POTENTIAL IMPACTS OF THE MONTEREY ACCELERATED RESEARCH SYSTEM (MARS) CABLE ON THE SEABED AND BENTHIC FAUNAL ASSEMBLAGES 2011

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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 2007-2008 and again in 2010. The most recent study was concluded 37 months 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 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 burial trench remains intact along deeper areas of the cable route,
  - Sediment is filling the cable trench, which is now nearly invisible in many locations.
  - In the limited areas where the cable was not buried, only minor suspensions of the cable are present
- 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 locations, 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.

- The MARS cable has little or no detectable 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 3 control stations and 1 cable station at each of 3 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 from the Monterey Bay Aquarium Research Institute (MBARI) to a science 'node' at a depth of 891 m on the continental slope just outside 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 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 ~20 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 carbonate and bedrock 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.

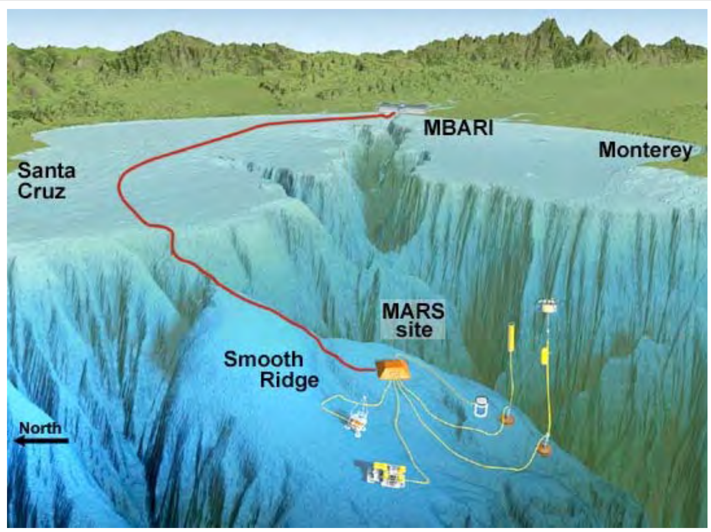

Figure 1. View of the MARS cable, node, and potential science instruments over exaggerated bathymetry of Monterey Bay, Monterey Canyon, and the continental slope. The science node is indicated as "MARS site".

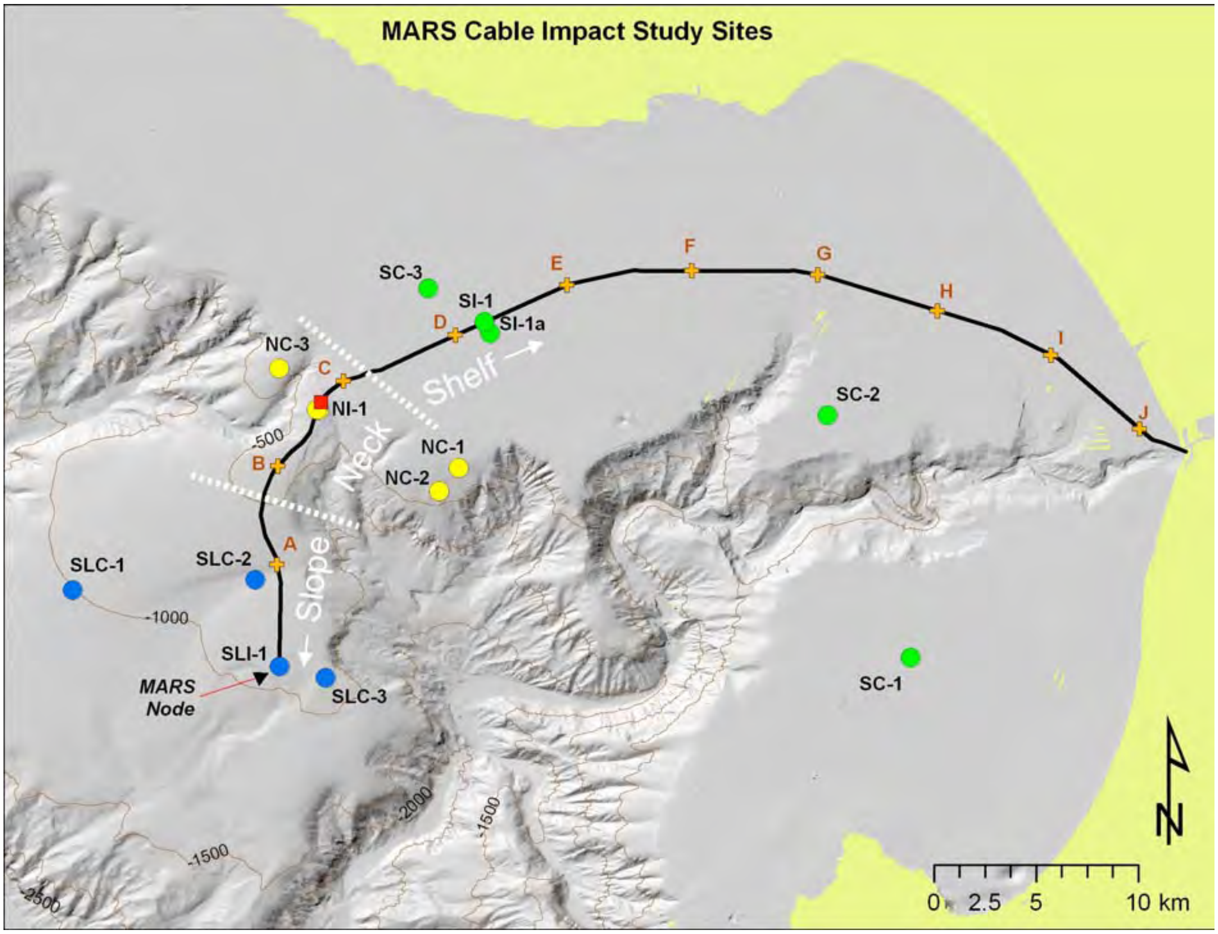

Figure 2. Map of MARS cable (black line) environmental studies sites. Colored circles represent regional sites for impact studies at Shelf (green), Neck (yellow), and Slope (blue) depths. Red box indicates location for Skate transects. Brown plus symbols (A-J) indicate transect locations for localized megafaunal studies.

Prior to MARS cable installation, an environmental impact report was prepared, including characterization of seabed biological communities along the cable route and initial sampling for future environmental impact assessment (2004). This survey included characterization of the megafaunal animals (organisms identifiable in video recordings) and macrofaunal organisms (worms, crustaceans, etc., captured from sieved sediment samples) along the cable route. Subsequent to MARS cable installation, a Post-Lay Inspection and Burial (PLIB) survey of the entire route was conducted (March 16 to March 22, 2007 and June 7, 2007) and 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, in 2007-2008 following cable installation, and again in 2010.

METHODS

Cable Condition Survey

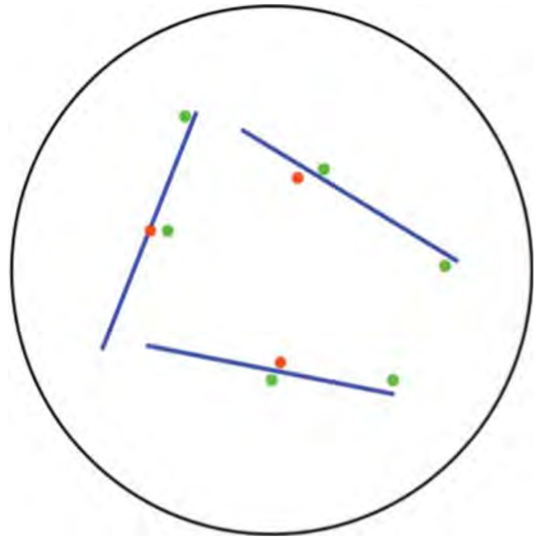

Figure 3. Sampling protocol for cable and control sites at each depth. Circle – 200 m diameter station. Blue lines – 100 m long video transects. Green circles – sediment core samples for macrofaunal assemblage characterization. Red circles = cores for sediment characteristic measurements.

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;

- 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 collection were performed using the ROV *Ventana*, supported by the R/V *Point Lobos* 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 HA10Xt.2 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 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 (~29 cm apart) 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 (width determined repeatedly during each transect using the paired laser system) were annotated (counted) 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.

Figure 4. Collection of sediment core.

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 zones" occupied by the cable (Figure 2). These include 1) the continental shelf (Shelf), 2) the continental shelf break and upper slope (Neck), and 3) the continental slope region near the MARS benthic node (Slope). These depths represent the principal habitat types along the cable path. Within each depth zone, 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, as well as rocks, debris, and other items, 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; %C, %N, grain size composition).

