SPICOSA 5-9 February 2008 4th Internal Workshop

SCIENCE AND POLICY INTEGRATION FOR COASTAL SYSTEM ASSESSMENT

Guadiana River Estuary

Field Guide

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SIXTH FRAMEWORK PROGRAMME

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INTRODUCTION

to the Draft Field Guide for the Guadiana Estuary SSA 11 PORTUGAL

This Guide will be a Deliverable later on in the project and we hope that it could act as template for other SSAs. It is therefore important that as many partners in SPICOSA see a draft and give an opinion on how it might be improved.The idea is to have a guide on General Topics (Geomorphology, Ecology,, History, Socioeconomics etc) that is strucutured so that there is a general description on each topic with links at the end of each topic to more detailed material such as reports, published articles, lists of species , web sites etc etc. At the end of the Guide we want illustrate how the general material can be used for specific products that are being developed by the project. This is a draft that will undergo many more transcriptons, but we wanted to take the opportunity of your visit to Portugal to learn from your experience

With thanks for your participation

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Guadiana Estuary – Study Site

The Guadiana River (Fig. 1) has the fourth largest drainage basin of any river in the Iberian Peninsula: it is 67,039 km^2 in area, rising in Spain at Campo de Montiel, province of Ciudad Real, and draining between Vila Real de Santo António (Portugal) and Ayamonte (Spain). The river flows for 810 km, of which 550 km is in Spanish territory, 150 km in Portugal and 110 km serving as a border between the two countries.

Figure 1 – The Guadiana River starts in Spain and follows south along the Portuguese border to the Guadiana estuary.

The Guadiana estuary is a mesotidal estuarine system (tidal amplitude ranges from 1.3 to 3.5 m) located in a temperate climate area, with moderate, humid winters and hot dry summers. Its tidal limit is near the village of Mértola, approximately 70 km from the mouth. The estuary occupies an area of 22 km^2 and its average depth is 6.5 m. Freshwater inputs to the estuarine zone vary sharply, depending on rainfall and water retention in dams. As the estuary receives both salt water from the sea and fresh water from the river, and these waters do not always get properly mixed, the estuary may be classified as partially stratified.

In the last 5 years mean monthly freshwater flow at Pulo do Lobo (80 km upstream) has varied abruptly from 3,000 m^3 s^{-1} in the winter and 0,01 m^3 s^{-1} in the summer (Morais, & Domingos, 2006). The freshwater flux that arrives to the estuary is very important for the dynamics of the area, since it transports sediments up to river mouth, enabling the construction of the estuarine margins and the sea bottom (Megasig, 2007). In addition, the estuary receives reduced freshwater inputs from some tributaries, whilst other inputs include sewage,

mainly near the mouth, from the cities of Vila Real de Santo António (13,880 inhabitants) and Ayamonte (17,500 inhabitants). A total of 1.92 million people inhabit the Guadiana River basin, 88% of whom are in Spain (Morais & Domingos, 2006).

Geomorphology of the estuarine area

Geomorphology is the study of the forms of the terrain. Considering the forms that exist in the Guadiana Estuary and its surrounding areas, it is possible to define thee primary domains:

- Continental domain
- Littoral domain
- Submarine domain

In the continental area surrounding the Guadiana Estuary it is possible to see some particular morphological features, some identifiable on both margins but others on only one. Older rocks associated with mountain ranges are more representative on the Portuguese side. On the other side, rocks formed after the creation of the mountain ranges are predominant; these are characterized by absence of large elevations, and gentle slopes without a strong incision of the drainage network. Separating the mountains from the coast there is an intermediate unit called Barrocal that only exists in the Portuguese territory.

Regarding the coastal zone contiguous to the Guadiana Estuary, the relief morphology is more homogenous, with flat areas as well as some small elevations. Sandy beaches are dominant, although dunes and dune ridges are also present. In the estuary there are tidal terraces and extensive salt marshes on both margins.

The submerged area fronting the estuary is characterized by the presence of an extensive continental shelf, which is progressively narrow to the west (Megasig, 2007).

Geology – The last 15.000 years

Nowadays, the Guadiana Estuary is a lot different from what it was several thousand years ago, during the last glacial period. At that time, most of the Northern Hemisphere was covered by ice caps and the sea level was much lower than today. In such conditions, a narrow and incised valley developed, being filled with sediments when the sea level rose.

