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Effects of EMF Emissions from Cables and Junction Boxes on Marine Species

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Project Overview

Effects of EMF Emissions from Cables and Junction Boxes on Marine Species: The project objectives were to characterize, through field measurement, the background electromagnetic field (EMF) and EMF emissions from live submarine cables on a Navy range off South Florida, and to monitor the responses of local aquatic species to such emissions, in support of characterizing the environmental impact of EMF emissions associated with an offshore marine and hydrokinetic (MHK) device.

The Challenge: A typical MHK device will have multiple subsea components and submarine cables that would emit significant levels of EMF in the water column. Potential impact of such emissions on marine species is not well understood and regulators therefore require that the impact be assessed and measures be taken to mitigate it. Laboratory studies show that diverse aquatic species are sensitive to anomalies in electric (0.5–1000 micro volts/m) and magnetic (≳50nT) fields. There is, however, sparse field data on potential responses of marine species to unnatural levels of EMF in the open water column. In support of filling this gap and making the necessary assessment, the present effort aims to provide the field data to aid (i) characterization of the distributions of EMF emissions from subsea cables in the water column, and (ii) identification of potential responses of aquatic species to such emissions and assessment of the impact of these emissions.

Partners: Florida Atlantic University (FAU) – Measure background EMF and EMF emissions from submarine cables in the water column; Nova Southeastern University (NSU) – Monitor and observe responses of marine species to anomalous EMF emissions from submarine cables; South Florida Ocean Measurement Facility (SFOMF), Naval Surface Warfare Center (NSWC) – Support field experiments through managing power supply through cables

Program Strategic Priorities

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Technology Maturity

- Test and demonstrate prototypes
- Develop cost effective approaches for installation, grid integration, operations and maintenance
- **Conduct R&D for innovative MHK components**
- Develop tools to optimize device and array performance and reliability
- Develop and apply quantitative metrics to advance MHK technologies

Deployment Barriers

- Identify potential improvements to regulatory processes and requirements
- Support research focused on retiring or mitigating environmental risks and reducing costs
- Build awareness of MHK technologies
- Ensure MHK interests are considered in coastal and marine planning processes
- Evaluate deployment infrastructure needs and possible approaches to bridge gaps

Market Development

- Support project demonstrations to reduce risk and build investor confidence
- Assess and communicate potential MHK market opportunities, including off-grid and non-electric
- Inform incentives and policy measures
- Develop, maintain and communicate our national strategy
- Support development of standards
- Expand MHK technical and research community

Crosscutting Approaches

- Enable access to testing facilities that help accelerate the pace of technology development
- Improve resource characterization to optimize technologies, reduce deployment risks and identify promising markets
- Exchange of data information and expertise

Increase MHK deployment in opportune markets

Deployment Barriers

- Identify potential improvements to regulatory processes and requirements
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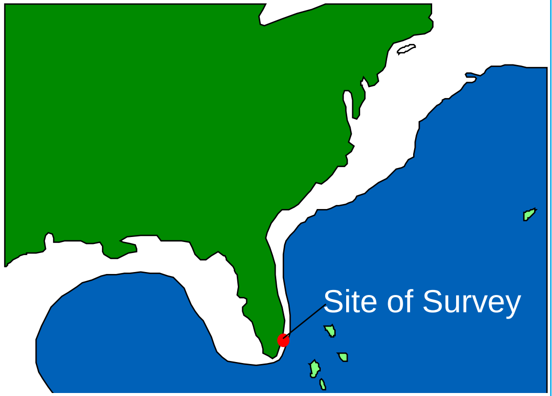
The Impact

- TARGET/METRIC: (a) Enable measurement of E-field in range 0.5 – 1000 micro volts /m; (b) Use accepted practices for monitoring marine animals.
- The autonomous underwater vehicle (AUV)-based EMF measurement system that has been developed could provide an inexpensive automated method for characterizing EMF levels at an MHK site for permitting considerations. The EMF field data that have been collected will aid validation of predictive models. The field data acquired in monitoring potential responses of marine species to anomalous EMF levels in the water column could supplement similar data from other sources in support of meeting permitting requirements.
- Deliverables: Final Report; peer-reviewed publications; database of field measurements and observations; an AUV-based EMF measurement system.