Skate Abundance at Neck Cable Region
An aggregation of Longnose skates 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-6* and *PERMANOVA+* (v.1.03; www.primer-e.com). This design was used for both multivariate and univariate data sets of biological or geological parameters. In most cases, raw counts of abundance (# 100 m^{-2} megafauna; # m^{-2} macrofauna) were transformed (4^{th} root) prior to analysis to increase homogeneity of variances among groups and to reduce the influence of very abundant species. 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 to be 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 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 four times, the field and analysis team completed 158 quantitative video transects, and collected and analyzed 210 sediment cores (120 for macrofaunal analyses, 72 for sediment characteristics, 18 spare cores).

2008

A total of 16 days of 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 crab pots.

2010

The 2010 cable survey was performed between January 8, 2010 and April 9, 2010 during 16 sea days and 34 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.

Condition of the Cable

Inspection of the cable and underlying seabed indicated that there was no apparent change in the position of the cable 13 months and again at about 36 months (survey dates vary), after installation. Survey observations verified that the cable is still buried from 0-1 m beneath the surface of the seabed, as measured during the PLIB survey (2007; Figure 5). There were no apparent changes along exposed sections, including portions of the cable with minor suspensions due to small-scale topographic highs and lows (Figure 6), which are largely confined to the Neck depth (Figure 4).

Frequent storms with heavy rainfall during the 2009-2010 winter led to high sediment outflow from coastal rivers, resulting in highly reduced visibility near the seabed in this region, particularly along the shallow (< 60 m water depth) portion of the cable route. Due to severely reduced visibility in this section, we relied on sonar imagery to verify that the cable was not present on the seabed. We were able to verify that the cable was fully buried at all sites in the shallow region (Figure 2), but were not able to survey approximately 12 km of the cable route (45-54 m water depth; 10 km between stations H to F and 2 km just west of site F).

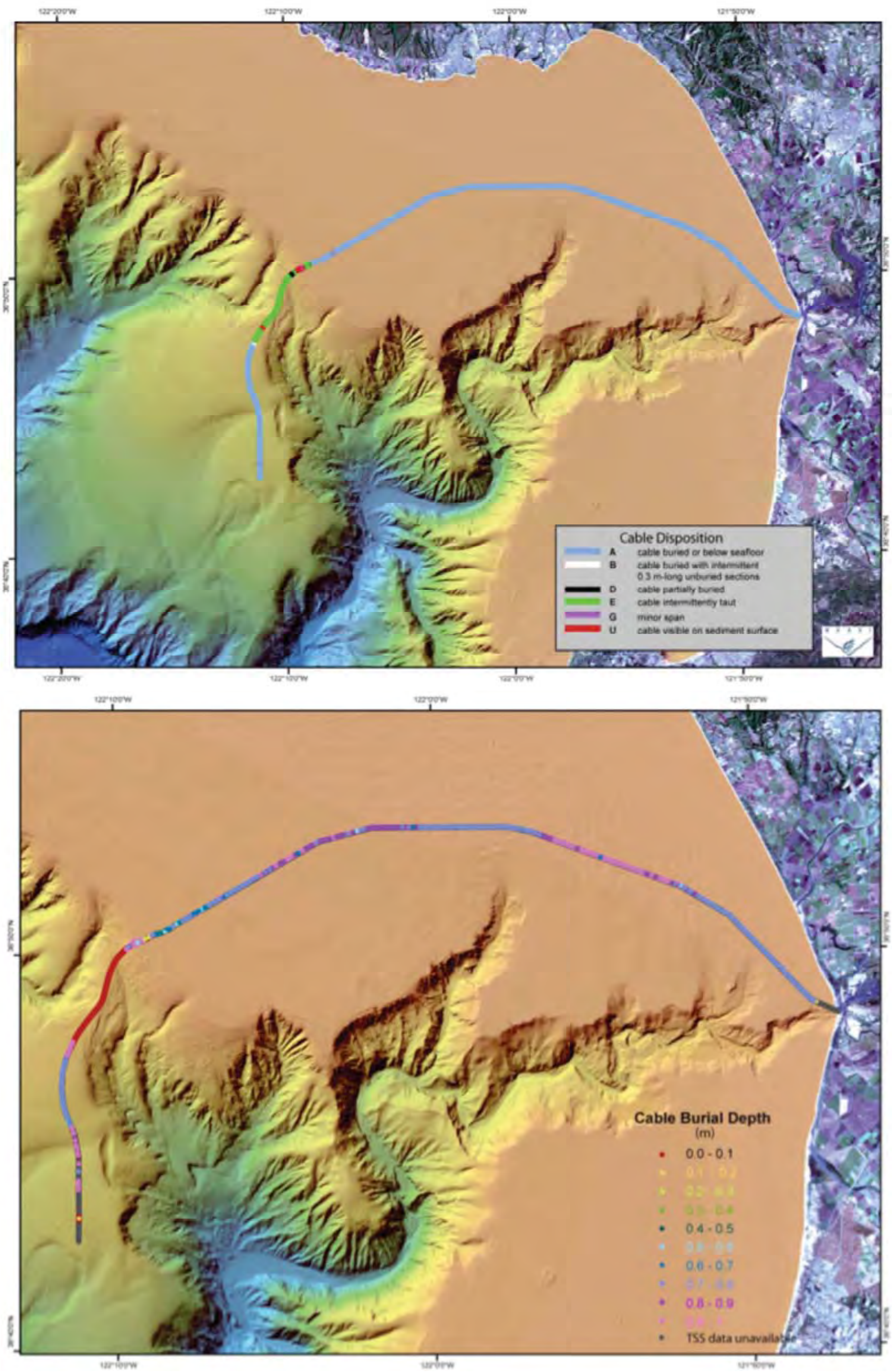

Figure 5. Exposure and depth of burial of the MARS. Upper map – buried versus exposed condition of cable. Note exposure in Neck Cable region. Lower panel – depth of burial of cable. These observations were made during the 2007 survey.

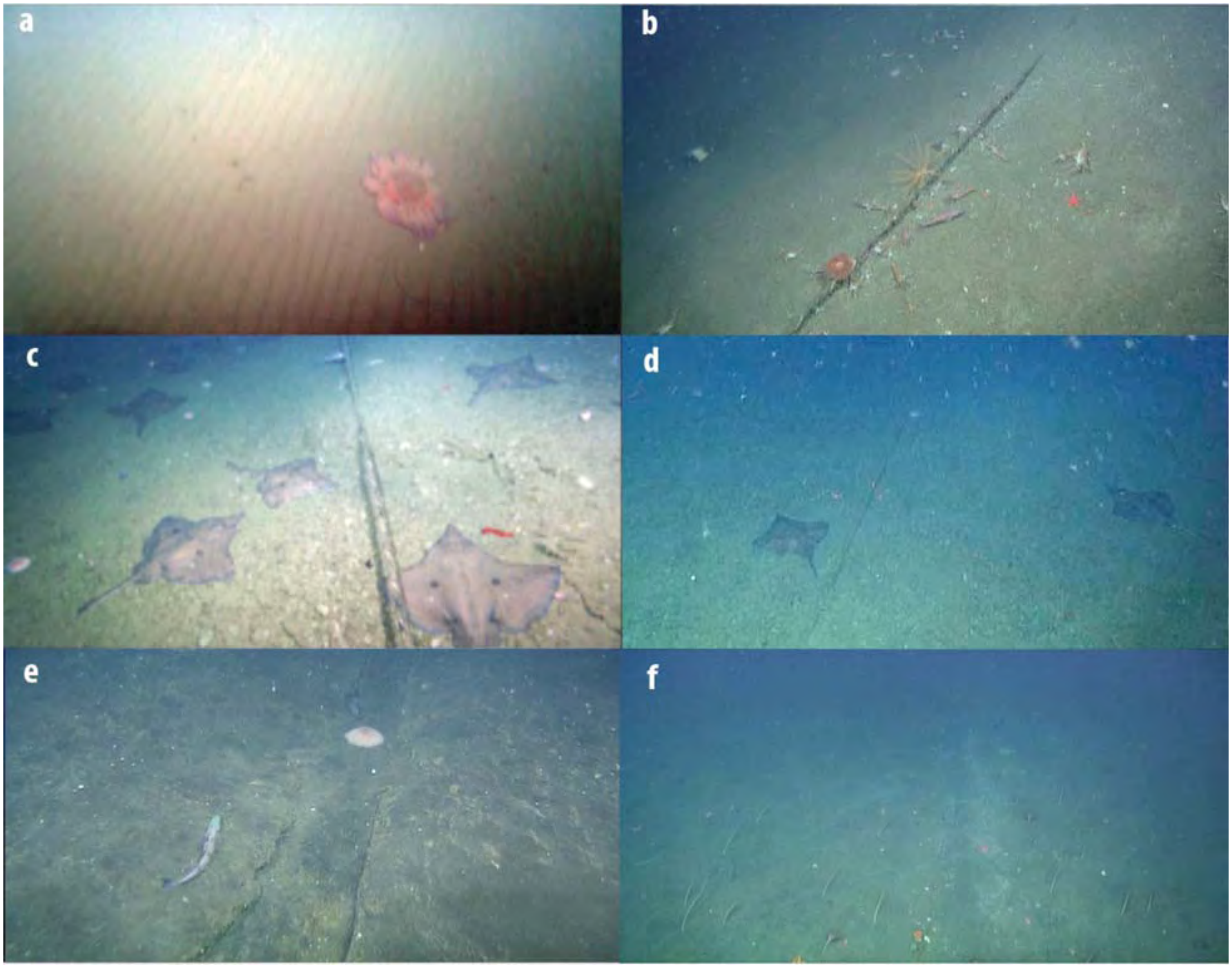

Figure 6. Images of the seabed along the cable route. A. Sand ripples at 31 m depth, cable not visible (2008). B. Cable on seabed at 226 m depth (2010). C. Skate (*Raja rhina*) aggregation at 303 m depth (2008). D. Far fewer skates were present in 2010. E. Cable trench sediment infilling at 447 m depth (2010). F. Cable trench is filled near the MARS node at 867 m depth (2010).

