

Integrated water resources and coastal zone management in European lagoons in the context of climate change



Project partners

- University of Aveiro (PT)
- Bioforsk- Norwegian Institute for Agricultural and Environmental Research (NO)
- Institute of Hydro-Engineering of the Polish Academy of Sciences (PL)
- Atlantic Branch of P. P. Shirshov Institute of Oceanology of Russian Academy of Sciences (RU)
- Sea Fisheries Institute in Gdynia (PL)
- University of Dundee (UK)
- Odessa State Environmental University (UA)
- Potsdam Institute for Climate Impact Research (DE)
- Universidad de Murcia (ES)

THEME: Case study area description and end users

Case study – Ria de Aveiro (Portugal)

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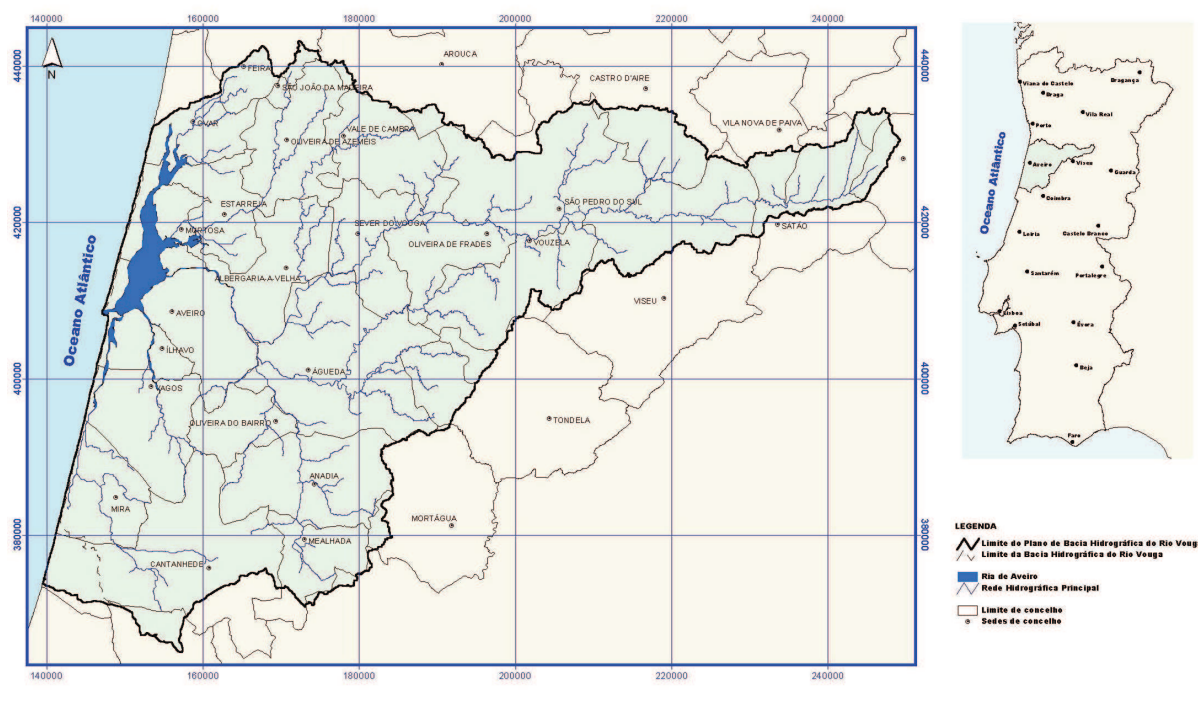
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Description of physical conditions (Vouga river basin and Ria de Aveiro coastal lagoon)

The basin of the Rio Vouga has an area of approximately 3362 km², located in the central part of Portugal (Figure 1). The Vouga river originates in the mountains of Lapa, at an altitude of about 930 m, covering about 141 km before flowing into the Ria de Aveiro coastal lagoon (Van der Weijden et al., 2006). Its main tributaries are the Sul, Caima, Antuã and Águeda rivers.

