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An environmental data integration and assessment tool for supporting marine energy adaptive management frameworks

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Abstract

PacWave South ("PacWave") is an open water wave energy test facility offshore of Newport, OR designed to provide a highly accessible marine environment for the evaluation of wave energy converter (WEC) technologies. As part of its infrastructure, PacWave will include environmental monitoring and an adaptive management framework (AMF) to define monitoring requirements, analysis methods, and organizational structure. Environmental data metrics, e.g., acoustic thresholds, will allow members of the adaptive management committee to make informed decisions on monitoring efficacy and need for defined protection, mitigation, and enhancement (PM&E) measures. These PM&E's include monitoring plans to collect data on underwater acoustics, electromagnetic fields, entanglement, interaction, and benthic surveys. The AMF and its PM&Es will ensure robust assessment of potential impacts of WECs on marine ecosystems and wildlife, ensuring that marine energy projects are developed responsibly and sustainably.

Environmental monitoring at marine energy sites can produce large and diverse volumes of data, with variable density across data types, for example, underwater acoustics that generates terabytes of information compared to interaction and entanglement observations that may occur intermittently and are summarized in spreadsheets and reports. The vast range of data volume and type requires a robust data management system to handle each PM&E measure.

The Environmental Data Integration and Assessment (EDIA) tool is currently under development to support the process for data interpretation and decision-making. The EDIA tool is a dashboard that facilitates aggregation of disparate environmental data types, application of identified metrics, and comparisons of data against outlined thresholds that may indicate the need to enact a specific PM&E measure. It integrates with a range of data types including real-time acoustic and metocean data, surveys to measure electromagnetic fields (EMF) signals and benthic, and ship-based observations and interfaces with data portals maintained by PacWave and its partners to streamline data handling and storage. It is a cloud-based, online, interactive data dashboard that promotes a streamlined assessment process. The EDIA tool allows users to investigate the PacWave site through maps of observation locations, compare between surveys or events, and filter for specific instances of conditions.

The goal is to provide both the adaptive management committee and PacWave operations staff a method for evaluating data that transparently meet the needs of technology developers, regulators, local stakeholders, and the environment. Showcasing the relevant environmental data and evaluation metrics through the dashboard ensures a consistent reference frame to make management decisions. Successful implementation of the EDIA tool will support PacWave's ability to minimize negative environmental impact and implement the prescribed adaptive management strategy.

Keywords: environmental data; integration; assessment tool; adapative management; marine energy

1. Introduction

A key challenge to advancing an economically competitive U.S. marine energy (ME) industry is reducing the time and cost required for environmental permitting and compliance with government regulations (1). Adaptive management frameworks (AMFs) have been adopted as a part of the permitting and compliance process to help address unknowns in environmental response due to the presence of a ME development. Therefore, the need to clearly understand environmental conditions to inform decision-making on additional monitoring and mitigation measures will be a critical component for project success.

The project objective is to develop a cloud-based Environmental Data Integration and Assessment (EDIA) tool that will support an environmental assessment process that transparently serves developers, stakeholders, regulators, and the environment. The data-based understanding of the response of environmental receptors to potential stressors will provide comprehensive and actionable information, which empowers developers with a tool to mitigate environmental risk, collaborate transparently with stakeholders, and support effective and efficient decision-making as illustrated in Figure 1.

There are five critical factors the EDIA tool aims to complete: 1) a software development plan to guide the development of a cloud-based database, server, and dashboard for managing, visualizing, and assessing ME environmental data; 2) a functional cloud database for storing and serving environmental data on a ME project that meets applicable industry standards for data quality and formatting; 3) A functional, user-friendly dashboard for visualizing and interacting with real-time environmental data to support AMFs; 4) collaboration with PacWave, and the National Laboratories to ensure that the EDIA will meet the site's environmental compliance needs and to facilitate transferability to future ME sites; and 5) documentation, distribution, training, and utilization of the database and dashboard at the PacWave site.

