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Contribution to the Themed Section: '*Case studies in operationalizing ecosystem-based management*'

Review Article

The ecosystem approach in the Gulf of Cadiz. A perspective from the southernmost European Atlantic regional sea

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This article considers the major events in recent history, current situation and prospects for developing an ecosystem-based style of management in the Gulf of Cadiz. This particular socio-ecosystem is characterised by a clear focal ecosystem component—the role of the estuary of the Guadalquivir River as a nursery area—that has an influence on the marine ecosystem and at the same time concentrates a number of sectoral human activities. This nursery role particularly concerns the anchovy fishery, which is the most economically and culturally important fishery in the region. As a transition zone between river and marine environments, estuaries are particularly sensitive to human activities, either directly developed within the aquatic environment and its surroundings or further upstream within its catchment area. The particularities of the Guadalquivir socio-ecosystem, with an area of influence that extends as far as the city of Seville, require the consideration of multiple sectors and the corresponding conflicting interests. These include the shipping and tourism sectors, the agriculture, aquaculture, salt and mining industries, and the fisheries and conservation interests. This article aims to give an overview of the high-level policy goals and the jurisdictional framework, scope the sectors involved and describe the pressures and risks of their activities. It will identify conflicting interests relating to different visions of the ecosystem as well as the institutional arrangements that could be used to balance them and finally, put forward a vision for using ecosystem-based information to improve multi-sectoral management decisions.

Keywords: agriculture, aquaculture, dredging, dam, fisheries, Gulf of Cadiz, Guadalquivir estuary, nursery, mining, shipping.

Introduction

An ecosystem approach to fisheries management (EAFM), ecosystem-based fisheries management (EBFM), or ecosystem based management (EBM) are nested concepts that differ in the extent to which a given management regime (e.g. fisheries) can be regarded as an ecosystem approach (Link and Browman, 2014). The ecosystem approach constitutes today the central paradigm that underlies living marine resources policy worldwide (Levin *et al.*, 2009; Patrick and Link, 2015). The overall objective is to manage natural resources in a holistic way, by considering the interacting influences of multiple use sectors on the environment (McLeod and Leslie, 2009; Levin *et al.*, 2009; Link, 2010).

In the European Union, important environmental directives, namely the Marine Strategy Framework Directive (MSFD, EC, 2008), the Water Framework Directive (WFD, EC, 2000), and the Common Fisheries Policy (CFP, EC, 2015), call for this approach. Furthermore, Spain is a member of the United Nations Food and Agriculture Organization (FAO) and OSPAR Commission, and signatory to a range of international agreements that promote the implementation of the ecosystem approach, such as the Convention on Biological Diversity. Theory behind this concept is well developed (Link and Browman, 2014; Patrick and Link, 2015). However, its implementation in Europe with regard to fisheries management is still at its infancy. Apart from a few

examples from the Baltic Sea, North Sea, and Barents Sea, where environmental conditions and food web interactions are to some extent considered when carrying out stock assessments (Möllmann *et al.*, 2014; Skern-Mauritzen *et al.*, 2016), European fishery assessments are still largely based on one species, ignoring the wider ecosystem context and impacts.

Integrated ecosystem assessments (IEAs) are useful tools to implement an ecosystem approach to fisheries management (EAFM) and eventually a comprehensive EBM (Rice, 2011). In anticipation of the future demands of applying an ecosystem approach, the International Council for the Exploration of the Seas (ICES) embraced the idea of IEAs and made it a core element of the ICES strategic plan (ICES, 2014). Accordingly, ICES developed a wide network of IEA working groups (Walther and Möllmann, 2014) with various levels of achievement (Dickey-Collas, 2014). Currently, there are IEA groups covering the whole North Atlantic regional seas.

One of the newest IEA groups is the Working Group on Ecosystem Assessment of Western European Shelf Seas (WGEAWESS), into which the Gulf of Cadiz (GoC) falls. This article reviews the current situation of the process of implementing an EBM in the region. Specifically, the aim of this paper is to describe the main components, players, and challenges faced by this socio-ecological system. This includes: (i) the ecological characteristics and focal mechanism, (ii) the legislative framework and the responsible institutional bodies, (iii) the trade-offs between the different sectors and their corresponding pressures, (iv) the institutional arrangements that could potentially be used to harmonize those conflicting interests, and finally (v) a diagnosis of the problems encountered when conflict has arisen.

The GoC

The GoC is a sub-basin between the Iberian Peninsula and the African Continent that connects the Atlantic Ocean and the Mediterranean Sea through the Straits of Gibraltar (Figure 1). The northern half of the GoC is the southernmost Atlantic European regional sea.

