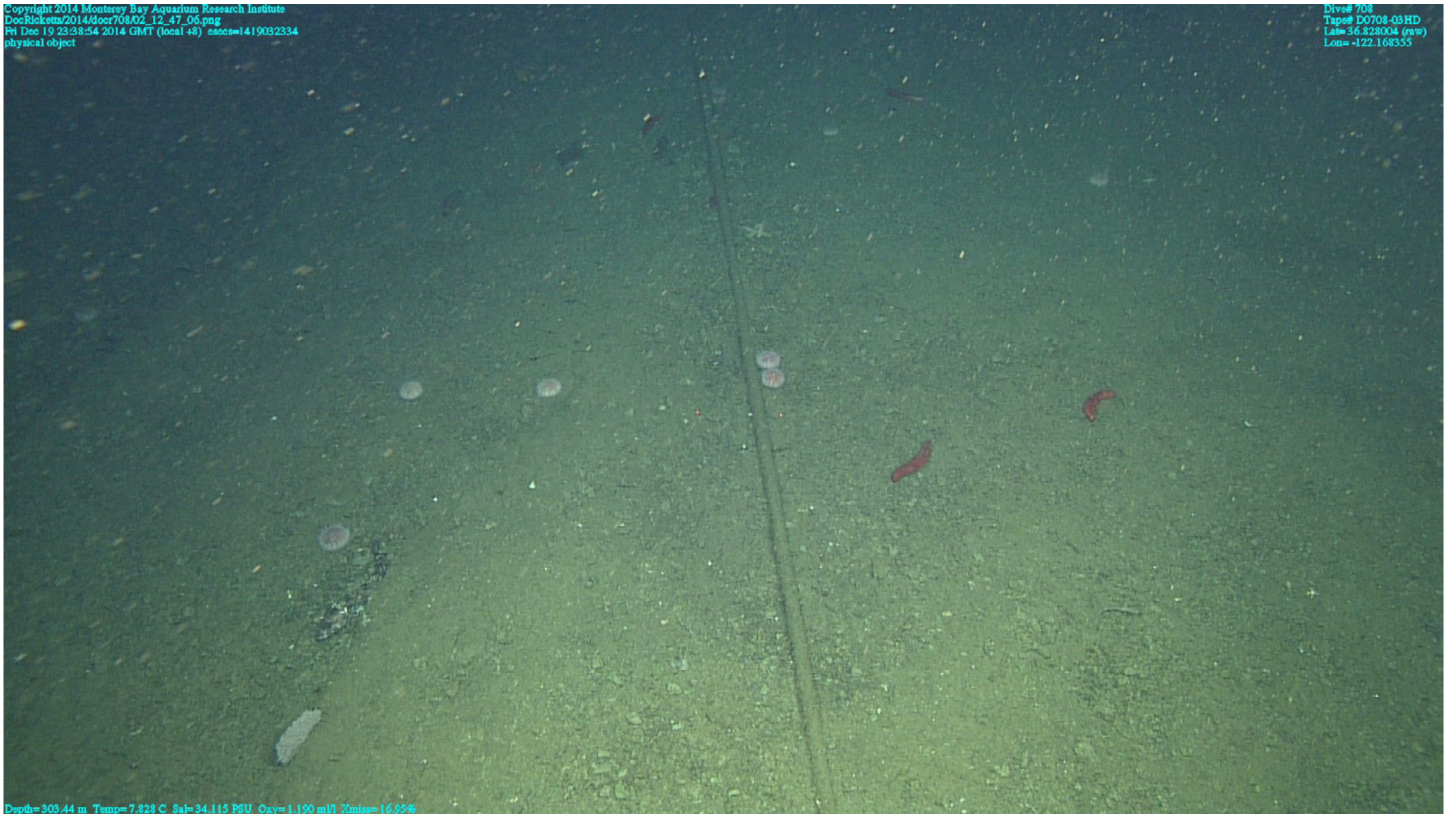
Appendix 2. Current condition of the MARS Cable



A. In shallow regions (0–115 m), the cable has been buried in sand since 2007 and no trace of the cable, trench or other disturbance is currently evident for the first 34.45 km of the route (38 m depth, V3445, TC 00:19).

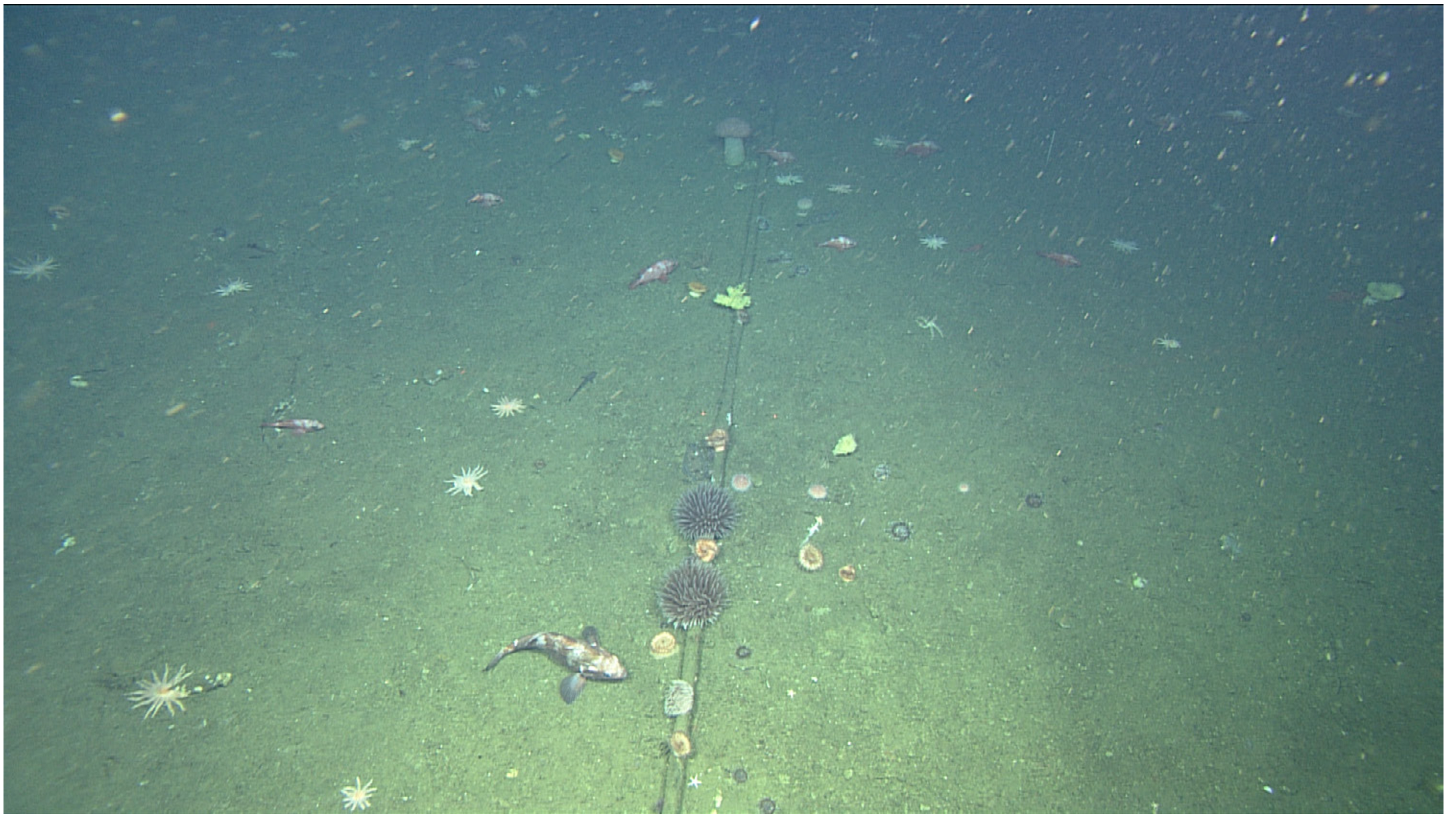


B. The neck of Smooth Ridge is comprised of rocky areas and authigenic carbonate crusts. The MARS cable could not be buried in these areas (445 m water depth, D705).