The Ria de Aveiro (40°38'N, 08°45'W) is a shallow coastal lagoon connected to the Atlantic Ocean through a single inlet (1.3 km in length, 350 m wide and 20 m deep) (Dias & Lopes, 2006), and is located in the central coastal zone of Portugal, integrating the Vouga river catchment area (Figure 1). It is c. 45 km in length (NNE-SSW), 10 km wide and in a spring tide covers an area of approximately 83 km² and 66 km² of wetland at high water and low water, respectively (Dias et al., 2000). The bathymetry of the Ria de Aveiro consists of four main channels which radiate from the mouth with several branches, islands and mudflats. The total fluvial discharge into the lagoon during a tidal cycle is about 1.8×10⁶ m³, while the tidal prism is 137×10⁶ m³ for maximum spring tide, and 35×10⁶ m³ for minimum neap tide (Dias et al., 2000). The circulation in the Ria de Aveiro is therefore essentially dominated by tidal forcing. The tidal phase lag, relative to the mouth, is in the order of 4 h in the upper reaches of the S. Jacinto channel, being lower (between 2-3 hours for the other main channels). Due to the combined effects of the freshwater discharge and tidal propagation, the central area of the Ria de Aveiro exhibits a longitudinal salinity gradient from about 0 in the upper reaches of the Espinheiro channel to about 36 at the bar entrance (e.g. Vaz & Dias, 2008). The average depth of the lagoon relative to the chart datum is about 1 m, except in navigation channels

where dredging operations are frequently carried out. Due to the small depth and to the significant tidal wave amplitude there are zones, especially along the borders of the lagoon and its central area, which are alternately wet and dry during each tidal cycle. The lagoon is mesotidal with an average tidal range of 2 m (tidal amplitude at the inlet ranges from 0.6 m in neap tides to 3.2 m in spring tides) (Dias *et al.*, 2000).



Sistema de projeção cartográfica Gauss-Kruger
Epsilão de Hayford, Datum de Lisboa
Origem das coordenadas rectangulares: Ponto fictício (unidades em metros)

Figure 1 – Location of Ria de Aveiro coastal lagoon and the Vouga River drainage basin (source: <http://www.arhcentro.pt/>)

The Ria de Aveiro and its main tributary (Vouga river) flood recurrently, inundating the low-lying adjacent lands. The surrounding littoral stretches of Esmoriz-Furadouro and Vagueira-Mira show coastal erosion problems with high risk of sand spit rupture (EEA 2006; www.reports.eea.europa.eu/eea_report_2006_6/en). Much of the flooding events occur during adverse weather conditions, with heavy rainfall causing high river flows. Low pressure N/NW of Portugal and high pressure S/SW and strong southerly winds cause surges in the Portuguese coast. High tides also impact on the level of flooding, as well as the mean sea level evolution. The morphodynamic of the inlet channel also depends on the mean sea level and on the north-east Atlantic wave climate regime. Furthermore, these last factors and the sediment supply also impact the coastal erosion of Ria de Aveiro Littoral (IHRH, 2003; www.euroasion.org/reports-online/reports.html).

Main water management problems (ecological/environmental, social and economic)

The Ria de Aveiro is highly productive and support a number of essential services of vast ecological and economic importance (Figure 2), while human pressure has increased during the past decades.

The productivity of Ria de Aveiro is sustained by the amount of nutrients that comes mainly from diffuse sources, namely from surface runoff and from agricultural fields drainage, and less than 10% from point sources (Ferreira *et al.*, 2003). With respect to environmental quality, the Ria de Aveiro has a moderately low degree of eutrophication and low overall human influence in comparison to other estuarine systems. However, despite some human interventions, like the construction of a submarine outfall that reduced the nutrient loads, the quality status of different areas within the

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system can vary (Lopes et al., 2007). This means that these particular areas should be taken under consideration for specific monitoring programmes and management measurements. The implementation of EU environmental policies has, furthermore, aided in reducing anthropogenic sources of contaminants. There is, however, substantial contamination in bottom sediments as a result of historical pollution and these may become a major source to the water column. In fact, the assessment of Ria sediment quality status, through metal-sediment characterization and through acute and chronic assays, identified the most impacted areas, i.e. the northern part of the estuary (Largo da Coroa), where most of the historical industrial units are concentrated, and near the industrial complex of Estarreja (Laranjo Basin), historically contaminated by mercury (e.g. Castro et al., 2006; Pereira et al., 2009).

