Salinas and nature conservation in the Mediterranean

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Despite their status of artificial wetlands, Mediterranean salinas are biologically rich and represent key habitats for bird conservation. This value is enhanced by the degradation of surrounding coastal wetlands through urbanisation and economic activities. But salinas are also fragile and present limiting factors for birds. An effective conservation policy appears to be necessary to promote their preservation and biological value.

1. INTRODUCTION

Located for the most part next to lagoons and coastal dunes, salinas are wetlands which have been marked by the hand of man. This situation has generated a rather unattractive image of artificiality which is often unjustified. This may be why salinas are not well-known to the general public or even the scientific community as illustrated by the several misleading terms used: salt marshes, salt pans, salines, salt-works or salinas

Salt works or salinas are part of the cultural heritage of the Mediterranean. Since time immemorial, salt production has been achieved through the natural evaporation of salt water from the sea, coastal or interior lagoons. Salt production depends heavily on climate and its variations. With long, hot, dry summers the Mediterranean climate is particularly suitable. Salinas are found all around the world where this climate occurs, and within the Mediterranean basin this activity extends over 1,000 km^2 [1].

Salinas, however, are not only sites of economic production. In contrast to preconceived ideas, they can be important sites for nature conservation. These heavily modified sites have become areas of high biological value supporting large numbers of waterbirds.. Bird species find there the tranquillity essential for much needed resting, feeding and reproduction. Today the biological value of salinas is of particular importance along a coastline that has been severely altered by urbanisation and expanding economic activities. Biological importance, high fragility, increasing pressures: these are the parameters to be taken into account in any systematic approach to the Mediterranean salinas which aims at the long term conservation of this remarkable habitat.

2. MEDITERRANEAN SALINAS TODAY

The active salinas of the Mediterranean are very diverse [2]. Based on the type of production, four main categories could be distinguished [1]:

- primitive salinas which are made up of a mosaic of bowls cut out by hand in the rocky coasts such as in Gozo island, Malta,
- rudimentary salinas mostly constituted of a pan of less than 1 ha in surface area where water level is maintained all year round. Salt is harvested by hand,
- traditional salinas made up of developed pans, linked by canals and dykes. The salt

harvesting from the pans is mainly done by hand,

- Modern salinas where the water is circulated by pumps and sluice gates over tens, if not hundreds of kilometres until it reaches saturation point. The salt extraction is done by machinery of high technology.

Thus the area covered by a salina varies considerably, from a rudimentary one of 1 ha to a large modern one of 12,000 ha.

Apart from the primitive salinas found on the islands and in the east of the Mediterranean, salinas avoid rocky coasts. Rudimentary and traditional salinas are found in the south and east of the Mediterranean. Other traditional and modern salinas are concentrated on the northern coast. A few recent modern salinas are found in Algeria, Tunisia and Egypt.

A survey of information has revealed the presence of 168 salinas at least in 18 Mediterranean countries [1]. Of the 90 active salinas, 75 % are located in the countries in the centre and north of the Mediterranean. Spain, Greece, Italy, France and Portugal hold 77 % of the salinas in the Mediterranean; followed by Turkey, Algeria and Tunisia. France is the highest producer with about 1.5 million tons, followed by Turkey, Spain and Italy. These four countries produce 84 % of Mediterranean salt.

The economics of salt markets and the cost of production have led to the closure of a certain number of small salinas in the north of the Mediterranean. Of the 64 salinas which became inactive, 83 % covered a surface area of only 9,230 ha [1]. The trend to stop salt production has been exacerbated by competition for space along the coastline from urbanisation and industry, which have been expanding rapidly in recent years. Some salinas, inactive for 40 years, have buildings and a hydraulic system which have fallen largely into ruin. Others are used intermittently. The small salinas were the first to close or to stop producing, beginning in the 1930's, due to the improvements in productivity of the bigger ones which were being modernised. Large numbers of salinas were closed during the period 1950-1990, especially in industrial countries, whereas in the south and east traditional production continued [1].

It was particularly in Portugal, Sicily and Greece that 11 salinas were transformed into fish farms. This transformation has increased rapidly over the past twenty years. Traditional fish-farm uses only part of the salina, so the appearance of the site is conserved, It is not the case with intensive ones where the landscape is largely destroyed [3].