Technical Approach

1. Develop an AUV-based system for measurement of EMF levels in the water column using
   - A towed magnetometer
   - Custom E-field sensor

   Conduct AUV surveys over a submerged Navy cable through which the power supply is varied. This is novel method of survey of the EMF levels in the water column that allows automated measurement from a mobile, tether-free platform that can potentially cover a large area.
2. Monitor for Responses of Marine Species using:
   - Diver-based point and transect surveys
   - Fixed bottom-mounted cameras
   - Cameras mounted on the AUV



3. Three survey sites selected on the Navy's South Florida Ocean Measurement Facility in South Florida: a) Shallow water depth (15ft) site, b) Mid-depth (30ft) site and c) Deeper (45ft) site. For each survey, three power states were considered, with the cable made to transmit in sequence AC current, DC current, and no current (for control).

Key Issues: Simultaneous measurement of E and B fields addressed. Analysis of acquired E and B field data addressed and compared with models. Marine species response data analyzed in terms of abundance and species richness. Improvements in geolocation capabilities of the AUV platform are being sought.

Technical Approach

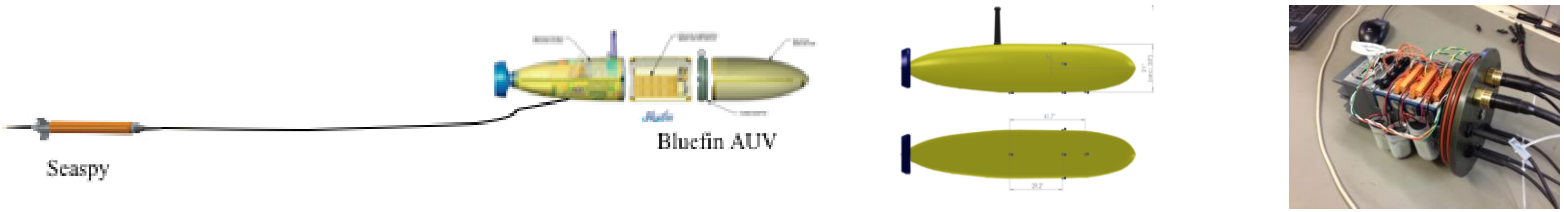


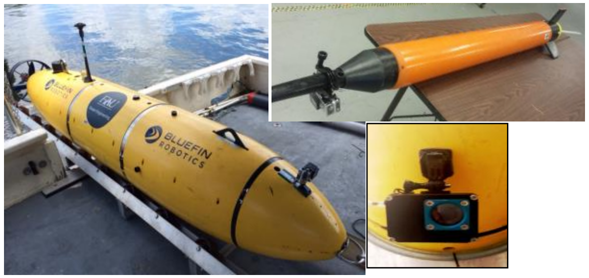
Fig. 2 EMF measurement system (a) schematics of towing of SeaSpy magnetometer from the Bluefin AUV, (b) location of E-field sensors on AUV hull, (c) E-field acquisition and processing unit

Fig 3. Monitoring for Potential Responses of Marine Species to EMF Emissions

Transect Survey

Point-Count Survey

Bottom-mounted cameras



AUV-based cameras

Accomplishments and Progress

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- Good-quality measurements of EMF emissions in the water column were obtained using the mobile AUV platform and the data from the surveys were used to characterize the distribution of the EMF levels in the water column above a live cable as well as characterize decay of these levels away from the cable (Fig 4). The measurements show good agreement with theoretical models of the how EMF levels decay away from the cable in open deep and shallow water environment. Thus, the field measurements of EMF emissions will serve to validate theoretical models of emission levels from subsea cables, as well as quantifying the EMF levels in the field experiments.
- Presence of several individual elasmobranch species, including sharks and stingrays, were recorded during the surveys. Electric fields in excess of 200µV/m were measured in the vicinity of the cable during AC power state; studies suggest such high levels serve to deter animals. However, no startle responses of fishes or other organisms to transitions of power among OFF, AC and DC states were observed at any of the three survey locations. Further, ANOVA analyses of our field data suggest no statistical difference in mean richness or abundance among the power states (Fig. 5), although somewhat higher abundance was recorded for the power OFF state at the middle and deep sites; the latter may be associated with possible outliers in the samples.

