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Artisanal Salina – Unique Wetland Habitats Worth Preserving

Natividade Vieira[1,2]* and Ana Bio[1]

[1]CIMAR/CIIMAR – Centro Interdisciplinar de Investigação Marinha e Ambiental, Universidade do Porto, Rua dos Bragas 289, 4050-125 Porto, Portugal
[2]Departamento de Zoologia e Antropologia, Faculdade de Ciências, Universidade do Porto, Rua Campo Alegre s/n, 4169-007, Porto, Portugal

Introduction

Artisanal salina is wetlands of particular interest in terms of biodiversity, but also as a cultural landscape and industrial heritage [1-4]. Composed of a series of successive ponds with decreasing depths, delimited and protected by dykes, which are subject to water regulation and evaporation for salt production, they display a range of brackish/marine to hyper-saline conditions, characterized by particular species assemblages [5]. Generally embedded in estuaries and salt marshes, considered valuable wetland ecosystems especially important as breeding and feeding grounds for water birds and as hatcheries for many fish species, salina ponds and dykes allow furthermore for different niches and are, particularly important as feeding grounds for birds.

In southern Europe artisanal salt production used to be an important economic activity between the 17th and early 20th centuries [6]. In the 1930's, however, the salt industry entered a deep crisis as salt consumption (especially for industry and food preservation) dropped and prices declined, while workforce became more difficult to find and more expensive [7]. Consequently an increasing number of Salina was converted to into extensive and semi-intensive fish culture plants, preserving at least some of the pond and dyke structures, or rice fields. Whereas many were completely abandoned to tides and currents causing dyke erosion and pond and channel silting-up. Salina are still found, e.g. on the Portuguese south coast and associated to estuaries on the country's west coast. Many of these are of considerable ecological interest, but few of them have been studied so far [8-11].

Salina Functioning and Ecology

Traditional salters, or Salina, have basically three types of compartments. Supply ponds, or pre-basins, are the biggest and deepest of the system. They communicate with the sea (or estuary) through channels that supply water to the system during spring tides. Water flows from the supply ponds through sluice gates into evaporation ponds; where part it evaporates, and finally into the crystalliser ponds where the brine reaches maximum salinities and deposition of sodium chloride for salt production takes place. Only ponds of the same type are levelled in order to allow water flow by gravity. Wind and solar energy are used for evaporation. Salt quality depends on the salinity gradient between compartments and the consequent differential precipitation of the different salts contained in the sea water [12]. Salina structure allows early precipitation of the less soluble, unwanted marine minerals – primarily $CaCO_3$ and $CaSO_4$-$2H_2O$ (gypsum), which would give the salt an unpleasant taste – and concentration and later precipitation of NaCl in the final crystalliser ponds [13,14].

But salt production is not only a physical process of evaporation. It is also linked to biological processes and brine organisms that aid salt production [15,10]. Quality and quantity of salt production benefit from: planktonic communities of species well adapted to narrow salinity ranges, that colour the water, increasing evaporation; halophilic bacteria that release energy heating up the water and favouring evaporation; and benthic communities that form mat-like structures on the pond floors with organic matter, minimizing accretion of organic substances and gypsum on pond floors and sealing the floor against brine leakage [16,17]. The most actively involved organisms are *Artemia* sp., which survive salinities above 300 ppt and are often very abundant in the evaporation ponds, passing with the brine flow into the crystallizers, where halophilic bacteria (*Halobacterium*) feed on dead *Artemia*. There are also organisms that harm salt production, such as the cyanobacterium *Coccochloris* sp., which produces mucus, raising the viscosity of the brine, thus hindering solar absorption and, consequently, water evaporation. Its presence is favoured by unbalanced nutrients, specifically high phosphorus concentrations.

Salina are mostly closed systems, exposed to annual cycles of salt production and resting periods, with drainage and drying, followed by flooding. These two periods are ecologically distinct in terms of physical, chemical and biological conditions [1,10]. During the resting period, the ponds constitute brackish water bodies where abundant fauna and flora can develop. But during salt production, salinity varies in the system reaching hyper-saline conditions in the final compartments. Species diversity diminishes with increasing salinity as less eurohaline organisms gradually disappear and each pond develops a characteristic ecological succession. Supply tanks maintain high species diversities throughout the year with benthonic, nektonic and neustonic organisms, including a great variety of algae. The assortment of benthonic organisms (algae, protozoa, annelids, molluscs, and others) form a dark layer called *mat,* which contributes to the soil's impermeabilisation and to nutrient recycling, enhancing the productivity of the salt pond ecosystem. In the evaporation ponds, which reach salinities of 3 to 7 times that of sea water during salt production, species diversity decreases, although some species may increase in abundance. Here, only *Artemia,* some halophilic algae and bacteria requiring salinities above 70 ppt survive. In the crystalliser ponds halophilic bacteria are the only organisms surviving. As sea water evaporates in the evaporation tanks and salinity rises, many organisms die, generating a considerable amount of dead organic matter [15].

The variable conditions in the different Salina sections and the distinct physicochemical and biological patterns are caused by the Salina structure itself, by seasonal effects and by the two periods of the salt production cycle [10]. Birds, and other animal groups, take advantage of a vast gradient of physical and chemical conditions and the consequent range of food resources. Little is known about the dynamics

***Corresponding author:** Natividade Vieira, CIMAR/CIIMAR – Centro Interdisciplinar de Investigação Marinha e Ambiental, Universidade do Porto, Rua dos Bragas 289, 4050-125 Porto, Portugal, Tel: +351 223 401 800; E-mail: mnvieira@fc.up.pt

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of, for instance, fish fauna populations in Salina, but birds have been well studied. Salina are the most important man-made birdlife habitats in many South-European coastal estuaries [6,18,19]. They can be considered supra-tidal feeding and roosting grounds, equivalent to North-European wetlands, often crucial to the survival of migrating birds when regular feeding grounds are unavailable or conditioned [20-22]. Abandonment and degradation of salt pond structures has a direct impact on the Salina using fauna [23]. A constant use of the Salina, with water supply and maintenance of water levels promotes the rise and subsistence of prey invertebrate populations and the best (shelter and nesting) conditions for birds are found in working artisanal Salina, though inactive Salina may also support various bird species and constitute important nesting areas.

Conclusion

From a conservational point of view and in terms of wetland management, artisanal Salina constitute valuable habitats worth preserving. They are unique wetland ecosystems of ecological, environmental, cultural and also potential economic importance, characterized by variable physicochemical water conditions and adapted biotic communities. To preserve the remaining Salina habitats and encourage Salina restoration and rehabilitation, artisanal salt production has to become an attractive activity again, or alternative uses have to be found [10,24]. This can be achieved making salt production more profitable or through an adequate choice of by-products and alternative activities, which allow increased returns from traditional Salina without changing their ecological characteristics. Knowledge about the structure and functioning of the Salina ecosystem and food chains, as well as about options for bio-manipulation, will help to improve both quantity and quality of the salt produced [25]. And the culture of, for instance, *Artemia* can provide additional income. This organism favours salt production and quality, and its cysts, naupli or adults are valued feed in aquaculture and aquaria [10,11,26]. Furthermore, the touristic, cultural and scientific value of Salina can be better explored [27,28].

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