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Within and between day variability in temperate reef fish assemblages: Learned response to baited video

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ABSTRACT

Many studies that test for spatial patterns in fish assemblages do not have temporal replication, and where they do, the scale of this replication is in the order of seasons or years. Rarely are patterns tested at the scale of days or time of day. As a result, any descriptions of spatial patterns are potentially confounded by within or between day variations, with differences between locations possibly due to the differences between times sampled. This study aimed to determine whether significant short-term temporal variability existed within and between days in a temperate, shallow-water reef fish assemblage in south-western Australia. Three sites were sampled at morning, midday and afternoon for five consecutive days using baited remote underwater stereo–video systems. Significant differences were detected in the fish assemblage at different times of the day with morning and midday assemblages different from afternoon assemblages. Differences were detected between days with a significant shift in the assemblage after day two. The use of bait in this study was thought to influence the behaviour of *Pseudocaranx* spp. which furthermore influenced sampling of the entire fish assemblage between days. This study shows that large scale monitoring and sampling programmes using baited cameras need to consider the possible influence of within and between day variability in their experimental designs and must carefully design sampling to test for spatial and temporal structures in fish assemblages.

1. Introduction

1.1. Background topic

Tests of spatial patterns provide important insights into ecological processes structuring assemblages (Krebs, 2009; MacNally, 1995; Morin, 1999). For studies of fish, such tests are common in investigations of changes in biogeographic range (Langlois et al., in press; Meekan and Choat, 1997) and the effect of spatial management (Roberts and Polunin, 1991; Watson et al., 2007; Willis et al., 2003). Frequently, these tests of spatial patterns do not have temporal replication, and where they do, the scale of this replication is in the order of seasons or years (e.g. Hare and Mantua, 2000; Lazzari et al., 1999). Rarely are patterns tested at the scale of days, or time of day. To control for the influence of within day variability will require sites to be either sampled at the same time, and on the same day or for sampling to be randomised over multiple days and at multiple times of day, which for the majority of studies are not logistically possible. As a result, descriptions of spatial patterns are potentially confounded by within or between day variation, with differences between locations possibly due to temporal differences in sampling (Gray, 1996; Underwood, 1997; Willis et al., 2006).

Large scale temporal variation (decades, years and seasons) in the composition and abundance of fish assemblages has been attributed to the influence of linear, cyclical and stochastic trends in environmental and anthropogenic processes (Dayton et al., 1998). For example, variation in fish assemblages has been linked to cyclically varying environmental conditions such as the Pacific Decadal Oscillation (Hare and Mantua, 2000; Tourre et al., 2007), the El Nino Southern Oscillation (Lehodey et al., 2006) and ocean currents with their corresponding upwelling events (Agostini et al., 2008; Caputi et al., 1996; Lehodey et al., 2006). Linear warming trends in ocean temperatures due to climate change have been found to result in broad scale range shifts of fish species to greater depths and towards the poles (Dulvy et al., 2008; Perry et al., 2005). Overfishing has caused species targeted by fisheries to suffer severe, and possibly irreversible declines over the last few decades and may have changed the structure of marine food webs globally (Hutchings and Reynolds, 2004; Myers and Worm, 2003; Pauly et al., 1998, 2002). Fishing generally targets larger individuals and as a result, there has been a temporal decrease in average size and age of fished species combined with increases in population variability (Anderson et al., 2008a; Bianchi et al., 2000; Hsieh et al., 2006). In contrast to this, protection from

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fishing via marine reserves and closed fishery areas has been shown to result in recoveries in the abundance and size of targeted fishes within their boundaries (Jennings, 2001; Watson et al., 2007; Willis et al., 2003). Natural disturbances such as storms, coral bleaching and predator outbreaks are known to cause stochastic shifts in fish assemblages (Adjeroud et al., 2002; Garpe et al., 2006; Lassig, 1983). Spawning has been observed to affect the distribution and behaviour of fish seasonally, which can result in large differences in their population density across particular habitats and depths (Wakefield, 2010). To accurately estimate these large scale changes, it is important to understand the short term temporal variation in fish assemblages.

Much of the documentation on shorter term temporal variability is focused on the shifts between diurnal and nocturnal periods with regular and well defined crepuscular changeover periods in the behaviour, distribution and abundance of reef fish (Colton and Alevizon, 1981; Rooker and Dennis, 1991; Starck and Davis, 1966). However, variability within daylight hours (diurnal) or between days has been less studied despite the risk of this variability confounding sampling and the description of patterns (Colton and Alevizon, 1981; Rooker and Dennis, 1991; Santos et al., 2002; Spyker and Vandenberghe, 1995; Willis et al., 2006). The few studies that do consider diurnal and between day variation in the composition and abundance of fish assemblages have found the relative density of some fishes to be influenced by the time of day, but generally no difference between days (Colton and Alevizon, 1981; Rooker and Dennis, 1991; Santos et al., 2002; Spyker and Vandenberghe, 1995; Willis et al., 2006). In particular, Willis et al. (2006) found no diurnal differences in assemblage composition, but differences in the relative density of certain species. Diurnal variation has been attributed to behavioural adaptations including foraging (Ogden and Buckman, 1973), predator avoidance (Wolf, 1985) and spawning aggregations (Colin, 1978; Samoilys, 1997). The feeding times of fish have been documented to vary diurnally (Polunin and Klumpp, 1989) in particular for herbivorous species (see Table 1 in Zemke-White and Choat, 2002). Feeding by zooplanktivorous species has been observed to be associated with currents bringing higher densities of zooplankton at the incurrent end of the reef at different times of the day (Bray, 1981). Fish from deeper water have also been observed to forage on the reef flat to feed as the tide rises, then retreat to deeper waters as the tide falls (Johannes, 1981; Polunin and Klumpp, 1989; Thompson and Mapstone, 2002). Diurnal variation during the spawning season has been observed for the coral trout (*Plectropomus leopardus*), where it is spatially dispersed in the morning and aggregates in the early afternoon for spawning (Samoilys, 1997). Therefore, we would expect that studies of fish population density are more likely to be confounded by variation within daylight hours than any between day variability.