Accomplishments and Progress

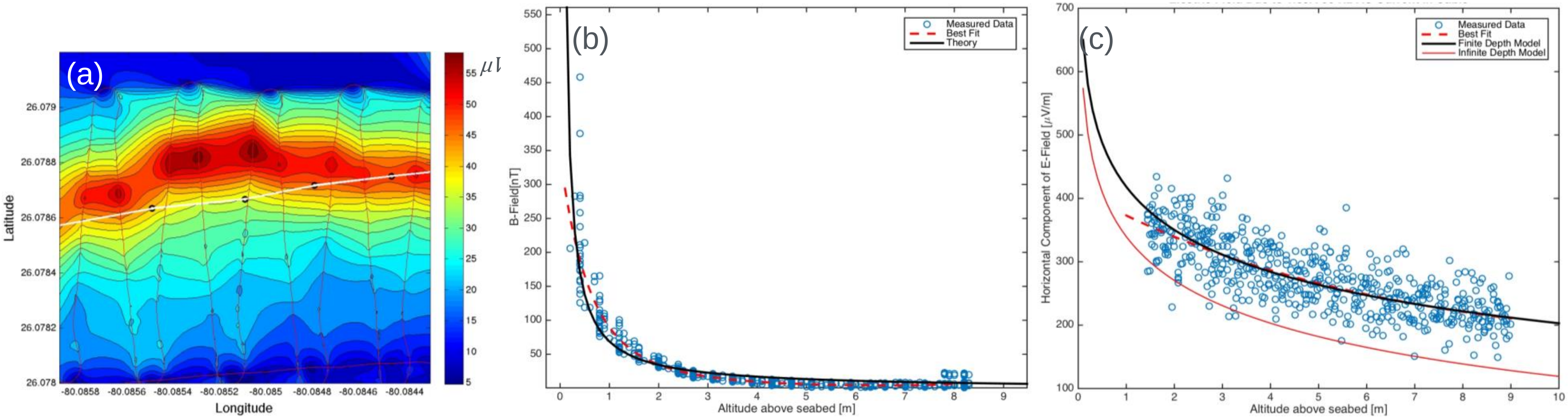

Fig 4. (a): Distribution map of E-field levels (at 10Hz) 4m above an energized submarine cable, developed using AUV-based measurements of the field. Comparison of field data with with theory: (b) measured B-field for a 2.4A DC current, and (c) measured E-field a 1.9A AC 60Hz current. A shielding factor of 4 is assumed.

