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Tidal currents, sampling effort and baited remote underwater video (BRUV) surveys: Are we drawing the right conclusions?

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ABSTRACT

Estuaries are hydrographically dynamic environments, and such variability can affect the distribution and abundance of estuarine fish. Baited remote underwater video (BRUV) can be used to quantify estuarine species, but BRUV-derived data may be confounded by variable bait plume area and the associated effect on relative sampling effort. This study investigated the potential effects of current velocity on estuarine fish abundance data, and whether associated changes in bait plume size are important for benthic BRUV surveys in estuaries. BRUV sampling was conducted across two zones in two adjacent estuaries, and current velocity measured with a drogue during each BRUV deployment. Current velocity ranged from 0.02 to 0.65 m s^{-1}, resulting in potential bait plume areas that varied by orders of magnitude. The maximum number of each species (*MaxN*) was processed to produce a standardised (by bait plume area) and unstandardised multivariate species data set. The two data sets, whilst developed from identical video footage, yielded contrasting results. Unstandardised data was more variable, but produced a stronger correlation between abiotic variables and community structure. In addition, repeated sampling at some sites revealed significant temporal variance in community structure when data was standardised by bait plume area. Variability in sampling effort resulting from variable current velocity and associated bait plume area may confound interpretation of BRUV data.

1. Introduction

Fish community composition in estuaries can be sampled using a variety of techniques, ranging from observation to extraction. The choice of sampling methods is dependent on the focus of the study, but bias associated with each technique must be considered. A relatively new technique which is rapidly growing in application involves the use of baited remote underwater video (BRUV). BRUV surveys are non-invasive, and have the advantage of removing biases associated with divers on visual surveys (Lowry et al., 2012). The BRUV technique may also be used in habitats, or at depths which are difficult for divers to access (Willis et al., 2000), and is cost-effective for surveys which require many hours of observation (Harvey et al., 2007). In addition, the video footage obtained from BRUV surveys affords researchers the opportunity to observe fish in their natural environment (Jury et al., 2001; Watson et al., 2005), and also to re-analyse archival video footage at a later date to answer new research questions.

The application of BRUV surveys in marine ecology is increasing in frequency as technological advancements and cost reduction have made the technique both accessible and affordable (Harvey et al., 2007). BRUV surveys are often applied to examine fish populations in marine reserves (Cappo et al., 2004; McKinley et al., 2011) where extractive sampling is not ideal, and also in tropical and temperate reef (Watson et al., 2005) and pelagic environments (Heagney et al., 2007). A key element of BRUV is the use of "bait" to attract fish into the field-of-view of the video camera. The type of bait varies between studies, and can be formulated to attract a wide range of species, or can be highly specific to attract a specific species of fish. Typically, the bait disperses into the water column to form a plume of attractant down-current of the BRUV, and acts as an olfactory stimulus to attract fish. Fish follow the plume up-current to the source where their image is captured by the video camera; however, fish species that are indifferent to the plume can be opportunistically filmed as well if they wander into the field of view. Secondary attraction of larger predators outside the plume to the BRUV unit can also occur, as a result of the aggregation of smaller fishes in a small area.

There are several biases associated with traditional techniques of fish census, such as size and species selectivity when using extractive sampling using nets, and diver avoidance when using underwater visual census (Birt et al., 2012; Lowry et al., 2012).

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Cappo et al. (2004) suggested that BRUV surveys incorporate many of the sampling advantages offered by these traditional methods, whilst avoiding some of the biases, however this and subsequent studies have illustrated several sources of potential bias in BRUV surveys. Such bias may include (1) selection for daytime BRUV deployments which can under-sample nocturnally active species (Harvey et al., 2012a); (2) selectivity by each particular bait type or formulation for only a subset of the fish community (Dorman et al., 2012); (3) the confounding effect of short-term temporal variability in fish populations (Birt et al., 2012); (4) a general negative relationship between light level (i.e. at depth or in turbid water) and fish abundance (Watson et al., 2005); (5) interspecific interactions, especially between abundant and rare species (e.g. Birt et al., 2012); and (6) the upper limit to the number of fish which can be accurately counted in the field of view (Wraith, 2007). The widespread application of BRUV surveys is now leading to an expanded literature which explicitly and quantitatively investigates the relative effect of these biases and implications for BRUV-derived data (e.g. Birt et al., 2012; Harvey et al., 2012a,b).