There is no evidence of strumming or other movement of the cable. As in the PLIB and 2008 surveys, the cable remains buried in 2010 with no trace of habitat disturbance in shallow sandy areas (Figure 6a), which comprise roughly 50 percent of the cable route. No evidence of trawling impact was observed during initial surveys, however three trawling incidents were documented during ROV visits to the science experiments attached to the MARS node between April 2009 and February 2010. The main cable has not moved, but instrumentation attached to the MARS node had been damaged.

In all other areas, habitat disturbance was less evident in 2010 than observed during the PLIB and 2008 surveys. The cable burial trench continues to fill in with time (Figure 6e), as indicated by the accumulation of soft, light-colored sediment in the trench. In 2008 there appeared to have been some minor redistribution of the tension in the cable. From 120–300 m depth, sections of the surface-laid cable are sinking into the surficial sediments; these continue to sink and be covered with sediment in 2010. As observed during the PLIB inspection, minor suspensions of the cable associated with topographic features between 136 and 450 m depth occurred, with the majority between 300 and 450 m. Of the 23 suspensions, most are less than 15 cm in length and none are more than 30 cm above the seabed. There were also 21 minor point suspensions where the cable is suspended < 10 cm above the seabed for a distance of <1 m each. Most suspensions are less than 10 cm above the seabed. None were higher than 30 cm above the seafloor and they all appear to be essentially unchanged in 2010.

Sediment Characteristics

In 2008 and 2010, the grain size and percentage carbon content of sediments varied significantly between treatments and sites for all three cable depth zones. However, because no "before" data were available, any effects of the cable on sediment grain size could only be inferred from comparisons between impact and control sites after installation of the cable.

Sediment Grain Size

Mean sediment grain size continued to be highly variable among and within cable depth zones ranging from 9 to almost 300 μm, with the coarsest sediments at Slope stations in 2010 (mean = 166 μm). These samples contained up to 38% coarse sand and very coarse sand, substantially more than in the 2008 samples (slope mean = 49 μm). Finer mean sizes characterized the Shelf (44 μm in 2008, 32 μm in 2010) and Neck (82.4 μm in 2008, 88 μm in 2010) depths.

Grain sizes at the shelf control sites were significantly smaller than at the impact station ($p<0.001$; Figure 7) in 2008, which might be expected in association with the installation of the cable. But because grain size also varied significantly between sites, irrespective of treatment (e.g. SC-1 < SC-2, SC-3; $p<0.05$), 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, mean grain size did not differ significantly between the impact and control sites ($p = 0.10$; Figure 7).

Variation in sediment grain size between treatments and among control stations was also observed at Neck and Slope depths (Figure 7). Within the Neck cable depth zone, mean grain size was larger at control stations than that measured at the impact station in 2008 (p<0.01). In 2010, no difference in grain size was detected at the neck depth zone (p = 0.09).

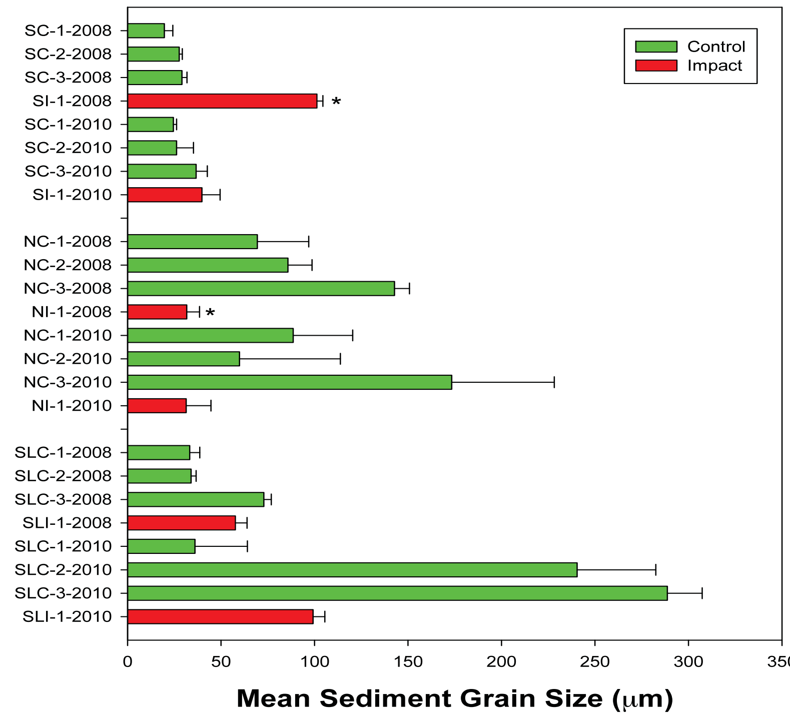

Figure 7. Mean sediment grain size (+/- SD) at control and cable (impact) stations for cable depth zones. *= significant difference between control and impact areas.

The interstation variation in grain size observed at shallower depth also occurred in the Slope depth zone. Although there was no detectable difference in mean grain size between control and impact treatments, and thus no apparent effect of the cable, grain size was generally large and more variable in 2010 compared to 2008.

Together, these results indicate that variation in mean sediment grain size varies greatly among depths, stations, and years, with little detectable variation related to the presence of the cable.

Sediment Percent Carbon Content

The carbon content of sediments varied considerably, ranging from 0.35 to 1.27 percent (Figure 8), with the more organic-rich sediments generally found in the finer grain sizes (R^2 = 0.28, p<0.06). During the 2008 survey, no differences between control and impact stations were detected for the Shelf or Slope depth zones, and a small, but significant difference was detected for the Neck depth. In 2010, samples from the Neck and Slope depths each had higher percentage carbon content at impact stations. This could represent natural variation or potentially an enhancement of organic rich material near control stations, perhaps 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.

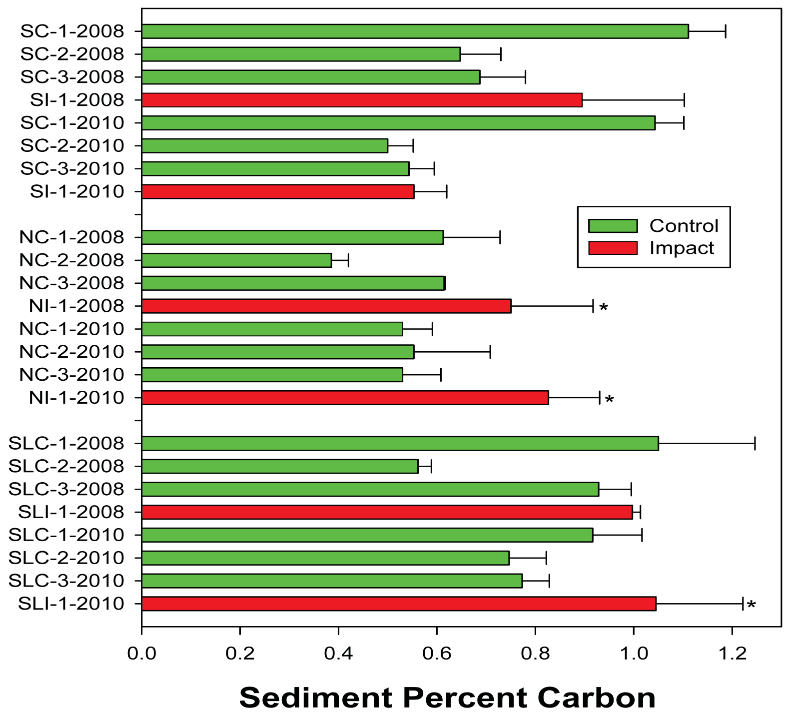

Figure 8. Mean percent organic carbon in surficial sediments for control and cable sites at three cable depth regions (+/- SD). Comparisons of control vs. cable (impact) sites within each depth were nonsignificant (Shelf, $p>0.6$, Slope ($p>0.3$) and marginally significant at the Neck depth ($p<0.05$). *= significant difference between control and impact areas.

