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Assessing potential impacts of energized submarine power cables on crab harvests

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ABSTRACT

Offshore renewable energy facilities transmit electricity to shore through submarine power cables. Electromagnetic field emissions (EMFs) are generated from the transmission of electricity through these cables, such as the AC inter-array (between unit) and AC export (to shore) cables often used in offshore energy production. The EMF has both an electric component and a magnetic component. While sheathing can block the direct electric field, the magnetic field is not blocked. A concern raised by fishermen on the Pacific Coast of North America is that commercially important Dungeness crab (*Metacarcinus magister* Dana, 1852)) might not cross over an energized submarine power cable to enter a baited crab trap, thus potentially reducing their catch. The presence of operating energized cables off southern California and in Puget Sound (cables that are comparable to those within the arrays of existing offshore wind energy devices) allowed us to conduct experiments on how energized power cables might affect the harvesting of both *M. magister* and another commercially important crab species, *Cancer productus* Randall, 1839. In this study we tested the questions: 1) Is the catchability of crabs reduced if these animals must traverse an energized power cable to enter a trap and 2) if crabs preferentially do not cross an energized cable, is it the cable structure or the EMF emitted from that cable that deters crabs from crossing? In field experiments off southern California and in Puget Sound, crabs were given a choice of walking over an energized power cable to a baited trap or walking directly away from that cable to a second baited trap. Based on our research we found no evidence that the EMF emitted by energized submarine power cables influenced the catchability of these two species of commercially important crabs. In addition, there was no difference in the crabs' responses to lightly buried versus unburied cables. We did observe that, regardless of the position of the cable, *Cancer productus* in southern California tended to move to the west and *Metacarcinus magister* tended to move to the east.

1. Introduction

It is likely that for the foreseeable future, offshore renewable energy technologies (e.g., wind and wave) will focus on the generation of electricity into the USA grid system. These technologies harness energy from an array of individual devices and, through power cables, send electricity to shore via submarine power cables. These cables will transmit either alternating current (AC) or direct current (DC). Electromagnetic field emissions (EMFs) are generated from the transmission of electricity through cables, such as the AC inter-array (between unit) and AC export (to shore) cables often used in offshore energy production. The EMF has both an electric component and a magnetic component. While sheathing blocks the direct electric field, the magnetic field is not blocked. It is this magnetic field (and the resultant induced electric field) that is present in the marine environment.

There has been considerable interest in siting offshore renewable energy facilities along the coast of the Pacific Northwest, particularly off the state of Oregon (Boehlert et al., 2013). During scoping workshops concerns were raised regarding EMF derived from energized submarine power cables. One of these concerns was that the commercially important Dungeness crab (*Metacarcinus magister* (Dana, 1852)) would not cross over an energized submarine power cable to enter a baited crab trap, thus potentially reducing harvest potential. The Dungeness crab fishery is the most valuable single-species fishery for Oregon, the highest-valued invertebrate fishery for Washington, and among the top four valued invertebrate fisheries for California (NOAA, 2013). Because crabs walk on the sea floor and would thus have the

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opportunity to come into direct contact with submarine power cables, these organisms are an excellent choice for a test of their responses to encountering EMFs in situ.

Early work on fishes demonstrated that cartilaginous fishes could detect EMF (Kalmijn, 1966) and this ability was later found to be widespread among such fishes as lampreys (Bodznick and Northcutt, 1981), sturgeons (Basov, 1999), Atlantic salmon (Tanski et al., 2005), and yellowfin tuna (Walker, 1984). Similarly, this ability has been found in a range of invertebrates (e.g., gastropods, Lohmann and Willows, 1987; isopods, Ugolini, 2006; spiny lobster, Lohmann, 1985), turtles (Lohmann et al., 1997), and at least some cetaceans (Kirschvink, 1990). The functional role for this ability is, among elasmobranchs, to detect prey and, among all sensitive organisms, may also include spatial orientation, homing, and navigation (Cain et al., 2005; Lohmann et al., 2007).

There are only a few studies that have specifically examined how crabs might respond to human-induced EMFs. Corte Rosaria and Martin (2010) found that freshwater crabs (*Barytelphusa cunicularis* (Westwood in Sykes, 1836)) exposed to low-frequency EMF exhibited increased feeding rates. Very limited laboratory studies by Wilson and Woodruff (2011) and Woodruff et al. (2013) observed the behavioral responses of Dungeness crabs exposed to artificially induced EMFs in a laboratory. Wilson and Woodruff, based on a single 3-day study of 10 crabs (five in experiment and five in control tanks), found some evidence for behavioral responses to EMF. Crabs tended to be found in the part of the experimental tank with high EMF levels and crabs were more active in zones of low EMF levels. Woodruff et al. (2013) found that there were "relatively few behavioral responses that would indicate explicit avoidance and attraction." Although, "for each species there were statistically significant differences related to the use of space and/or activity level within the experimental tanks. Further study is needed to clarify whether these results are related to the directional flow of water current in the tanks, a response to a change in EMF vector orientation to background, or some other tank effect." Lastly, Love et al. (2015) found that caged rock crabs (genera *Metacarcinus* and *Cancer*) responded identically to energized and unenergized cables off the coast of southern California.