One particular bias involves the standardisation of sampling effort among BRUV deployments. Many organisms employ a phased strategy during olfactory-guided searches for prey or bait (e.g. Lokkeborg et al., 2000; Stiansen et al., 2010). Fish typically employ two phases of behaviour in relation to olfactory stimuli; plume-search (search for relevant stimuli), followed by the bait-search (search when an olfactory stimulus has been encountered Vabø et al., 2004). Variable bait plume size affects the probability that a fish will encounter the relevant stimuli or attractant, and thus affects the ability of any baited apparatus to sample fish or invertebrates; including fish traps (Stiansen et al., 2010), baited nets (Hill and Wassenberg, 1999), and BRUV (Heagney et al., 2007). Many BRUV studies simply hold the duration of video footage constant, or where duration differs, use time to standardise measurements taken during different deployments. Implicit in this is the assumption that each deployment samples an equivalent area of water per unit time (e.g. Hill and Wassenberg, 1999; Jones et al., 2003); however, this assumption may not be reasonable in all environments. Heagney et al. (2007) described in detail the measurement and application of bait-plume size when deploying BRUV units in often turbulent pelagic configuration in coastal areas, however few studies have yet applied this approach to either benthic or pelagic BRUV surveys. Current velocity at the bottom of the water column can vary substantially as a result of stress at the sediment–water interface (Thomas and Schallenberg, 2008). The effect of this variability on bait plume penetration and dispersal, and the importance for fish abundance needs quantitative assessment.

This study uses benthic BRUV surveys to investigate the potential effects of tidal current velocity on estuarine fish abundance data, and whether consideration of the effect of current velocity and thus associated changes in bait plume size are an important consideration for benthic BRUV surveys. Specifically, we aim to assess the effect of standardisation by current velocity and associated plume area on (1) interpretation of analyses of fish community structure using standard multivariate techniques; (2) temporal changes in fish community structure.

2. Materials and methods

2.1. Study sites and experimental design

The study was conducted in Botany Bay/Georges River estuary (34.01°S, 151.24°E) and Port Hacking (33.83°S, 151.28°E), two adjacent estuaries in the Sydney metropolitan area. Botany Bay/Georges River estuary (subsequently referred to as 'Botany Bay') is a heavily urbanised drowned river valley feeding into a coastal embayment of waterway area 92 km^2. Port Hacking is a drowned river valley of approximately 180 km^2 and a waterway area of 11 km^2. Both Port Hacking and Botany Bay are recreational fishing reserves, and contain mangrove, saltmarsh and seagrass beds.

BRUVs were deployed following a typical experimental design to examine the difference between estuarine fish assemblages within different hydrographic zones (e.g. McKinley et al., 2011). Specifically, the design included three factors: (1) zone (2-levels, Inner and Outer, fixed); (2) estuary (2-levels, Botany Bay and Port Hacking, random); and (3) site (random, nested within Zone). Estuary was included as a random factor to explore generality in any differences between Zones. Site was included as a random factor to partition variability across the spatial scale of each Zone. Zones were defined primarily on the basis of salinity. Within the 'Outer' zone, the dominant salinity influence was the tidal flows from the open ocean into the mouth of the estuary. The salinity influence of the 'Inner' zone was a combination of tides and freshwater influxes from the land including rivers and tributaries which feed into the estuary. Ten sites (~0.25 km^2) approximately 2 km apart, were selected within each zone and surveyed, with two single-camera BRUVs deployed within each site (Fig. 1).

A second, smaller experiment was also completed to assess aim 2, and evaluate the effect of standardisation on interpretation of temporal changes in fish community structure. Five sites (Site, 5-levels, fixed) within the outer zone of Port Hacking were randomly sampled at four times (Time, 4-levels, random) spread over multiple days, to capture variation in tidal and diel conditions. Two BRUV drops were simultaneously performed at random locations within each Site, at each time point.

2.2. Equipment and data collection

Each BRUV apparatus consisted of a digital video camera (Sony DCR-HC21E) mounted inside a custom-built PVC housing. The camera housing was attached to a mooring and float, and suspended ~1 m above the mooring to avoid potential interference from the epi-benthic layer of phytoplankton often present in estuaries. The bait arm extended horizontally from the camera housing, and a 13 cm × 8 cm bait housing was attached to the end of the arm exactly 1 m from the camera lens. The camera and bait arm were free to swing in the direction of the current, thus allowing fish to be observed swimming upcurrent into the bait plume. The bait housing contained a 100 g mixture of minced pilchards (80 g), falafel (10 g) and tuna oil (10 g, Folpp et al., 2011; Heagney et al., 2007; Lowry et al., 2012). Previous studies have indicated that this standardised mixture provided a constant rate of dissolution over the deployment times under a variety of conditions (Lowry et al., 2012).

Deployments across all sites were undertaken over a period of 10 deployment days during the period 22 March–4 April 2010, between 08:00 and 18:00 h. Deployments were performed in a random order, thus there was no correlation between the order in which sites were sampled, and tide or time of day. Deployments typically occurred in 5–10 m of water, and BRUVs were retrieved within 60 min of deployment. Water temperature, salinity and turbidity were recorded for each deployment using a YEO-KAL Model 611 Water Quality Analyser, with measurements taken at the same depth as the camera housing.

Water current data was collected using a drifting drogue (as described in Heagney et al., 2007). We used the drogue drift rates to determine current velocity and estimate plume area. A drifting drogue only represents two dimensions of the three dimensional advection of the plume, and does not account for turbulence and dispersion, but despite these potential limitations we assume that this relatively easy approach to collecting current velocity data to