The abrupt change in coastline orientation at Cabo de São Vicente creates a discontinuity in the Portuguese-Canary Current Upwelling System, which frees most of the GoC from the tight control of the upwelling regime off Portugal (Fiúza 1983; Relvas and Barton, 2002). This is particularly true to the east of Cabo de Santa Maria, where the influence of the Portuguese upwelling vanishes, the shelf widens and waters here reach the highest temperatures in the region.

The GoC is heavily influenced by the Guadalquivir River, which drains one of the major European catchments areas (650 km, 57 000 km^2) contributing to the area's high productivity (Figure 1). Sediments carried by the Guadalquivir form marshes and wetlands that host a rich diversity of wildlife and are relied upon by commercially valuable species. Estuaries are known for their role as nursery areas for many marine species and the Guadalquivir is no exception (Drake *et al.*, 2002; Baldó *et al.*, 2006; Ruiz *et al.*, 2006; Drake *et al.*, 2007). It is this estuarine factor, where terrestrial and marine processes converge, that makes the GoC a unique case study.

Warm water pool

The presence of the Guadalquivir estuary and marshes together with the tidal forcing generate a pool of warm water off the river mouth during spring and summer (García Lafuente *et al.*, 2006; García-Lafuente and Ruiz, 2007). This feature systematically appears in satellite imagery analyses (Vargas *et al.*, 2003; Navarro and Ruiz, 2006). The tidal forcing and the river flow also contribute to maintaining high nutrient and chlorophyll levels all year round, which is particularly important in the summer, when the rest of the basin is stratified and oligotrophic. These particular conditions make the area off the Guadalquivir the most productive of the GoC (Navarro and Ruiz, 2006).

Figure 1. Satellite view of the Gulf of Cadiz featuring a high turbidity event that illustrates the influence of the Guadalquivir River. NASA MODIS, 12/11/2012. Source: earthobservatory.nasa.gov. NASA image courtesy Jeff Schmaltz, LANCE MODIS Rapid Response Team at NASA GSFC.

Traditionally, the local cyclonic surface circulation pattern described during spring-summer has been put forward as a favourable mesoscale feature with regard to the maintenance of this warm and productive cell (García-Lafuente *et al.*, 2006; Criado-Adeanueva *et al.*, 2006, 2009). See also Garel *et al.* (2016).

Winds, upwelling, and retention

There is a local upwelling regime to the west of Cabo de Santa Maria, which is independent of that of the Canary Current and considered a coastal process with a short time response to changes in the wind regime (Criado-Aldeanueva *et al.*, 2006). Westerlies are the winds responsible for upwellings while easterlies, known as levanters (Dorman *et al.*, 1995), have the opposite effect leading to a remarkable increase in temperatures (Prieto *et al.*, 2009). Furthermore, the westerlies/easterlies regime plays a central role in the continental shelf dynamics of the area, affecting retention within the warm cell. Under westerlies conditions, local upwellings enhance productivity and plankton is confined inside the cyclonic cell. In contrast, levanters would favour oligotrophy and the westward advection of plankton and larvae (Relvas and Barton, 2002; Catalán *et al.*, 2006).

The Guadalquivir estuary

The estuary of the Guadalquivir River comprises the lower course of the river, a 90 km stretch from its mouth to the first dam at Alcalá del Río, and covers an area of 1800 km^2 (Andalusian Water Authority, 2009).

Human interventions have drastically modified the entire system, particularly from the 18th century onwards. From this time several major interventions produced the current morphology: (i) continuous cutting off of river meanders (1795–1983) to preserve its navigability as far as Seville, (ii) drainage and filling of large expanses of marshland (1920s) followed by the establishment of new settlements, (iii) construction of dams (1930) and dikes (1985) for flood control or water diversion and (iv) stabilization of banks. As a result, the original 120 km of the estuary has been reduced to the current 90 km length, the flooded surface by 85% and the total freshwater input by 60% (CSIC, 2010). All these changes resulted in a heavily modified estuary, restricted to a canal where dams control the freshwater flux and marshes are isolated from the main course.

Nursery role

The exchange of material between the fresh water mass and the sea contributes to a nutrient-rich estuary and a high biological wealth. In addition, the high productivity and temperature contribute to make the estuary and adjacent marine waters a nursery ground for several commercial species, such as anchovy, sardine, langostine, or prawn. High abundances of eggs, larvae and post-larvae of these species are found in spring and summer (Drake *et al.*, 2002, 2007; Baldó *et al.*, 2006). This nursery function is the main regulating service the region provides in relation to the GoC fisheries.

