Technical Summary

Study Title: Renewable Energy in situ Power Cable Observation
Report Title: Renewable Energy in situ Power Cable Observation
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Sponsoring OCS Region: Pacific
Applicable Planning Area: Southern California
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Cumulative Project Cost: $1,232,660
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Background and Objectives

It is likely that for the foreseeable future, offshore renewable energy technologies (e.g., wind and wave) will focus on the generation of electricity. These technologies harness energy from an array of individual devices and, through power cables, send electricity to shore via cables. These cables will transmit either alternating current or direct current, and, if the cable uses alternating current, this current will generate both electric and magnetic fields.

Research has shown that some cartilaginous and bony fishes, as well as at least some invertebrates, are sensitive to electromagnetic fields (EMF) and that these fields can alter the behavior of these organisms (Kalmin 1982, Formicki et al. 2004, Tanski et al. 2005). However, worldwide, very few studies have been conducted to document the effects of EMF on marine organisms in situ (Ohman et al. 2007). Only one survey on the Pacific Coast has examined, in the marine environment, the role that EMF emitted from a cable might play. That study, Barry et al. (2008), found that longnose skate (Raja rhina) appeared to have been attracted to an energized sea-bed cable. However, it should be noted that rather than comparing energized and unenergized cables, this survey compared organism densities along a sea bed before and after an energized cable was installed. Thus it was difficult to differentiate the effects of the EMF emanating from the cable from the effects of the cable structure itself.
Submarine transmission cables that power offshore oil platforms in the Pacific Region provide a unique opportunity to assess potential behavior and reaction of electromagnetic-sensitive species to industry activities. In particular, the chance occurrence of both energized and unenergized cables in a corridor on the seafloor within the Santa Ynez Unit Offshore Southern California Planning Area, allows for an experiment testing the effects of EMF on marine organisms. The identical cables stretch several miles from Platforms Heritage, Harmony, and Hondo (at depths to about 326 m) to Los Flores on the mainland. The cables run from the platforms toward the mainland to a sea floor depth of 10 m and from there are buried inshore. One

unenergized cable runs from a platform to the border of federal and state waters at a bottom depth of about 150 m. All of these cables use the industry standards of the power cables that will be used for connecting devices (35 KV) within renewable energy installations. These cables were emplaced concurrently by the manufacturer. Thus, the cables form a natural experiment, allowing a comparison of an energized power cable with one that is unenergized to determine the potential impacts from electromagnetic fields while controlling for the habitat effect contributed by the cables themselves.

The goal of this study was to more fully understand the potential effects of energized, seabed deployed, power cables on marine organisms.

Specific objectives of this study were to determine:

1) The differences among fish and invertebrate communities associated with energized and unenergized cable habitat and those communities in soft seafloor habitats lacking cables.
2) Whether electrosensitive species that are regionally important such as sharks and rays respond (via either attraction or repulsion) to the EMF's of an in situ power transmission cable.
3) The strength, spatial extent, and variability of EMF's along both energized and unenergized cables.
4) The potential effectiveness of the commonly proposed mitigation of cable burial.

Knowledge gained from this study will be directly applicable to renewable energy projects not only in the Pacific OCS region, but to any OCS planning area.

Description

The research was divided into two parts: Task 1 took place in inshore waters (10–14 m) and Task 2 in offshore waters (76–213 m). Here following, we will divide the descriptions and significant results of our research into those two categories.

Task 1

Between 1 February 2012 and 26 February 2014 using scuba, we surveyed the fishes, invertebrates, and marine plants living on two energized submarine power cables, adjacent pipe, and natural habitat. Along cable, pipe, and over sandy bottom, we installed six permanent 30 m-long transects; three at a shallow depth (10–11 m) and three in slightly deeper waters (13–14 m depth). The end of the shallow transects and beginning of the deep ones were separated by about 120 m. The beginning and ending of each transect at each site was marked by sand anchors as was each 5 m segment along each transect. Transects were 2 m wide, centered on the pipe or cable or an imaginary line between sand anchors that delineated the sandy control transect. During the surveys, we measured the electromagnetic fields (EMF) emitted by the cable, pipe, and natural habitat. Fishes and plant surveys were conducted from the beginning to end of the study — from 1 February 2012 to 26 February 2014. Invertebrate surveys were conducted beginning on 22 June 2012 and continued until the end of the study. We conducted a total of 38 days of fish surveys, 30 days of invertebrate studies, and 38 days of plant studies during the three years.