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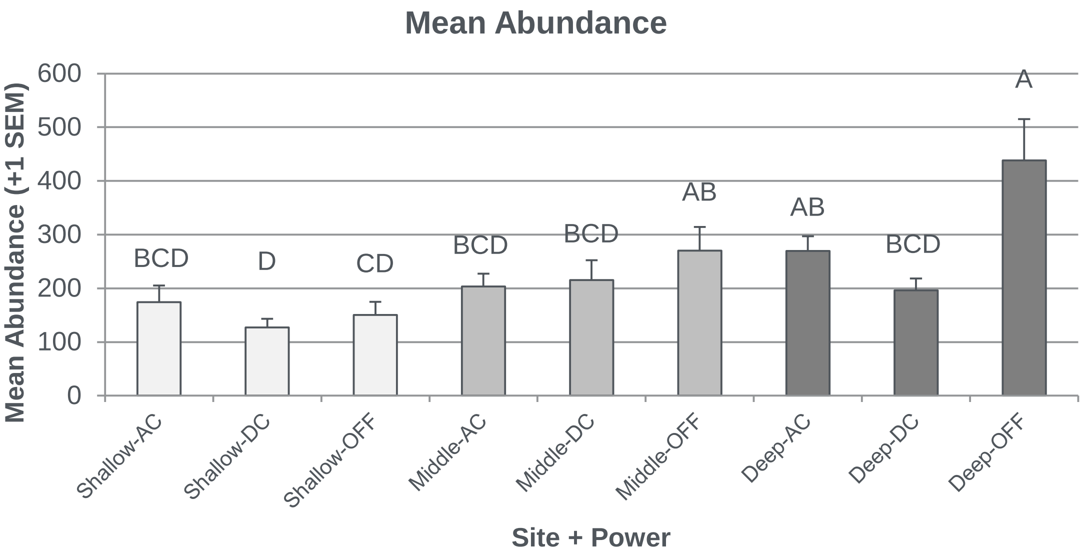

Fig. 5a Mean abundance of fishes using the full data set, from each site during each power state (ambient OFF, energized AC, and energized DC); entire species assemblage with all quarters and sites combined. Letters indicate significant differences and shared groupings (SNK, $p<0.05$). (Shallow N = 24 AC, 20 DC, 44 OFF; Middle N = 28 AC, 24 DC, 36 OFF; Deep N = 28 AC, 23 DC, 36 OFF)

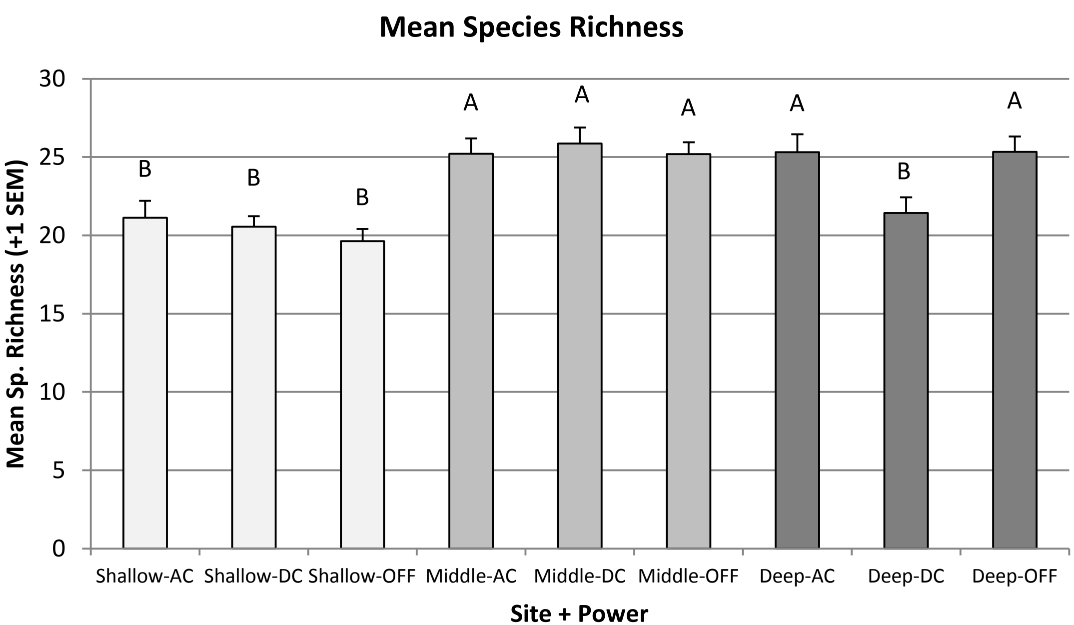

Fig. 5b: Mean species richness of fishes, using the full dataset, from each site during each power state (ambient OFF, energized AC, and energized DC); entire species assemblage with all quarters and sites combined. Letters indicate significant differences and shared groupings (SNK, $p<0.05$). (Shallow N = 24 AC, 20 DC, 44 OFF; Middle N = 28 AC, 24 DC, 36 OFF; Deep N = 28 AC, 23 DC, 36 OFF)

