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COMPARATIVE ANALYSIS OF TRADITIONAL SOLAR SALTWORKS AND OTHER ECONOMIC ACTIVITIES IN A PORTUGUESE PROTECTED ESTUARY

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ABSTRACT

This study shows that Traditional Solar Saltworks can be competitive with other land uses in the Nature Reserve of Castro Marim and Vila Real de Santo Antonio Saltmarshes ("Reserva Natural do Sapal de Castro Marim e Vila Real de Santo António", in Portuguese), sited in the estuary of the Guadiana River (SW Iberian Peninsula, Europe); particularly, if they are specialized in extraction of Fleur de Sel (or Flower of Salt), a gourmet variety of sea salt. Artisanal sea salt production based on solar evaporation methods of millennial history in the area is an environmentally sustainable activity in harmony with saltmarsh landscape. Two crystallizers of a 1 ha Traditional Solar Saltworks were monitored during 70 days from June to August 2015 with the purpose of gathering detailed production data. Monitoring comprised weighing of daily Fleur de Sel harvest while coarse salt survey in one crystallizer, implied packing and weighing after two months. The competitiveness of this new commercialized variety of sea salt was assessed with respect to other ongoing economic activities in the area, such as aquaculture, industrial salt production, and tourism. Comparison focused on the relationship between the occupied surface and production´s revenue. Water consumption was used as an economic and environmental sustainability indicator. Data were obtained through in-situ monitoring, literature review and from official statistics and spatial data sources. The results indicate that Fleur de Sel extraction in Traditional Solar Saltworks can be a high profile land use form in the area of Nature Reserve, which on a long-term basis is a sustainable activity from a socio-economic and environmental point of view.

KEY WORDS: Protected natural area, Artisanal saltworks, Coastal wetland, Integrated management, Estuary.

RESUMEN

Análisis comparativo entre salinas solares tradicionales y otras actividades económicas en un estuario protegido portugués. Este estudio muestra que las salinas solares tradicionales pueden competir económicamente con otros usos del suelo en la Reserva Natural de las Marismas de Castro Marim y Villa Real de Santo Antonio, situada en el estuario del río Guadiana (SO de la Península Ibérica, Europa), sobre todo, si se especializan en la extracción de Flor de Sal, una variedad gastronómica de la sal marina. La producción de sal marina artesanal por evaporación solar cuenta con una historia milenaria

en la zona y es una actividad ambientalmente sostenible en armonía con el paisaje marismeño. Dos cristalizadores de una salina solar tradicional de 1 ha fueron monitorizados durante 70 días de junio a agosto de 2015, con el propósito de obtener datos detallados de la producción. La monitorización consistió en recoger y pesar la Flor de Sal diariamente en dos cristalizadores, mientras que la sal gruesa se recogió y pesó pasados dos meses en uno solo. La competitividad de esta nueva variedad comercializada de sal marina se evaluó con respecto a otras actividades económicas en curso en la zona, tales como la acuicultura, la producción industrial de sal y el turismo. La comparación se centró en la relación entre la superficie ocupada y los ingresos de la producción. El consumo de agua se utilizó como indicador de sostenibilidad económica y ambiental. Los datos se obtuvieron mediante monitorización in situ, revisión de bibliografía, de estadísticas oficiales y de fuentes de datos espaciales. Los resultados indican que la extracción de Flor de Sal en salinas solares tradicionales puede ser una forma de uso del suelo altamente competitiva en el área de la Reserva Natural, siendo a largo plazo una actividad sostenible desde el punto de vista socioeconómico y ambiental.

PALABRAS CLAVE: Área natural protegida, Salinas artesanales, Humedal costero, Gestión integrada, Estuario.

INTRODUCTION

The Guadiana River Estuary is an area where multiple natural, social and economic processes overlap. The objective of this study is the support to policies oriented to promote traditional salt production as part of a competitive and integrated coastal zone management in the Nature Reserve of Castro Marim and Vila Real de Santo Antonio Saltmarshes (NR). Its comparison to other economic activities in the NR (aquaculture, industrial salt production and tourism) is done through land use efficiency using environmental and economic indicators. Salt harvesting plays an important role in the local economy, as it is one of the few economic activities allowed in the NR. However, it competes with other economic activities and during the last century Traditional Solar Saltworks (TSS) have been abandoned mainly for financial reasons, since they could not compete with other, mostly mine/industrial sources of salt. According to Rodrigues *et al.* (2011), after 1936 the Portuguese salt industry entered into a deep crisis due to the development of cold conservation techniques and the introduction of industrialized processes that could provide higher production at lower cost; and this decay increased in the 1980s, when Portugal became an European Union (EU) member (1986) and subsidies were attributed to agriculture and aquaculture, encouraging workers to change the seasonal salt-harvesting activity for an alternative continuous activity.

Inactive TSS decrease biodiversity and changes traditional landscape (Ménanteau *et al.*, 2006) as saltworks can be considered a particular ecosystem, which includes a series of microorganisms, a unique bird biodiversity and well-adapted vegetation (Galvis-Sánchez *et al.*, 2013). According to de Medeiros Rocha *et al.* (2012), these hypersaline wetlands represent refuge zones for many species of migratory birds and it becomes imperative to promote its conservation. Thus, it is

essential to preserve the salt production for the protection of these ecosystems. Solar Saltworks are described by Korovessis and Lekkas (2009) as integrated, constructed coastal ecosystems, where regular and hypersaline environments coexist and establish significant shelters for wildlife, unique in terms of their architecture, combining salt production process with environmental conservation. The former makes TSS an environmental sustainable activity and part of the so-called green economy. Regarding carbon account, wetland ecosystems (including saltmarshes) provide an ideal natural environment for the sequestration and storage of carbon dioxide from the atmosphere (Mitsch *et al.*, 2012). Actually, wetland management can be chosen to be accounted for on a voluntary basis by EU Member States for Emissions Trading System reporting on national emissions reduction, balancing carbon emissions and capture by wetlands and other ecosystems; these rules were developed by the Intergovernmental Panel of Climate Change (IPCC) and adopted by the United Nations Framework Convention on Climate Change (UNFCCC) and transferred into EU law in form of the EU land use, land-use change and forestry (LULUCF) (EU, 2013).

Castro Marim saltworks are mentioned for the first time in the XII century (Ménanteau *et al.*, 2006) and its maintenance and working methods can be considered as indigenous knowledge. Thompson (1999) highlighted the importance of conserving these artisanal systems for the preservation of the cultural landscapes and to safeguard indigenous knowledge transfer, otherwise included neither in environmental conservation legislation nor in cultural heritage protection policies.