As a short-lived small pelagic species, anchovy population dynamics are strongly affected by year-to-year fluctuations in environmental processes. Temperature, winds and discharges from the river have been identified as key factors influencing its recruitment (Ruiz *et al.*, 2006, 2009). Discharges have different effects on the nursery role depending on their volume. Low levels of freshwater discharges constrain primary productivity on the shelf limiting the food supply for juveniles (Prieto *et al.*, 2009) while very high discharges cause salinity to drop below the threshold forcing juveniles to leave the protective environment of the estuary (Ruiz *et al.*, 2009). However, the combination of both natural (weather) and anthropogenic (discharges) effects, plus the timing and volume discharged, results in a broad range of combinations that makes the ecological response of the ecosystem to freshwater inputs be not unequivocal (González-Ortegón and Drake, 2012; González-Ortegón *et al.*, 2012, 2015).

Legislative and jurisdictional frameworks

The associated legislation and governance is rather complex. It involves decision makers at local and international level, a number of regional, national and international protection norms and governance that is fragmented across multiple institutions.

As noted in the introduction, two EU Directives protect the marine (MSFD) and transitional (WFD) water bodies. Additionally, the CFP regulates the fisheries in the GoC. The Guadalquivir Hydrographical Federation (CHG, Confederación Hidrográfica del Guadalquivir) is the governmental body responsible for the management of this basin and consequently of its estuarine stretch. Instituto Español de Oceanografía (IEO) is the institution responsible for the implementation of the MSFD and the CFP directives. CHG and IEO report to the Spanish Government.

The marine protected area

The first comprehensive study of the estuary and neighbouring marine coastal area (IEO, 2005) led to the establishment of a Marine Protected Area (MPA). This MPA was designed to preserve the nursery service due to its importance for the species that inhabit the GoC. It includes one estuarine zone and three marine zones to the northwest of the river mouth (Figure 2). This area overlaps with the warm and productive body of water previously described. Moreover, the Guadalquivir estuary is flanking Doñana National Park (1969) and is also under the umbrella of a number of environmental protection regulations.

The regional government 'Junta de Andalucía' has considerable management control over the estuary and its surroundings (Doñana, MPA). The estuarine water body (CHG) and marine waters (IEO) status are, however, the responsibility of the Spanish government.

Sectoral activities and stakeholders

As described earlier the estuary serves as nursery ground for several commercial species, of which anchovy (*Engraulis encrasicolus*) can be considered the most emblematic, due to its economic and cultural importance. The diversity of activities carried out in the estuary and adjacent areas is very high as are the impacts on its functioning and the extent of its habitat.

Freshwater balance: agriculture, tourism, and discharges regulation

The Guadalquivir marshes are vast plains that are periodically flooded by the river. Their topographic and climatic conditions are ideal for the cultivation of rice (Figure 2). However, their location within an estuarine habitat imposes a saline constraint, which demands a high supply of freshwater.

The lower Guadalquivir has been turned into one of the most important tourist destinations in Spain. This has led to a significant increase in water demand following the process of urbanization.

Agriculture and tourism demand freshwater, which has consequences on the freshwater balance of the estuary. Water supply for irrigation and tourism is one of the main drivers of the timing of the discharges. The irrigation period (April–October) and peak tourist season (mid-June through August) coincides with the dry season, when the natural flow of freshwater is at its lowest.

The Alcalá del Río dam, 110 km upstream from the river mouth (Figure 3) is the most important infrastructure regarding the flow of freshwater into the estuary, contributing 80% of the total (CSIC, 2010).

At present, river discharges are regulated mainly for economic purposes, such as irrigation and/or water supply to urban settlements and hydroelectric power generation. Therefore, human activities impose the timing, frequency and magnitude of the discharges with consequences on the physicochemical conditions of the estuary, which eventually affect its production (González-Ortegón and Drake, 2012) and food web (González-Ortegón *et al.*, 2012, 2015).