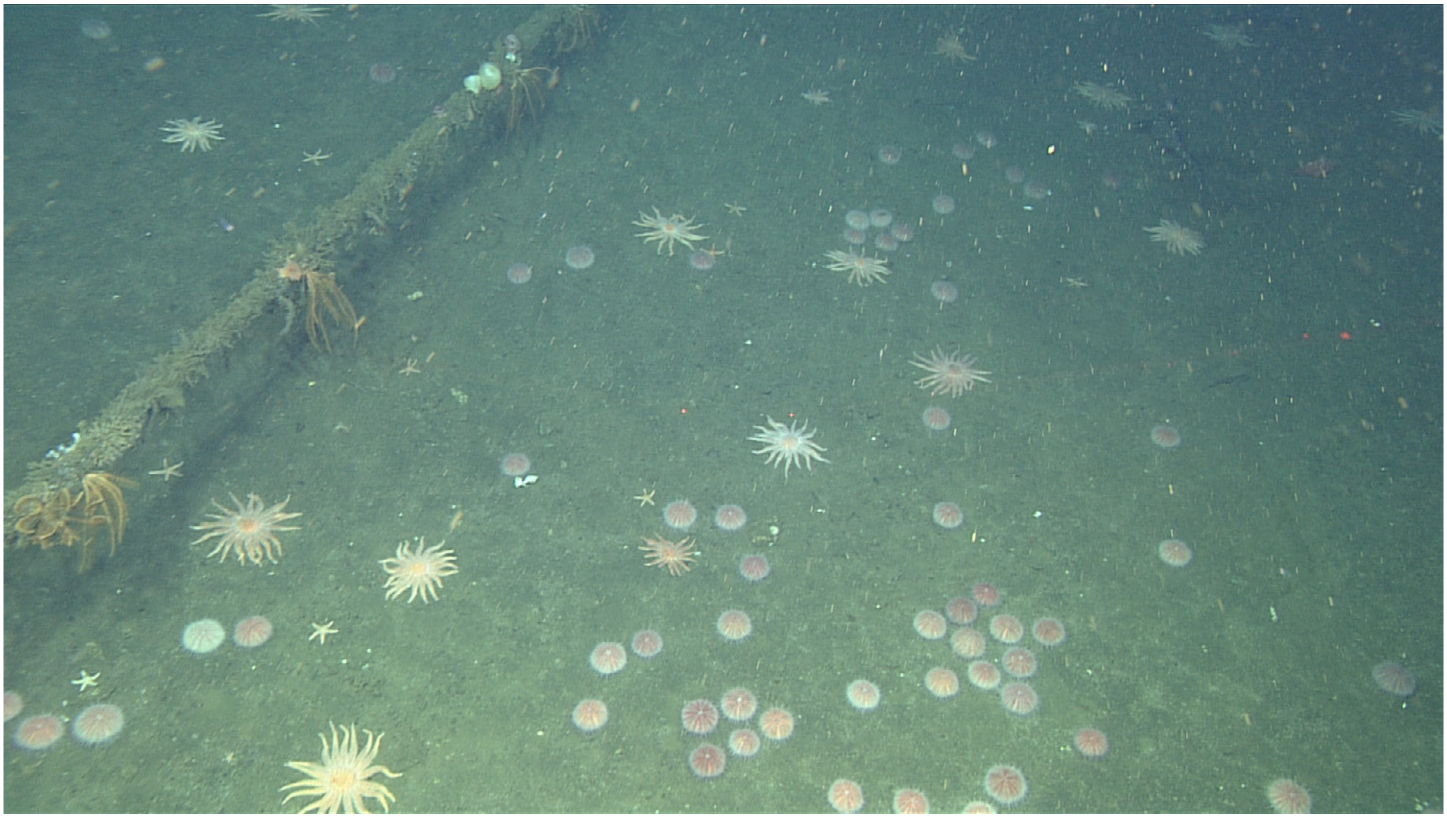


C. The cable rests on the seafloor in areas with hard substrate below (303 m depth, D708, TC 02:12).

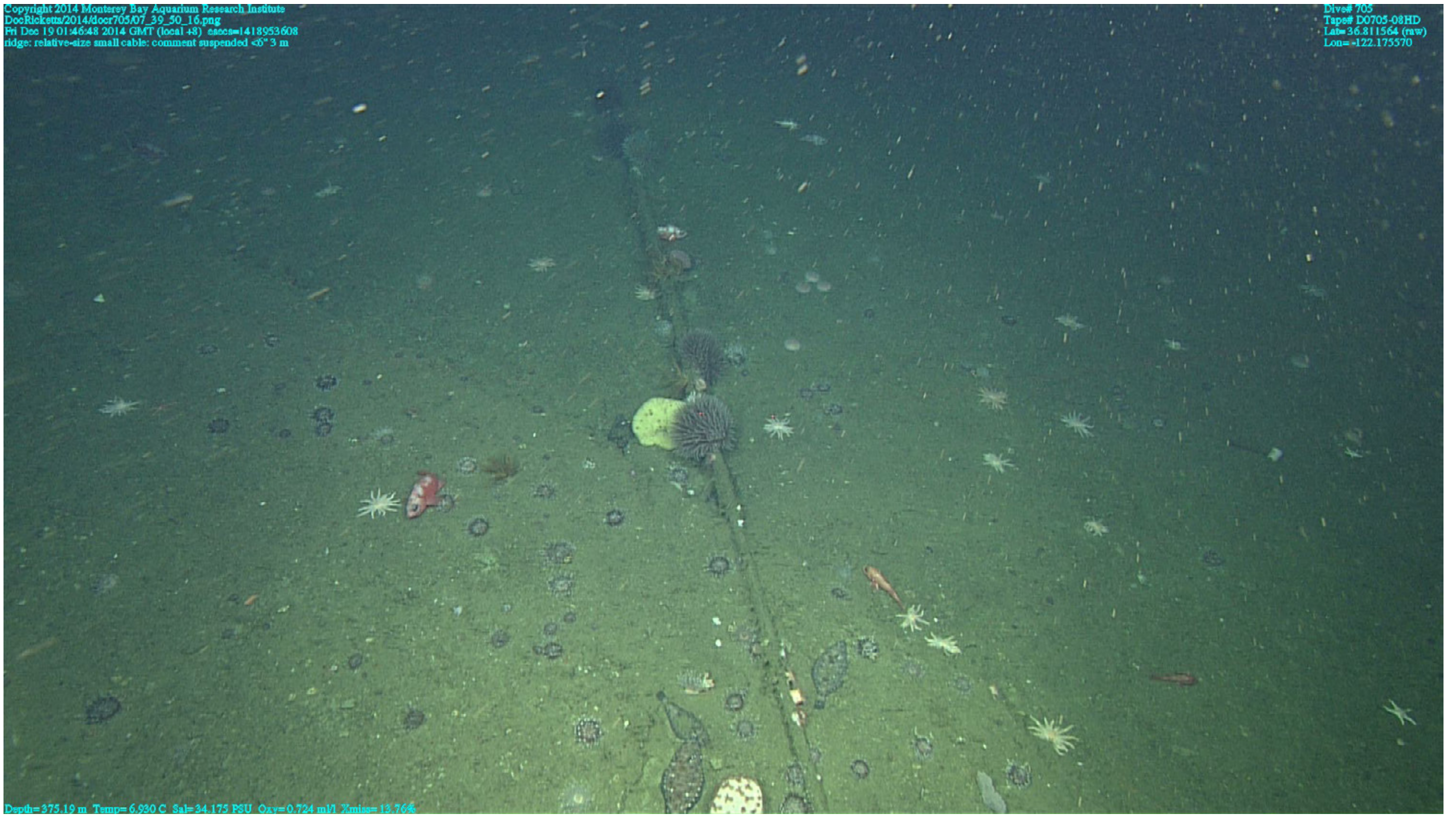
D. On Smooth Ridge, there are muddy areas where the surface-laid cable is now sinking into the sediment (left; 453 m water depth, D705, TC 05:31). The cable can no longer be seen in many places (right; 448 m, D705, TC 05:36).