Saltpans are usually organised in systems of interconnected ponds to which, marine water is introduced first for storing, followed by evaporation in smaller ponds and crystallization ponds where concentration of dissolved salts reaches oversaturation (Villalobos *et al.*, 2003). Fleur de Sel (FS) is formed in the crystallizers, the last brine ponds of the water circuit where coarse salt is also collected on a later stage. Fontana *et al.* (2011) described FS as an "inverted hollow Mayan pyramid shaped hopper crystal" (see Figure 1), a two-dimensional crystallization of NaCl, formed in the brine surface where only one face of cube is attached, and in contact with the high-density film growth takes place only along its edges, and combined with gravitational sedimentation creates this kind of hopper crystal attached to the surface by the base. FS and coarse salt have distinctive physicochemical characteristics (Galvis-Sánchez *et al.*, 2013); carotenoid- derived aroma compounds could be found in the first formed crystals in saltponds (the FS) as these aromas are free in the saltpan after the death of microorganisms or resulting from microorganism metabolism (Donadio *et al.*, 2011). In contrast to the industrially processed sea salt for consumption that passes through the stages of washing, centrifugation and drying by the heat of combustion, grounding and sieving, FS is packed with no other processing (de Medeiros Rocha *et al.*, 2012).

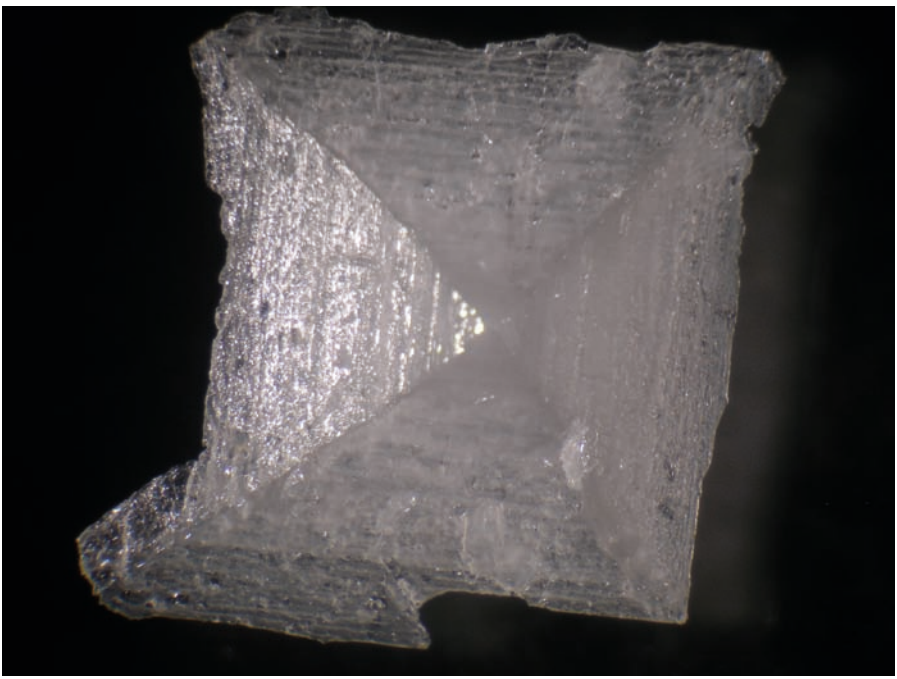

Figure 1. Fleur de Sel microscopic photograph (Microscope Olympus SZ11).

STUDY AREA

The NR comprises 2 312 ha at the Portuguese side of the estuary of the Guadiana River, the natural border between Portugal and Spain (Figure 2) and it was established in 1975 (Ministério do Equipamento Social e do Ambiente, 1975). The Guadiana watershed is situated within Mediterranean climate zone with around 80% of precipitation occurring during autumn and winter months, and summers experiencing prolonged droughts. Annual average rainfall fluctuates between 561 and 600 mm, and the annual average air temperature varies from 14 to 18 °C (Morais *et al.*, 2009). The natural river flow is highly variable on inter-seasonal scale (climatic factor) and on inter-annual scale due to the forcing by NAO – North Atlantic Oscillation (Dias *et al.*, 2004). The Guadiana River Estuary, which in chemical sense embraces the last 9-10 km of the river channel may be classified as mesotidal, with average tidal amplitude of about 2 m (Garel *et al.*, 2009).

The economic activities on the NR are: fishing, saliculture and tourism. The number of active saltworks in Castro Marim was 98 in 1790, 57 in 1977, and 7 in 2005. Saltworks at the Spanish side of the Guadiana Estuary followed the same declining trend and in 2001 there were only 2 active saltworks; compared to 14 in