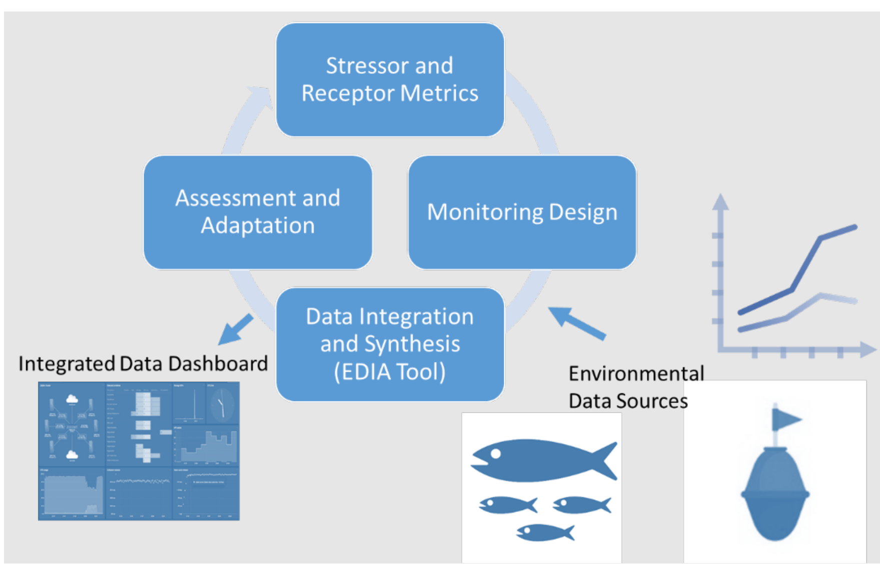

Figure 1. Conceptual diagram of the role of the EDIA tool in environmental monitoring.

This tool consists of a user-facing front-end and a backend data pipeline. These components function in concert to provide essential data products to PacWave and the regulatory agencies in charge of reviewing monitoring data. The front-end component provides a way to visualize and interact with the disparate data streams collected at PacWave and the data pipeline provides a method for accessing, processing, and storing data for rapid consumption and display by the front-end.

1.1. Backend Data Pipeline

The backend implementation plan has been developed with scheduled automated jobs to extract data from Marine Hydrokinetic Data Repository (MHKDR) to a focused database housed on Digital Ocean which will be accessed by the dashboard for display. This database copy will be structured similarly to MHKDR and the front-end will rely on this data with minimal or no processing in order to ensure optimal dashboard performance. Currently, work on the dashboard has been completed with example data formatted in flat files. The backend data pipeline extracts the data from the disparate data streams, cleans the data, and transfers the cleaned data into storage locations. The original, raw data retrieved from MHKDR will be housed within the Azure blob, and the structured data will be housed in an Azure database. Currently, all the development occurs locally based on the provided example data files. In the future, this database will be housed in an Azure PostgreSQL Pod database which can be accessed by the deployed dashboard, as depicted in Figure 2.

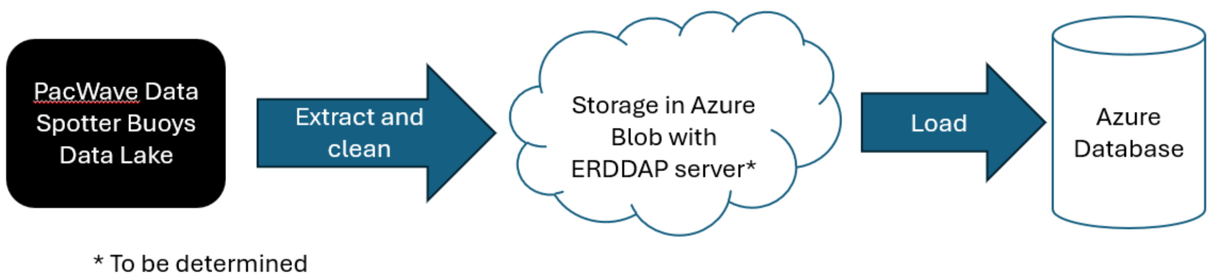

Figure 2. Backend data pipeline consisting of extracting the data, cleaning the data and loading the data both into storage locations.

The steps of the data pipeline consist of the following:

1. Extract data from external locations.
2. Clean data and store data onto Azure Blob. At this point, an ERDDAP server might be implemented to ensure that data extraction from the Blob to the database is consistent and uniform. The ERDDAP server is currently being experimented with to determine its utility.
3. Extract data from the Azure blob and into the Azure database.