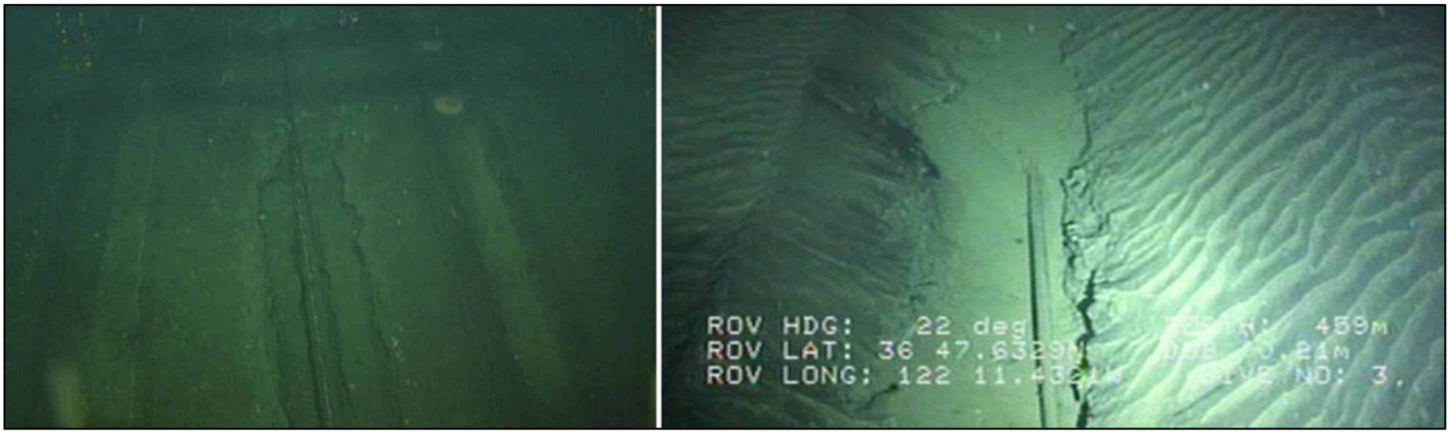
E. The cable is taut and is stretched so that it is 1–6 cm off the seabed in some places where hard substrate is present (364 m depth, D708, TC 07:55).



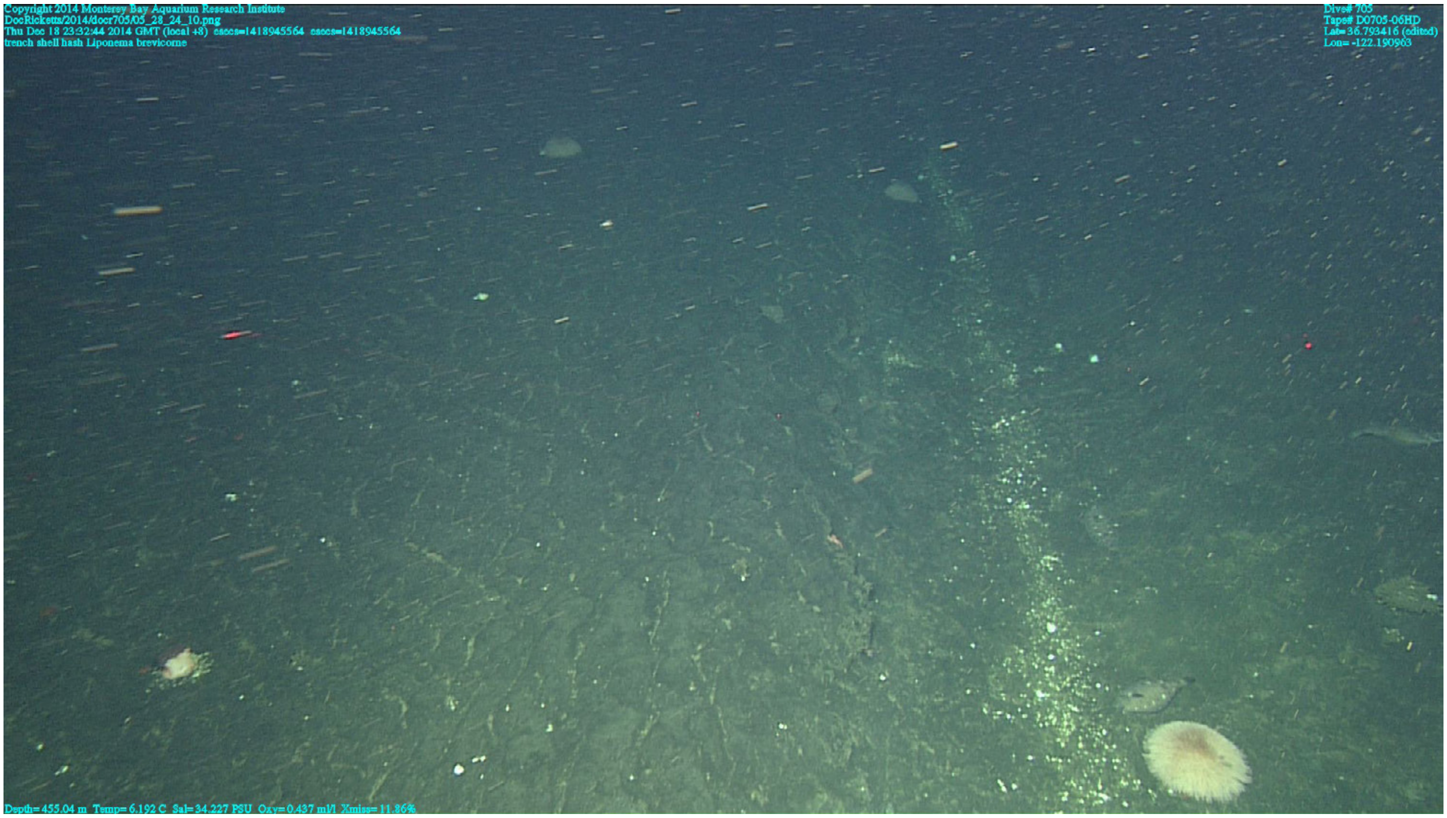
F. In areas with ledges, rock or uneven substrate, minor spans were observed. This one, at 309 m depth, is estimated to extend 20 linear meters (D708, TC 02:25).



