GUADIANA RIVER ESTUARY

Investigating the past, present and future

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6. A brief journey along time in the Guadiana estuary

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The physical characteristics of the Guadiana estuary and the richness of its adjacent territories were essential in defining the historical and cultural context of the entire region. The extended navigability of the estuary was fundamental to establish trade routes with the Mediterranean civilizations, namely with the Phoenicians, Greeks, and Carthaginians. These civilizations created several commercial harbors along the Guadiana, namely in Mértola, Alcoutim, Castro Marim and Ayamonte. In these locations the human presence dates back as far as the Neolithic (12,000 to 4,000 BCE) and the Chalcolithic periods (4,000 to 3,100 BCE). Later, the Romans (II BCE to V CE), the Alans (V to VI CE.), the Visigoths (VI to VIII CE), and the Arabs (VIII to XIII CE) successively settled in this Iberian region, until the borders of the continental Portuguese territory were set in the 13th century. The predominant North-South direction of the estuary is intrinsically linked with the definition of the Portuguese and Spanish territories, as it serves as a natural border in its last 50 km.

Ore extraction and cereal production in the surrounding areas of the estuary turned Mértola into the most important trading center, up to the Portuguese conquest in 1238 (Fig. 6.1). Copper, iron, and manganese were the main ore resources, but silver and gold were exploited as well. With the Portuguese conquests, the economic importance of the Guadiana estuary decreased sharply. In the 15th and 16th centuries, cereals were shipped to the Portuguese forts of northern Africa, but it was only in the late 19th century that all the regions around the estuary had a new economic burst.

Figure 6.1.
The castle of Mertóla viewed from the Ribeira de Oeiras valley in April 2004 (Photography by Pedro Morais).

In the late 18th century, the Portuguese Prime-Minister, Marquês de Pombal, ordered the construction of a new city, Vila Real de Santo António, located near the river mouth. The main goals were political, economical and strategic-related, but primarily to face the economic boom of the Spanish city of Ayamonte, in the opposite margin. Ayamonte's prosperity derived from an intense fishing activity targeting sardine in the Gulf of Cadiz and Bay of Montegordo, which attracted Spanish and Portuguese fishermen. However, Vila Real de Santo António only prospered in the late 19th century, due to a strong development of ore extraction, fisheries, canning and shipyard industries (see Box 6.1.)

Box 6.1. Marquês de Pombal

Sebastião José de Carvalho e Melo (Lisbon, May 13, 1699 – Pombal, May 8, 1782), mostly known as Marquês de Pombal, was the prime-minister of King D. José I. Marquês de Pombal was a controversial political personality during the 18th century, and he is recognized for commissioning the reconstruction of Lisbon after the 1755 earthquake. Marquês de Pombal tried to improve the country's economic status by developing the agriculture, industry and commerce. The city of Vila Real de Santo António, was built with the purpose to divert part of Ayamonte's fisheries profit, which is a city located in the opposite margin to Castro Marim and Vila Real de Santo António.

Ore extraction, specifically of copper, began in 1858 in re-discovered Roman mines at Minas de São Domingos (Fig 6.2). Ships transported the ore to the estuary mouth, where it was re-transferred to bigger ships heading England and Germany. The end of the mining activity in 1965 caused a deep economic and demographic recession. Between 1961 and 1971, the county of Mértola lost 50% of its population, which migrated either to Lisbon and surrounding cities, or abroad. Presently, the upper estuary is one of the poorest regions of the European Union.

The fishery activity developed in the late 19th century with the rise of sardine and tuna canning industry, which were promoted by Spanish, Italian and Greek entrepreneurs.

Figure 6.2.
Abandoned ore extraction facilities at Mina de São Domingos in September 2014 (photography by Pedro Morais).