In the last 1000 years sedimentation has continued, forming the estuary as we know it today.

Sea level rise was now much slower and the sediments that came from the continental shelf and transported by the Guadiana were accumulating.

Sea-level continued to rise, increasing around 1 metre every 100 years

The glaciers and ice caps started to melt and the sea level rose, progressively flooding the Guadiana River valley

Around 18,000 years ago the sea level was more than 120 metres below the present one and the coastline was located around 22 km south of its present position (Megasig, 2007).

History

The navigable branch of the Guadiana River, which extends along 70 kilometres from the mouth, has always been the main factor affecting livelihoods in the Lower Guadiana region. This nature of this effect has changed over the centuries as a result of changes in natural conditionings, the historical context and also commerce. The occupation of the area owes itself to what both the river and the sea can offer (Megasig, 2007).

The physical characteristics of the Guadiana estuary were essential in defining the historical and cultural context of this region. The extended navigability of the estuary was fundamental to establishing trade routes with the Mediterranean civilisations, namely with the Fenicians, Greeks and Carthaginians. These civilisations created several commercial harbours along the Guadiana, namely in Mértola, Alcoutim, Castro Marim and Ayamonte. In these locations the human presence dates back as far as the Neolithic (12000 to 4000 b.C) and the Chalcolithic periods (4000 to 3100 b.C.). Later, the Romans (II b.C to V a.C), the Alans (V to VI a.C.), the Visigoths (VI to VIII a.C) and the Arabs (VIII to XIII a.C.) successively established in this Iberian region, until the delineation of the continental Portuguese territory in the 13th century. The predominant North-South direction of the estuary was intrinsically linked to 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 along the surrounding areas of the estuary turned Mértola into the most important trading centre, up to the Portuguese conquest in 1238. 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, and it was only in the late 19th century that all the regions around the estuary experienced a new economic revival.

In the late 18th century, the Portuguese Prime-Minister, Marquis of 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 strong economical development of the Spanish city of Ayamonte, on the opposite margin. The prosperity of Ayamonte derived from an intense fishing activity, mainly focused on sardine, in the Gulf of Cadiz and Bay of Montegordo, attracting both 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, and of preserve and shipyards industries.

The fisheries activity developed in late 19th century through investment by Spanish, Italian and Greek entrepreneurs, who promoted the tinned fish industry, mainly of sardine and tuna. Truly, Vila Real de Santo António is the birth place of the Portuguese tinned fish industry, where the tinning of tuna was pioneered in 1865. Tinned fish soon became one of the most important export goods in Portugal, similar to wine and cork, mainly during World War II. The fisheries started to decline in the 1960s and today no tinned fish industry remains in the village.