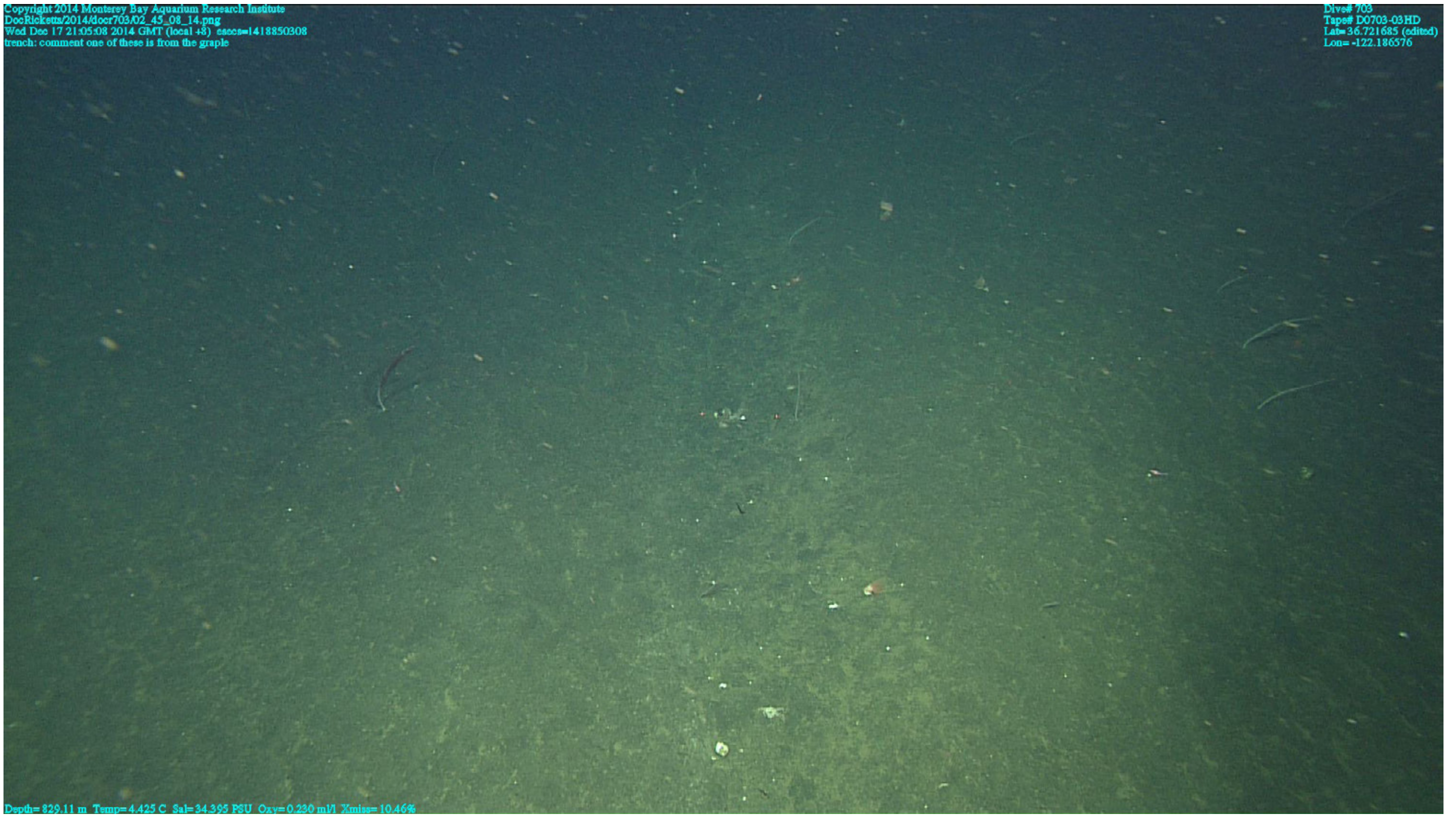
G. Example of a minor point suspension resulting from the presence of a low ledge (375 m depth, D705, TC 07:39).



H. At mid-depths, the cable was trenched in and was lying below the surrounding sediment surface. The cable was visible within the trench (2007, left = 451 m depth, right = 459 m depth).

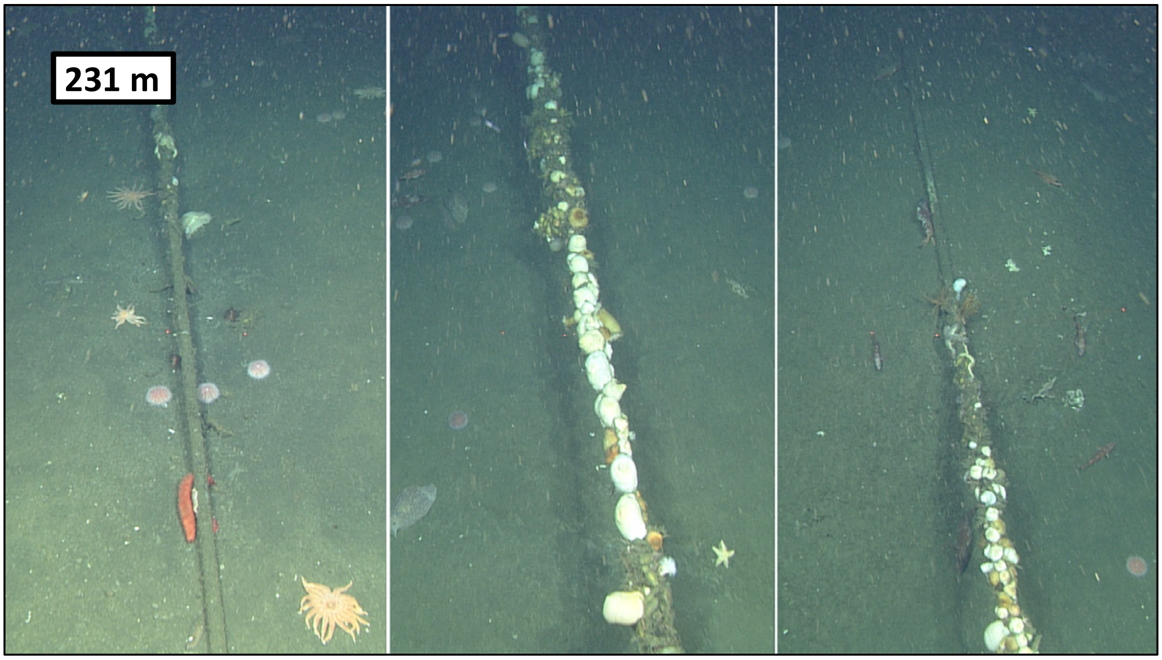


I. The trench in this area is now filled with sediment (455 m depth, D705.06 TC 05:28). While some stretches like this are about 90% filled, most of the trench is 100% filled.

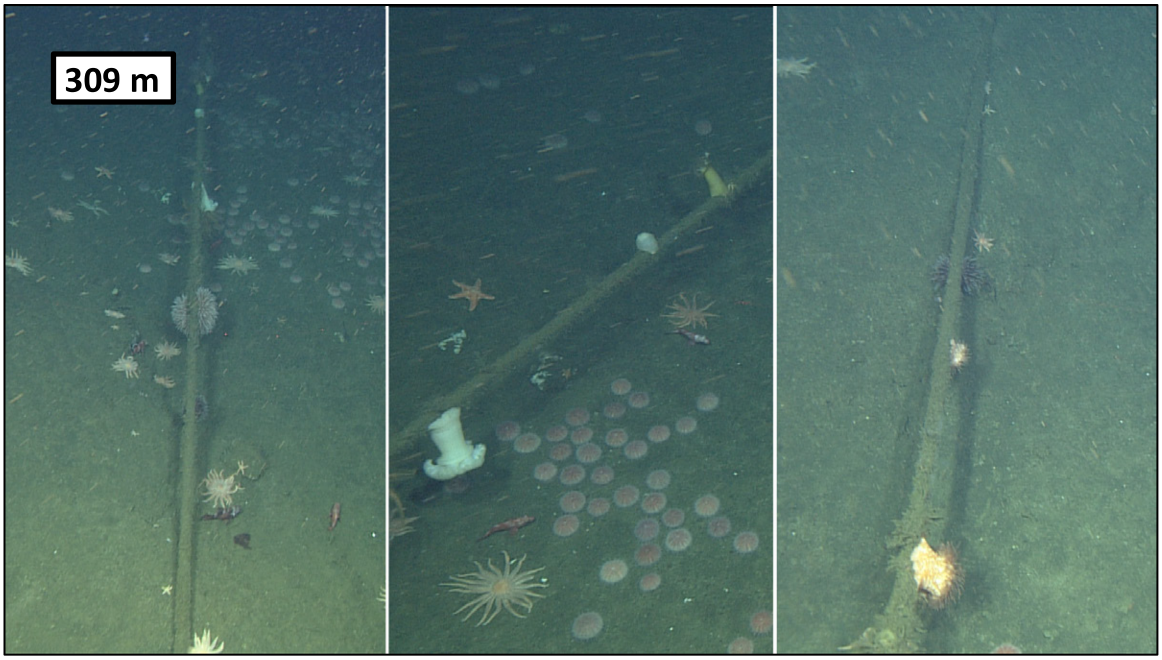


J. Muddy sediment filled the cable trench immediately in this region, and only mild disturbance delineates the trench. (829 m depth, D703.03 TC 02:45).

