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Assessing pelagic fish populations: The application of demersal video techniques to the mid-water environment

Tom B. Letessier[a,*], Jessica J. Meeuwig[b], Matthew Gollock[c], Lloyd Groves[a], Phil J. Bouchet[d], Lucille Chapuis[e], Gabriel M.S. Vianna[b], Kirsty Kemp[c], Heather J. Koldewey[c]

[a] *Centre for Marine Futures, Oceans Institute, The University of Western Australia (M470), 35 Stirling Highway, Crawley WA 6009, Australia*

[b] *Centre for Marine Futures, Oceans Institute, and School of Animal Biology, The University of Western Australia (M470), 35 Stirling Highway, Crawley WA 6009, Australia*

[c] *Zoological Society of London, Regent's Park, London, UK*

[d] *Centre for Marine Futures, Oceans Institute (M470) and School of Animal Biology, The University of Western Australia (M470), 35 Stirling Highway, Crawley WA 6009, Australia*

[e] *Oceans Institute and School of Animal Biology, The University of Western Australia (M317), 35 Stirling Highway, Crawley WA 6009, Australia*

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ABSTRACT

In the open ocean, the movements and habitat use of large mobile predators are driven by dynamic interactions between biological and physical variables and complex predator–prey relationships. Understanding the spatial and temporal distributions of pelagic fishes and sharks is a critical component of conservation and fisheries management. Here, we report on a novel non-extractive method for the study of pelagic wildlife, based on baited stereo-camera rigs. The mid-water rigs were derived from existing methodology commonly used in demersal fish surveys. We present new data from 66 moored deployments in Shark Bay, Western Australia (26°10′S, 113°06E) in seabed depths of up to 60 m as a demonstration of the rigs' ability to resolve spatial variability in pelagic fish and shark assemblages, and to make accurate stereo-measurements of animal lengths. We observed 248 pelagic

* Corresponding author. Tel.: +61 420668617.

E-mail addresses: tom.letessier@uwa.edu.au (T.B. Letessier), jessica.meeuwig@uwa.edu.au (J.J. Meeuwig), Matthew.Gollock@zsl.org (M. Gollock), lloyd.groves@uwa.edu.au (L. Groves), phil.bouchet@uwa.edu.au (P.J. Bouchet), lucille.chapuis@grs.uwa.edu.au (L. Chapuis), gabe.vianna@aim.gov.au (G.M.S. Vianna), Kirsty.Kemp@ioz.ac.uk (K. Kemp), Heather.Koldewey@zsl.org (H.J. Koldewey).

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fishes and sharks from 27 species and 10 families and were able to distinguish between assemblages based nominally on location. We make some general recommendations on optimal deployment protocols and sampling effort regimes, based upon species accumulation rates and times of Max *N* (maximum number of individuals of a given species in a single video frame). Regression analyses between high quality and low quality stereo-measurements of fish fork-lengths and range were highly significant, indicating that body lengths and distance estimates were consistent even when stereo-measurements were deemed of low quality. Mid-water stereo-video camera rigs represent an efficient tool for the rapid and non-extractive monitoring of pelagic fish and shark populations, with particular relevance for application in no-take marine protected areas.

1. Introduction

Following the overexploitation of a number of coastal fish species in the 20th century (Jackson et al., 2001), many populations of now threatened pelagic fish and sharks have collapsed (Dulvy et al., 2008; Myers and Worm, 2003; Clarke et al., 2006; Collette et al., 2011). Declines in pelagic fish and shark numbers (henceforth referred to as 'pelagics') have been a source of debate, in part because of difficulties in managing high-seas fisheries (Sumaila et al., 2007; Cullis-Suzuki and Pauly, 2010), but also because the lack of fishery independent time series data impairs the assessment and quantification of long-term trends in abundance (Myers and Worm, 2003; MacKenzie et al., 2009; Polacheck, 2006; Sibert et al., 2006; Hampton et al., 2005). Commercial catch statistics have several limitations (Schnute and Richards, 2001), such as temporally and spatially uneven sampling effort, discrepancies in gear efficiency, and imprecise reporting. Further challenges associated with the robust sampling of pelagics relate to the animals' low overall densities (Ramirez-Llodra et al., 2010), their temporally and spatially heterogeneous distributions (Graves, 1996), and complex associations with seabed topography (Worm et al., 2003; Morato et al., 2010).

Scientific tagging efforts have provided a wealth of knowledge on the movements of large marine predators, allowing the investigation of habitat use by a variety of species over both meso- (Brill et al., 1999) and ocean-wide scales (Block et al., 2011, 2005). However, such studies are invasive, and can be expensive (e.g. satellite tags may cost up to US$5000 each), and logistically challenging, particularly with regards to animal handling. Active acoustic biomass assessments are becoming widespread in fishery-related surveys (MacLennan, 1992) as they can provide information on the abundance and biomass of pelagic assemblages. These techniques have particular vessel requirements such as low noise outputs (Fernandes et al., 2000), and they do not typically provide accurate information on species composition, particularly when diversity is high. Moreover, the low densities of popular commercial species typically encountered in open waters (for example 1.3 yellowfin tuna per km^2, Bertrand and Josse, 2000) means that acoustic surveys of pelagics are often conducted around fish aggregation devices (FADs, Doray et al., 2009; Josse et al., 1999; Moreno et al., 2007), which are themselves subject to high temporal variability (Doray et al., 2009). As FADs act as 'ecological traps' by aggregating pelagics (Girard et al., 2004), populations may appear stable due to continuous replenishment from neighbouring waters ('hyperstability') (Hilborn and Walters, 1992) and the large catchment area (10 km diameter, see Dagorn et al. (2010)) inherent to FADs may be inappropriate for detecting local trends in animal abundance.

Large marine protected areas (>10,000 km; MPAs), where fishing activities are restricted to varying degrees, offer broad protection for marine biodiversity and are increasingly being advocated as refuges for pelagics (Sumaila et al., 2007; Koldewey et al., 2010; Game et al., 2009). Consequently, there is a need for effective and non-invasive monitoring of pelagics such that the benefits of MPAs with respect to population recovery or maintenance (in the case of healthy populations) can be

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