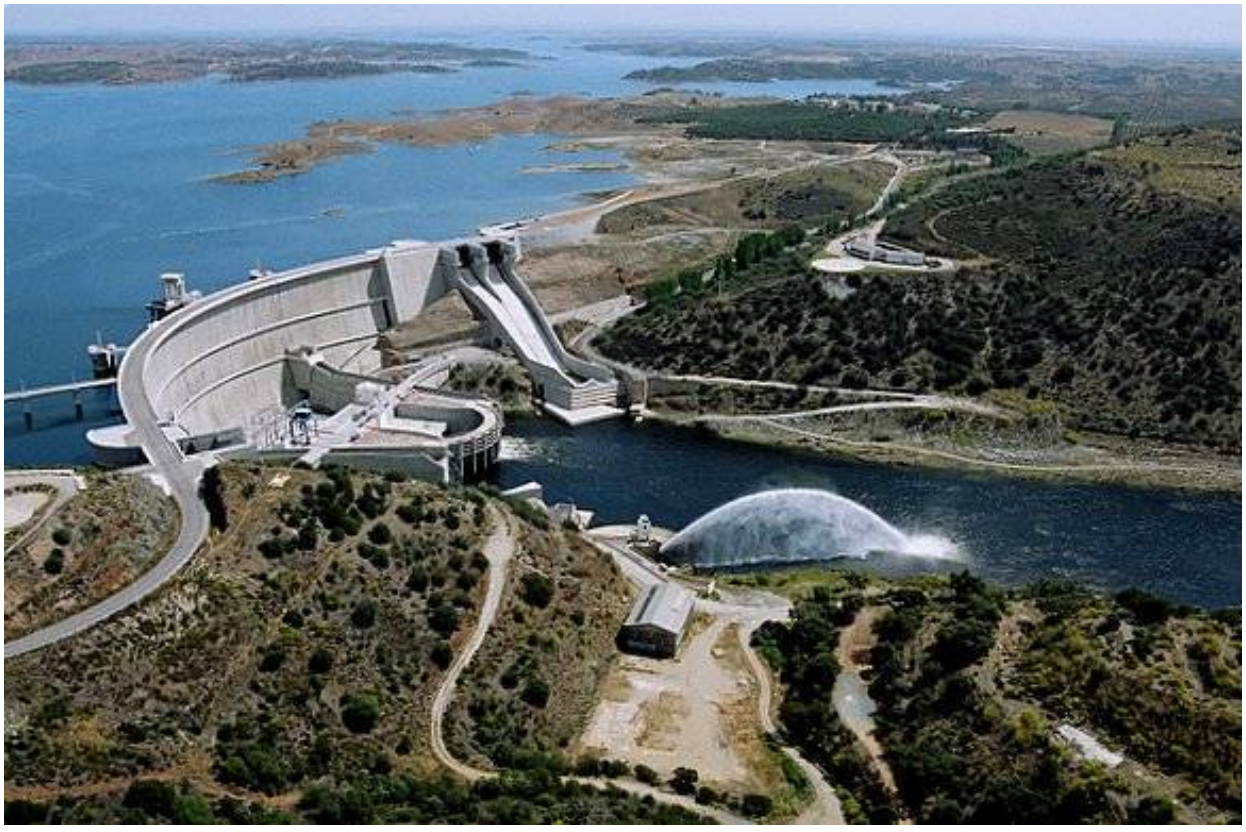
From 1929 to 1937 the “wheat campaign” was imposed by the Portuguese government, as an attempt to make Portugal self-sufficient and end its reliance on US and Canadian imported wheat. During this period, economic activity increased along the estuary, especially in Alcoutim, where the wheat was distributed and fertilizers were received. However, the “wheat campaign” was made on poor soils, leading to their complete exhaustion, once the traditional rotation system of cultures and resting of soils was abandoned. Today, tourism is the main economical activity, not only in the Guadiana estuary, but in all of the Algarve, the southern Portuguese region.

Whereas from the late 19th century, mining and tinned fish industries were the most deleterious activities around the Guadiana estuary, at present water abstraction and water retention in dams are probably those of most concern as regards the estuary. Since the mid-1950s, the Guadiana basin has been intensively dammed, allowing the development of extensive irrigation areas, electricity production and other public and industrial demands. The

Alqueva dam was the last to be built; its floodgates were closed on February 8th 2002 and river flow regulation increased from 75% to 81%. This dam is located approximately at 150 km from the Guadiana river mouth and creates, at its maximum capacity (152 m level), one of the biggest artificial lakes in Europe, with an area of 250 km^2, a perimeter of approximately 1,100 km and a total capacity of 4.15 x 10^9 m^3. With this dam, the Portuguese government aims, besides controlling the Guadiana river flow, to reinforce the capacity of hydroelectric energy production, to develop the tourist potentialities of the area, to promote the regional employment market, to organize intervention in environmental and patrimony domains, to fight physical desertification andclimate change, and to modify the agriculture specialization model of southern Portugal, by implementing an irrigation area of 110,000 ha.

Other important constructions in the Guadiana estuary during the 1970s were of two jetties that stabilised the once highly dynamic river mouth, but they drastically changed local sediment dynamics. The main consequence was the interruption of the predominantly eastward littoral drift and sediment deposition in the river mouth, especially in the Spanish margin. However, due to sediment retention in dams and lower freshwater flows, coastal erosion is expected to be enhanced in the future.

The company in charge of the Alqueva dam construction intensively monitors the water quality in the Alqueva reservoir. 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. From 2002 onwards, cyanobacteria dominated the phytoplankton community, not only during summer months, but in the autumn and winter as well. Cyanobacteria dominance in the estuary represents a serious concern to local populations, given that many species can produce potent toxins responsible for gastrointestinal, dermatological and neurological problems (Morais, & Domingos, 2006).



Ecology

The salt-marsh ecosystem

Salt marshes are composed of unique plant species with characteristics very specific to this type of wetland. Salt-marsh vegetation enables the retention and exchange of nutrients and detritus between the salt marsh and other zones of the estuary, and creates important habitats for a wide range of animals.