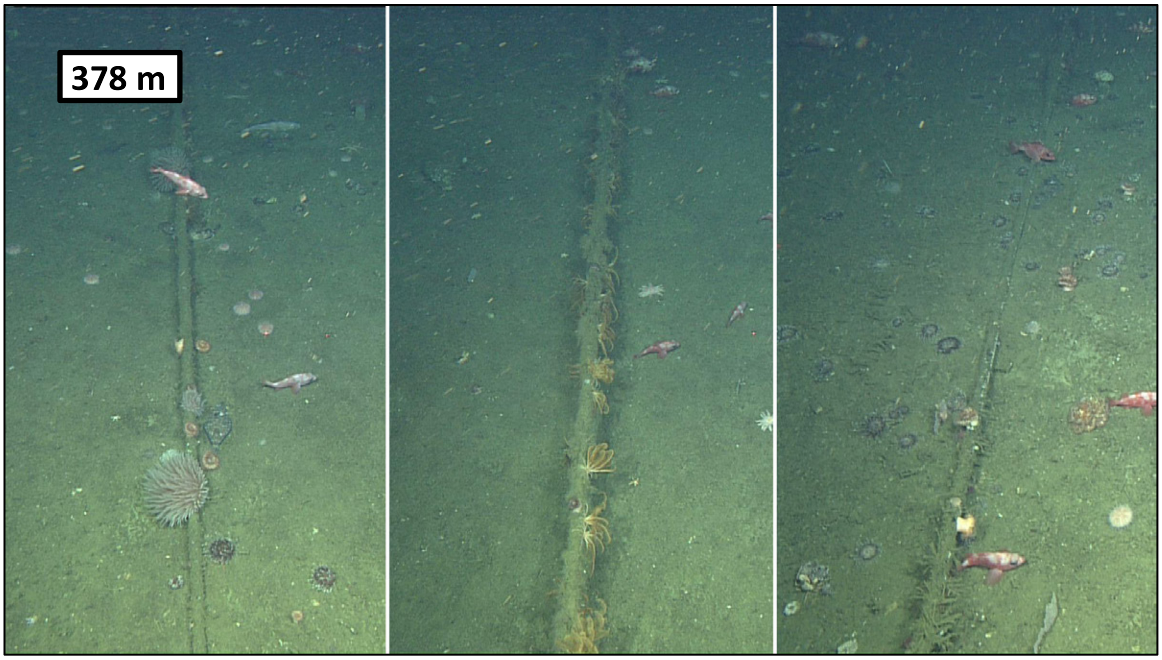
Appendix 3. Minor spans and point suspensions in the MARS cable.

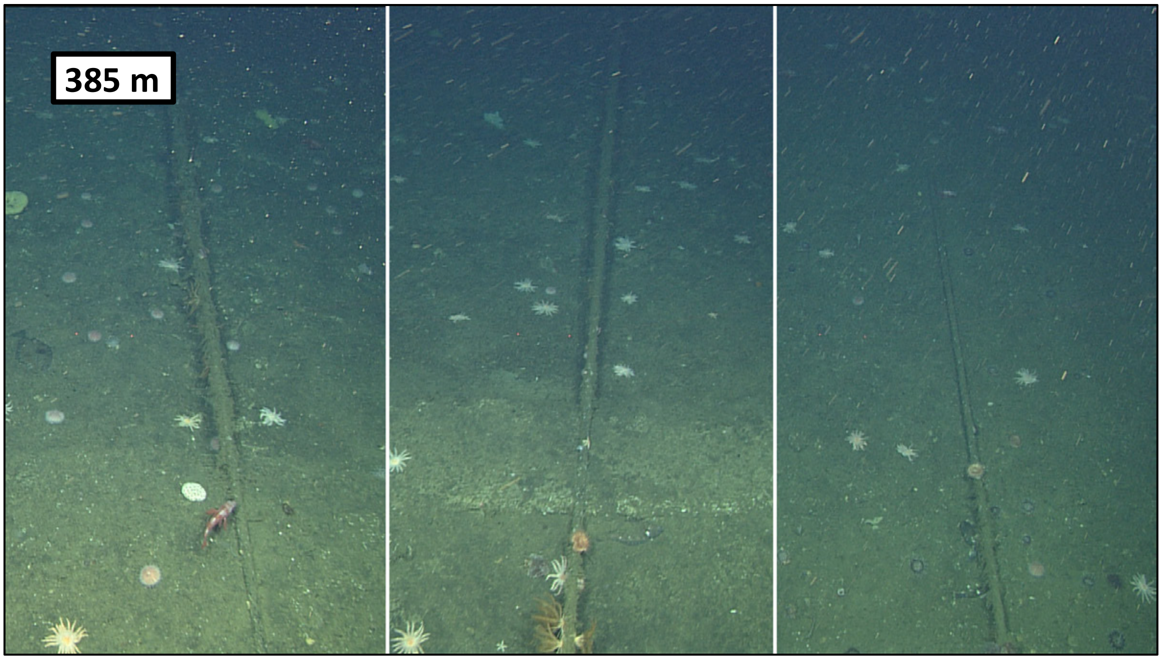


Appendix 3. Minor spans and point suspensions in the MARS cable.

