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Fish and habitats on wellhead infrastructure on the north west shelf of Western Australia

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ABSTRACT

When production ceases, offshore oil and gas wells are taken out of service which involves safely plugging, abandoning and usually removing most of the associated subsea equipment. This process must consider impacts to marine ecosystems to meet regulatory requirement and for best environmental practice. However, there is a paucity of information globally on the ecosystem value of these structures, despite the many thousands that are installed throughout our oceans. This study provides the first assessment of fish assemblages and habitats formed by colonising invertebrates on oil and gas wellheads and associated infrastructure in depths of 78–825 m on the north west shelf of Western Australia. Video footage was obtained from Remotely Operated Vehicles deployed by industry on 25 wellhead structures, with six surveyed in each of four distinct depth zones: 78–85 m, 125–135 m, 350–395 m and 490–550 m, and one in 825 m depth. A total of 7278 individual fish from 60 species and 35 families were observed. Commercially important lutjanid (snapper) and epinephelid (grouper) species were common and most abundant on well infrastructure to depths of 135 m, but were absent in depths > 350 m. An as yet unidentified species of roughy, recorded here as *Gephyroberyx* sp. was the most common fish species observed on well infrastructure in depths > 350 m. Two speckled swellsharks (*Cephaloscyllium speccum)*, believed to be endemic to north-west Australia, were observed for the first time in situ. Numerous fish species were observed at depths beyond their known limits and two IUCN vulnerable species were recorded: the grey nurse shark (*Carcharias taurus;* 135 m depth) and the round ribbontail ray (*Taeniura meyeni;* 78 m depth). Fish assemblages and colonising invertebrate habitats present on wellheads and associated infrastructure were strongly influenced by depth, age and height of the structures. Older, taller wellheads in depths < 135 m possessed greater abundances of groupers, snappers, site-attached reef species, and transient pelagic fish species. Beyond 350 m depth, the number of species and total fish abundance declined markedly, as did the percent cover of ascidians, black/octocorals, sponges and Gorgonocephalidae (basket stars) observed growing on the infrastructure. Deeper structures were characterised by an abundance of *Gephyroberyx* sp. and, while these structures had less colonising invertebrate coverage in general, crinoids (490–550 m) and crustacea (barnacles; 350–395 m) were dominant at these depths. With very little known about marine ecosystems in depths > 100 m, or about wellheads as a type of subsea structure, this study demonstrates the ecological value of ROV footage obtained during industry operations and is indicative of the importance of subsea oil and gas infrastructure as a habitat for fish, and potentially as structures with value to fisheries.

1. Introduction

Globally, there are more than 900 large-scale offshore platforms serving the oil and gas industry (Lange et al., 2014; Cordes et al., 2016) and associated with each is an extensive network of subsea pipelines and wells. The global distribution of this infrastructure is extensive, with oil and gas reserves exploited in waters ranging from sub-Arctic/Antarctic, through the tropics to equatorial zones, and with industrial extractive activities taking place at a wide depth range from the shallow nearshore to many hundreds of meters depth. To understand the ecology of the habitats formed by these numerous offshore structures and, in particular, to identify the commonalities and specialities at

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different individual sites, studies are needed from many and diverse locations. In Australia, the tropical shallow seas of the north west shelf region of Western Australia is home to the country's largest resources development project (North West Shelf Project; Acil Tasman Ltd, 2009). More than 2000 km of pipelines are in place between Exmouth and Dampier (ENCOM data sourced by Woodside Energy) and there are 1710 wells servicing the industry in depths of 70 to > 1000 m between Exmouth and Port Headland offshore (NOPIMS, 2017). When this infrastructure reaches the end of its field life it must be taken out of service (decommissioned). In countries where legislation requires it (e.g. Australia, the UK, Norway, Denmark and The Netherlands) decommissioning involves safely plugging wells, and, in general, removing almost all of the associated subsea infrastructure. Nevertheless, for best practice, a review of decommissioning options is undertaken prior to each decommissioning case and each review has to consider impacts to marine ecosystems. Such understanding is critical to ensure appropriate evidence is available to decision makers, with emphasis placed on minimisation of environmental impact. There are, however, very few scientific published studies that examine marine communities that have developed on wellheads and their associated infrastructure over their operational life, despite the enormous number of these structures that are deployed worldwide. This is largely due to the high costs and logistical difficulties of surveying and comparing communities on and off wellheads at depth. Globally, we know little about marine organisms that exist in our deep oceans (Snelgrove, 2016; Horton et al., 2017), including the deeper parts of our continental shelves.