Salt marshes are areas occupied by herbaceous plants and low shrubs, subjected to periodic inundation by saline or brackish water. They are situated in coastal zones and have characteristics of both terrestrial and marine systems. However, it is the vascular plants of terrestrial origin which are most important in shaping the marsh ecosystem.

The presence of salt water is the main factor which distinguishes salt marshes from the other types of wetland that one finds in the more interior zones of an estuary and that are more influenced by fresh water. In reality there is not a clear delimitation between the two regimes, but rather a gradual transition. The ecological importance of salt marshes arises from the diversity of habitats that they support, as well as the exchange of nutrients, detritus and organisms between the marshes and other part of the estuary (Megasig, 2007).

The salt-marsh flora

The diversity of plant species inhabiting a salt marsh is relatively low. This is due to the demanding conditions that the plants have to cope with here. One finds specialist plants which are adapted to the high salinities and periodic inundation. The most successful ones sometimes end up dominating extensive areas of marshland.

The plant species which are characteristic of salt marshes are called halophytes, that is to say, species adapted to live in zones where the water has a higher salinity than that of fresh water. Halophytes usually live only in saline or brackish areas and are generally of small stature. This reduced size is a result of low relative productivity, given that a large amount of energy and material produced by these species is expended on adapting to the saline environment, instead of being used for plant growth as would be the case in other environments.

Owing to the different levels of specialisation and tolerance to be found in salt-marsh plants, a clear zonation between different communities is often evident. This zonation reflects variation in the prevailing environmental conditions and the different niches that plants have along their spectrum.

The vegetation is responsible for the building of the salt marsh; without vegetation there cannot exist a marsh. In order for a marsh to develop it is necessary that the sediments start to accumulate in certain areas of the estuary. When this first begins to happen, the plants are not yet present but instead there will be small algae growing on the surface of the sediments. It is these algae which create the conditions for colonisation by plants. When the plants start to establish themselves, the marsh grows in height – not just with the increase in the size of the plants but also the laying down of sediments – and also width and length, starting to occupy new areas. The development of the vegetation accelerates sedimentation. This happens because the stems and leaves of the plants, in impeding the water currents, trap the sediments in suspension and cause them to settle out to the bottom. When they are ths

deposited, they are stabilised by the root growth of the plants so that they are not swept away again by the currents.
In this way the marsh grows further, being built up by these sediments and plant and animal detritus, either *in-situ* or arriving with the tidal flows (Megasig, 2007).

Recreational and educational value
The salt marshes are also important areas from the point of view of recreation, given that many people like to pass time here observing wildlife, especially water birds, and also appreciating the coastal landscapes away from built development.
Because marshes are such rich natural areas, they can easily be used to show the importance of wildlife for our everyday existence. Things as simple as the importance of looking after fish nursery areas or bird colonies can be made evident by a visit to a salt marsh (Megasig, 2007).

Importance of bivalves in the estuary
The abundance of bivalves of economic importance to be found, especially in the lower estuary, demonstrates the importance of this zone for shell fishing. Additionally, the bivalve beds in the Guadiana Estuary can be highly significant in the maintenance of water quality. With some considerable effect, through their filtration activity, bivalves take out particular matter in suspension as well as ingesting alga cells or propagules, thus controlling the occurrence of blooms. In order to assure the conservation of bivalves in the estuary, whether for their economic interest or for their ecological importance, large changes in the sediments and salinity must be avoided, for example changes brought about by dramatic alteration of the river flows.
The coastal areas next to the Guadiana Estuary are rich in species of commercially important bivalves, such as Cerastoderma edule (cockle), Spisula solida (white clam) or Donax trunculus (razor-shell).
Beyond their importance for fishing, bivalve molluscs can be used as environmental indicators, being fixed filter-feeders which are very sensitive to natural or anthropogenic alterations (Megasig, 2007).

Importance of Crustaceans in the estuary.
Crustaceans are of vital importance for all macroscopic organisms which inhabit the estuary. Through them, a food web is established in which the principal beneficiaries are fish.
These organisms – including the microscopic varieties that are a component of zooplankton – enable the transference of energy between producers (plants and phytoplankton) and consumers of larger stature.
In this way, one can see that the study of the relative abundance of this group allows us to understand the dynamics of the estuary in terms of food availability, reflecting whether or not there exist favourable conditions for the proliferation of fish species of economic value, and their likely abundance (Megasig, 2007)
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Fish of the Guadiana
The fish community of the Guadiana Estuary is very dynamic, changing over time and from one site to another according to the conditions preferred by each species.