Land reclamation: aquaculture and salt production

Aquafarming in salt pans has been a traditional activity since antiquity. In the 1970s aquaculture re-emerged with the exploitation of abandoned salt pans. Aquaculture is now a growing sector (Andalusian Water Authority, 2009) (Figure 3). The sector claims

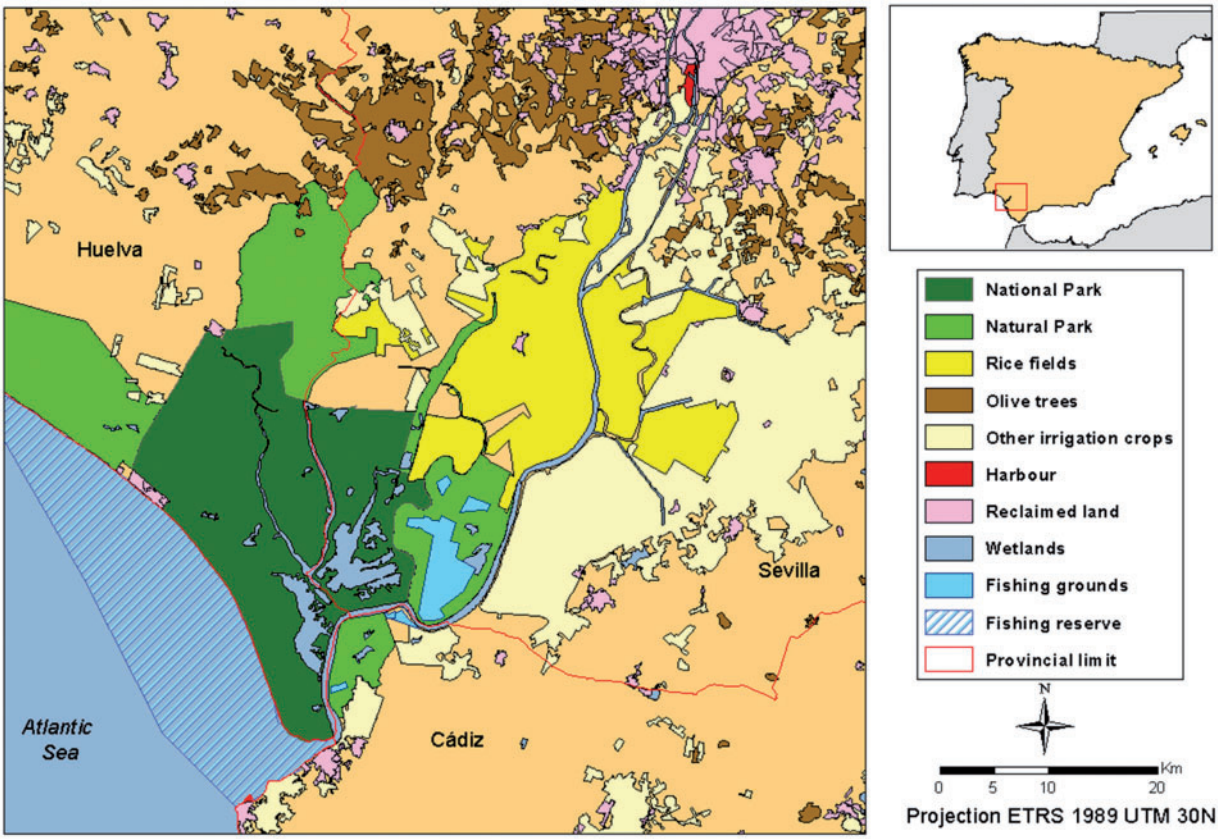

Figure 2. Main water uses in the lower Guadalquivir valley (from Vargas and Paneque, 2015).

that aquafarming does not imply a net consumption of water. But aquaculture facilities are built on previously flooded land. Salt evaporation in ponds is another economic activity in the proximity of the estuary. Some of the land taken by salterns could also potentially return to its primitive state.

Besides this, the activity of the aquaculture and salt industries affects the hydrodynamics of the estuary because of the need to control the propagation of the tidal wave with locks.

Diffuse pressures: shipping and mining

The Guadalquivir River is the navigable gateway to the city of Seville (fourth Spanish city) and the only Spanish river port. To preserve the navigability of the river, major alterations have been performed in the past (cuts off described earlier) and maintenance dredging works are carried out every year.

The Seville Harbour Authority (Spanish Government) is responsible for the management of the so-called Guadalquivir European Waterway (E.62_02). The Harbour Authority is determined to facilitate the access of larger vessels and higher cargo capacity through the construction of major infrastructures. The most controversial of these infrastructures has been a plan to carry out major dredging of the riverbed, which will be reviewed below.

Apart from the ecological alterations derived from the maintenance dredging, shipping poses the risk of accidental spills, the introduction of alien species (Cuesta *et al.*, 1996; Frisch *et al.*, 2006; González-Ortegón *et al.*, 2010) and increases in the erosion of river banks.