Task 2
We conducted surveys of energized and unenergized cables and of the nearby sea floor during 2012 (6–9 October), 2013 (3–5 October) and 2014 (23–25 October) at depths between 76 and 213 m using a manned submersible. During 2012, only the east side of each cable was surveyed, while in 2013 and 2014 we surveyed both sides of the cables at similar depths. All natural habitat surveys were conducted between 100 and about 500 m from the nearest cable.

In 2012, we measured the EMF levels at three distances from energized Cable A. These measurements were taken at four locations along the cable (at bottom depths of 108 m, 112 m, 135 m, and 158 m). In 2013 and 2014, we measured EMF on all energized and unenergized cables on the cable at one location each, and on the sea floor.

Significant Results

Task 1
Over the course of the study, average EMF levels at the two cables (A and B) were statistically similar (Cable A = 73.0μT, Cable B = 91.4μT) and were much higher at the two cables than at either the pipe (average = 0.5μT) or sand (0μT).

Fishes
Overall, our study demonstrated that 1) the fish communities on cables, pipe, and natural habitat strongly overlapped (global R=0.097, p=0.01) and 2) the difference between the shallower and deeper fish communities was negligible (global R=0.097, p=0.001).

Over all habitats, we observed 4,671 individuals of a minimum of 44 species. Dominant species included adults of benthic-oriented, schooling taxa (i.e., kelp perch, senorita, white seaperch, and shiner perch), young-of-the-year (YOY) rockfishes that had newly settled out of the plankton (particularly black-and-yellow, gopher, and kelp rockfishes), and relatively solitary substrate-oriented species (i.e., sanddabs and kelp perch). Senorita, sanddabs, white seaperch, YOY rockfishes, and kelp perch were the most abundant taxa. Cables: At least 35 species and 1,721 individuals were observed over the energized cables. Senorita, sanddabs, kelp perch, white seaperch, and YOY rockfishes were most abundant (Table 2-4). Pipe: The number of taxa (37) and individuals (1,829) were similar to those observed on the cables. Senorita, YOY rockfishes, vermilion rockfish YOY, pile perch, black perch, and sanddabs were the most important taxa on the pipe (Table 2-5). Natural Habitat: Fewest species (25) and individuals (1,121) were observed over the natural habitat. Shiner perch, sanddabs, senorita, YOY shortbelly rockfish, white seaperch, and tubesnout were most often observed here (Table 2-6).

All of the fish communities were composed primarily of small fishes and the majority of these individuals were less than 20 cm long. The mean length of fishes varied significantly among the three habitats (Welch's Test, $F = 43.7$, $df = 2$, $p < .0001$) as did the size distributions. However, we note that the difference of mean lengths among sites is very small and it is unlikely that these differences, although statistically significant, are biologically meaningful. The abundance of all fishes combined varied seasonally at every site. In general, fishes were more abundant from early spring through early fall at all sites. This was reflective of the seasonal influx of newly settled rockfishes, young seaperches, and the general increase in fish abundance in nearshore waters that takes place as the turbulent winter waters subside.

Invertebrates

Similar to the fish assemblages, the invertebrate communities on the cables, pipe, and natural habitats were quite similar overall (global R=0.111, p=0.001) and the shallower and deeper invertebrate assemblages were indistinguishable (global R=0.000, p=0.51). Over all habitats, we observed a total of 822 individuals comprising a minimum of 19 species. Bat star, several species of sea stars, purple urchin (but noted on only one occasion), California sea hare, Comb sea star, and Kellet's whelk were observed most often. By group, sea stars were the most abundant, comprising 56.8% of all invertebrates recorded. Cables: We observed 157 individuals of at least 15 species at the cable sites. Bat star, sea stars, and California sea hare were most abundant. Pipe: Four hundred and forty two individual invertebrates, the most of any site, were observed at the pipe. However, 100 of these individuals were comprised of a one-time recorded aggregation of purple sea urchin. Like the cables, we recorded 15 species along the pipe. Natural Habitat: Bat star and Kellet's whelk predominated in the natural habitat, where we recorded 223 individuals, of 13 species.