The margins of estuaries undergo ever more intensive pressure from human occupation and this is reflected in the negative impact on fish populations, which go down in both their diversity and abundance. The populations of estuarine fish are very vulnerable to changes in their habitat, such as various types of pollution, dredging, drainage and reclamation, alterations in the flow of freshwater and the tidal regimes. The construction of dams up river can be responsible for several of these changes. They can affect the estuary in its entirety and create impassable obstacles, threatening the reproductive success of migratory species(Megasig, 2007).

The Importance of Estuaries for Fish

Beyond their natural beauty, estuaries are vital areas for feeding, reproduction and maternity for many species of marine fish, supporting traditional coastal fisheries nearby. The characteristics of these systems, associated with their high biological productivity, create conditions suitable for the colonisation of a diverse range of species, creating habitats sought out by fish for spawning and maternity.

Estuaries are in this way vital for the survival of many fish species. Only rarely does one find a small number of species, and in these cases the number of individuals is usually still high. In turn, many other organisms depend on estuaries during at least one stage of their life-cycle.

Because of their mobility and involvement at various trophic levels, fish fulfill a very important biological function in the working of an estuary. Fish use estuaries at different stages in their life-cycle, using them as nurseries, permanent habitat, migration routes and occasional feeding areas (Megasig, 2007).

The Guadiana salt marshes Birds

Owing to their characteristics, salt marshes represent one of the most productive biotopes on the planet. In other words, the biomass produced and made available to the food chain is very high, supporting the existence of innumerable animal species which find here excellent conditions for their survival. In turn, ideal conditions are created for a large number of aquatic birds which concentrate on the marshes, benefiting from the vast feeding areas.

The most common salt-marsh birds are mostly waders, being thus called because of their special adaptations for feeding in muddy or silty areas. They feed on invertebrates that they collect from the mud flats and the bottom of the salt pans, small fish and vegetation. They possess bills and feet of particular dimensions which allow them to feed in different strata, avoiding competition with others. It is therefore normal to see mixed flocks feeding together (Megasig, 2007).

Black-winged Stilt - *Himantopus himantopus*
The Black-winged Stilt is the symbol of the Castro Marim Nature Reserve, this area being one of the most important in the country for this species. It inhabits different types of wetland, being fairly common in the salt pans. It lays four eggs in a nest which it constructs on top of tufts of vegetation or from a hollow in the ground which it covers with sticks. The chicks, when they hatch, rapidly become active in search for small insects at the water surface under the watchful eye of their parents, who at the slightest sign of danger give a strident alarm call.

Flamingo - *Phoenicopterus ruber*
This species is particularly abundant at the Nature Reserve after the breeding season and during the winter. In the summer it is only the non-breeders, generally birds that are too young or old, that remain. The breeders migrate at the beginning of spring to the nearest breeding areas (Fonte Piedra – Spain and the Camargue – France). The salt pans of Castro Marim represent one of the few localities in Portugal where it is possible to see Flamingos regularly.

Geographical Setting

The Guadiana Estuary, part of the Lower Guadiana region, represents a large, rich wetland zone, where salt marshes dominate and salt pans, intertidal flats, barrier islands and sandy spits are also present. Besides wetlands, the estuary region also incorporates agricultural land, pine woods, scrublands and cork oak plantations.
All these high natural value areas are now subject to urban areas in rapid expansion. On the Portuguese shore, the towns of Vila Real de Santo António and Castro Marim, together with the settlements of Monte Gordo and Monte Francisco, are the largest population centres. On the Spanish side, Ayamonte and Isla Cristina are the most important centres, followed by Isla Canela and Punta Umbria together with the fast growing Costa Ezuri urbanization.
A large part of the estuary is naturally flooded by tides, by which marine waters enter and circulate within the estuary, controlling the complex natural cycles. However, the growing influence of mankind in the estuary has lead to the reclamation of estuarine areas. Some of these areas are now dry land, while

others, like the salt pans, undergo cycles of flooding and dryness as a result of active management.

Socio-economic description

During the last decades, the Guadiana river basin has undergone a significant demographic change trough rural depopulation and parallel (and compensating) development of tourism activities in the coastal zone. The latter is most significantly seen in the summer with the arrival of countless numbers of tourists which leads to a considerable increase in the seasonal population of the estuary.