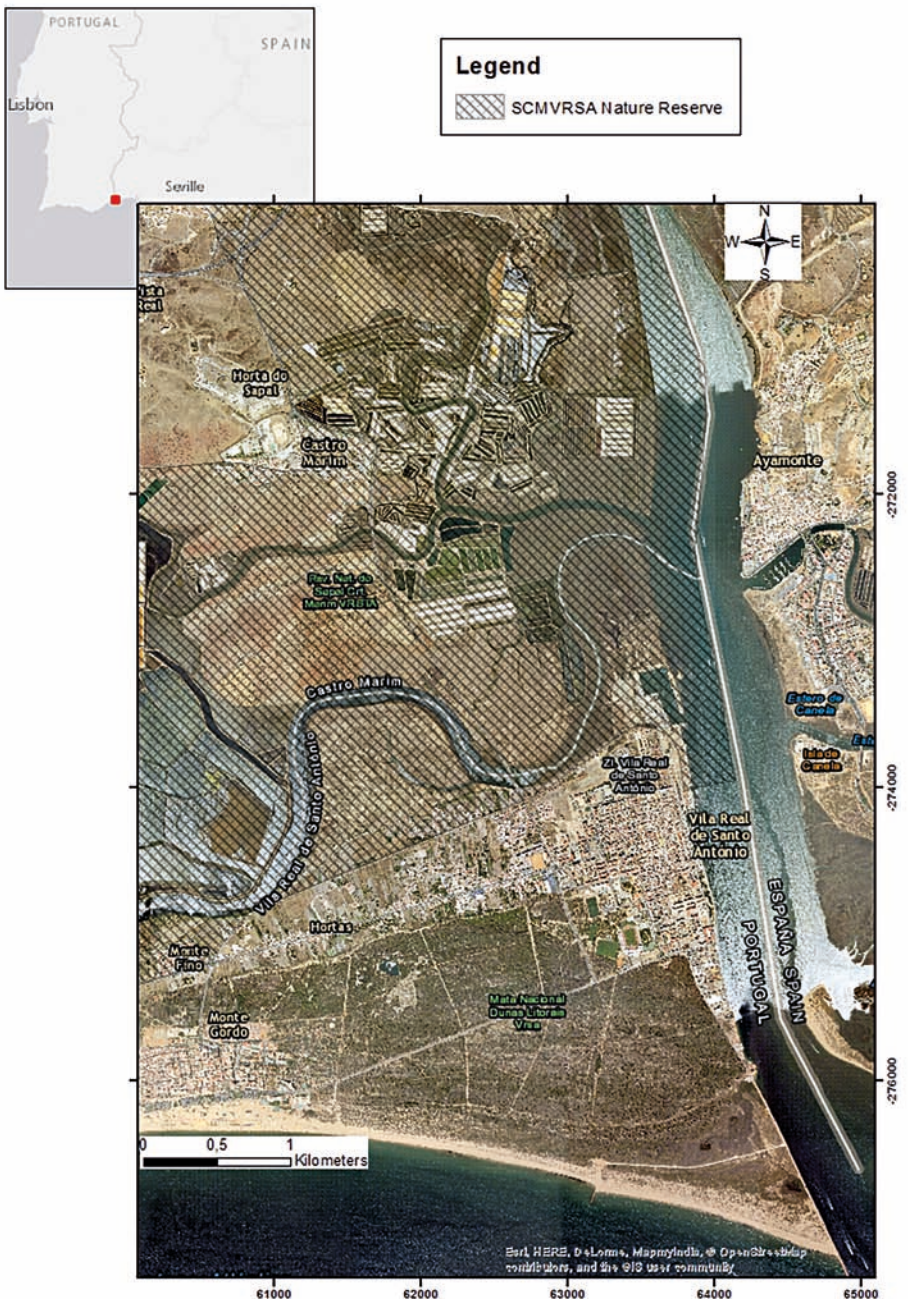

Figure 2. Guadiana River Estuary and "Sapal de Castro Marim e Vila Real de Santo António" (SCMVRSA) Nature Reserve. Image from aerial photographs 2005 and GPS coordinates obtained by in-situ measurements with Trimble® 5800 GPS Receiver.

1960 (Ménanteau *et al.*, 2006) (Figure 3). This loss of a productive activity must be seen in the context of region strongly affected by unemployment. The causes affecting the entire Portuguese traditional salt industry are reflected in the area of Nature Reserve of Castro Marim and Vila Real de Santo Antonio Saltmarshes, i.e. decrease in number of traditional saltworks due to the introduction of the industrial scale saltmaking unit of 400 ha that operates since 1970 with 25-30 000 t/year output and decrease in salt based food preservation in favour of refrigeration (Ménanteau *et al.*, 2006). In the last decades saltworks underwent a progressive loss of economical attractiveness in the rest of the Mediterranean area, due to the competition with less expensive salt production systems, as for example salt mining (Cimmaruta *et al*., 2010). The same fate have followed artisanal salt extraction in other areas of the Iberian Peninsula, such as in the Bahía de Cádiz Nature Park (Spain), approximately 130 km away from the NR, where abandonment due to industrialization, low profitability and loss of markets took place during the 20th century (Camilleri *et al.*, 2015). In industrial saltworks sited in South Eastern Iberian Peninsula, the following weaknesses and pressures have been identified: high urban and touristic pressure, coastal erosion, low salt prices in national market, increase of international and national competition, and decrease of profit margins (Ballesteros Pelegrín and Fernández Ramos, 2013). Several meetings with local stakeholders in the Guadiana Estuary in 2006 and 2010 attributed high ecological values to the saltmarshes (Videira *et al.*, 2009) and to the existing tourism services in the estuary, recognizing that more economic benefit could be obtained from the environmental characteristics of this area while preserving the local attractiveness (Guimarães *et al.*, 2014).

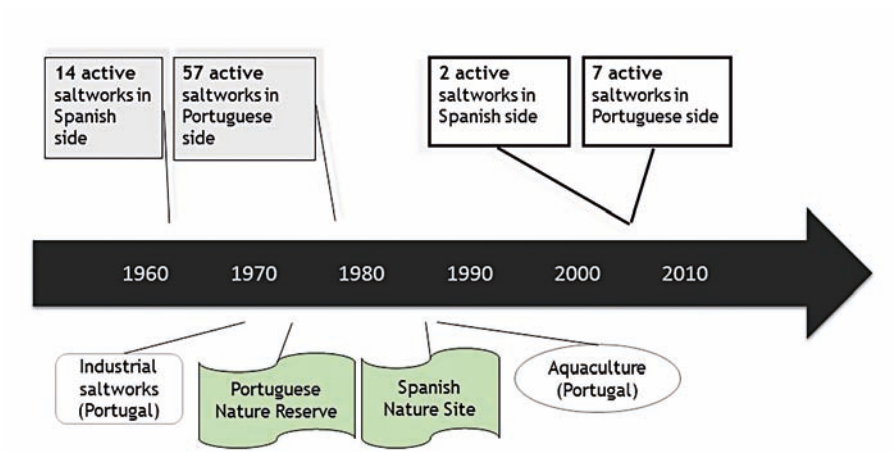

Figure 3. Timeline for principal economic activities in the NR, and establishment of first protected areas and saltworks changes in the Guadiana River Estuary.

The spatial planning instruments involving the study area include: Nature Reserve Plan (2008); Castro Marim Municipality Plan (last revision 2009); Guadiana River Basin Plan (2013); Algarve Regional Plan (2007); Natura 2000 Plan (2008) under European Union Habitats Directive 92/43/EEC which was included in Portuguese legislation by Resolução de Conselho de Ministros nº 142/97. It benefits also from international protection status through Special Protection Zone established under Birds Directive (79/409/EEC) and transposed to Portuguese legislation (Dec. Lei nº 384-B/99); and, since 1996, 2 235 ha are included in the list of Wetlands of International Importance (Ramsar, 2013). In agreement with all those management plans, land uses developed at the NR comprise: salt extraction; ecotourism and health treatments; aquaculture; scientific research and education (unsustainable from a strictly economic point of view); and, agriculture/livestock (only shepherding occasionally takes place in the saltworks area).