Biological Characteristics

Megafaunal Assemblage

The seabed megafaunal assemblage along the cable route included 116 taxa observed in 156 ROV video transects (Appendix 1, 2). The overall average density of megafauna averaged 158 ind. 100 m^{-2} (Table 1). By phyla and taxonomic groups, cnidarians were most abundant, comprising just over 44 percent of the total megafaunal abundance and were represented mainly by sea pens (Pennatulacea) and anemones (Actinaria). Echinoderms ranked second among phyla with almost 29 percent of the total abundance, particularly sea stars (Asteroidea), urchins (Echinoidea), and sea cucumbers (Holothuroidea) (Table 1). Fishes (Chordata) were the third most abundance phylum with over eight percent of the total abundance.

The top seven ranking megafaunal species accounted for nearly 60 percent of the total abundance. Three common taxa (Figure 9a-c, Appendix 2) comprised 35 percent of the total megafauna. *Funiculina* sp., a common sea pen at slope depths near 500 – 1000 m was the most abundant species (32 ind. 100 m^{-2}), with 20.2 percent of the total megafaunal abundance. Small anemones (*Isosicyonis* sp.), common at the deeper depths of the study, and *Stronglylocentrotus fragilis,* a common urchin at upper slope depths, ranked second and third, with 7.3 percent each.

Eighteen months after installation, there were 59 organisms attached to the cable in the neck region where the cable is 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).

Table 1. Summary of megafaunal abundance by phyla and groups. Abundance is listed as a mean (# ind. 100 m^2, standard deviation (SD), and percent of total abundance (%).

Phylum / Group	Mean	SE	%
Cnidaria	**69.89**	**12.96**	**44.17**
Pennatulacea	50.28	9.46	31.78
Actiniaria	17.10	2.98	10.81
Ceriantharia	1.91	0.27	1.21
Gorgonacea	0.24	0.12	0.15
Corallimorphidae	0.13	0.05	0.08
Alcyonacea	0.09	0.04	0.06
Trachymedusae	0.11	0.02	0.06
Anthozoa	0.03	0.02	0.02
Echinodermata	**45.59**	**14.87**	**28.81**
Asteroidea	15.58	3.10	9.85
Echinoidea	11.60	3.31	7.33
Holothuroidea	11.06	5.17	6.99
Ophiuroidea	7.14	3.16	4.51
Crinoidea	0.21	0.13	0.13
Vertebrata	**14.62**	**6.29**	**8.34**
Scorpaenidae	5.58	0.92	3.53
Pleuronectiformes	4.52	0.61	2.86
Zoarcidae	1.69	3.09	0.33
Agonidae	0.44	0.13	0.28
Stichaeidae	0.42	0.21	0.27
Phylum / Group	**Mean**	**SE**	**%**
Merlucciidae	0.37	0.15	0.24
Osteichthyes	0.29	0.11	0.18
Macrouridae	0.19	0.09	0.12
Rajiformes	0.21	0.06	0.13
Myxinidae	0.14	0.52	0.09
Zaniolepididae	0.12	0.05	0.07
Moridae	0.08	0.04	0.05
Liparidae	0.05	0.02	0.03
Scyliorhinidae	0.05	0.03	0.03
Anoplopomatidae	0.04	0.02	0.02
Embiotocidae	0.04	0.03	0.02
Ophidiidae	0.04	0.02	0.02
Squalidae	0.03	0.03	0.02
Alepocephalidae	0.01	0.01	0.01
Chimaeridae	0.01	0.01	0.01
Hexagrammidae	0.14	0.06	0.01
Osmeridae	0.15	0.07	0.01
Torpedinidae	0.01	0.01	0.01
Detritus (plant/kelp)	**10.92**	**1.69**	**6.9**
Mollusca	**12.48**	**3.06**	**7.89**
Gastropoda	12.01	2.90	7.59
Cephalopoda	0.47	0.16	0.30
Arthropoda	**2.86**	**0.88**	**1.81**
Decapoda	2.28	0.67	1.44
Anomura	0.50	0.17	0.32
Caridea	0.08	0.04	0.05
Porifera	**1.58**	**0.50**	**1.00**
Urochordata	**0.10**	**0.08**	**0.07**
Brachipoda	**0.06**	**0.06**	**0.04**
Echiura	**0.05**	**0.03**	**0.03**
Annelida (Polychaeta)	**0.05**	**0.02**	**0.03**
Grand Total	**158.22**		

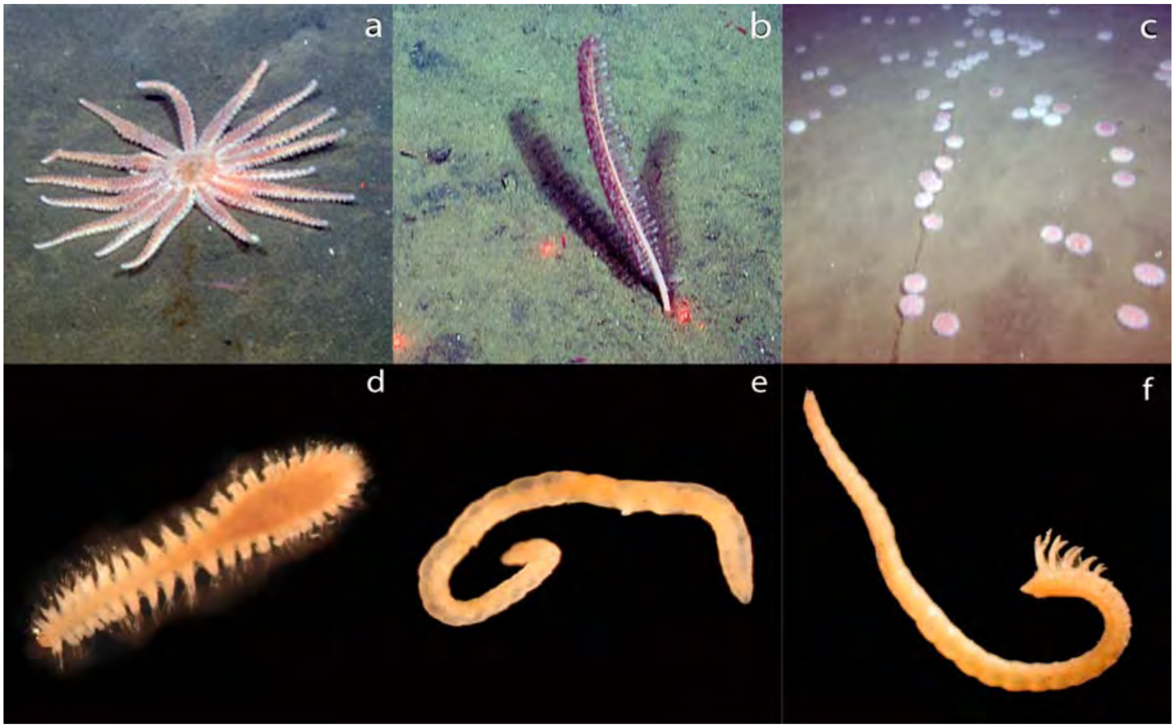

Figure 9. Common megafaunal and macrofaunal animals along the MARS Cable route. A-C: Megafauna: A. *Rathbunaster californicus* (sea star). B. *Funiculina* sp. (sea pen). C. *Stronglylocentrotus fragilis*, (urchin). D-F: Macrofauna: D. *Cossura* sp. (polychaete). E. Oligochaeta. F. *Prionospio* sp. (polychaete). 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 10, 11). Multivariate tests comparing cable and control treatments for all species or all groups were non-significant ($p = 0.96$). 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.

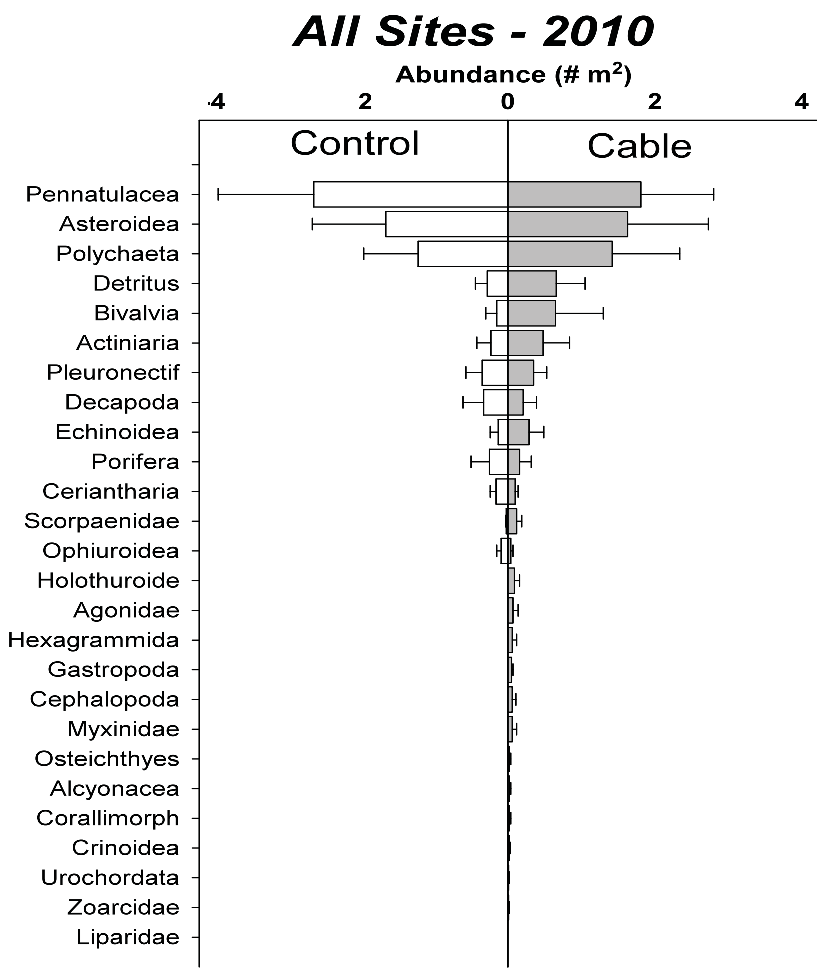

Figure 10. Variation in abundance of megafaunal groups along the cable route. Paired transects show little variation in densities of megafauna over 10 sites along the cable (p = 0.96). Cable = directly over the cable route. Control = 50 m away from and parallel to the cable.