Project Plan & Schedule

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- Project original initiation date: 1/1/2014
- Project planned completion date: 12/31/2015
- The project was extended via a no-cost-extension to 6/30/2016 to accommodate a possible additional survey during January-February timeframe when the area is typically visited by a large number of sharks from the north. Unfortunately, they did not come as far south as the Navy range in 2016.
- Go/No-Go decision points for
  - FY14: 1) At the end of the first quarter, the state of the E-sensor implementations on the AUV will be evaluated through independent verification of measurements; 2) The installation of the second bottom-mounted camera will be discussed with Navy site; 3) At the end of first and second quarters, the effectiveness of the operational procedures for the surveys will be evaluated.
  - FY15: Meeting with DOE after Budget Period I and review of annual technical report and project progress.

Project Budget

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Budget History					
FY2014		FY2015		FY2016	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$93.912k	$29.120k	$125.307k	$43.402k	$180.779k	$28.872k

- No significant variances from the proposed budget
- All budget has been expended
- No other sources of funds supported this project

Research Integration & Collaboration

Partners, Subcontractors, and Collaborators: Nova Southeastern University and SFOMF (NSWC-CD) partnered with FAU. Principal Team Members were: Dr. Manhar Dhanak (PI, FAU); Dr. Richard Spieler (Co-PI, NSU); Dr. William Venezia (Co-PI, SFOMF); Kirk Kilfoyle (graduate student), NSU; Christopher Dibiasio (graduate student, FAU); Robert Jermain (graduate student, NSU); John Frankenfield (Engineer, FAU); Edward Henderson (Engineer, FAU); Robert Coulson (Engineer, FAU); Shirley Ravenna (Engineer, FAU); George Valdes (Engineer, SFOMF)

Communications and Technology Transfer: Peer-reviewed Publications:

- AUV-Based Characterization of EMF Emissions from Submerged Power Cables. Manhar Dhanak et al. 2015. MTS/IEEE Oceans Conference, Genoa, Italy, May 2015.
- Characterization of EMF Emissions from Submarine Cables and Monitoring for Potential Responses of Marine Species. Dhanak, M., Kilfoyle, A., Ravenna, S., Coulson, R., Frankenfield, J., Jermain, R., Valdes, G., Spieler, R. 11th European Wave and Tidal Energy Conference. Nantes, France, September 2015.
- Assessment of Electromagnetic Field Emissions from Subsea Cables. Dhanak, M., R. Coulson, C. Dibiasio, J. Frankenfield, E. Henderson, D. Pugsley, G. Valdes. 2016 NHA METS Poster, Washington, DC, April, 2016.
- Effects of EMF Emissions from Undersea Electric Cables on Coral Reef Fishes. Kilfoyle, A., R. Jermain, M. Dhanak, J. Huston, R. Spieler. Submitted to Bioelectromagnetics.

Research Integration & Collaboration

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Communications and Technology Transfer: The project makes impact on the following:

- Development of procedures and sensor to measure E-M fields in the water column over power-transmitting cables using an AUV
- Concurrent collection of underwater video, EMF measurements, and SCUBA diver-based observations for aquatic species' responses to power transmitting cables in both power on and power off conditions
- Development of procedures to collect video over power-transmitting cables from fixed seafloor stations and moving AUV platforms
- Development of a database of EMF measurements and observed potential marine species' response
- The E-field sensors developed for the AUV are being utilized in a separate Naval Air Systems Command (NAVAIR)-funded project to measure E-fields generated by subsea sources in the water column

Next Steps and Future Research

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FY17/Current research: The project is complete. No funding is allocated for FY2017.

Proposed future research: Improvement in AUV-based system for measurements of EMF levels in the water column, allowing for simultaneous measurements of E and B fields from co-located sensors towed from the AUV, together with improved geo-location capabilities.