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Strong direct and inconsistent indirect effects of fishing found using stereo-video: Testing indicators from fisheries closures

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ABSTRACT

Candidate indicators of the direct and indirect effects of fishing can be developed by investigating fisheries closures. We tested a suite of such indicators in areas open to fishing but with suspected differences in effort, using baited remote underwater stereo-video methods. In particular, we predicted that greater fishing would result in decreased biomass of high risk target species and indirectly increase the biomass of small-bodied non-target species. As predicted, the biomass of target species was found to be greater in areas of lower fishing effort and in deeper waters. However, no indirect effects of fishing were detected and any community-level effects were driven by differences in the biomass of target species. In particular, assemblage length class analysis of covariance (ANCOVA), size spectra analysis and the abundance-biomass comparison (ABC) method did not provide any evidence of indirect effects of fishing. The magnitude of the differences in fishing effort between the two areas sampled, may be sufficient to significantly affect target fisheries species, but insufficient to lead to indirect effects on non-target populations. It is also possible that the predicted indirect effects do not occur in this assemblage, due to weak trophic linkages between species. Differences observed using the ABC method were attributed to variation in the abundance of large herbivorous fishes, which are not fished. We also found assemblage length class ANCOVA and size spectra to be insensitive to the direct effects of fishing where large numbers of non-target individuals are sampled along with fished species. We suggest diet studies and comparisons across stronger gradients in fishing pressure to further investigate the indirect effects of fishing in this assemblage.

1. Introduction

Reliable indicators of the community-level and indirect effects of fishing are thought to be essential to understand how the exploitation of species (direct effects) impact the marine ecosystem (Link et al., 2002). Hundreds of such quantitative indicators for ecosystem based fisheries management (EBFM) have been proposed (Rochet and Trenkel, 2003; Shin et al., 2005). These range in complexity from the abundance of single species and simple estimates of mean biomass of the assemblage (Nicholson and Jennings, 2004) to more complex estimates of mean trophic level (Pauly and Watson, 2005) and vulnerability (based on the life-history traits, Cheung et al., 2007). Indicators of indirect effects, are typically designed to measure any disproportionate increase in small-bodied non-target species (Rubolini et al., 2006), that may be prey or competitors of fished species. Methods that consider the relative distribution of size/biomass in the assemblage, should be sensitive to such indirect effects (Daan et al., 2005). These methods include indicators based on length information, generally found to be reliable for investigating the effects of fishing (assembalge length distribution and size spectra, Dulvy et al., 2004; Rice and Gislason, 1996; Rochet and Trenkel, 2003), and the abundance-biomass comparison method, which has not been found to be consistently reliable (ABC, Blanchard et al., 2004; Rogers et al., 1999; Yemane et al., 2005).

For indicators of indirect ecosystem effects, it can be difficult to demonstrate a causal link between the direct effects of fishing and the observed patterns (Murawski, 2000; Thrush and Dayton, 2010), which limits their use for developing operational objectives for EBFM. Comparisons of fished and closed areas can provide good

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opportunities to observe community-level and indirect effects of fishing, link the pattern to the process, and develop candidate indicators for EBFM (Langlois and Ballantine, 2005). The current study aims to test the sensitivity of indicators, developed from studies of fisheries closures, to detect direct, community-level and indirect effects of fishing in a defined region open to fishing but with a gradient of decreasing pressure with increasing distance from a metropolitan centre.

In sub-tropical southwestern Australia community-level and indirect effects of fishing have been demonstrated by comparing fish assemblages inside and outside Reef Observation Areas around the Houtman-Abrolhos Islands (Watson et al., 2009). Within these areas only the extraction of spiny lobster is allowed, whilst outside these areas the region is subjected to significant fishing pressure from both commercial and recreational fishers (Nardi et al., 2004). This manipulation of fishing pressure has resulted in a greater abundance and biomass of target fisheries species within the Reef Observation Areas. High risk demersal fishery species, such as coral trout *Plectropomus leopardus* and baldchin groper *Choerodon rubescens* are 2–3 times more abundant inside the Reef Observation Areas compared to areas open to all fishing, as observed by studies using baited remote underwater stereo-video systems (stereo-BRUVS, Watson et al., 2009). In contrast, outside the fisheries closures there is a greater abundance and biomass of smaller bodied non-target species such as the western king wrasse *Coris auricularis* and the damsel fish *Pomacentrus milleri*. These differences are reflected as significant effects in multivariate analyses, which are attributed to differences in both the target species and an increase dominance of small bodied non-target species (Watson et al., 2009). Both the small bodied non-target species identified are common dietary items for *P. leopardus* (St John, 1999), leading to the model that greater biomass of these prey species in fished areas is indirectly related to fishing pressure in the region. The current study tests these indicators of direct, community-level and indirect effects, demonstrated inside and outside Reef Observation Areas around the Houtman-Abrolhos Islands, by using the same stereo-BRUVS sampling method in a region with contrasting levels of fishing pressure.