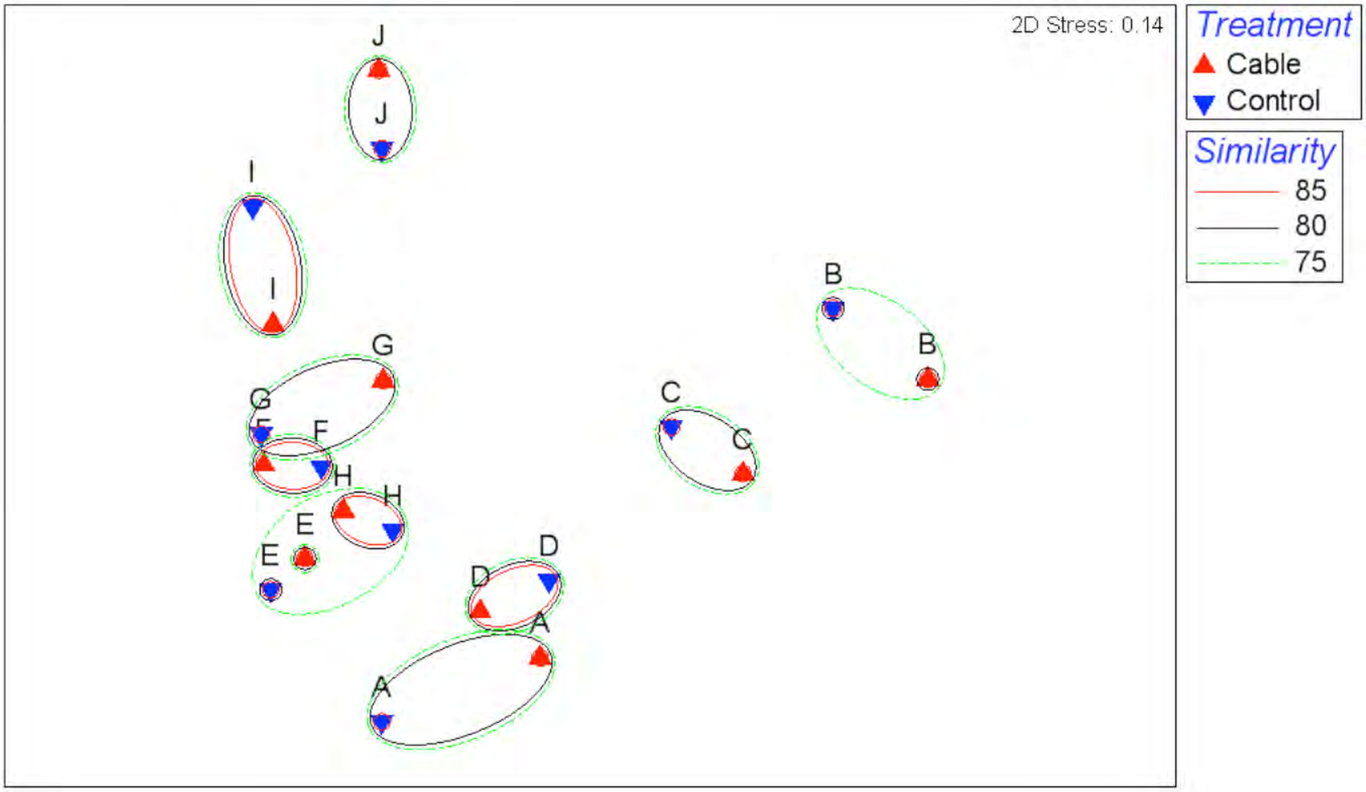

Figure 11. MDS plot based on Bray-Curtis Similarity Index for megafaunal assemblages at local stations sampled in 2010, showing high similarity between biological communities at control and impact sites along the cable route and 50 m away. Letters refer to stations along the cable route (A = deepest station at 890 m, J = shallowest station at 19 m; Figure 2).

Within this 300 long segment of the cable route, the density of Longnose skates (*Raja rhina*) was anomalously high (Figure 6c). 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 ($p<0.027$). The densest aggregations were concentrated along a 75 - 100 m section, with the skates resting on the seafloor within 5 - 10 m of the cable. We also noted somewhat higher than normal numbers of the elasmobranchs *Parmaturus xaniurus* (catsharks) and *Hydrolagus colliei* (spotted rat fish) in this general area of the cable route, but off the transect. In 2010, there was no longer a statistically significant difference in the number of skates present over the cable (Figure 6d); 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.

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 is apparently 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 12-15). 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 Shelf, Neck, and Slope depths, multivariate comparisons (i.e. comparisons between the entire megafaunal assemblage) indicated no significant Period x Treatment interaction terms ($p>0.71$, 0.17, 0.60, for Shelf, Neck, and Slope, respectively) (Table 2). These 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. These results were found for multivariate tests using either species-level data or higher taxon-level data.

There were few changes in the abundances of individual species or higher taxa in relation to the installation 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 2), very few significant PxT interaction terms were found, indicating little effect of the MARS cable. Univariate tests were conducted for most major taxa shown in Figure 11-13. Among these, the PxT interaction term was significant for only 6 of 28 tests. *Phyllospadix* sp. (surf grass) is detritus that was not observed at the Slope cable station during the pre-installation survey, but occurred there during the 2008 and 2010 surveys. It may have accumulated in the trench after cable installation. Kelp and surf grass were not observed collecting near the exposed cable in the Neck depth zone. This is a high-energy region and detritus is subject to high current speeds on the seabed. Marine snails (Gastropoda) and the actiniaria (anemones) that attach to them (*Isoscyonis sp.*) may have been affected by the cable installation, as indicated by the significant PxT interactions (Table 2). Snails were low in abundance at the Slope cable station prior to cable installation (0.3 100 m^{-2}), but increased by 2008 to a mean of 45 ind. 100 m^{-2} and to 153 100 m^{-2} in 2010. During both periods, snail densities at the control stations averaged 17-22 ind. 100 m^{-2}. While this may represent natural variability, it is likely that snails aggregated near the cable stations and in the cable trench in association with increased abundance of detritus and other material. The PxT interaction term was also highly significant at the Slope Depth for the deep-sea cucumber, *Pannychia moseleyi*. This species was initially abundant at the Slope cable station (40 ind. 100 m^{-2}), but sparse at Slope control stations (mean = 0.3 ind. 100 m^{-2}). During the 2008 survey, *P. moseleyi* was not observed at any Slope stations. Because this sea cucumber appears to vary considerably between stations and periods, the observed changes in density may be due simply to natural variability rather than specific cable effects. Large fluctuations in the abundance of this species have been observed in our local benthic studies; this variation is evident at the Neck depth stations (Table 2). We have observed that the density of the sea pens (Pennatulacea) *Funiculina* sp. and *Umbellula lindahli* varies widely on a scale of only 10's of meters. In 2010, we observed 4.03 *Funiculina* sp. 100 m^{-2} at the MARS node station (SLI-1) vs. 0.24-1.07 100 m^{-2} at the control station.

Although few effects of cable installation were detected, significant main effects (Treatment or Period) were found for some taxa and cable depth zones (Table 2). 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.

