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Deep-sea observations at hydrocarbon drilling locations: Contributions from the SERPENT Project after 120 field visits

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ABSTRACT

The SERPENT Project has been running for over ten years. In this time scientists from universities and research institutions have made more than 120 visits to oil rigs, drill ships and survey vessels operated by 16 oil companies, in order to work with the industry's Remotely Operated Vehicles (ROV). Visits have taken place in Europe, North and South America, Africa and Australasia at water depths from 100 m to nearly 3000 m. The project has directly produced >40 peer reviewed publications and data from the project's >2600 entry online image and video archive have been used in many others. The aim of this paper is to highlight examples of how valuable data can be obtained through collaboration with hydrocarbon exploration and production companies to use existing industry infrastructure to increase scientific discovery in unexplored areas and augment environmental monitoring of industrial activity.

The large number of industry ROVs operating globally increases chance encounters with large, enigmatic marine organisms. SERPENT video observations include the deepest known records of species previously considered epipelagic such as scalloped hammerhead (*Sphyrna lewini*) and southern sunfish (*Mola ramsayi*) and the first *in situ* observations of pelagic species such as oarfish (*Regalecus glesne*). Such observations enable improvements to distribution records and description of behaviour of poorly understood species. Specimen collection has been used for taxonomic descriptions, functional studies and natural products chemistry research. Anthropogenic effects been assessed at the local scale using *in situ* observations and sample collection at the time of drilling operations and subsequent visits have enabled study of recovery from drilling.

Future challenges to be addressed using the SERPENT approach include ensuring unique faunal observations by industry ROV operators are reported, further study of recovery from deep-water drilling activity and to carry out *in situ* studies to improve the understanding of potential future decommissioning of obsolete hydrocarbon infrastructure.

1. Introduction

The world's deep seas provide important services (Thurber et al., 2014) and, increasingly, resources (Levin and Le Bris, 2015). They are subject to anthropogenic disturbance from global change and industrial exploitation (Glover and Smith, 2003; Ramirez-Llodra et al., 2011). For example, hydrocarbon exploration and production is now common in the deep-sea (Pinder, 2001). Despite this, there is limited research and few institutions and even countries in the world have extensive deep-sea research programmes (Ruth, 2006). Even at relatively shallow water depths *in situ* observational studies become more limited as depth increases beyond the reach of divers. Existing deep-sea research programmes are limited, as multi-disciplinary open ocean research requires specialist infrastructure, such as ships, autonomous underwater vehicles and Remotely Operated Vehicles (ROVs), as well as significant financial resources.

The hydrocarbon industry operates in water depths to over 3000 m and has the financial resources to invest in the large scale offshore surveys and the infrastructure required to work in these areas. The industry has hundreds of deep-water ROVs in use globally on a daily basis. During routine operations these vehicles

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may also be on standby for long periods of time. The SERPENT Project (**S**cientific and **E**nvironmental **R**OV **P**artnership using **E**xisting i**N**dustrial **T**echnology) (www.serpentproject.com) aims to collaborate with hydrocarbon companies to make use of the offshore infrastructure, primarily through access to ROVs in standby time, in order to collect scientific data (Jones, 2009). Formed through collaboration with BP, Transocean and Subsea 7 to facilitate field visits to oil rigs in the North East Atlantic in 2002, the SERPENT Project has since worked with 16 oil companies (Table 1) and numerous ROV contractors and rig operators around the world (Fig. 1). The SERPENT Project is based in Southampton at the National Oceanography Centre and SERPENT hubs also work independently in Australia, New Zealand and SE Asia (SEA SERPENT) and the USA (Gulf SERPENT) with a focus on the Gulf of Mexico.

The SERPENT Project has proved important to deep-sea scientists, providing a valuable research infrastructure to access water beyond diver depth in hydrocarbon exploration areas. In addition, it has tangible benefits to industry through improvement of environmental management of activity areas. Data collected though SERPENT are primarily marine biological in nature and address scientific questions under two main themes:

(1) the distribution and behaviour of deep-sea organisms and
(2) the effects of hydrocarbon exploration on deep-sea organisms

This paper aims to highlight examples of how valuable data can be obtained through collaboration with oil and gas companies, increasing scientific discovery in unexplored areas and supplementing environmental monitoring. The paper considers possible future directions using the approach to enhance understanding of deep-sea ecosystems, in particular in areas impacted by industry.

