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Assessing the impacts of bait collection on inter-tidal sediment and the associated macrofaunal and bird communities: The importance of appropriate spatial scales

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ABSTRACT

Bait collection is a multibillion dollar worldwide activity that is often managed ineffectively. For managers to understand the impacts on protected inter-tidal mudflats and waders at appropriate spatial scales macrofaunal surveys combined with video recordings of birds and bait collectors were undertaken at two UK sites. Dug sediment constituted approximately 8% of the surveyed area at both sites and is less muddy (lower organic content) than undug sediment. This may have significant implications for turbidity. Differences in the macrofaunal community between dug and undug areas if the same shore height is compared as well as changes in the dispersion of the community occurred at one site. Collection also induces a 'temporary loss of habitat' for some birds as bait collector numbers negatively correlate with wader and gull abundance. Bait collection changes the coherence and ecological structure of inter-tidal mudflats as well as directly affecting wading birds. However, as β diversity increased we suggest that management at appropriate hectare/site scales could *maximise* biodiversity/function whilst still supporting collection.

1. Introduction

Invertebrate species are increasingly exploited for human use with a dramatic rise in catch levels in recent decades (Anderson et al., 2011a), but not all are collected for food. Polychaete bait is an integral part of coastal life, but is perceived as a low value resource as fisheries are data-limited, locally focussed, and largely unregulated. However, a recent assessment has shown that the global catch is approximately 121,000 tonnes per annum with a retail value of £5.5 billion (Watson et al., 2017). This is comparable to many of the world's most important fisheries, but in addition, productivities (i.e. biomass removed per m^2 of inter-tidal sediment) are orders of magnitude greater than many sub-tidal invertebrate fisheries (Watson et al., 2017).

In many locations ragworms are the major group collected from inter-tidal soft sediment shores with *Alitta* (*Nereis*) *virens* one of the most important species in Europe and the USA (Olive, 1994). For example, the UK fishery alone for this species is estimated to be 1500 t per annum (Watson et al., 2017). *A. virens* is a keystone inter-tidal species as prey for fish, birds and crustaceans; as a predator of other invertebrates and as an important bioturbator (McIntosh, 1908–1910; Ambrose, 1986; Ambrose et al., 1998; Caron et al., 2004). Many studies have investigated the impacts of collecting a variety of bait species including lugworms (Blake, 1979; McLusky et al., 1983; van den Heiligenberg, 1987; Olive, 1993; Harvard and Tindal, 1994; Beukema, 1995); bloodworms (Brown and Wilson, 1997; Ambrose et al., 1998; Beal and Vencile, 2001; Miller and Smith, 2012) and shrimps (Contessa and Bird, 2004; Skilleter et al., 2005, 2006; Winberg and Davis, 2014). Several have also investigated the impacts of sediment disturbance from other invertebrate inter-tidal fisheries (e.g. Beal and Vencile, 2001; Kaiser et al., 2001; Dernie et al., 2003; Logan, 2005; Griffiths et al., 2006; Masero et al., 2008; Navedo and Masero, 2008). Whilst all have shown impacts, the responses have been inconsistent; underlining the difficulty of extrapolating results across systems (e.g. different

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target species and source habitats). For those that have assessed ragworm collection (Blake, 1978; Olive, 1993; Brown and Wilson, 1997; Watson et al., 2007) and for many of the other studies, the relevant spatial scales (hectares) that bait collection covers have not been used. Instead, small experimental plots have been established, but these suffer considerable artefacts such as macrofaunal migration from surrounding areas and that recovery rates and size of the effect are related to the area of disturbance (Munari et al., 2006; Carvalho et al., 2013). In addition, collection areas often correlate with spatial coverage of MPAs (Marine Protected Areas) used as a management tool in coastal areas (Wood et al., 2008). Surveys, therefore, assessing the impacts of ragworm collection on the macrofaunal community representative of the spatial scales (hectares) that bait collection covers are needed to support evidence-based management of these fisheries within MPAs.

The impacts of bait collection also extend to wading bird populations which may be affected by reductions in key prey species (Shepherd and Boates, 1999; Masero et al., 2008) or by the presence of collectors on the shore (i.e. disturbance). As disturbance results in either a loss of feeding time or increased energy expenditure, it has the potential to negatively affect energy balance and survival (Davidson and Rothwell, 1993). A variety of coastal activities including bait collection can induce disturbance (e.g. Shepherd and Boates, 1999; Townshend and O'Connor, 1993; Ravenscroft et al., 2007; Liley and Fearnley, 2012; Stillman et al., 2012). However, for bait collection these studies were extremely limited in their scope because they a) simultaneously assessed multiple coastal activities; b) were not at the appropriate spatial scale or c) did not control for season and year.