The resident population of the Guadiana Estuary, especially in the cities of Vila Real de Santo António, Castro Marim, Ayamonte and Isla Cristina, has always been connected to the exploration of the land and the sea, but also taking advantage of the privileged location as a centre of commerce between the two nations. Therefore, it is not surprising that the primary economic activities in the estuary are:

- Agriculture
- Salt production
- Aquaculture
- Fishing
- Tourism
- Commerce

Contrast between Spain and Portugal

Spain has undergone much more rapid development with particular emphasis on tourism development. The Esuri Project is a development estimated for 40000 people which overlooks the Natural Reserve of Castro Marim on the Portuguese side. This imbalance in development puts substantial pressure on the Portuguese Authorities to allow similar Developments on the Portuguese side of the estuary. It is of course very nice for the occupants of the Ezuri development to overlook a national reserve.

An example of how a Field Training Experience could be linked to the objectives of SPICOSA

The Stakeholders along the Guadiana Estuary were invited to fill a questionnaire in order to determine the issue relevance for the site (Figure 2). The questionnaire had more than 20 different issues and also a free space where they could suggest other different ones that were not available.

With the data a ranking was calculated (Figure 3).The final ranking showed three issues all related to water quality and pollutants as the main concerns of the stakeholders. These issues formed a cluster that was used to make a conceptual diagram (Figure 4).

The diagram based on pollutants from a virtual system (Figure 5) was then transposed to the EXTEND© software to create a model that is still under development (Figure 6) The objective of the model is to obtain a qualitative description of the relationship between water quality and the human activities that depend on the estuary. This is important as it will serve to demonstrate to policy makers how the two are linked and may help them to test scenarios and make decisions based on a more complete understanding of the social economic and ecological system. A management tool is envisaged that will display this in a simple manner that is understandable to a non specialist.

Figure 2 - ISSUE RELEVANCE ACCORDING TO STAKEHOLDERS

STAKEHOLDER	1st	2nd	3rd	4th	5th
ALMARGEM	Land use models and projects unsuitable to development	Landscape and habitat destruction	Untreated wastewater discharges into estuarine waters	Recession of traditional economical activities	Excessive tourism pressure
CM ALCOUTIM	Soil desertification	Untreated wastewater discharges into estuarine waters	Resident population aging	Water and sediment quality	Recession of traditional economical activities
CM MÉRTOLA	Untreated wastewater discharges into estuarine waters	River discharge reduction due to dams	Eutrophication	Toxic algae blooming	Water and sediment quality
CM VRSA	Water and sediment quality	Untreated wastewater discharges into estuarine waters	Unsuitable legal tools		
EDIA	Recession of traditional economical activities	Water and sediment quality	Excessive tourism pressure	River discharge reduction due to dams	Unsuitable legal tools
FAUSTO NASCIMENTO	Unsuitable legal tools; Untreated wastewater discharges into estuarine waters (both in 1st)		Landscape and habitat destruction; Resident population aging; Inefficient ability to apply laws and plans (both in 2nd)		
INAG	Untreated wastewater discharges into estuarine waters; Resident population aging; Inefficient ability to apply laws and plans; Invasion of exotic fish and bivalve species; River discharge reduction due to dams; Water and sediment quality (both in 1st)				
LANDS	Untreated wastewater discharges into estuarine waters	Landscape and habitat destruction	Recession of traditional economical activities	Maintenance of protected areas economically unproductive	Water and sediment quality
LPN	Recession of traditional economical activities; Untreated wastewater discharges into estuarine waters; Coastal erosion on the Spanish beaches; River discharge reduction due to dams; Water and sediment quality				
PN VALE GUADIANA	Water and sediment quality	River discharge reduction due to dams	Untreated wastewater discharges into estuarine waters	Fishing of *Angula angula* with illegal techniques	Excessive tourism pressure
RNS CASTRO MARIM (2 perceptions)	River discharge reduction due to dams	Sediment infilling of tidal creeks and channels on saltmarshes	Salinity increase of the estuarine waters	Substitution of fine sediment stock with sand intrusion over tidal plans	Water and sediment quality
	Weak social awareness to environmental issues	Lack of law enforcement capacity	Landscape and habitat destruction	Low governmental spending on administration of protected areas	Recession of traditional economical activities

