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Distribution, abundance, diversity and habitat associations of fishes across a bioregion experiencing rapid coastal development

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A B S T R A C T

Knowledge of the factors that influence spatial patterns in fish abundance, distribution and diversity are essential for informing fisheries and conservation management. The present study was conducted in the nearshore Pilbara bioregion of north-western Australia where the dynamic marine environment is characterised by large embayments, numerous islands and islets, coexisting with globally significant petrochemical and mineral industries. Within Western Australia, this nearshore bioregion has high biodiversity and is considered to play an essential role in the recruitment of species of commercial importance. To better inform future investigations into both ecological processes and planning scenarios for management, a rapid assessment of the distribution, abundance and associations with nearshore habitats of fishes across the region was conducted. Baited remote underwater stereo-video systems (stereo-BRUVs) were used to simultaneously sample the fish assemblage and habitat composition. Generalised additive mixed models (GAMMs) were used to determine whether the abundance of fishes were related to habitat and a range of environmental variables (visibility, depth, distance to 30 m and 200 m depth isobars, boat ramps and the nearest large embayment (Exmouth Gulf). A diverse fish assemblage comprising 343 species from 58 families was recorded. The abundance and distribution patterns of fishery-target species and of the five most common and abundant species and families were linked positively with areas of high relief, hard coral cover, reef and macroalgae and negatively with the distance to the nearest oceanic waters (200 m depth isobar). This study provides information that can contribute to future marine spatial planning scenarios for management of the Pilbara using a unique, analytical approach that has broad application in biogeography.

1. Introduction

Information on relationships between fish and habitats is essential for understanding the processes driving patterns of fish diversity and abundance. Habitat type and complexity are important determinants of the structure of fish assemblages (Friedlander and Parish, 1998; Almany, 2004; Travers et al., 2006, 2010; 2012; Giakoumi and Kokkoris, 2013; Wakefield et al., 2013). Fish abundance, diversity and distribution has been shown to be positively correlated with the structural complexity of habitats, likely due to the additional refuge from predators and availability of resources (e.g. food) that complex habitats offer (Newman and Williams, 1996, 2001; Newman et al., 1997; Friedlander et al., 2003; Willis and Anderson, 2003; Wilson et al., 2012). Understanding these relationships and natural patterns in fish abundance and diversity enables natural and anthropogenic impacts to be assessed. Knowledge of the spatial distribution of habitats and their relationship with fish is therefore essential for informing fisheries

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management and conservation (Curley et al., 2002).

The Pilbara region hosts fish assemblages characterised by high diversity and economically important, but low productivity, fisheries (MPRSWG, 1994; Fox and Beckley, 2005; Molony et al., 2011; Newman et al., 2014). In addition, rapid coastal development has been occurring at multiple locations throughout the region to support the mineral and petrochemical industries (PDC, 2015). This development has the potential to directly impact the biodiversity and productivity of vulnerable nearshore ecosystems via dredging, construction, pollution, shipping and other indirect pressures associated with increased human populations (e.g. fishing) (Pandolfi et al., 2003; Crain et al., 2009; Waycott et al., 2009). Management is challenged with finding a balance between the economic benefits of non-renewables, sustainable fisheries development and maintenance of biodiversity and ecosystem services. Knowledge of the patterns and processes that support productivity biodiversity of these nearshore marine ecosystems is therefore essential for informing management decisions (Parsons et al., 2014).

Nearshore marine habitats in the Pilbara, including macrophyte and sessile invertebrate assemblages, are likely to be vulnerable to coastal development pressures, with these habitats considered to be essential for the recruitment of important fishery species. In this region, recruits and juveniles of important commercial and recreational fishery species are thought to be spatially partitioned from adult populations and associated with different habitats (Evans et al., 2014). Knowledge of fish-habitat relationships across the Pilbara is lacking, but is required for the identification of priority areas for the recruitment of target fish species, areas of high biodiversity and vulnerable habitats. Such information would inform research into how these important areas may be affected by ongoing coastal development associated with the petrochemical and mineral industries.