Industry routinely uses Remotely Operated Vehicles (ROVs) to monitor the integrity of subsea infrastructure and, in doing so collects terabytes of video recordings from some of the world's most inaccessible and poorly understood marine environments (Macreadie et al., 2018; McLean et al., 2018). Where these data are available for research, they can provide information on how organisms utilise infrastructure, their behaviour and community ecology (e.g. Benfield et al., 2009; Pradella et al., 2014; Moore and Gates, 2015; McLean et al., 2017). Such information is critical for informing decommissioning decisions. The SERPENT Project (**S**cientific and **E**nvironmental **R**OV **P**artnership using **E**xisting I**N**dustrial **T**echnology www.serpentproject.com) has been instrumental in highlighting the value of industrial ROV operations around the world (Gates et al., 2017). For wellheads, there is a limited, but growing body of research examining marine ecosystems that have developed around these structures. For example, Cummings et al. (2011) collected decapods from wellheads that were removed from the North West Shelf (NWS) of Western Australia and performed stable isotope analyses to provide insights into the animals' trophic positions. Fowler and Booth (2012) sampled the same decommissioned wellheads to assess the length and age structures of small basslet serranids (*Pseudanthias rubrizonatus)* and showed the wellheads were sustaining full populations (from juveniles to adults) of this species. Pradella et al. (2014) described a diverse fish assemblage associated with wellheads in 85–175 m depth. These studies provide important insights into marine communities that have developed on a small number of wellheads in depths < 200 m on the NWS of Australia and hint at the potential ecological value of infrastructure in this region. These pioneering studies require further observations from other structures and locations if general conclusions are to be made about wellheads as habitats, particularly in the case of deeper infrastructure where data are largely lacking.

Marine research in north-west Australia is increasing as operators, regulators, managers and scientists focus their efforts on understanding the potential environmental impacts of the offshore oil and gas industry in this region. For fish, the majority of research has been conducted in depths < 50 m and has documented diverse nearshore fish communities (Hutchins et al., 1996; Wilson et al., 2012; McLean et al., 2016), has identified important nearshore nursery environments (Wilson et al., 2010; Evans et al., 2014), and has also examined dredging-related impacts on fish (Wenger et al., 2017). Given the prevalence of subsea infrastructure in depths > 100 m, there is a need for research that describes and quantifies marine communities at greater depths. Information on fish at depths below 50 m on the NWS has been historically provided primarily by commercial fishing operation logbooks (trap, trawl and line fisheries) and specific research trawling expeditions (e.g. Althaus et al., 2006). The North West Shelf Joint Environmental Management Study (http://www.cmar.csiro.au/nwsjems/about/background.htm) produced 18 technical reports on the region that provide a wealth of information on the marine environment in depths < 200 m. During the years between 1959–1990 these depths were heavily fished in the region, predominantly by foreign trawling vessels (Sainsbury et al., 1997) with effort peaking in 1973 at over 30,000 trawl hours and with fish catches then exceeding 37,000 t (Ramm, 1994). Following a marked reduction in catches foreign trawling was banned and a smaller suite of local fisheries was established with far lower catch quotas (Sainsbury et al., 1997). Nevertheless, as a result of this historical fishing activity, fish assemblage composition changed from one comprising high value snappers (Lutjanidae) and emperors (Lethrinidae), which dominated catches in the middle of twentieth century, to one with a higher proportion of lower value lizardfish (Synodontidae) and threadfin bream (Nemipteridae) (Sainsbury et al., 1997). In a region where benthic habitats have been damaged by historical trawling activities, recent research is hinting at the potential habitat-value of offshore infrastructure for fish on the NWS (Fowler and Booth, 2012; Pradella et al., 2014; McLean et al., 2017). There exists an enormous opportunity to utilise ROV video obtained during industry operations to dramatically improve our understanding of marine organisms around offshore infrastructure in northwest Australia, particularly at depths where scientific sampling can be challenging (200–1000 m). At this location mesopelagic fish of the tropical biogeochemical mesopelagic province (TROP) identified by Reygondeau et al. (2017), are likely to be found together with benthic and demersal fish living above and on the upper bathyal regions of the continental slope.

This study assesses species richness and the relative abundance of fish in addition to the composition, complexity and coverage of colonising invertebrate habitats on 25 wellheads and their associated infrastructure in depths of 78–825 m on the NWS of Western Australia. We examine relationships between fish assemblages and predictor variables including habitat-forming marine growth, depth, wellhead age and height. Further, we describe fish assemblages present on the top half, lower half and entirety of each wellhead structure to better understand how fish are utilising these structures and how this research compares to that previously only conducted on the upper half of wellheads (Pradella et al., 2014). In doing so, this study discusses the potential value of subsea oil and gas infrastructure as complex habitat for fish and important commercial species.

2. Methods

2.1. Study location & wellheads

Video recordings were collected from ROV footage obtained during industry operations undertaken at 25 wells across the NWS between 28/10/13 and the 29/05/17 in depths of 78–825 m (Table 1; Fig. 1). Each well possessed a wellhead, flowbase and Christmas tree (assembly of valves, spools and fittings) in slightly varying designs to suit their role for gas production, hydrocarbon production, or water injection (see Fig. 2). For simplicity, we herein refer to the entire structure as a 'wellhead'. The wellheads were installed at varying times since 1994 and, as such, were present on the seabed for as long as 23 years (one wellhead - WA6) or as few as two years (two wellheads - BAL05, BAL08) (Table 1). Wellhead 'age' and the height of each structure above the seabed were recorded and considered in analyses (Table 1).

The video records analysed in this study were obtained from two

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