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Can aggregate quarry silt lagoons provide resources for wading birds?

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ABSTRACT

Wading birds have declined across Europe as the intensification of lowland agriculture has resulted in the loss and degradation of wetland areas. Lowland aggregate extraction sites that incorporate areas of fine, waste sediments deposited in silt lagoons have the potential to be restored for wader conservation. We set out to determine the potential value of silt lagoons to wading birds by comparing the water quality, sediment profiles, aquatic invertebrate abundance and diversity (prey availability) and wader site use at five sites representing various stages of active aggregate extraction and restoration for conservation purposes. Wader counts were conducted monthly over a twelve month period using replicated scan samples, and the invertebrate communities studied during the breeding and autumn migration season (June–September). Water quality variables were similar between sites, but sediments from active quarries were dominated by moderately sorted fine sands in comparison to the coarser sediment profiles of restored areas. June and September there was no significant difference in invertebrate diversity between sites, however richness was significantly lower on quarry sites and total abundance a factor of ten higher at restored sites than on silt lagoons, with the dominant taxa similar across all sites. Waders used all sites; albeit at lower abundance and richness on silt lagoons and two species were recorded breeding on active silting sites. We conclude that the fine, uniform sediments of modern silt lagoons limited invertebrate diversity and abundance, diminishing the value of silt lagoons to waders. Simple low-cost intervention measures increasing substrate heterogeneity and creating temporary ponds could increase invertebrate richness and abundance, and enhance the conservation potential of these sites.

1. Introduction

Wetlands, a globally threatened habitat, are internationally important for water bird and wader communities (Grygoruk and Ignar, 2015; Kloskowski et al., 2009). Large-scale land use changes within the last century have led to significant declines in lowland perennial and seasonal wetlands within Europe (Gumiero et al., 2013; Verhoeven, 2014). Agricultural intensification leading to the abandonment of wet areas (Joyce, 2014), land reallocation or agricultural encroachment, over grazing, changes in water management or wetland drainage have been held largely accountable for the loss of 50% of European wetlands within the last century (Silva et al., 2007; Henle et al., 2008). The internationally important European wetlands, salt marshes and mud flats support populations of over-wintering and migrating waterbirds and waders along the East Atlantic Flyway (EAF) (Rehfisch et al., 2003; Stroud et al., 2006; Holt et al., 2015). Recent estimates indicate that 37% of wader populations along the EAF have undergone a decline in recent decades (Delaney et al., 2013).

On an international scale, 44% of known wader populations are contracting (Wetlands International, 2010). According to Eaton et al. (2015) the number of UK wader species now classified as amber or red listed has increased over the last 30 years. Eight species are reliant on lowland wet grassland for breeding and all are recognized as being at varying levels of conservation concern (Wilson et al., 2007; Eaton et al., 2015). Black-Tailed Godwit *Limosa limosa* and Ruff *Philomachus pugnax* show very restricted breeding ranges within UK lowlands, often constrained to coastal grasslands, another declining habitat (Wilson et al., 2004). Other species such as Northern Lapwing (*Vanellus vanellus*), Eurasian Curlew (*Numenius arquata*) and Common Redshank (*Tringa totanus*) have demonstrated marked breeding population declines both within UK and Europe (Sheldon et al., 2004; O'Brien and Wilson, 2011; Eaton et al., 2015). *Changes to seasonal tilling* and sward height management along with grazing intensification and land drainage are thought to have been associated with breeding habi-

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tat loss (Sheldon et al., 2004; Wilson et al., 2004). Despite several attempts through numerous Agri-Environment Schemes (AES) to enhance lowland areas for breeding waders (e.g. Verhulst et al., 2007), declines continue (Wilson et al., 2004; Eglington et al., 2007; O'Brien and Wilson, 2011).

Aggregate extraction sites are typically located in flat, lowland valleys; areas that would have supported seasonal or permanent water bodies and wetlands (Andrews and Kinsman, 1990; Nicolet et al., 2004; Poschlod et al., 2005). Once sites have reached the end of their extraction life span, they have the potential to be restored with the end result supporting a comparatively elevated biodiversity to that of the active extraction site (Milne, 1974; Bell et al., 1997; Bradshaw, 1997; Santoul et al., 2004; Whitehouse, 2008). Post-extraction restoration guidelines tend to focus solely on the creation of lakes and the rapid establishment of reed beds (Ailstock et al., 2001; Jarvis and Walton, 2010). For example, open water areas in restored quarries benefit wintering and breeding waterfowl whilst reed beds provide breeding areas for species of conservation concern such as Bitterns (*Botaurus stellaris*) (Blaen et al., 2015), Bearded tit (*Panurus biarmicus*), Reed bunting (*Emberiza schoeniclus*) and Reed warbler (*Acrocephalus scirpaceus*) (Andrews and Kinsman, 1990; Peach et al., 1999; Poulin et al., 2002). However, reed beds provide little foraging or nesting opportunities for waders, who prefer open areas for foraging and shorter sward open grassland habitats for breeding (Cramp and Simmons, 1983; Milsom et al., 1998).