A few salinas have acquired nature reserve status.

3. BIOLOGICAL RICHNESS OF SALINAS

Salinas are biologically rich despite being artificial habitats. This is partly because human interventions ensure the circulation of water despite the unpredictable Mediterranean climate which often varies greatly from year to year. In addition, they are relatively undisturbed habitats in relation with their private status.

Among the animal and plant communities which characterise salinas and which can tolerate the gradients of salinity and water regime, two groups stand out by their productivity: unicellular organisms and aquatic invertebrates [4]. They are essential elements of the food chain which provide food for high densities of a wide range of birds.

3.1 Unicellular organisms

In the salinas suitable for aquatic life, plankton and benthic unicellular organisms are the most abundant. The species are similar to those found in salt water of marine or of continental origin (salt lakes); the species vary, however, according to the physical and chemical characteristics of water and the substrate [4].

In contrast to lagoons, the main salinity gradient in salinas occurs not in time, but in space. The species-richness of each pan or lagoon is a function of its position in the water circuit, and therefore, its specific salinity. The gradual evaporation of water results in precipitation of dissolved salts across a range of concentrations. As a consequence, the ionic composition of the water is increasingly different from that of sea water the further the pan is from the sea-water pump.

In salinity of up to 150 g/l diatoms and blue-green bacteria such as *Lyngbya estuarii* dominate. Carpets of the blue-green bacteria *Microcoleus chthonoplastes*, for example, may be several centimetres thick and develop best between 55-150 g/l salinity [4].

From 150 g/l, the precipitation of gypsum modifies the community. The lamella structure characteristic of hypersaline habitat is due to the vertical gradient in oxygen content and light, both of which decline with depth [5]: from top to bottom appears a succession of layers of blue-green bacteria (*Aphanothece*) on the surface of the gypsum and, underneath, blue-green filamentous bacteria of *Phormidium* and purple sulphurous bacteria of *Chromatium* and *Thiocapsa*. The two latter contribute to reducing the sulphates to sulphides, through the activity of the reducing bacteria *Desufovibrio*, present in the sediment.

Above 180 g/l, the production of green unicellular algae, *Dunaliela salina* and autotrophic bacteria like *Halobacterium* is high [4]. They create the red colour of the water in the most concentrated salt pans.

3.2 Aquatic invertebrates

Aquatic invertebrates occur in all salinas. A two year study of the salinas of Giraud (France) showed the presence of twenty five taxa and thirty four species [4]. Although there are fewer species when salinity is high, the correlation it is not linear, a large decline in species diversity is accompanied by an increase in biomass, when the precipitation of carbonates and gypsum occur. When the salinity is 70 g/l, carbonates and borates of calcium begin to precipitate. Thus the copepod *Eurytemora velox*, the amphipod *Gammarus inaequicaudata* and the dipterous *Chironomus salinarius* disappear. This is also the case with molluscs and decapods, whose skeleton and shell can no longer be produced following the precipitation of carbonates.

Between 70-150 g/l, the number of species remains relatively stable. Above this, it declines: calcium sulphate precipitates which leads to the disappearance of the cyanophyceae *Microcoleus chthonoplastes*, and as a result those that eat them, like *Halocladius varians* and *Cletocamptus retrogressus*; simultaneously their predator, *Berosus spinosus* disappears.

Three species resist very high salinity, (>280 g/l): the two dipterous *Thinophilus achilleus* and *Ephydra bivittata,* and brine shrimps. The density of the last two species is highest at concentrations above 150 g/l because of the small number of predators.

The daily temperature range in the water and desiccation are the other limiting factors for the life cycles of invertebrates.

Aquatic invertebrates occur at relatively low densities compared to other salty habitats. The salinas are an oligotrophic system. Only brine shrimps have similar densities as analogous habitats, *i.e.* 16,000 to over 100,000 individuals/m^3 in optimal conditions. The rapid succession of the different phases of development (about fifteen days) explains their incredible productivity [6]. They are key species in the food chain.. Eaten by many waterbirds the brine shrimps contribute to the diversity of birds in salinas.