2. The SERPENT approach to deep-sea data collection

There are two main ways industry data can be collected by SERPENT:

(1) Deep-sea ROV observations provided by industry to SERPENT scientists and
(2) Visits by scientists to offshore infrastructure (oil rigs, dill ships, survey vessels and support vessels)

2.1. Material provided by industry

The SERPENT Project has many links with industry, fostered through a continued presence and clear brand. This has been developed and maintained by promotion at conferences, in trade magazine articles, video material, online presence, lectures and in specific training given to ROV operators by SERPENT scientists. These methods, as well as targeted campaigns, have encouraged ROV operators and company staff operating in deep water to look for and record observations of deep-sea species and habitat features, which are sent to the project coordinators. These are identified to the highest taxonomic resolution possible from the imagery and recorded in the SERPENT archive (http://archive.serpentproject.com). The SERPENT archive is a publicly available online database of images and video clips sent to the project and collected during offshore fieldwork. At the time of article submission it contains >2600 records from the offshore waters off 22 countries. Each entry shows thumbnail images or video clips with metadata and taxonomic information. Higher resolution versions are available on request. The SERPENT archive spans most areas of active offshore oil industry activity (Fig. 1). The archive is compliant with the Open Archives Protocol for Metadata Harvesting so it can be incorporated into other global databases. As an example, the SERPENT archive is harvested by the Encyclopaedia of Life (www.eol.org) (EOL, 2015) providing images of often poorly known deep-sea species (http://eol.org/content_partners/248). Independently the Australian Museum hosts images from Australian waters (*e.g.* http://australianmuseum.net.au/fishes-by-habitat-deepsea-fishes).

2.2. Visits

At the time of article submission the SERPENT Project had completed 127 visits to drilling rigs, survey vessels and support vessels in 13 countries (study locations are listed in Table 1 and shown in red on Fig. 1). Visits are normally made to exploration drilling rigs during drilling programmes, when ROVs can be accessed in stand-by time, when the ROV is prepared for diving but has no tasked work. Crucially, SERPENT observations are normally carried out at times that do not interfere with industry operations (exceptions are pre-drilling surveys which may delay onset of drilling). At exploration drilling sites ROV dives are used for general visual inspections of risers and blow-out preventers (BOPs) on a near daily basis. SERPENT ROV access is most often provided after this scheduled operational work. As well as enabling the collection of scientific observational data or samples, this provides opportunities for the less experienced ROV team members to increase their piloting experience to the benefit of their professional development.

On several occasions it has also been possible to visit installations before any drilling (and hence seabed disturbance) has taken place. While desirable for scientific investigations, these pre-drilling visits are more challenging because time is limited at this stage in the drilling process. Pre-drilling SERPENT surveys will normally delay the onset of drilling so require additional negotiation or a particular interest from the host company. In such cases, the SERPENT observations can be carried as an enhancement of the ROV 'as found' survey, which is designed to assess the presence of obstacles, munitions or obvious features to avoid, and to create a record of site condition prior to drilling, so the company can 'leave it as they found it' when drilling activity is completed.

Many SERPENT offshore visits have been in relatively well-studied deep-sea areas such as the Gulf of Mexico and the North East Atlantic, but even in these areas novel observations are relatively common. Data collected by SERPENT supplement ongoing studies in these areas and add to environmental monitoring in hydrocarbon exploration areas. In the north east Atlantic, 21 drilling sites have been visited off Norway and UK, covering a range of water depth from 150 m to over 1700 m.

The study of poorly known areas, which have been largely neglected by institutions and expeditions in nationally funded research programmes, can be enhanced by using industry infrastructure. Examples include visits to the Orinoco fan off Venezuela (Jones et al., 2012b), the Gulf of Guinea off Nigeria (Jones et al., 2013); the Nile submarine fan, off Egypt, the deepest SERPENT site visited so far, located at 2720 m depth (Gates et al., 2012); and in the western Indian Ocean off Tanzania (Gates, 2016).

2.3. ROVs and ROV time

In 127 SERPENT visits to offshore installations a variety of types of ROV have been used (Fig. 2). The majority have been Oceaneering, Subsea 7 or Fugro systems. Industry ROV systems are increasingly acquiring HD video (*e.g.* 1920×1080 pixels or more), improving the quality of material collected through SERPENT. For example, Oceaneering International's Millennium ROVs, an important component of the deep-water offshore industry ROV fleet, are now routinely equipped with the Ocean ProHD® camera

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