This lagoon plays an important ecological role, being the habitat for several species of flora and fauna that are supported by the dynamics of the lagoon. The system is composed of a wide range of biotopes (e.g. wetlands, seagrasses, salt marshes and mudflats) used as nursery areas for many valuable species that include bivalves, crustaceans, fish and birds. It is classified as a special area of conservation under the EU directive on the conservation of wild birds (79/ 409/EEC). Under the Berne Convention it has several species classified as protected, strictly protected or as endangered. In its northern part, between S. Jacinto and Torreira, there is a nature reserve—“Reserva Natural das Dunas de S. Jacinto”. Moreover, from the conservational point of view this system is considered a high priority since it is a fundamental step in the migration of aquatic birds and an ideal place for winter shelter and nesting. The whole area of the Ria de Aveiro also supports agriculture farms and activities intrinsically associated with major towns in coastal areas: port facilities, industries, aquacultures, salt production and fishing.

According to recent climate change scenarios (IPCC, 2007, <http://www.pnud.cl/recientes/IPCC-Report.pdf>) southern Europe will tend to become dryer despite winter torrential rain events becoming more frequent, increasing freshwater discharges. Consequently, erosion processes and material loads are expected to increase, leading to an aggravation of light-limiting conditions to phytoplankton and consequently to primary production. This will inevitably disturb the trophic structure of the system, and consequently affect the system secondary production including fishery-stocks. Sea level rise is also expected to cause changes inside estuaries (intertidal areas), affecting the hydrodynamics of these transition systems.

Ria de Aveiro was recently selected as a Portuguese long term monitoring site (LTER-site) and can be seen as one of the most important Southern European LTER Estuary reference study site.

End users

On national level:

- ICNF I.P. - Instituto Conservação da Natureza e Florestas (Institute of Nature Conservation and Forestry);
- APA - Agência Portuguesa do Ambiente I.P (Portuguese Environmental Agency);
- DGT - Direcção Geral do Território (Directorate- General for Territory)
- ITP - Turismo de Portugal (Portuguese Institute for Tourism)

On regional and local level:

- CCDR Centro – Comissão de Coordenação e do Desenvolvimento Regional do Centro (Centro Regional Coordination and Development Commission);
- Direcção Regional de Agricultura e Pescas do Centro (Centro Regional Directorate for Agriculture and Fisheries)
- Comunidade Intermunicipal da Ria de Aveiro (Intermunicipal Community for Ria de Aveiro);
- Reserva Natural das Dunas de S. Jacinto (Natural Reserve of Dunes of S. Jacinto);
- Municipalities (Ovar, Murtosa, Estarreja, Aveiro, Ílhavo, Vagos e Mira);

- Sectoral associations, namely: farming (Associação da Lavoura do Distrito de Aveiro), artisanal fisheries (Associação de Pesca Artesanal da Região de Aveiro), saltpans producers (Associação de Produtores e Marnotos da Ria de Aveiro) and other local users of the lagoon.