Given this level of uncertainty regarding whether *M. magister* responds to the EMF present around submarine power cables, we conducted in situ controlled experiments to address the following questions:

1) Is the catchability of crabs reduced if these animals must traverse an energized power cable to enter a trap?
2) And, if crabs preferentially do not cross an energized cable, is it the cable structure or the EMF emitted from that cable that deters crabs from crossing?

2. Materials and methods

2.1. Basic protocol for the crab two-choice experiment

Experiments were conducted on energized submarine power cables in the Santa Barbara Channel (SBC) (southern California, USA) and offshore of San Juan Island (SJI) (Washington State, USA) (Fig. 1). The cables at both locations were oriented north to south, with the northern end in the shallowest waters, and both experiments were conducted at bottom depths of 10–13 m. Previous studies have shown that the magnetic field component of EMF from the SBC cable declines to background levels at about one meter from the cable (Love et al., 2015).

For these experiments we used *Cancer productus* Randall, 1839 (red rock crab) in the SBC and *M. magister* off SJI; both species are of commercial importance. The goal of the experiment was to give each crab the option of either walking in one direction over an energized cable into a baited trap (a cable that was either exposed or barely covered in sand) or walking in the opposite direction away from that cable into another baited trap.

Each experimental apparatus (unit) consisted of 1) two crab traps with their openings facing each other and 2.5 m apart, 2) a 10" high × 12" wide mesh tunnel (the *arena*) that connected the traps, and 3) a small (10" h × 16" w × 20" l) cage (the *chute*) held in place by bungee cords on top of the arena midway between the two traps. Aligned openings on the bottom of the chute and the top of the arena connected these two structures (Figs. 2 and 3). Traps, arenas, and chutes were constructed of 2" × 2" PVC-coated wire mesh. Traps were identical to those used by crab fishermen in the SBC (rectangular in shape) and SJI (round in shape, not depicted) and were constructed by local fishermen.

Traps were emplaced on the substrate so that the energized power cable was adjacent and in front of the opening of one trap (Fig. 4). A crab entering this trap would necessarily have to walk along the arena to the cable and step directly on it (if exposed) in order to enter. At the opening of each trap, we installed plastic panels on the sidewalls and ceiling inside of the tunnel. The panels prevent a crab from climbing the walls or clinging to the ceiling of the arena at the two ends of the experimental unit, thus forcing a crab to enter either trap by walking on the bottom of the arena. Every crab found in a trap adjacent to the cable unavoidably walked over and directly contacted the cable.

In all, 12 experimental units were installed on the seafloor. In half of these units, the crabs were introduced to the system to the east of the power cable, the other half to the west. Half of the 12 units were installed where the power cable was fully exposed above the sand, while in the other half, the cable was covered by a thin layer of sand. In this manner, we examined the possibility that the cable structure itself, situated at the trap's entrance, was enough to prevent a crab from entering a trap. Using a hand-held magnetic field detector, divers measured the EMF strength where the cable was exposed and partly raised above the substrate and where buried. The magnetic field strength over the sand that lightly covered the embedded sections of cable was comparable to measurements taken directly on the exposed cable sections.

2.2. Study sites

2.2.1. Santa Barbara Channel – rock crab experiment

We conducted experiments between January and June of 2015 at an energized (35 kV) 8" diameter submarine power cable located off the coast of Las Flores Canyon, Santa Barbara Channel, southern California (34°27.6'N, 120°02.7'W) (Fig. 1). For this experiment, we used the standard commercial crab trap used by fishermen in the Santa Barbara area. These traps are 36" l, 28" w, and 12" h. We note that commercial rock crab fishing occurs in this area.

Trials were run for five consecutive days (Monday–Friday) per month. Each morning, all traps were freshly baited (with identical bait) and a single crab was placed in each chute. All crabs, of market size, were purchased from commercial crab fishermen. When the crab was placed in the chute, the diver noted time of deployment, the trap identifier, and the size and sex of the crab as well as its condition (missing legs or claws or presence of eggs).

After all crabs were in place in the chutes, divers left the area for a short time and then, swimming well above the bottom and away from the traps, observed each crab's behavior. In many instances, crabs would leave the chutes, walk through the arenas, and enter a trap within a few minutes. When a crab entered a trap, a diver noted which trap it was in and the time of the observation. The crab was then removed from the trap and placed in a color-coded bag (to mark that it had been an experimental animal), and a new, naïve crab placed in the chute. Monday through Thursday, any crab at the end of the experimental day that had not yet made its way into a trap was left overnight and checked the following morning. All crabs were used only once in the study. Every crab used in the experiment was tagged with a plastic cable tie on a hindmost leg to prevent the unlikely repeated use of individuals and, at the end of the day, released in the water about 16 km