Number of issues identified by stakeholders in Top 5: 22 (18 were previously suggested by the SSA Team)

Figure 3 - ISSUES RELEVANCE RANKING*

ISSUES	Ranking*
Untreated wastewater discharges into estuarine waters	43
Water and sediment quality	30
River discharge reduction due to dams	25
Resident population aging	17
Recession of traditional economical activities	16
Inefficient ability to apply laws and plans	13
Landscape and habitat destruction	11
Unsuitable legal tools	8
Land use models and projects unsuitable to development	5
Excessive tourism pressure	5
Soil desertification	5
Invasion of exotic fish and bivalve species	5
Coastal erosion on the Spanish beaches	5
Weak social awareness to environmental issues	5
Sediment infilling of tidal creeks and channels on saltmarshes	4
Salinity increase of the estuary water	4
Eutrophication	3
Toxic algae blooming	3
Maintenance of protected areas economically unproductive	2
Fishing of *Anguilla anguilla* with illegal techniques	2
Substitution of fine sediment stock with sand intrusion over tidal plans	2
Weak Governmental investment on protected areas	2

* = (N° of occurrences in 1st x 5) + (N° of occurrences in 2nd x 4) + … + (N° of occurrences in 5th x 1)

Figure 4 – Conceptual model

Conceptual Model.

The beginning…

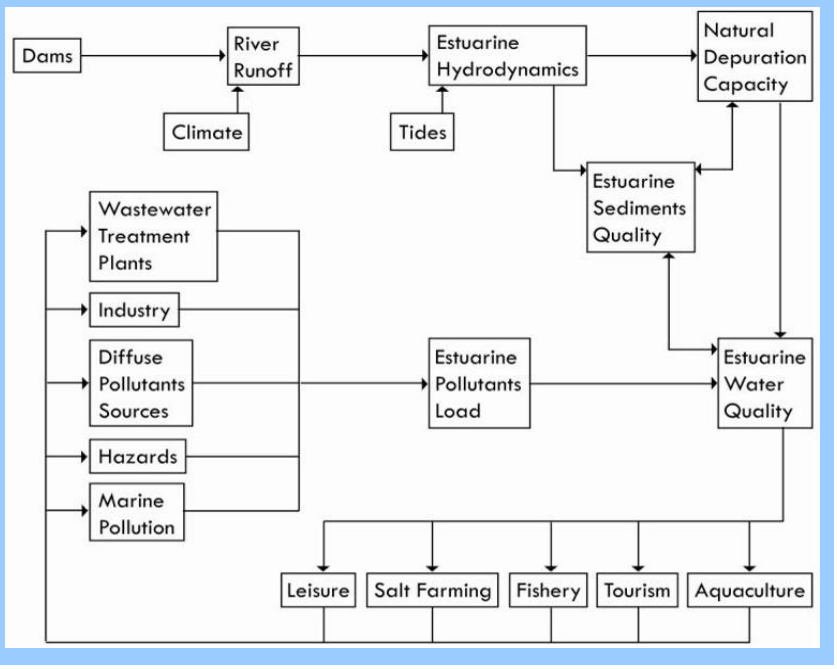


Figure 5 – Natural system used for model .