Mining is an economically important activity in the Iberian Pyrite Belt and some of these mines lay on the tributary basins of the Guadalquivir. Hence, this activity poses a risk that needs to be considered (see below).

Fishing and conservation

Spanish fishing fleets are organised in the traditional "Cofradías de Pescadores". At a regional level there are those fleets targeting anchovy or several other species outside the MPA, which could be potentially affected by changes in the nursery service. At the local level there is fishing activity within the marine MPA zones. Despite their long-standing tradition, the "Cofradías" are not fully developed in the MPA area. Interestingly, even though the fishermen's organisations are not yet totally functional, women's associations play an active role in speaking on behalf of their menfolk and enthusiastically participate as stakeholders when given the opportunity.

Due to the ecological importance of the area, conservation organisations have a long standing interest in the region. Of particular relevance is WWF and the local SOLDECOCOS.

WWF has played an important role, fiercely campaigning against some of the sector's plans, in particular against the proposed dredging of the river. WWF has a clear agenda for the estuary. This includes an increase in freshwater flows, modification of maintenance dredging, recovery of tidal plains, reconnection of cut-off meanders, improvement of river banks and removal of dikes (WWF, 2012).

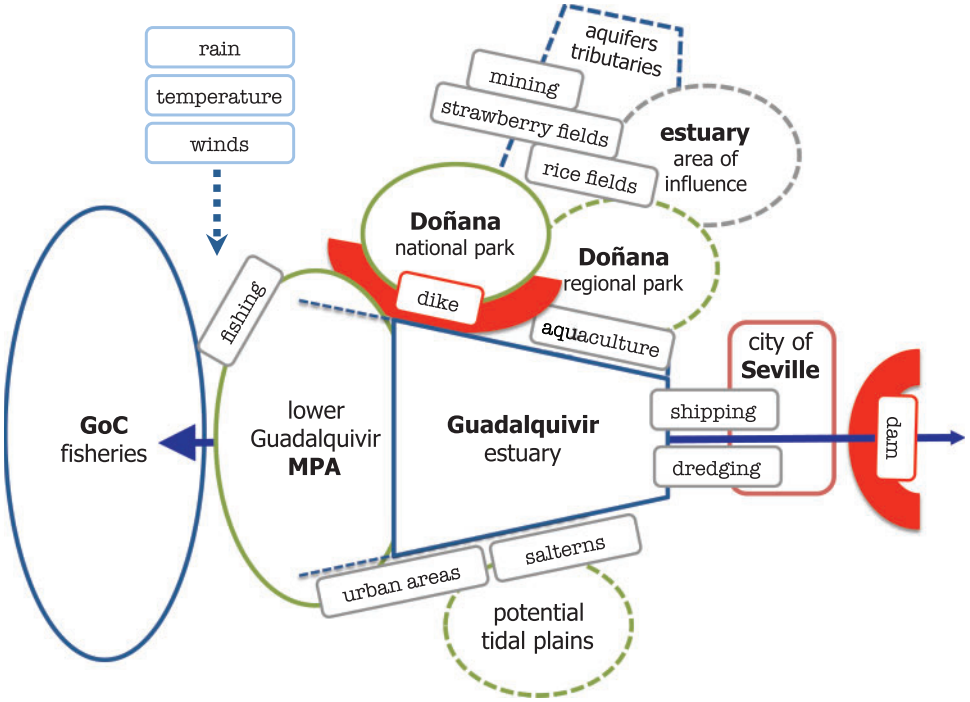

Figure 3. Conceptualized ecosystem. The horizontal blue arrow represents the estuarine gradient, from the lower Guadalquivir MPA, which includes its lower 16 km and the adjacent coastal area, to the upper end beyond the city of Seville. Major infrastructures are shown in red: namely, the "Montaña del Río" dike and the "Alcalá del Río" dam. Sectors whose activities have consequences through tributaries (mining), aquifers (strawberries) or directly on the freshwater flow (rice) are piled up on the upper side. Activities occupying potential tidal plains (aquaculture, salt production, urban areas) are placed on the estuary. Diffuse infrastructures and risks (dredging, shipping) are shown close to Seville. Non manageable environmental factors (rain, temperature and winds) are shown between the sea and the estuary.

SOLDECOCOS (in partnership with WWF) has been closely interacting with the local communities, creating spaces for dialogue and encouraging the organisation of fishermen.