3.3 Birds

In degraded coastlines, salinas represent an important capital for the conservation of birds in the Mediterranean. They support up to one hundred species of waterbirds from 18 different families [1]. Most of them are

vulnerable species. For example 70 % of the Audouin's Gull population *Larus audouinii*, endemic to the Mediterranean basin, is concentrated today in the Trinitat salinas (Ebro delta). Similarly, nearly all the nesting colonies of flamingos *Phoenicopterus r. roseus* and Slender-billed Gull *Larus genei* have been established in salinas in the Mediterranean.

Highly mobile, birds require vast areas to satisfy their basic needs, feeding and breeding. Their use of a salina will depend on disturbance, as well as the location in relation to the migration route and the richness of surrounding habitats.

3.3.1 Breeding

The choice of the nesting site is essential for successful breeding. Chosen without care, it can lead to the abandonment or the destruction of the clutch. There are two major constraints: a suitable site for the construction of the nest and feeding areas close by [7].

Ducks and certain waders nest as solitary pairs. They build their nest on the dykes of the salinas or on islands inaccessible to mammal predators (rats, dogs, cats or foxes), even though their discreet behaviour and camouflaged nests are already good protection. The Kentish plover's nest *Charadrius alexandrinus* is a small dip in the ground; the camouflage of the eggs and their small size are its only defence.

Other birds form colonies, like gulls, terns, avocets, flamingos which can have up to 10,000 pairs. They are very visible, particularly since their social behaviour is accompanied by noisy calling. Consequently they look for sites, such as islands, inaccessible by terrestrial predators, against which they have no defence. Here, similarly to predators, the human disturbance is a critical point. In salinas, it is low compared to coastal lagoons which are used by people for numerous activities.

A combination of three factors make the islands inaccessible: water depth, distance from the dyke and salinity [8]. With low salinity, dogs or foxes *Vulpes vulpes* will not go across to the island if they have to swim more than 150 m. In water with salinity higher than 100 g/l, colonies can establish themselves only a few metres from the dyke. It is probable that because carnivores lick themselves clean, they cannot go into high salinity water particularly as there are few freshwater points in the salinas.

These birds living on islands do not have the same nest habitat requirements [7]. The Black-headed gull *Larus ridibundus* uses *Salicornia* plants to build its nest, whereas the Mediterranean gull *L. melanocephalus* lays its eggs in more open vegetation. Terns and Avocet prefer areas free of vegetation with a loose sandy substrate, in which it scrapes a dip for its eggs. All of them form mixed colonies.

Large colonies require rich feeding habitats. Consequently, the choice of the breeding site depends on the distance to the feeding area. Like all waders, avocets nest close to food resources in order to be able to move their chicks there easily. Chicks of other colonial species are fed at the nest. Thus the distance to the feeding area depends also on the size of the birds and on their method of transporting food. Flamingos use a secretion from their crops to feed their single chick, so they can travel more than 100 km from the colony. On the contrary, terns bring back fish one by one in their beak. Their colony site needs to be situated closer. In addition to areas where water is flowing, like near the pumps or between two lagoons, the smallest one, the Little Tern *Sterna albifrons,* feed on the coast 5-10 km from the colony whereas the largest Sandwich Tern *S. sandvicensis* feed at sea on pelagic fish and go more than 20 km [1]. The presence of these birds in the salinas is linked to the neighbouring marine fish resources.

3.3.2 Feeding

In active salinas, the flooding cycle is the reverse of that of natural wetlands. The presence of shallow, permanent water in spring and summer ensures abundant food on sites which would normally dry out progressively. By improving the availability and accessibility of food, this water management encourages the use of these salinas by birds [1].

Resource partitioning between bird species using the salinas as feeding sites contributes to their diversity. Birds may be herbivores, fish-eaters, or invertebrate feeders. The shape and the length of the beak, and the length of the legs are adapted to different feeding behaviour for capturing their preferred prey. Thus, flamingos feed on the same invertebrates as avocets or small waders (*Calidris sp.*), but its longs legs enable it to feed in deeper water.

Terns, which dive for fish, require clear water to be able to see their prey, while Spoonbills *Platalea leucorodia*, with flat, tactile beaks can fish in turbid water.

Herbivorous birds, (geese, duck and coot), are not common because there is little emergent vegetation. In winter, if they are not disturbed by hunting, groups of several thousand ducks use the salinas as a roost, flying out to neighbouring freshwater marshes for feeding.

