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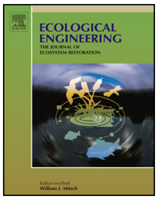

Managed realignment for habitat compensation: Use of a new intertidal habitat by fishes

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ABSTRACT

Managed realignment has become an increasingly common mechanism to increase the efficiency and sustainability of flood defences, reduce defence costs or compensate for habitat losses. This study investigated the use by fishes of a new intertidal habitat, created by managed realignment, intended to compensate for the loss of mudflat associated with a major port development. Although broadly similar, statistically significant differences in fish species composition, abundance, biomass, size structure, diversity and diet composition indicate that the managed realignment is not yet functioning in an identical manner to the mudflat in the adjacent estuary, most likely due to differences in habitat between sites. Notwithstanding, similarity in the species composition of fyke catches in the managed realignment and estuary increased annually during the 5-year study period, suggesting that the mudflat in the realignment is still developing. Indeed, the site will inevitably change over time with accretion, establishment of vegetation and possibly development of creeks. This will not necessarily prevent the aim of the realignment scheme being achieved, as long as sufficient suitable mudflat remains.

1. Introduction

Intertidal habitats support high biological productivity (McLusky et al., 1992; Ysebaert et al., 2003), contribute to flood defence (Dixon et al., 1998) and provide important habitats for fishes (Elliott et al., 2007; Ramos et al., 2012) and birds (Atkinson et al., 2004; Mander et al., 2007). Many intertidal areas, however, are subjected to a range of anthropogenic pressures. Of particular importance is land claim for industrial development (McLusky et al., 1992; Esteves, 2014). Land claim can have direct negative impacts on intertidal biota, and profound implications for ecosystem functioning through the role of the biological communities in sediment dynamics, biogeochemical cycling, benthic metabolism and trophic interactions (Herringshaw and Solan, 2008). Loss of intertidal areas can also increase the risk of flooding, which is likely to be exacerbated by the effects of climate change, especially in areas already experiencing coastal squeeze (Mazik et al., 2007; Pontee, 2013; Esteves, 2014). It is therefore desirable, sometimes necessary, to compensate for habitat losses due to land claim, especially those predicted to compromise the integrity of designated conservation areas (Morris, 2013; Esteves, 2014).

Managed realignment – the deliberate process of realigning river, estuary or coastal flood defences – has become an increasingly common mechanism to increase the efficiency and sustainability of flood defences, reduce defence costs or compensate for habitat losses (e.g. Ledoux et al., 2005; Garbutt et al., 2006; Mazik et al., 2007; Rupp-Armstrong and Nicholls, 2007; Shih and Nicholls, 2007; Esteves, 2013; Morris, 2013; Pétillon et al., 2014). Managed realignment also has the potential to enhance fish diversity, recruitment and production by increasing the availability and diversity of intertidal habitats, such as mudflats and salt marshes (Dixon et al., 1998; Colclough et al., 2005; French, 2006). It is essential, however, that the physical characteristics and biological communities of managed realignments replicate those being lost if habitat compensation is to be truly successful (Mazik et al., 2010).

A port and logistics centre is being developed on the north bank of the Thames Estuary, England. The development includes a container terminal to accommodate the largest deep-sea container ships, and was considered likely to have an adverse impact on the integrity of the Thames Estuary and Marshes Special Protection Area (SPA) and Ramsar Site. Predicted direct impacts of the development on physical habitats included: (1) conversion of 5 ha of designated intertidal habitat to shallow subtidal habitat; (2) destruction of 25 ha of undesignated intertidal habitat; (3) changes in accretion over 60 ha of intertidal habitat, potentially converting 10 ha of mudflat to saltmarsh; (4) long-term impacts on 90 ha of

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subtidal habitat affected by capital dredging; and (5) temporary damage to >1700 ha of subtidal habitat outside the SPA and Ramsar Site (Morris and Gibson, 2007). To compensate for part of the impacts on the Thames Estuary and Marshes SPA and Ramsar Site and ensure the overall coherence of the Natura 2000 network is maintained, a minimum of 74 ha of new intertidal mudflat is being created through managed realignment (Morris and Gibson, 2007). Habitat creation and improvement of flood defences are common objectives of managed realignment schemes (French, 2006; Esteves, 2013), but few studies have assessed their use by fishes (e.g. Colclough et al., 2005). The aim of this study was to advance the understanding of the use by fishes of intertidal habitats created through managed realignment by investigating changes over a 5-year period. The hypothesis was that the species composition, size structure, abundance, biomass and diet composition of fishes in the realignment and adjacent estuary would increase in similarity as the mudflat in the realignment developed. High similarities in these parameters in the two sites should suggest that the realignment is functioning in a similar manner to the mudflat in the adjacent estuary, and that the aim of the realignment scheme, namely to compensate for losses of mudflat associated with port development, is being achieved (cf. Mazik et al., 2007, 2010; Mossman et al., 2012).