Truly, Vila Real de Santo António is the birthplace of the Portuguese fish canning industry, where the first tuna canning factory was built in 1865. Canned fish soon became one of the most famous Portuguese export goods, like wine and cork, and mainly during the World War II. Fisheries started to decline in the 1960's, and today no fish canning industry remains working in Vila Real de Santo António.
From 1929 to 1937 the "wheat campaign" was imposed by the Portuguese government, as an attempt to make Portugal self-sufficient and end its reliance on US and Canadian wheat. During this period, the economic activity increased along the estuary, especially in Alcoutim, where the wheat was flowed-off, and fertilizers were received. However, the "wheat campaign" was made in poor soils, leading to their complete exhaustion,once the traditional rotation system of cultures and fallow practices were abandoned. Today, tourism is the main economic activity, not only in the Guadiana estuary but in all the Algarve, the southern Portuguese region.
Whereas from the late 19th century, mining and canned fish industries were the most harmful activities around the Guadiana estuary, presently water abstraction and retention on dams are probably those of most concern to the estuary. Since mid-1950's, the Guadiana basin has been intensively dammed, allowing the development of extensive irrigation areas, electrical production and other public and industrial demands. The Alqueva dam, located at approximately 150 km from the river mouth, was the last to be built. The floodgates closed on February 8th 2002, and river flow regulation increased from 75% to 81% (Fig. 6.3). With this dam, the Portuguese government aimed, besides regularizing the Guadiana river flow, to reinforce the capacity of hydroelectric energy production, develop the tourist potentialities of the area, promote the regional employment market, organize intervention in environmental and patrimony domains, fight physical desertification and climate change, and modify the agriculture specialization model of southern Portugal by implementing an irrigation area of 110,000 ha. (see Box 6.2.)

Box 6.2. Alqueva dam

The Alqueva dam is located approximately at 150 km from the river mouth. It forms at its maximum capacity (152 m level) one of the biggest artificial lakes in Europe, with an area of 250 km^2 (63 km^2 in Spain), a perimeter of approximately 1000 km, a total capacity of 4150 hm^3, and an useful capacity of 3150 hm^3.

Figure 6.3.
Downstream face of the Alqueva dam in July 2009 (photography by Pedro Morais).

Other significant constructions in the Guadiana estuary during the 1970's were the two jetties that stabilized the once highly dynamic river mouth, which drastically changed local sediment dynamics. The main consequence was the interruption of the predominant eastward littoral drift and sediment deposition in the river mouth. However, due to sediment retention in dams and lower freshwater flows, coastal erosion is expected to be enhanced in the future.

The company responsible for constructing the Alqueva dam monitors the reservoir's water quality . However, the impact of altered river flow on downstream ecosystems is significant. The first changes were observed on the phytoplankton community. Before the Alqueva dam construction, phytoplankton exhibited a typical uni-modal cycle, with a biomass maximum during spring, corresponding to the diatom bloom, and a summer cyanobacteria bloom. During 2002-2004, when the Alqueva dam was being filled and freshwater flowing into the estuary was tremendously reduced, cyanobacteria dominated the phytoplankton community, not only during summer months, but in the autumn and winter as well. In the post-filling period, river flow became more constant throughout the year, significantly affecting phytoplankton dynamics. The abundance of diatoms and cyanobacteria decreased in the post-filling period. The decrease of cyanobacteria represents an improvement in water quality since many species produce toxins responsible for gastrointestinal, dermatological, and neurological problems. However, the overall decrease in phytoplankton biomass and, specifically, the decline in diatom biomass may have major negative consequences for higher trophic levels that depend on planktonic food.

The impacts of the altered river flow are also evident in fish populations. The main consequence is a reduced use of the Guadiana estuary as a habitat for freshwater fishes, and as a spawning ground for marine species. Several barbells, endemic of the southern Iberian Peninsula, are today classified as threatened, and other species occurring in brackish and freshwater habitats are considered vulnerable, such as allis shad (*Alosa alosa*) and twaite shad (*Alosa fallax*). The cyprinidae *Anaecypris hispanica*, an endemism once abundant in the Guadiana basin, is today threatened with extinction. Damming, water abstraction for agriculture irrigation systems, habitat degradation, polluted effluents, and introduction of non-indigenous competitors are the probable causes of these losses. Other problems, namely overfishing and damage of spawning grounds by sand and gravel extraction, resulted in the disappearance the European sturgeon *Acipenser sturio*, an emblematic migratory fish from the Guadiana basin. The last sturgeon was caught in the early 1980's. Coastal fisheries are also affected by the Guadiana river flow (Fig. 6.4). In years of low river discharge, sardine landings decreased 69%, from 886 to 279 ton, while landings of carnivorous fish (e.g. seabreams) increased between 112% and 128% (see Boxes 6.3. to 6.5.)