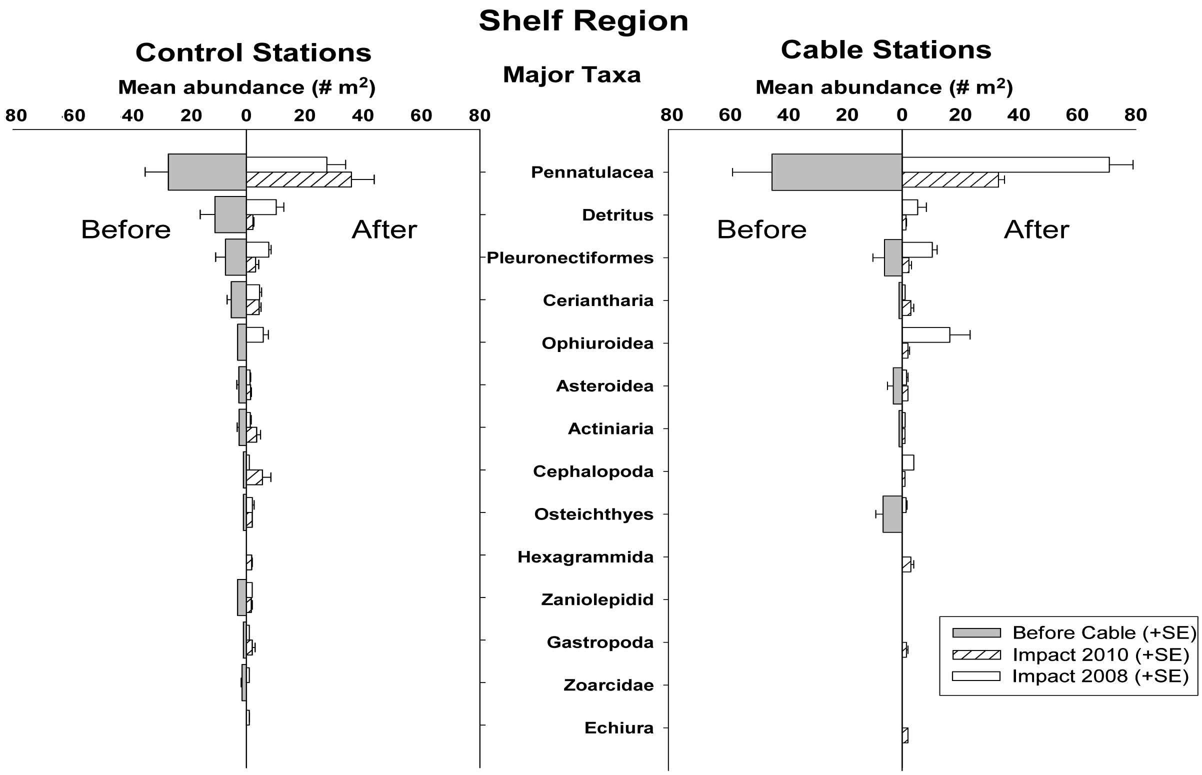

Figure 12. Variation in megafaunal abundance among treatments and periods at Shelf depth stations. BACI analysis indicated no overall significant effect of cable installation ($p>0.05$) in this region for higher-level taxonomic groups.

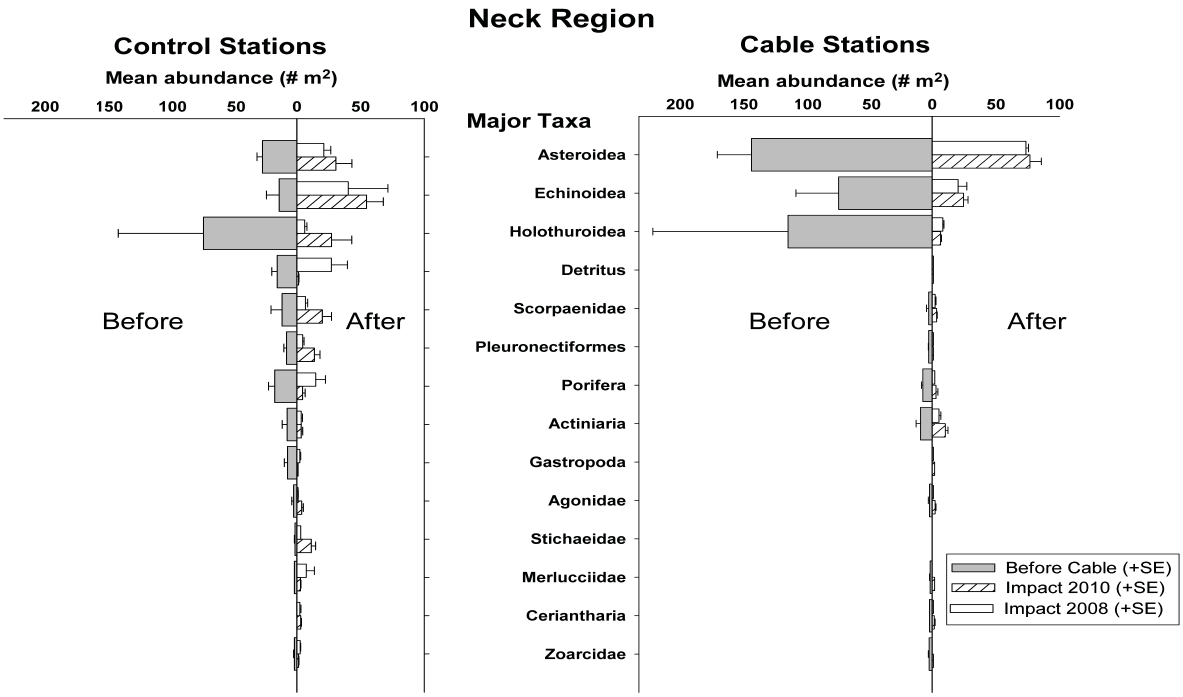

Figure 13. Variation in megafaunal assemblage among periods and treatments at Neck depth stations. BACI analysis indicated no overall significant effect of cable installation (p>0.05) in this region for higher-level taxonomic groups.

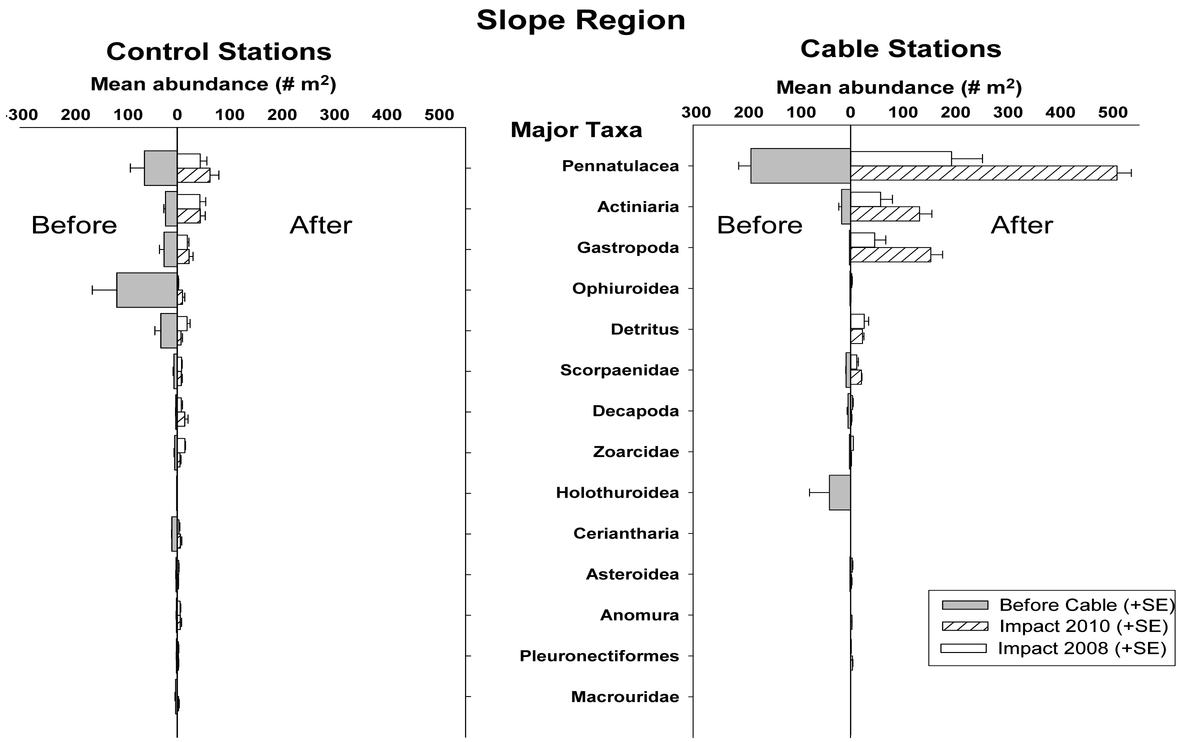

Figure 14. Variation in megafaunal abundance among treatments and periods at Slope depth stations. BACI analysis indicated no overall significant effect of cable installation ($p>0.05$) in this region for higher-level taxonomic groups.