Major events

Aznalcóllar disaster

The first event that had a substantial impact on the general perception of the estuary was the Aznalcóllar mine disaster. In 1998, a retaining dam used to store toxic mining waste at Aznalcóllar broke releasing 4–7 10^6 m^3 of mine tailings consisting of acid sludge and water into the Guadiamar River, which is a tributary of the Guadalquivir (Achterberg *et al.*, 1999). Fortunately, after huge economic investments and a rapid response following scientific guidelines, the mining waste was prevented from reaching the estuary.

As a consequence, a restoration plan called Doñana 2005 was conceived and launched after the disaster. The plan aimed at recovering the natural dynamics of the water and included restoration of marshlands, tidal plains and tributaries, reconnection of cut-off meanders and the permeation of dikes between Doñana and the estuary (Andalusian Water Authority, 2009). It is worth noting that these objectives agree with WWF's current agenda for the estuary (WWF, 2012). The project was never fully accomplished and international organisations (UNESCO, Ramsar, UICN) raised concerns about this lack of commitment. Eighteen years later, the regional government is determined to reopen the mine, not without much controversy and legal problems.

Interestingly, right after the disaster water discharges were increased in order to flux any pollution that could have reached the estuary. This seemingly sensible management action did not consider the implications on the nursery service. That year, anchovy larvae, which are typically found in high abundances in spring were not detected in the estuary until the summer (González-Ortegón pers. comm.). Higher than normal water flow during a key period might have prevented anchovy larvae from entering the estuary.

Dredging

The second and most important event started in 2000 when the Seville Harbour Authority presented a project with the aim of improving the navigability of the river and, in consequence, the size of the ships that could arrive to the port. The project included a major action; the dredging of the river in order to widen and deepen the navigable channel from its current minimum depth of 6.5 m to 8 m. The main argument in favour of such an impacting endeavour was the positive economic consequences, the creation of jobs and attraction of cruise tourists.

The project produced significant conflict between stakeholders and led to the formation of two coalitions. One in favour of the project led by Seville's Habour Authority, trade unions and companies and one against composed of the rice agricultural sector, which feared that an increase in depth would increase salinity and turbidity, as well as conservation associations and Doñana's national park.

In 2005 following recommendations of an environmental impact assessment a scientific committee was constituted to evaluate the impact on the ecosystem. The work resulted in an advisory document (CSIC, 2010) whose final conclusions rejected the projected dredging. Most national public agencies endorsed these recommendations except CHG.

National and international agencies engaged in the debate, including UNESCO's World Heritage Committee (UNESCO, 2013) and the European Commission (EC, 2013). Finally, the project was stopped by the Spanish High Court (Supreme Court, 2015) at the request of WWF. However, the court ruling did not mention 'lack of participation' among the reasons for stopping the dredging works (as mandated by WFD).

The conflict is thoroughly described and analysed in Vargas and Paneque (2015) who stress "the preservation of navigability" as the main concern and driving force regarding any project that could have an impact on the river. Surprisingly, the authors do not mention fishers as having been active stakeholders in the conflict.

At the time of this writing the CHG has commissioned a second environmental impact assessment, which shows its intention to reactivate the plan.

Turbidity

Occasionally, heavy rains and the major discharges which follow result in high and persistent turbidity events. Similar events have also been observed during dry years and seem to be the result of a particular operation of the dam and probably, other anthropogenic processes occurring upstream within the basin (González-Ortegón *et al.*, 2010).

These events affect the estuary and adjacent marine area and are clearly visible from space as illustrated in Figure 1. Three major turbidity events have been recorded since 1997. One of them—November 2007 to June 2008—raised much concern amongst rice producers, and the aquaculture and fishing sectors. As a result, the regional government announced the setting up of an 'interagency commission' with the aim of developing an integrated management of the estuary (Andalusian Water Authority, 2009). Unfortunately, the activity of this multi-sectoral and multi-administrative commission—a clear attempt to establish an EBM arrangement—left little trace.

Ecosystem visions

The three major events described above represented tipping points in the general perception of the estuary. They raised concern and awareness about its current state, resilience and ability to continue to deliver services. Most importantly they led to a clear positioning of the stakeholders that can be used to figure out three ecosystem visions or "ways things should be" paraphrasing Sainsbury and Sumaila (2003).