Buoyed by the construction and operation of major coastal development projects in the Pilbara, levels of boat-based recreational activity peaked in 2012/13 (Fletcher and Santoro, 2015; Ryan et al., 2013, 2015). There is a seasonal peak in angling activity during the winter months when local populations are inflated by significant numbers of metropolitan and inter-state tourists in addition to the contribution from the workforce associated with construction or operation of major developments in the region (Fletcher and Santoro, 2015). Owing to the large tidal range in the Pilbara, nearshore recreational angling activity is mainly boat based for a variety of finfish species including barramundi (*Lates calcarifer*), mangrove jack (*Lutjanus argentimaculatus*), trevallies (Carangidae) and groupers (Epinephelidae) in nearshore waters. Tropical snappers (Lutjanidae), emperors (Lethrinidae), groupers (Epinephelidae), trevallies (Carangidae), tuskfish (*Choerodon* spp.) and mackerels (Scombridae) are also targeted further from shore (Fletcher and Santoro, 2015). The two main commercial fisheries operating within nearshore Pilbara waters are the Onslow and Nickol Bay prawn trawl fisheries that predominantly target banana prawns (*Penaeus merguiensis*) and the mackerel managed fishery that predominantly targets Spanish mackerel (*Scomberomorus commerson*) (Fletcher and Santoro, 2015). Commercial fisheries (fish trap, fish trawl and line) operate in continental shelf waters (30–500 m).

The current study is the first contribution from a five-year project aiming to create ecological models for use by management agencies assessing the impacts of coastal development associated with petrochemical and mineral extraction industries on biodiversity values and fisheries productivity in the Pilbara. As part of this integrated study, a novel application of a standardised benthic classification system was adopted to simultaneously collect semi-quantitative measures of habitat from an established fish survey method, baited remote underwater stereo-video (stereo-BRUV). These data were subjected to multivariate analyses to investigate ecological processes underlying the distribution, abundance and diversity of fishes along the extensive coastline of the Pilbara bioregion through the following hypotheses: (1) The relative abundance and diversity (species richness) of fishes are greatest in more structurally complex habitat types such as hard and soft corals, (2) The relative abundance and diversity of fishes will be greatest closer to large embayments where fish nursery habitats occur, (3) The relative abundance and diversity of fishes will be greatest in areas furthest from boat ramp access where fishing pressure may be least. Emphasis will be placed on identifying areas of notable abundance and diversity and the species and family groups mainly responsible for the observed patterns along the length of the Pilbara coastline.

2. Materials and methods

2.1. Study site

This study took place in the western Pilbara region of Western Australia spanning a distance of approximately 340 km from the eastern end of the Exmouth Gulf in the south (114° 8′ 55.47 E, 21° 55′ 19.15 S) to the Dampier Archipelago in the north (116° 56′ 12.945 E, 20° 24′ 19.94 S; Fig. 1). The marine environment is tropical with a component of sub-tropical species, which are more prominent in the assemblage towards higher latitudes (Hutchins, 2001).

2.2. Sampling protocol and equipment

Surveys were conducted over a ten day period in May 2014 using baited remote underwater stereo-video systems (stereo-BRUVs; Video 1). A total of 212 deployments were conducted in 6–21 m depth (mean 9.7 ± 0.1 m) across a range of habitat types, in areas open to recreational and charter fishing. Stereo-BRUVs were deployed on reefs or areas in close proximity to reefs with seabed structure present, *i.e.* we attempted to minimise large expanses of sand and as such these habitats are likely underrepresented in this study.

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Ten stereo-BRUVs were used concurrently to maximise sampling efficiency. These systems comprised a pair of high definition video cameras, either Canon Legria HFG25 or GoPro Hero3+ (silver and black models) set to record at 25 and 60 frames per second, respectively. The cameras are inwardly converged at 7° to provide an overlapping field of view and are fixed to a galvanised steel bar within a trapezium-shaped frame (see Langlois et al., 2010; Watson et al., 2010; see Video 1). Further information on the design configuration and calibration of these stereo-BRUVs can be found in Harvey and Shortis (1996, 1998). To maximise calibration stability, the systems used a purpose-built, dual housing mounted on a base bar with a design that minimises camera movement within the housing, and between the cameras.

Each stereo-BRUV was baited with approximately ~1 kg of pilchards (*Sardinops* spp.) contained within a plastic-coated wire mesh basket, attached to a conduit rod and positioned 1.2 m in front of the cameras. Bait was crushed to promote dispersal of the flesh and fish oil. Each system was deployed by boat and left to film remotely for at least 60 min on the seafloor before being retrieved and re-deployed. Neighbouring deployments were separated by at least 400 m to reduce the likelihood of fish swimming between stereo-BRUVs (see Cappo et al., 2004).