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Development of rapid sampling procedures for an exploited bivalve in the swash zone on exposed ocean beaches

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ABSTRACT

We assessed a time-based technique for estimating the relative abundance and size composition of populations of the beach clam, *Donax deltoides*, in the swash zone of exposed ocean beaches by comparing it with a standard quadrat-based method. The time-based method consisted digging small plots of sand by hand and scooping sediment and clams into a mesh bag attached to a rigid frame. We tested three digging times (30, 60 and 120 s) and two mesh sizes (12 and 19 mm). Compared to a standard box-quadrat, the time-based diggings were more effective and efficient in terms of numbers of clams collected per time taken to do a sample. The timed digging technique was also much simpler and less problematic to use in the swash zone, which is important when industry are involved in sampling. Although a greater total number of clams were collected in the 120 s diggings, when the CPUE data were standardized to number per 30 s, a greater proportion of clams were collected in the shortest time frame tested. This suggests most clams were captured in the first 30 s of digging, with fewer caught per unit of time thereafter. A major benefit of using the shortest digging time is that a greater number of replicate samples and patches of clams on a beach can be sampled per given unit of time, potentially improving overall precision without large increases in costs. An optimal sampling design would involve sampling more patches on a beach than replicates within a patch. Given a sampling window of 3 h either side of low tide, we suggest that future sampling should incorporate 6 replicate 30-s diggings at each of 8 patches on a beach. We further recommend that a 12 mm mesh bag be used as it retained a greater proportion of small clams (<20 mm). This study highlights the importance of doing pilot studies to develop appropriate sampling gears and for determining optimal, cost-effective sampling strategies for large-scale surveys.

1. Introduction

Burrowing bivalve molluscs of the families Donacidae, Mesodermatidae, Solenidae and Veneridae, commonly known as beach or surf clams, are found on exposed sandy beaches worldwide (Ansell, 1983; McLachlan et al., 1995, 1996; Castilla and Defeo, 2001). Beach clams can occur in high densities, contribute greatly to overall benthic faunal biomass, and thus play important trophic and ecological roles in ocean beach ecosystems (McLachlan et al., 1996; Defeo and McLachlan, 2005). Many species are of anthropogenic importance both socially and economically, as they are harvested for human consumption and bait (McLachlan et al., 1996; Murray-Jones and Steffe, 2000; Defeo, 2003).

The beach clam *Donax deltoides* (Lamarck, 1818) is the largest and most common burrowing bivalve inhabiting exposed, coastal, sandy beaches in eastern and southern Australia (James and Fairweather, 1995; Murray-Jones and Ayre, 1997; Ferguson and Mayfield, 2006). They are primarily distributed in the swash zones (shallow subtidal to high intertidal areas) of high-energy dissipative beaches (King, 1976), with dense aggregations often accounting for up to 85% of the total benthic faunal biomass on some beaches (Murray-Jones, 1999). Like other burrowing bivalves, *D. deltoides* can exhibit large temporal and spatial fluctuations in abundance and are potentially vulnerable to anthropogenic disturbances including over-harvesting (Defeo and De Alava, 1995; Ferguson and Mayfield, 2006; Ortega et al., 2012).

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Population levels and commercial catches of *D. deltoides* have declined across numerous east Australian beaches over the past decade, with the New South Wales (NSW) total landed commercial catch decreasing from over 500 tonnes to less than 100 tonnes between 2004 and 2010 (Rowling et al., 2010; O'Connor and O'Connor, 2011). This has occurred despite increasing product prices and markets (Rowling et al., 2010). The paucity of current demographic information on east coast populations has hampered assessments and development of harvest plans for the species (Murray-Jones, 1999; Murray-Jones and Steffe, 2000). This contrasts the situation in southern Australia where the major commercial fishery is regularly assessed and managed by annual quota controls (Ward et al., 2010; Ferguson, 2013).

In response to the declines in commercial catches of *D. deltoides* in NSW, restrictions on minimum legal shell length (MLSL–40 mm shell length), a daily possession (trip limit) of 40 kg per fisher per day and a 6-month (December–May inclusive) closure to commercial harvesting were implemented in 2011. To further promote stock recovery, the MLSL was increased to 45 mm in June 2012. These harvest restrictions elevated the need for an assessment of populations of *D. deltoides* across beaches throughout NSW to assess the effectiveness of these management measures.

A challenge in low value, data-poor fisheries is obtaining cost-effective data required for assessment and management (Smith et al., 2009). Catch sampling by industry representatives has proven to be an efficient way of collecting data for incorporation in stock assessments in such fisheries (Starr and Vignaux, 1997). Whilst standard scientific techniques to sample beach clams such as corers and box-quadrats are available and widely used (Defeo and De Alava, 1995; James and Fairweather, 1995; Laudien et al., 2003), they are not always easily transferable to industry representatives and using these methods directly in the swash zone can be problematic.