2. Methodology

2.1. Sampling strategy, methods and techniques

London Gateway Site A managed realignment (51.50232°N, 0.44799°E; also known as Stanford Wharf Nature Reserve) is located to the east of Mucking Creek, near Stanford-le-Hope, on the north bank of the Thames Estuary, England. The site was created in 2010 by reducing the level of 27 ha of former agricultural land and creating a 300-m-wide breach in the sea defences to the south. Fish surveys were conducted during spring tides in October and November 2010 and April, June and August 2011–2014. These timeframes coincide with the larval and juvenile periods of many fishes, thus enabling assessment of the function of the habitat (e.g. nursery) for specific species (cf. Nunn et al., 2007). The sampling frequency therefore accounts for temporal variations in fish community structure associated with the phenology of fish hatching and ontogenetic and seasonal shifts in habitat use. A combination of active (seine, epibenthic trawl) and passive (fyke) gear types with replicated sampling stations was included in the design, to provide as accurate an assessment as possible of the species composition, size structure, density and biomass of fishes in the realignment and adjacent estuary (immediately to the east of the realignment); using a range of methods at fixed stations in a seasonal format is recommended to obtain a robust assessment of intertidal fish communities (Colclough et al., 2005). Gear types were selected based on the potential operational constraints imposed by realignment sites (e.g. deep mud, benthic obstructions, semi-permanent flooding regimes, deep creeks) and the usual development of newly created intertidal areas (e.g. accretion, establishment of vegetation). Fine-meshed gears were employed due to the expected dominance of small-sized species or individuals in the fish assemblages using newly created intertidal areas. Multi-method approaches, recognised as European best practice (Hemingway and Elliott, 2002), have been successfully employed elsewhere to examine the use of intertidal areas by fishes, including in managed realignments, and as a tool for assessing the ecological status of estuaries (e.g. Laffaille et al., 2000; Colclough et al., 2002, 2005; Coates et al., 2007). Up to 50 individuals of each fish species were measured (total length, L_T, mm) and weighed (0.01 g) for each sample, with the remainder identified and counted. There were no significant differences in water temperature (paired t-test, d.f. = 13, t = 0.929, P = 0.370) or salinity (paired t-test, d.f. = 11, t = 0.150, P = 0.884), recorded at 15-min intervals using an Aqua TROLL 200 data logger, in the realignment and adjacent estuary.

2.1.1. Fyke netting

Fykes were deployed at four stations in the realignment and two in the estuary, and left for one tidal cycle. The nets were emptied as they became exposed by the receding tide and then left for another tidal cycle, thereby allowing separate analysis of diurnal and nocturnal catches (total n = 180). Each gear consisted of two fykes (53-cm entrance, 10-m central panel, 14-mm mesh) joined entrance-to-entrance by their leader panels; data from each gear were expressed as the abundance and biomass of fishes per ‘fyke-hour’ (i.e. the number of hours that the gear was inundated). Fykes were set at the same shore height in the realignment and estuary to ensure they sampled comparable water depths, allowing an assessment of the larger fishes using the area (Colclough et al., 2005).

2.1.2. Seine netting

A micromesh beach seine (25-m long, 3-m deep, 3-mm hexagonal mesh) was set at eight stations in the realignment and two in the estuary; data from each sample (total n = 150) were expressed as the abundance and biomass of fishes per m^2. The area sampled by the seine was calculated from direct in situ measurements (i.e. length × width of the area enclosed by the net). This method allowed an assessment of the smaller fishes using the area (Cowx et al., 2001; Colclough et al., 2002, 2005; Coates et al., 2007).

2.1.3. Trawling

Trawling was conducted using an epibenthic sledge fitted with a tickle chain and a 0.5-mm-meshed cod-end (Nitex cloth), to target benthic species and individuals for which the fyke mesh was too large (Colclough et al., 2002, 2005; Coates et al., 2007). The trawl was pulled by hand at ~1 m s^{-1}; data from each sample (total n = 135) were expressed as the abundance and biomass of fishes per m^2. The area sampled by the trawl was calculated by multiplying the width of the trawl entrance (1 m) by the length of each transect (20 m). Three replicates were collected at each of three stations in the realignment (nine trawls in total); trawling was not conducted in the estuary due to safety issues.

2.2. Data analysis

The relative abundance of each fish species in the managed realignment and the estuary was calculated for the entire study period and each gear type. Bray–Curtis similarity matrices (Bray and Curtis, 1957) were calculated using the relative abundance of each fish species and ordinated using non-metric multidimensional scaling (MDS) to investigate similarities in the species composition of fyke and seine catches in the realignment and estuary. The matrices were then submitted to permutational multivariate analysis of variance (PERMANOVA) (9999 random permutations) to assess the statistical significance of any differences in the species composition of fyke and seine catches in the realignment and estuary (Anderson, 2001; Anderson et al., 2008). In addition, similarity percentages (SIMPER) analysis was used to calculate the percentage contributions of key fish species to dissimilarities in fyke and seine catches in the realignment and estuary (Clarke and Warwick, 2001). Mean Shannon–Wiener diversity (H') and Pielou's evenness (J) were compared for fyke and seine catches in the realignment and estuary using independent samples t-tests (Washington, 1984).