ARTICLE IN PRESS

Ocean Engineering xx (xxxx) xxxx–xxxx

Contents lists available at ScienceDirect

Ocean Engineering

journal homepage: www.elsevier.com/locate/oceaneng

Fine-scale monitoring of fish movements and multiple environmental parameters around a decommissioned offshore oil platform: A pilot study in the North Sea

Toyonobu Fujii*, Alan J. Jamieson

Oceanlab, School of Biological Sciences, University of Aberdeen, Main Street, Newburgh, Aberdeenshire, AB41 6AA UK

ARTICLE INFO

Keywords:
Artificial reefs
Environmental monitoring
Offshore oil/gas platforms
Underwater observatory
Fish movement
North Sea

ABSTRACT

A new underwater monitoring system was constructed using time-lapse photography and a suite of oceanographic instruments to characterise the dynamic relationships between changing environmental conditions, biological activities and the physical presence of offshore infrastructure. This article reports the results from a pilot study on fine-scale monitoring of fish movements in relation to changes in multiple environmental parameters observed at an offshore oil platform in the North Sea. Temporal changes in the number of saithe *Pollachius virens* were readily observed with a strong indication of diurnal rhythm of vertical movements. Key environmental parameters such as temperature, salinity, currents, tidal cycle, illumination, chlorophyll and dissolved oxygen also varied spatially (i.e. different depths) and/or temporally. If the monitoring system is to be deployed systematically at multiple offshore locations for longer duration as appropriately controlled experiments, this approach may greatly help understand the influence of redundant offshore man-made structures on the marine ecosystem.

1. Introduction

Any decisions on the issues of decommissioning of offshore infrastructure will need to be made based on an array of selection criteria including, but not limited to, environmental, health and safety, financial, socioeconomic, technological and political considerations (Fowler et al., 2014; Wilkinson et al. 2016). In the North Sea, the question of how aging offshore infrastructure is utilised by different marine fauna has become increasingly important in terms of the environmental considerations. This is because recent studies have suggested that the physical presence of offshore platforms, together with associated subsea infrastructure such as pipelines, wellheads and manifolds, may have beneficial effects on present-day ecosystem functioning as they may serve as artificial reefs that attract marine life (Stachowitsch et al., 2002; Whomersley and Picken, 2003), including species of conservation importance, e.g. a cold-water coral *Lophelia pertusa* (Gass and Roberts, 2006), and thereby increase the number of economically important fishes in the proximity of these foundations (Love and Westphal, 1990; Stanley and Wilson, 1991, 1997; Fabi et al., 2004; Love and York, 2005; Love et al., 2006; Jablonski, 2008).

The North Sea has long been a vital ground for the exploitation of natural resources, supporting one of the world's most active fisheries as well as oil and gas exploration which has led to installation of over 500 offshore platforms across the region primarily since the 1960 s. In this region, commercially important fishes, such as saithe, *Pollachius virens* cod *Gadus morhua*, and haddock *Melanogrammus aeglefinus* have been known to show coherent patterns in their local distributions where significantly higher number of individuals can be found in the immediate vicinity of offshore structures when compared with surrounding open soft-bottom areas (Valdemarsen, 1979; Aabel et al., 1997; Løkkeberg et al., 2002; Soldal et al., 2002; Fujii, 2015). Although there is also a growing body of evidence to confirm that a variety of fish species aggregate around artificial hard structures in marine environments worldwide (e.g. Bohnsack and Sutherland, 1985; Picken and McIntyre, 1989; Aabel et al., 1997; Stanley and Wilson, 1997; Baine, 2001; Løkkeberg et al., 2002; Soldal et al., 2002; Fabi et al., 2004; Love and York, 2005; Wilhelmsson et al., 2006), causality of such attraction effect, however, has not yet been satisfactorily identified. Several mechanisms may be responsible for the increase, for example, enhanced food availability (e.g. Page et al., 2007), shelter from predation (e.g. Hixon and Beets, 1989) or reference point (e.g. Soria et al., 2009), but it still remains unclear whether the fish individuals merely concentrate around offshore artificial structures from surrounding areas or whether such effects can facilitate the reproductive ability of fish populations and thereby produce any net increase in fish stock sizes overall. To ultimately determine the ecological consequences of

