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INTEGRATED INSTRUMENTATION FOR MARINE ENERGY MONITORING

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ABSTRACT

Integrated instrumentation packages designed for operation at marine renewable energy sites have the potential to reduce the risk uncertainty around high-priority interactions between stressors and receptors. Such packages can leverage the competitive strengths of individual instruments and reduce risk in a rapid, cost-effective manner. One emerging example of environmental infrastructure to achieve these objectives, the Adaptable Monitoring Package, is presented and its capabilities described. The development and adoption of such packages requires close coordination between resource managers, technology developers, and researchers.

INTRODUCTION

Sustainable approaches for power generation from marine renewable resources require that the benefits associated with the electricity produced not be exceeded by its environmental cost. While the environmental impacts that could be associated with large-scale implementation of marine renewables remain uncertain [1-3], pilot and early commercial projects have the potential to provide valuable guidance. Even at this scale, reducing the uncertainty of environmental risks [4] has been a continual challenge. Here, we define risk as the product of the significance of an outcome and its frequency of occurrence. Risk reduction has been particularly difficult to achieve when the frequency of occurrence is likely to be low but the outcome severe (e.g., direct interactions between marine energy converters and marine animals) or when interaction is frequent but the outcome is mild (e.g., behavioural modification due to distant underwater noise). Environmental research seeks to reduce risk uncertainty by either identifying real risks or responsibly “retiring” implausible ones. Presently, for a number of high-priority environmental receptors, the level of scientific and regulatory uncertainty spans the spectrum between these more certain risk end states.

ENVIRONMENTAL INSTRUMENTATION

Instrumentation plays a critical role in reducing risk uncertainties by providing objective, quantifiable data about the interactions between marine energy converters (MECs) and environmental receptors. To investigate the needs, capabilities, and gaps associated with instrumentation around MECs, an expert workshop was held in Seattle, WA (USA) in June, 2013. The workshop participants considered different classes of instrumentation (active acoustics, passive acoustics, and optical systems) and their ability to develop information about near-converter interactions, changes in marine animal distribution and habitat use at larger spatial scales, and characterization of the sound produced by MECs. The outcomes of this workshop are summarized in [5].

One of the themes that emerged from the workshop discussions is that the “fastest” way to reduce risk uncertainty may be to adopt spatially comprehensive and temporally continuous monitoring strategies. This is particularly suitable for low-frequency, severe outcome interactions (e.g., mortality of a marine mammal in a protected population). However, continuous and comprehensive monitoring with high-bandwidth instruments that can collect enough data to identify marine animals to the species level and characterize their interaction with a MEC (e.g., optical cameras, imaging sonars, radars) would rapidly accrue “data mortgages” in which the curation of data would inhibit analysis. A pure hardware solution to this challenge would involve developing instruments that collect only the information desired (e.g., taxonomic classification and trajectory of an individual marine animal), rather than raw data that must be refined to obtain this information. Conversely, a pure software solution would be to post-process vast streams of data in real time or allow it to accrue in petabyte-scale databases and investigate specific hypotheses in a post-hoc manner. Neither approach is likely to be viable in isolation, but a middle ground would be to integrate instrumentation in a single package that makes targeted use of high-bandwidth instruments. For example, to observe marine mammal interactions with a MEC, a passive acoustic system could detect and localize marine mammal vocalizations in real-time, triggering an active sonar to track trajectory, and, in-turn, trigger an imaging system at close range. Using such an architecture, one would collect and archive data from high-bandwidth instruments during periods of time when an interaction of interest is likely to occur.

An integrated approach to instrumentation does, however, require high data and power bandwidth (generally necessitating a cable to shore) and a mechanism to tie multiple instruments together in a single package. A shore connection and larger package size increase the challenge of deploying and maintaining instrumentation at marine renewable

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energy sites. As the capability increases for an instrumentation package to reduce risk uncertainty, so does the difficulty to deploy and maintain the system.

ENVIRONMENTAL INFRASTRUCTURE

Solving this apparent paradox requires the development of new “environmental infrastructure”, that is, infrastructure that can facilitate the study of environmental changes associated with the long-term operation of marine renewable energy projects. An expression of this concept is a package that integrates instrumentation to conduct environmental studies, but is expressly designed for the challenging conditions present in these study environments (e.g., high structural loads, limited windows for maintenance intervention). Such a package must be able to survive similar structural loads to a MEC, be deployed and recovered rapidly and without the need for specialized equipment, not interfere with MEC operation or maintenance, and support high bandwidth instruments. To this end, researchers at the Northwest National Marine Renewable Energy Center have developed a concept for an Adaptable Monitoring Package (AMP) and a customized tool skid (dubbed the “Millennium”) built up around an inspection-class ROV (SeaEye Falcon) [6]. The prototype conceptual design is shown in Figure 1. The “Millennium” tool skid includes five additional vectored thrusters that double the horizontal and vertical thrust of the stock ROV and allow it to operate against significant currents. In addition to manoeuvring the AMP into position, the “Millennium” Falcon also includes the actuators to latch it to a docking station on or near a MEC. Once the AMP is secured to the docking station, the “Millennium” Falcon disengages and is recovered to the surface. The docking station includes an electro-optical wet-mate connector, with a mating end on the AMP. Power to the AMP (up to 1 kW at 48 V DC) and data connectivity for instruments (up to 2 Gps) are provided via the MEC’s export cable to shore. The docking station can be thought of as a “science port” for a MEC and can be customized and maintained independently from the MEC itself. Given the high cost of wet-matable electro-optical connectors (~$100k per mating connector) and limited service life (100 mating/de-mating cycles before maintenance is required), future enhancements to the system architecture may include non-contact power and data transfer between the AMP and docking station.