The former activities take place in different ecological units of the Nature Reserve (Lavinas, 2004) (Figure 4):

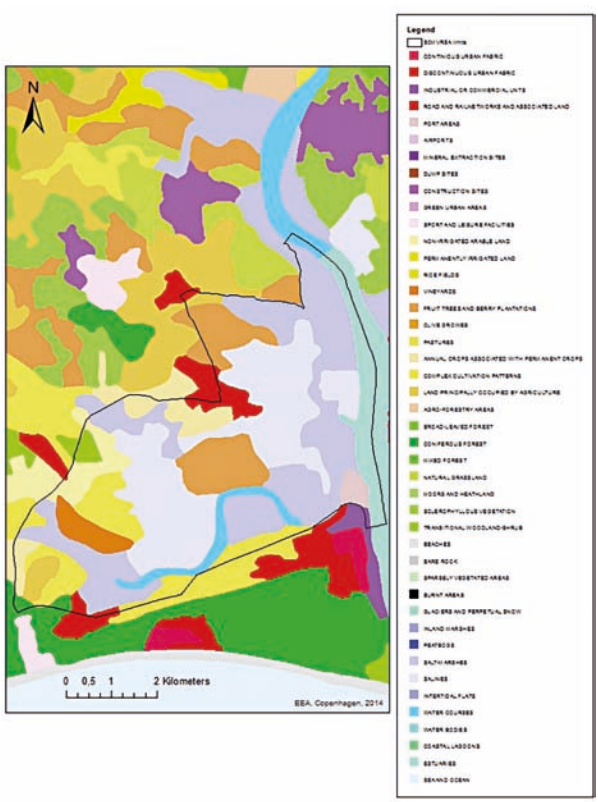

Figure 4. Sapal de Castro Marim e Vila Real de Santo António (SCMVRSA) Nature Reserve Limits and Land Cover (Corine) (adapted from EEA, 2015).

- Wetland (1550 ha):
    - o Semi-intensive aquaculture: 33 ha (since 1987).
    - o Saltworks: 539 ha; of which 284 ha are industrial, 34 ha semi-industrial, and 221 ha artisanal (124.5 ha were inactive in 2004) (Figure 5)
    - o Marshes: 654 ha
    - o Rivers, tidal inlets and banks: 299 ha
    - o Lagoons: 17 ha
    - o Agriculture land subject to flooding: 6 ha
- Agriculture land: 518 ha
- Forest and semi-natural environments: 147 ha

For the above reasons it is clear that a desirable competitiveness of the area can be achieved only by means of a truly integrated management.

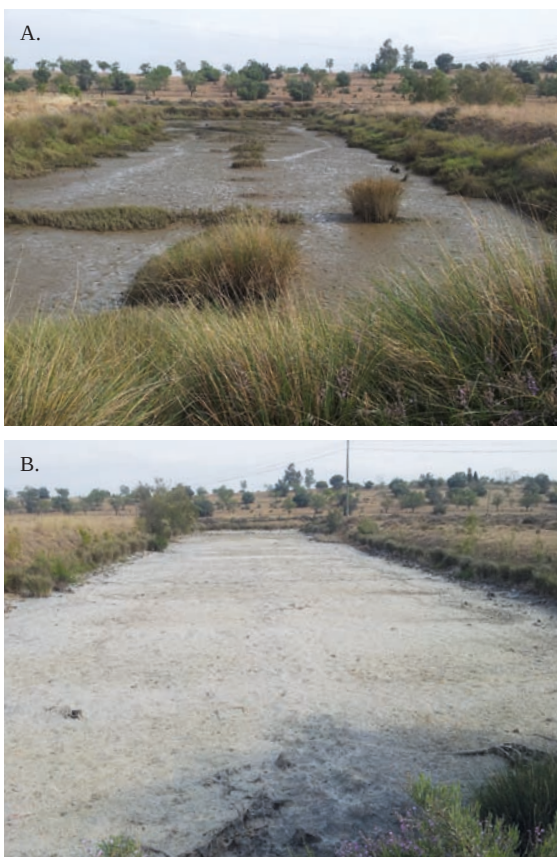

Figure 5. Abandoned TSS in SCMVRSA Nature Reserve, 2015: A. Tide-influenced; B. Not influenced by tides.

MATERIALS AND METHODS

Two criteria were considered to analyse the economic and environmental sustainability of the principal economic activities taking place in the NR: 1. Forecasted gross annual revenues (in €); and 2. Forecasted consumption of estuarine water from the same Guadiana River tidal inlet (in m^3). These two criteria were associated to the surface used for production (in occupied ha). Water consumption and gross revenues were forecasted for industrial salt extraction, artisanal salt production, semi-intensive aquaculture and SPA tourism. Gross revenues were also forecasted for birdwatching activities. Calculations and graphs were produced using Microsoft Excel.

Salt harvesting season in the South of Portugal runs from May to September, with preparatory work usually initiating in March-April (see Figure 6.A), depending on the weather. Artisanal salt production was monitored in-situ and data for this study was acquired during 70 days FS harvesting campaign during the months of June, July and August 2015, in a 1 ha private TSS situated in the protected area. Two crystallizers were monitored every day and FS was collected at the end of the day every time it was formed (see Figure 6.B). After collection, FS remained normally for a day, depending on the atmospheric humidity, draining in a holey plastic box (see Figure 6.C). Then, it was weighted before sun drying on a nylon net before packaging. Coarse sea salt was harvested from one of the crystallizers after the first 60 days of formation, it was heaped at a side of the crystallizer for 1 week (see Figure 6.D), then it was packed in 20 kg plastic bags.

Data on other activities taking place at the studied Nature Reserve were obtained through literature review and from official statistics and spatial data sources. Literature research was done in information centres (Salt Museum in Castro Marim and Nature Reserve Information Centre), local libraries (Castro Marim, Vila Real de Santo António and University of the Algarve), and through website searchers like Web of Science, Google Scholar, and Academia and ResearchGate platforms, during 2015, 2016 and 2017. Statistical data was obtained from the Portuguese National Statistics Institute which provided data on aquaculture. Socioeconomic factors were obtained from Eurostat, the statistical office of the European Union, providing information on minimum wage. Spatial data was obtained from the European Environmental Agency, the Portuguese Institute of Nature Conservation and ArcGIS spatial analyst.

