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TURBULENCE, TROPHIC INTERACTIONS, AND SUSTAINABLE ENERGY EXTRACTION

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ABSTRACT

This interdisciplinary study seeks to investigate the poorly understood role of turbulence in sites appropriate for tidal energy extraction, drawing on expertise from ecology and engineering. These highly energetic environments represent a challenge in data collection and analysis. Variable surface wind/wave interactions, extreme tidal friction effects and intense shear in the wake of obstacles lead to the vertical advection of bubbles and deep turbulent circulations. The resulting complex flow environments are a challenge for the design of devices and arrays, as well important ecologically as foraging habitats of many mobile species. This project utilises a variety of acoustic instruments to provide new information on the physical properties and ecological implications of turbulence in these environments. This study will lead to a better understanding of the scale and significance of the impacts of marine energy extraction.

INTRODUCTION

Ambitious renewable energy targets and technological advancements mean that the development of arrays of tidal stream turbines in sites around the UK is likely. A large number of companies are working on the development of devices, with a variety of device types currently being tested. In the UK this activity is focused at the European Marine Energy Centre (EMEC) tidal test site at the Fall of Warness in the Orkney Islands.

Despite the extensive interest in marine energy extraction the ecological implications of energy extraction are poorly understood[1]. Ecological and physical data from sites suitable for energy extraction is often extremely limited due to the highly localised nature of sites and challenges of investigating such energetic environments.

Acoustic Doppler Velocity Profiling (ADCP) technologies have made a significant contribution to the understanding of velocity profiles and turbulence characteristics in highly dynamic marine environments. As a result there have been numerous deployments of ADCPs at EMEC for site assessment and turbulence analysis[2]. However ADCP derived measurements are limited by their assumptions and resolution, and normally don't offer any information on marine organisms within the sampled area.

Backscatter information from EK60 multifrequency and multibeam echosounders (MBES) can offer high resolution physical and biological information in these sites. This project benefits from data collected in the NERC funded FLOWBEC[3] and RESPONSE[4] projects yielding backscatter data from stationary platform deployments in the proximity of devices at EMEC and boat survey transects through the Fall of Warness site. These data have recorded the behaviour of organisms throughout the water column and variations in turbulence simultaneously.

Turbulence leads to intense non-biological scattering obscuring acoustic responses from organisms requiring innovative forms of backscatter analysis and supporting sources of information to separate signals due to physical processes from biological targets. This will see the interdisciplinary approach of combining target identification from multifrequency echosounders, behavioural observations from MBES, and velocity information from ADCP records and an Acoustic Doppler Velocimeter (ADV), to investigate the complex nature of turbulent flows and the effects on marine animals.

METHODOLOGY

The interdisciplinary approach taken in this project utilises spatially overlapping and often concurrent data types from a variety of instruments summarised in Table 1.

Table 1. Primary data summary. Deployments indicate amount of data and resolution given in along beam spatial/temporal

Data	Type	Deployments	Resolution
Static EK60	Multifrequency backscatter	5 x 2 week	0.76m / 1s
Mobile EK60	Multifrequency backscatter	103 transects	0.76m / 1s
ADCP	Velocity and ping strength	1 month	1m / 1s
MBES	Multibeam backscatter	5 x 2 week	0.08m / 0.14s
ADV	Velocity	5 x 2 week	-

Information from static deployment of EK60, MBES, and the ADV are based on the self-contained autonomous FLOWBEC platform deployed approximately 20m from full scale test turbines and at a control location at EMEC's tidal test site using a unique upward facing echosounder arrangement.