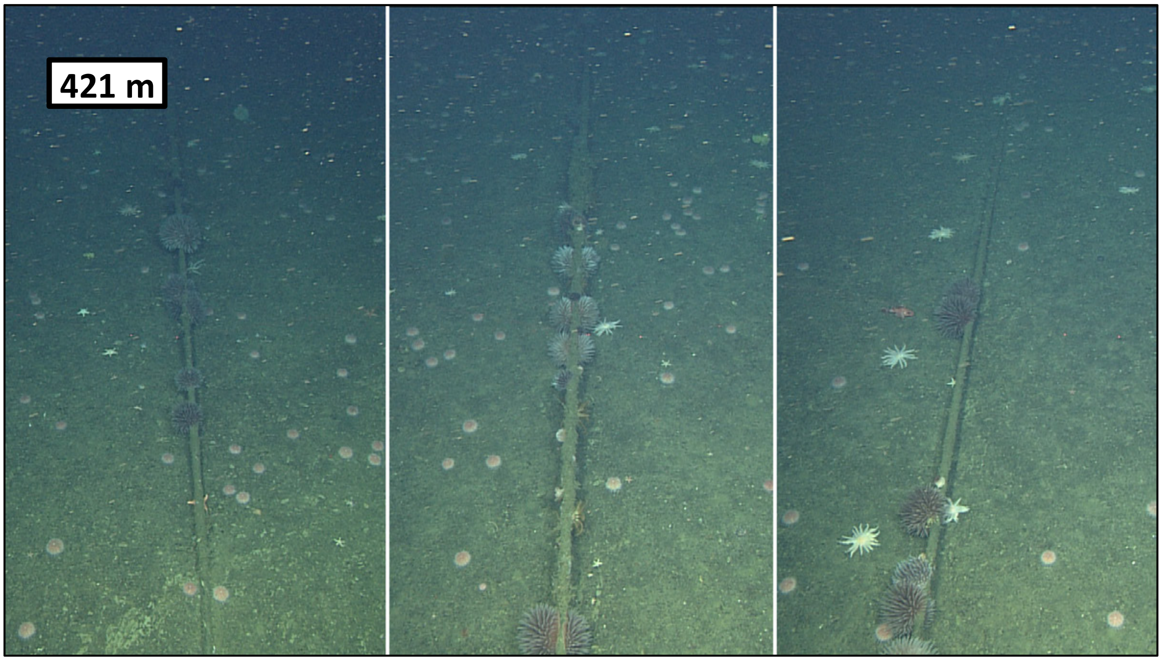


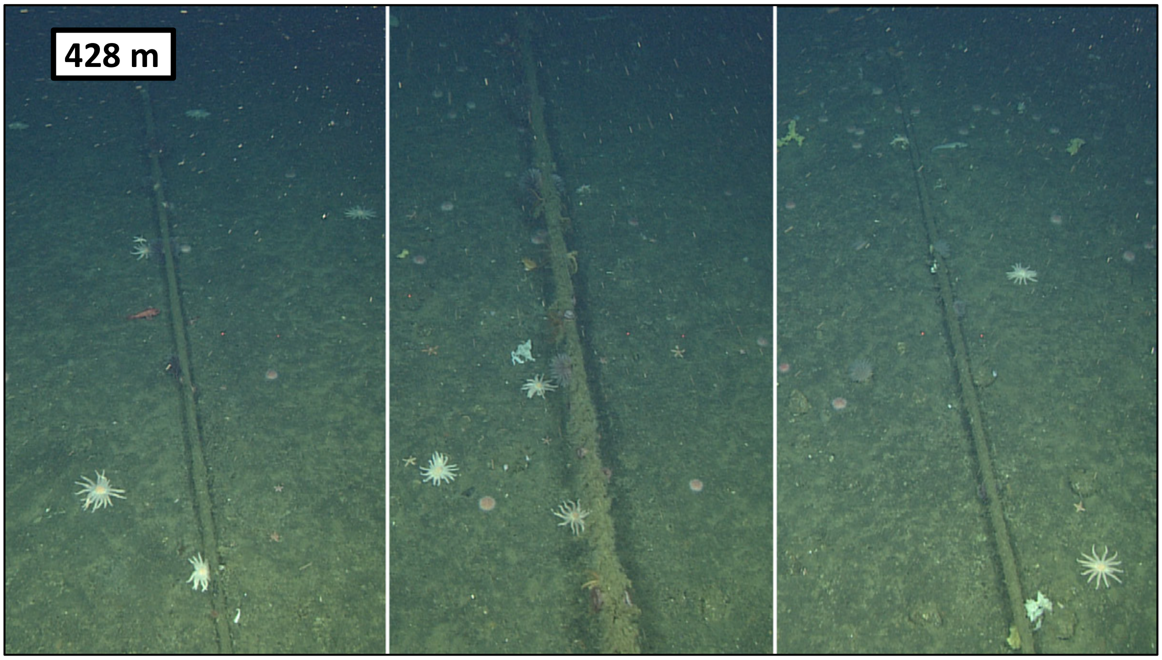
Appendix 3. Minor spans and point suspensions in the MARS cable.



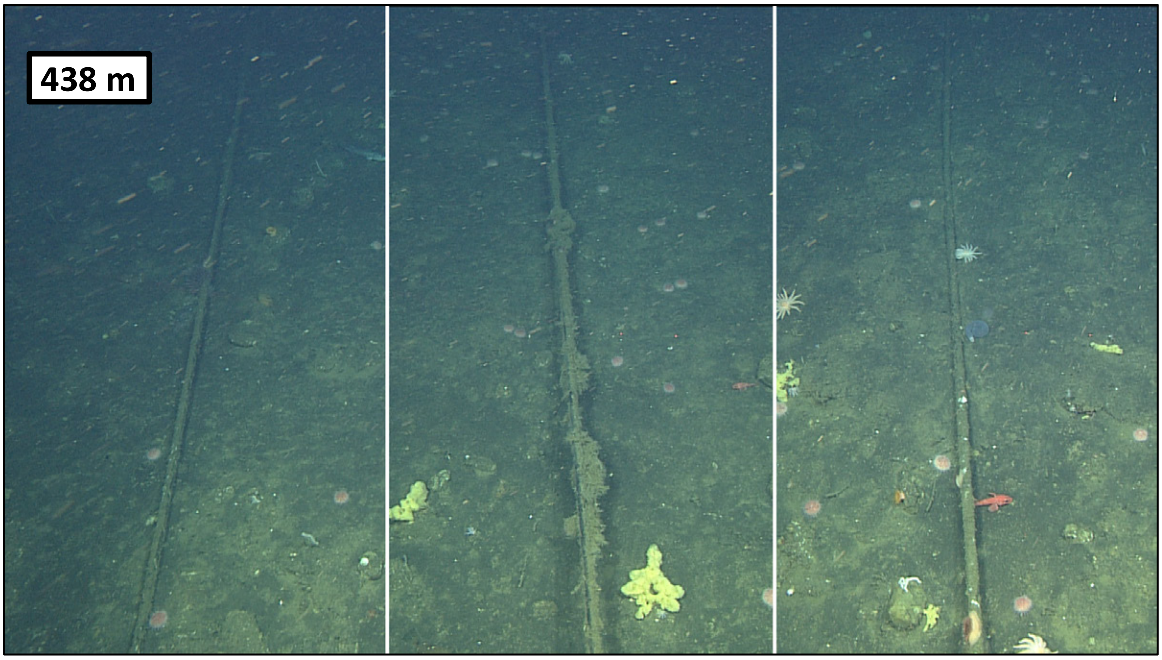


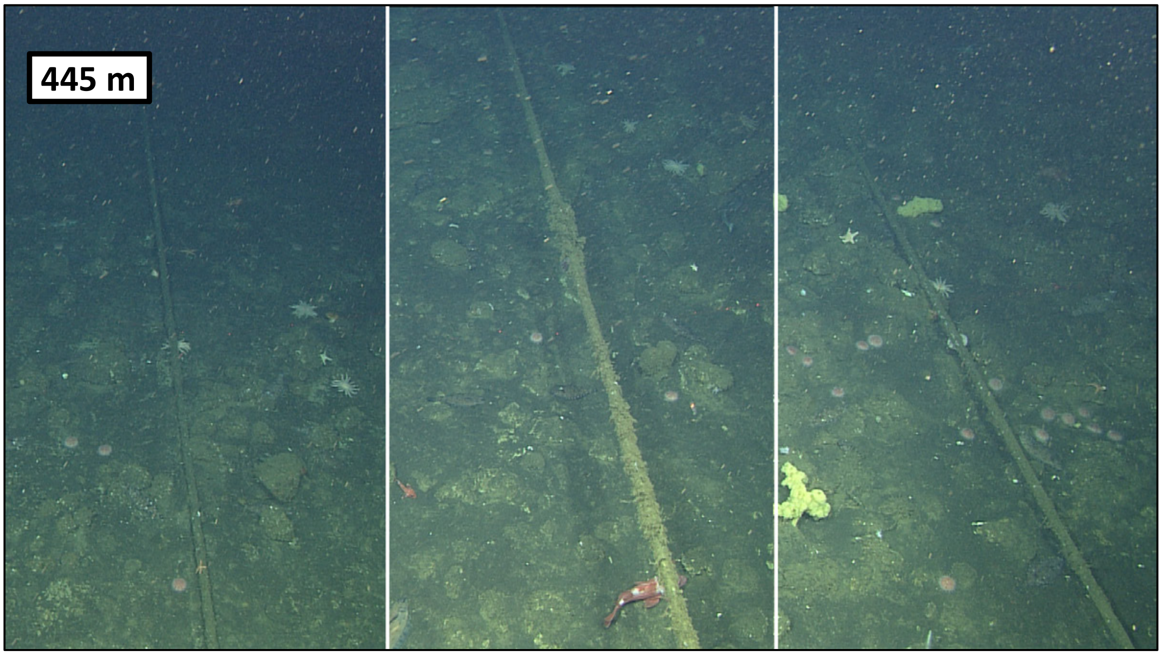
Appendix 3. Minor spans and point suspensions in the MARS cable.