There is limited evidence that active aggregate sites can provide opportunities for waders, with some species nesting in gravel scrapes (e.g. Little Ringed Plover, *Charadrius dubius*) (Catchpole and Tydeman, 1975; Parrinder, 1989). Given the ubiquity of such settlement areas in quarry operations, there is the potential for them to contribute to regional, national and international wader conservation goals by replacing lost lowland wet areas both during operation and after post-extraction restoration. Little is known about wader use of active silting areas and management strategies for such areas aimed at wader conservation are not well-developed (Andrews and Kinsman, 1990). We wanted to assess the potential value of active silt lagoons in lowland areas for wader conservation. By integrating environmental and biological data from three active silt lagoon sites of different ages and two restored sites we aimed to (1) characterize the physico-chemical nature of these areas, (2) determine the important environmental factors influencing aquatic invertebrate diversity and abundance, (3) assess how wader richness and abundance varied between sites and 4) how waders actively used these areas. We hoped to use this information to provide recommendations on the management of silt lagoons to improve their potential as sites for wader conservation.

2. Methods

2.1. Study sites and location

Five sites were selected representing a range of conditions from highly disturbed and dynamic (ongoing deposition at active extraction sites) to minimal disturbance (well-established restored nature reserve sites). All sites were in lowland locations (<60 m above sea level) within the same broad geographic region: North and East Yorkshire, UK (Fig. 1). The active quarry sites were selected based upon safety considerations and access permissions and the general details of each site provided in Table 1. The two restored sites are man-made nature reserves managed for breeding waders and wildfowl by the Yorkshire Wildlife Trust; North Cave represented a restored aggregate extraction site and Filey Dams, a marshland near the coast, was included as an example of a mature, well-established site for comparison (Fig. 1). All sites had a mixture of terrestrial and aquatic areas with exposed mineral substrate (ranging from extremely coarse to fine sediment), an open aspect, natural terrestrial vegetation and shallow and deep lentic waters.

2.2. Environmental parameters and invertebrate diversity

Major labile physico-chemical water parameters (pH, electrical conductivity (COND), oxygen reducing potential (ORP), dissolved oxygen (DO) and temperature (TEMP)) were obtained across all sites. Surface waters were sampled with a Myron Ultrameter (for pH, COND, ORP, TEMP) and an YSI550 Dissolved Oxygen meter for measuring DO. Sample alkalinity (ALK) was assessed in the field via titration against 1.6 N H_2SO_4 with bromocresol green-methyl red indicators (to pH 4.6) using a Hach Digital Titrator. On each sampling occasion, this was repeated three times across each site.

During autumn 2015, three 250 cm^3 core sediment samples were collected from the bottom of the lake at a depth of 20–25 cm at each site to characterize the sediment profile. Particle size distribution was obtained by oven drying samples at 105 °C, and then fractions separated through a standard nest of sieves (2, 1 mm; 500, 250, 125, 90, 63 and 38 μm) and the percentage of each fraction calculated (Gee and Or, 2002). Sediment fractions incorporated into the analysis included gravels (G; <2 mm), very coarse sand (VCS; 1–2 mm), coarse sand (CS; 500 μm–1 mm), medium sands (MS; 250–500 μm), fine sands (FS; 125–200 μm), very fine sands (63–125 μm) and coarse silts (38–65 μm). The median particle size (D50) was used to summarise sediment size, and sediment profiles determined using Gradistat software (version 4.0) (Rice and Haschenburger, 2004). Organic content (LOI) of the substrate was obtained through loss on ignition at 550 °C until constant weight was achieved (Generowicz and Olek, 2010).

To describe the food available to foraging waders (Warrington et al., 2014), freshwater invertebrates were collected on a monthly basis between June and September 2015. The same worker sampled all sites using a kick sampling method, walking backwards at a constant steady pace for 30 s to dislodge invertebrates from the substrate into a D-frame pond net (0.25 mm mesh, 350 m × 180 mm frame) at a depth of 15–20 cm. Three replicate samples were collected on each sampling occasion and water depth was restricted to <20 cm (García-Criado and Trigal, 2005) ensuring only invertebrates accessible to waders were collected. Samples were returned to the laboratory and invertebrates identified to Order/Class (Pawley et al., 2011) and the number of individuals in each taxon recorded for each replicate.

2.3. Wader site use

Bird surveys were conducted on a monthly basis at each site between (August 2014 and September 2015) to record changes in wader diversity and abundance over time. Scan sampling was undertaken from a fixed point at each site, with a sampling unit comprising of four replicate scan samples conducted every 15 min over a 1 h period (Altmann, 1974; Cresswell, 1994). During each scan, the total number of individuals of each species was recorded along with their observed behaviour (e.g. foraging (feeding on the substrate), roosting (sleeping or preening) or other – used for all additional behaviours observed) to reflect site use.

2.4. Statistical analysis

For all replicate sample from each site collected between June and September, invertebrate family richness (S), total invertebrate abundance (N) and the Shannon Wiener diversity index (H') were calculated using the PRIMER software package (Clarke and Warwick, 2001). The N, S and H' data conformed to a normal distribution (Kolmogorov Smirnov test, P > 0.05 in all cases) and