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Beyond the meta-ecosystem? The need for a multi-faceted approach to climate change planning on coastal wetlands: An example from South Uist, Scotland

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A R T I C L E I N F O

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A B S T R A C T

Exposed, low-lying dune-wetland habitat complexes may have multi-faceted functionality that means they are effectively meta-ecosystems, where inter-acting nearshore, littoral, dune and freshwater components and processes must be considered together, sometimes in conjunction with interactions with contiguous inland habitats. The low-lying dune-machair-marsh-loch (lake) ecosystems of South Uist, Benbecula and North Uist in the Outer Hebrides of Scotland exhibit such functionality, and investigation of a former loch basin at the south end of South Uist has revealed an unexpected level of complexity that also identifies a particularly high exposure to climate change in the coastal hinterland, particularly in terms of water relationships, though the possibility of significant change to the coastal frontage must also be considered in contingency planning. This investigation is described by sector, then drawn together in the context of climate change. It is suggested that the environmental setting of the Uists conforms to the concept of the meta-ecosystem in spatial terms, but with additional legacy and socio-economic components, so that there is effectively a socio-spatio-temporal meta-ecosystem. It is vital that this complexity is understood and accommodated in all flood contingency and adaptation planning, and the paper attempts to assist this by presenting an overview of the functional role and context of water in the coastal lowlands of the Uists.

1. Introduction

It is a truism to assert that an island is an area of land surrounded by water, but in terms of temperate coastal islands such as the Outer Hebrides (Fig. 1), this can mean that they are surrounded laterally by the sea, below by a water table, on the surface in the form of numerous standing waters, and above in the form of precipitation; efficient dispersal of this precipitation is critically important to maintenance of current land management.

The islands of South Uist, Benbecula and North Uist and their satellite islands, collectively known as the Uists, lie off the north-west coast of Scotland (Fig. 1), seemingly exposed to the full fetch of the Atlantic on their western seaboards. Their western coasts consist of an extensive ‘machair’, an extreme form of dune grassland extending up to 2 km inland, defined in terms of its morphology (generally flat and low-lying, mainly below 10 m OD (Ordnance Datum)), high winter water table, sands with a high calcareous, shell-derived component, an oceanic climate characterised by high winds and humidity, and a history of human management (Ritchie, 1979; Angus, 2006). The machair is usually fronted by a higher dune ridge, and in the Uists tends to have a negative gradient with a chain of marshes and lochs (lakes) straddling the machair's inland boundary. The lochs are extremely low-lying, so that they may be brackish where sea water gains access and, in addition to a salinity gradient, may also have a pH gradient. The integrity of the dune ridge is critical to the protection of the inland habitats from marine overtopping or, if breached, marine incursion, and the entire dune-machair-marsh-loch complex or ‘machair system’ is of high natural heritage value (Angus, 1994, 1996).

In a landscape so low-lying and vulnerable to flooding from the sea and from rainfall, it is vital that water relationships are fully understood so that adaptation planning is as well-informed as it can be. Despite a long-standing awareness of the complex inter-relationships of this system and the importance of inland water (Ritchie, 1966, 1979, 2006; Muir et al., 2014), even the most recent strategic planning (Comhairle nan Eilean Siar, 2016) co-ordinated by the Local Authority in partnership with Scottish Water and the Scottish Environment Protection Agency (SEPA), and informed by SEPA's *Flood Risk Management Strategy* (SEPA, 2015), concentrates on civil vulnerability: the aim of the current study is to inform the next phase of strategic planning in respect of the wider function and context of marine and inland flooding in the

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Fig. 1. Situation of South Uist, Outer Hebrides. © Crown copyright and database rights 2018 OS 100017908.

western lowlands of the Uists.

The *Local Flood Risk Management Plan* (Comhairle nan Eilean Siar, 2016) was designed to integrate with other plans and undertakes to consult with the statutory adviser Scottish Natural Heritage (SNH) in respect of actions that might impact the natural heritage, but does not directly address environmental function. SNH does not yet have a detailed local climate change strategy for the Uist coasts and the current work is designed as a contribution to any such strategy that might be developed, as well as to wider flood risk management.

The history of the drainage network is of considerable importance in nature conservation and land use contexts, as it informs the likely behaviour of water – fresh and saline – in respect of climate change. Lochs and saline lagoons, and their associated marshes and swamps, form important components of the designated nature conservation features of the Uists, but the interconnectivity of surface and subsoil water means that aquatic connectivity is of vital importance to all low-lying habitats. Because changing one aspect can have impacts elsewhere, it is vital that this connectivity is well understood in adaptation planning. Each Site of Special Scientific Interest (SSSI) has a list of Operations Requiring Consent (ORCs) but neither the SSSI network nor its associated ORCs are currently equipped to address the challenges posed by the extreme aquatic connectivity evident within the western coastlands of South Uist and Benbecula, or the possible impacts of climate change on this connectivity.