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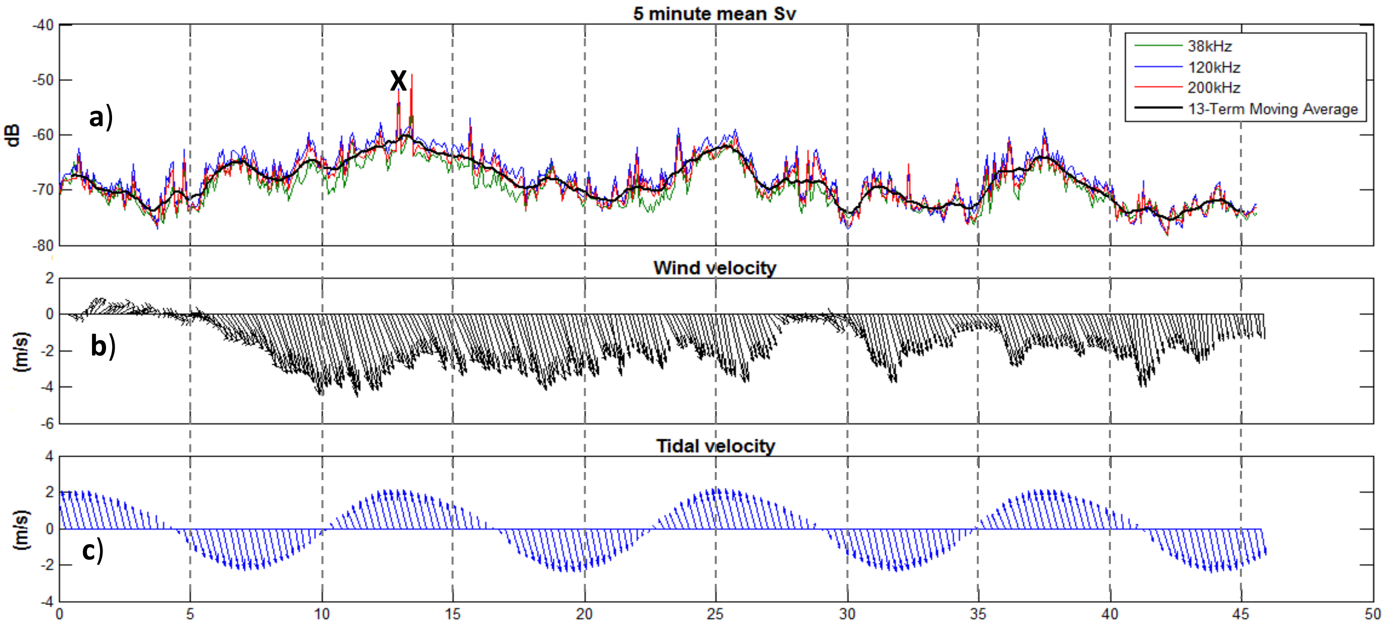

Figure 1. Data from FLOWBEC deployment. Section shows almost 2 days of data from 00:54 on 07/06/2013 with x-axis given in hours. a) Multifrequency mean backscatter variation from 5 minute integrations through entire water column. b) Wind velocity vectors recorded at nearby EMEC operated weather station. c) Tidal velocity vectors from model data.

Supporting data collected in parallel by a moving vessel during the RESPONSE transects covers much of the test site and overlaps with static deployments. Detailed information on flow velocities throughout the water column comes from an ADCP deployment adjacent to a FLOWBEC deployment, providing information on velocity fluctuations which can be used for standard turbulence assessment and the comparison of estimated backscatter variations derived from ping strength records. Other data types collected at the site also assists analysis, including meteorological and surface current records, tidal model data, and fluorescence and turbidity variability records.

OBSERVATIONS

Analysis of volume backscatter strength (Sv) through time shows a complex picture of turbulent generation from different sources and biological interaction with turbulent structures at a variety of scales. Preliminary analysis has involved the investigation of mean backscatter through the water column within regions defined by time (Figure 1a). This has revealed the overlapping responses from biology and physical processes. Clear spikes characterised by a differential frequency response correspond to brief but clear school features (Figure 2), whereas broad trends with a relative frequency agreement often agree with physical variations such as wind and tide direction (Figure 1b, 1c).

CONCLUSIONS

This study will lead to increases in both the physical and ecological understanding of the effects of the types and scales of turbulence features on the behaviour, trophic interactions, and foraging habitats of important species. This will provide vital information needed for a better understanding of the highly complex effects that marine tidal energy extraction will have on the turbulent hydrodynamics of these environments and the resulting scale and significance of ecological implications.

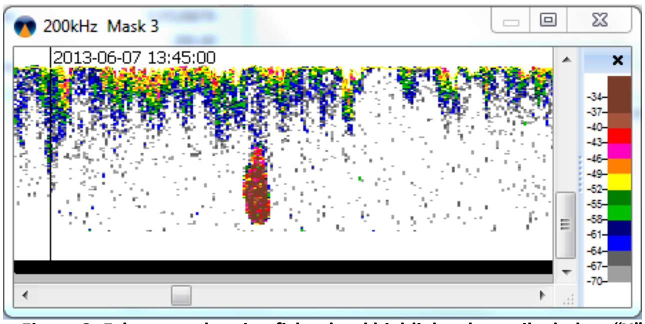

Figure 2. Echogram showing fish school highlighted as spike below "X" marked in Figure 1. Data from 200kHz transducer and scale in relative dB.

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