* Corresponding author.
E-mail address: t.fujii@abdn.ac.uk (T. Fujii).

http://dx.doi.org/10.1016/j.oceaneng.2016.09.003
Received 20 January 2016; Received in revised form 30 June 2016; Accepted 6 September 2016
Available online xxxx

alternative decommissioning options of obsolete offshore infrastructures, it would be necessary to design an appropriate ecological field experiments which allows identification of both causal mechanisms of attraction effect and temporal nature of fish movements in association with the physical presence of the offshore structures. However, there has been a lack of fundamental information on how the life cycle and/or the temporal variations in the movements of fish populations around offshore structures is related to any changes in key environmental factors (environmental cues) such as water temperature, salinity, currents, tidal cycle, light intensity (illumination), surface primary production (chlorophyll *a*), prey availability, dissolved oxygen and so on, which in turn hampers progress in advancing research in this field.

The aim of this article is to describe the design of a newly developed underwater monitoring system which uses time-lapse digital photography and a suite of oceanographic instruments in an attempt to provide sufficient background measurements to characterise the dynamic relationships between changing environmental conditions and biological activities in association with offshore oil/gas platforms at fine temporal resolution. Using the monitoring system, a pilot study was conducted at three different sampling depths in the immediate vicinity of an offshore oil platform in the North Sea, the results of which is therefore presented thereafter. Based on the findings from the pilot study, together with the relevant literature, implications for the ecological influence of obsolete offshore platforms on the marine ecosystem are discussed. If the fine scale monitoring system is to be deployed systematically at multiple offshore locations over longer periods of time as appropriately controlled experiments, this approach may provide a useful tool to help identify the precise role of large offshore man-made structures in the ecology of fish populations in the North Sea.

2. Material and methods

2.1. Study site

The pilot study was conducted at BP's Miller platform situated in the northern central North Sea (Fig. 1). The platform was installed in 1991 in a water depth of approximately 103 m on a dense sandy seafloor. The platform has a large steel jacket supporting structure (eight-legged) weighing approximately 18,600 t with a size of 71×55 m at the base on the seabed, tapering to 71×30 m at the top just under the topsides modules. The Miller platform ceased production in September 2007 and the initial phase of decommissioning has already been completed. A detailed decommissioning programme has also been planned for dealing with the topsides, jacket and drill cuttings pile, and the platform is therefore currently being maintained with minimum on-board personnel, representing some of the redundant offshore oil/gas installations found in the region.

2.2. A new underwater monitoring system

An autonomous underwater monitoring system was newly designed and constructed in an attempt to describe and characterise the dynamic relationship between biological activities and an offshore oil platform in relation to fine-scale changes in various environmental parameters. This system comprised a surface float, three identical observatory frames (Fig. 2) and ballast weights (approximately 1400 kg), all attached to a single mooring rope (Fig. 3). Each observatory unit contained a suite of oceanographic instrumentations (Fig. 2), including: (1) a 10 megapixel digital stills camera and strobe (OE14-408 & OE11-442: Kongsberg Maritime, UK) programmed to take time-lapse photographs of the sea floor or the water column and associated fauna at 60 min intervals; (2) a 3D current metre (Aquadopp Current Metre: Nortek, Norway) programmed to measure current speed (m/s) and direction (degree) at 10 min intervals; (3) a CTD probe (RBRmaestro: RBR Ltd., Canada) programmed to measure salinity, water temperature (°C) and hydrostatic pressure (dbar) at 10 min intervals; (4) a PAR (photosynthetically active radiation) sensor (PAR Quantum 192SA: LI-COR, Inc., US) programmed to measure the photosynthetic photon flux