Overall, the numbers of invertebrates living at the study sites remained fairly constant over the course of the study. What changes occurred were due to influxes of sea stars and bat stars. Of the eight most common species observed, the densities of five species (sea stars, bat star, sea cucumbers, and rock crabs) varied with site. Between cables and pipe, densities of four species (sea stars, bat stars, sea cucumbers, and rock crabs) were different. sea stars, bat stars, and sea cucumbers were more abundant at the pipe and rock crabs were more often encountered at the cable. The densities of three taxa or taxa groups, sea stars, California sea hare, and sea cucumbers were higher at the pipe than at the natural habitat. Lastly, rock crabs and California sea hare were found at higher densities at the cables compared to natural habitat and, contrarily, bat stars were more abundant at the natural habitat.

Plants

Unlike the fish and invertebrate assemblages, the plant communities of the three sites were different. First, there were intra-site differences in the shallower and deeper plant communities within the cables and pipe habitats, although not in the natural habitat. In addition, there were differences in the plant communities between the three habitats (global R=0.986, p=0.001; R>0.8, p=0.001). Over all habitats, a total of 72,999 individual plants (many likely observed repeatedly on sequential survey days) were tallied, comprising at least five species. Overall, *Zostera marina* was most abundant, followed by *Pterygophora californica*, *Cystoseira* spp., *Laminaria* spp., and *Macrocystis pyrifera*. Cables: Among all plants, *Pterygophora californica* dominated the cable community, although *Cystoseira* spp. and *Laminaria* spp. were not uncommon.

Pterygophora californica was very abundant on Cable B (particularly shallower), but absent from Cable A (although both were energized). Eelgrass grew on the sand near the cable. *Macrocystis pyrifera* grew very sparsely on the shallower Cable B habitat, was more common on the shallower part of Cable A, and was essentially absent from the deeper cables. Pipe: *Cystoseira* spp. and *Laminaria* spp. were by far the most common plants on the pipe. *Cystoseira* spp. was nearly twice as abundant shallower than deeper while *Laminaria* spp. was almost absent from the shallower site and nearly as abundant as *Cystoseira* spp. deeper. Relatively few *P. californica* were observed on the pipe and both *M. pyrifera* and *Z. marina* were almost absent. Natural Habitat: *Zostera marina* was the only plant growing on the sandy sea floor of the natural habitat. It was dense at both the shallower and deeper sites. With the exception of *Z. marina* living on the natural habitat, we did not observe any strong seasonality in plant densities. Densities of *Z. marina* in both the shallower and deeper areas tended to increase over the course of the study.

Regarding the specific objectives of this study:

> 1) *The differences among fish and invertebrate communities associated with energized and unenergized cable habitat and those communities in soft seafloor habitats lacking cables.*

We did not find any biologically significant differences among fish and invertebrate communities between energized cables, pipe, and natural habitat. In particular, only three species of fish showed statistically significant, but slight, differences in densities between the cables and pipe. Plant communities did differ among habitats and within habitats between depths. These differences were almost certainly structure and depth, rather than EMF, related.

> 2) *Whether electro-sensitive species that are regionally important, such as sharks and rays, respond (via either attraction or repulsion) to the EMFs of an in situ power transmission cable.*

We observed only one elasmobranch individual, a swell shark, during the course of this study. Thus, it would appear that the EMFs generated by these energized cables are either unimportant to these organisms or that at least other environmental factors take precedence.

> 3) *The strength, spatial extent, and variability of EMFs along both energized and unenergized cables.*

The strength of the EMF along the energized cable was relatively stable over time and along its length. The EMF produced by the energized cables diminishes to background levels about one meter away from the cable. Similarly, both the pipe and natural habitat sites had extremely small or undetectable EMFs.