In many locations bait collection remains a contentious issue for collectors, those organisations charged with minimising impact, and the associated coastal communities. Conservation legislation (e.g. European Union Natura 2000 sites) requires direct (Special Areas of Conservation [SACs]) and indirect (sub-features of Special Protection Areas [SPAs]) protection of inter-tidal mudflats to maintain them in favourable condition. In other words, subject to natural change, the range and distribution of characteristic biotopes and abundance of prey species for birds of interest must be maintained (English Nature, 2001). Overlap of protected coastal habitat and areas with high levels of collection gives great scope for conflict in many parts of the world. Effective management of bait collection in areas of protected inter-tidal mudflat (including areas protected for wading birds and wildfowl) requires an understanding of these impacts. Using two popular UK collection sites within the Solent region (part of the Solent European Marine Site [SEMS]) as case studies we mapped the extent of dug areas and collected cores for macrofaunal and sediment analysis from multiple transects located in dug/undug and low and mid shore areas to test hypothesis one: 1. Collection of *A. virens* by digging will significantly alter the macrofaunal community and the associated sediment characteristics over large (i.e. MPA-relevant covering several hectares) spatial scales. Remote Closed Circuit Television [CCTV] cameras were then used to record the numbers of collectors and abundance and diversity of birds on the inter-tidal sediment to test hypothesis two: 2. The presence of collectors on the sediment will reduce the bird abundance of waders and wildfowl utilising the same location.

2. Materials and methods

2.1. Biotope surveys and sample collection

Fareham Creek is a key bait collection area within the Portsmouth Harbour SPA (Fowler, 2001). An additional MPA prohibiting commercial collection within the SNCO (Special Nature Conservation Order) has been in force since 2003/4 (Fig. S1). Dell Quay in Chichester Harbour is also an important collection site (Fowler, 2001), but it contains many intertidal moorings and jetties. Consequently, the local NGO implemented a byelaw to prohibit bait collection within 15 m of any mooring or 6 m of any structure (Fig. S2).

Each site was surveyed once on spring tides between August and September 2011 approximately three hours either side of low tide. A biotope survey (Connor et al., 2004) assessment of the inter-tidal sediment (excluding the channels) was conducted and bait-collected areas mapped using a Differential Global Positioning System (DGPS) (approximately 10 cm accuracy) in conjunction with hand-drawings of habitat boundaries on aerial photographs (scale 1: 10000). Points were recorded by walking along the outer boundary of dug areas and any polygons considered too small to be mapped with DGPS, were numbered on the aerial photographs. Bait dug areas matched in the field were then digitised in GIS (ArcMap) and compared with the MPA boundary areas and the total substrate mapped.

Bait dug areas were defined as those exhibiting characteristics based on our own observations and those of Coates (1983), Brown and Wilson (1997) and Fearnley et al. (2013). These included: uneven topography (the area has mounds, water-filled depressions and troughs); the presence of empty bivalve shells and stones on the surface; a lack of algal mat cover; and the presence of darker (anoxic) sediment on the surface. Turned over sediment can persist for variable lengths of time depending on the energy of the site (Coates, 1983; McLusky et al., 1983; Sypitkowski et al., 2010; Fearnley et al., 2013). It was not possible to directly record the 'age' of the dug sediment from which cores were taken as collectors were not individually tracked. However, monthly assessment (January–June 2016) of four replicate 1 m^2 dug areas in the Solent intertidal area confirms dug sediment is observable for 83 ± 30 days SD in low energy shores. We, therefore, assumed that dug areas were dug a maximum of 12 weeks prior to sampling.

A systematic sampling strategy for macrofaunal and sediment analysis was performed with 10 transects at Fareham Creek (Fig. S1) and 11 transects at Dell Quay (Fig. S2) covering both nominally protected and unprotected areas. Four sampling stations (two mid-shore and two low-shore either side of the central channel) were located and at each one 0.01 m^2 (15 cm deep) core was taken and fixed in 10% formalin in seawater for faunal analysis. An additional 5 cm diameter core was taken at each station and frozen (−20 °C) for future sediment analysis.

2.2. Sample processing

Sediment cores were heated at 60 °C until completely dry and processed using wet sieving for particle size analysis and loss on ignition at 475 °C for 4.5 h for organic content (Buchanan, 1984). All cores (39 cores in total) from Fareham Creek and all except one from transect 7 (40 cores in total) for Dell Quay were analysed for sediment characteristics. Samples to be processed for macrofaunal analysis were chosen *a posteriori* according to the following scheme due to financial restrictions. At Fareham Creek all cores from the low shore were processed except one unprotected from transect 4 due to its loss (19 cores in total). All cores (low and mid shore) for Dell Quay from transects 2–10 except one from transect 10 were processed (35 cores in total) (see Figs. S1 and S2).

2.3. CCTV installation and video analysis for bird disturbance

Two Sanyo HD 4600 cameras with external hard-drives were used for direct recording and were rotated between the sites (see Watson et al., (2015) for details), focussing on areas of the inter-