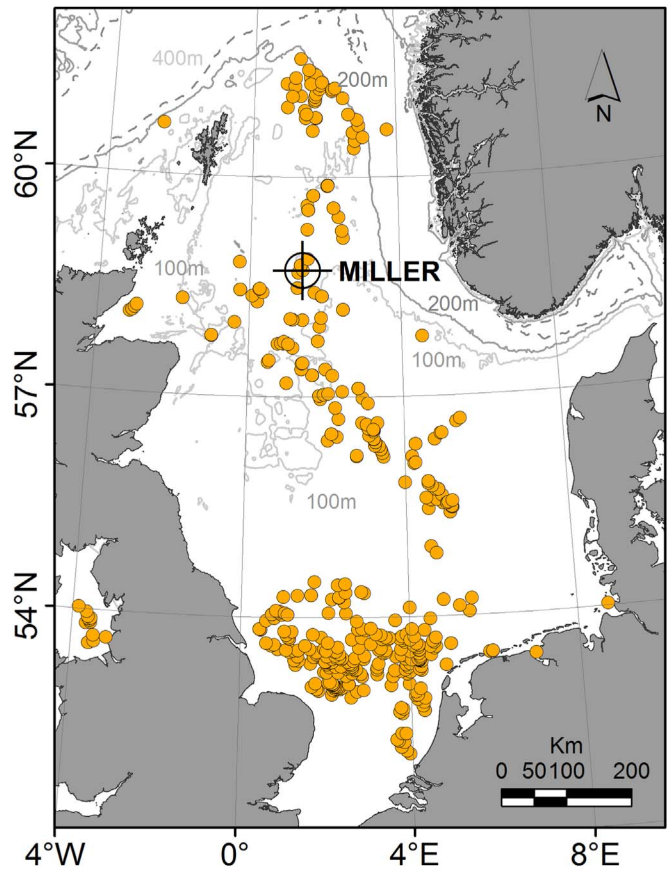

Fig. 1. Map of the North Sea showing the locations of offshore oil/gas platforms (the filled orange circles) (Source: OSPAR, 2012). The black circle and cross symbol indicates the location of the Miller platform. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

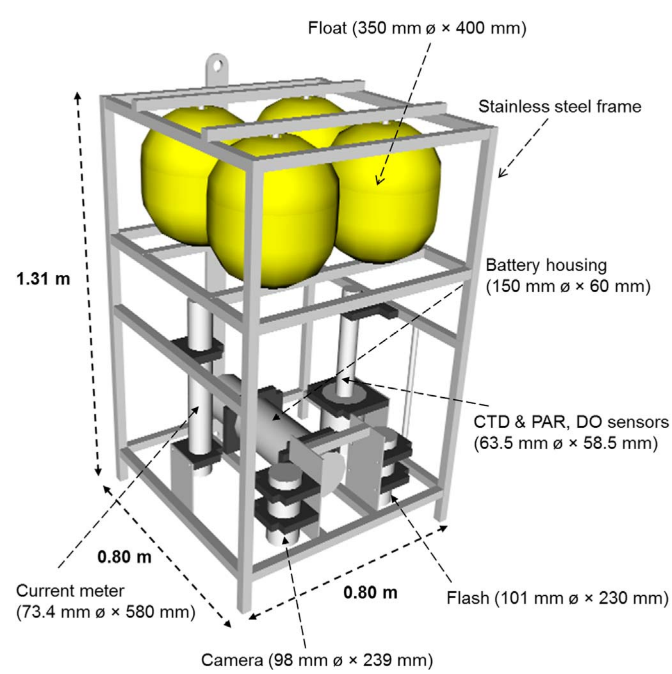

Fig. 2. Schematic diagram of the underwater observatory unit designed and constructed for this study.