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Conflictive uses of coastal areas: A case study in a southern European coastal lagoon (Ria de Alvor, Portugal)

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ABSTRACT

Estuaries and coastal lagoons are naturally stressed and highly variable ecosystems, and are also frequently exposed to strong anthropogenic pressures. Such pressures can be particularly pronounced in small systems such as the Ria de Alvor, a small tidal lagoon in southern Portugal. The Ria de Alvor is a priority area for conservation, being a RAMSAR wetland of international importance since 1996 and is part of the European Ecological Network, *Natura 2000*. Nevertheless, intensive anthropogenic uses exert increasing pressures on its ecological features, causing stresses and challenges which are addressed in this paper. The resources that the Ria de Alvor provides are both marine and terrestrial in nature, and are subject to various kinds of exploitation. Urban, industrial and tourist developments, as well as agriculture and animal rearing, have resulted in habitat loss and change, altered morphology and hydrodynamics, and the discharge of effluents into the system. This paper reviews the key features and issues existing in the Ria and highlights the need for more research into this and other small estuaries and their management.

1. Introduction

The Ria de Alvor is a small meso-tidal estuary in Portugal's southern coastal region of the Algarve and, having some lagoonal characteristics, is often described as a coastal lagoon. Estuaries and tidal lagoons are transitional systems acting as buffers at the land–sea interface. These environments are highly dynamic, and are also notable for their biological diversity and valuable ecosystem services such as decomposition of organic matter, nutrient recycling, nursery for some fish species, and removal of pollutants. These particular features confer a high ecological value on coastal lagoons, a fact that is acknowledged by European legislation in the Habitats Directive and the Natura 2000 network (European Commission, 2011). Many of these coastal systems are also characterized by intense human occupation, population growth and economic development, frequently leading to significant transformation and degradation of natural resources. In Portugal, human occupation and associated land-use changes over the last two centuries have had higher impact on coastal ecosystems than sea-level rise or any other environmental change (Almeida et al., 2014b). The Ria de Alvor is a significant socio-economic resource for the western Algarve region based on tourism, aquaculture and fisheries.

Estuaries and coastal lagoons are naturally stressed and highly variable ecosystems, and are also frequently exposed to strong anthropogenic pressures (eg. Newton et al., 2014; Pérez-Ruzafa et al., 2013). The physical characteristics of many coastal lagoons, such as the limited exchange with adjacent coastal waters, make them particularly vulnerable to eutrophication (e.g. Cloern, 2001; Scanes et al., 2007). This can be as a direct consequence of increasing population density, but also throughincreased use of agricultural fertilizers in the surrounding watershed, or implementation of aquaculture production units within estuarine waters. Most of these pressures are expected to be aggravated under the predicted climate change scenarios (Brito et al., 2012a; Lloret et al., 2008).

Callaway et al. (2014) demonstrate that large estuaries tend to attract more attention than small estuaries owing to their size and

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socio-economic importance and the potentially large impacts they are often exposed to. Nevertheless, conclusions and managment practices are not always directly transferible to small estuaries (<50 km^2). In a small estuary environment, limited interventions can still be relatively big and of significant impact, and disturbances and changes in internal and external processes can affect the overall estuary, rather than damaging a limited area of a greater estuary. Small estuaries are also more vulnerable to point source pollution, and to the effects of morphological and ecological alterations (Callaway et al., 2014). In Portugal, with the exception of the Tagus and Sado estuaries, Ria de Aveiro and Ria Formosa, estuaries fall into the small estuary category, emphasising the importance of this current analysis of the conflictive uses of the Ria de Alvor.

The Ria Formosa is a coastal lagoon system in the eastern Algarve and has been the subject of many studies over the past decades (e.g. Brito et al., 2009; 2012a; Loureiro et al., 2006; Newton et al., 2003; Newton and Mudge, 2003), mostly because of its significant size and geographic location, since it surrounds the city of Faro, the regional capital. In contrast, the Ria de Alvor has only been the focus of a few published studies (Almeida et al., 2014b; Antunes et al., 1988; Brito et al., 2012b; Campos and Cachola, 2007) and is very different in character from the Ria Formosa which is a barrier island system (Vila-Concejo et al., 2002). As a result of its small size, the effects of natural and anthropogenic change are more pronounced and deserve more attention.

The aim of the paper is to identify the most relevant human activities and natural processes that disrupt the ecological status of the Ria de Alvor. We identify potential cause–effect relationships between the use of the Ria and the state of the system and go on to highlight the conflicting nature of the uses of the site. Scenarios of urban expansion suggest that the surrounding areas of the Ria will undergo a significant level of urbanization, highlighting the need for adequate management measures to cope with the vulnerability of the system (Martins et al., 2012; Vaz et al., 2012). As such, this paper can be seen as a first step in an integrative study towards a management model for this coastal lagoon.