Industry-based monitoring programs require sampling techniques that are simple, rapid and efficient (Starr, 2010; Lordan et al., 2011; Kraan et al., 2013). Before implementation of any such program, there is a need to develop and test appropriate sampling techniques with industry representatives. Ideally, any sampling technique adopted should allow quantitative, comparative assessments of populations of beach clams to be made across multiple spatial and temporal scales by industry, scientists and managers. Rapid sampling techniques have been successfully developed and implemented in monitoring and assessment programs in both aquatic (Besley and Chessman, 2008; Parravicinia et al., 2010) and terrestrial (Tomlinson, 1981; Abril and Gomez, 2013) systems.

In this study, we tested the effectiveness of digging small plots of sand by hand for 3 time intervals as a way of quickly and quantitatively sampling populations of *D. deltoides* in the swash zone of exposed beaches. We compared this technique to a standard box-quadrat sampling tool. A key focus was determining the efficiency of the 3 sampling times as opposed to ascertaining which sample time caught most individuals. The time-based digging method is similar to that used by commercial operators to harvest beach clams in the swash zone, whereby sand is scooped into a mesh bag attached to a rigid frame.

Estimates of relative abundance based on catch per-unit effort (CPUE) data are directly influenced by spatial heterogeneity in the distribution and abundance of the target species (Kennelly, 1989). To account for the inherent spatial patchiness of beach clam populations, analyses (Underwood, 1981; Kennelly, 1989) were performed to estimate the optimal levels of spatial replication at different scales to ensure that future sampling strategies provide the most representative results given the available time for sampling. The study was done across two beaches to provide greater generality of results. The developmental approach and general outcomes of our study are applicable to sampling other species of bivalves, as well as other organisms in other environments (Rotherham et al., 2007).

2. Methods

2.1. Beaches

This study was done on two adjacent, high-energy, exposed ocean sandy beaches in eastern Australia: (1) Killick (−31°07′S, 153°00′E) and (2) Smoky (−30°58′S, 153°02′E) (Short, 2007). Historically, commercial, recreational and indigenous fishers have harvested *D. deltoides* on both of these beaches. Sampling was done in February and March 2013 during the 6-month (December to June) temporary closure to commercial fishing. Throughout sampling, the swell ranged between 0.5 and 1.8 m in height and was generally from an easterly direction. Three licensed commercial beach-clam harvesters were involved in sampling activities.

2.2. Comparisons of sampling techniques

We specifically tested whether hand digging for different lengths of time (30, 60 and 120 s) in the swash zone caught different numbers and sizes of *D. deltoides* and compared these samples with those obtained concurrently using a standard, square box-quadrat (0.32 m long × 0.32 m wide × 0.20 m high; area 0.1 m^2; James and Fairweather, 1995). The time-based, hand-digging technique involved scooping sediment and clams from a specified area of approximately 0.1 m^2 into a mesh bag (1.2 m long, 1.1 m circumference), which was constructed from either 12 or 19 mm (2 mm-twine diameter) polyethylene netting hung on the bar (i.e. square-shaped) and attached to an aluminum frame (0.35 m long × 0.21 m high; area 0.07 m^2). Each frame was held on the substratum and the bags kept open by wave-mediated water flow. Square-shaped mesh was used to ensure that meshes stayed open and each net remained a fixed sampling unit as the geometry and selectivity of diamond-shaped mesh can be affected by many factors including the weight of accumulated catch (Broadhurst et al., 2004). The contents of each box-quadrat were also scooped by hand into both mesh bag configurations. Industry members under strict supervision of scientific staff did the time-based digging, with the same member doing all sampling on a particular beach.

The sampling design involved using each configuration of method and treatment to sample two identified patches of clams in the swash zone on each of two consecutive days (18 and 19 February 2013) on the two beaches. On each day, the two patches of clams sampled on each beach were picked at random from all swash zone patches on the beach visually identified by commercial fishers and scientific staff who drove along each beach prior to sampling. The actual position sampled within a patch was haphazardly selected, with each individual sample being interspersed at least 1 m along a narrow strip parallel to the shore. A total of 4 replicate samples of each treatment and mesh size were made (total 32 samples) within each patch. The order in which replicate samples of each treatment were collected was randomly selected. It took approximately 2 h to sample each patch, with all sampling occurring within 3-h either side of predicted low tide (total 6 h period). All retained clams in each replicate sample were counted and measured for maximum shell length (to the nearest mm below) using digital Vernier calipers. The time taken to complete each replicate sample was recorded.

2.3. Determination of optimal levels of sampling

Two-randomly selected patches of clams on each of Killick and Smoky beaches were sampled on two randomly selected days (19