Fisheries Research
June 2014, Volume 154, Pages 44–62
http://dx.doi.org/10.1016/j.fishres.2014.01.019

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

*: Corresponding author : Delphine Mallet, email addresses : delphine.mallet@yahoo.fr ; Delphine.Mallet@ifremer.fr

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.

Highlights

► Underwater video is increasingly used in marine ecology. ► Video is less used than catch and underwater visual census. ► Video techniques comprise baited, unbaited, towed and diver-operated techniques. ► Video is a cost-efficient complement or alternative to other observation techniques.

Keywords: Underwater video ; Monitoring ; Coastal biodiversity ; Fish ; Habitat

Table of contents

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: remote underwater video, baited remote underwater video, towed video and diver-operated video. Note that the term “remote” is used here to designate a technique which does not require human presence underwater, while the term “autonomous” indicates a system that is not linked to a vessel or a platform. Baited Remote Underwater Video will be denoted BRUV following most studies using this technique, while unbaited Remote Underwater Video will be simply termed RUV for the sake of concision. RUV thus includes here all remote video systems that are not baited, whether dropped from the boat or set by divers. Note that trademarks on “BRUVS” and “RUVS” of the Australian Institute of Marine Science were not used as they are too specific and do not encompass all the techniques discussed in this review.

2.1. Remote Underwater Video (RUV)

The first published work reporting the use of underwater video systems in the coastal environment dates back to the 1950s.The Scottish Marine Biological Association of Millport developed an underwater video program in 1948, and tested it in the Aquarium of the Zoological Society of London in 1949 (Barnes, 1952, 1953). In 1951, the Royal Navy constructed a system which was successfully used to identify a Royal Navy submarine lost at sea in 1951. It then served for other projects on bottom fauna (Barnes, 1955) as suspended in a mid-water environment (Backus and Barnes, 1957) and for other Navy applications (Barnes, 1963). RUV has used more frequently in marine sciences since the 1960s (Table 1). It provided the first data on fish movement and behaviour in daytime and at night, which had not been previously studied without human disturbance (Barnes, 1952; Kumpf and Lowenstein, 1962; Booda, 1966; LaFond, 1968). RUV systems exhibit different designs and technical features, including additional sensors, and can be distinguished in terms of their autonomy (linked or autonomous).

Linked systems

The system developed by LaFond et al. (1961) filmed from the surface to the bottom (20 m depth) while moving up and down a vertical-rail track placed under a platform (Table 1). It was used to study diurnal and nocturnal fish movements along with plankton dispersion (see section 3). Over the same period of time, an experimental RUV equipped with hydrophones and lights for night vision (AC-RUV, "AC" for acoustic) was developed by Kumpf and Lowenstein (1962) and Kronengold et al. (1964). The system was permanently set on sea bottom in the Bahamas (Steinberg and Koczy, 1964), in order to (i) identify the sounds present in a supposedly silent environment; (ii) learn about wildlife behavioural response to sound disturbance; (iii) describe the temporal patterns of sounds, and (iv) evaluate the advantages and limitations of systems coupling video and acoustics. Initial problems resulting from a large system size and from fouling on the camera housing led to an improved smaller AC-RUV system (Holt, 1967; Stevenson, 1967; Table 1).

More recently, Stokesbury et al. (2004) developed a vertical RUV system (Table 1) to study scallop distribution off the northeastern coast of the United States. Tyne et al. (2010) used the same system to record benthic habitats in Western Australia. The camera filmed a 1 m^2 bottom quadrat area at depths ranging between 2 and 16 m. Recorded images were automatically analysed by a computer, providing estimates of the percent seagrass cover, and the type and abundance of sponges within the quadrat.

The latest linked systems are permanent observatories using cables for energy supply, data transfer and instrument control (Aguzzi et al., 2012). In an area south of Taiwan, Jan et al. (2007) placed a system linked to an internet video server, making the videos viewable in real time on the World Wide Web. In the western Mediterranean, Aguzzi et al. (2011) set the OBSEA system at 20 m depth to monitor fish assemblages (Table 1).

Autonomous systems

Fedra and Machan (1979) used the first autonomous RUV in the North Adriatic Sea (Mediterranean) (Table 1). The system was set on the seabed by a diver and then left for a week, in order to study the behaviour and distribution of benthic and demersal species, their feeding activities and movement patterns, along with species interactions and the influence of environmental conditions (see section 3). Chabanet et al. (2012) recently introduced a similar system to investigate the temporal variability of undisturbed fish populations over a twenty day time period. Dunbrack and Zielinski (2003) devised a system with a camera mounted on a tripod. It was placed at the edge of the reef slope to film down the reef and study the ecology, behaviour and population status of the bluntnose sixgill shark (*Hexanchus griseus*) in the Georgia Strait, British Columbia (see also Dunbrack, 2006, 2008).

The rotating RUV system (ROT-RUV: "ROT" for rotation, termed "STAVIRO" by the authors) of Pelletier et al. (2012) (Table 1) is fixed on a tripod, dropped from the boat onto the seabed, and retrieved using buoys and rigging. It has been used in the New Caledonian lagoon (South Pacific) since 2007 and in the Western Mediterranean since 2010 to study and monitor the spatio-temporal distribution of marine macrofauna and habitat (Pelletier et al., 2012; D. Mallet, M. Bouchoucha, D. Pelletier, unpublished data). Unlike other RUV systems, the 360° view afforded by rotation provides panoramic images and a much larger surveyed area than fixed systems, while avoiding the image distortion characteristic of fisheye lenses. Potential double counting is minimized by paying particular attention to the direction of fish movement with respect to rotation, and by calculating the mean abundance over rotations, to average out the variability between rotations (Pelletier et al., 2012).

Most of the above techniques were implemented with the help of divers, except for Stokesbury et al. (2004), Tyne et al. (2010) and Pelletier et al. (2012). Only four RUV techniques identified in this review did not use artificial light (Stevenson, 1967; Petrell et al., 1997; Dunbrack and Zielinski, 2003; Pelletier et al., 2012).

Video systems remaining underwater for several days inevitably face the problem of fouling, i.e. the accumulation of organisms, impairing the quality of images. Yet in the literature examined, this problem was raised and addressed only by Stevenson (1967) and Chabanet et al. (2012), who used automatic windshield wipers to clean the lens surface regularly.

2.2. Baited Remote Underwater Video (BRUV)

A BRUV system uses either a single camera or two cameras (see subsection 2.5) filming the area surrounding a bait used to attract fish. The bait bag is placed close to the camera, at a distance ranging between 0.5 m and 1.5 m (Ellis and DeMartini, 1995; Willis and Babcock, 2000; Heagney et al., 2007). The species attracted and the bait range of action depend on the bait used (Harvey et al., 2007; Stobart et al., 2007; Wraith, 2007). Pilchards (*Sardinops sp.*) are currently used in most studies (McLean et al., 2010, 2011; Watson et al., 2010; Bassett and Montgomery, 2011; Göetze et al., 2011; Harvey et al., 2012a; Langlois et al., 2012a, 2012b). BRUV systems are directly deployed from the boat (Watson et al., 2005, Cappo et al., 2007a, Bassett and Montgomery, 2011). Willis and Babcock (2000) and Watson et al. (2005) showed that a soak time of 25 to 40 minutes underwater was required to obtain representative observations for the majority of fish species, but they recommended a duration of 50 to 60 minutes for observing most target fish species in the census. The main differences among BRUV systems concern the orientation of the system in relation to the sea bottom (horizontal or vertical, Table 2), which result in distinct observed abundances and species compositions (Langlois et al., 2006; Wraith, 2007). BRUV has also been used with infrared light to study nocturnal fish; for example Bassett and Montgomery (2011) studied the olfactory capabilities of nocturnal fish species and their influence on response to bait using this system.

Horizontally oriented BRUV

Horizontal BRUV (H-BRUV) (Ellis and DeMartini, 1995) provides a wide viewing angle for observing the area surrounding the bait. An array of species can be observed, in particular those not approaching the bait bag because of fish behaviour or competition for the bait (Cappo et al., 2004; Harvey et al., 2007). H-BRUV systems have been mainly used to study spatio-temporal variations in reef fish assemblages, the influence of depth and location upon fish and species distribution, and the effect of MPAs on biodiversity (Cappo et al., 2007b and section 3). H-BRUVs are generally set on the seafloor, though Heagney et al. (2007) used mid-water BRUV to study pelagic fish.

Vertically oriented BRUV

Vertical BRUV (V-BRUV) has been used for studying the size and abundance of carnivorous fish (Babcock et al., 1999; Willis and Babcock, 2000) and the effect of protection by MPAs (Willis et al., 2000, 2003; Denny and Babcock, 2004; Denny et al., 2004; Willis and Millar, 2005). The restricted field of vision due to the camera pointing downwards ensures a constant field of view and a constant focal length, particularly where water clarity or topography varies between observations (T. Willis, personal communication). Langlois et al. (2006) suggested that some species would rarely approach the system when the camera was positioned above the bait. Other authors suggested that recent V-BRUV does not affect blue cod and various other species (T. Willis, personal communication). Lightweight stands have been shown to provide precise relative density estimates of carnivorous fishes (Willis et al., 2000).

2.3. TOWed Video (TOWV)

Machan and Fedra (1975) introduced the first TOWed Video technique (TOWV) in shallow waters. The system was towed by a vessel at low speed (0.1 to 1 m s^{-1}). TOWV films along a transect of predefined size and trajectory (30 m to 20 km). The various systems developed (Table 3) were linked to the vessel by a coaxial cable and a rope. The main difference among them lies in the position at which the system operates in the water column, i.e. seabed or mid-water.

Seabed TOWV

In the coastal domain, the first TOWV systems were towed on the seabed using a sledge (seabed-TOWV, Table 3). These were used in the Mediterranean Sea (Machan and Fedra, 1975), in South-West England (Holme and Barrett, 1977) and in Alaska (Spencer et al., 2005, and Rooper and Zimmermann, 2007). The video camera is slightly angled downwards on the sledge, which carries additional equipment (Table 3). Seabed-TOWVs have been used to study sea floor and epifaunal species (mostly crustaceans and flat fish) (see section

3). It should be noted that in shallow waters such as lagoon areas, vagile species were found to be sensitive to the boat noise (D. Pelletier and G. Hervé, unpublished data).

Mid-water-TOWV

Mid-water-TOWV systems are more recent than seabed-TOWVs in shallow waters (Norris et al., 1997). These systems are towed at a constant elevation in the water column, thus providing a wider view of the seafloor compared to seabed-TOWVs. The system of Riegl et al. (2001) is set on each side of the boat with vertical tubes that can be lowered or raised between 0.5 and 3.5 m below the sea surface, so as to adjust to varying depth (Table 3). Most mid-water-TOWVs are equipped with a depth sounder (Hayashizaki and Ogawa, 2006; see also Schaner et al., 2009, for a freshwater application). They have mostly been used to characterize, quantify and assess changes in benthic flora (seagrass, macro-algae and coral) and fauna.

2.4. Diver-Operated Video (DOV)

The diver-operated video technique (DOV) consists of a diver holding a video system and filming a defined area. Similarly to UVC, the observation area may vary in size (transects from 2 to 500 m, Table 4) and shape (along a predefined line, inside a quadrat, or rotating around a fixed point). The diver is sometimes towed (Carleton and Done, 1995; Vogt et al., 1997; Kenyon et al., 2006), recalling the “Manta tow” technique, where a towed snorkeler implements a transect (Fernandes, 1990). Towed DOV has been used to record benthic habitat along long transects (up to 500 m long).

The DOV technique (Alevizon and Brooks, 1975) involves a diver filming vertically along a transect line. DOV is generally conducted at a constant swimming speed over the entire transect (0.1 to 3 m s^{-1}, Table 4). Elevation above the seafloor ranges from 0.15 to 0.5 m (parameter documented in 16 papers out of 22). But in some cases, transects are conducted at a larger elevation (1 to 3 m) to ensure a wider viewing angle (Table 4). A reference bar attached to the camera housing is sometimes used to control the camera elevation (Leonard and Clark, 1993; Vogt et al., 1997; Rogers and Miller, 2001; Lam et al., 2006; Cruz et al., 2008).

Pelletier et al. (2011) presented the browsing video transect technique, where the diver browses inside the strip transect area, at varying elevation, speed and angle, and zooming when needed. This technique mimics the behaviour of UVC divers in strip transects. These authors demonstrated that more individuals and species were recorded from browsing transects than from straight ones conducted at a constant elevation.

Bortone et al. (1991, 1994) proposed a protocol where the diver simultaneously rotates and records images, mimicking the UVC stationary point count technique (Bohnsack and Bannerot, 1986). DOV was also used to study fish behaviour by Krohn and Boisclair (1994) (energy expenditure of swimming fish) and Hall and Hanlon (2002) (observation of particular individuals for up to 1.5 h).

2.5. Stereo-video technique

The stereo-video technique is not additional to those described above, but it involves a particular recording that produces a 3-dimensional (3D) image. It was developed by Harvey and Shortis (1995) to improve fish size estimation by divers. The technique simultaneously uses two cameras to record the same scene. Left and right images are synchronized on the computer based on a light-emitting diode (LED) placed at 2.5 m from the cameras and seen on both images. Images are then cross-checked from ad hoc software to obtain a 3D image allowing individual size measurement. A 1.4 m distance between the two cameras was found to provide a trade-off between the precision afforded by a greater distance and diver's ability to manoeuvre the system (Harvey and Shortis, 1995). This system recorded and measured individuals in a distance range of 2 to 10 m, depending on underwater visibility. Length measurements were found to be more accurate and repeatable when the orientation of the subjects to the stereo-cameras was less than 50° (Harvey and Shortis, 1995, 1998). Stereo-video has been shown to provide more accurate estimates of both fish length and distance than visual estimation by divers (Harvey et al., 2001a, 2001b, 2002a, 2004) or single video

(Harvey et al., 2002b). As such, it also helps distinguishing individuals (Harvey et al., 2003, 2007).

The stereo system has been adapted to all underwater video techniques (RUV and BRUV, TOWV, and DOV), but it has been mostly implemented on H-BRUV systems (Watson et al., 2007, 2009; Chatfield.et al., 2010; McLean et al., 2010, 2011; Göetze et al., 2011; Birt et al., 2012; Dorman et al., 2012; Fitzpatrick et al., 2012; Harvey et al., 2012a, 2012b, 2012c; Langlois et al., 2012a, 2012b). Several comparisons of underwater observation techniques used stereo-video (Watson et al., 2005, 2010; Langlois et al., 2010). Shortis et al. (2009) provide a detailed review of the status of underwater stereo-video measurement and marine and ecology applications. With the same objective of measuring fish, Heppell et al. (2012) used two lasers fixed on each side of a single camera, rather than stereo-video.

2.6. Technological progress

The first video systems used (Barnes, 1952, 1953, 1955; Backus and Barnes, 1957, Myrberg et al., 1969, 1973) suffered from (i) difficulties in setting and retrieving systems; (ii) malfunctioning of electronically driven systems; and (iii) the limitations of video sensors which severely impaired image quality.

Various systems have been developed and used over time (Figure 1). The emergence and evolution of such systems was primarily driven by technological progress, enabling considerable improvements in performance, while making these tools more robust, smaller and cheaper. The digital revolution led to increased sensor resolution, with a dramatically improved image quality, in particular with the advent of High Definition (HD). Regarding energy supply, batteries have become smaller and more powerful. Data storage devices now make it possible to record and archive more images, since camera internal memory or Secure Digital (SD) cards can now store up to 120 Gigabytes (GB), while the capacity of standard external hard drives is 1 or 2 Terabyte (TB). The increasing volume of observation files is therefore matched by a corresponding increase in information storage capacities.

3. Underwater video: Where is it used and what is it used for?

Video systems are increasingly used around the world, particularly over the last decade (Figure 1). Nevertheless, there are not many teams using these techniques. Numerous studies have been published in Australia (63 papers from 1995 to 2012), the USA (24 papers from 1957 to 2012) and New Zealand (24 papers from 1995 to 2011), and in comparison, relatively few papers from other countries (Figure 2 and Supplementary Material A). The first publications on RUV systems originated in Europe (United Kingdom in 1952) and North America (USA in 1957), and then extended to all continents (Oceania in 1995, Asia in 1997 and Africa in 2008). Twenty papers were published from the Bahamas AC-RUV between 1962 and 1973. BRUV has mainly been used in Australia since 2003 (32 of the 52 BRUV-based papers), and in New Zealand since 1999 (11 papers). In Australia only H-BRUV has been used, whereas in New Zealand V-BRUV has mostly been used (9 of the 11 BRUV-based papers). Studies involving TOWV and DOV are both more widespread and less numerous, with respectively 23 and 28 papers published since 1975. Note that the grey literature and studies outside the scope of this review (deep environment and freshwater) contain a large amount of work which has not been cited here (including some of the authors' work).

The techniques described in the previous section have been used for a variety of purposes in the context of coastal biodiversity. Applications were classified according to five main subjects (Table 5) to provide an overview. Studies of animal behaviour and activity are a major field of application (52 references published between 1952 and 2012). Six papers used video to investigate the effect of human-induced disturbances upon species behaviour. Forty-eight papers investigate spatial and temporal patterns of fish abundance, size and of fish assemblage composition, in particular to appraise the effects of habitat, anthropogenic pressures and MPAs. Thirty-two references dealt with habitat mapping and benthic cover monitoring, but benthos monitoring at species level was addressed by only four references. Not surprisingly, video techniques have been specialized, depending on these areas of application. RUV has been preferably used for behaviour-related studies (45 references), and only recently become of interest for assessing species response to environmental conditions and habitat through spatially-replicated designs (8 references from 2008). In contrast, BRUV has been extensively used for this latter purpose (25 references), with an emphasis on size estimation through stereo-video, whereas it has been hardly used for behavioural studies. TOWV has been almost exclusively used for habitat mapping and monitoring purposes (15 references); studies mostly focused on benthic macrofauna (e.g. coral cover and scallops) and macroflora (e.g. sea grass and algae), though some examined demersal fish species. DOV has also been used for assessing fish abundance and assemblages (13 references), habitat mapping and monitoring (15 references), and investigating fish behaviour (2 references). It is important to note that each technique was tested in both temperate and tropical ecosystems. It should also be underlined that Table 5 provides an average picture over the review period. Technological progress entails new observation capacities, and therefore new fields of investigation, such as exemplified by recent applications of RUV to fish and habitat monitoring. In addition to these applications, the great potential of video for addressing specific biodiversity-related topics was also illustrated by unusual applications, e.g. seals in underwater caves (Dendrinos et al., 2007).

Lastly, attention was paid to the kind of information collected by each technique. Fish species are most often identified at the lowest possible taxonomic level, notwithstanding a small fraction of individuals, in general small species, identified only at higher levels such as genus or family (see e.g. Pelletier et al., 2011). This must be taken into account when calculating metrics based on species counts. In some instances, metrics may only be calculated at genus or family level. In general, epifauna and epiflora are identified according to broad categories, e.g. sponges (Tyne et al., 2010), macroalgae (Bucas et al., 2007), tunicates and ophiuroids (Carbines and Cole, 2009). Benthos and habitat are generally characterized through percent covers of the sea bottom. In all cases, the species that can be observed in a reliable way must be carefully listed. Cryptic species are poorly observed and the limitations of visual counts due to underwater visibility are also valid for video techniques. Small species may be more difficult to identify from video images than from visual counts, whereas diver-avoiding species are more likely observed from diver-free video systems (Mallet et al., 2014).

A large number of metrics can then be obtained from all the techniques (Table 6). Species are counted over the observation duration to provide presence/absence, occurrences and species richness. In the case of vagile species, abundance is estimated over the whole video sequence or part of it for RUV, DOV and TOWV. In contrast, for BRUV the metric used is the time of first appearance per species (Wraith, 2007), and most often MaxN, the maximum abundance per species seen over the observation period (Ellis and DeMartini, 1995). MaxN is a conservative estimate of abundance (Willis et al., 2000). Bacheler et al. (2013) proposed using the mean number of fish observed in a series of snapshots over a viewing interval (MeanCount). Schobernd et al. (2013) compared MaxN and MeanCount from simulations, laboratory experiment and modelling. They found that MeanCount was generally linearly related to true abundance with a variability similar to MaxN. Fixed species and habitat are quantified either through abundance or percent cover. Estimating the size of individuals is generally done using stereo-video. Counts may also be assigned to size classes to avoid the issue of size estimation. Lastly, depending on the way cameras are set, video may allow other metrics to be considered, such as the number of bites from herbivores, the occurrence of activities, or parameters describing habitat (Table 6).

4. Complementarity of techniques

4.1. Comparative studies

From our literature search, we identified forty-two papers comparing two or more observation techniques (Table 7). More than 65% (28 out of 42) of papers compared UVC with a video technique: RUV (5 papers), TOWV (3), DOV (8), BRUV (9), and stereo-RUV (5). As video is perceived as a relatively new observation technique, it was often compared to UVC, which is commonly used for observing fish communities and habitats in shallow areas. Other comparisons involved two or more video techniques for (i) testing the effect of using two cameras compared to a mono-camera (stereo-RUV versus RUV); (ii) testing the effect of baiting (BRUV versus RUV); and (iii) evaluating their respective relevance for studying reef fish assemblages (BRUV versus TOWV, stereo-RUV versus stereo-DOV, stereo-BRUV and stereo-DOV). Finally, several papers compared underwater video with, on the one hand, experimental fishing (two papers dealing with RUV, five with BRUV, two with stereo-BRUV and one with TOWV) and, on the other, acoustic techniques (one paper about BRUV).

Comparisons always used metrics based on species counts (species richness, taxonomic diversity, and frequency of occurrence), and on abundance estimates (Table 8). Note that each study presented a number of distinct results, which may vary across taxa and across environmental settings. Hence, although some techniques may have been compared using the same metric in several studies, conclusions might differ from one study to another. For instance, in some studies greater fish diversity was recorded with BRUV than with DOV (Langlois et al., 2010), TOWV and SRUV (Watson et al., 2005), and UVC (Willis and Babcock, 2000), while others show that more fish species were detected with UVC than with BRUV (Tessier et al., 2005; Langlois et al., 2006; Stobart et al., 2007; Colton and Swearer, 2010; Lowry et al., 2012) and DOV (Greene and Alevizon, 1989; Pelletier et al., 2011). In general, differences in observed abundances between techniques also depend on taxa (Watson et al., 2010; Pelletier et al., 2011), thereby determining distinct observed assemblage structures (Table 8).

Directly comparing techniques in the field is rather difficult in that observations may be influenced by many factors, either natural or linked to fine-scale system deployment. Paired observations are needed to control for observation conditions, such as time of the day, weather, and the precise observation location. But since implementation in the field may depend on the technique, the number of observations that can be carried out within a given time period, as well as the habitat and depth constraints, may also differ from one technique to another. Thus, a paired comparison may only address the issue of comparing two observations of the same seascape and species, and not the actual advantages and shortcomings of each technique, and therefore not all facets of their complementarity.

For comparisons involving a diver-based technique, i.e. UVC or DOV vs TOWV, RUV or BRUV, the main differences between techniques were due to the presence of divers. The influence of divers' presence on UVC observations has been widely documented (Chapman et al., 1974; Harmelin-Vivien et al., 1985; Kulbicki, 1998; Dearden et al., 2010). UVC also raise a number of additional issues such as the need for species identification skills, the variability of observations between divers, and the influence of swimming speed (Brock, 1982; Bell et al., 1985; Lincoln-Smith, 1988; Kulbicki et al., 2010; Dickens et al., 2011). In the case of diver-free video observations, the factors inherent in each technique, that may affect observations, have not been evaluated from specifically designed studies. These include, for instance, the bait plume or noise, the use of artificial light, and more generally the behaviour of animals with respect to the video system. In addition, the area actually surveyed by each technique inevitably affects the number of species and individuals detected.

Hence, many factors can explain differences between observations obtained from distinct techniques. Because not all these factors can be controlled, it is important to bear them in mind when interpreting the outcomes of comparisons.

From the published studies, no single technique clearly appears to outperform the others; although some are more appropriate for particular purposes. Thus RUV appeared as an appropriate diver-free observation technique, as it can be left in place for a long time, at a range of depths, and in low light conditions when using additional lights (see Supplementary material B, C and D for detailed outcomes of the comparisons in Table 8). It can be used to investigate areas, parameters and factors that cannot be observed from techniques relying on divers, and it enables a high level of temporal and spatial replication. RUV was often found appropriate for surveying common and conspicuous species. BRUV was found particularly appropriate for sampling generalist carnivores, large predators and mobile species. Because it relies on attracting species, it may be usefully deployed in areas when fish are scarce, e.g. pelagic areas or sandy substrates in lagoon areas. The main advantage of TOWV lies in its ability to sample a large area in a short period of time, thereby increasing the spatial coverage of habitats, and the probability of observing species, including rare species (although motile species may be sensitive to boat noise). DOV was deemed adequate for studies at smaller scales, e.g. to study changes in corals, gorgonians and macro-algae, and to provide representative observations of fish abundance and species diversity. The various techniques should thus be seen as providing complementary standpoints on shallow biodiversity and species.

4.2. Cost-efficiency considerations

In addition to the information provided by each kind of observation, investment and operating costs are crucial parameters when considering an observation technique. Overall, few papers documented implementation costs for the techniques used, whereas the time required for image analysis is often seen as a shortcoming of underwater video techniques. Francour et al. (1999) found that underwater video was more cost-efficient than UVC in terms of total time spent in the field and in the laboratory. Based on a subset of papers, Murphy and Jenkins (2010) found that relative costs were AUD$1,000–5,000 for RUV and AUD$5,000–10,000 for BRUV. However, financial costs are difficult to evaluate for a given technique, because of the various ways of manufacturing systems, and because of differences in the characteristics of the camcorders and sensors used. It is thus more relevant to compare required staff time rather than financial costs of equipment. Note also that time spent at sea is always more expensive than laboratory time (Pelletier et al., 2011; Bernard and Gotz, 2012). The cost-efficiency of several observation techniques were compared by Leujak and Ormond (2007) (six techniques for surveying coral communities) and by Langlois et al. (2010) (stereo-BRUV versus stereo-DOV transects for observing fish assemblages) (Table 9). Pelletier et al. (2011, 2012) detailed observation costs (including both field and image analysis) for DOV and ROT-RUV, with respect to UVC.

Cost-efficiency considerations must account for the fact that a technique which is better at observing or detecting species, either because of attraction (BRUV) or because of a higher image resolution, will inevitably require increased time for image analysis. For example, Bernard and Götz (2012) found that a BRUV station required 7 hours of staff time versus 3.5

hours for RUV, but this was mostly due to the fact that BRUV detected more species and individuals than RUV (Table 9). Consequently, a larger time for post-field analysis should not be considered as a weakness if higher diagnostic power is the end result (Bernard and Gotz, 2012).

5. Underwater video in the light of current monitoring challenges

As mentioned in the introduction, conservation objectives and sustainable management of coastal biodiversity and resources involve monitoring the status of several biodiversity components in large areas. This is the case for MPA assessment and for regional or global conservation agendas. Present global commitments to reduce biodiversity loss entail setting up MPAs in most regions of the world. MPAs are not only more numerous, but also larger, and how they achieve conservation objectives must be assessed. Consistently with MPA conservation objectives (Pelletier, 2011), monitoring and assessment should include fish and macroinvertebrate resources, but also fixed fauna, essential habitats, and protected or emblematic species. Maintaining the diversity of taxa and the functioning of species assemblage are additional conservation objectives. Yet, biodiversity is rarely observed and assessed on large spatial scales due to observation costs.

Underwater video may help in making good some of these monitoring gaps. Three main questions are generally raised by the use of video techniques for observing and monitoring biodiversity, species and habitat in shallow waters: i) how much does it cost?; ii) is image analysis (i.e. identifying and counting species) an issue?; and iii) what are the observation area and the required duration of observations? Cost-efficiency questions were addressed in subsection 4.2 when comparing video techniques. Issues ii) and iii) are addressed below in subsections 5.1 and 5.2. We will then discuss the two main advantages of most underwater video techniques: their non-obtrusive nature and the potential for high replication (subsections 5.3 and 5.4). Finally, we will compare the advantages and shortcomings of observation techniques in subsection 5.5.

5.1 Is image analysis an issue?

The issue of image analysis is often raised by the use of video, in particular the ability to identify and count species, along with the time required to do this. Underwater visibility is a limitation for all visual techniques, whether UVC, video or photo. However, divers conducting UVC or DOV may compensate for reduced visibility by moving toward the observation target. Moreover, the larger the observation surface area, the more critical the visibility. In this respect, RUV may be more dependent upon visibility than BRUV which attracts species closer to the camcorder. High Definition was not always used in recent studies, yet we believe it substantially improves the quality of the resulting data at little extra cost. Being able to take time to identify and count, including the possibility of consulting identification books or experts is actually convenient. Because video footage is archived, it may be shared and analysed independently, thereby enabling discussion about identifications and cross-validation of image analyses. In addition, archiving footage ensures data traceability. Identifying species and counting individuals from two-dimensional images may be initially challenging to people trained in other techniques, but most people learn to do so within a month or two.

The second issue concerns the time needed for image analysis. From our experience, the post-treatment of images balances the time gained in the field through diver-based visual techniques (Pelletier et al., 2011, 2012). This required time may vary depending on the kind of information extracted, e.g. the list of taxa studied, and on the experience of the observer. But it is mostly dependent upon the abundance and species richness in the observation area, which should not be seen as a drawback (see end of section 4).

5.2. Observation area and duration

Video techniques exhibit large differences in terms of information provided. First, observed surface areas are not all the same. Horizontal RUV enables observed surfaces and distances to be estimated through horizontal vision, in a similar way to UVC. However, the accuracy and precision of these estimates, whether from RUV or from UVC, should not be neglected. Delineation of the observed surface area (e.g. from strip transects) or mark setting to standardize surveyed areas is possible, but inevitably increases observation duration and may influence observations, because it requires divers. Stereo-video makes it possible to precisely estimate the observation distance and the size of observed individuals, which are otherwise visually estimated either from post-field image analysis (RUV, TOWV, non stereo-BRUV, DOV) or underwater (UVC). For such visual estimations, training from silhouettes has proved useful (Thompson and Mapstone, 1997; N. Guilpart, D. Mallet, D. Pelletier, unpublished data). For vertically-oriented systems (TOWV or RUV), the observed surface may be estimated based on lens and zoom parameters, provided that the camera elevation above the floor is controlled and known. In the particular case of BRUV, the unknown bait plume prevents the evaluation of the actual surface concerned by the observation.

Regarding observation duration, BRUV is constrained by effective bait attraction, which needs a minimum amount of time, from 25 to 40 minutes (Willis and Babcock, 2000; Watson et al., 2007, Bernard and Gotz, 2012). TOWV allows continuous recording of images along the vessel trajectory and footage is often subsampled for image analysis (see references in Table 3). The duration of a single RUV observation varies from a few minutes to an hour (see references in Table 5), depending on the study objective and the system characteristics.

5.3. Non-obtrusive observations of species assemblages?

Underwater video techniques provide direct observations of species in their natural habitat, and they are not extractive. Diver-free video techniques are also less intrusive than UVC (see section 1 for references). Among these, TOWV may disturb the ecosystem through vessel noise, though this can be circumvented by using appropriate engines. BRUV data rely on bait attraction within an unknown distance around the observation system. In this respect, observations resemble fishing data, as they are selective, depending on both species and bait. The effect of bait composition and size on catch was well studied (Salia et al., 2002; Smith, 2002; Lowry et al., 2006; Alos et al., 2009; Dorman et al., 2012), as was the behaviour of species near baited fishing gear (e.g. in deep environment: Craig et al., 2005) or near fishery discards (Hill and Wassenberg, 2000). But the distance and range of attraction of vagile fauna by the bait is difficult to test, and to our knowledge, no such study was published at the time of the review. Regarding (unbaited) RUV, our own experience indicates that while some fish already present nearby may be curious when a system is first set up, they rapidly resume their normal behaviour, and the video system does not seem to attract distant fish (D. Mallet and D. Pelletier, unpublished data).

5.4. Temporal and spatial replication

With the exception of DOV, for which the number of observations that can be carried out per day is limited by diver's presence (although DOV is quicker than UVC in the field), a large amount of data may be collected per day, making it possible to accomplish highly spatially and temporally replicated designs. Most RUV techniques were indeed designed to be set for a long time and to provide information on behaviour, diurnal rhythms and species activity over long periods of undisturbed observation. This enables an array of questions to be addressed that cannot be studied by other observation techniques. The ability of video systems to produce a large number of observations can also be used in a spatial perspective, for instance to investigate changes in macrofauna and population behaviour, and to correlate communities with environmental variables or anthropogenic pressures. Hence, the response of biodiversity to fishing, MPA protection and other impacts of coastal uses may be addressed at relevant scales. Observation designs may be properly replicated with respect to factors influencing the distribution of biodiversity, such as site and habitat on several scales. A high level of replication then enables relationships between biodiversity metrics and environmental variables to be investigated by increasing the statistical power of analyses and diagnostics.

Beyond the replication issue, the consistency between data collected in distinct areas by different teams is reinforced by the use of identical systems. Within an ecosystem-based approach to fisheries management, a better understanding of the temporal variations in spatial patterns of biodiversity and resources is needed. In this respect, diver-free techniques may at the same time enable small-scale studies with an increased resolution and enlarge the spatial coverage of designs up to the ecosystem scale. For DOV, data consistency is also increased, as there are no differences between videos filmed by distinct divers. Moreover, additional sensors can be coupled to video systems and thus collect additional information on biotic and abiotic variables, as recently advocated by Johnson et al. (2013).

5.5. Which technique for observing and monitoring coastal biodiversity?

The choice of a video technique first depends on the object of the study. Reviewed applications of video techniques in shallow waters were listed in Section 3. These are only a sample of the potential use of each technique, as in this area, technological progress is swift (subsection 2.6) and there is room for innovation and alternative types of implementation. General recommendations may thus be made regarding the scope of each technique (Table 10, last column), but these main features should be seen as indicative rather than prescriptive. For instance, none of the references specifically dealt with the observation of juvenile or larval fish. Yet this could be achieved by several existing RUV techniques, by setting them in appropriate locations with adequate camera settings. Likewise, shy species may be monitored using automated systems regularly recording species activity. Indeed a wide spectrum of applications is feasible with the current technologies.

There are still advantages and shortcomings associated with each technique. These were discussed in the previous subsections (5.1 to 5.4) and summarized in Table 10. Choosing a technique must thus stem from both the general features of each technique and their proven outcomes, but technical adaptations and fast technological changes should also be taken into account. The techniques most often used for observing and monitoring coastal biodiversity and resources remain UVC, fishing and, to a lesser extent, acoustics. This situation prevails for both research studies and management-oriented monitoring. Although not recent, the advent of video techniques has not altered this situation. Indeed, many video systems developed in the past only served during a given research project, and were not intended to be transferred to other contexts or users. This situation changed with the development of BRUV, where the same technique is now repeatedly used in many different contexts.

In the process of selecting a technique for a given study, investment and operating costs are two crucial parameters, particularly when replicated designs involving a large number of observations are envisaged. Although these costs were not often documented in the papers, the review showed that compared to UVC, i) video techniques generally involved less time spent on the field at the expense of more time spent in post-treatment, for image analysis; and ii) a lower level of scientific expertise was required during field work. Other features may vary from one technique to another (see Section 2 for description of techniques).

5.6. Future prospects for underwater video monitoring

The technological progress seen in the last decade (see subsection 2.6) will continue, so that system autonomy, storage capacity, and sensor resolution will increase. Human-operated systems will continue to be used, particularly for research and in the context of participative management in coastal areas. But there is a wide scope for automated systems. These can be permanent stations with multiple sensors, either cabled (see e.g. ESONET project: http://www.esonet-noe.org/About-ESONET and Aguzzi et al., 2011, 2012) or mobile systems transmitting information, e.g. programmed gliders (Moline and Schofield, 2009). Such advances will considerably increase the amount of data collected by underwater video systems (among other techniques). It will thus be essential to analyse and manage these large data sets. Automated image analysis will be key for gaining time. Several projects have been set up with this objective, see for instance the Fish4Knowledge project, which aims to analyse undersea fish videos (www.Fish4Knowledge.eu, Phoenix et al., 2013). However, species identification and counting not requiring human intervention still remains a challenge. Properly managed data is the second issue, particularly in view of long-term monitoring. Furthermore, data for biodiversity monitoring and assessment are often collected at the scale of an entire ecosystem, and they are to be shared within collaborative projects. Developing shared protocols and data management utilities for collecting and utilizing the wealth of data that will be made available in the future should be a priority.

Global commitments to conservation also entail research issues at larger scales, particularly regarding spatial patterns of biodiversity and ecosystem approaches to management and conservation (Christensen et al., 1996). Hence, for both research and monitoring purposes, observations with improved spatial coverage and resolution should be carried out in all habitats; they should document exploited and non-exploited species, as well as benthic coverage, including sensitive taxa such as sea grass and coral. These considerable information needs cannot be achieved solely through the techniques used so far, and complementary observation techniques are needed, among which video techniques, either on stand-alone basis or preferably combined with other techniques, are definitely a good candidate.

Acknowledgements

The authors thank two anonymous reviewers and the editor for their helpful comments on an earlier version of this paper. This work has benefitted from numerous exchanges with colleagues working with video techniques, particularly Trevor Willis, Mike Cappo and Tim Langlois. We also thank Thierry Laugier for comments on an earlier draft of this paper. This work is part of a PhD Thesis jointly funded by the French Institute for the Exploitation of the Sea (IFREMER) and the Agence des Aires Marines Protégées.

We are extremely grateful to the various authors and publishers who allowed us to reproduce pictures of their video systems. In order of appearance in the publication:

1) the Horizontal Remote Underwater Video system of LaFond *et al.* (1961) reproduced with the permission of E.C. LaFond, “Photographic problems in oceanography”, Underwater Photo-Optical Instrumentation Applications, Seminar Report, SPIE, pp. 11-18. San Diego, California, (1968).

2) the Acoustic Remote Underwater Video system of Kumpf and Lowenstein (1962) reproduced with the permission from H.E. Kumpf and J.M. Lowenstein, “Undersea Observation Station”, Sea Frontiers, volume 8, 198-206, (1962).

3) the Acoustic Remote Underwater Video system of Stevenson (1967) reproduced with the permission of R.A. Stevenson, “Underwater television”, Oceanology Intl, volume 2, 30-35, (1967).

4) the Horizontal Remote Underwater Video system of Fedra and Machan (1979) reproduced with the permission from Springer, Marine Biology, K. Fedra and R. Machan, “A Self-Contained Underwater Time-Lapse Camera for in situ Long-Term Observations”, Marine Biology, volume 55, 239-246, (1979).

5) the Vertical Remote Underwater Video system of Stokesbury et al. (2004) and Tyne et al. (2010) reproduced with the permission of Julian A. Tyne, N.R. Loneragan, M. Krützen, S.J. Allen and L. Bejder, “An integrated data management and video system for sampling aquatic benthos”, Marine and Freshwater Research, volume 61, 1023-1028, (2010).

6) the Horizontal Remote Underwater Video system of Jan et al. (2007) reproduced with the permission of Dr. Rong-Quen Jan, Yi-Ta Shao, Fang-Pang Lin, Tung-Yung Fan, Yueh-Yuan Tu, Hsien-Shiow Tsai and Kwang-Tsao Shao, “An underwater camera system for real-time coral reef fish monitoring”, The Raffles Bulletin of Zoology, volume 14, 273-279, (2007).

7) the Horizontal Baited Remote Underwater Video system of Ellis and DeMartini (1995) reproduced with the permission from the U.S government, D. Ellis and E. DeMartini, “Evaluation of a video camera technique for indexing abundances of juvenile pink snapper, *Pristipomoides filamentosus*, and other Hawaiian insular shelf fishes”, Fisheries Bulletin, volume 93, 67-77, (1995).

8) the vertical Baited Remote Underwater Video system of Willis and Babcock (2000) reproduced with the permission of Marine and Freshwater Research 51(8), 755-763 (Trevor J. Willis and Russell C. Babcock). Copyright CSIRO 2000. Published by CSIRO

PUBLISHING, Collingwood, Victoria Australia – http://www.publish.csiro.au/nid/126/paper/MF00010.htm.

9) the Mid-water Horizontal Baited Remote Underwater Video system of Heagney et al. (2007) reproduced with the permission from E.C. Heagney, T.P. Lynch, R.C. Babcock and I.M. Suthers, “Pelagic fish assemblages assessed using mid-water baited video: standardising fish counts using bait plume size”, Marine Ecology Progress Series, Volume 350, 255-266, (2007).

10) the Seabed Towed Video system of Machan and Fedra (1975) reproduced with the permission from Springer, Marine Biology, R. Machan and K. Fedra, “A New Towed Underwater Camera System for Wide-Range Benthic Surveys”, Marine Biology, volume 33, 75-84, (1975).

11) the Seabed Towed Video system of Holme and Barrett (1977) reproduced with the permission of N.A. Holme and R.L. Barrett, “A sledge with television and photographic cameras for quantitative investigation of the epifauna on the continental shelf”, Journal of the Marine Biological Association of the United Kingdom, Volume 57, 391-403, (1977).

12) the Mid-water Towed Video system of Riegl et al. (2001) reproduced with the permission of B. Riegl, J.L. Korrubel and C. Martin, “Mapping and monitoring of coral communities and their spatial patterns using a surface-based video method from a vessel”, Bulletin of Marine Science, Volume 69, 869-880, (2001).

13) the Seabed Towed Video system of Spencer et al. (2005) reproduced with the permission of Mara L. Spencer, A.W. Stoner, C.H. Ruer, J.E. Munk, “A towed camera for estimating abundance of juvenile flatfishes and habitat characteristics: Comparison with beam trawls and divers”, Estuarine, Coastal and Shelf Science, volume 64, 497-503, (2005).

14) the Seabed Towed Video system of Rooper and Zimmermann (2007) reproduced with the permission from Karna McKinney, Alaska Fisheries Science Center, NOAA Fisheries.

References

Aguzzi, J., Company, J.B., Costa, C., Matabos, M., Azzurro, E., Manuel, A., Menesatti, P., Sarda, F., Canals, M., Delory, E., Cline, D., Favali, P., Juniper, S.K., Furushima, Y., Fujiwara, Y., Chiesa, J.J., Marotta, L., Bahamon, N., Priede, I.G., 2012. Challenges to assessment of benthic populations and biodiversity as a result of rhythmic behaviour: Video solutions from cabled observatories, in: Gibson, R.N., Atkinson, R.J.A., Gordon, J.D.M., Hughes, R.N. (Eds.), Oceanography and Marine Biology: An Annual Review, Vol 50, pp. 235-285.

Aguzzi, J., Manuel, A., Condal, F., Guillen, J., Nogueras, M., del Rio, J., Costa, C., Menesatti, P., Puig, P., Sarda, F., Toma, D., Palanques, A., 2011. The New Seafloor Observatory (OBSEA) for Remote and Long-Term Coastal Ecosystem Monitoring. Sensors 11, 5850-5872.

Alevizon, W.S., Brooks, M.G., 1975. The comparative structure of two Western Atlantic reef-fish assemblages. Bulletin of Marine Science 25, 482-490.

Alos, J., Arlinghaus, R., Palmer, M., March, D., Alvarez, I., 2009. The influence of type of natural bait on fish catches and hooking location in a mixed-species marine recreational fishery, with implications for management. Fisheries Research 97, 270-277.

Aronson, R.B., Edmunds, P.J., Precht, W.F., Swanson, D.W., Levitan, D.R., 1994. Large-scale, long-term monitoring of Caribbean coral reefs: simple, quick, inexpensive techniques. Atoll Research Bulletin 421, 1-19.

Assis, J., Narváez, K., Haroun, R., 2007. Underwater towed video: a useful tool to rapidly assess elasmobranch populations in large marine protected areas. Journal of Coastal Conservation 11, 153–157.

Babcock, R.C., Kelly, S., Shears, N.T., Walker, J.W., Willis, T.J., 1999. Changes in community structure in temperate marine reserves. Marine Ecology Progress Series 189, 125-134.

Bacheler, N.M., Schobernd, C.M., Schobernd, Z.H., Mitchell, W.A., Berrane, D.J., Kellison, G.T., Reichert, M.J.M., 2013. Comparison of trap and underwater video gears for indexing reef fish presence and abundance in the southeast United States. Fisheries Research 143, 81-88.

Backus, R.H., Barnes, H., 1957. Television-echo sounder observations of midwater sound scatterers. Deep-Sea Research 4, 116-119.

Barans, C.A., Arendt, M.D., Moore, T., Schmidt, D., 2005. Remote video revisited: A visual technique for conducting long-term monitoring of reef fishes on the continental shelf. Marine Technology Society Journal 39, 110-118.

Barans, C.A., Schmidt, D., Brouwer, M.C., 2002. Potential for coupling of underwater TV monitoring with passive acoustics, in: Rountree, R., Goudey, C., Hawkins, T., Luczkovich, J.J., Mann, D. (Eds.), Listening to Fish: Proceedings of the International Workshop on the Applications of Passive Acoustics to Fisheries. Massachusetts Institute of Technology Cambridge, USA, p. 172.

Barnes, H., 1952. Under-water television and marine biology. Nature 169, 477-479.

Barnes, H., 1953. Underwater television and research in marine biology, bottom topography and geology. I. A description of the equipment and its use on board ship. Deutsche Hydrographische Zeitschrift 6, 123-133.

Barnes, H., 1955. Underwater television and research in marine biology, bottom topography and geology. II. Experience with the equipment. Deutsche Hydrographische Zeitschrift 8, 213-236.

Barnes, H.B., 1963. Underwater television. Oceanography and Marine Biology: An Annual Review 11, 115-128.

Bassett, D.K., Montgomery, J.C., 2011. Investigating nocturnal fish populations in situ using baited underwater video: With special reference to their olfactory capabilities. Journal of Experimental Marine Biology and Ecology 409, 194-199.

Becker, A., Cowley, P.D., Whitfield, A.K., 2010. Use of remote underwater video to record littoral habitat use by fish within a temporarily closed South African estuary. Journal of Experimental Marine Biology and Ecology 391, 161 - 168.

Bell JD, Craik GJS, Pollard DA, Russell BC (1985) Estimating length frequency distributions of large reef fish underwater. Coral Reefs 4:41 - 44

Bellwood, D.R., Fulton, C.J., 2008. Sediment-mediated suppression of herbivory on coral reefs: decreasing resilience to rising sea levels and climate change? Limnology and Oceanography 53, 2695-2701.

Bellwood, D.R., Hoey, A.S., Choat, J.H., 2003. Limited functional redundancy in high diversity systems: resilience and ecosystem function on coral reefs. Ecology Letters 6, 281-285.

Bellwood, D.R., Hughes, T.P., Hoey, A.S., 2006. Sleeping functional group drives coral-reef recovery. Current Biology 16, 2434−2439.

Bennett, S., Bellwood, D.R., 2011. Latitudinal variation in macroalgal consumption by fishes on the Great Barrier Reef. Marine Ecology Progress Series 426, 241-U269.

Bernard, A.T.F., Götz , A., 2012. Bait increases the precision in count data from remote underwater video for most subtidal reef fish in the warm-temperate Agulhas bioregion. Marine Ecology Progress Series 471, 235-252.

Birt, M.J., Harvey, E.S., Langlois, T.J., 2012. Within and between day variability in temperate reef fish assemblages: Learned response to baited video. Journal of Experimental Marine Biology and Ecology 416-417, 92-100.

Bloomfield, H.J., Sweeting, C.J., Mill, A.C., Stead, S.M., Polunin, N.V.C., 2012. No-trawl area impacts: perceptions, compliance and fish abundances. Environmental Conservation 39, 237-247.

Bohnsack, J.A., Bannerot, S.P., 1986. A Stationary Visual Census Technique for Quantitatively Assessing Community Structure of Coral Reef Fishes. NOAA Technical Report NMFS 41, 1-15.

Bond, M.E., Babcock, E.A., Pikitch, E.K., Abercrombie, D.L., Lamb, N.F., Chapman, D.D., 2012. Reef Sharks Exhibit Site-Fidelity and Higher Relative Abundance in Marine Reserves on the Mesoamerican Barrier Reef. PLoS ONE 7.

Booda, L.L., 1966. Industry bees swarm at NEL. UnderSea Technology 7, 23-25.

Bortone, S.A., Martin, T., Bundrick, C.M., 1991. Visual census of reef fish assemblages: A comparison of slate, audio, and video recording devices. Northeast Gulf Science 12, 17-23.

Bortone, S.A., Martin, T., Bundrick, C.M., 1994. Factors Affecting Fish Assemblage Development on a Modular Artificial Reef in a Northern Gulf of Mexico Estuary. Bulletin of Marine Science 55, 319-332.

Bräger, S., Chong, A., Dawson, S., Slooten, E., Würsig, B., 1999. A combined stereo-photogrammetry and underwater-video system to study group composition of dolphins. Helgoland Marine Research 53, 122-128.

Brock, R.E., 1982. A critique of the visual census method for assessing coral reef fish populations. Bulletin of Marine Science 32, 269-276.

Brock, V.E., 1954. A preliminary report on a method of estimating reef fish population. Journal of Wildlife Management 18, 297–308.

Bucas, M., Daunys, D., Olenin, S., 2007. Overgrowth patterns of the red algae Furcellaria lumbricalis at an exposed Baltic Sea coast: The results of a remote underwater video data analysis. Estuarine, Coastal and Shelf Science 75, 308-316.

Buhl-Mortensen, L., Buhl-Mortensen, P., Dolan, M.F.J., Dannheim, J., Bellec, V., Holte, B., 2012. Habitat complexity and bottom fauna composition at different scales on the continental shelf and slope of northern Norway. Hydrobiologia 685, 191-219.

Burge, E.J., Atack, J.D., Andrews, C., Binder, B.M., Hart, Z.D., Wood, A.C., Bohrer, L.E., Jagannathan, K., 2012. Underwater Video Monitoring of Groupers and the Associated Hard-Bottom Reef Fish Assemblage of North Carolina Bulletin of Marine Science 88, 15-38.

Burkepile, D.E., Hay, M.E., 2011. Feeding complementarity versus redundancy among herbivorous fishes on a Caribbean reef. Coral Reefs 30, 251-362.

Burrows, M.T., Kawai, K., Hughes, R.N., 1999. Foraging by mobile predators on a rocky shore: under- water TV observations of movements of blennies Lipophrys pholis and crabs Carcinus maenas. Marine Ecology Progress Series 187, 237-250.

Cappo, M., De'ath, G., Speare, P., 2007a. Inter-reef vertebrate communities of the Great Barrier Reef Marine Park determined by baited remote underwater video stations. Marine Ecology Progress Series 350, 209–221.

Cappo, M., Harvey, E., Malcolm, H., Speare, P., 2003. Potential of video techniques to monitor diversity, abundance and size of fish in studies of marine protected areas, in: Beumer, J.P., Grant, A., Smith, D.C. (Eds.), APAC Congress 2002: Aquatic protected areas - What works best and how do we know ? World Congress on Aquatic Protected Areas proceedings. National Library of Australia, Cairns,Qld, Australia, pp. 455 - 464.

Cappo, M., Harvey, E., Shortis, M., 2007b. Counting and measuring fish with baited video techniques - an overview, in: Lyle, J.M., Furlani, D.M., Buxton, C.D. (Eds.), Proceedings of the 2006 Australian Society of Fish Biology Conference and Workshop Cuttingedge Technologies in Fish and Fisheries Science, Hobart, August 2006, pp. 101-114.

Cappo, M., Speare, P., De'ath, G., 2004. Comparison of baited remote underwater video stations (BRUVS) and prawn (shrimp) trawls for assessments of fish biodiversity in inter-reefal areas of the Great Barrier Reef Marine Park. Journal of Experimental Marine Biology and Ecology 302 123–152.

Cappo, M., Stowar, M., Syms, C., Johansson, C., Cooper, T., 2011. Fish-habitat associations in the region offshore from James Price Point – a rapid assessment using Baited Remote Underwater Video Stations (BRUVS). Journal of the Royal Society of Western Australia 94, 303-321.

Carbines, G., Cole, R.G., 2009. Using a remote drift underwater video (DUV) to examine dredge impacts on demersal fishes and benthic habitat complexity in Foveaux Strait, Southern New Zealand. Fisheries Research 96 230–237.

Carleton, J.H., Done, T.J., 1995. Quantitative video sampling of coral reef benthos: large-scale application Coral Reefs 14, 35-46.

Chabanet, P., Loiseau, N., Join, J.-L., Ponton, D., 2012. VideoSolo, an autonomous video system for high-frequency monitoring of aquatic biota, applied to coral reef fishes in the

Glorioso Islands (SWIO). Journal of Experimental Marine Biology and Ecology 430-431, 10-16.

Chapman, C.J., Johnstone, A.D.F., Dunn, J.R., Creasey, D.J., 1974. Reactions of Fish to Sound Generated by Divers' Open-Circuit Underwater Breathing Apparatus. Marine Biology 27, 357-366.

Chatfield, B.S., Van Niel, K.P., Kendrick, G.A., Harvey, E.S., 2010. Combining environmental gradients to explain and predict the structure of demersal fish distributions. Journal of Biogeography 37, 593-605.

Christensen, N.L., Bartuska, A.M., Brown, J.H., Carpenter, S., Dantonio, C., Francis, R., Franklin, J.F., MacMahon, J.A., Noss, R.F., Parsons, D.J., Peterson, C.H., Turner, M.G., Woodmansee, R.G., 1996. The report of the ecological society of America committee on the scientific basis for ecosystem management. Ecological Applications 6, 665-691.

Colin, P.L., 1971. Interspecific Relationships of the Yellowhead Jawfish, Opistognathus aurifrons (Prisce, Opistognathidae). Copeia 1971, 469-473.

Colin, P.L., 1972. Daily Activity Patterns and Effects of Environmental Conditions on the Behavior of the yellowhead Jawfish, Opistognathus aurifons with Notes on its Ecology. Zoologica, N. Y. 57, 137-169.

Colin, P.L., 1973. Burrowing Behavior of the yellowhead Jawfish, Opistognathus aurifrons. Copeia 1973, 84-90.

Colton, M.A., Swearer, S.E., 2010. A comparison of two survey methods: differences between underwater visual census and baited remote underwater video. Marine Ecology Progress Series 400, 19-36.

Condal, F., Aguzzi, J., Sarda, F., Nogueras, M., Cadena, J., Costa, C., Del Rio, J., Manuel, A., 2012. Seasonal rhythm in a Mediterranean coastal fish community as monitored by a cabled observatory. Marine Biology 159, 2809-2817.

Cooke, S.J., Schreer, J.F., 2002. Determination of fish community composition in the untempered regions of a thermal effluent canal - The efficacy of a fixed underwater videography system. Environmental Monitoring and Assessment 73, 109-129.

Craig, S.R., Stoner, A.W., Matterson, K., 2005. Use of high-frequency imaging sonar to observe fish behaviour near baited fishing gears. Fisheries Research 76, 291-304.

Cruz, I.C.S., kikushi, R.K.P., Leão, Z.M.A.N., 2008. Use of the video transect method for characterizing the Itacolomis reefs, eastern Brazil. Brazilian Journal of Oceanography 56, 271-280.

Cummings, W.C., Brahy, B.D., Spires, J.Y., 1966. Sounds production, schooling, and feeding habits of the margate, Haemulon album Cuvier, off North Bimini, Bahamas. Bulletin of Marine Science 16, 626-640.

Cvitanovic, C., Bellwood, D.R., 2009. Local variation in herbivore feeding activity on an inshore reef of the Great Barrier Reef. Coral Reefs 28.

Davis, G.E., Anderson, T.W., 1989. Population estimates of four kelp forest fishes and an evaluation of three in situ assessment techniques. Bulletin of Marine Science 44, 1138-1151.

Dearden, P., Theberge, M., Yasué, M., 2010. Using underwater cameras to assess the effects of snorkeler and SCUBA diver presence on coral reef fish abundance, family richness, and species composition. Environmental Monitoring and Assessment 163, 531-538.

Delcourt, J., Denoël, M., Ylieff, M., Poncin, P., 2012. Video multitracking of fish behaviour: a synthesis and future perspectives. Fish and Fisheries, online 2 MAR 2012.

Dendrinos, P., Tounta, E., Karamanlidis, A.A., Legakis, A., Kotomatas, S., 2007. A Video Surveillance System for Monitoring the Endangered Mediterranean Monk Seal (Monachus monachus). Aquatic Mammals 33, 179-184.

Denny, C.M., Babcock, R.C., 2004. Do partial marine reserves protect reef fish assemblages? Biological Conservation 116, 119 - 129.

Denny, C.M., Willis, T.J., Babcock, R.C., 2004. Rapid recolonisation of snapper Pagrus auratus: Sparidae within an offshore island marine reserve after implementation of no-take status. Marine Ecology Progress Series 272, 183 - 190.

Dickens, L.C., Goatley, C.H.R., Tanner, J.K., Bellwood, D.R., 2011. Quantifying Relative Diver Effects in Underwater Visual Censuses. PLoS ONE 6, e18965.

Dorman, S.R., Havrey, E.S., Newman, S.J., 2012. Bait Effects in Sampling Coral Reef Fish Assemblages with Stereo-BRUVs. PLoS ONE 7, e41538.

Dunbrack, R.L., 2006. In situ measurement of fish body length using perspective-based remote stereo-video. Fisheries Research 82, 327-331.

Dunbrack, R.L., 2008. Abundance trends for Hexanchus griseus, Bluntnose Sixgill Shark, and Hydrolagus colliei, Spotted Ratfish, counted at an automated underwater observation station in the Strait of Georgia, British Columbia. Canadian Field-Naturalist 122, 124-128.

Dunbrack, R.L., Zielinski, R., 2003. Seasonal and diurnal activity of sixgill sharks (Hexanchus griseus) on a shallow water reef in the Strait of Georgia, British Columbia. Canadian Journal of Zoology 81, 1107-1111.

Dunlap, M., Pawlik, J.R., 1996. Video-monitored predation by Caribbean reef fishes on an array of mangrove and reef sponges. Marine Biology 126, 117-123.

Ellis, D., DeMartini, E., 1995. Evaluation of a video camera technique for indexing abundances of juvenile pink snapper, Pristipomoides filamentosus, and other Hawaiian insular shelf fishes. Fishery Bulletin 93, 67-77.

Enstipp, M.R., Gremillet, D., Jones, D.R., 2007. Investigating the functional link between prey abundance and seabird predatory performance. Marine Ecology Progress Series 331, 267-279.

Fedra, K., Machan, R., 1979. A Self-Contained Underwater Time-Lapse Camera for in situ Long-Term observations. Marine Biology 55, 239-246.

Fernandes, L., 1990. Effect of the distribution and density of benthic target organisms on manta tow estimates of their abundance Coral Reefs 9, 161-165.

Fischer, P., Weber, A., Heine, G., Weber, H., 2007. Habitat structure and fish: assessing the role of habitat complexity for fish using a small, semiportable, 3-D underwater observatory. Limnology and Oceanography: Methods 5, 250-262.

Fitzpatrick, B.M., Harvey, E.S., Heyward, A.J., Twiggs, E.J., Colquhoun, J., 2012. Habitat Specialization in Tropical Continental Shelf Demersal Fish Assemblages. PLoS ONE 7.

Fox, R.J., Bellwood, D.R., 2007. Quantifying herbivory across a coral reef depth gradient. Marine Ecology Progress Series 339, 49-59.

Fox, R.J., Bellwood, D.R., 2008a. Direct versus indirect methods of quantifying herbivore grazing impact on a coral reef. Marine Biology 154, 325-334.

Fox, R.J., Bellwood, D.R., 2008b. Remote video bioassays reveal the potential feeding impact of the rabbitfish Siganus canaliculatus (f: Siganidae) on an inner-shelf reef of the Great Barrier Reef Coral Reefs 27, 605-615.

Francour, P., Liret, C., Harvey, E., 1999. Comparison of fish abundance estimates made by remote underwater video and visual census. Naturalista Sicil 23, 155 - 168.

Gladstone, W., Lindfield, S., Coleman, M., Kelaher, B., 2012. Optimisation of baited remote underwater video sampling designs for estuarine fish assemblages. Journal of Experimental Marine Biology and Ecology 429, 28-35.

Gledhill, C.T., Lyczkowski-Shultz, J., Rademacher, K., Kargard, E., Crist, G., Grace, M.A., 1996. Evaluation of video and acoustic index methods for assessing reef-fish populations. Journal of Marine Science 53, 483-485.

Göetze, J.S., Langlois, T.J., Egli, D.P., Harvey, E.S., 2011. Evidence of artisanal fishing impacts and depth refuge in assemblages of Fijian reef fish. Coral Reefs 30, 1-11.

Gomelyuk, V.E., 2009. Fish assemblages composition and structure in three shallow habitats in north Australian tropical bay, Garig Gunak Barlu National Park, Northern Territory, Australia. J Mar Biol Assoc Uk 89, 449-460.

Grabowski, T.B., Boswell, K.M., McAdam, B.J., Wells, R.J.D., Marteinsdottir, G., 2012. Characterization of Atlantic Cod Spawning Habitat and Behavior in Icelandic Coastal Waters. PLoS ONE 7.

Greene, L.E., Alevizon, W.S., 1989. Comparative accuracies of visual assessment methods for coral reef fishes. Bulletin of Marine Science 44, 899 - 912.

Grizzle, R.E., Brodeur, M.A., Abeels, H.A., Greene, J.K., 2008. Bottom habitat mapping using towed underwater videography: subtidal oyster reefs as an example application. Journal of Coastal Research 24, 103-109.

Hall, K.C., Hanlon, R.T., 2002. Principal features of the mating system of a large spawning aggregation of the giant Australian cuttlefish Sepia apama (Mollusca : Cephalopoda). Marine Biology 140, 533-545.

Handley, S., Kelly, S., Kelly, M., 2003. Non-destructive video image analysis method for measuring growth in sponge farming: preliminary results from the New Zealand bath-sponge Spongia (Heterofibria) manipulatus. New Zealand Journal of Marine and Freshwater Research 37, 613-621.

Hannah, R.W., Jones, S.A., 2012. Evaluating the behavioral impairment of escaping fish can help measure the effectiveness of bycatch reduction devices. Fisheries Research 131, 39-44.

Harmelin-Vivien, M.L., Harmelin, J.G., Chauvet, C., Duval, C., Galzin, R., Lejeune, P., Barnabé, G., Blanc, F., Chevalier, R., Duclerc, J., Lasserre, G., 1985. The underwater observation of fish communities and fish populations: Methods and problems. Revue d'Ecologie (Terre Vie) 40:44, 467-539.

Harvey, E., Cappo, M., Shortis, M., Robson, S., Buchanan, J., Speare, P., 2003. The accuracy and precision of underwater measurements of length and maximum body depth of southern bluefin tuna (*Thunnus maccoyii*) with a stereo–video camera system. Fisheries Research 63, 315-326.

Harvey, E., Fletcher, D., Shortis, M., 2001a. A comparison of the precision and accuracy of estimates of reef-fish lengths determined visually by divers with estimates produced by a stereo-video system. Fisheries Bulletin 99, 63-71.

Harvey, E., Fletcher, D., Shortis, M., 2001b. Improving the statistical power of visual length estimates of reef fish: a comparison of divers and stereo-video. Fisheries Bulletin 99, 72 - 80.

Harvey, E., Fletcher, D., Shortis, M., 2002a. Estimation of reef fish length by divers and by stereo-video. A first comparison of the accuracy and precision in the field on living fish under operational conditions. Fisheries Research 57, 255-265.

Harvey, E., Fletcher, D., Shortis, M.R., Kendrick, G.A., 2004. A comparison of underwater visual distance estimates made by scuba divers and a stereo-video system : implications for underwater visual census of reef fish abundance. Marine and Freshwater Research 55, 573-580.

Harvey, E., Shortis, M., 1995. A system for Stereo-Video Measurement of Sub-Tidal organisms. Marine Technology Society Journal 29, 10-22.

Harvey, E., Shortis, M., Stadler, M., Cappo, M., 2002b. A comparison of the accuracy and precision of measurements from single and stereo-video systems. Marine Technology Society Journal 36, 38-49.

Harvey, E.S., Butler, J.J., McLean, D.L., Shand, J., 2012a. Contrasting habitat use of diurnal and nocturnal fish assemblages in temperate Western Australia. Journal of Experimental Marine Biology and Ecology 426, 78-86.

Harvey, E.S., Cappo, M., Butler, J.J., Hall, N., Kendrick, G.A., 2007. Bait attraction affects the performance of remote underwater video stations in assessment of demersal fish community structure. Marine Ecology Progress Series 350, 245-254.

Harvey, E.S., Dorman, S.R., Fitzpatrick, C., Newman, S.J., McLean, D.L., 2012b. Response of diurnal and nocturnal coral reef fish to protection from fishing: an assessment using baited remote underwater video. Coral Reefs 31, 939-950.

Harvey, E.S., Newman, S.J., McLean, D.L., Cappo, M., Meeuwig, J.J., Skeeper, C.L., 2012c. Comparison of the relative efficiencies of stereo-BRUVs and traps for sampling tropical continental shelf demersal fishes. Fisheries Research 125-126, 108-120.

Harvey, E.S., Shortis, M.R., 1998. Calibration Stability of an Underwater Stereo Video System: Implications for Measurement Accuracy and Precision. Marine Technology Society Journal 32, 3 - 17.

Hayashizaki, K.-i., Ogawa, H., 2006. Introduction of underwater video system for the observation of coastal macroalgal vegetation. Coastal Marine Science 30, 196-200.

Heagney, E.C., Lynch, T.P., Babcock, R.C., Suthers, I.M., 2007. Pelagic fish assemblages assessed using mid-water baited video: standardising fish counts using bait plume size. Marine Ecology Progress Series 350, 255-266.

Heppell, S.A., Semmens, B.X., Archer, S.K., Pattengill-Semmens, C.V., Bush, P.G., McCoy, C.M., Heppell, S.S., Johnson, B.C., 2012. Documenting recovery of a spawning aggregation through size frequency analysis from underwater laser calipers measurements. Biological Conservation 155, 119-127.

Hill, B.J., Wassenberg, T.J., 2000. The probable fate of discards from prawn trawlers fishing near coral reefs: A study in the northern Great Barrier Reef, Australia. Fisheries Research 48, 277-286.

Hoey, A.S., 2010. Size matters: macroalgal height influences the feeding response of coral reef herbivores. Marine Ecology Progress Series 411, 299-U341.

Hoey, A.S., Bellwood, D.R., 2009. Limited Functional Redundancy in a High Diversity System: Single Species Dominates Key Ecological Process on Coral Reefs. Ecosystems 12, 1316-1328.

Hoey, A.S., Bellwood, D.R., 2010. Cross-shelf variation in browsing intensity on the Great Barrier Reef. Coral Reefs 29, 499-508.

Hoey, A.S., Bellwood, D.R., 2011. Suppression of herbivory by macroalgal density: a critical feedback on coral reefs? Ecology Letters 14, 267-273.

Holme, N.A., Barrett, R.L., 1977. A sledge with television and photographic cameras for quantitative investigation of the epifauna on the continental shelf. J Mar Biol Assoc Uk 57, 391-403.

Holt, D., 1967. opportunities for research utilizing underwater TV and acoustic systems. BioScience 17, 635-636.

Houk, P., Van Woesik, R., 2006. Coral Reef Benthic Video Surveys Facilitate Long-Term Monitoring in the Commonwealth of the Northern Mariana Islands: Toward an Optimal Sampling Strategy. Pacific Science 60, 177-189.

Jan, R.-Q., Shao, Y.-T., Lin, F.-P., Fan, T.-Y., Tu, Y.-Y., Tsai, H.-S., Shao, K.-T., 2007. An underwater camera system for real-time coral reef fish monitoring. The Raffles Bulletin of Zoology 14, 273-279

Jenkins, S.R., Mullen, C., Brand, A.R., 2004. Predator and scavenger aggregation to discarded by-catch from dredge fisheries: importance of damage level. Journal of Sea Research 51, 69-76.

Jones, D.T., Wilson, C.D., Robertis, A.D., Rooper, C.N., Weber, T.C., Butler, J.L., 2012. Evaluation of rockfish abundance in untrawlable habitat: combining acoustic and complementary sampling tools. Fisheries Bulletin 110, 332-343.

Johnson AF, Jenkins SR, Hiddink JG, Hinz H (2013) Linking temperate demersal fish species to habitat: scales, patterns and future directions. Fish and Fisheries 14:256-280

Jouffre, D., Borges, M.d.F., Bundy, A., Coll, M., Diallo, I., Fulton, E.A., Guitton, J., Labrosse, P., Abdellahi, K.o.M., Masumbuko, B., Thiao, D., 2010. Estimating EAF indicators from scientific trawl surveys: theorical and pratical concerns. Journal of Marine Science 67, 796-806.

Kenyon, J.C., Brainard, R.E., Hoeke, R.K., Parrish, F.A., Wilkinson, C.B., 2006. Towed-Diver Surveys, a Method for Mesoscale Spatial Assessment of Benthic Reef Habitat: A Case Study at Midway Atoll in the Hawaiian Archipelago. Coastal Management 34, 339-349.

Krohn, M.M., Boisclair, D., 1994. Use of a stereo-video system to estimate the energy expenditure of free swimming fish. Canadian Journal of Aquatic and Fisheries Science 51, 1119-1127.

Kronengold, M., Dann, R., Green, W.C., Loewenstein, J.M., 1964. An acoustic-video system for marine biological research : description of the system, in: Tavolga, W.N. (Ed.), Marine Bio-acoustics. Pergamon Press, New York, pp. 47-57.

Kulbicki, M., 1998. How the acquired behaviour of commercial reef fishes may influence the results obtained from visual censuses. Journal of Experimental Marine Biology and Ecology 222, 11-30.

Kulbicki, M., Cornuet, N., Vigliola, L., Wantiez, L., Moutham, G., Chabanet, P., 2010. Counting coral reef fishes: Interaction between fish life-history traits and transect design. Journal of Experimental Marine Biology and Ecology 387, 15-23.

Kumpf, H.E., 1964. Use of underwater television in bio-acoustic research, in: Tavolga, W.N. (Ed.), Marine Bio-Acoustics. Pergamon Press, New York, pp. 47-57.

Kumpf, H.E., Lowenstein, J.M., 1962. Undersea Observation Station. Sea Frontiers 8, 198-206.

LaFond, E.C., 1968. Photographic problems in oceanography, Underwater Photo-Optical Instrumentation Applications, Seminar Report, SPIE, San Diego, California, pp. 11-18.

LaFond, E.C., Barham, E.G., Armstrong, W.H., 1961. Use of underwater television in oceanographic studies of a shallow-water marine environment - Research and Development Report. U.S. Navy Electronics Laboratory, San Diego, California, p. 32.

Lam, K., Shin, P.K.S., Bradbeer, R., Randall, D., Ku, K.K.K., Hodgson, P., Cheung, S.G., 2006. A comparison of video and point intercept transect methods for monitoring subtropical coral communities. Journal of Experimental Marine Biology and Ecology 333, 115-128.

Langlois, T., Chabanet, P., Pelletier, D., Harvey, E., 2006. Baited underwater video for assessing reef fish populations in marine reserves, Secretariat of the South Pacific Community Fisheries Newsletter, pp. 53-56.

Langlois, T.J., Fitzpatrick, B.R., Fairclough, D.V., Wakefield, C.B., Hesp, S.A., McLean, D.L., Harvey, E.S., Meeuwig, J.J., 2012a. Similarities between Line Fishing and Baited Stereo-Video Estimations of Length-Frequency: Novel Application of Kernel Density Estimates. PLoS ONE 7, e45973.

Langlois, T.J., Harvey, E.S., Fitzpatrick, B., Meeuwig, J.J., Shedrawi, G., Watson, D.L., 2010. Cost-efficient sampling of fish assemblages: comparison of baited video stations and diver video transects. Aquatic Biology 9, 155-168.

Langlois, T.J., Harvey, E.S., Meeuwig, J.J., 2012b. Strong direct and inconsistent indirect effects of fishing found using stereo-video: Testing indicators from fisheries closures. Ecological Indicators 23, 524-534.

Lefèvre, C.D., Bellwood, D.R., 2011. Temporal variation in coral reef ecosystem processes: herbivory of macroalgae by fishes. Marine Ecology Progress Series 422, 239-251.

Leonard, G.H., Clark, R.P., 1993. Point quadrat versus video transect estimates of the cover of benthic red algae. Marine Ecology Progress Series 101, 203-208.

Leujak, W., Ormond, R.F.G., 2007. Comparative accuracy and efficiency of six coral community survey methods. Journal of Experimental Marine Biology and Ecology 351, 168 - 187.

Lincoln-Smith, M.P., 1988. Effects of observer swimming speed on sample counts of temperate rocky reef fish assemblages. Marine Ecology Progress Series 43, 223 - 231.

Longo, G.O., Floeter, S.R., 2012. Comparison of remote video and diver's direct observations to quantify reef fishes feeding on benthos in coral and rocky reefs. Journal of Fish Biology 81, 1773-1780.

Lowry, M., Folpp, H., Gregson, M., 2011. Evaluation of an underwater solid state memory video system with application to fish abundance and diversity studies in south east Australia. Fisheries Research 110, 10-17.

Lowry, M., Folpp, H., Gregson, M., Suthers, I., 2012. Comparison of baited remote underwater video (BRUV) and underwater visual census (UVC) for assessment of artificial reefs in estuaries. Journal of Experimental Marine Biology and Ecology 416-417, 243-253.

Lowry, M., Steffe, A., Williams, D., 2006. Relationships between bait collection, bait type and catch: A comparison of the NSW trailer-boat and gamefish-tournament fisheries. Fisheries Research 78, 266-275.

Machan, R., Fedra, K., 1975. A New Towed Underwater Camera System for Wide-Range Benthic Surveys. Marine Biology 33, 75-84.

Malcolm, H.A., Gladstone, W., Lindfield, S., Wraith, J., Lynch, T.P., 2007. Spatial and temporal variation in reef fish assemblages of marine parks in New South Wales, Australia—baited video observations. Marine Ecology Progress Series 350, 277–290.

Mallet, D., Wantiez, L., Lemouellic, S., Vigliola, L., Pelletier, D., 2014. Complementarity of rotating video and underwater visual census for assessing species richness, frequency and density of reef fish on coral reef slopes. PLoS ONE 9, e84344.

Mantyka, C.S., Bellwood, D.R., 2007a. Direct evaluation of macroalgal removal by herbivorous coral reef fishes. Coral Reefs 26, 435-442.

Mantyka, C.S., Bellwood, D.R., 2007b. Macroalgal grazing selectivity among herbivorous coral reef fishes. Marine Ecology Progress Series 352, 177-185.

Martinez, I., Jones, E.G., Davie, S.L., Neat, F.C., Wigham, B.D., Priede, I.G., 2011. Variability in behaviour of four fish species attracted to baited underwater cameras in the North Sea Hydrobiologia 670, 23-34.

Masuda, R., Matsuda, K., Tanaka, M., 2012. Laboratory video recordings and underwater visual observations combined to reveal activity rhythm of red-spotted grouper and banded wrasse, and their natural assemblages. Environmental Biology of Fishes 95, 335-346.

McCauley, D.J., McLean, K.A., Bauer, J., Young, H.S., Micheli, F., 2012. Evaluating the performance of methods for estimating the abundance of rapidly declining coastal shark populations. Ecological Applications 22, 385-392.

McDonald, J.I., Coupland, G.T., Kendrick, G.A., 2006. Underwater video as a monitoring tool to detect change in seagrass cover. Journal of Environmental Management 80, 148 - 155.

McLean, D.L., Harvey, E.S., Fairclough, D.V., Newman, S.J., 2010. Large decline in the abundance of a targeted tropical lethrinid in areas open and closed to fishing. Marine Ecology Progress Series 418, 189-199.

McLean, D.L., Harvey, E.S., Meeuwig, J.J., 2011. Declines in the abundance of coral trout (Plectropomus leopardus) in areas closed to fishing at the Houtman Abrolhos Islands, Western Australia. Journal of Experimental Marine Biology and Ecology 406, 71-78.

Meynecke, J.-O., Poole, G.C., Werry, J., Lee, S.Y., 2008. Use of PIT tag and underwater video recording in assessing estuarine fish movement in a high intertidal mangrove and salt marsh creek. Estuarine, Coastal and Shelf Science 79, 168–178.

Michalopoulos, C., Auster, P.J., Malatesta, R.J., 1992. A comparison of transect and species-time counts for assessing faunal abundance from video surveys. Marine Technology Society Journal 26, 27-31.

Moline, M.A., Schofield, O., 2009. Remote Real-Time Video-Enabled Docking for Underwater Autonomous Platforms. Journal of Atmospheric and Oceanis Technology 26, 2665-2672.

Monk, J., Ierodiaconou, D., Harvey, E., Rattray, A., Versace, V.L., 2012. Are We Predicting the Actual or Apparent Distribution of Temperate Marine Fishes? PLoS ONE 7.

Morrison, M., Carbines, G., 2006. Estimating the abundance and size structure of an estuarine population of the sparid Pagrus auratus, using a towed camera during nocturnal periods of inactivity, and comparisons with conventional sampling techniques. Fisheries Research 82, 150 - 161.

Murphy, H.M., Jenkins, G.P., 2010. Observational methods used in marine spatial monitoring of fishes and associated habitats: a review. Marine and Freshwater Research 61, 236-252.

Myrberg, A.A., 1972a. Social dominance and territoriality in the bicolor damselfish, Eupomacentrus partitus (Poey) (Pisces: Pomacentridae). Behaviour 41, 207-231.

Myrberg, A.A., 1972b. Using sound to influence the behaviour of free-ranging maruine animals, in: Winn, H.E., Olla, B.L. (Eds.), Behavior of marine animals-Current perspectives in research. PLenum Press, New York, pp. 435-468.

Myrberg, A.A., 1973. Underwater television-a tool for the marine biologist. Bulletin of Marine Science 23, 825-836.

Myrberg, A.A., Banner, A., Richard, J.D., 1969. Shark attraction using a video-acoustic system. Marine Biology 2, 264-276.

Myrberg, A.A., Spires, J.Y., 1972. Sound discrimination by the bicolor damselfish, Eupomacentrus partitus. Journal of Experimental Biology 57, 727-735.

Ninio, R., Delean, S., Osborne, K., Sweatman, H., 2003. Estimating cover of benthic organisms from underwater video images: variability associated with multiple observers. marine Ecology Progress Series 265, 107-116.

Ninio, R., Meekan, M., Done, T., Sweatman, H., 2000. Temporal patterns in coral assemblages on the Great Barrier Reef from local to large spatial scales. Marine Ecology Progress Series 194, 65-74.

Norris, J.G., Wyllie-Echeverria, S., Mumford, T., Bailey, A., Turner, T., 1997. Estimating basal area coverage of subtidal seagrass beds using underwater videography. Aquatic Botany 58, 269-287.

Parker, R.O., Chester, A.J., Nelson, R.S., 1994. A video transect method for estimating reef fish abundance, composition, and habitat utilization at Gray's Reef National Marine Sanctuary, Georgia. Fishery bulletin 92, 787-799.

Pelletier, D., 1991. Les sources d'incertitude en gestion des pêcheries: Evaluation et propagation dans les modèles. Institut National Agronomique Paris-Grignon, p275.

Pelletier, D., 2011. Constructing and validating indicators of MPA effectiveness, in: Claudet, J. (Ed.), Marine Protected Areas: Effects, networks and monitoring – A multidisciplinary approach. Cambridge University Press, pp. 247-289.

Pelletier, D., Leleu, K., Mallet, D., Mou-Tham, G., Hervé, G., Boureau, M., Guilpart, N., 2012. Remote High-Definition Rotating Video Enables Fast Spatial Survey of Marine Underwater Macrofauna and Habitats. PLoS ONE 7, e30536.

Pelletier, D., Leleu, K., Mou-Tham, G., Guillemot, N., Chabanet, P., 2011. Comparison of visual census and high definition video transects for monitoring coral reef fish assemblages. Fisheries Research 107, 84 - 93.

Petitgas, P., Cotter, J., Trenkel, V., Mesnil, B., 2009. Fish stock assessments using surveys and indicators. Aquatic Living Resources 22, 119-119.

Petrell, R.J., Shi, X., Ward, R.K., Naiberg, A., Savage, C.R., 1997. Determining fish size and swimming speed in cages and tanks using simple video techniques. Aquacultural Engineering 16, 63-84.

Phoenix, X.H., Boom, B.J., Fisher, R.B., 2013. Underwater Live Fish Recognition Using a Balance-Guaranteed Optimized Tree, in: Lee, K.M., Matsushita, Y., Rehg, J.M., Hu, Z. (Eds.), Computer Vision –ACCV 2012,11th Asian Conference on Computer Vision Daejeon, Korea, November 5-9, 2012. Revised Selected Papers, Part I: 422-433., pp. 422-433.

Picciulin, M., Sebastianutto, L., Codarin, A., Farina, A., Ferrero, E.A., 2010. In situ behavioural responses to boat noise exposure of Gobius cruentatus (Gmelin, 1789

Richard, J.D., 1968. Fish Attraction with Pulsed Low-Frequency Sound. Journal of Fisheries Research Board of Canada 25, 1441-1452.

Riegl, B., Korrubel, J.L., Martin, C., 2001. Mapping and monitoring of coral communities and their spatial patterns using a surface-based video method from a vessel. Bulletin of Marine Science 69, 869-880.

Robertson, D.R., Smith-Vaniz, W.F., 2008. Rotenone: An Essential but Demonized Tool for Assessing Marine Fish Diversity. BioScience 58, 165-170.

Rogers, C.S., Miller, J., 2001. Coral bleaching, hurricane damage, and benthic cover on coral reefs in St. John, U.S. Virgin Islands: A comparison of surveys with the chain transect method and videography Bulletin of Marine Science 69, 459-470.

Rooper, C.N., Zimmermann, M., 2007. A bottom-up methodology for integrating underwater video and acoustic mapping for seafloor substrate classification. Continental Shelf Research 27, 947–957.

Rosenkranz, G.E., Byersdorfer, S.C., 2004. Video scallop survey in the eastern Gulf of Alaska, USA. Fisheries Research 69, 131-140.

Sale, P.F., 1980. Assemblages of fish on patch reefs - predictable or unpredictable? Environmental Biology of Fishes 5, 243 - 249.

Salia, S.B., Nixon, S.W., Oviatt, C.A., 2002. Does lobster trap bait influence the Maine inshore trap fishery? North American Journal of Fisheries Management 22, 602-605.

Sarradin, P.M., Sarrazin, J., Allais, A.G., Almeida, D., Brandou, V., Boetius, A., Buffier, E., Coiras, E., Colaco, A., Comack, A., Dentrecolas, S., Desbruyeres, D., Dorval, P., du Buf, H., Dupont, J., Godfroy, A., Gouillou, M., Gronemann, J., Hamel, G., Hamon, M., Hoge, U., Lane, D., Le Gall, C., Leroux, D., Legrand, J., Leon, P., Leveque, J.P., Masson, M., Olu, K., Pascoal, A., Sauter, E., Sanfilippo, L., Savino, E., Sebastiao, L., Santos, R.S., Shillito, B., Simeoni, P., Schultz, A., Sudreau, J.P., Taylor, P., Vuillemin, R., Waldmann, C., Wenzhoefer, F., Zal, F., 2007. EXtreme ecosystem studies in the deep OCEan: Technological developments. Oceans 2007 - Europe, New York.

Schaner, T., Fox, M.G., Taraborelli, A.C., 2009. An Inexpensive System for Underwater Video Surveys of Demersal Fishes. Journal of Great Lakes Research 35, 317-319.

Schobernd, Z.H., Bacheler, N.M., Conn, P.B., 2013. Examining the utility of alternative video monitoring metrics for indexing reef fish abundance. Journal canadien des sciences halieutiques et aquatiques (doi: 0.1139/cjfas-2013-0086).

Schultz, A.L., Malcolm, H.A., Bucher, D.J., Smith, S.D.A., 2012. Effects of Reef Proximity on the Structure of Fish Assemblages of Unconsolidated Substrata. PLoS ONE 7.

Shortis, M.R., Seager, J.W., Williams, A., Barker, B.A., Sherlock, M., 2009. Using stereo-video for deep water benthic habitat surveys. Society Journal 42, 28-37.

Shucksmith, R., Hinz, H., Bergmann, M., Kaiser, M.J., 2006. Evaluation of habitat use by adult plaice (Pleuronectes platessa L.) using underwater video survey techniques. Journal of Sea Research 56, 317–328.

Smith, C.J., Banks, A.C., Papadopoulou, K.-N., 2007. Improving the quantitative estimation of trawling impacts from sidescan-sonar and underwater-video imagery. ICES Journal of Marine Science 64, 1692–1701.

Smith, C.L., Tyler, J.C., 1973. Population ecology of a Bahamian suprabenthic shore fish assemblage. American Museum novitates 2528, 37p.

Smith, P.A., 2002. The relationship between stock and catch and the effect of bait on catch as determined for a UK recreational catch and release fishery. Fisheries Management and Ecology 9, 261-266.

Spencer, M.L., Stoner, A.W., Ryer, C.H., Munk, J.E., 2005. A towed camera sled for estimating abundance of juvenile flatfishes and habitat characteristics: Comparison with beam trawls and divers. Estuarine, Coastal and Shelf Science 64, 497 - 503.

Steinberg, J.C., Cummings, W.C., Brahy, B.D., MacBain Spires, J.Y., 1965. Further Bio-Acoustic Studies off the West Coast of North Bimini, Bahamas Bulletin of Marine Science 15, 942-963.

Steinberg, J.C., Koczy, F.F., 1964. An acoustic-video system for marine biological research : Objectives and requirements, in: Tavolga, W.N. (Ed.), Marine Bio-acoustics. Pergamon Press, New York, pp. 1-9.

Stevenson, R.A., 1967. Underwater television. Oceanology International 2, 30-35.

Stevenson, R.A., Myrberg, A.A., 1966. Behavior of the bicolor damselfish, Eupomacentrus partitus, in the field and in the aquarium. American Society of zoologists 6, 516.

Stobart, B., García-Charton, J.A., Espejo, C., Rochel, E., Goñi, R., Reñones, O., Herrero, A., Crec'hriou, R., Polti, S., Marcos, C., Planes, S., Pérez-Ruzafa, A., 2007. A baited underwater video technique to assess shallow-water Mediterranean fish assemblages: Methodological evaluation. Journal of Experimental Marine Biology and Ecology 345 158–174.

Stokesbury, K.D.E., harris, B., P., Marino, M.C., Nogueira, J.I., 2004. Estimation of sea scallop abundance using a video survey in off-shore US waters. Journal of Shellfish Research 23, 33-40.

Stoner, A.W., Laurel, B.J., Hurst, T.P., 2008. Using a baited camera to assess relative abundance of juvenile Pacific cod: Field and laboratory trials. Journal of Experimental Marine Biology and Ecology 254, 202-211.

Tessier, E., 2005. Dynamique des peuplements ichtyologiques associés aux récifs artificiels à l'île de la Réunion (ouest de l'océan Indien) - Implication dans la gestion des pêcheries côtières., Ecologie Marine. Université de la Réunion, p. 254.

Tessier, E., Chabanet, P., Pothin, K., Soriae, M., Lasserre, G., 2005. Visual censuses of tropical fish aggregations on artificial reefs: slate versus video recording techniques. Journal of Experimental Marine Biology and Ecology 315 17-30.

Thompson, A.A., Mapstone, B.D., 1997. Observer effects and training in underwater visual surveys of reef fishes Marine Ecology Progress Series 154, 53-63.

Thresher, R.E., Gunn, J.S., 1986. Comparative analysis of visual census techniques for highly mobile, reef associated piscivores (carangidae). Environmental Biology of Fishes 17, 93–116.

Tilot, V., Leujak, W., Ormond, R.F.G., Ashworth, J.A., Mabrouk, A., 2008. Monitoring of South Sinai coral reefs: influence of natural and anthropogenic factors. Aquatic Conservation: Marine and Freshwater Ecosystems 18, 1109-1126.

Trenkel, V.M., Cotter, J., 2009. Choosing survey time series for populations as part of an ecosystem approach to fishery management. Aquatique Living Resources 22, 121-126.

Trenkel, V.M., Ressler, P.H., Jech, M., Giannoulaki, M., Taylor, C., 2011. Underwater acoustics for ecosystem-based management: state of the science and proposals for ecosystem indicators. Marine Ecology-Progress Series 442, 285-301.

Tyne, J.A., Loneragan, N.R., Krützen, M., Allen, S.J., Bejder, L., 2010. An integrated data management and video system for sampling aquatic benthos. Marine and Freshwater Research 61, 1023–1028.

Vergés, A., Bennett, S., Bellwood, D., 2012. Diversity among macroalgae-consuming fishes in coral reefs: a transcontinental comparison. PLoS ONE 7, e45543.

Vogt, H., Montebon, A.R.F., Alcala, M.L.R., 1997. Underwater video sampling: an effective method for coral reef surveys?, in: Lessios, H.A., Macintyre, I.G. (Eds.), Proceedings of the 8th International Coral Reef Symposium Vol. 2, Smithsonian Tropical Research Institute, Panama, pp. 1447-1452.

Watson, D.L., Anderson, M.J., Kendrick, G.A., Nardi, K., Harvey, E.S., 2009. Effects of protection from fishing on the lengths of targeted and non-targeted fish species at the Houtman Abrolhos Islands, Western Australia. Marine Ecology Progress Series 384, 241-249.

Watson, D.L., Harvey, E.S., 2007. Behaviour of temperate and sub-tropical reef fishes towards a stationary SCUBA diver. Marine and Freshwater Behaviour and Physiology 40, 85–103.

Watson, D.L., Harvey, E.S., Anderson, M.J., Kendrick, G.A., 2005. A comparison of temperate reef fish assemblages recorded by three underwater stereo-video techniques. Marine Biology 148, 415 - 425.

Watson, D.L., Harvey, E.S., Fitzpatrick, B.M., Langlois, T.J., Shedrawi, G., 2010. Assessing reef fish assemblage structure: how do different stereo-video techniques compare? Marine Biology 157, 1237 - 1250.

Watson, D.L., Harvey, E.S., Kendrick, G.A., Nardi, K., Anderson, M.J., 2007. Protection from fishing alters the species composition of fish assemblages in a temperate-tropical transition zone. Marine Biology 152, 1197-1206.

Watson, R.A., Carlos, G.M., Samoilys, M.A., 1995. Bias introduced by the non-random movement of fish in visual transect surveys. Ecological Modelling 77, 205-214.

Wells, R.J.D., Boswell, K.A., Cowan, J.H., Jr., Patterson, W.F., 2008. Size selectivity of sampling gears targeting red snapper in the northern Gulf of Mexico. Fisheries Research 89, 294-299.

Westera, M., Lavery, P., Hyndes, G., 2003. Differences in recreationally targeted fishes between protected and fished areas of a coral reef marine park. Journal of Experimental Marine Biology and Ecology 294, 145– 168.

Willis, T.J., 2001. Visual census methods underestimate density and diversity of cryptic reef fishes. Journal of Fish Biology 59, 1408–1411.

Willis, T.J., Babcock, R.C., 2000. A baited underwater video system for the determination of relative density of carnivorous reef fish. Marine and Freshwater Research 51, 755–763.

Willis, T.J., Millar, R.B., 2005. Using marine reserves to estimate fishing mortality. Ecology Letters 8, 47–52.

Willis, T.J., Millar, R.B., Babcock, R.C., 2000. Detection of spatial variability in relative density of fishes: comparison of visual census, angling, and baited underwater video. Marine Ecology Progress Series 198, 249 - 260.

Willis, T.J., Millar, R.B., Babcock, R.C., 2003. Protection of exploited fish in temperate regions: high density and biomass of snapper Pagrus auratus (Sparidae) in northern New Zealand marine reserves. Journal of Applied Ecology 40, 214 - 227.

Wraith, J.A., 2007. Assessing reef fish assemblages in a temperate marine park using baited remote underwater video. University of Wollongong, p. 100.

Young, M.A.L., Bellwood, D.R., 2012. Fish predation on sea urchins on the Great Barrier Reef. Coral Reefs 31, 731-738.

Table 1. Technical specifications of unbaited RUV systems. Horizontal (H) and vertical (V) in the second column refer to the direction of image recording.

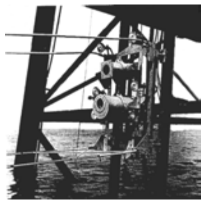
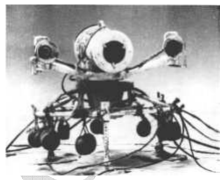
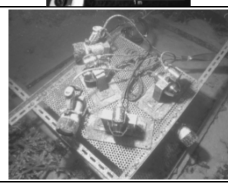
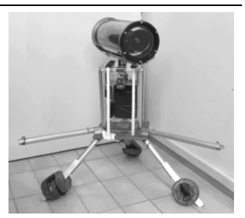
Source	Type	Technical details	Illustration
LaFond et al. (1961)	H-RUV	Mounted on a vertical rail Linked to mobile platform Additional equipment: six floodlights	
Kumpf and Lowenstein (1962); Kronengold et al. (1964)	AC-H-RUV	Linked to laboratory control panel by a multi-conductor cable. Observation duration: 24 h Lens view angle: wide 2 spotlights, hydrophones, sound projector	
Stevenson (1967); Holt (1967)	AC-HV-RUV	Linked to laboratory control panel Energy supplied through a submarine cable Observation duration: 24 h Pan tilt mechanism (360° horizontally and 50° vertically), lens view angle: wide Remotely controlled windshield-wiper, releasing a toxic material, hydrophones, sound projector	
Fedra and Machan (1979)	H-RUV	Autonomous Observation duration: 1 week Lens view angle: wide Side flash reflectors (12 V battery in separate housing), Electronic timer (6V batteries)	
Dunbrack and Zielinski (2003)	V-RUV	Autonomous Observation duration: 240h (20 days) Black & white camera, electronic timer Additional time-lapse video recorder	NA
Stokesbury et al. (2004) and Tyne et al. (2010)	V-RUV	Downward-oriented video camera, attached to the apex of a stainless steel pyramid Linked to boat Black & white camera linked to a laptop computer Additional infrared illumination	
Jan et al. (2007)	H-RUV	Linked to laboratory, internet video streaming Continuous recording: Colour camera Additional illumination for night time	
Aguzzi et al. (2011); Condal et al. (2012)	H-RUV	Linked to laboratory, transmission of audio and video for internet streaming Pan tilt mechanism (360° horizontally and ° 210° vertically)	NA
Pelletier et al. (2012)	ROT-H-RUV	2 waterproof housings connected by an axis. Engine lower housing sets in motion the upper housing Programmed rotations of 60°every 30 seconds Autonomous Observation duration: 9 min (i.e. 3 rotations) Colour HD camera, Lens view angle: 60°	

Table 2. Technical specifications of Baited RUV systems. Horizontal (H) and vertical (V) in the second column refer to the direction of image recording.

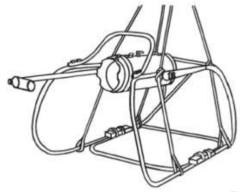
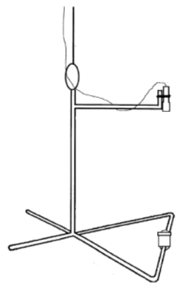
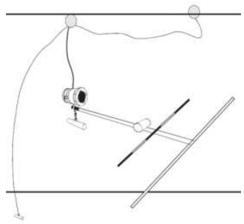
Source	Type	Technical details	illustration
Ellis and DeMartini (1995)	H-BRUV	Autonomous Set on bottom Observation duration: 10 to 60 min Colour camera (red filter for underwater vision) Lens view angle: wide No additional sensors	
Willis and Babcock (2000)	V-BRUV	Linked to boat Observation duration: 30 or 60 min Colour camera	
Heagney *et al.* (2007)	Mid-water H-BRUV	Autonomous Mid-water device Observation duration: 45 min Lens view angle: wide Depth sounder	

Table 3. Technical specifications of Towed video systems (TOWV). Camera orientation is reported in the third column.

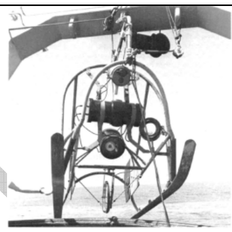
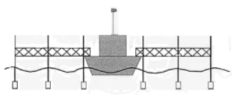
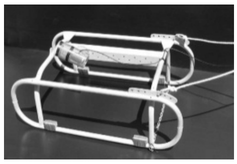
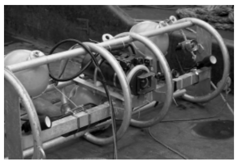
Source	Type	Technical details	Illustration
Machan and Fedra (1975)	Seabed TOWV	Angled down (30°) Linked to boat Boat speed: max 1 $m.s^{-1}$ Observation distance: 20 km in 1 day Still camera, spotlight, flash	
Holme and Barrett (1977)	Seabed TOWV	Angled down (45°) Linked to boat Boat speed: ½ - 1 knot (0.257-0.514 $m.s^{-1}$) Transect length: around 3.5 km Observation duration: 2.5 h (max 3h) Still camera, light	
Norris et al. (1997)	Mid-Water TOWV	Angled down Linked to boat Boat speed: max 1 $m.s^{-1}$ Transect length: 174 m Observation duration: 183 s Colour camera Additional light	NA
Riegl et al. (2001)	Mid-Water TOWV	Vertical The video cameras were individually linked to six onboard recorders Transect length: 50 m Colour camera Lens view angle: wide	
Spencer et al. (2005)	Seabed TOWV	Vertical Linked to boat Boat speed: 0.6 $m.s^{-1}$ Transect length: 30, 100, and 200 m Observation duration: 2 h Black & white camera Lens view angle: field of view = 5 m^2 Temperature sensor	
Hayashizaki and Ogawa (2006)	Mid-Water TOWV	Vertical Linked to boat Transect length: 50 m GPS, depth sounder	NA
Rooper and Zimmermann (2007)	Seabed TOWV	Angled down (35°) Linked to boat Boat speed:1.8-2.7 $km.h^{-1}$ Observation duration: 45 to 55 min Colour camera Three lasers, lights	

Table 4. Referenced studies involving DOV, with main protocol features, and study focus. For comparison, Bortone et al. (1991, 1994) presented the stationary rotating point count technique for counting fish, with an observation radius of 5.64 m (see text for details). ST: straight transect; TC: time census; TT: towed transect; BT: browsed transect.

Source	Census type	Length (m)	Distance above the bottom (cm)	Speed ($m.s^{-1}$)	Study Fish / Habitat
Alevizon and Brooks (1975)	ST	50	NA	NA	Fish
Davis and Anderson (1989)	ST	200	100	0.33	Fish
Greene and Alevizon (1989)	ST	NA	NA	constant	Fish
Leonard and Clark (1993)	ST	2	50	0.07	Habitat
Aronson et al. (1994)	ST	25	NA	slowly	Fish & Habitat
Parker et al. (1994)	TC (15 min)	NA	100	with prevailing current	Fish
Carleton and Done (1995)	TT	200	100 – 150	1 - 1.23	Habitat
	ST	200	100 – 150	0.63 - 0.78	Habitat
Vogt et al. (1997)	TT	500	50 – 70	0.11 - 0.25	Habitat
Ninio et al. (2000)	ST	50	25 - 30	NA	Habitat
Rogers and Miller (2001)	ST	20 and 100	40	0.03	Habitat
Ninio et al. (2003)	ST	50	25 to 30	NA	Fish & Habitat
Tessier (2005); Tessier et al. (2005)	ST	24	300	0.3	Fish
Watson et al. (2005)	ST	25	NA	NA	Fish & Habitat
Houk and Van Woesik (2006)	ST	15, 35 and 50	NA	0.15	Habitat
Kenyon et al. (2006)	TT	19.2 to 38.6	100	0.69 – 0.97	Habitat
Lam et al. (2006)	ST	50	40	0.10	Habitat
Leujak and Ormond (2007)	ST	50	30 – 35	0.12	Habitat
Cruz et al. (2008)	ST	20	40	0.05	Habitat
Langlois et al. (2010)	ST	25	30	3	Fish & Habitat
Watson et al. (2010)	ST	50 and 100	30	0.34	Fish & Habitat
Pelletier et al. (2011)	ST	50	150	0.2 - 0.3	Fish
	BT	50 x 4	varying elevation	speed	Fish

Table 5. Applications of underwater video techniques according to five main topics. NR indicates that No reference was found in the literature search.

	RUV	BRUV	TOWV	DOV
Natural behaviour and activity patterns (e.g. circadian)	Kumpf (1964); Steinberg and Koczy (1964); Steinberg et al. (1965); Cummings et al. (1966); Stevenson and Myrberg (1966); Stevenson (1967); LaFond (1968); Richard (1968); Myrberg et al. (1969); Colin (1971,1972,1973); Myrberg (1972a, 1972b); Myrberg and Spires (1972); Smith and Tyler (1973); Fedra and Machan (1979); Dunlap and Pawlik (1996); Barans et al. (2002, 2005); Bellwood et al. (2003) ; Dunbrack and Zielinski (2003); Jenkins et al. (2004); Bellwood et al. (2006); Dendrinos et al. (2007); Enstipp et al. (2007); Fischer et al. (2007); Fox and Bellwood (2007); Mantyka and Bellwood (2007a, 2007b); Bellwood and Fulton (2008); Fox and Bellwood (2008a); Meynecke et al. (2008); Cvitanovic and Bellwood (2009); Hoey and Bellwood (2009); Hoey (2010); Hoey and Bellwood (2010, 2011); Bennett and Bellwood (2011); Burkepile and Hay (2011); Lefèvre and Bellwood (2011); Burge et al. (2012); Hannah and Jones (2012); Masuda et al. (2012); Vergés et al. (2012) **(45 references)**	Burrows et al. (1999); Bond et al. (2012); Burge et al. (2012)	Bräger et al. (1999) ; Grabowski et al. (2012	Krohn and Boisclair (1994); Hall and Hanlon (2002
Effect of human-induced disturbance on species behaviour (diver, bait, acoustics)	Dearden et al. (2010); Watson and Harvey (2007); Picciulin et al. (2010)	Watson and Harvey (2007); Dorman et al. (2012); Langlois et al. (2012b); Young and Bellwood (2012)	NR	NR

Spatial and temporal patterns of abundance, size and fish assemblage composition (including effects of habitat, anthropogenic pressures and protection)	Dunbrack (2008) ; Becker et al. (2010); Aguzzi et al. (2011); Bloomfield et al. (2012); Burge et al. (2012); Chabanet et al. (2012); Condal et al. (2012); Pelletier et al. (2012) **(8 references)**	Willis and Babcock (2000); Willis et al. (2000, 2003); Denny and Babcock (2004); Denny et al. (2004); Cappo et al. (2007a); Malcolm et al. (2007); Stobart et al. (2007); Wraith (2007); Stoner et al. (2008); Gomelyuk (2009); Watson et al. (2009); Chatfield et al. (2010); McLean et al. (2010, 2011); Cappo et al. (2011); Göetze et al .(2011); Lowry et al. (2011) ;Martinez et al. (2011) ; Birt et al. (2012); Fitzpatrick et al. (2012) ; Gladstone et al. (2012) ; Harvey et al. (2012a,b); Schultz et al. (2012) **(25 references)**	Shucksmith et al. (2006); Carbines and Cole (2009)	Alevizon and Brooks (1975); Davis and Anderson (1989); Greene and Alevizon (1989); Aronson et al. (1994); Bortone et al. (1991, 1994); Parker et al. (1994); Ninio et al. (2000); Tessier et al. (2005) ; Watson et al. (2005, 2010); Langlois et al. (2010); Pelletier et al. (2011) **(13 references)**
Benthos abundance and size monitoring	Handley et al. (2003); Dunbrack (2006)	NR	Holme and Barrett (1977); Spencer et al. (2005)	NR
Habitat mapping, Benthic cover monitoring and impact of fishing gears on habitat	Tyne et al. (2010) ; Pelletier et al. (2012)	NR	Machan and Fedra (1975); Holme and Barrett (1977); Norris et al. (1997); Riegl et al. (2001); Rosenkranz and Byersdorfer (2004); Spencer et al. (2005); Hayashizaki and Ogawa (2006); McDonald et al. (2006); Bucas et al. (2007); Rooper and Zimmermann (2007); Smith et al. (2007); Grizzle et al. (2008); Carbines and Cole (2009); Bulh-Mortensen et al. (2012); Grabowski et al. (2012) **(15 references)**	Leonard and Clark (1993); Aronson et al. (1994); Carleton and Done (1995); Vogt et al. (1997); Ninio et al. (2000); Rogers and Miller (2001); Watson et al. (2005, 2010); Houk and Van Woesik (2006); Kenyon et al. (2006); Lam et al. (2006); Leujak and Ormond (2007); Cruz et al. (2008); Tilot et al. (2008); Langlois et al. (2010) **(15 references)**

Table 6. Metrics computed from the main video techniques. The list of metrics may depend on the particular implementation of the technique.

Technique	Fish and Macrofauna-related metrics	Benthos- and Habitat-related metrics
RUV and DOV	Frequency of occurrence, presence/absence per species Species richness Abundance or abundance density per species or per size class of the species : maximum abundance seen during the observation period, or mean abundance over viewing intervals during the observation period Number of bites by herbivores Distance from fish to the camcorder Occurrences of activities per individual	Percent cover of abiotic substrate Habitat topography and complexity Percent cover of epifauna and epiflora
BRUV	Number of species within the field of view during the observation period Maximum fish abundance seen during the observation period Maximum number of individuals per species simultaneously observed during the observation (MaxN) Time to first appearance per species	
TOWV	Abundance and percent cover of some macro-invertebrate species	Abundance of epibenthic species Percent cover of epifauna and epiflora Percent cover of biotic and abiotic substrate and habitat Habitat topography and complexity

Table 7. Studies comparing techniques. NR indicates that No reference was found in the literature search. Only studies with a protocol aimed at comparing data from distinct techniques were quoted.

	RUV	Stereo RUV	BRUV	Stereo BRUV	TOWV	DOV
RUV	NR	Harvey et al. (2002b)	Harvey et al. (2007); Bernard and Götz (2012)	NR	NR	NR
Stereo BRUV	NR	Watson et al. (2005)	NR	NR	NR	NR
TOWV	NR	NR	Morrison and Carbines (2006); Monk et al. (2012)	NR	NR	NR
Stereo DOV	NR	Watson et al. (2005)	NR	Watson et al. (2005); Langlois et al. (2010); Watson et al. (2010)	NR	NR
UVC	Francour et al. (1999); Cooke and Schreer (2002); Fox and Bellwood (2008); Burge et al. (2012); Longo and Floeter (2012); McCauley et al. (2012)	Harvey et al. (2001a,b, 2002a, 2004); Cappo et al. (2003)	Willis and Babcock (2000); Willis et al. (2000); Westera et al. (2003); Langlois et al. (2006); Morrison and Carbines (2006); Stobart et al. (2007); Colton and Swearer (2010); Burge et al. (2012); Lowry et al. (2012)	NR	Morrison and Carbines (2006); Assis et al. (2007); Leujak and Ormond (2007)	Greene and Alevizon (1989); Michalopoulos et al. (1992); Leonard and Clarck (1993); Rogers and Miller (2001); Tessier et al. (2005); Lam et al. (2006); Pelletier et al. (2011)
Fishing	Cooke and Schreer (2002); Wells et al. (2008)	NR	Ellis and DeMartini (1995); Willis et al. (2000); Cappo et al. (2004); Morrison and Carbines (2006); Bloomfield et al. (2012)	Harvey et al. (2012c); Langlois et al. (2012a)	Morrison and Carbines (2006)	NR
Acoustic	NR	NR	Gledhill et al. (1996)	NR	NR	NR

Table 8. Main outcomes of comparative studies involving video techniques (see references and Supplementary material B, C and D for details). For each topic of interest, symbols “>”, “≥”, “≠”,” ≈” compare the number of items or the assemblage structure detected by the two techniques, which may represent a qualitative summary over several results.

FISH	
Species richness	
UVC > H-BRUV > V-BRUV UVC > BRUV	Langlois et al. (2006) Colton and Swearer (2010)
UVC > RUV	Francour et al. (1999)
RUV > UVC & Experimental fishing	Cooke and Schreer (2002)
UVC ≥ DOV UVC >DOV	Pelletier et al. (2011) Green and Alevizon (1989)
TOWV > UVC	Assis et al. (2007)
BRUV > RUV & DOV	Watson et al. (2005) ; Bernard and Götz (2012)
RUV > BRUV	Harvey et al. (2007)
BRUV > DOV	Langlois et al. (2010); Watson et al. (2010)
BRUV > Exp. Fishing / Traps	Ellis and DeMartini (1995); Harvey et al. (2012b)
Assemblage structure	
UVC ≠ BRUV	Colton and Swearer (2010)
BRUV ≈ UVC	Westera et al. (2003)
BRUV ≠ RUV ≠ DOV	Watson et al. 2005)
BRUV ≠ DOV	Langlois et al. (2010); Watson et al. (2010)
BRUV ≠ TRAWL	Cappo et al. (2004)
BRUV > Traps	Harvey et al. (2012b)
Abundance	
UVC > BRUV	Langlois et al. (2006); Colton and Swearer (2010)
UVC ≥ DOV	Pelletier et al. (2011)
TOWV > UVC	Assis et al. (2007)
RUV > UVC & Exp. Fishing	Cooke and Schreer (2002)
BRUV > RUV	Harvey et al. (2007) ; Bernard and Götz (2012)
BRUV ≠ DOV (depends on family)	Watson et al. (2010)
UVC ≠ DOV (depends on family)	Pelletier et al. (2011)
BRUV > Traps	Harvey et al. (2012b)
Occurrences	
BRUV > Experimental fishing	Ellis and DeMartini (1995); Harvey et al. (2012b)
HABITAT – BENTHOS	
UVC > DOV: Diversity of coralline algae observed	Leonard and Clark (1993)
DOV ≈ UVC: Live coral cover	Rogers and Miller (2001)
DOV > UVC: % Coral cover Occurrence of Gorgonians & Macroalgae, % Bleached coral	Lam et al. (2006) Rogers and Miller (2001)
TOWV > UVC: % Benthic cover	Leujak and Ormond (2007)

Table 9. Cost-related information per technique.

	Reference	Staff time per station (hrs)
RUV	Bernard and Götz (2012)	3.5
	Pelletier et al. (2012) (ROT-RUV)	0.5-1.6
BRUV	Langlois et al. (2010) (stereo-BRUV)	1.75-3
	Bernard and Götz (2012)	7.0
	Gladstone et al. (2012)	1.5 (soaktime only)
DOV	Leujak and Ormond (2007)	
	Langlois et al. (2010) (stereo-DOV)	0.75-1.8
	Pelletier et al. (2011)	0.4-2.5
TOWV	See Table 3	depends on tow length
UVC	*Pelletier et al. (2011) (strip transect)*	*0.75-1.5*
	Bohnsack and Bannerot (1986) (stationary point count)	*0.2*
	Leujak and Ormond (2007) (Line Intercept Transect)	*1.25*

Table 10. Comparison of the main advantages and shortcomings of each observation technique and recommendations for future use. UVC, fishing and acoustics are reported for comparison.

Methods	Advantages	Shortcomings	Recommendations
RUV	Non extractive Least invasive method Constant observation duration Does not require diver Possible observation at large depth Fast implementation Possible participation of non-scientific staff	Duration of image analysis Management of large data sets	Diurnal and seasonal patterns of behaviour, species activity and abundance over long periods/at high frequencies Highly spatially-replicated designs Monitoring of conspicuous and target species
BRUV	Non extractive Increased observed fish abundance through baiting Constant observation duration Does not require diver Opportunity to work in deep water Possible participation of non-scientific staff	Unknown effect of bait plume Relatively long observation duration Duration of image analysis Management of large data sets	Monitoring populations of fishes, and particularly carnivorous species Monitoring in areas where diversity and abundance are low
TOWV	Non extractive Does not require diver Opportunity to work in deep water Fast implementation Large spatial coverage Possible participation of non-scientific staff	May disturb the ecosystem due to vessel noise Management of large data sets Duration of image analysis	Monitoring habitat and fixed benthic species over large areas
DOV	Non extractive Does not require scientific diver	All effects associated with the presence of a diver underwater (see below) Duration of image analysis	Study benthic cover and macrofauna
UVC	*Non extractive* *Widely used* *Possible participation of volunteers for simplified protocols*	*Observer effect* *Diver effect* *Depth limitation* *Requires diver trained to species identification and counting* *Observation duration*	*Studies at species level* *Inventories and species counts* *Small species*
Fishing	*Extractive* *Does not require diver* *Possible observation at large depth* *Possible participation of fishers*	*Unknown observation volume and species catchability*	*Monitoring of resources*
Acoustics	*Non extractive* *Spatial coverage* *Possible observation at large depth*	*High-tech analysis of data* *No species identification*	*Monitoring of resources coupled with another technique, e.g. fishing* *More suitable for pelagic species*

Figures

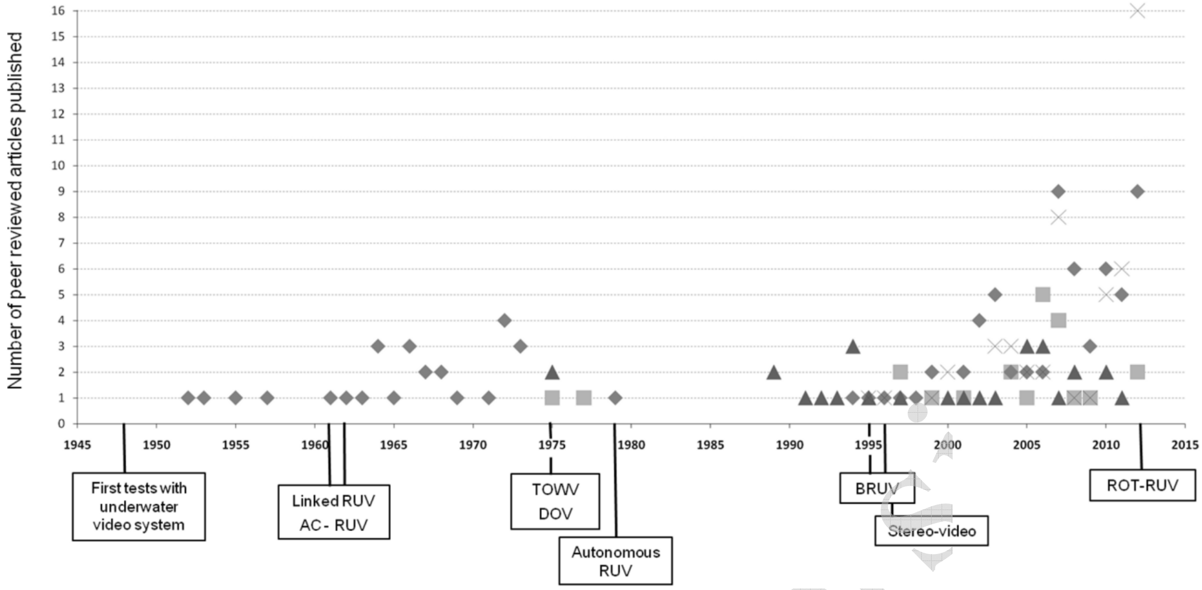


Figure 1. Historical perspective on the development of underwater video systems, with associated papers (◆RUV; ■ TOWV; ▲ DOV; X BRUV).

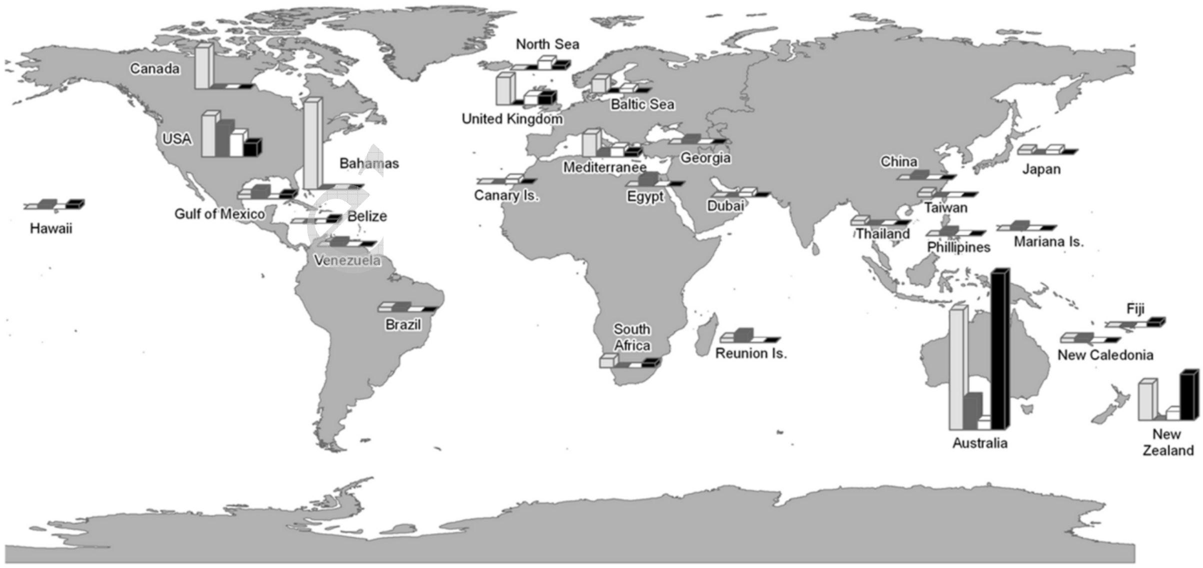


Figure 2. Geographical distribution of published studies. Each bar is proportional to the number of papers published for each technique: ▭ RUV; ■ DOV; ▭ TOWV and ■ BRUV. The number of papers published by year and country per technique are given in Supplementary Material A.

Supplementary material A. Geographical distribution of reviewed studies. Numbers after each region correspond to references available at the end of this document. They are classified from the oldest to the most recent reference for each region.

Technique	Region	Published years
RUV	United Kingdom [9, 10, 11, 31, 7]	1952 - 2002
	USA [6, 108, 23, 136, 59, 8, 30, 78, 126]	1957 - 2012
	Bahamas [106, 12, 104, 105, 157, 158, 48, 160, 98, 159, 107, 147, 138, 41, 42, 134, 135, 43, 154]	1962 - 1973
	Mediterranean sea [62, 46, 52, 146, 1, 45]	1979 - 2012
	Canada [103, 145, 58, 56, 61, 57]	1994 - 2008
	New Zealand [79, 80, 68, 81, 82, 83, 84, 77, 85, 87]	1995 - 2007
	Australia [16, 35, 89, 171, 17, 65, 122, 123, 172, 15, 66, 67, 130, 49, 94, 93, 95, 167, 18, 96, 114, 168]	2003 - 2012
	Ireland [101, 72]	2004 - 2009
	Baltic sea [63]	2007
	Taiwan [100]	2007
	Gulf of Mexico [175]	2008
	Thailand [51]	2010
	South Africa [14, 19]	2010 - 2012
	Brazil [117]	2012
	Japan [125]	2012
	New Caledonia [144]	2012
	Reunion Is.[39]	2012
TOWV	Mediterranean sea [120, 155]	1975 - 2007
	United Kingdom [97, 153]	1977 - 2006
	Philippines[169]	1997
	USA [141, 151, 162, 156, 150, 75]	1997 - 2008
	New Zealand [26, 133, 37]	1999 - 2009
	Dubai [148]	2001
	Australia [127, 132]	2006 - 2012
	Hawaï [102]	2006
	Japan [91]	2006
	Baltic sea [27]	2007
	Canary Is. [4]	2007
	Iceland [73]	2012
	Norway [28]	2012

Technique	Region	Published years
DOV	Venezuela [2]	1975
	USA [2, 50, 74, 131, 115, 3, 149]	1975 - 2001
	Gulf of Mexico [24, 25]	1991 - 1994
	Georgia [142]	1994
	Australia [38, 139, 76, 140, 171, 112, 174]	1995 – 2010
	Philippines [169]	1997
	Reunion Is. [164, 165]	2005
	China [109]	2006
	Hawaï [102]	2006
	Mariana Is. [99]	2006
	Egypt [116, 166]	2007 - 2008
	Brazil [47]	2008
	New Caledonia [143]	2011
BRUV	Hawaï [60]	1995
	Gulf of Mexico [70]	1996
	New Zealand [5, 177, 179, 180, 53, 54, 178, 111, 133, 87, 13]	1999 - 2011
	Australia [35, 176, 32, 171, 33, 34, 92, 121, 170, 181, 173, 112, 174, 40, 44, 129, 36, 118, 128, 20, 55, 64, 69, 86, 88, 90, 110, 113, 119, 132, 152, 182]	2003 - 2012
	Mediterranean sea [161]	2007
	USA [163, 29]	2008 - 2012
	Fiji [71]	2011
	North sea [124]	2011
	Belize [22]	2012
	United Kingdom [21]	2012

Supplementary material B. Main outcomes of the studies comparing a video technique with UVC (62% of comparative studies, Table 7). H-BRUV=Horizontal Remote Underwater Video, RUV=Remote Underwater Video, SRUV=stereo remote underwater video, DOV= Diver-Operated Video, TOWV= towed video, UVC=underwater visual census, V-BRUV=Vertical Remote Underwater Video.

	Main outcomes
RUV UVC	Highlight known taxa-specific attraction or repulsion effects with respect to diver[68]. Divers could make observations that were not possible from RUV (underwater perception & mobility)[68]. Density estimates of the five most abundant fish species were always greater from UVC than from RUV[68]. RUV permitted the detection of the most species and the largest number of individuals[46]. RUV was more cost-effective than UVC[68]. Variable visibility was the main limitation of the video technique[46].
SRUV UVC	Highlight diver effect (difference in estimates made by beginners vs. experienced scientific divers)[81, 82, 83]. Low variability around true lengths estimates made by SRUV[81, 83]. The coefficient of variation of fish length estimate was significantly lower for SRUV than for UVC[81, 82]. The power to detect changes in mean length was higher with SRUV[81, 82]. Diver-based estimates were more accurate (mean error 0.87 cm) than UVC but less precise (SD 5.29 cm)[83] and precision depended on the distance[84]. The error in the estimates increased as the individual moved away from the diver[84]. Diver-based estimates were less accurate than the stereo-video technique[83]. Distance was underestimated by divers[84].
BRUV UVC	BRUV recorded a larger number of species[110, 172, 176], more mobile predators[48] and a larger abundance of *Lethrinidae*[175] than UVC UVC recorded larger species richness and abundance (in terms of all species, herbivores, cryptic species, and most territorial species), higher richness, and higher biodiversity[44, 111, 165]. Data from BRUV could not be converted into density estimates per unit area[133]. BRUV was not suitable for the estimation of small snapper densities in an area of very high juvenile densities[133].
V-BRUV UVC	Density and average size was significantly larger for V-BRUV than for UVC[176, 178]. UVC recorded a larger abundance and diversity of fish[110]. Relative fish density was similar for both methods[178]. V-BRUV was an effective (and sometimes superior) alternative to UVC methods for estimating relative densities of predatory reef fish[176]. Lethrinidae and Serranidae did not approach the video system when the camera was above them[110].
TOWV UVC	Species richness, abundance, overall sampling effort and total surveyed area (121.968 ha vs. 0.310 ha) were higher when using TOWV[4]. TOWV estimates provided the most accurate coverage of major categories of benthic substrate[116]. TOWV only partially detected the very small fish but was more appropriate for larger individuals[133]. TOWV was more effective in term of observed size range, abundance estimates and cost[133].
DOV UVC	UVC recorded more red algae taxa than DOV, and DOV tended to overestimate the percent cover of rock and articulated coralline algae[115] DOV detected more individuals but UVC identified more species[74]. UVC was more accurate, better detected trends over time[109], recorded larger abundance and species richness[143], and was more cost-effective[115]. DOV provided representative observations of fish abundance and species diversity, although fewer species and individuals were detected[143]. Coral cover estimates were similar, but DOV-based cover estimates were higher for coral bleaching, gorgonians and macroalgae[149]. UVC overestimated the percent coral cover in coral-rich areas[109]. DOV and UVC yielded similar values for coral cover[149]. Browsing DOV detected more individuals and species than straight DOV, conducting DOV before or after UVC did not affect DOV observations[143]. The proportion of fish that were not identified up to the species level was 3.3% in High Definition video observations vs 1.7% in UVC[143].

Supplementary material C. Main outcomes of comparisons between video techniques (19% of all comparative studies, Table 7)

Techniques	Main outcomes
stereo-RUV RUV	Estimates were significantly more accurate and precise with the stereo-RUV than with the monovideo[84].
stereo-RUV stereo-BRUV	Species richness based on stereo-RUV was larger in diversified habitat and lesser in lower reef relief, while species richness based on stereo-BRUV was similar in the 2 habitats, and the relative abundance of rare and large predators and species richness were larger[172]. None of the techniques sampled small cryptic species (s.a. Gobiidae and Blenniidae)[172].
Stereo-RUV Stereo-DOV	Stereo-DOV recorded more species (42 vs. 23) and sampled more smaller or cryptic species than other methods (divers looked for them)[172]. Labridae richness was higher from stereo-RUV[172]. Both techniques detected a larger number of species in diversified habitat and a lesser number in lower reef relief[172]. None of the techniques identified small cryptic species (s.a. Gobiidae and Blenniidae)[172].
RUV BRUV	BRUV recorded difference in fish assemblages between habitats (in both temperate and tropical regions)[87]. The bait attracted a larger number of carnivores and scavengers without decreasing the representativeness of other trophic groups such as herbivores or omnivores[87].
H-BRUV V-BRUV	H-BRUV detected more fish individuals than V-BRUV[111]. (which was found to work well in New Zealand[176, 178]) H-BRUV recorded 14 species versus 3 species from V-BRUV[111].
stereo-BRUV DOV	DOV detected a larger number of species in diversified habitat and lesser in lower reef relief[172]. DOV detected a larger abundance of small Pomacentridae, Labridae and Scaridae[171]. Species richness based on stereo-BRUV was similar in the 2 habitats, and the relative abundance of rare and large predators and species richness were larger[172]. Stereo-BRUV observed larger species richness, larger relative biomasses of generalist carnivores. Spatial and temporal changes in fish assemblage were better detected from stereo-BRUV[110]. Stereo-BRUV was cost-effective for monitoring fish assemblages[110]. Observed species richness was 40% higher with stereo-BRUV compared to DOV. The number and abundance of large target species were larger, as well as many non target species[171]. None of the techniques detected small cryptic species (s.a. Gobiidae and Blenniidae)[172]. No difference in the biomass of herbivores observed by the 2 techniques[110].
V-BRUV TOWV	Data from BRUV could not be converted into density estimates per unit area[133]. BRUV were not suitable for the estimation of small snapper densities in an area of very high juvenile densities[133]. TOWV only partially detected the very small fish but was more appropriate for larger individuals[133]. TOWV was more effective in term of observed size range, abundance estimates and cost[133].