1.2. Frontend Dashboard

The EDIA tool frontend dashboard in a modular structure. The dashboard contains a series of data investigation tools for each of the five PM&E's outlined in the adaptive management plan under the scrutiny of regulatory agencies. These include benthic data, electromagnetic fields, entanglement, interaction, benthic change, and acoustics. The ability to interact with real-time metocean data is also in development and data can be viewed both spatially or as timeseries depending on the data type.

The framework of the dashboard is being developed in R Shiny using the {golem} package for application development, with code housed on GitHub for collaborative development access. A first draft of the dashboard has been developed based on example data that have been provided and/or created for all components (acoustics, benthic, EMF, entanglement, interactions, and metocean). This was created using R Shiny and using the R package {golem} to create an organized and reproducible framework. Each component is represented by a page in the dashboard and can be navigated to via a collapsible side panel which is shown in the landing page below.

The landing page currently includes a map with loadable shapefiles (Figure 3). The lease area is initially loaded, but more features can be selected such as PacWave area, cable routes, state waters, etc. Future development will include adding sampling points for each component so the user can have an overview of different kinds of sampling and how they relate to each other spatially. The landing page will connect to spatial data from the Metocean buoy locations, survey locations, and will have the ability to select spatial data types for each PM&E type to display on the same map.

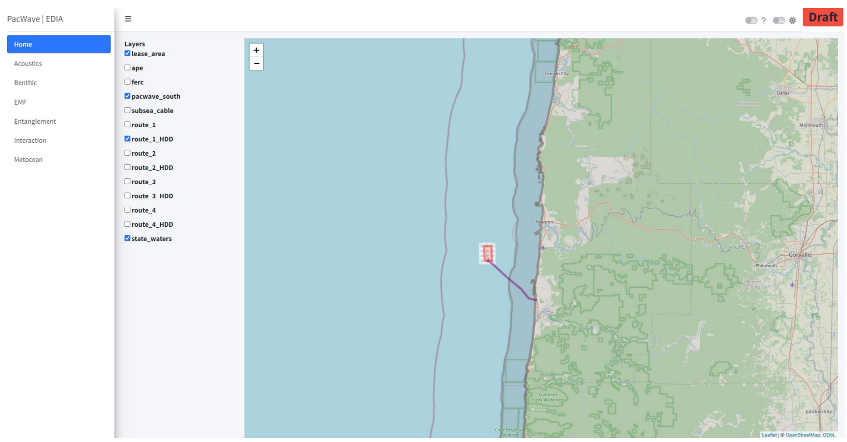

Figure 3. Landing page after initial loading of the dashboard.

