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Review

Underwater video techniques for observing coastal marine biodiversity: A review of sixty years of publications (1952–2012)

Delphine Mallet[a,b,*], Dominique Pelletier[a]

[a] IFREMER, Unité de Recherche Lagons, Ecosystèmes et Aquaculture Durable en Nouvelle Calédonie (LEAD-NC), Nouméa, New Caledonia
[b] EA 4243 LIVE, Université de la Nouvelle-Calédonie, Nouméa, New Caledonia

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ABSTRACT

Underwater video techniques are increasingly used in marine ecology studies. Technological progress regarding video cameras, sensors (such as sounders), battery life and information storage make these techniques now accessible to a majority of users. However, diver-based underwater visual censuses, and catch and effort data, remain the most commonly used for observing coastal biodiversity and species. In this paper, we review the underwater video techniques that have been developed since the 1950s to investigate and/or monitor coastal biodiversity. Techniques such as remote underwater video, whether baited or not, diver-operated video and towed video are described, along with corresponding applications in the field. We then analyse the complementary of techniques, first from studies comparing video techniques with other observation techniques, whether video-based or not, and second by documenting their respective cost efficiencies. These findings are discussed with respect to current challenges in monitoring and investigating coastal biodiversity. Video should be more often considered and used, either in addition to or as an alternative to diver-based, fishing and acoustic techniques, as it may be particularly suited for monitoring coastal biodiversity in a variety of areas and on larger scales than hitherto and within an ecosystem-based approach to management and conservation.

Contents

* Corresponding author at: IFREMER, Unité de Recherche Lagons, Ecosystèmes et Aquaculture Durable en Nouvelle Calédonie (LEAD-NC), BP 2059, 98846 Nouméa Cedex, New Caledonia. Tel.: +687 285 171; fax: +687 287 857.
E-mail addresses: delphine.mallet@yahoo.fr, Delphine.Mallet@ifremer.fr (D. Mallet).

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1. Introduction

The conservation of marine and coastal biodiversity and associated ecosystem services through ecosystem-based management (Christensen et al., 1996) requires appraising a wide array of biodiversity components on large spatial scales. Biodiversity here encompasses mostly fish and macroinvertebrate species, whether or not exploited, and corresponding assemblages and habitats. Biodiversity is rarely observed and assessed on such scales due to observation costs. The main techniques used to study and monitor biodiversity are either extractive (e.g. fishing, dredging), based on acoustics, or based on Underwater Visual Censuses (UVC).

Extractive techniques have been used mostly for fish, macrobenthic organisms and endogenous fauna, primarily for the assessment of fished populations. Fishing-based surveys (see e.g. Petitgas et al., 2009) focus on catchable species, whether or not exploited. The potential of catch-based surveys for an ecosystem approach to fisheries management has been addressed by Trenkel and Cotter (2009) and Jouffre et al. (2010), among others. Catch-based monitoring provides information about catchable species, but not on other species, nor on habitat. Catchability may vary across species and as a function of weather conditions (Trenkel and Cotter, 2009) and vessels (Pelletier, 1991). Sampling effort by fisheries is considerable, but data interpretation may be tricky due to the uncontrolled sampling design. Scientific catch surveys circumvent this problem, but provide small sample sizes compared to fisheries catch (Trenkel and Cotter, 2009). In addition, extractive techniques have an impact on biodiversity, which may not be desirable in the context of monitoring conservation strategies. Rotenone sampling is similar to fishing, in that it is extractive, focuses on fish species, and selects only part of the fish assemblage (Robertson and Smith-Vaniz, 2008). It is thus used more for inventories and small-scale observations than for monitoring. Underwater acoustics is currently effective for pelagic and semi-demersal species, and for zooplankton (Trenkel et al., 2011). However, species present in the acoustic data have to be identified through complementary techniques, and benthic species are not well-observed. For instance, Jones et al. (2012) combined acoustics and video to estimate rockfish biomass in untrawlable areas.

In shallow areas, UVC techniques have been used for over sixty years to monitor fish, macrobenthic organisms and habitats (Brock, 1954). They are considered to be reliable and cost effective (Thresher and Gunn, 1986). Advantages and disadvantages of UVC for estimating fish abundance and diversity have been reported and discussed in several papers (Chapman et al., 1974; Sale, 1980; Brock, 1982; Harmelin-Vivien et al., 1985; Watson et al., 1995; Thompson and Mapstone, 1997; Willis, 2001; Kulbicki et al., 2010; Dickens et al., 2011). The main limitation of UVC lies in the need for divers' presence underwater, which influences the observation of vagile macrofauna, restricts the number of observations that can be carried out, and constrains depth observation.

In recent years, underwater video techniques have been increasingly used for observing macrofauna and habitat in marine ecosystems (see e.g. Sarradin et al., 2007 for a review concerning deep ecosystems). Technological progress regarding video cameras, sensors (such as sounders), battery life and information storage now make these techniques accessible to the majority of users. The term "underwater video" encompasses an array of techniques developed around the world, and used in a variety of contexts and for different purposes. Murphy and Jenkins (2010) reviewed the observation methods used for spatial monitoring of fish and associated habitats. They summarized the applications, advantages and shortcomings of all methods used, including UVC, remote sensing, acoustics, experimental catch and effort data, and underwater video. Because of this broad scope, the paper did not document the various video techniques and their applications. To our knowledge, there are no published papers describing underwater video techniques and their applications, and discussing their respective relevance for observing shallow water marine biodiversity. Yet many papers have been published using video techniques in this context, and video-based techniques have considerably evolved over time. The present review focuses on the video techniques developed and used for this purpose, from the first published papers through to 2012. Section 2 describes the main techniques, along with technological issues. Applications of each technique are summarized in section 3. In section 4, studies comparing video techniques with other observation techniques are listed, and their conclusions are summarized. The last section discusses the potential of video techniques for monitoring and investigating biodiversity issues in coastal environments, in order to provide guidance in choosing among techniques.

2. State of the art regarding underwater video techniques

Literature searches were conducted using the ISIS Web of Knowledge^{SM} and Google Scholar for relevant keywords, including "underwater video", "underwater television", "remote underwater video", "baited video", "BRUV", "towed video", "video transect" and "stereo-video". In addition to database searches, we also hand-checked the reference lists of all studies retrieved to identify all relevant primary research published in peer-reviewed journals, books and proceedings of international conferences. Thus a substantial amount of grey literature was not taken into account in this review.

We restricted the literature search to environments shallower than 100 m. At greater depths, observations are more constrained by technological issues, scuba diving is not routinely feasible, and artificial light is needed. Papers pertaining to freshwater ecosystems were not included in the review either. Studies using photography, photogrammetry, underwater video for evaluating fishing gear catchability or acoustic techniques, and video tracking (Delcourt et al., 2012) fell outside the scope of the paper. The search resulted in a list of 182 peer-reviewed papers, taking into account the majority of peer-reviewed papers within the scope of the present review. As video systems are increasingly used around the world, the number of published studies has greatly increased over the last decade (67% of the papers were published from 2002 onwards). Papers were sorted according to four main techniques: