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Comparison of baited remote underwater video (BRUV) and underwater visual census (UVC) for assessment of artificial reefs in estuaries

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Fish communities associated with a series of artificial reefs deployed in three estuaries in southeastern Australia (151° 34′ E, 33° 7′ S to 150° 37′ E, 35° 8′ S) were surveyed using both Baited Remote Underwater Video (BRUV) and Underwater Visual Census (UVC). Abundance estimates, frequency of observations, and species indicators (richness and diversity) provided the basis for comparison between methods. UVC recorded significantly greater numbers of species in all estuaries and significantly greater species richness and diversity at two of the three estuaries. Variation in the number and frequency of species detected by each method directly related to the ecological niche and behaviour of each species. UVC provided better estimates of the rare or cryptic reef associated species. BRUV sampled a smaller proportion of species overall but did observe key recreational species such as *Acanthopagrus australis*, *Pagrus auratus* and *Rhabdosargus sarba* with increased frequency, although the presence of large numbers of schooling species such as *Pelates sexlineatus* reduced the detection frequency of these species. In summary, results indicate that BRUV is an effective method for recording species associated with artificial reefs with the exception of cryptic species that are located within the reef structure itself. BRUV techniques complement UVC by providing increased coverage of species known to be diver averse as well as providing important information regarding behaviour of the species identified. Given the limitation of each method, it is recommended that monitoring plans for artificial structures should adopt a multi-method approach utilising BRUV and UVC where possible.

1. Introduction

Artificial reefs serve as management tools and research platforms (Bortone et al., 2011), but a critical element in understanding how artificial reefs can be integrated into resource management is the ability to evaluate their performance. Despite significant developments in construction and reef design, artificial reef projects have been criticised for a lack of appropriate experimental design and monitoring techniques (Claudet and Pelletier, 2004; Seaman and Jensen, 2000). Monitoring of artificial reefs is difficult, as the assemblage structure and recruitment patterns are also influenced by the relatively small size and isolated nature of many artificial reefs. Monitoring strategies which cover the entire artificial reef community are required to understand the broader effects of artificial structures and their role in fisheries management. Despite the application of various in situ visual monitoring methodologies in the assessment of artificial reefs, the relative biases associated with each method remain poorly understood, especially in estuaries. The assessment of these structures requires standardised sampling protocols and reliable data to underpin impact assessment and comparison between reefs (Bortone, 2006; Sale, 1980; Wilding and Sayer, 2002).

Sampling artificial reefs falls into two broad methods: 1) direct observation by divers' underwater visual census or UVC, (underwater visual census or UVC, Abelson and Shlesinger, 2002; Bohnsack et al., 1994); and 2) extractive methods including rotenone sampling (Randall 1963; Starck 1968) and variations of commercial fishing methods such as long-lining and gill netting (Gannon et al., 1985; Kelch et al., 1999). The practical limitations of destructive sampling methodologies, which are often prohibited in sensitive areas such as marine parks (Cappo et al., 2004; Lipej et al., 2003; Willis et al., 2003) have resulted in the widespread use of a range of visual census techniques to monitor fish assemblages on a variety of shallow marine habitats. In situ visual methods are relatively rapid, provide adequate levels of replication and simultaneously provide a broad suite of variables, e.g. relative abundance, density, size structure species composition and habitat characteristics (Bortone et al., 2000; Samoilys and Carlos, 2000). The limitations of diver-based methodologies, however, have been well documented (Kulbicki, 1998; Lincoln Smith, 1989; Smith, 1988; Thompson and Mapstone, 1997; Thresher and Gunn, 1986) and relate to the physical limitations of the diver (e.g. water depth and

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visibility) and various species specific sources of "detection heterogeneity" (Kulbicki, 1998; MacNeil et al., 2008).

The recent expansion of video sampling techniques such as baited remote underwater video (BRUV) has been a direct response to the limitations of existing in situ methods. BRUV systems provide an alternative method which can improve assessment of the fish community, and when used concurrently with traditional approaches will allow quantitative assessment of the potential method-based bias (Colton and Swearer, 2010; Willis et al., 2000). Studies comparing BRUV data with a variety of other video and UVC methods (Cappo et al., 2004; Colton and Swearer, 2010; Langlois et al., 2006; Tessier et al., 2005; Ward-Paige et al., 2010) have identified species, and site-related bias. This includes a negative effect of visibility on sampling efficiency, an inability to detect more cryptic reef associated species (Watson et al., 2005) and difficulties in determining the area sampled due to variables associated with the dispersion of bait (Bailey and Priede, 2002; Priede and Merrett, 1996, 1998).

The assessment of species assemblages associated with artificial structures needs to account for both species and site-related sources of detection heterogeneity. In general, artificial reefs are smaller, isolated habitats, and have a higher degree of structural complexity than naturally occurring reefs. Longer term studies indicate that assemblage differences between natural and artificial reefs may persist over extended periods (20–30 years) (Santos and Monteiro, 2007). The comparison of artificial and natural reef systems is central to assessing the potential of artificial reef as part of broader fisheries management frameworks. An assessment of conventional sampling techniques is required to determine the suitability of existing methodologies to accurately reflect the dynamics of the communities associated with artificial structures.

Previous studies associated with artificial structures which provide direct comparison of methods are limited to an evaluation of UVC and video transect surveys of tropical species (Tessier et al., 2005). Currently, there is no information comparing the use of BRUV and UVC methodologies to record fish assemblages on estuarine artificial structures. The objective of this study is to compare complementary UVC and BRUV data collected from estuarine artificial reefs to: 1) investigate the suitability of these techniques for describing the species assemblages associated with estuarine artificial reefs; 2) determine relative sources of bias associated with each method; and, 3) develop a sampling strategy that will provide a comprehensive and accurate assessment of artificial reefs.

2. Material and methods

2.1. Study sites

Surveys were carried out on artificial reefs in three coastal estuaries (Lake Macquarie, Botany Bay and St Georges Basin) along the coast of NSW in southeast Australia. Lake Macquarie (33° 7′ S 151° 34′ E) is 24 km long, covers an area of over 120 km^2 with an average depth of 7 m and is the largest coastal lake system in Australia. St Georges Basin (35° 08′ S 150° 37 E) and Botany Bay (33° 00′ S 151° 23′ E) have less than half the area of Lake Macquarie at 42 km^2 and 38 km^2 respectively. Lake Macquarie and St Georges Basin are classified as "wave-dominated" estuaries which rely predominantly on wind induced waves for water transport, and are characterised by narrow entrances that restrict marine flushing via tidal cycles (Roy et al., 2001). In contrast, Botany Bay is classified as a "tide-dominated" estuary being exposed to oceanic swells and having a wide entrance (1.8 km) which promotes efficient marine flushing through tidal cycles and wave action.

Botany Bay has undergone extensive modification by industrial, urban and port developments and includes shipping terminals, airport runways and large-scale shoreline modification (Albani, 2008). Lake Macquarie is a source of cooling water for three power stations located adjacent to the lake shore and has also been extensively modified by urban development. In comparison, St Georges Basin is relatively undeveloped with 80% of the area adjacent to the lake consisting of native vegetation (NLWRA, 2009). Temperature and salinity profiles reflect differences in location and morphology of the estuaries, with salinity in Botany Bay and St Georges Basin ranging from 30 to 35 and the salinity of Lake Macquarie ranging from 28 to 41. The temperature of Botany Bay and St Georges Basin ranges from 13 to 28 °C whereas the temperature of Lake Macquarie ranges from 10 to 28 °C annually (NLWRA, 2009).

Artificial reef systems were constructed using Minni-Bay Reef Ball® units. The bell shaped concrete units that weigh approximately 80 kg are open at the top and bottom with a large central void which can be accessed by several holes randomly spaced around the sides of the structure. Artificial reef systems in each estuary consisted of 180 Reef Ball® modules divided into six individual artificial reefs in a clumped arrangement (footprint $<$ 20 m^2) collectively defined as an artificial reef complex (AR complex). Each of the reefs was assigned a designator to identify estuary; Lake Macquarie (LM) Botany Bay (BB) and St Georges Basin (SGB) and reef type AR1–AR6. The Lake Macquarie reefs were deployed in December 2005 over an area of approximately 3 km^2 and approximately 200 m apart. The six reefs deployed at the St Georges Basin site were deployed in February 2007 over a larger area (5 km^2) and approximately 400 m apart. Lake Macquarie and St Georges Basin reefs were all deployed on sandy bottom along the 6 m depth contour at least 3 km from naturally occurring reef. The Botany Bay reefs deployed in June 2006 were spread over approximately 4 km^2 with the distance between reef units ranging from 500 to 800 m. Two of the Botany Bay reefs were inundated by sand limiting sampling to the remaining four artificial reefs.

2.2. Sampling design

Complementary BRUV and UVC sampling was conducted on 6 randomly selected sampling days within alternate 3 month periods resulting in 4 time periods ($4 \times 6 = 24$ sample days) for each estuary over the 2 year time frame. All artificial reefs in each estuary were sampled by both BRUV and UVC on each sample day. Surveys were carried out between 0800 h and 1600 h. Three BRUV systems were deployed on separate reefs concurrently for a 30 minute period until all reefs in each estuary were sampled. In order to eliminate potential bias associated with the effect of bait UVC observations were always carried out prior to BRUV sampling. To minimise possible bias related to diver effects on fish behaviour BRUV observations were carried at least 40 min after the completion of UVC.

2.3. Baited remote underwater video (BRUV) apparatus

Three BRUV systems were built based on the design of Cappo et al. (2004), with a stainless steel frame to mount the camera housing. A bait arm (20 mm diameter plastic conduit) extended 1 m from the face of the camera housing supported a plastic bait container. Units were baited using standardised bait consisting of a matrix of vegetable meal (falafel) and tuna oil that was replenished prior to every deployment. Initial trials indicated that the standardised mixture provided a constant rate of dissolution over the deployment times under a variety of conditions.

Three Sony DCR-HC21E Mini DV video cameras fitted with Sony 0.7X conversion lens (VCL-HGO737X) were used, each mounted inside a submersible housing. Cameras were set on 'short play' (SP) mode and focus set to "manual infinity". Analysis of tapes was carried out using the BRUV tape reading interface (Ericson and Cappo, 2006). Interrogation of video was carried out by the same reader according to the method used by Cappo et al. (2004, 2007a, 2007b). The maximum number (Max N) of each species observed in a single frame