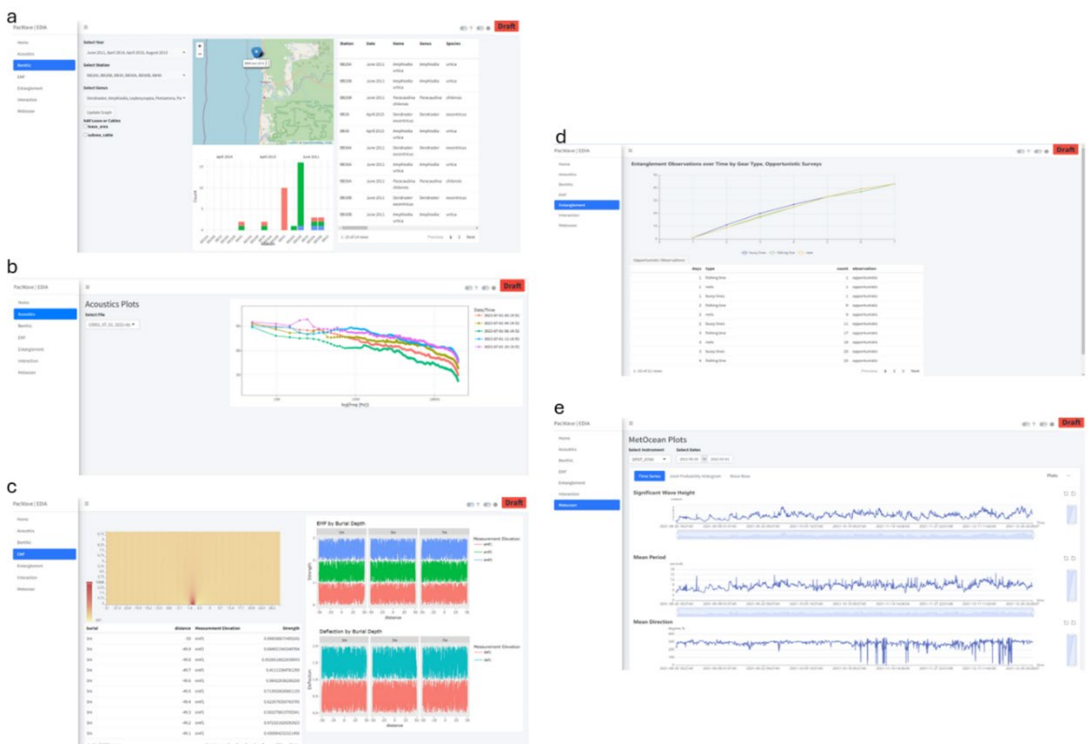

Figure 4. Data investigation pages consisting of five disparate streams: (a) benthic page (b) acoustic page (c) EMF page (d) entanglement and interaction page and (e) met-ocean data

The example acoustics page (Figure 3b) displays spectral density (dB re1\muPa^2/Hz) on the y-axis and frequency on the x-axis for a 24-hour period of acoustic recording. The specific 24-hour recording period can be selected by the user in the GUI using the dropdown menu. As such, exceedance over the 120 dB threshold can currently be viewed within a frequency bandwidth. For each plot a line is drawn for each recording that occurred in the selected 24-hour window and is labeled by date and time. There are 5-6 recordings per 24-hour time period in the current example files. Currently available for the acoustics section of the application are several example datasets with semi-processed acoustic recording data from a moored hydrophone collecting data on background noise conditions. An R script was created to extract GPS and acoustic data from each example data file and calculate the spectral density for plotting. Benthic data sets will be collected and interpreted by Oregon State University researchers and provided to PacWave for inclusion in their regulatory submissions. The EDIA dashboard will provide links to these data and limited methods for comparison and interpretation.

Methods for determining EMF emissions through measurements and numerical models are still being determined by the PacWave team. The goal is to compare EMF readings or estimates with literature values of aquatic organisms' response to gauge potential effects to marine life. The EMF page, shown in Figure 3c, visualizes EMF readings and provides a data table of EMF strength based on depth of burial, distance from center, and height above seafloor. The EMF data interpretation and presentation methods will be revised as new information and data becomes available.

Entanglement and interaction data will be collected opportunistically via observations from vessels and via ROV. The entanglement and interaction page, shown in Figure 3d, displays information on the number of surface or sub-surface interactions with animals have occurred and with which gear type. For now, an example dataset has been used to develop a framework for the entanglement and interaction pages. The difference in the entanglement and interaction pages is only in the type of chart and type of data table used for creating the UI.

The metocean page, shown in Figure 3e, include ocean currents data provided from the ADCPs and the wave data from the Spotter and additional measurement buoys. The wave data includes: 1) significant wave height; 2) peak wave period; 3) mean wave period; 4) mean wave direction; 5) peak wave direction; 6) mean wave directional spread; and 7) peak wave directional spread. The metocean data visualization consists of three main tabs: 1) time series; 2) joint probability histogram, and 3) directional rose of either wave height or period. For all three plots, the user can select a specific spotter buoy and constrain the time range using a drop-down menu and calendar, allowing the user to select time periods concurrent with other measurements, putting site response into context with forcing conditions relevant to wave energy converters and their operation.

1.3. Next Steps

The EDIA Tool development team is engaging in discussions with subject matter experts and entities tasked with data collection at PacWave to determine appropriate display methods for interpretation and reporting. Over the next few months, a linkage between the dashboard's local database and the MHKDR repository will be made with presently available or proxy data. PacWave will be provided with access to the beta version along with training materials on the Dashboard's use and the development team will incorporate their feedback into future iterations of the tool.

1.4. Acknowledgements

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