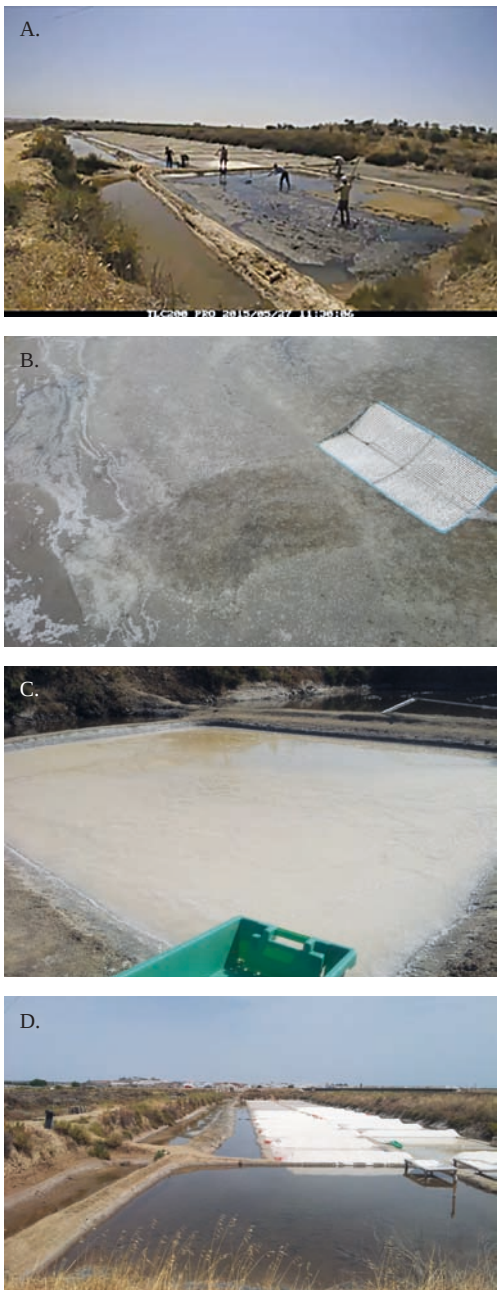

Figure 6. A. Remodelling works before harvesting season, 2015. B. FS collector. C. Crystallizer: FS formed in the surface before collection and holey plastic box for draining. D. View of the saltworks where coarse salt is being collected and drying up in small heaps next to the crystallizers (August 2015, Castro Marim, Portugal).

RESULTS AND DISCUSSION

One of the objectives of this study is to support policy making by proving land use competitiveness information of new sustainable products obtained from traditional activities in a protected area. In 2015, 10 firms were harvesting traditional sea salt (including FS) in the NR. These companies were mainly private (Small and Medium Enterprises –SMEs-), except two public companies, one linked to Castro Marim Municipality, and the other to the Nature Reserve Entity which is legally part of National Institute of Nature Conservation. The two crystallizers monitored during the beginning of the harvesting season are part of one of the SMEs and harvesting conditions were not changed during the research.

The two crystallizers which were followed up on a daily basis, produced a total amount of FS of: 174.5 kg and 119.5 kg, each; it has to be taken into consideration that one of the crystallizers took one more day to fill up because it was deeper, as these hand-shaped crystallizers do not have exactly same dimensions. Considering that the described production unit comprises the total of 36 crystallizers that account, the FS production for two months with a final retail price of 5 €/kg can produce the gross income of 18 000 € while 100 kg per crystallizer is considered a conservative estimate. Taking into account that the minimum monthly wage in Portugal is 589.17 € (Eurostat, 2016) and that the production and packaging expenses include two salaries, the net benefit can be 16 233 €.

Coarse sea salt production after two months in one of the crystallizers was 800 kg. Considering a final retail price of 0.5 €/kg a gross benefit of 14 400 € can be obtained for the entire saltworks. Taking into account the production and packaging expenses which are done by external workers, the net benefit can be 13 320 €. This comparison eludes taking into consideration supporting materials or machinery used for saltponds´ preparation, as it is used the same for both techniques.

According to Ménanteau *et al.* (2006), 30 ha of the NR are being exploited and 200 ha could be potentially recovered. However the area is not occupied exclusively by the crystallizers. If one assumes that crystallizers occupy 10% of a TSS, it would mean that there are 23 ha of crystallizers for the whole NR and, hence, 9 200 crystallizers of 25 m^2 each would produce 1 840 000 kg for a harvesting season of four months. Therefore, the easily recovering of abandoned TSS and its specialization on production of FS could represent a gross income of 9 200 000 € as a conservative estimate.

According to Official National Statistics (INE, 2011), in 2010 the production of coarse sea salt on Portuguese mainland declined by 38.4 % from 2009, due to the fact that many producers turned to the production of FS, which brings trading

incomes per unit weight higher than the coarse salt recovered from the crystallizer bottom. Most of the coarse salt produced in NR comes from industrial saltworks 25-30 000 t per year which represents significant revenues (see Table 1). If the industrial income in the NR is considered by unit of hectare, this will be lower than the income obtained with FS specialization (Figure 7). Besides, industrial sea salt must undergo a process of washing, centrifugation, drying, grounding and sieving before its commercialization which lowers its net revenues.

Table 1. Main economic activities in SCMVRSA Nature Reserve and forecast of revenues. [a] 1 ha, operating time four months. [b] 100 ha, operating time one year. [c] 1 ha, optimal operation 8 hours/day, 6 days/week, four months, maximum 10 persons/hour. [d] 33 ha. [e] 100 ha, optimal operation 2 shifts/day, 6 days/week, 12 months, maximum 10 persons/shift. [f] n. d. = not determined

Activity	Sale price	Forecasted anual gross revenue (€)
TSS[a]	5 € /kg (Fleur de Sel) 0.5 € /kg (Coarse salt)	64 800
Industrial saltponds[b]	0.15 € /kg	3 750 000
Healthcare tourism[c]	25 € /hour	192 000
Semi-intensive aquaculture[d]	6 € /kg (*S. aurata*) 6.6 € /kg (*D. labrax*)	630 000
Bird-watching[e]	49-58 € /shift	308 160
Agriculture	Small scale	n. d.[f]
Fishing and hunting	Forbidden (some exceptions)	n. d. [f]
Environmental education and research	-	n. d.[f]

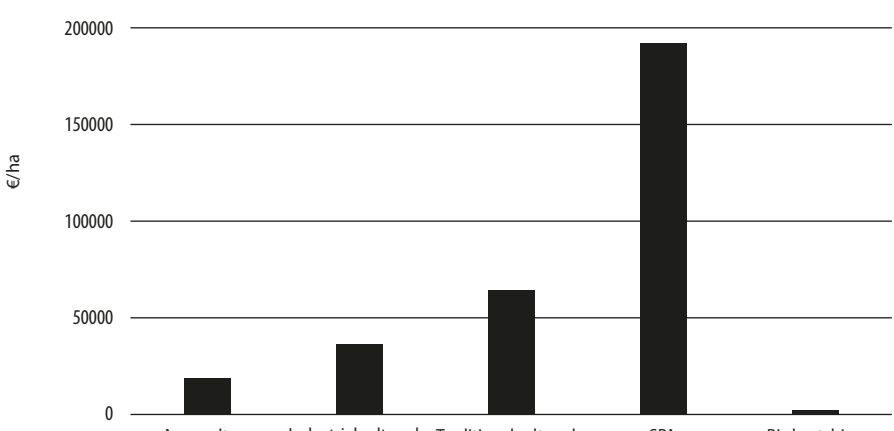

Figure 7. Forecast of production value or gross revenue by surface unit per activity in the NR.