Box 6.3.Migratory fish

Migratory fish species are those that need to perform regular migrations between different ecosystems (river, estuary, ocean/sea), or habitats within ecosystems, at specific stages of their life cycle. There are three main types of migratory fish: i) potamodromous fish- perform migrations between distinct freshwater habitats; i) diadromous fish- perform migrations along a salinity gradient, between rivers and/or estuaries and the ocean; iii) oceanodromous fish- perform migrations in the oceanic environment. The most emblematic migratory fish species present in the Guadiana estuary are the diadromous fish European ell *Anguilla anguilla* (Linnaeus, 1758), twaite shad *Alosa fallax* Lacépède, 1800, allis shad Alosa alosa (Linnaeus, 1758), and sea lamprey *Petromyzon marinus* Linnaeus, 1758. The emblematic European sturgeon *Acipenser sturio* Linnaeus, 1758 is extirpated from the Guadiana basin since early 1980's.

Box 6.4. Diadromous fish

Fish species that perform migrations along a salinity gradient. There are three types of diadromous fish. Amphidromous fish are those that hatch in rivers and then migrate into the ocean, but that return back to rivers still as post-larvae or as young juveniles (e.g. species of the family Galaxiidae). Anadromous fish are those that migrate from the ocean into freshwater/brackish ecosystems to spawn (e.g. shad, sturgeon, lamprey). Catadromous fish are those that migrate from rivers/estuaries to spawn in the ocean (e.g. eel).

Box 6.5. Cyanobacteria

Group of photosynthetic bacteria that live in a wide range of habitats, including marine and freshwater ecosystems. Many cyanobacteria species produce toxins that can cause gastrointestinal, dermatological, and neurological problems. Cyanobacteria that live and drift freely in the water column in aquatic ecosystems are part of phytoplankton, a heterogeneous group of photosynthetic organisms that is responsible for 50% of the world's total primary productivity.

Damming and water abstraction are not the only threats to the Guadiana estuary. Agricultural, industrial, and urban pressures are not significant in the Guadiana, compared to other Iberian estuaries. However, the lack of land use and proper management is responsible for other problems, as the increased probability of forest fires. Lack of forest management results from complex social-economical problems. The upper estuarine region is one of the poorest in the European Union, and the manpower is scarce due to the aging of local populations. Nevertheless, tourism infrastructures are still being developed in the lower Guadiana estuary. One of these is in its late stages of construction in the Spanish margin; this tourist resort will host 20,000 inhabitants and will be equipped with houses and hotels, shopping centers, golf courts, and a marina, representing an enormous change in land and estuarine use.

Figure 6.4.
Fishing boat (Princesa do Guadiana) entering the Guadiana estuary in December 2002 (Photography by Pedro Morais).

The creation of a Biosphere Reserve or the International Natural Park of the Lower Guadiana was proposed by Almargem, a local environmental organization, during the first decade of the 21st century to avoid the massive construction of tourism infrastructures and to compensate for the loss of biological diversity. Currently, the only protected landscapes around the Guadiana estuary are the Natural Reserve of Castro Marim and Vila Real de Santo António, located near the river mouth, and the Natural Park of the Guadiana Valley, occupying an area of 70,000 ha around the village of Mértola. A demosite was implemented in the Guadiana estuary, with the support of the UNESCO's International Hydrological Program, to demonstrate how it is possible to mitigate and restore the functioning of estuaries and coastal areas impacted by dam construction using ecohydrological solutions. This is a new approach to achieve sustainable water management, based on the study of functional inter-relationships between hydrology and biota at the catchment scale.

