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Assessing the potential of autonomous submarine gliders for ecosystem monitoring across multiple trophic levels (plankton to cetaceans) and pollutants in shallow shelf seas

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A B S T R A C T

A combination of scientific, economic, technological and policy drivers is behind a recent upsurge in the use of marine autonomous systems (and accompanying miniaturized sensors) for environmental mapping and monitoring. Increased spatial–temporal resolution and coverage of data, at reduced cost, is particularly vital for effective spatial management of highly dynamic and heterogeneous shelf environments. This proof-of-concept study involves

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integration of a novel combination of sensors onto buoyancy-driven submarine gliders, in order to assess their suitability for ecosystem monitoring in shelf waters at a variety of trophic levels. Two shallow-water *Slocum* gliders were equipped with CTD and fluorometer to measure physical properties and chlorophyll, respectively. One glider was also equipped with a single-frequency echosounder to collect information on zooplankton and fish distribution. The other glider carried a Passive Acoustic Monitoring system to detect and record cetacean vocalizations, and a passive sampler to detect chemical contaminants in the water column. The two gliders were deployed together off southwest UK in autumn 2013, and targeted a known tidal-mixing front west of the Isles of Scilly. The gliders' mission took about 40 days, with each glider travelling distances of >1000 km and undertaking >2500 dives to depths of up to 100 m. Controlling glider flight and alignment of the two glider trajectories proved to be particularly challenging due to strong tidal flows. However, the gliders continued to collect data in poor weather when an accompanying research vessel was unable to operate. In addition, all glider sensors generated useful data, with particularly interesting initial results relating to subsurface chlorophyll maxima and numerous fish/cetacean detections within the water column. The broader implications of this study for marine ecosystem monitoring with submarine gliders are discussed.

1. Introduction

Shelf and adjacent coastal seas host highly productive ecosystems and are shared by an increasing variety of stakeholders utilizing limited space, e.g. shipping, fishing, aquaculture, recreation, hydrocarbon and aggregate extraction, and renewable energy (Collie and Adamowicz et al., 2013; Sharples and Ellis et al., 2013). These potentially conflicting demands require appropriate management, e.g. through Marine Spatial Planning, a complex task that is dependent upon high quality data and evidence (Gilman, 2002; Douvere and Ehler, 2011).

In addition to the management of multiple stakeholders to ensure that ecosystem health and services are maintained, additional data from shelf seas are required to meet international statutory obligations such as establishment of Marine Protected Areas (MPAs) and implementation of the EU Marine Strategy Framework Directive (MSFD) (European Union, 2008; Brennan and Fitzsimmons et al., 2013). However, marine mapping and monitoring using dedicated research and survey vessels is expensive, and offshore operations can be hindered due to weather constraints (Schofield and Glenn et al., 2013). In addition, the spatial and temporal resolution of vessel-based data are often insufficient to fully capture ecosystem dynamics, including the linkage of physical and biological processes, predator–prey interactions, community structure, and the spatio-temporal variability of different ecosystem components (Day, 2008). Satellite remote sensing of the oceans can provide useful supporting data at large spatial scales, but is restricted to the uppermost layers of the sea surface. Fixed moorings and profiling floats may provide long time series, but the former only collects data at a single point and the latter are difficult to spatially control (L'Heveder and Mortier et al., 2013).

Submarine (buoyancy-driven) gliders are a type of Autonomous Underwater Vehicle (AUV) that oscillates through the water column and can remain unattended at sea for several weeks to months (Rudnick and Crowley et al., 2012). Gliders carrying appropriate sensors can simultaneously monitor a range of physical and biological parameters, and regular surface communications with satellite allow their movement to be controlled and data to be uploaded in near real-time. However, gliders