Appendix 3. Minor spans and point suspensions in the MARS cable.





Appendix 3. Minor spans and point suspensions in the MARS cable.

Appendix 4. Mean megafaunal (154 taxa) density on transects along the MARS cable route and control sites, with phylum (or subphylum) and group designations. The density (# 100 m^{-2}) of each taxon at regional video transects (n = 199) in all years and at all depths were averaged to produce an overall average density. SE = standard error of the mean. Percent indicates the percentage of the total average faunal density (150.53 megafaunal individuals 100 m^{-2}).

Phylum	Group	Taxa	Mean Density	SE	%
Cnidaria	Actiniaria	Actiniaria	0.56	0.04	0.37
Cnidaria	Actiniaria	Actiniidae sp. 1	0.77	0.05	0.51
Vertebrata	Actinopteri	Actinopteri	0.48	0.03	0.32
Cnidaria	Actiniaria	Actinostolidae	3.39	0.24	2.25
Vertebrata	Alepocephalidae	*Alepocephalus tenebrosus*	0.01	0.00	0.00
Vertebrata	Anoplopomatidae	*Anoplopoma fimbria*	0.04	0.00	0.02
Cnidaria	Pennatulacea	*Anthoptilum grandiflorum*	0.28	0.02	0.19
Cnidaria	Anthozoa	Anthozoa	0.02	0.00	0.01
Vertebrata	Moridae	*Antimora microlepis*	0.04	0.00	0.03
Echinodermata	Holothuroidea	*Apostichopus californicus*	0.00	0.00	0.00
Echinodermata	Holothuroidea	*Apostichopus leukothele*	0.68	0.05	0.45
Vertebrata	Zoarcidae	*Aprodon cortezianus*	0.18	0.01	0.12
Echinodermata	Asteroidea	Asteroidea	0.78	0.06	0.52
Echinodermata	Asteroidea	Asteroidea sp. 1	0.04	0.00	0.02
Echinodermata	Asteroidea	Asteroidea sp. 2	0.17	0.01	0.11
Echinodermata	Ophiuroidea	Asteronyx	0.01	0.00	0.01
Echinodermata	Ophiuroidea	*Asteronyx longifissus*	0.25	0.02	0.17
Echinodermata	Asteroidea	Astropecten	0.04	0.00	0.03
Mollusca	Gastropoda	Bathybembix	1.60	0.11	1.06
Vertebrata	Rajiformes	*Bathyraja abyssicola*	0.01	0.00	0.00
Vertebrata	Rajiformes	*Bathyraja kincaidii*	0.05	0.00	0.03
Echinodermata	Asteroidea	Benthopecten	0.16	0.01	0.11
Vertebrata	Rajiformes	*Beringraja binoculata*	0.01	0.00	0.00
Mollusca	Bivalvia	Bivalvia	0.41	0.03	0.27
Vertebrata	Zoarcidae	*Bothrocara brunneum*	0.02	0.00	0.01
Arthropoda	Decapoda	Brachyura	0.01	0.00	0.00
Echinodermata	Echinoidea	Brisaster	0.06	0.00	0.04
Mollusca	Gastropoda	Calliostoma	0.21	0.02	0.14
Cnidaria	Alcyonacea	Calyptrophora	0.02	0.00	0.01
Vertebrata	Liparidae	*Careproctus melanurus*	0.12	0.01	0.08
Arthropoda	Decapoda	Caridea	0.30	0.02	0.20
Cnidaria	Ceriantharia	Ceriantharia	1.60	0.11	1.06
Cnidaria	Ceriantharia	Ceriantharia sp. 1	0.14	0.01	0.09
Cnidaria	Ceriantharia	Ceriantharia sp. 2	1.16	0.08	0.77
Cnidaria	Ceriantharia	Ceriantharia sp. 3	0.08	0.01	0.05
Arthropoda	Decapoda	*Chionoecetes tanneri*	2.39	0.17	1.59
Arthropoda	Decapoda	*Chorilia longipes*	0.12	0.01	0.08
Vertebrata	Pleuronectiformes	Citharichthys	0.85	0.06	0.57

Phylum	**Group**	**Taxa**	**Mean Density**	**SE**	**%**
Porifera	Porifera	Cladorhiza	0.15	0.01	0.10
Tunicata	Tunicata	*Cnemidocarpa finmarkiensis*	0.01	0.00	0.01
Cnidaria	Corallimorpharia	*Corallimorphus pilatus*	0.17	0.01	0.11
Vertebrata	Macrouridae	Coryphaenoides	0.10	0.01	0.07
Echinodermata	Asteroidea	*Crossaster borealis*	0.38	0.03	0.25
Arthropoda	Decapoda	Decapoda	0.02	0.00	0.01
Annelida	Polychaeta	Diopatra	5.92	0.42	3.93
Cnidaria	Pennatulacea	*Distichoptilum gracile*	0.08	0.01	0.06
Mollusca	Gastropoda	Doridacea	0.02	0.00	0.01
Mollusca	Cephalopoda	*Dosidicus gigas*	0.05	0.00	0.03
Cnidaria	Rhodaliidae	*Dromalia alexandri*	0.02	0.00	0.01
Echiura	Echiura	Echiura	0.11	0.01	0.07
Vertebrata	Pleuronectiformes	*Embassichthys bathybius*	0.17	0.01	0.11
Mollusca	Cephalopoda	*Enteroctopus dofleini*	0.00	0.00	0.00
Vertebrata	Pleuronectiformes	*Eopsetta jordani*	0.02	0.00	0.01
Vertebrata	Myxinidae	Eptatretus	0.21	0.01	0.14
Arthropoda	Decapoda	*Eualus macrophthalmus*	0.64	0.05	0.42
Porifera	Porifera	Farrea	0.07	0.00	0.04
Echinodermata	Crinoidea	*Florometra serratissima*	0.28	0.02	0.19
Cnidaria	Pennatulacea	Funiculina	30.00	2.13	19.93
Arthropoda	Decapoda	Galatheoidea	0.05	0.00	0.03
Mollusca	Gastropoda	Gastropoda	5.59	0.40	3.72
Mollusca	Gastropoda	Gastropoda sp. 2	0.04	0.00	0.03
Mollusca	Gastropoda	Gastropoda sp. 3	0.06	0.00	0.04
Mollusca	Gastropoda	Gastropoda sp. 4	0.01	0.00	0.00
Vertebrata	Pleuronectiformes	*Glyptocephalus zachirus*	0.62	0.04	0.41
Echinodermata	Asteroidea	Goniasteridae	0.02	0.00	0.01
Cnidaria	Alcyonacea	Gorgonacea	0.01	0.00	0.00
Echinodermata	Asteroidea	*Halipteris californica*	0.20	0.01	0.13
Echinodermata	Asteroidea	Henricia sp. 1	0.06	0.00	0.04
Echinodermata	Asteroidea	Henricia sp. 2	0.01	0.00	0.01
Cnidaria	Alcyonacea	*Heteropolypus ritteri*	0.16	0.01	0.10
Echinodermata	Asteroidea	Hippasteria	0.14	0.01	0.09
Echinodermata	Holothuroidea	Holothuroidea	0.03	0.00	0.02
Cnidaria	Actiniaria	Hormathiidae sp. 1	0.66	0.05	0.44
Vertebrata	Chimaeridae	*Hydrolagus collei*	0.01	0.00	0.00
Cnidaria	Actiniaria	Isosicyonis	8.25	0.59	5.48
Brachiopoda	Brachiopoda	*Laqueus californianus*	0.05	0.00	0.03
Vertebrata	Liparidae	Liparidae	0.03	0.00	0.02
Cnidaria	Actiniaria	*Liponema brevicorne*	0.24	0.02	0.16
Echinodermata	Asteroidea	*Luidia foliolata*	0.51	0.04	0.34
Vertebrata	Stichaeidae	*Lumpenus sagitta*	0.24	0.02	0.16
Vertebrata	Zoarcidae	*Lycenchelys crotalinus*	0.73	0.05	0.49