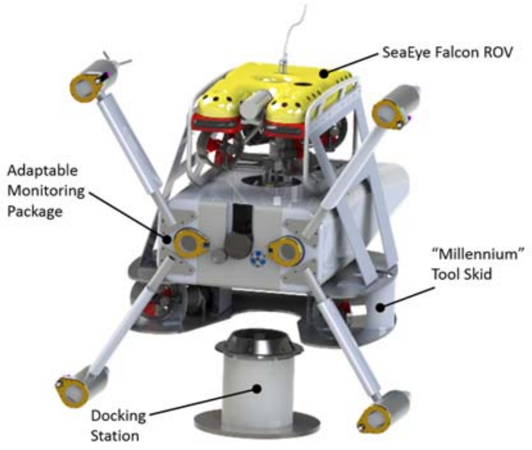

Figure 1 Adaptable Monitoring Package and “Millennium” Falcon ROV Prototype Design

Table 1. Adaptable Monitoring Package Instrumentation Payload (prototype)

Instrument Type	Instrument Specification	Monitoring Capabilities
Stereo-optical camera system	Custom integration	Near-field marine animal interaction classification
Acoustical camera	BlueView P900/2250	Near-field marine animal interaction detection
Hydrophone array	icListen HF	Marine mammal localization
Acoustic Doppler current profiler	Nortek Aquadopp	Near-field wave and current profile
Acoustic Doppler velocimeter	Nortek Vector	Near-field current point measurement
Water quality sensor	SeaBird 16+ v2 CTDO	Temperature, salinity, and dissolved oxygen
Cetacean click detector	Chelonia C-POD (autonomous)	Cetacean presence/absence
Fish tag receiver	Vemco VR2W (autonomous)	Presence of tagged fish

The AMP’s initial instrumentation payload, summarized in Table 1, includes systems suitable for studying interactions with high-risk uncertainty. These include a stereo-optical camera package [7], active sonars, and passive acoustic hydrophones. Excepting autonomous systems (click detector and fish tag receiver), these instruments are integrated over a Gigabit Ethernet network, either through native Ethernet connectivity or network-addressable serial device servers. The internal structure of the AMP utilizes modular bulkheads that can be swapped out to accommodate alternative payloads and configurations. The instrumentation payload for the prototype AMP constrains its form factor, particularly the camera-light separation required to reduce optical backscatter [8] and hydrophone element separation required for marine mammal localization by a synchronous hydrophone array [9]. This increase in cross-sectional area acts in opposition to the drag minimization needed to survive extreme waves and currents. The prototype AMP shown in Figure 1 is intended for incorporation with a tidal turbine, where the horizontal currents will be much stronger than the vertical. This favours an asymmetric form factor. Conversely, an AMP optimized for near-surface observations of a wave converter would favour a symmetric hull since wave orbital velocities will impart nearly equivalent loads in both the horizontal and vertical directions.

Given the need to minimize drag, both for survival and ease of deployment, hull shape optimization has been a critical aspect of the AMP development. Our research has employed both computational fluid dynamic simulations and one-quarter scale experimental methods (free-decay pendulum motion in water) [10]. Numerical simulations of the ROV alone have shown good agreement with experiments and suggest that deployment operations will be possible in turbulent currents up to 1 m/s. Static stability analysis has driven the internal configuration and motivated the use of neutrally buoyant materials throughout the hull and internal structure.

During 2014/2015, the prototype system will progress through a series of field trials, beginning with launch and docking operations in calm waters and culminating in deployment at a tidal energy site. The AMP is intended to be used operationally for the first time in support of environmental research around a dual-turbine deployment in Puget Sound, WA, USA (partnership between Public Utility District No. 1 of Snohomish County and OpenHydro).

CONCLUSIONS

For marine renewable energy to continue to be developed in a sustainable and cost-effective manner, environmental risk uncertainty needs to be reduced. This will require information about interactions between marine animals and marine renewable energy converters, some of which will be infrequent, but of ecological significance. Characterizing these interactions will require advances in instrumentation hardware and software, as well as infrastructure that can integrate these instruments and facilitate their operation in high-energy wave and current environments. One concept for this integrated approach (the Adaptable Monitoring Package) is described. Environmental risk uncertainty can be reduced, but requires collaboration and coordination between resource managers, technology developers, and researchers.

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