The biological richness of the salinas is based for the most part on invertebrates, and the birds that feed on them are characteristic of this habitat. The flamingo has to eat about 10 % of its body weight each day, the equivalent of 135,000 brine shrimp. Five thousand flamingos feeding in the Camargue salinas require 1.4 tons of invertebrates per day [1]. This is also the case for 26 of 33 wader species that are most common in the western Mediterranean. Nearly 500,000 birds spend the winter on the Mediterranean coast [9]. Because of the small tides, intertidal zones and mudflats are rare. Therefore, because salinas present areas of mud temporarily exposed by the wind, they play an important role providing replacement feeding habitats for both wintering and migrating birds. They are a major stop-over point for rest and reconstitution of fat reserves. For example 40-50 % of 25,000 waders wintering in Cadiz Bay (S.W. Spain) use the salinas [10].

4. LIMITING FACTORS AND MANAGEMENT

If water management influences the richness of the feeding habitats, the stabilisation and predictability of water level have negative effects [8]. Permanent flooding results in erosion and loss of the islets, which are no longer being replaced naturally. Moreover, the predictability of the water levels favours species adapted to stable habitats. In such condition, the Yellow-legged Gull *Larus cachinnans* is a powerful competitor for nesting site. Because it is a predator of eggs and chicks, it is avoided by the other species. In the salinas of Giraud, 38.5 % of islands formerly colonised by small gulls and terns species are now occupied by this larger gull whereas 33.6 % of islets have disappeared after erosion [8]. In the long term, the stability of the salinas causes a decrease in numbers and in the diversity of the bird community.

This situation is repeated in all the salinas along the French coastline, and probably in most of the Mediterranean salinas where the Yellow-legged Gull population are expanding.

The best method of improving nesting conditions is the construction of islets; in the long term these must be managed to avoid their colonisation by Yellow-legged Gull. An experiment in the salinas of Giraud provide a useful example [1, 8]. In January 1995, a bare and degraded islet were restored with the help of the Compagnie des Salins du Midi to create one of 1,600 m2. Fifteen square metres of gravel and mussel shells were spread out on nine beaches covering 17 % of the islet's area. By the end of April, 122 pairs

of Avocet had installed, closely followed by 390 Slender-billed gulls, 138 Common terns *Sterna hirundo*, 45 Little terns and 10 Black-headed gulls. Their numbers on the island represented respectively 44 %, 99 %, 33 %, 66 %, and 5 % of the total breeding pairs in the salinas.

The advantage of inactive salinas over active ones is the possibility of managing the water levels for conservation. Actually, the biological richness of salinas disappears quickly in the absence of water management.

It is possible to promote the production of invertebrates, and to facilitate access by birds to this resource. The productivity of lagoons declines when the salinity is over 240 g/l. When this salinity is reached the water circuit could be stopped. In relation to the active salinas, the carrying capacity of birds would be greater [1].

Small waders use only a small part of the benthic fauna available, either because their hunting methods required exposed surfaces, or because their short legs do not allow them to feed in deep water. Experiments on water level management were carried out in the salinas of Berg River (South Africa) during the wintering period [11]. The waders responded rapidly to the lowering of the water level. The density of feeding birds went from 19 to 404 birds per hectare, and from 70 to 500 in December and January respectively. No significant modification in the number of waders was seen in the control pan where water level was maintained.

The water level manipulation may be used also to manage breeding site reducing competition between species by the regulation of access to nesting sites [1].

5. CONCLUSION

Water management for salt production is at the root of the richness of salinas. But the resulting high stability is in contrast to the natural instability of coastal wetlands. It induces limiting factors for breeding birds of high conservation value and a decline in the biodiversity. Specific management measures to reconcile contradictory imperatives are then necessary.

Today salinas are at a turning point in their history. Facing numerous constraints, some of the salinas have become or are becoming inactive. Above all, when they are located along a heavily urbanised coastline, they often become the subject of land speculation, and thus may be filled in and disappear. Conservation efforts, must apply the principles of sustainable development in order to have some chance of success. Collaboration between salt producers, with their socio-economic constraints, and biologists with the environmental constraints, can allow the emergence of an effective conservation policy of the natural and cultural heritage of Mediterranean salinas.

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