- The canal vision conceives the estuary as a navigable waterway to the city of Seville. This vision would favour commercial shipping and tourist cruises (Figure 4). It would be compatible with urban development, mining and hydropower generation but confronted by the alternative visions, legislation and policy statements. In addition, this 'way the estuary should be' is more likely to be an unsustainable vision in economic and ecological terms. The CHG is the jurisdictional body closest to this vision. Its organisational chart lists a "discharges commission". The purpose of this board is to advise the CHG regarding the discharges management regime. It could be transformed into a multi-sectoral institutional arrangement in support of EBM.
- The land uses vision perceives the estuary as a productive asset (Figure 4). It challenges the dredging and mining activities and would like to see the frequency and intensity of high turbidity events reduced. It would be in conflict with the healthy ecosystem vision to some extent. Rice producers are represented in CHG board.
- The healthy ecosystem vision conceives the estuary as a degraded and threatened ecosystem that must enhance its functionality and biodiversity (Figure 4). It is in synchrony with the local, national and international legislative frameworks. This vision could be shared to a large extent by both the conservation and fishing sectors. It could, however, collide with some uses and practices developed by the agriculture, aquaculture and salt industries and totally clashes with the canal vision. The MPA advisory board holds fluent dialogue with the fishing sector, scientists and conservationists and is another potential EBM support structure in place.

These two institutional arrangements would appear to have their areas of influence distributed along the length of the estuary. The CHG revolves around the city of Seville and rice fields, while the MPA connects better with those from the lower Guadalquivir and adjacent marine area. No single entity seems to completely incorporate all sectors.

Discussion

Although the ecosystem approach has been formally adopted in fisheries management since the 1990s, tactical management rarely incorporate ecosystem processes. Skern-Mauritzen *et al.* (2016) estimated that only about 2% of world fish stocks incorporate physical or biological drivers in management advice. Interestingly most of these cases are found within ICES, reflecting its efforts to endorsing the ecosystem approach. Remarkably, none of those cases making up the 2% incorporate estuarine processes.

The closest example to the GoC anchovy case presented here is the Bay of Biscay (BoB) anchovy, a European Atlantic stock managed within ICES. Despite the presence of important estuaries in the area (Gironde River), its recruitment does not seem to rely much on these ecosystems. While spawning occurs over the shelf, mainly in the river plumes, juveniles are regularly observed off the shelf. An alternative mechanism by which anchovy may use off-shelf waters as a spatio-temporal loophole of lower predation has been hypothesised here (Irigoien *et al.*, 2007).

The GoC case study analysed here would differ from the above in that estuarine processes need to be taken into account if we aim to implement ecosystem style of management. Estuarine conditions are not the only environmental drivers affecting the ecology of the species. As described above, the wind regime (upwellings, retention) and temperature also play a role, but estuarine conditions are the only over which we can have some sort of control. The simplest and most effective intervention is through the regulation of freshwater discharges.

Vision for using ecosystem-based information

In order to operationalize EBM that help us improve multi-sectoral management decisions it is necessary to select indicators

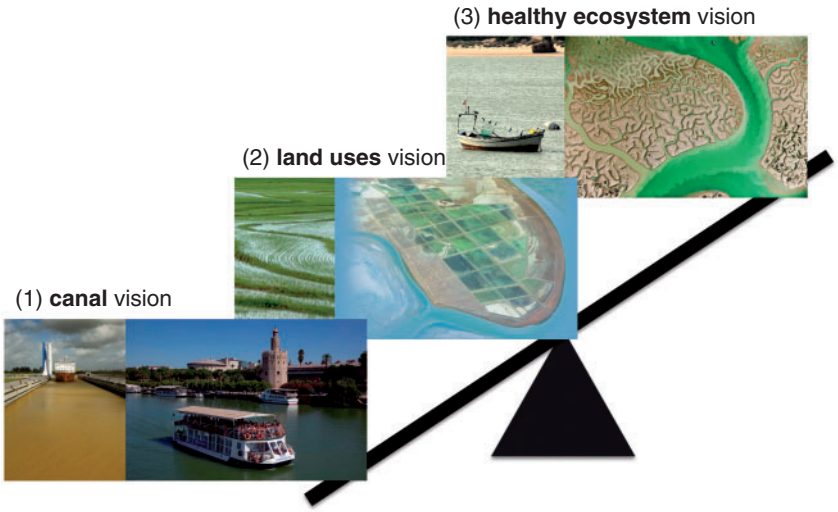

Figure 4. Balance diagram illustrating the three visions of the system: (1) canal, (2) land uses and (3) healthy ecosystem. Panel 1 shows Seville harbour's lock (photo: Julián Rojas, elpais.com) and Guadalquivir tourist boat (photo: Naturanda Turismo Ambiental). Panel 2 illustrates a rice field and Veta la Palma estate, the main aquaculture infrastructure (photo: PESQUERIAS ISLA MAYOR, S.A.). Panel 3 depicts the meandering design of the Guadalquivir wetland's hydrological network (photo: Héctor Garrido/EBD-CSIC) and a fishing boat in the MPA (photo: José Luis Oróñez).

and propose a framework to define reference levels to those indicators. This requires data, models and institutional arrangements.