2. The study site

2.1. Location

The Ria de Alvor (Fig. 1) is a shallow bar-built estuary or lagoon system located on Lagos Bay, on the south coast of the Algarve (37°08.22′N, 8°36.43′W). The system has a freshwater input from four tributaries within the watershed, all with origins on the south flank of the Serra de Monchique (altitude 902 m). The two largest are Rio de Arão and Ribeira de Odiáxere which drain southwards to the east and west of the central peninsula of Quinta da Rocha, giving the Ria its characteristic U shape. The Ria is separated from Lagos Bay by two barrier peninsulas, with sand dunes, and connects to the open sea by a single inlet which has been stabilized by the construction of two breakwaters since the early 1990s. With its surrounding farmland and market gardens, its total area covers approximately 15 km^2

2.2. Hydrodynamic regime

The Ria has some features that are typical of meso-tidal tide-dominated systems (where tides are 2–4 m in amplitude), such as the flood-tide delta inland of the mouth and the network of channels and mudflats fringed by saltmarsh vegetation in the inner areas. However, it also has some features of wave dominated systems, such as the almost complete closure by a barrier. Tides are semi-diurnal, with a mean spring tidal range of 2.85 m in Lagos Bay, and they are the main process generating currents in the Ria. The relatively low freshwater inflow, associated with the tide-dominated hydrodynamic regime, makes this system a euhaline (salinity range from 30 to <40) coastal lagoon (Perez-Ruzafa et al., 2011).

Outside of the navigation channel, the Ria has a maximum depth of approximately 2 m, depending on the tide, but the main channel has been extensively dredged to maintain navigability to the recreational and fishing port of Alvor. The total flooded area during high tide is estimated to be around 3 km^2 (including intertidal areas), and at low tide the surface area of the residual water is around 1 km^2 (Fig. 2). This means that, with the exception of tidal channels, most of the bed of the lagoon is exposed at low tide. Also during this phase of the tide, the residual water is mostly confined to the inner channels and creeks. Given these conditions, the water is almost entirely renewed at each tide in the outer part of the Ria, resulting in strong tidal currents (Quintino and Rodrigues, 1989). The flushing time, together with the topography of the Ria, is a modulating factor in terms of the hydrodynamics of the system and this, in turn, shapes the ecological patterns.

Freshwater input from the rivers shows strong seasonal variation, being torrential in wet months and dry in summer months, with the Rio de Arão and Ribeira de Odiáxere being the most significant in terms of flow (Table 1).

2.3. Sediments

Sand facies predominate in the sediment, with more than 65% of the area (almost the entire outer Ria) covered by medium clean sand (Quintino and Rodrigues, 1989). A gradual increase in the proportion of fine sediments is observed along the longitudinal axis of the system (from the mouth towards both the western and eastern extremities of the inner regions). Mud facies predominate in the inner areas.

2.4. Main ecological features

Ria de Alvor is listed as a priority area for conservation, being a RAMSAR site (Wetland of International Importance)[1] since 1996 and is part of the European Ecological Network, Natura 2000, as a Special Area of Conservation.[2] The Planning and Management Authority for the Algarve Region (CCDRA) highlights the Ria de Alvor as the most important wetland in the western Algarve area (CCDRA, 2005). The Ria contains a diversity of habitats and species, including 15 habitats listed in Annex 1 of the EU Habitats Directive as of 'European interest'. Estuary, coastal sand spits, sand and mud banks, and the saltmarshes are some of the most significant features that confer the Natura 2000 status on the Ria. Of these Annex 1 habitats there are a number of priority habitats to be found in the Ria, such as coastal lagoons (habitat 1150), Mediterranean salt steppes - *Limonietalia* (habitat 1510) fixed coastal dunes with herbaceous vegetation - grey dunes (habitat 2130) and *Crucianellion maritimae* fixed beach dunes (habitat 2210).

The lagoon is a nursery area for a number of fish species and supports a highly diverse and ecologically significant shoreline biota. Approximately 250 species of birds have been recorded, and the Ria is an important staging post during spring and autumn bird migrations. Three aquatic species (Kentish plover *Charadrius alexandrinus*, Little tern *Sterna albifrons*, and Black-winged stilt *Himantopus himantopus*) nest in the sand dunes, salt pans and

[1] Under the 1971 Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention).

[2] Under Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora (EU Habitats Directive).