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Predicting risk of catastrophic events at Marine Renewable Energy Sites

John K. Horne[1], Dale A. Jacques[1], and Noble Hendrix[1,2]

[1]School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA, USA

[2]QEDA Consulting, LLC, Seattle, WA, USA

Marine Renewable Energy (MRE) projects involve risk. An important risk factor is the potential for interactions between marine mammals or fish aggregations and devices (e.g. tidal turbines, wave energy convertors) that may lead to a catastrophic impact. Objectives of operation and environmental monitoring plans all include preventing catastrophic impacts between organisms and devices. Ideally, there would be analytic techniques that, based on local data, predict temporal windows when catastrophic impacts (i.e. extreme events) are likely to occur. These model predictions could then be used to define conditions of operating licenses, increase monitoring vigilance, modify operations, or curtail operations during high risk periods. We use a suite of methods to define thresholds of extreme events and then use Extreme Value Analysis (EVA) to model the periodicity of extreme events.

Before the probability of an interaction can be calculated, it is imperative to determine the threshold of an extreme event. Conceptually this is a deviance from a measure of location or trend in an empirical data set or theoretical model. Three methods were applied to a baseline acoustic data set characterizing density of fish and macrozooplankton in Admiralty Inlet, Washington, USA to identify extreme events: Generalized Autoregressive Conditional Heteroskedasticity (GARCH) models, Scale-Averaged Wavelets (SAW), and Mean Residual Life (MRL) functions. GARCH models and SAW use peaks in temporal variability to identify extreme data points. We assume that high densities relative to the variability in series are associated with extreme biological interactions at MRE sites. Statistically significant deviations from GARCH models, which quantify localized variability as a function of the variability in the time series, are extreme events where the monitored variable(s) deviate from the variance structure of the series in the recent past. SAW also identify extreme events as significant deviations of localized variability, but uses localized deviations from the variability in the series, averaged across temporal scales. In a MRL function, if a Generalized Pareto Distribution (GPD) is assumed for extreme events and that mean values above a threshold are linearly related to the threshold, then discontinuities from linearity can be used to identify a threshold

Having identified thresholds using MRL, shape and scale parameters of the GPD for fish density were estimated by maximizing the log likelihood of the acoustic data. By using the GPD to model the probability of events beyond the threshold, the return period (i.e. mean time until an event at least as strong) of each observed value can be inferred. The GPD can also be used to extrapolate the return period for events more extreme than what was observed, analogous to predicting the amplitude of the “100 year flood.”

From an MRE perspective, this approach can be applied to any environmental monitoring variable and when designing MRE components to predict the periodicity of catastrophic events.