Fish aquaculture in the NR is only developed by one company which is placed in former saltworks, occupying 33 ha (Lavinas, 2004). It can produce around 100 t per year considering a pond area of 2 ha of mainly *Sparus aurata* and *Dicentrarchus labrax* (Hussenot, 2003), in semi-intensive systems with the market value of *S. aurata* in 2014 6 €/kg and *D. labrax* 6.6 €/kg (INE, 2015) it represents an important income (see Table 1). Due to environmental regulations since 1986, no more aquaculture units were allowed to operate in the area. However one of the main actions aiming to increase economic output from coastal areas, foreseen in the Strategic Plan for Aquaculture of the Portuguese Government for 2013-2020 is to convert saltponds and wetlands into aquaculture ponds, and increase public investment (DGRM, 2014) in this domain. Currently, the Nature Reserve of Castro Marim and Vila Real de Santo Antonio Saltmarshes is not included in this plan. Another consideration regarding the presence of aquaculture is the fact that it is probable that the aquaculture installation will encounter water salinization in the near-future as its input water comes directly from the estuary, and the former is under a salinization process due to upstream excess damming of the river which reduces fresh water inflows (Chícharo *et al*., 2006). Despite the prospects of fast and hefty economic returns, large scale aquaculture leads to the impoverishment of saltpans landscape, to an aggravation of the conflicts with farmers, and it can cause environmental impacts by reducing the area available for birds and other species, increasing organic load and nutrient concentrations, diminishing dissolved oxygen levels in the water and introducing hormones, antibiotics, pesticides and various compounds that affect the food chain (Rodrigues *et al.* 2011). The former, together with the need of feeds, would imply lower net revenues.

Despite its clear economic potential, there is no *Artemia* aquaculture operating at the NR. According to studies developed in the Mekong delta (Van Hoa and Sorgeloos, 2015) over 500 families of salt farmers have improved their income with more than 5 000 US$/household/dry season with the production and sales of *Artemia*; however, large quantities are required to make this a profitable business. Industrial and biotechnological applications of microalgae are currently being tested in some saltworks sited at the Nature Park of Ria Formosa (10 km from the studied NR) (Cooke *et al.*, 2011).

The main attractions of tourism in the NR are linked to guided visits to active saltworks and birdwatching. In summer 2015, prices oscillated 5-15 €/person for saltworks visits and 49-58 € per one day excursion for birdwatching. During 2015 summer, therapeutic health treatments started in a converted saltworks; prices were 5-15 €/person for baths, and 5-55 €/person for beauty treatments. Ideas for the development of thalassotherapy as a way of economic recovery of abandoned

saltworks were postulated by Derzec (2002) in association with the trading of salt, brine and sulphur compound rich mud, sold under a natural park brand. Moreover, a traditional salt making recreational activity was offered to tourists in a private saltworks during 2015 salt harvesting season. One day learning of the profession salt harvester (*marnoto* in Portuguese), was proposed at 5-15 €/person. The former activities i.e. birdwatching, health treatments and sharing of traditional knowledge of saltmaking are highly seasonal and depend significantly on weather conditions and consumer demand. It is difficult to assess their sustained feasibility and consequently the competitiveness because of very recent inclusion in the commercial offer (summer of 2015). Nevertheless, an estimate of the annual gross revenues of birdwatching and SPA (health treatments and bathing) were calculated assuming optimal conditions: offered to the public eight hours per day, six days per week, with a maximum capacity of 10 persons per hour, over four months. Birdwatching revenues calculations considered the following optimal operation: two shifts per day, six days per week, with a maximum capacity of 10 persons per shift, over 12 months (Table 1).

Regarding research and education, the last decade of collaboration between the persons and entities in NR and the University of Algarve (Portugal) brought new knowledge and digital applications for education tourism and management, but the actual financial benefits resulting from their application are difficult to estimate. According to Hueso and Petanidou (2011), traditional guided tours and school visits are two well-trodden paths to the respectful exploitation of the Mediterranean's salt heritage, although both are hardly profitable by themselves and are thus, as things now stand, unsustainable from a strictly economic point of view.

A comparison of the above mentioned activities was carried out taking into consideration the competitiveness indicator "annual gross revenue/surface" and the economic and sustainability indicator "estuarine water consumption/surface". Water consumption values were estimated as follows: 1. Aquaculture brine consumption was calculated considering that for the production of 1kg of sea bass in a recovered saltworks 44 m^3 are needed (Hussenot, 2003); 2. Industrial saltworks are considered to need 1.5 million m^3 for a yearly production of 10 000 tonnes (Mannar, 1982); 3. Artisanal saltworks water circuit was monitored in-situ and it is considered to be completely renewed every two spring tides (one each month) with a total wet area of less than 3 000 m^3; 4. Health tourism water consumption was calculated assuming optimal conditions as described above for a 1 ha area saltworks where brine should be recycle on a daily basis; 5. Birdwatching was not included for the second indicator. The first indicator showed that the new activity of health tourism taking place in a saltworks would have the highest income by hectare, followed by

traditional solar saltworks (Figure 7). The second indicator showed that traditional salt extraction is the activity with the lowest water requirements (Figure 8).

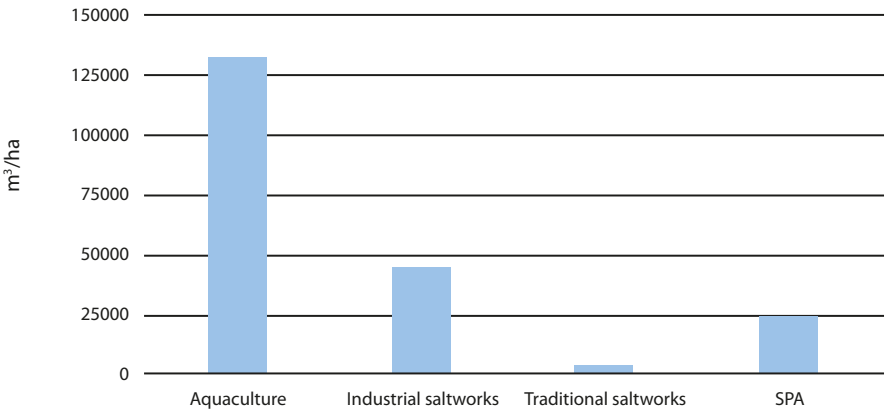

Figure 8. Forecast of water consumption by surface unit from a Guadiana River tidal inlet by activity in the NR.