Currently, the future environmental sustainability of the Guadiana estuary has to rely on an ecohydrological approach of the Guadiana basin. The conjunction of efforts between academia, NGO's, local populations, local and regional authorities, basin managers, and even tourism entrepreneurs is compulsory to achieve the environmental sustainability of the Guadiana estuary.

Consulted bibliography

Almaça, C. & Elvira, B. 2000. Past and present distribution of *Acipenser sturio* L., 1758 on the Iberian Peninsula. *Boletín Instituto Español de Oceanografia* 16: 11-16.

Bettencourt A., Gomes, V., Dias, J. A., Ferreira, G., Silva, M. C., Costa, L., Eds., 2003. Estuários Portugueses. Instituto da Água, Portugal, 300p.

Chícharo, L. M., Chícharo, M. A. & Morais, P. 2003. Effects of Guadiana river inflow on coastal fisheries. *Thalassas* 19: 99-100.

Chícharo, L.M., Chícharo, M. A., Ben-Hamadou, R. & Morais, P. 2006. Sustainable estuarine zone management for control of toxic blooms, invasive species and conserving biodiversity, Guadiana demonstration site, Portugal. *GLOBEC International Newsletter* 12: 25-27.

Chícharo, M. A., Chícharo, L. M., Galvão, H., Barbosa, A., Marques, M. H., Andrade, J. P., Esteves, E., Miguel, C. & Gouveia, I. 2001. Status of the Guadiana estuary (South Portugal) during 1996-1998: an ecohydrological approach. *Aquatic Ecosystem Health and Management* 4: 73-90.

Collares-Pereira, M.J., Cowx, I. G., Ribeiro, F., Rodrigues, J. A. & Rogado, L. 2000. Threats imposed by water resource development schemes on the conservation of endangered fish species in the Guadiana River Basin in Portugal. *Fisheries Management and Ecology* 7: 167-178.

Dias, J. M. A., González, R. & Ferreira, Ó. 2004. Natural versus anthropic causes in variations of sand export from river basins: An example from the Guadiana river mouth (southwestern Iberia). *Polish Geological Institute* 11: 95-102.

Domingues, R. B., Barbosa, A. & Galvão, H. 2005. Nutrients, light and phytoplankton succession in a temperate estuary (the Guadiana, south-western Iberia). *Estuarine, Coastal and Shelf Science* 64: 249-260.

Domingues, R. B., Sobrino, C. & Galvão, H. 2007. Impact of reservoir filling on phytoplankton succession and cyanobacteria blooms in a temperate estuary. *Estuarine, Coastal and Shelf Science* 74: 31-43.

Domingues, R. B., Barbosa, A. B. & Galvão, H. M. 2014. River damming leads to decreased phytoplankton biomass and disappearance of cyanobacteria blooms. *Estuarine, Coastal and Shelf Science* 136: 129-138.

Erzini, K. 2005. Trends in NE Atlantic landings (southern Portugal): identifying the relative importance of fisheries and environmental variables. *Fisheries Oceanography* 14: 195-209.

Fundação Calouste Gulbenkian, 2003. Rios de Portugal. CD-ROM.
Lello, J., Lello, E., (Eds.), 1973. Lello Universal. Dicionário Enciclopédico Luso-Brasileiro. Volume Segundo. Lello & Irmão, Porto, 1227 p.
Lobo, F. J., Hernández-Molina, J., Somoza, L., Diáz del Rio, V. & Dias, J. M. A. 2002. Stratigraphic evidence of an upper Pleistocene TST to HST complex on the Gulf of Cádiz continental shelf (south-west Iberian Peninsula). Geo-Marine Letters 22: 95-107.
Morais, P. 2008. Review on the major ecosystem impacts caused by damming and watershed development in an Iberian basin (SW-Europe): focus on the Guadiana estuary. *Annales de Limnologie - International Journal of Limnology* 44:105-117.
Morais, P. & Daverat, F. (Eds.), 2016. An introduction to fish migration. CRC Press, USA, 307 p.