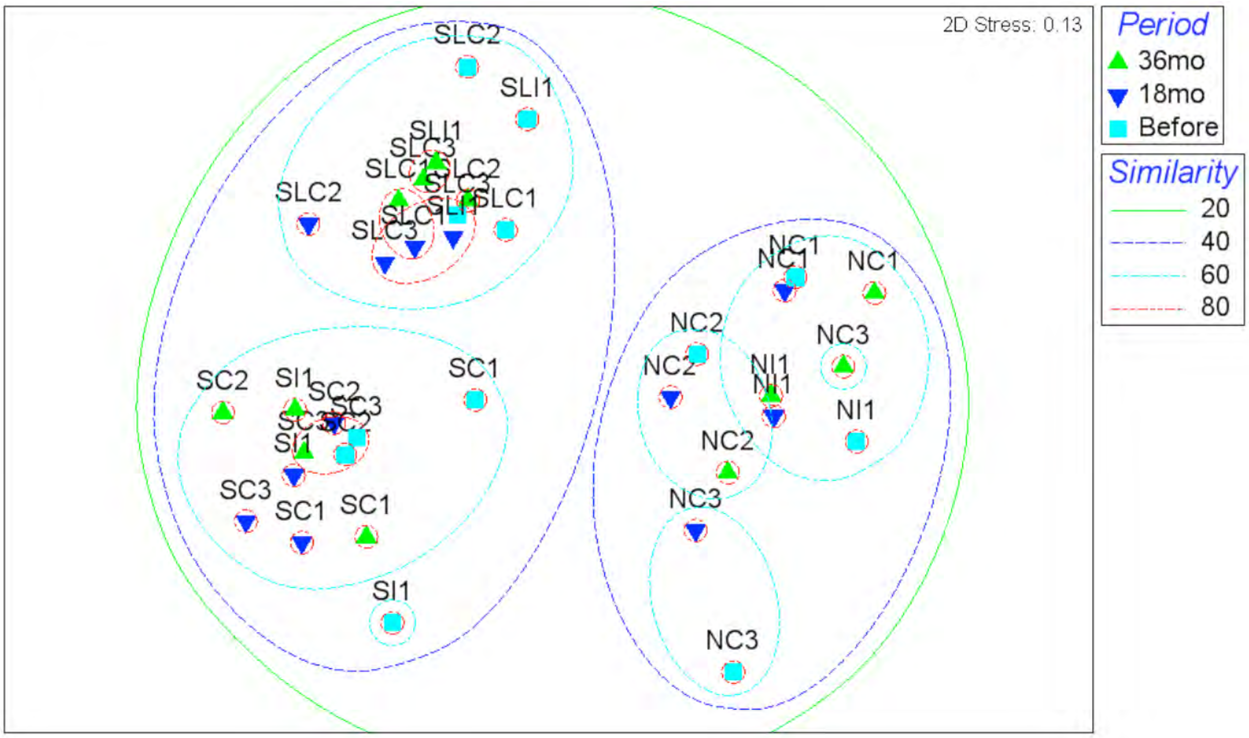

Figure 15. MDS plot based on Bray-Curtis Similarity Index. Regional megafaunal communities remained at least 60 percent similar in a comparison of community structure before the MARS cable was installed, and at 18 and 36 months post-installation. Stations clustered based on depth, with shelf, neck and slope stations most similar to each other.

Table 2. Summary of univariate BACI analysis for megafaunal taxa for all cable depths. 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.

	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	**	*	*	> after cable inst.
Ceriantharia (tube anemones)	ns	*	ns	ns	*	ns	ns	ns	ns	Sig. station variability
Pennatulacea (sea pens)	ns	ns	ns	ns	ns	ns	**	ns	ns	Sig. station variability
Phyllospadix (surfgrass detritus)	**	*	ns	**	**	*	**	ns	**	> after cable inst.
Asteroidea (sea stars)	ns	ns	ns	ns	**	ns	ns	ns	ns	Sig. Station variability
Echinoidea (sea urchins)	-	-	-	ns	*	ns	ns	ns	ns	Cable > Control
Holothuroidea (sea cucumbers)	*	ns	ns	ns	ns	ns	**	ns	**	Natural variability?
Ophiuroidea (brittle stars)	**	ns	ns	-	-	-	ns	ns	ns	Natural variability?
Gastropoda (snails)	ns	ns	ns	ns	ns	ns	**	ns	**	> after cable inst.
Pleuronectiformes (flatfishes)	ns	ns	ns	*	**	**	*	ns	ns	Control > Cable
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	ns	Cable > Control
Stronglylocentrotus fragilis(urchin)	-	-	-	ns	*	ns	ns	ns	ns	Cable > Control
Psolussquamatus (sea cucumber)	-	-	-	ns	ns	ns	-	-	-	
Isoscyonis sp. (anemone)	-	-	-	-	-	-	**	*	*	> after cable inst.
Umbellula lindahli (sea pen)	-	-	-	-	-	-	ns	**	ns	Cable > Control
Sebastolobus sp. (fish)	-	-	-	ns	ns	ns	ns	*	ns	
Pannychia moseleyi (sea cucumber)	-	-	-	-	-	-	**	**	**	Natural variability?
Actinostolidae (anemone)	ns	ns	ns	ns	*	ns	**	*	*	> after cable inst.
Florometra serratissima	-	-	-	ns	**	ns	-	-	-	> after cable inst.

Regional Effects of Cable Installation – Macrofauna

Macrofaunal assemblages (Table 3) along the cable route appear to be largely unaffected by the installation of the cable, as found for the megafaunal assemblages.

Multivariate tests for the Shelf and Neck depth zones, indicate a significant PxT interaction term at the taxa level (Table 4), and there was no detectable cable effect at the Slope depth (i.e. PxT = ns), even though there were significant main effects (Period, Treatment, Table 4). Owing to the overwhelming dominance of polychaete worms in the macrofauna (Figures 16, 17, 18), 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 16, 17, 18). Simultaneously, the abundance of most other macrofaunal taxa at control stations decreased. 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) have greater influence on polychaete abundance. A large pulse of brittlestars (ophiuroids, Figure 16) was present in 2010, particularly at the control station. This is a normal phenomenon and unrelated to the presence or absence of the cable. Amphipods are also dominant infauna in the Neck depth zone. Before the cable was installed, they were far more abundant at the cable station compared to the control station. Abundance was even higher 18 months-post installation, but trended more toward the “before” numbers in 2010.

These results, indicating few detectable effects of the MARS cable on seabed biology, 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 3. Mean density of macrofaunal taxa, by group over all samples. Density is listed as number per core (area = 37.39 cm^2). % indicates the percentage of the taxon of the total macrofaunal abundance.

Phylum	Group	Mean (#/core)	SE	%
Annelida		**25.572**	**1.664**	**50.705**
	Polychaeta	23.668	1.370	46.930
	Oligochaeta	1.904	0.294	3.775
Arthropoda		**15.858**	**1.847**	**31.444**
	Amphipoda	10.084	1.023	19.996
	Tanaidacea	1.939	0.311	3.845
	Isopoda	1.439	0.172	2.853
	Ostracoda	1.146	0.179	2.273
	Cumacea	1.178	0.132	2.336
	Mysida	0.063	0.024	0.124
	Decapoda	0.008	0.006	0.016
	Pycnogonida	0.001	0.001	0.001
Mollusca		**4.909**	**0.558**	**9.733**
	Bivalvia	3.819	0.367	7.573
	Scaphopoda	0.456	0.069	0.904
	Gastropoda	0.481	0.076	0.954
	Aplacophora	0.136	0.037	0.270
	Polyplacophora	0.016	0.009	0.032
Echinodermata		**2.530**	**0.520**	**5.017**
	Ophiuroidea	2.480	0.494	4.918
	Echinoidea	0.014	0.008	0.028
	Holothuroidea	0.036	0.018	0.072
Nemertea		**1.122**	**0.146**	**2.224**
Cnidaria		**0.299**	**0.116**	**0.593**
	Actiniaria	0.265	0.102	0.526
	Hydrozoa	0.034	0.014	0.068
Sipuncula		**0.052**	**0.016**	**0.103**
Echiura		**0.040**	**0.017**	**0.079**
Enteropneusta		**0.034**	**0.024**	**0.068**
Phoronida		**0.011**	**0.008**	**0.023**
Platyhelminthes		**0.006**	**0.006**	**0.011**
Total		**50.432**		

Table 4. Summary of Univariate 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. C= Control Stations, I = Cable Stations, B = Before Stations, A = After Stations, * = p<0.05, **= p<0.01, - indicates absent from region

	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	> after cable inst.
Amphipoda (crustacea)	ns	ns	ns	ns	**	ns	**	*	*	Impact>control, Control>Impact all periods
Bivalvia (clams)	**	ns	ns	ns	**	ns	ns	*	ns	Natural variation
Oligochaeta (worms)	ns	ns	ns	ns	*	ns	*	ns	ns	Impact>control, >all stations > inst.
Tanaidacea (crustacea)	**	ns	ns	ns	**	ns	ns	ns	ns	> all stations > inst., Impact>control
Isopoda (crustacea)	ns	ns	ns	ns	ns	*	ns	ns	ns	
Ostracoda (crustacea)	ns	ns	ns	ns	**	ns	ns	ns	ns	Impact>control
Ophiuroidea (brittle stars)	**	ns	ns	ns	ns	ns	ns	ns	ns	> after cable inst. all stations, natural variation.