Currently, the FS in some of the TSS in the Guadiana River Estuary hold the international certificates *Sativa* and *Nature et Progress*, but none possess any of the European certificates of Protected Geographical Indication (PGI), Traditional Speciality Guaranteed (TSG), or Protected Designation of Origin (PDO). Obtaining one of this certifications and matching international standards of labelling, would certainly contribute to an increased competitiveness of FS from the Guadiana Estuary. In order to boost competitiveness of this specific, labour intensive product on the international markets, the Guadiana FS could be promoted and protected as TSG, PGI or PDO, acquiring a label that characterizes FS as both originating from the Guadiana Estuary as well as a handmade product produced in traditional saltworks. Numerous empirical studies indicate that consumers are willing to pay a superior price for origin-guaranteed products and that these products increase rural income and rural development (Winson, 2013). Therefore, these certificates can promote socio-economic development in this semi-rural area, through a product with a historical bond to the community, increasing employment by creating new jobs and recycling old ones. Donadio *et al*. (2011) have studied the carotenoid derived aroma compounds, also denominated norisoprenoids, in saltpan environment of FS to link the product with a geographical area in order to help small producers to obtain theses labels (PGI or TSG). As a matter of fact, a Geographical Indication is already registered for FS produced in the Town of Tavira, situated also in the Ria Formosa

Nature Park 30 km W from Castro Marim, under the denomination "Flor de Sal de Tavira" (Regulamento CE, 2006). At the same time, FS production is the kind of activity that stakeholders in the area would agree to support, as one of the main outcomes of a public event to discuss the future of Low Guadiana River management organized in 2010 included the promotion of low impact economic activities that can benefit from natural resources without decreasing its quality (Guimarães *et al.*, 2014).

Climate change effects need to be taken into account in the competitiveness of TSS. According to Sainz and Boski (2015), the reduction of the Guadiana River inflow due to extensive damming in the watershed has produced salinity increase in the Guadiana Estuary and the observed salinization, applied to traditional salt production would cause an increase of 46.3% in the salt produced at the same land surface and assuming the same evaporation rate for both levels of initial salinity.

CONCLUSIONS

Due to the favourable natural conditions, artisanal heritage, and legal framework for nature protection, the Guadiana River Estuary has a high potential in terms of production of FS. Compared to other land uses permitted in the NR, the extraction of FS showed revenues higher than a semi-intensive aquaculture system and the extraction of artisanal and industrial coarse sea salt. Forecasted revenues from health tourism practiced in saltworks were higher than those from FS production, although they were calculated considering an optimal operational situation which needs to be related to the real situation. TSS showed the lowest consumption of estuarine water of all the activities carried out at the NR.

The commercial value and likewise the competitiveness of this commodity rely on its recognized quality, formally endorsed by the international certificates like *Sativa* and *Nature et Progress*. There are possibilities for further improvements of the market image of FS from Guadiana by obtaining a origin/geographical denomination label. The preservation of traditional knowledge applied to manufacturing of a high quality good is an added value in terms of fostering the territorial competitiveness of the area. Even if FS competitiveness can be influenced by changes in the environment, in the case of the Guadiana River Estuary, where over-damming of the river are causing its salinization, this type of pollution would not be a major problem for sea salt extraction to continue opposite to the effects that this would mean for aquaculture.

Integrated management of coastal areas where there is an important presence of TSS, points out the problem of the abandonment of saltworks which

causes significant biodiversity loses. Therefore, it is encouraged the revitalization of traditional salt harvesting specialized on FS production by endorsement of integrated public policies. This study aims to support future integrated research initiatives; it is paramount to highlight the need of searching for long-lasting and environmental sustainable activities according to each territory; in this case, by the specialization on FS production. A revitalization of TSS would be part of the green economy, representing a sustainable development of these coastal territories and an increase of the competitiveness of the region.

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LITERATURE CITED

Ballesteros Pelegrín, G. A. and J.F. Fernández Ramos. 2013. La explotación industrial de las salinas de San Pedro del Pinatar (Murcia). Pap. Geogr., 57-58: 55-68.

Camilleri, S., A. Pérez-Hurtado de Mendoza and G. Gabbianelli. 2015. Multiple DPSI frameworks for support of integrated research: a case study of the Bahía de Cádiz Nature Park (Spain). J. Coast. Conserv., 19(5): 677-691.

Chícharo, M.A., L. Chícharo and P. Morais. 2006. Inter-annual differences of ichthyofauna structure of the Guadiana estuary and adjacent coastal area (SE Portugal/SW Spain): Before and after Alqueva dam construction. Estuar. Coast. Shelf Sci., 70: 39-51.

Cimmaruta, R., S. Blasi, D. Angeletti and G. Nascetti. 2010. The recent history of the Tarquinia Salterns offers the opportunity to investigate parallel changes at the habitat and biodiversity levels. Transit. Wat. Bull., 4(2): 53-59.

Cooke, P., J. Porter, H. Pinto, A.R. Cruz and F.Z. Zhang. 2011. Notes from the Iberian Algae Belt. Eur. Plan. Stud., 19: 159-173.

De Medeiros Rocha, R., D.F.S. Costa, M.A. Lucena-Filho, R.M. Bezerra, D.H.M. Medeiros, A.M. Azevedo-Silva, C.N. Araújo and L. Xavier-Filho. 2012. Brazilian solar saltworks - ancient uses and future Possibilities. Aq. Biosyst., 8(1): 8 p.

Derzec, P. 2002. A rescue plan for the traditional salinas: Vision of a long-term development of the Landscape Park of Secovlje Saltworks, Piran. 58-61. In: Petanidou T., H. Dahm and E. Vayanni. (Ed.). Salt and salinas as natural resources and alternative poles for local development. University of the Aegean, Mytilene. 261 p.

DGRM. 2015. Plano Estratégico Aquicultura Portuguesa 2014-2020. Direcção Geral de Recursos Naturais, Segurança e Serviços Marítimos. Lisbon. 90 p.