Non-destructive methods of sampling fish populations are increasingly being employed, particularly in studies of spatial management (Langlois et al., 2010). The majority of temporal studies have used underwater visual census methods (UVC, Rooker and Dennis, 1991; Thompson and Mapstone, 2002; Willis et al., 2006). In recent years baited remote underwater stereo–video systems (stereo-BRUVS) have been demonstrated to be a cost effective monitoring and sampling tool (Langlois et al., 2010; Watson et al., 2010) to describe spatial (Moore et al., 2009) and temporal changes in fish assemblages (McLean et al., 2010; Shortis et al., 2009; Watson et al., 2007, 2009). Stereo-BRUVS differ from UVC in that they are fixed in space and gather an 'average' measure of the fish assemblage at a particular location over a predetermined time period. Using stereo-BRUVS eliminates some of the bias caused by UVC and stationary fish counts such as the influence of a diver on fish behaviour (Dearden et al., 2010; Watson and Harvey, 2007; Watson et al., 2005), variation in diver swimming speed, failure to estimate fish length accurately and observer and interobserver variability (Harvey et al., 2001a, 2001b, 2002, 2004; Kulbicki, 1998). However, the stereo-BRUVS method introduces biases of its own such as conservative relative density measures and complexities in determining area sampled when using bait (Bailey and Priede, 2002; Cappo et al., 2001, 2003, 2004; Watson et al., 2005). Consequently, it is important to understand how the data collected by this particular sampling tool are influenced by short-term temporal variability.

This study used stereo-BRUVS to specifically investigate whether significant within (diurnal) and between day variability exist in the structure of typical shallow water temperate reef fish assemblage in southwestern Australia. We predicted that no differences would be detected in the composition of the fish assemblage within and between days, however, we expected that certain individual species would exhibit diurnal patterns in their relative density.

2. Methods

2.1. Study area

This study was conducted at Two Peoples Bay, approximately 30 km to the east of Albany in south-western Australia (Fig. 1). The reef habitats of Two Peoples Bay were dominated by a canopy of macroalgae (*Ecklonia radiata*, *Sargassum* spp.), occasional patches of hard coral, and an understory of smaller alga and invertebrates. Three reefs of similar depth (8–12 m) and substrate were selected as representative and replicate sites (Fig. 1). The sites were approximately 500 m apart which increased the likelihood of independence between sites, but were close enough to minimise travel between sites. This was important to ensure that sufficient replicates could be collected at each site within the time allocated. The separation distance was designed to reduce the overlap of bait plumes and the likelihood of fish moving between sites during the sampling period which was based on the estimated swimming speeds of common reef fish (Cappo et al., 2001, 2003).

2.2. Experimental design

The experimental design consisted of three factors. Time of day was fixed with three levels (0800–1000 h, 1130–1330 h and 1430–1630 h), Site was random with 3 levels (Sites 1, 2 and 3) and Day was fixed with

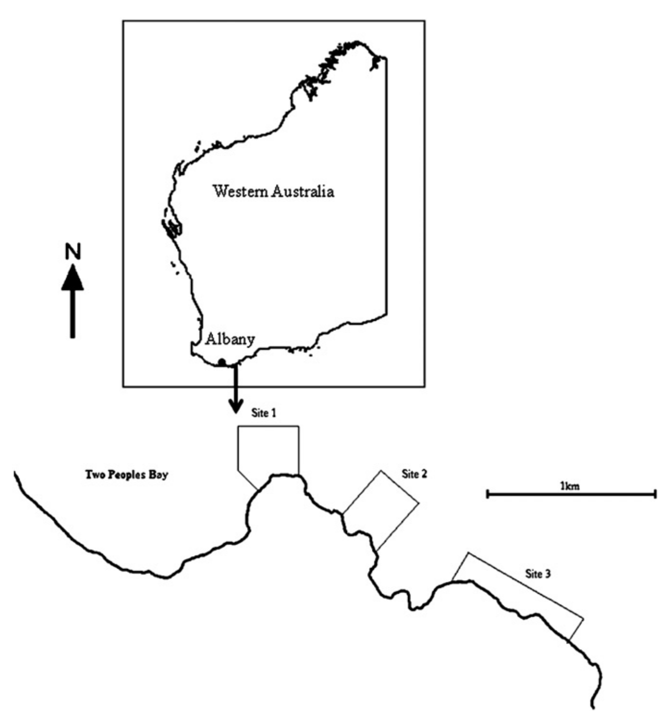

Fig. 1. Two Peoples Bay, Australia. The three study sites shaded in grey.