2. Marine processes of coastal significance

Few rocky headlands interrupt the sandy beach that fronts almost all of the west coast of South Uist. The sand, which has a very high proportion of shell fragments, is now largely littoral and terrestrial, having been deposited there by marine and aeolian processes over millennia. The sublittoral is predominantly rocky, and the low gradient that distinguishes the machair terrains is also evident offshore, where the 20 m contour (Chart Datum) lies some 7 km west of Low Water Spring Tide (LWST) (Admiralty Chart 2772). This shallow, rocky platform supports a vast forest of kelp *Laminaria hyperborea*, and the combined rocky seabed and kelp bed lie at a depth that interacts with the wave base, so that despite the vast fetch of the Atlantic waves, they have been deprived of a significant proportion of their energy by the time they crash on the western shores of the Uists (Angus and Rennie, 2014). The growth response of kelp to Relative Sea Level Rise (RSLR) is unknown, but it is possible that in the [usually] clear waters west of the Hebrides, responses would not include upward growth and, even if they did, this might involve additional stipe (stem) flexibility and thus possible reduction of the wave attenuation function. Beach-cast *Laminaria* is used by crofters (agricultural smallholders) to fertilise fodder grain crops on the sandy machair soil of the Uists, where the algae supply not only nutrients but a binding medium, useful when bare sand has been exposed by ploughing in a windy environment; machair crops fertilised with algae appear to have a higher botanical diversity than those fertilised with commercial fertiliser (Angus, 2017a). When left on the shore, beach-cast algae also provide a nutrient-rich rooting medium in sand for strandline plants that can build into foredune, occasionally persisting sufficiently to provide additional protection for the coastal frontage (Angus, 2017a). Breakdown and shedding of kelp also contribute high levels of Particulate Organic Matter (POM) and Dissolved Organic Matter (DOM) to coastal waters, both of which play a vital role in driving inshore marine and littoral ecosystems (Orr, 2013). Beaches with high wrack deposition tend to have a finer grain size and support higher biomass than would be expected in such exposed situations and the ecosystems of kelp beds and sandy beaches of the Uists have been described as "tightly linked" (Orr, 2013). Beach-cast kelp thus not only has a littoral and coastal influence on beach and strandline ecology and sand build-up, but its importation to the machair as fertiliser by crofters transfers marine productivity inland where it then has a positive influence on biodiversity.

3. Water table

The Uist machairs have a high winter water table that is in surplus over extensive areas in winter, while the summer water table is low (Ritchie, 1979). The winter situation involves a series of linear seasonal lochs behind the dune ridge; the lochs have neither inflow nor outflow and are best regarded as surplus water table. These were subject to salinity measurement within four weeks of a major storm in January 2005 that involved extensive marine overtopping, so that even accounting for a dilution of the marine flood water by existing inland surface waters, salinity should have remained high (approaching the 35.00 of sea water), but instead was around 20% of the salinity of sea water. With no surface flushing mechanism available, it was suggested that the lochs had interacted with the subsoil water table, in an attempt to bring the two to equilibrium, i.e. the saline flood had salinized the subsoil water table (Angus and Rennie, 2014). Though this is a superb adaptation for recovery of surface waters following a short-lived storm in which flood waters disperse quickly or a very localised marine flood, such an adaptation becomes a liability if the flood is prolonged, e.g. by blocked drains or a sequence of several storms involving overtopping, and the water table becomes saline over a wide area, perhaps including areas scheduled for cultivation in the following spring. The duration and areal extent of such saline influence on the water table are not known. Beach discharge of fresh water testifies to subsurface seaward flow via groundwater forcing (Ritchie, 1966); such subsurface flow is well-known in dune water tables (Davy et al., 2010) but rate of flow is unknown.

4. Precipitation

Annual precipitation in the Uists is around 1200 mm with the driest months in April to June and the wettest October–January (Table 1). Comparing the two long-term data series, monthly precipitation is increasing in January–April. Local perceptions of increasingly wet soils at the time of ploughing are thus justified. An increase is also evident in August, coinciding with harvest of machair crops. Decreases in May, June and July coincide with the main crop growth, exacerbating any problem of drought at a time of year when water tables are low. The