Data and models

When compared with other European ecosystems where monitoring programs have been running for 30-50 years, the GoC is relatively young (20+). Nevertheless, surveys are in place and the number of models has been growing lately (Ruiz *et al.*, 2009; Torres *et al.*, 2013; Rincón *et al.*, 2016; Carvalho-Souza *et al.*, in prep.).

Of special relevance is the estuarine monitoring programme. This survey has been recording the abundance of fish larvae and plankton in relation to water properties at every new moon since 1997. Several articles describing how the estuarine biological community restructures and responds to climate and discharges have originated from this database (see references above). This long term programme is commissioned by the regional government (co-financed by CFP funds) and its ultimate purpose should be to inform fisheries policy.

Indicators

Indicators are metrics used to determine the state of the ecosystem and to detect changes that occur due to anthropogenic or environmental impacts (Rice and Rochet, 2005). Hence, they are at the interface between science (ecosystem state and functioning) and policy (management alternatives).

Despite the complexity of the socio-ecological system here described, much of it converges in two water properties, salinity and turbidity. These two metrics affect anchovy juveniles and larvae (and eventually its fishery) and are of concern to agriculture uses. High turbidity and low salinity have a negative effect on the nursery role while high turbidity and high salinity have detrimental effects for rice production. These two water properties are affected by the timing, frequency, volume and type of discharges and hence, subject to management. Roughly, high discharges reduce salinity posing a trade-off between agriculture and fisheries. There exists enough scientific knowledge based on historical time series and salinity and turbidity are currently monitored on real time (CSIC, 2010). For these reasons they stand out as candidate indicators.

The definition of reference points to these indicators could serve to reconcile multi-sectoral management decisions, basically visions 2 and 3 described earlier (Figure 4).

Governance

Lack of governance structures and mandates to implement EBM have been frequently invoked (Walther and Möllmann, 2014; Patrick and Link, 2015). In the previous sections the high-level goals and supranational bodies were enumerated and permanent as well as ephemeral (or event-driven) institutional arrangements were identified.

The fisheries sector was, however, not always sufficiently represented when conflict has arisen. In the last couple of years this situation has started to change. Since 2014 WWF and SOLDECOCOS have been developing an intense programme with local communities and the MPA board. This includes scoping workshops that managed to bring together fishermen, women's associations, scientists and the regional government. At the moment these meetings are very much centred on direct threats and fishing regulations within the MPA and do not address distant pressures. In particular, they haven't succeeded in attracting the agriculture sectors. This does not mean that the local communities are not aware of the impact of upstream sectoral activities on their livelihoods. Rather, they feel that they lack the political clout to enter into the process. In this sense, the development of functional organisational structures would empower and enable them to become active players. This is actually one of the development goals set by WWF and SOLDECOCOS.

The challenge for the coming years will be to bridge the gap between fisheries and agriculture by bringing these players together.

The outcome of such a dialogue should be to reach an agreement on salinity and turbidity reference points in order to inform and improve multi-sectoral management decisions.

Lack of political willingness and leadership on the part of regional authorities, who have jurisdiction over most sectoral activities, has also been identified as a problem (CSIC, 2010; Vargas and Paneque, 2015). Hence, further commitment and endorsement by the political authorities would de desirable.

Conclusions

In the last years enough scientific knowledge, data and models have been developed and could be readily used to formulate alternative ecosystem management strategies in the GoC. Stakeholder interests and agendas are well defined and a number of existing advisory boards are in place and could be easily transformed into multi-sectoral institutional arrangements in support of EBM.

The pressures and conflicts affecting this socio-ecosystem are not at a standstill, rather the same old struggle is knocking at the door one more time. The dredging project, the reopening of the mine, the active land uses, raising conservation concerns, and a fluctuating pressure from the fishing sector, depending on whether the EU-Moroccan fisheries partnership agreement is at work or not, represent some of the latent tensions. Most sectors are desperately calling for an ecosystem approach and there is capacity to make decisions cognizant of trade-offs.

Previous conflicts have revealed that lack of participation and stakeholder acceptance resulted in an expensive and time-consuming way to get nowhere. Located in one of the most deprived Spanish regions, with the highest unemployment rate in the entire EU (>30%), the GoC has a clear stake in operationalizing an ecosystem approach capable of balancing various political, social, economic and conservation interests and by doing so take advantage of Blue Growth opportunities (EC, 2014).

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