The waters adjacent to the Perth metropolitan region (out to 250 m deep), have a history of selective commercial wetline and gillnet fisheries (Marriott et al., 2011). The high risk demersal fisheries species in the region are currently assessed as overfished (Wise et al., 2007), and it has been recommend that catches should be reduced by 50% (Lenanton et al., 2009), in particular for the two most targeted high risk demersal species (West Australian dhufish *Glaucosoma herbraicum* and snapper *Pagrus auratus*). Commercial fisheries data has been collected at a scale that does not allow the separation of particular areas within the Perth metropolitan region. However, Sumner et al. (2008) observed a gradient in activity of recreational fishers, with a greater number of fishing trips in the central and southern areas of the Perth metropolitan region, compared to the more northern areas further from the main centres of human population. This is reflected in the distribution of recreational vessel registrations across postcodes within the region (Fig. 1, Nicole Neild, Pers. Comm.). Sumner et al. (2008) also observed a greater frequency of recreational fishing activity within the shallow and nearshore areas than in the deeper offshore waters of the region. This observed gradient provides a framework with which the direct and indirect effects of fishing can be investigated (after Thrush and Dayton, 2010). This study will first establish whether the biomass of high risk demersal fisheries species is greater in areas observed to have lower fishing pressure (direct effects), and then use such differences to test candidate indicators of community-level and indirect effects.

Studies of fish assemblages across depth gradients, concomitant with the effects of fishing, have found evidence of increased fishing pressure in shallow waters (Goetze et al., 2011; Polunin and Roberts, 1993). In western Australia particular habitat and depth associations are know for certain fisheries species; with the breaksea cod *Epinephelides armatus* thought to be typically found in waters less than 40 m deep (Platell et al., 2010) whilst adult *G. hebraicum* can be found down to 100 m (Hesp et al., 2002). Depth associations of particular species may therefore confound any comparison between areas of different fishing pressure (see Goetze et al., 2011). Modern recreational angling studies have found that high risk demersal fisheries species are typically rare in shallow near shore areas (Smallwood et al., 2006) and more common in deeper offshore waters (Sumner et al., 2008). This contrasts with historical accounts that describe these species as common in shallow near shore areas in the central Perth metropolitan region (Watson, 1998). We suggest a refuge from fishing pressure may now occur in the study region, in deeper offshore waters. Any depth refuge effect for these fished species may then result in depth related patterns in indicators of indirect effects of fishing, but should be viewed with caution given the known depth associations of particular species which could confound these interpretations.

The current study is the first to explicitly test candidate indicators of the community-level and indirect effects of fishing, using data collected with a stereo-video based fisheries independent survey method. All previous studies of such indicators for EBFM in waters greater than 30 m, have used fisheries independent methods adapted from fishing techniques (e.g. trawl or seine nets with a fine mesh, Jennings, 2005; Nicholson and Jennings, 2004; Trenkel and Rochet, 2003). Video based sampling methods are increasingly used in ecological studies, as advances in video definition and photometric software improve our ability to identify species and accurately measure the size of individuals (Harvey et al., 2010). Baited remote underwater stereo-video systems (stereo-BRUVS) are ideal for assessing changes in the composition of fish assemblage, as they have been found to sample a range of feeding guilds, including carnivorous, herbivorous and planktivorous fishes but are not limited by depth (Watson et al., 2005). This method can provide accurate estimates of the size–structure and spatial variability of fished populations, that are comparable with experimental fishing (Willis et al., 2000). Length data can provide useful information on the effects of fishing (Rochet and Trenkel, 2003) and can also be used to estimate biomass using established length-weight relationships. Using assemblage composition, abundance, length and biomass estimates provided by such methods, a range of indicators for community-level and indirect effects of fishing can be calculated.

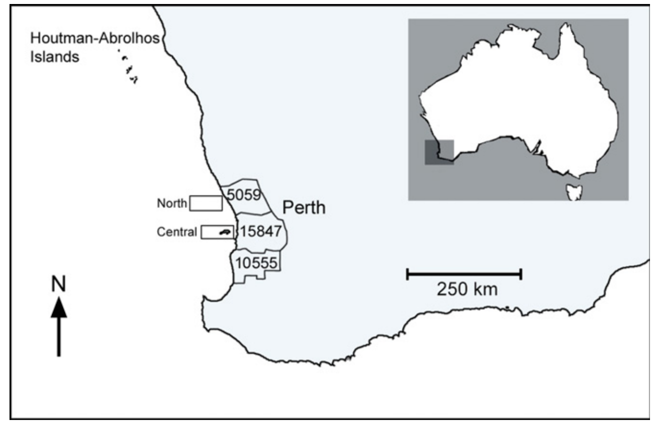

Fig. 1. Map of Western Australia, showing the sampling areas in the North and Central areas of the Perth metropolitan area and the corresponding numbers of recreation vessel registrations between July 2006 and June 2007 based on postcode boundaries (Nicole Neild, Pers. Comm.). Postcode boundaries have been smoothed for presentation.