Dias, J.M.A., R. Gonzalez and O. Ferreira. 2004. Natural versus anthropic causes in variations of sand export from river basins: An example from the Guadiana river mouth (Southwestern Iberia). Polish Geol. Inst. Spec. Pap., 11: 95-102.

Donadio, C., A. Bialecki, A. Valla and L. Dufossé. 2011. Carotenoid-derived aroma compounds detected and identified in brines and speciality sea salts (fleur de sel) produced in solar salterns from Saint-Armel (France). J. Food Compost. Anal., 24: 801-810.

EU (European Union). 2013. Decision No 529/2013/EU of the European Parliament and of the Council of 21 May 2013 on accounting rules on greenhouse gas emissions and removals resulting from activities relating to land use, land-use change and forestry and on information concerning actions relating to those activities. O.J.E.U. 165: 80-97.

Eurostat. 2016. Data: Monthly minimum wages - bi-annual data. http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do. Accessed on: 11-02-2016.

Fontana, P., J. Schefer and D. Pettit. 2011. Characterization of sodium chloride crystals grown in microgravity. J. Cryst. Growth, 324: 207-211.

Galvis-Sánchez, A.C., J. Almeida Lopes, I. Delgadillo and A.O.S.S. Rangel. 2013. Chapter 26 – Sea Salt. 719-740. In: de la Guardia, M. and A. Gonzalvez (Eds.). Food Protected Designation of Origin. University of Valencia, Valencia. 741 p.

Garel, E., L. Pinto, A. Santos and O. Ferreira. 2009. Tidal and river discharge forcing upon water and sediment circulation at a rock-bound estuary (Guadiana estuary, Portugal). Estuar. Coast. Shelf Sci., 84: 269-281.

Guimarães, M.H., C. Sousa, T. Dentinho and T. Boski. 2014. Economic base model for the Guadiana estuary, Portugal an application for Integrated Coastal Zone Management. Mar. Policy 43: 63-70.

Hueso, K. and T. Petanidou. 2011. Cultural aspects of Mediterranean salinas. 213-226. In: Papayannis, T. and D. E. Pritchard (Eds.). Culture and wetlands in the Mediterranean: An Evolving Story. Med-INA, Athens. 438 p.

Hussenot, J.M.E. 2003. Emerging effluent management strategies in marine fish-culture farms located in European coastal wetlands. Aquaculture, 226: 113-128. INE. 2011. Statistical Yearbook of Portugal 2010. Instituto Nacional de Estatística, I.P. Lisbon. 628 p.

INE. 2015. Estatísticas da Pesca 2014. Instituto Nacional de Estatística, I.P. Lisbon. 144 p.

Korovessis, N.A. and T.D. Lekkas. 2009. Solar saltwork´s wetland function. Global NEST J., 11(1): 49-57.

Lavinas, C. 2004. Reserva Natural do Sapal de Castro Marim e Vila Real de Santo António, uma contribuição para a sua gestão. Instituto da Conservação da Natureza / Centro de Zonas Húmidas, Lisbon. 103 p.

Mannar, V. 1982. Guidelines for the establishment of solar salt facilities from seawater, underground brines and salted lakes. United Nations Industrial Development Organization (UNIDO).Vienna, Austria. 149 p.

Ménanteau, L., C. Chadenas and C. Choblet. 2006. Les marais du Bas-Guadiana (Algarve, Andalousie): emprise, déprise et reprise humaines. Estuarium, Aestuaria, 9: 309-331.

Mitsch, W.J. , B. Bernal, A. M. Nahlik, U. Mander, L. Zhang, C.J. Anderson, S.E. Jørgensen and H. Brix. 2012. Wetlands, carbon, and climate change. Landscape Ecol. 28(3): 583-597.

Morais, P., M.A. Chícharo and L. Chícharo. 2009. Changes in a temperate estuary during the filling of the biggest European dam. Sci. Total Environ., 407: 2245-2259.

Ramsar. 2013. The Annotated Ramsar List: Portugal. The Ramsar Convention on Wetlands. http://archive.ramsar.org/cda/en/ramsar-documents-list-anno-portugal/main/ramsar/1-31-218%5E16081_4000_0. Accessed on: 23-03-2017.

Regulamento CE. 2006. Regulamento (CE) N.o 510/2006 con Conselho relativo à proteção das indicações geográficas e denominações de origem dos produtos agrícolas e dos géneros alimentícios: «SAL DE TAVIRA»/«FLOR DE SAL DE TAVIRA» N. o CE: PT-PDO-0005-0913-07.12.2011.

Rocha, R. D. M., D. F. Costa, M. A. Lucena-Filho, R. M. Bezerra, D. H. Medeiros, A. M. Azevedo-Silva and L. Xavier-Filho. 2012. Brazilian solar saltworks-ancient uses and future possibilities. Aq. Biosyst., 8(1): 8 p.

Rodrigues, C.M., A. Bio, F. Amat and N. Vieira. 2011. Artisanal salt production in Aveiro/Portugal – an ecofriendly process. Saline Syst., 7: 3.

Sainz, N. and T. Boski. 2015. The Guadiana River Estuary salinization, an opportunity for traditional sea salt production recovery. 357. In: Environmental protection in a multi-stressed world: challenges for science, industry and regulators Abstracts Book SETAC Europe 25th Annual Meeting. Society of Environmental Toxicology and Chemistry Europe, Barcelona. 520 p.

Thompson, I.B. 1999. The role of artisan technology and indigenous knowledge transfer in the survival of a classic cultural landscape: the marais salants of Guérande, Loire-Atlantique, France. J. Hist. Geogr., 25(2): 216-234.

Van Hoa, N. and P. Sorgeloos. 2015. Integrated salt and brine shrimp *Artemia* production in artisanal salt works in the Mekong delta in Vietnam: a socio-economic success story as model for other regions in the world. 137-144. In: Sandrine, L. (Ed.). Proceedings of the International Conference Solar Saltworks and the Economic Value of Biodiversity. European Salt Producers Association – EuSalt, Trapani. 245p.

Videira, N., P. Antunes and R. Santos. 2009. Scoping river basin management issues with participatory modelling: The Baixo Guadiana experience. Ecol. Econ., 68: 965-978.

Villalobos, C.A., F.J.G. Prieto and L. Ménanteau. 2003. Las Salinas De La Bahía De Cádiz Durante La Antigüedad: visión geoarqueológica de un problema histórico. SPAL, 12: 317-332.

Winson, T. 2013. Economic competitiveness through geographic indications. Int. J. Mark. Financ. Serv. Manag. Res., 2(9): 182-185.

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