4) *The potential effectiveness of the commonly proposed mitigation of cable burial.*

Given the rapidity with which the EMF produced by the energized cables diminishes and the lack of response to that EMF by the shallower fish and invertebrates, cable burial would not appear necessary strictly for biological reasons. In this and similar cases, cable burial, at sufficient depth, would be an adequate tool to prevent EMF emissions from being present at the seafloor.

Task 2

In 2012, at all four locations along the energized cable, EMF levels dropped off precipitously with distance from the cable and, at one meter from the cable, approached background levels at three of the four locations. In general, field strengths on the energized cables were around 100 μT, while those on the unenergized cables were very low and near background (sea floor) levels.

Fishes
We found that fish species communities were structured by depth more so than by habitat type (Global R=0.176, p=0.001). There was no statistical difference between the fish assemblages along the energized and unenergized cables. The natural habitat community statistically differed from both the energized cable and unenergized cable communities. Within species (or in several cases species-groups) that formed at least one percent of the fishes observed, we found no differences in densities between energized and unenergized cables. We did find differences based on cable side (shortspine combfish densities were higher on the west side of cables), depth strata (stripetail rockfish, unidentified poachers, shortspine combfish, greenstriped rockfish, lingcod, and unidentified eelpouts), and year (halfbanded rockfish, stripetail rockfish, and lingcod). Total fish densities were significantly higher around the cables than over the natural habitat. Among the more important species, densities of halfbanded, stripetail, and greenstriped rockfishes, shortspine combfish, and lingcod were higher at the cables and eelpouts were found at higher densities over natural habitat. There were no significant differences in the densities of unidentified sanddabs and unidentified poachers. There were very slight, but statistically significant, differences in both mean lengths and size distributions of fishes among the three study habitats as fishes at the unenergized cables tended to be slightly larger (mean = 14.8 cm) than those at both natural habitats (mean = 13.7 cm) and energized cables (mean = 13.0 cm). Over all habitats we observed 9,675 individuals of at least 41 species. Dominant species included halfbanded, stripetail, and greenstriped rockfishes, and lingcod, and unidentified flatfishes, poachers, and combfishes.
Energized cables: In the vicinity of the energized cables, we observed at least 33 species of fishes, comprising 4,455 individuals. Halfbanded rockfish dominated this habitat, comprising 56% of all fishes observed and present during 82.3% of the transects. Other important species or species groups included unidentified flatfishes and poachers, stripetail and shortspine combfish. Unenergized cables: Similar to the fish assemblage found around energized cables, there were at least 35 fish species in proximity to the unenergized cables and 3,691 individuals. As with the energized cables, halfbanded rockfish were by far the most abundant species, comprising 37.4% of all fish observed. Other important species included stripetail and greenstriped rockfishes and unidentified flatfishes, poachers, and combfishes. Natural habitats: Fewest species (at least 23)

and fishes (1,529) were observed on the natural habitats. Here, unidentified flatfishes, eelpouts, poachers, combfishes, sanddabs and halfbanded rockfish predominated.

Invertebrates

The structure of the invertebrate communities living around energized and unenergized cables and natural habitats was similar to that of fishes. We found that invertebrate communities were structured by habitat type and depth. Similar to the fishes, there was no statistical difference between the invertebrate assemblages along the energized and unenergized cables. The natural habitat community of invertebrates strongly differed from the energized cable and unenergized cable communities.

To determine if there were significant differences in species densities between energized and unenergized cables, we compared the densities of those important species that comprised at least 1% of individuals observed in this study in the same way as for fishes. We did note slight but statistically significant differences in densities for only two of nine of the most abundant species. Sand star and black crinoid densities differed between unenergized and energized cables [sand star greater at unenergized cables, 4/1/m3 v 2.7 m^3, and black crinoid at energized cables, $1.7/m^3$ v $0.3/m^3$]. Three species, thin sea pen, red octopus, and white sea urchin differed between cable sides. Seven species, white-plumed anemone, spot prawn, thin sea pen, California sea cucumber, red octopus, unidentified *Urticina* anemone, and black crinoid exhibited bottom depth differences. Densities of two species, thin sea pen and sand star, varied among years.