Supplementary material D. Main outcomes of comparisons between a video technique and fishing or acoustics (14% of all comparative studies about fishing techniques and 5% about acoustics, Table 7)

Techniques	Main outcomes
RUV Fishing	RUV detected more species and individuals[46]. Variable visibility was the main limitation of the video technique[46].
BRUV Fishing	BRUV recorded more species and individuals than fishing[46]. Trawling recorded mostly sedentary, cryptic and demersal species, but also more nocturnal species[32]. BRUV recorded larger and more mobile species[32].
V-BRUV Fishing	Observed size structures were consistent between the two techniques[178]. Relative densities were similar for both techniques[178]. Fishing recorded the largest species number[133]. Data from V-BRUV could not be converted into density estimates per unit area[133]. V-BRUV was not suitable for the estimation of small snapper densities in an area of very high juvenile densities[133].
TOWV Fishing	Fishing recorded the largest species number[133]. TOWV only partially detected the very small fish but was more appropriate for larger individuals[133]. TOWV was more effective in term of observed size range, abundance estimates and cost[133].
BRUV Acoustic	Acoustics coupled with a video camera produced complementary estimates of reef fish abundance[70]. Video data provided species identifications and abundance estimates that may vary with water clarity[70]. Acoustic data were not dependent on visibility[70].

References cited in supplementary materials

1. Aguzzi, J., Manuel, A., Condal, F., Guillen, J., Nogueras, M., del Rio, J., Costa, C., Menesatti, P., Puig, P., Sarda, F., Toma, D., Palanques, A., 2011. The New Seafloor Observatory (OBSEA) for Remote and Long-Term Coastal Ecosystem Monitoring. Sensors 11, 5850-5872.
2. Alevizon, W.S., Brooks, M.G., 1975. The comparative structure of two Western Atlantic reef-fish assemblages. Bulletin of Marine Science 25, 482-490.
3. Aronson, R.B., Edmunds, P.J., Precht, W.F., Swanson, D.W., Levitan, D.R., 1994. Large-scale, long-term monitoring of Caribbean coral reefs: simple, quick, inexpensive techniques. Atoll Research Bulletin 421, 1-19.
4. Assis, J., Narváez, K., Haroun, R., 2007. Underwater towed video: a useful tool to rapidly assess elasmobranch populations in large marine protected areas. Journal of Coastal Conservation 11, 153–157.
5. Babcock, R.C., Kelly, S., Shears, N.T., Walker, J.W., Willis, T.J., 1999. Changes in community structure in temperate marine reserves. Marine Ecology Progress Series 189, 125-134.
6. Backus, R.H., Barnes, H., 1957. Television-echo sounder observations of midwater sound scatterers. Deep-Sea Research 4, 116-119.
7. Barans, C.A., Arendt, M.D., Moore, T., Schmidt, D., 2005. Remote video revisited: A visual technique for conducting long-term monitoring of reef fishes on the continental shelf. Marine Technology Society Journal 39, 110-118.
8. Barans, C.A., Schmidt, D., Brouwer, M.C., 2002. Potential for coupling of underwater TV monitoring with passive acoustics, in: Rountree, R., Goudey, C., Hawkins, T., Luczkovich, J.J., Mann, D. (Eds.), Listening to Fish: Proceedings of the International Workshop on the Applications of Passive Acoustics to Fisheries. Massachusetts Institute of Technology Cambridge, USA, p. 172.
9. Barnes, H., 1952. Under-water television and marine biology. Nature 169, 477-479.
10. Barnes, H., 1953. Underwater television and research in marine biology, bottom topography and geology. I. A description of the equipment and its use on board ship. Deutsche Hydrographische Zeitschrift 6, 123-133.
11. Barnes, H., 1955. Underwater television and research in marine biology, bottom topography and geology. II. Experience with the equipment. Deutsche Hydrographische Zeitschrift 8, 213-236.
12. Barnes, H.B., 1963. Underwater television. Oceanography and Marine Biology: An Annual Review 11, 115-128.
13. Bassett, D.K., Montgomery, J.C., 2011. Investigating nocturnal fish populations in situ using baited underwater video: With special reference to their olfactory capabilities. Journal of Experimental Marine Biology and Ecology 409, 194-199.
14. Becker, A., Cowley, P.D., Whitfield, A.K., 2010. Use of remote underwater video to record littoral habitat use by fish within a temporarily closed South African estuary. Journal of Experimental Marine Biology and Ecology 391, 161 - 168.
15. Bellwood, D.R., Fulton, C.J., 2008. Sediment-mediated suppression of herbivory on coral reefs: decreasing resilience to rising sea levels and climate change? Limnology and Oceanography 53, 2695-2701.
16. Bellwood, D.R., Hoey, A.S., Choat, J.H., 2003. Limited functional redundancy in high diversity systems: resilience and ecosystem function on coral reefs. Ecology Letters 6, 281-285.
17. Bellwood, D.R., Hughes, T.P., Hoey, A.S., 2006. Sleeping functional group drives coral-reef recovery. Current Biology 16, 2434−2439.
18. Bennett, S., Bellwood, D.R., 2011. Latitudinal variation in macroalgal consumption by fishes on the Great Barrier Reef. Marine Ecology Progress Series 426, 241-U269.
19. Bernard, A.T.F., Götz, A., 2012. Bait increases the precision in count data from remote underwater video for most subtidal reef fish in the warm-temperate Agulhas bioregion. Marine Ecology Progress Series 471, 235-252.

20. Birt, M.J., Harvey, E.S., Langlois, T.J., 2012. Within and between day variability in temperate reef fish assemblages: Learned response to baited video. Journal of Experimental Marine Biology and Ecology 416-417, 92-100.
21. Bloomfield, H.J., Sweeting, C.J., Mill, A.C., Stead, S.M., Polunin, N.V.C., 2012. No-trawl area impacts: perceptions, compliance and fish abundances. Environmental Conservation 39, 237-247.
22. Bond, M.E., Babcock, E.A., Pikitch, E.K., Abercrombie, D.L., Lamb, N.F., Chapman, D.D., 2012. Reef Sharks Exhibit Site-Fidelity and Higher Relative Abundance in Marine Reserves on the Mesoamerican Barrier Reef. PLoS ONE 7.
23. Booda, L.L., 1966. Industry bees swarm at NEL. UnderSea Technology 7, 23-25.
24. Bortone, S.A., Martin, T., Bundrick, C.M., 1991. Visual census of reef fish assemblages: A comparison of slate, audio, and video recording devices. Northeast Gulf Science 12, 17-23.
25. Bortone, S.A., Martin, T., Bundrick, C.M., 1994. Factors Affecting Fish Assemblage Development on a Modular Artificial Reef in a Northern Gulf of Mexico Estuary. Bulletin of Marine Science 55, 319-332.
26. Bräger, S., Chong, A., Dawson, S., Slooten, E., Würsig, B., 1999. A combined stereo-photogrammetry and underwater-video system to study group composition of dolphins. Helgoland Marine Research 53, 122-128.
27. Bucas, M., Daunys, D., Olenin, S., 2007. Overgrowth patterns of the red algae Furcellaria lumbricalis at an exposed Baltic Sea coast: The results of a remote underwater video data analysis. Estuarine, Coastal and Shelf Science 75, 308-316.
28. Buhl-Mortensen, L., Buhl-Mortensen, P., Dolan, M.F.J., Dannheim, J., Bellec, V., Holte, B., 2012. Habitat complexity and bottom fauna composition at different scales on the continental shelf and slope of northern Norway. Hydrobiologia 685, 191-219.
29. Burge, E.J., Atack, J.D., Andrews, C., Binder, B.M., Hart, Z.D., Wood, A.C., Bohrer, L.E., Jagannathan, K., 2012. Underwater Video Monitoring of Groupers and the Associated Hard-Bottom Reef Fish Assemblage of North Carolina Bulletin of Marine Science 88, 15-38.
30. Burkepile, D.E., Hay, M.E., 2011. Feeding complementarity versus redundancy among herbivorous fishes on a Caribbean reef. Coral Reefs 30, 251-362.
31. Burrows, M.T., Kawai, K., Hughes, R.N., 1999. Foraging by mobile predators on a rocky shore: underwater TV observations of movements of blennies Lipophrys pholis and crabs Carcinus maenas. Marine Ecology Progress Series 187, 237-250.
32. Cappo, M., De'ath, G., Speare, P., 2007. Inter-reef vertebrate communities of the Great Barrier Reef Marine Park determined by baited remote underwater video stations. Marine Ecology Progress Series 350, 209–221.
33. Cappo, M., Harvey, E., Malcolm, H., Speare, P., 2003. Potential of video techniques to monitor diversity, abundance and size of fish in studies of marine protected areas, in: Beumer, J.P., Grant, A., Smith, D.C. (Eds.), APAC Congress 2002: Aquatic protected areas - What works best and how do we know ? World Congress on Aquatic Protected Areas proceedings. National Library of Australia, Cairns,Qld, Australia, pp. 455 - 464.
34. Cappo, M., Harvey, E., Shortis, M., 2007. Counting and measuring fish with baited video techniques - an overview, in: Lyle, J.M., Furlani, D.M., Buxton, C.D. (Eds.), Proceedings of the 2006 Australian Society of Fish Biology Conference and Workshop Cuttingedge Technologies in Fish and Fisheries Science, Hobart, August 2006, pp. 101-114.
35. Cappo, M., Speare, P., De'ath, G., 2004. Comparison of baited remote underwater video stations (BRUVS) and prawn (shrimp) trawls for assessments of fish biodiversity in inter-reefal areas of the Great Barrier Reef Marine Park. Journal of Experimental Marine Biology and Ecology 302 123–152.
36. Cappo, M., Stowar, M., Syms, C., Johansson, C., Cooper, T., 2011. Fish-habitat associations in the region offshore from James Price Point – a rapid assessment using Baited Remote Underwater Video Stations (BRUVS). Journal of the Royal Society of Western Australia 94, 303-321.
37. Carbines, G., Cole, R.G., 2009. Using a remote drift underwater video (DUV) to examine dredge impacts on demersal fishes and benthic habitat complexity in Foveaux Strait, Southern New Zealand. Fisheries Research 96 230–237.

38. Carleton, J.H., Done, T.J., 1995. Quantitative video sampling of coral reef benthos: large-scale application Coral Reefs 14, 35-46.
39. Chabanet, P., Loiseau, N., Join, J.-L., Ponton, D., 2012. VideoSolo, an autonomous video system for high-frequency monitoring of aquatic biota, applied to coral reef fishes in the Glorioso Islands (SWIO). Journal of Experimental Marine Biology and Ecology 430-431, 10-16.
40. Chatfield, B.S., Van Niel, K.P., Kendrick, G.A., Harvey, E.S., 2010. Combining environmental gradients to explain and predict the structure of demersal fish distributions. Journal of Biogeography 37, 593-605.
41. Colin, P.L., 1971. Interspecific Relationships of the Yellowhead Jawfish, Opistognathus aurifrons (Prisce, Opistognathidae). Copeia 1971, 469-473.
42. Colin, P.L., 1972. Daily Activity Patterns and Effects of Environmental Conditions on the Behavior of the yellowhead Jawfish, Opistognathus aurifons with Notes on its Ecology. Zoologica, N. Y. 57, 137-169.
43. Colin, P.L., 1973. Burrowing Behavior of the yellowhead Jawfish, Opistognathus aurifrons. Copeia 1973, 84-90.
44. Colton, M.A., Swearer, S.E., 2010. A comparison of two survey methods: differences between underwater visual census and baited remote underwater video. Marine Ecology Progress Series 400, 19-36.
45. Condal, F., Aguzzi, J., Sarda, F., Nogueras, M., Cadena, J., Costa, C., Del Rio, J., Manuel, A., 2012. Seasonal rhythm in a Mediterranean coastal fish community as monitored by a cabled observatory. Marine Biology 159, 2809-2817.
46. Cooke, S.J., Schreer, J.F., 2002. Determination of fish community composition in the untempered regions of a thermal effluent canal - The efficacy of a fixed underwater videography system. Environmental Monitoring and Assessment 73, 109-129.
47. Cruz, I.C.S., kikushi, R.K.P., Leão, Z.M.A.N., 2008. Use of the video transect method for characterizing the Itacolomis reefs, eastern Brazil. Brazilian Journal of Oceanography 56, 271-280.
48. Cummings, W.C., Brahy, B.D., Spires, J.Y., 1966. Sounds production, schooling, and feeding habits of the margate, Haemulon album Cuvier, off North Bimini, Bahamas. Bulletin of Marine Science 16, 626-640.
49. Cvitanovic, C., Bellwood, D.R., 2009. Local variation in herbivore feeding activity on an inshore reef of the Great Barrier Reef. Coral Reefs 28.
50. Davis, G.E., Anderson, T.W., 1989. Population estimates of four kelp forest fishes and an evaluation of three in situ assessment techniques. Bulletin of Marine Science 44, 1138-1151.
51. Dearden, P., Theberge, M., Yasué, M., 2010. Using underwater cameras to assess the effects of snorkeler and SCUBA diver presence on coral reef fish abundance, family richness, and species composition. Environmental Monitoring and Assessment 163, 531-538.
52. Dendrinos, P., Tounta, E., Karamanlidis, A.A., Legakis, A., Kotomatas, S., 2007. A Video Surveillance System for Monitoring the Endangered Mediterranean Monk Seal (Monachus monachus). Aquatic Mammals 33, 179-184.
53. Denny, C.M., Babcock, R.C., 2004. Do partial marine reserves protect reef fish assemblages? Biological Conservation 116, 119 - 129.
54. Denny, C.M., Willis, T.J., Babcock, R.C., 2004. Rapid recolonisation of snapper Pagrus auratus: Sparidae within an offshore island marine reserve after implementation of no-take status. Marine Ecology Progress Series 272, 183 - 190.
55. Dorman, S.R., Havrey, E.S., Newman, S.J., 2012. Bait Effects in Sampling Coral Reef Fish Assemblages with Stereo-BRUVs. PLoS ONE 7, e41538.
56. Dunbrack, R.L., 2006. In situ measurement of fish body length using perspective-based remote stereo-video. Fisheries Research 82, 327-331.
57. Dunbrack, R.L., 2008. Abundance trends for Hexanchus griseus, Bluntnose Sixgill Shark, and Hydrolagus colliei, Spotted Ratfish, counted at an automated underwater observation station in the Strait of Georgia, British Columbia. Canadian Field-Naturalist 122, 124-128.

58. Dunbrack, R.L., Zielinski, R., 2003. Seasonal and diurnal activity of sixgill sharks (Hexanchus griseus) on a shallow water reef in the Strait of Georgia, British Columbia. Canadian Journal of Zoology 81, 1107-1111.
59. Dunlap, M., Pawlik, J.R., 1996. Video-monitored predation by Caribbean reef fishes on an array of mangrove and reef sponges. Marine Biology 126, 117-123.
60. Ellis, D., DeMartini, E., 1995. Evaluation of a video camera technique for indexing abundances of juvenile pink snapper, Pristipomoides filamentosus, and other Hawaiian insular shelf fishes. Fishery Bulletin 93, 67-77.
61. Enstipp, M.R., Gremillet, D., Jones, D.R., 2007. Investigating the functional link between prey abundance and seabird predatory performance. Marine Ecology Progress Series 331, 267-279.
62. Fedra, K., Machan, R., 1979. A Self-Contained Underwater Time-Lapse Camera for in situ Long-Term observations. Marine Biology 55, 239-246.
63. Fischer, P., Weber, A., Heine, G., Weber, H., 2007. Habitat structure and fish: assessing the role of habitat complexity for fish using a small, semiportable, 3-D underwater observatory. Limnology and Oceanography: Methods 5, 250-262.
64. Fitzpatrick, B.M., Harvey, E.S., Heyward, A.J., Twiggs, E.J., Colquhoun, J., 2012. Habitat Specialization in Tropical Continental Shelf Demersal Fish Assemblages. PLoS ONE 7.
65. Fox, R.J., Bellwood, D.R., 2007. Quantifying herbivory across a coral reef depth gradient. Marine Ecology Progress Series 339, 49-59.
66. Fox, R.J., Bellwood, D.R., 2008. Direct versus indirect methods of quantifying herbivore grazing impact on a coral reef. Marine Biology 154, 325-334.
67. Fox, R.J., Bellwood, D.R., 2008. Remote video bioassays reveal the potential feeding impact of the rabbitfish Siganus canaliculatus (f: Siganidae) on an inner-shelf reef of the Great Barrier Reef Coral Reefs 27, 605-615.
68. Francour, P., Liret, C., Harvey, E., 1999. Comparison of fish abundance estimates made by remote underwater video and visual census. Naturalista Sicil 23, 155 - 168.
69. Gladstone, W., Lindfield, S., Coleman, M., Kelaher, B., 2012. Optimisation of baited remote underwater video sampling designs for estuarine fish assemblages. Journal of Experimental Marine Biology and Ecology 429, 28-35.
70. Gledhill, C.T., Lyczkowski-Shultz, J., Rademacher, K., Kargard, E., Crist, G., Grace, M.A., 1996. Evaluation of video and acoustic index methods for assessing reef-fish populations. Journal of Marine Science 53, 483-485.
71. Goetze, J.S., Langlois, T.J., Egli, D.P., Harvey, E.S., 2011. Evidence of artisanal fishing impacts and depth refuge in assemblages of Fijian reef fish. Coral Reefs 30, 1-11.
72. Gomelyuk, V.E., 2009. Fish assemblages composition and structure in three shallow habitats in north Australian tropical bay, Garig Gunak Barlu National Park, Northern Territory, Australia. J Mar Biol Assoc Uk 89, 449-460.
73. Grabowski, T.B., Boswell, K.M., McAdam, B.J., Wells, R.J.D., Marteinsdottir, G., 2012. Characterization of Atlantic Cod Spawning Habitat and Behavior in Icelandic Coastal Waters. PLoS ONE 7.
74. Greene, L.E., Alevizon, W.S., 1989. Comparative accuracies of visual assessment methods for coral reef fishes. Bulletin of Marine Science 44, 899 - 912.
75. Grizzle, R.E., Brodeur, M.A., Abeels, H.A., Greene, J.K., 2008. Bottom habitat mapping using towed underwater videography: subtidal oyster reefs as an example application. Journal of Coastal Research 24, 103-109.
76. Hall, K.C., Hanlon, R.T., 2002. Principal features of the mating system of a large spawning aggregation of the giant Australian cuttlefish Sepia apama (Mollusca : Cephalopoda). Marine Biology 140, 533-545.
77. Handley, S., Kelly, S., Kelly, M., 2003. Non-destructive video image analysis method for measuring growth in sponge farming: preliminary results from the New Zealand bath-sponge Spongia (Heterofibria) manipulatus. New Zealand Journal of Marine and Freshwater Research 37, 613-621.
78. Hannah, R.W., Jones, S.A., 2012. Evaluating the behavioral impairment of escaping fish can help measure the effectiveness of bycatch reduction devices. Fisheries Research 131, 39-44.