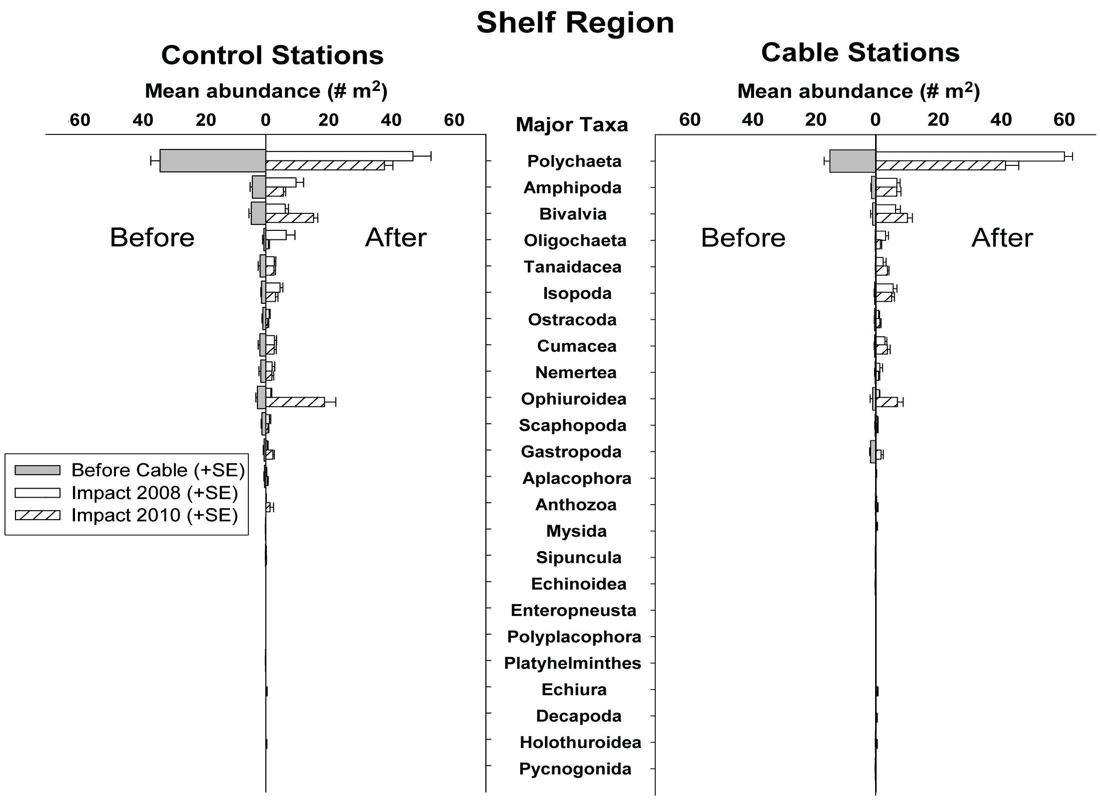

Figure 16. Variation in the abundance of macrofaunal taxa at the Shelf cable depth region among treatments and periods.

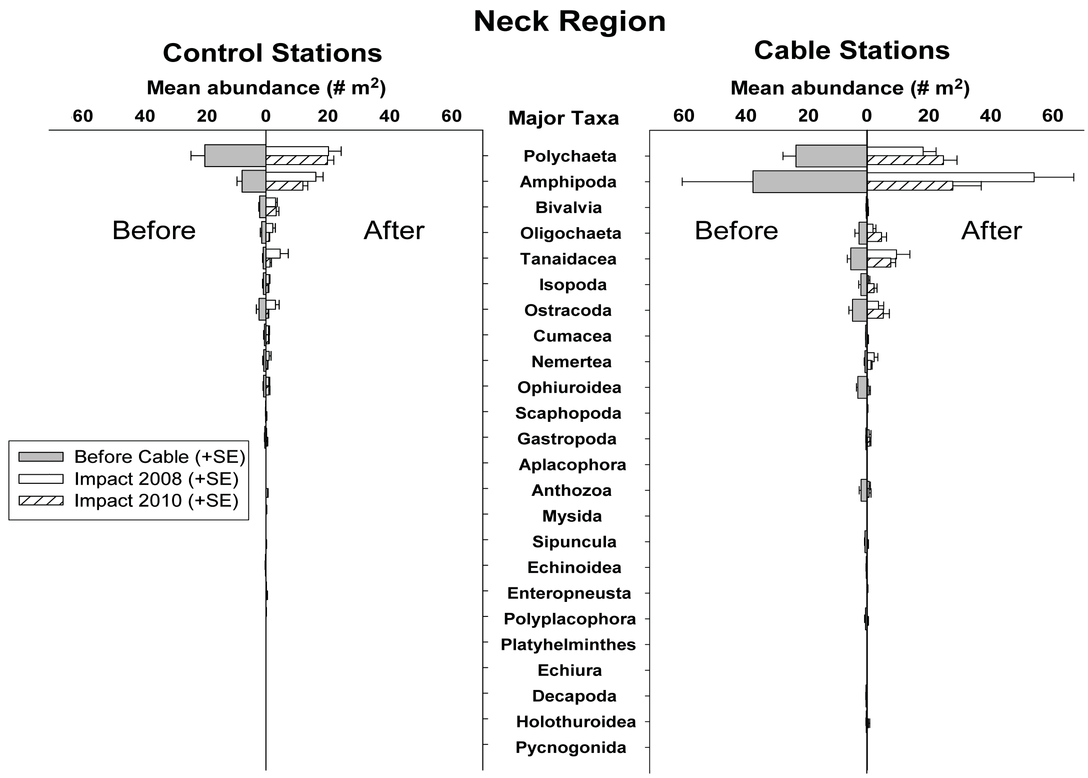

Figure 17. Variation in the abundance of macrofaunal taxa at the Neck cable region among treatments and periods.

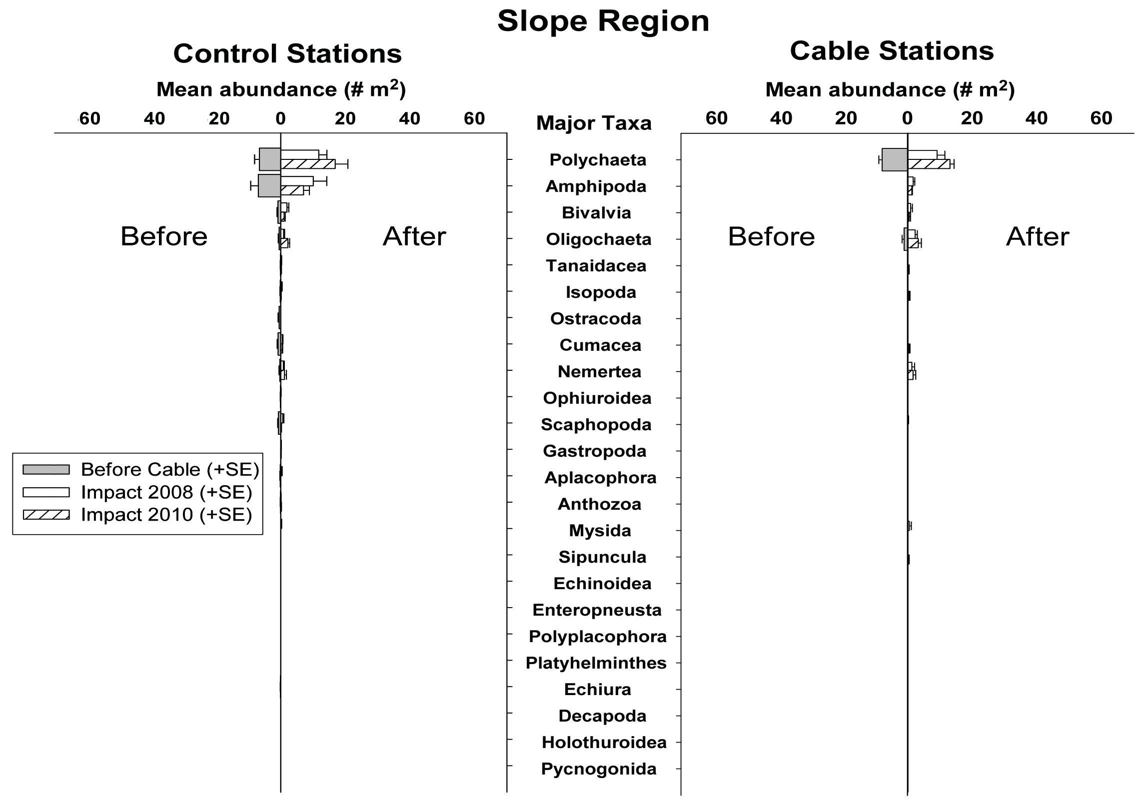

Figure 18. Variation in the abundance of macrofaunal taxa (higher groups) at the Slope cable zone among treatments and periods.

Other factors
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 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 locations, 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. During 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 3 control stations and 1 cable station at each of 3 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.

ACKNOWLEDGEMENTS

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