Phylum	Group	Taxa	Mean Density	SE	%
Vertebrata	Zoarcidae	Lycenchelys sp. 1	0.38	0.03	0.25
Vertebrata	Zoarcidae	Lycodapus	0.07	0.01	0.05
Vertebrata	Zoarcidae	*Lycodes diapterus*	0.09	0.01	0.06
Vertebrata	Zoarcidae	*Lycodes pacificus*	0.12	0.01	0.08
Vertebrata	Zoarcidae	*Lyconema barbatum*	0.01	0.00	0.00
Vertebrata	Pleuronectiformes	*Lyopsetta exilis*	0.12	0.01	0.08
Echinodermata	Asteroidea	*Mediaster aequalis*	4.80	0.34	3.19
Tunicata	Tunicata	*Megalodicopia hians*	0.09	0.01	0.06
Vertebrata	Merlucciidae	*Merluccius productus*	0.24	0.02	0.16
Arthropoda	Decapoda	*Metacarcinus magister*	0.09	0.01	0.06
Cnidaria	Actiniaria	Metridium	0.01	0.00	0.01
Cnidaria	Actiniaria	*Metridium farcimen*	0.25	0.02	0.16
Vertebrata	Pleuronectiformes	*Microstomus pacificus*	0.78	0.06	0.52
Arthropoda	Mysidae	Mysidae	0.04	0.00	0.03
Mollusca	Gastropoda	Neptunea-Buccinum Complex	0.73	0.05	0.48
Mollusca	Gastropoda	Nudibranchia	0.01	0.00	0.01
Mollusca	Cephalopoda	*Octopus californicus*	0.01	0.00	0.00
Mollusca	Cephalopoda	*Octopus rubescens*	1.49	0.11	0.99
Echinodermata	Ophiuroidea	Ophiacanthidae	0.08	0.01	0.05
Vertebrata	Hexagrammidae	*Ophidion scrippsae*	0.01	0.00	0.01
Vertebrata	Hexagrammidae	*Ophiodon elongatus*	0.00	0.00	0.00
Echinodermata	Ophiuroidea	Ophiuroidea	6.63	0.47	4.40
Vertebrata	Liparidae	Osteodiscus	0.01	0.00	0.01
Arthropoda	Decapoda	*Pagurus tanneri*	0.45	0.03	0.30
Arthropoda	Decapoda	*Pandalus platyceros*	0.02	0.00	0.01
Echinodermata	Holothuroidea	*Pannychia mosleyi*	0.62	0.04	0.41
Arthropoda	Decapoda	Paralithodes	0.03	0.00	0.02
Vertebrata	Scyliorhinidae	*Parmaturus xaniurus*	0.06	0.00	0.04
Vertebrata	Pleuronectiformes	*Parophrys vetulus*	0.02	0.00	0.01
Cnidaria	Pennatulacea	*Pennatula phosphorea*	3.16	0.22	2.10
Cnidaria	Pennatulacea	Pennatulacea	11.38	0.81	7.56
Echinodermata	Asteroidea	*Pisaster brevispinus*	0.01	0.00	0.01
Arthropoda	Decapoda	*Platymera gaudichaudii*	0.01	0.00	0.01
Mollusca	Gastropoda	*Pleurobranchaea californica*	0.22	0.02	0.15
Vertebrata	Pleuronectiformes	Pleuronectiformes	3.56	0.25	2.37
Annelida	Polynoidae	Polynoidae	0.01	0.00	0.00
Echinodermata	Asteroidea	Poraniopsis	0.02	0.00	0.01
Porifera	Porifera	Porifera	1.93	0.14	1.28
Echinodermata	Holothuroidea	*Psolus squamatus*	5.28	0.37	3.51
Cnidaria	Pennatulacea	*Ptilosarcus gurneyi*	0.07	0.01	0.05
Echinodermata	Asteroidea	*Pycnopodia helianthoides*	0.01	0.00	0.01
Vertebrata	Rajiformes	*Raja rhina*	0.12	0.01	0.08
Vertebrata	Rajiformes	Rajiformes	0.00	0.00	0.00
Echinodermata	Holothuroidea	*Rathbunaster californicus*	8.53	0.60	5.67

Phylum	**Group**	**Taxa**	**Mean Density**	**SE**	**%**
Mollusca	Cephalopoda	*Rossia pacifica*	0.00	0.00	0.00
Annelida	Sabellidae	Sabellidae	0.32	0.02	0.22
Vertebrata	Sebastidae	Sebastes	0.09	0.01	0.06
Vertebrata	Sebastidae	*Sebastes aurora*	0.07	0.00	0.05
Vertebrata	Sebastidae	*Sebastes babcocki*	0.01	0.00	0.00
Vertebrata	Sebastidae	*Sebastes diploproa*	1.66	0.12	1.10
Vertebrata	Sebastidae	*Sebastes elongatus*	0.00	0.00	0.00
Vertebrata	Sebastidae	*Sebastes jordani*	0.01	0.00	0.01
Vertebrata	Sebastidae	*Sebastes paucispinis*	0.01	0.00	0.00
Vertebrata	Sebastidae	*Sebastes rosaceus*	0.01	0.00	0.00
Vertebrata	Sebastidae	*Sebastes saxicola*	0.04	0.00	0.03
Vertebrata	Sebastidae	*Sebastes semicinctus*	0.04	0.00	0.03
Vertebrata	Sebastidae	Sebastolobus	1.32	0.09	0.88
Vertebrata	Sebastidae	Sebastomus complex	0.01	0.00	0.00
Vertebrata	Squalidae	*Squalus suckleyi*	0.23	0.02	0.15
Cnidaria	Actiniaria	*Stomphia didemon*	1.80	0.13	1.19
Echinodermata	Echinoidea	*Strongylocentrotus fragilis*	11.96	0.85	7.94
Echinodermata	Asteroidea	*Stylasterias forreri*	0.15	0.01	0.10
Cnidaria	Alcyonacea	*Swiftia kofoidi*	0.02	0.00	0.01
Cnidaria	Alcyonacea	*Swiftia simplex*	0.15	0.01	0.10
Vertebrata	Pleuronectiformes	Symphurus	0.01	0.00	0.00
Vertebrata	Torpedinidae	*Tetronarce californica*	0.01	0.00	0.01
Mollusca	Gastropoda	*Tritonia tetraquetra*	0.03	0.00	0.02
Cnidaria	Pennatulacea	*Umbellula lindahli*	3.47	0.25	2.30
Cnidaria	Actiniaria	Urticina	3.25	0.23	2.16
Cnidaria	Pennatulacea	Virgulariidae	0.21	0.01	0.14
Vertebrata	Agonidae	*Xeneretmus latifrons*	0.51	0.04	0.34
Vertebrata	Embiotocidae	Zalembius	0.04	0.00	0.02
Vertebrata	Hexagrammidae	*Zaniolepis latipinnis*	0.41	0.03	0.27
Total, all taxa			**150.53**		**100.00**