79. Harvey, E., Cappo, M., Shortis, M., Robson, S., Buchanan, J., Speare, P., 2003. The accuracy and precision of underwater measurements of length and maximum body depth of southern bluefin tuna (Thunnus maccoyii) with a stereo–video camera system. Fisheries Research 63, 315-326.
80. Harvey, E., Fletcher, D., Shortis, M., 2001. A comparison of the precision and accuracy of estimates of reef-fish lengths determined visually by divers with estimates produced by a stereo-video system. Fisheries Bulletin 99, 63-71.
81. Harvey, E., Fletcher, D., Shortis, M., 2001. Improving the statistical power of visual length estimates of reef fish: a comparison of divers and stereo-video. Fisheries Bulletin 99, 72 - 80.
82. Harvey, E., Fletcher, D., Shortis, M., 2002. Estimation of reef fish length by divers and by stereo-video. A first comparison of the accuracy and precision in the field on living fish under operational conditions. Fisheries Research 57, 255-265.
83. Harvey, E., Fletcher, D., Shortis, M.R., Kendrick, G.A., 2004. A comparison of underwater visual distance estimates made by scuba divers and a stereo-video system : implications for underwater visual census of reef fish abundance. Marine and Freshwater Research 55, 573-580.
84. Harvey, E., Shortis, M., 1995. A system for Stereo-Video Measurement of Sub-Tidal organisms. Marine Technology Society Journal 29, 10-22.
85. Harvey, E., Shortis, M., Stadler, M., Cappo, M., 2002. A comparison of the accuracy and precision of measurements from single and stereo-video systems. Marine Technology Society Journal 36, 38-49.
86. Harvey, E.S., Butler, J.J., McLean, D.L., Shand, J., 2012. Contrasting habitat use of diurnal and nocturnal fish assemblages in temperate Western Australia. Journal of Experimental Marine Biology and Ecology 426, 78-86.
87. Harvey, E.S., Cappo, M., Butler, J.J., Hall, N., Kendrick, G.A., 2007. Bait attraction affects the performance of remote underwater video stations in assessment of demersal fish community structure. Marine Ecology Progress Series 350, 245-254.
88. Harvey, E.S., Dorman, S.R., Fitzpatrick, C., Newman, S.J., McLean, D.L., 2012. Response of diurnal and nocturnal coral reef fish to protection from fishing: an assessment using baited remote underwater video. Coral Reefs 31, 939-950.
89. Harvey, E.S., Newman, S.J., McLean, D.L., Cappo, M., Meeuwig, J.J., Skeeper, C.L., 2012. Comparison of the relative efficiencies of stereo-BRUVs and traps for sampling tropical continental shelf demersal fishes. Fisheries Research 125-126, 108-120.
90. Harvey, E.S., Shortis, M.R., 1998. Calibration Stability of an Underwater Stereo Video System: Implications for Measurement Accuracy and Precision. Marine Technology Society Journal 32, 3 - 17.
91. Hayashizaki, K.-i., Ogawa, H., 2006. Introduction of underwater video system for the observation of coastal macroalgal vegetation. Coastal Marine Science 30, 196-200.
92. Heagney, E.C., Lynch, T.P., Babcock, R.C., Suthers, I.M., 2007. Pelagic fish assemblages assessed using mid-water baited video: standardising fish counts using bait plume size. Marine Ecology Progress Series 350, 255-266.
93. Hoey, A.S., 2010. Size matters: macroalgal height influences the feeding response of coral reef herbivores. Marine Ecology Progress Series 411, 299-U341.
94. Hoey, A.S., Bellwood, D.R., 2009. Limited Functional Redundancy in a High Diversity System: Single Species Dominates Key Ecological Process on Coral Reefs. Ecosystems 12, 1316-1328.
95. Hoey, A.S., Bellwood, D.R., 2010. Cross-shelf variation in browsing intensity on the Great Barrier Reef. Coral Reefs 29, 499-508.
96. Hoey, A.S., Bellwood, D.R., 2011. Suppression of herbivory by macroalgal density: a critical feedback on coral reefs? Ecology Letters 14, 267-273.
97. Holme, N.A., Barrett, R.L., 1977. A sledge with television and photographic cameras for quantitative investigation of the epifauna on the continental shelf. J Mar Biol Assoc Uk 57, 391-403.
98. Holt, D., 1967. opportunities for research utilizing underwater TV and acoustic systems. BioScience 17, 635-636.
99. Houk, P., Van Woesik, R., 2006. Coral Reef Benthic Video Surveys Facilitate Long-Term Monitoring in the Commonwealth of the Northern Mariana Islands: Toward an Optimal Sampling Strategy. Pacific Science 60, 177-189.

100. Jan, R.-Q., Shao, Y.-T., Lin, F.-P., Fan, T.-Y., Tu, Y.-Y., Tsai, H.-S., Shao, K.-T., 2007. An underwater camera system for real-time coral reef fish monitoring. The Raffles Bulletin of Zoology 14, 273-279.
101. Jenkins, S.R., Mullen, C., Brand, A.R., 2004. Predator and scavenger aggregation to discarded by-catch from dredge fisheries: importance of damage level. Journal of Sea Research 51, 69-76.
102. Kenyon, J.C., Brainard, R.E., Hoeke, R.K., Parrish, F.A., Wilkinson, C.B., 2006. Towed-Diver Surveys, a Method for Mesoscale Spatial Assessment of Benthic Reef Habitat: A Case Study at Midway Atoll in the Hawaiian Archipelago. Coastal Management 34, 339-349.
103. Krohn, M.M., Boisclair, D., 1994. Use of a stereo-video system to estimate the energy expenditure of free swimming fish. Canadian Journal of Aquatic and Fisheries Science 51, 1119-1127.
104. Kronengold, M., Dann, R., Green, W.C., Loewenstein, J.M., 1964. An acoustic-video system for marine biological research : description of the system, in: Tavolga, W.N. (Ed.), Marine Bio-acoustics. Pergamon Press, New York, pp. 47-57.
105. Kumpf, H.E., 1964. Use of underwater television in bio-acoustic research, in: Tavolga, W.N. (Ed.), Marine Bio-Acoustics. Pergamon Press, New York, pp. 47-57.
106. Kumpf, H.E., Lowenstein, J.M., 1962. Undersea Observation Station. Sea Frontiers 8, 198-206.
107. LaFond, E.C., 1968. Photographic problems in oceanography, Underwater Photo-Optical Instrumentation Applications, Seminar Report, SPIE, San Diego, California, pp. 11-18.
108. LaFond, E.C., Barham, E.G., Armstrong, W.H., 1961. Use of underwater television in oceanographic studies of a shallow-water marine environment - Research and Development Report. U.S. Navy Electronics Laboratory, San Diego, California, p. 32.
109. Lam, K., Shin, P.K.S., Bradbeer, R., Randall, D., Ku, K.K.K., Hodgson, P., Cheung, S.G., 2006. A comparison of video and point intercept transect methods for monitoring subtropical coral communities. Journal of Experimental Marine Biology and Ecology 333, 115-128.
110. Langlois, T., Chabanet, P., Pelletier, D., Harvey, E., 2006. Baited underwater video for assessing reef fish populations in marine reserves, Secretariat of the South Pacific Community Fisheries Newsletter, pp. 53-56.
111. Langlois, T.J., Fitzpatrick, B.R., Fairclough, D.V., Wakefield, C.B., Hesp, S.A., McLean, D.L., Harvey, E.S., Meeuwig, J.J., 2012. Similarities between Line Fishing and Baited Stereo-Video Estimations of Length-Frequency: Novel Application of Kernel Density Estimates. PLoS ONE 7, e45973.
112. Langlois, T.J., Harvey, E.S., Fitzpatrick, B., Meeuwig, J.J., Shedrawi, G., Watson, D.L., 2010. Cost-efficient sampling of fish assemblages: comparison of baited video stations and diver video transects. Aquatic Biology 9, 155-168.
113. Langlois, T.J., Harvey, E.S., Meeuwig, J.J., 2012. Strong direct and inconsistent indirect effects of fishing found using stereo-video: Testing indicators from fisheries closures. Ecological Indicators 23, 524-534.
114. Lefèvre, C.D., Bellwood, D.R., 2011. Temporal variation in coral reef ecosystem processes: herbivory of macroalgae by fishes. Marine Ecology Progress Series 422, 239-251.
115. Leonard, G.H., Clark, R.P., 1993. Point quadrat versus video transect estimates of the cover of benthic red algae. Marine Ecology Progress Series 101, 203-208.
116. Leujak, W., Ormond, R.F.G., 2007. Comparative accuracy and efficiency of six coral community survey methods. Journal of Experimental Marine Biology and Ecology 351, 168 - 187.
117. Longo, G.O., Floeter, S.R., 2012. Comparison of remote video and diver's direct observations to quantify reef fishes feeding on benthos in coral and rocky reefs. Journal of Fish Biology 81, 1773-1780.
118. Lowry, M., Folpp, H., Gregson, M., 2011. Evaluation of an underwater solid state memory video system with application to fish abundance and diversity studies in south east Australia. Fisheries Research 110, 10-17.
119. Lowry, M., Folpp, H., Gregson, M., Suthers, I., 2012. Comparison of baited remote underwater video (BRUV) and underwater visual census (UVC) for assessment of artificial reefs in estuaries. Journal of Experimental Marine Biology and Ecology 416-417, 243-253.
120. Machan, R., Fedra, K., 1975. A New Towed Underwater Camera System for Wide-Range Benthic Surveys. Marine Biology 33, 75-84.

121. Malcolm, H.A., Gladstone, W., Lindfield, S., Wraith, J., Lynch, T.P., 2007. Spatial and temporal variation in reef fish assemblages of marine parks in New South Wales, Australia—baited video observations. Marine Ecology Progress Series 350, 277–290.
122. Mantyka, C.S., Bellwood, D.R., 2007. Direct evaluation of macroalgal removal by herbivorous coral reef fishes. Coral Reefs 26, 435-442.
123. Mantyka, C.S., Bellwood, D.R., 2007. Macroalgal grazing selectivity among herbivorous coral reef fishes. Marine Ecology Progress Series 352, 177-185.
124. Martinez, I., Jones, E.G., Davie, S.L., Neat, F.C., Wigham, B.D., Priede, I.G., 2011. Variability in behaviour of four fish species attracted to baited underwater cameras in the North Sea Hydrobiologia 670, 23-34.
125. Masuda, R., Matsuda, K., Tanaka, M., 2012. Laboratory video recordings and underwater visual observations combined to reveal activity rhythm of red-spotted grouper and banded wrasse, and their natural assemblages. Environmental Biology of Fishes 95, 335-346.
126. McCauley, D.J., McLean, K.A., Bauer, J., Young, H.S., Micheli, F., 2012. Evaluating the performance of methods for estimating the abundance of rapidly declining coastal shark populations. Ecological Applications 22, 385-392.
127. McDonald, J.I., Coupland, G.T., Kendrick, G.A., 2006. Underwater video as a monitoring tool to detect change in seagrass cover. Journal of Environmental Management 80, 148 - 155.
128. Mclean, D.L., Harvey, E.S., Fairclough, D.V., Newman, S.J., 2010. Large decline in the abundance of a targeted tropical lethrinid in areas open and closed to fishing. Marine Ecology Progress Series 418, 189-199.
129. Mclean, D.L., Harvey, E.S., Meeuwig, J.J., 2011. Declines in the abundance of coral trout (Plectropomus leopardus) in areas closed to fishing at the Houtman Abrolhos Islands, Western Australia. Journal of Experimental Marine Biology and Ecology 406, 71-78.
130. Meynecke, J.-O., Poole, G.C., Werry, J., Lee, S.Y., 2008. Use of PIT tag and underwater video recording in assessing estuarine fish movement in a high intertidal mangrove and salt marsh creek. Estuarine, Coastal and Shelf Science 79, 168–178.
131. Michalopoulos, C., Auster, P.J., Malatesta, R.J., 1992. A comparison of transect and species-time counts for assessing faunal abundance from video surveys. Marine Technology Society Journal 26, 27-31.
132. Monk, J., Ierodiaconou, D., Harvey, E., Rattray, A., Versace, V.L., 2012. Are We Predicting the Actual or Apparent Distribution of Temperate Marine Fishes? PLoS ONE 7.
133. Morrison, M., Carbines, G., 2006. Estimating the abundance and size structure of an estuarine population of the sparid Pagrus auratus, using a towed camera during nocturnal periods of inactivity, and comparisons with conventional sampling techniques. Fisheries Research 82, 150 - 161.
134. Myrberg, A.A., 1972. Social dominance and territoriality in the bicolor damselfish, Eupomacentrus partitus (Poey) (Pisces: Pomacentridae). Behaviour 41, 207-231.
135. Myrberg, A.A., 1972. Using sound to influence the behaviour of free-ranging maruine animals, in: Winn, H.E., Olla, B.L. (Eds.), Behavior of marine animals-Current perspectives in research. PLenum Press, New York, pp. 435-468.
136. Myrberg, A.A., 1973. Underwater television-a tool for the marine biologist. Bulletin of Marine Science 23, 825-836.
137. Myrberg, A.A., Banner, A., Richard, J.D., 1969. Shark attraction using a video-acoustic system. Marine Biology 2, 264-276.
138. Myrberg, A.A., Spires, J.Y., 1972. Sound discrimination by the bicolor damselfish, Eupomacentrus partitus. Journal of Experimental Biology 57, 727-735.
139. Ninio, R., Delean, S., Osborne, K., Sweatman, H., 2003. Estimating cover of benthic organisms from underwater video images: variability associated with multiple observers. marine Ecology Progress Series 265, 107-116.
140. Ninio, R., Meekan, M., Done, T., Sweatman, H., 2000. Temporal patterns in coral assemblages on the Great Barrier Reef from local to large spatial scales. Marine Ecology Progress Series 194, 65-74.

141. Norris, J.G., Wyllie-Echeverria, S., Mumford, T., Bailey, A., Turner, T., 1997. Estimating basal area coverage of subtidal seagrass beds using underwater videography. Aquatic Botany 58, 269-287.
142. Parker, R.O., Chester, A.J., Nelson, R.S., 1994. A video transect method for estimating reef fish abundance, composition, and habitat utilization at Gray's Reef National Marine Sanctuary, Georgia. Fishery bulletin 92, 787-799.
143. Pelletier, D., Leleu, K., Mallet, D., Mou-Tham, G., Hervé, G., Boureau, M., Guilpart, N., 2012. Remote High-Definition Rotating Video Enables Fast Spatial Survey of Marine Underwater Macrofauna and Habitats. PLoS ONE 7, e30536.
144. Pelletier, D., Leleu, K., Mou-Tham, G., Guillemot, N., Chabanet, P., 2011. Comparison of visual census and high definition video transects for monitoring coral reef fish assemblages. Fisheries Research 107, 84 - 93.
145. Petrell, R.J., Shi, X., Ward, R.K., Naiberg, A., Savage, C.R., 1997. Determining fish size and swimming speed in cages and tanks using simple video techniques. Aquacultural Engineering 16, 63-84.
146. Picciulin, M., Sebastianutto, L., Codarin, A., Farina, A., Ferrero, E.A., 2010. In situ behavioural responses to boat noise exposure of Gobius cruentatus (Gmelin, 1789
147. Richard, J.D., 1968. Fish Attraction with Pulsed Low-Frequency Sound. Journal of Fisheries Research Board of Canada 25, 1441-1452.
148. Riegl, B., Korrubel, J.L., Martin, C., 2001. Mapping and monitoring of coral communities and their spatial patterns using a surface-based video method from a vessel. Bulletin of Marine Science 69, 869-880.
149. Rogers, C.S., Miller, J., 2001. Coral bleaching, hurricane damage, and benthic cover on coral reefs in St. John, U.S. Virgin Islands: A comparison of surveys with the chain transect method and videography Bulletin of Marine Science 69, 459-470.
150. Rooper, C.N., Zimmermann, M., 2007. A bottom-up methodology for integrating underwater video and acoustic mapping for seafloor substrate classification. Continental Shelf Research 27, 947–957.
151. Rosenkranz, G.E., Byersdorfer, S.C., 2004. Video scallop survey in the eastern Gulf of Alaska, USA. Fisheries Research 69, 131-140.
152. Schultz, A.L., Malcolm, H.A., Bucher, D.J., Smith, S.D.A., 2012. Effects of Reef Proximity on the Structure of Fish Assemblages of Unconsolidated Substrata. PLoS ONE 7.
153. Shucksmith, R., Hinz, H., Bergmann, M., Kaiser, M.J., 2006. Evaluation of habitat use by adult plaice (Pleuronectes platessa L.) using underwater video survey techniques. Journal of Sea Research 56, 317–328.
154. Smith, C.J., Banks, A.C., Papadopoulou, K.-N., 2007. Improving the quantitative estimation of trawling impacts from sidescan-sonar and underwater-video imagery. ICES Journal of Marine Science 64, 1692–1701.
155. Smith, C.L., Tyler, J.C., 1973. Population ecology of a Bahamian suprabenthic shore fish assemblage. American Museum novitates 2528, 37p.
156. Spencer, M.L., Stoner, A.W., Ryer, C.H., Munk, J.E., 2005. A towed camera sled for estimating abundance of juvenile flatfishes and habitat characteristics: Comparison with beam trawls and divers. Estuarine, Coastal and Shelf Science 64, 497 - 503.
157. Steinberg, J.C., Cummings, W.C., Brahy, B.D., MacBain Spires, J.Y., 1965. Further Bio-Acoustic Studies off the West Coast of North Bimini, Bahamas Bulletin of Marine Science 15, 942-963.
158. Steinberg, J.C., Koczy, F.F., 1964. An acoustic-video system for marine biological research : Objectives and requirements, in: Tavolga, W.N. (Ed.), Marine Bio-acoustics. Pergamon Press, New York, pp. 1-9.
159. Stevenson, R.A., 1967. Underwater television. Oceanology International 2, 30-35.
160. Stevenson, R.A., Myrberg, A.A., 1966. Behavior of the bicolor damselfish, Eupomacentrus partitus, in the field and in the aquarium. American Society of zoologists 6, 516.
161. Stobart, B., García-Charton, J.A., Espejo, C., Rochel, E., Goñi, R., Reñones, O., Herrero, A., Crec'hriou, R., Polti, S., Marcos, C., Planes, S., Pérez-Ruzafa, A., 2007. A baited underwater video technique to assess shallow-water Mediterranean fish assemblages: Methodological evaluation. Journal of Experimental Marine Biology and Ecology 345 158–174.

162. Stokesbury, K.D.E., harris, B., P., Marino, M.C., Nogueira, J.I., 2004. Estimation of sea scallop abundance using a video survey in off-shore US waters. Journal of Shellfish Research 23, 33-40.
163. Stoner, A.W., Laurel, B.J., Hurst, T.P., 2008. Using a baited camera to assess relative abundance of juvenile Pacific cod: Field and laboratory trials. Journal of Experimental Marine Biology and Ecology 254, 202-211.
164. Tessier, E., 2005. Dynamique des peuplements ichtyologiques associés aux récifs artificiels à l'île de la Réunion (ouest de l'océan Indien) - Implication dans la gestion des pêcheries côtières., Ecologie Marine. Université de la Réunion, p. 254.
165. Tessier, E., Chabanet, P., Pothin, K., Soriae, M., Lasserre, G., 2005. Visual censuses of tropical fish aggregations on artificial reefs: slate versus video recording techniques. Journal of Experimental Marine Biology and Ecology 315 17-30.
166. Tilot, V., Leujak, W., Ormond, R.F.G., Ashworth, J.A., Mabrouk, A., 2008. Monitoring of South Sinai coral reefs: influence of natural and anthropogenic factors. Aquatic Conservation: Marine and Freshwater Ecosystems 18, 1109-1126.
167. Tyne, J.A., Loneragan, N.R., Krützen, M., Allen, S.J., Bejder, L., 2010. An integrated data management and video system for sampling aquatic benthos. Marine and Freshwater Research 61, 1023–1028.
168. Vergés, A., Bennett, S., Bellwood, D., 2012. Diversity among macroalgae-consuming fishes in coral reefs: a transcontinental comparison. PLoS ONE 7, e45543.
169. Vogt, H., Montebon, A.R.F., Alcala, M.L.R., 1997. Underwater video sampling: an effective method for coral reef surveys?, in: Lessios, H.A., Macintyre, I.G. (Eds.), Proceedings of the 8th International Coral Reef Symposium Vol. 2, Smithsonian Tropical Research Institute, Panama, pp. 1447-1452.
170. Watson, D.L., Anderson, M.J., Kendrick, G.A., Nardi, K., Harvey, E.S., 2009. Effects of protection from fishing on the lengths of targeted and non-targeted fish species at the Houtman Abrolhos Islands, Western Australia. Marine Ecology Progress Series 384, 241-249.
171. Watson, D.L., Harvey, E.S., 2007. Behaviour of temperate and sub-tropical reef fishes towards a stationary SCUBA diver. Marine and Freshwater Behaviour and Physiology 40, 85–103.
172. Watson, D.L., Harvey, E.S., Anderson, M.J., Kendrick, G.A., 2005. A comparison of temperate reef fish assemblages recorded by three underwater stereo-video techniques. Marine Biology 148, 415 - 425.
173. Watson, D.L., Harvey, E.S., Fitzpatrick, B.M., Langlois, T.J., Shedrawi, G., 2010. Assessing reef fish assemblage structure: how do different stereo-video techniques compare? Marine Biology 157, 1237 - 1250.
174. Watson, D.L., Harvey, E.S., Kendrick, G.A., Nardi, K., Anderson, M.J., 2007. Protection from fishing alters the species composition of fish assemblages in a temperate-tropical transition zone. Marine Biology 152, 1197-1206.
175. Wells, R.J.D., Boswell, K.A., Cowan, J.H., Jr., Patterson, W.F., 2008. Size selectivity of sampling gears targeting red snapper in the northern Gulf of Mexico. Fisheries Research 89, 294-299.
176. Westera, M., Lavery, P., Hyndes, G., 2003. Differences in recreationally targeted fishes between protected and fished areas of a coral reef marine park. Journal of Experimental Marine Biology and Ecology 294, 145– 168.
177. Willis, T.J., Babcock, R.C., 2000. A baited underwater video system for the determination of relative density of carnivorous reef fish. Marine and Freshwater Research 51, 755–763.
178. Willis, T.J., Millar, R.B., 2005. Using marine reserves to estimate fishing mortality. Ecology Letters 8, 47–52.
179. Willis, T.J., Millar, R.B., Babcock, R.C., 2000. Detection of spatial variability in relative density of fishes: comparison of visual census, angling, and baited underwater video. Marine Ecology Progress Series 198, 249 - 260.
180. Willis, T.J., Millar, R.B., Babcock, R.C., 2003. Protection of exploited fish in temperate regions: high density and biomass of snapper Pagrus auratus (Sparidae) in northern New Zealand marine reserves. Journal of Applied Ecology 40, 214 - 227.
181. Wraith, J.A., 2007. Assessing reef fish assemblages in a temperate marine park using baited remote underwater video. University of Wollongong, p. 100.

182. Young, M.A.L., Bellwood, D.R., 2012. Fish predation on sea urchins on the Great Barrier Reef. Coral Reefs 31, 731-738.