A number of species were more abundant around the cables than over the natural habitats. Important species that were more abundant around cables were white-plumed anemone, spot prawn, thin sea pens, California sea cucumber, sand star, and unidentified *Urticina* anemone. Red octopus and white sea urchin were denser over natural habitats and densities of black crinoid did not differ between the two habitats.

Over all habitats, we observed a total of 30,523 invertebrates of at least 43 invertebrate species. The whiteplumed anemone was by far the most abundant animal and comprised 43.4% of all invertebrates recorded. Spot prawns, thin sea pens, California sea cucumbers, sand stars, and the red octopuses were also found at relatively high densities. Energized cables: We observed 13,388 individuals, of at least 36 species, living on or near the energized cables. White-plumed anemones, thin sea pens and spot prawns were the species found in highest densities, forming in aggregate 79.7% of all invertebrates observed. California sea cucumbers, sand stars, red octopuses, black crinoids, and *Urticina* anemones were also common. Unenergized cables: At least 35 species and 14,619 individuals were observed along the unenergized cables. Three species, white-plumed anemones, spot prawns, and thin sea pens, were by far the most dense, in aggregate forming 79.2% of all invertebrates surveyed. California sea cucumbers, sand stars, red octopus, unidentified *Urticina* anemones, and serpulid worms were also characteristic of this habitat. Natural habitats: We observed the fewest number of species (a minimum of 27) and individuals (2,516) over the natural habitat. Thin sea pens, red octopuses, white sea urchins and sand stars dominated this habitat, along with smaller numbers of white-plumed anemones, fragile pink urchins, California sea cucumbers, and sea slugs.

Regarding the specific objectives of this study:

> 1) *The differences among fish and invertebrate communities associated with energized and unenergized cable habitat and those communities in soft seafloor habitats lacking cables.*

We did not observe any significant differences in the fish communities living around energized and unenergized cables and natural habitats. A very slight, and likely biologically insignificant, difference in mean sizes was observed as fishes at unenergized cables were marginally larger than those around energized ones. Overall species diversity and the densities of the most important fish species (define as comprising at least 1% of all fishes observed) were higher at the cables than at the natural habitats. This is likely reflective of the more complex habitats afforded by the cables than the primarily soft substrata natural habitats.

Similar to the fish communities, the invertebrate assemblages living around energized and unenergized cables and natural habitats were similar to one another and variability between these communities was primarily driven by sea floor depth. Among the three habitat types, there were some statistically significant differences in densities for all nine of the most abundant species. These differences included: 1) two species, sand star and black crinoid, whose densities differed between energized and unenergized cables, 2) three species, thin sea pen, red octopus, and white sea urchin which differed between cable sides, 3) seven species, white-plumed anemone, spot prawn, thin sea pen, California sea cucumber, red octopus, unidentified *Urticina* anemone, and black crinoid that exhibited bottom depth differences, and 4) two species, thin sea pen and sand star, whose densities varied among years. Sand star densities were greater at unenergized cables, 4/1/m3 v 2.7 m3, and black crinoid densities were greater at energized cables, 1.7/m^3 v 0.3/m^3.

> 2) *Whether electro-sensitive species that are regionally important, such as sharks and rays, respond (via either attraction or repulsion) to the EMFs of an in situ power transmission cable.*

We observed very few individuals of electro-sensitive species on the energized or unenergized cables or on the natural habitats. Only five ratfish (three at the energized cables and two on the unenergized ones) and one California skate (at the unenergized cable) were noted. Thus, we found no compelling evidence that the EMF produced by the energized power cables in this study were either attracting or repelling these fishes.

3) *The strength, spatial extent, and variability of EMFs along both energized and unenergized cables.*

The EMFs produced by the energized cables were similar both over the three years of the study and along the cables. EMF strength dissipated relatively quickly with distance from the cable and approached background levels at about one meter from the cable. The EMF at unenergized cables was similar to that found at the natural habitats.

4) *The potential effectiveness of the commonly proposed mitigation of cable burial*.

Given the rapidity with which the EMF produced by the energized cables diminishes and the lack of response to that EMF by the fishes and invertebrates in this study, cable burial would not appear necessary strictly for biological reasons. In this and similar cases, cable burial, at sufficient depth, would be an adequate tool to prevent EMF emissions from being present at the seafloor.

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