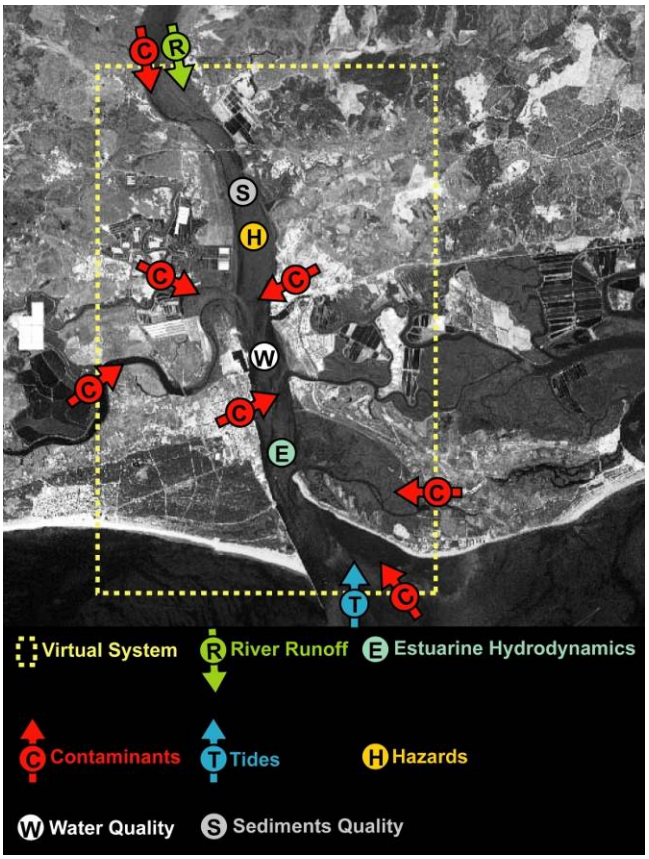
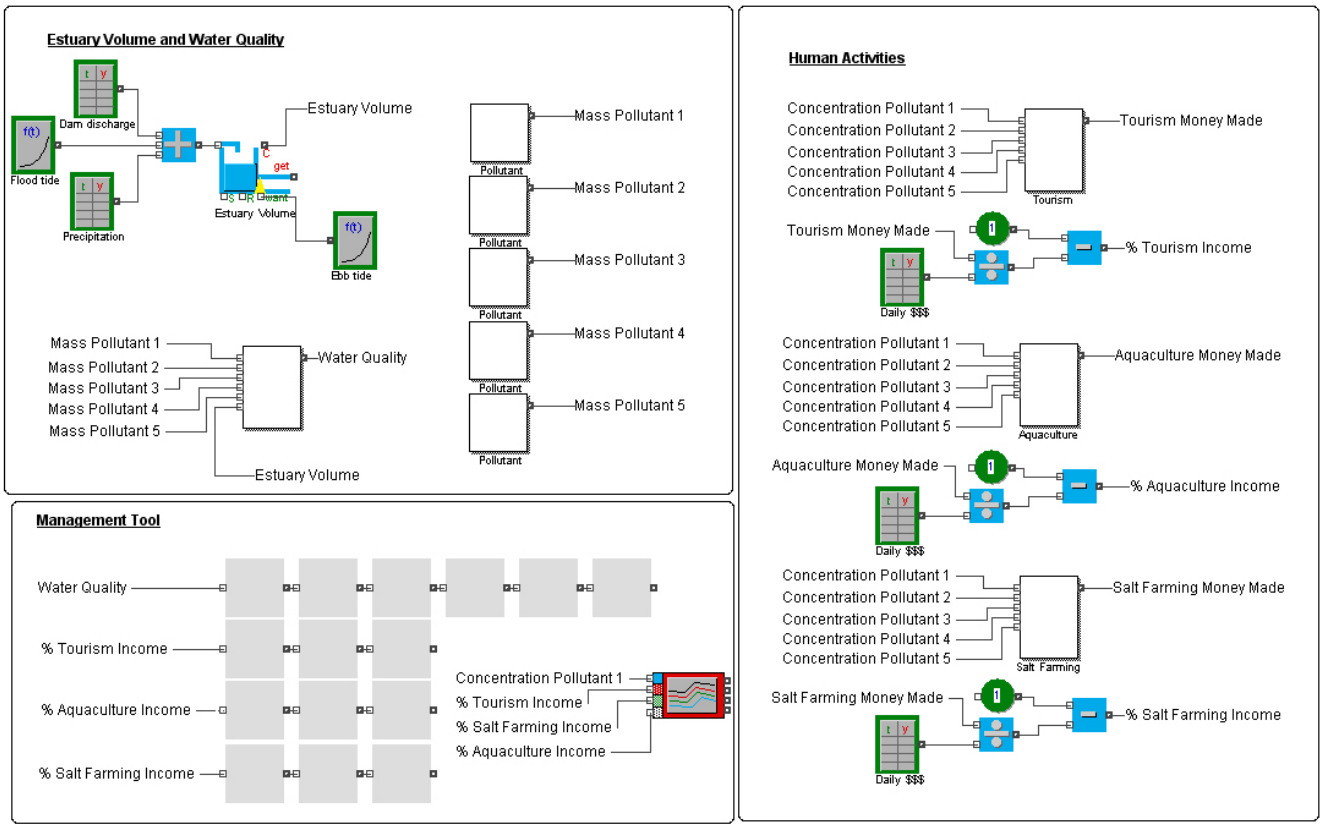


Figure 6 – Extend model.



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