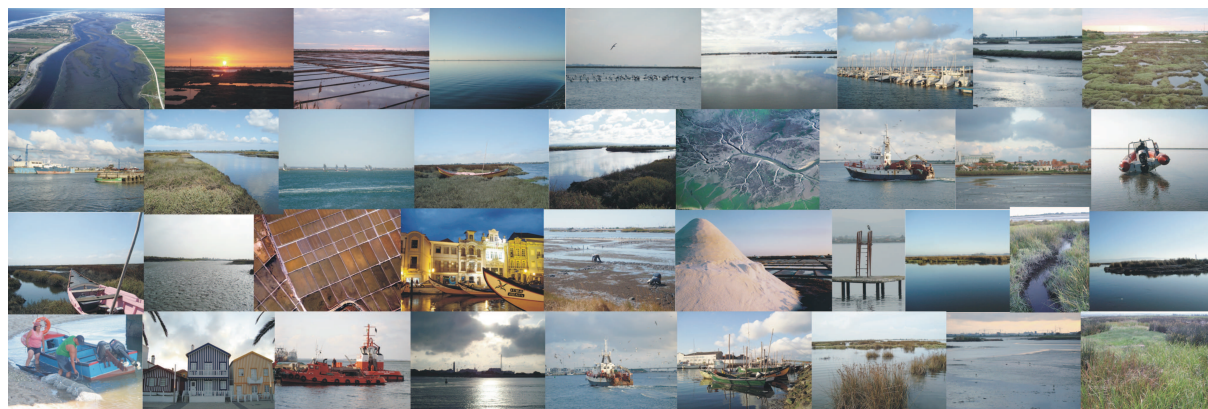


Figure 2 – Landscape and ecosystem services provided by Ria de Aveiro (source Lillebø et al, 2011)

References

- Castro, H.; Ramalheira, F.; Quintino, V. E Rodrigues, A.M., 2006. Amphipod acute and chronic sediment toxicity assessment in estuarine environmental monitoring: An example from Ria de Aveiro, NW Portugal. *Marine Pollution Bulletin*, 53, 91–99.
- Dias, J.M.; Lopes, J.F., Dekeyser, I., 2000. Tidal propagation in Ria de Aveiro Lagoon, Portugal. *Phys Chem Earth (B)* 25 (4), 369-374
- Dias, J.M., Lopes J.F., 2006. Implementation and Assessment of Hydrodynamic, Salt and Heat Transport Models: The Case of Ria de Aveiro Lagoon (Portugal). *Environmental Modelling & Software*. 21, 1-15
- Lillebø, A.I., H. Queiroga, J.M. Dias, F. Alves, D.F.R. Cleary (2011) Ria de Aveiro: Uma Visão dos Processos Ambientais, Ecológicos e Socioeconómicos. In: Almeida, A., Alves, F.L., Bernardes, C., Dias, J.M., Gomes, N.C.M., Pereira, E., Queiroga, H., Serôdio, J., Vaz, N. (Eds). *Actas das Jornadas da Ria de Aveiro*, Universidade de Aveiro, CESAM-Centro de Estudos do Ambiente e do Mar, pp.334-339
- Lopes, C.M.B.; Pereira, M.E.; Vale, C.; Lillebø, A.I.; Pardal, M.A. E Duarte, A.C., 2007 Assessment of spatial environmental quality status in Ria de Aveiro (Portugal). *Scientia Marina*, 71, 2, 293-304.
- Ferreira, J.G.; Simas, T.; Nobre, A.; Silva, M.C.; Shifferegger, K. e Lencart-Silva J., 2003 Identification of sensitive areas and vulnerable zones in transitional and coastal Portuguese systems. In: INAG- Instituto da Água and IMAR-Instituto do Mar (eds.), *Application of the United States National Estuarine Eutrofication Assessement to the Minho, Lima, Douro, Ria de Aveiro, Mondego, Tagus, Sado, Mira, Ria Formosa and Guadiana systems*, pp 53-65.
- Pereira M.E.; Lillebø A.I.; Pato P.; Válega M.; Coelho J.P.; Lopes C.; Rodrigues S.; Cachada A.; Otero M.; Pardal M.A.; Duarte A.C., 2009 Mercury pollution in Ria de Aveiro (Portugal): a review of the system assessment. *Environment Monitoring and Assessment*, 155, 39–49.
- Van der Weijden C.H., Pacheco F.A.L. 2006. Hydrogeochemistry in the Vouga River basin (central Portugal): Pollution and chemical weathering. *Applied Geochemistry* 21, 580–613
- Vaz, N. e Dias, J.M., 2008. Hydrographic characterization of an estuarine tidal channel. *Journal of Marine Systems*, 70 (1–2), 168–181.