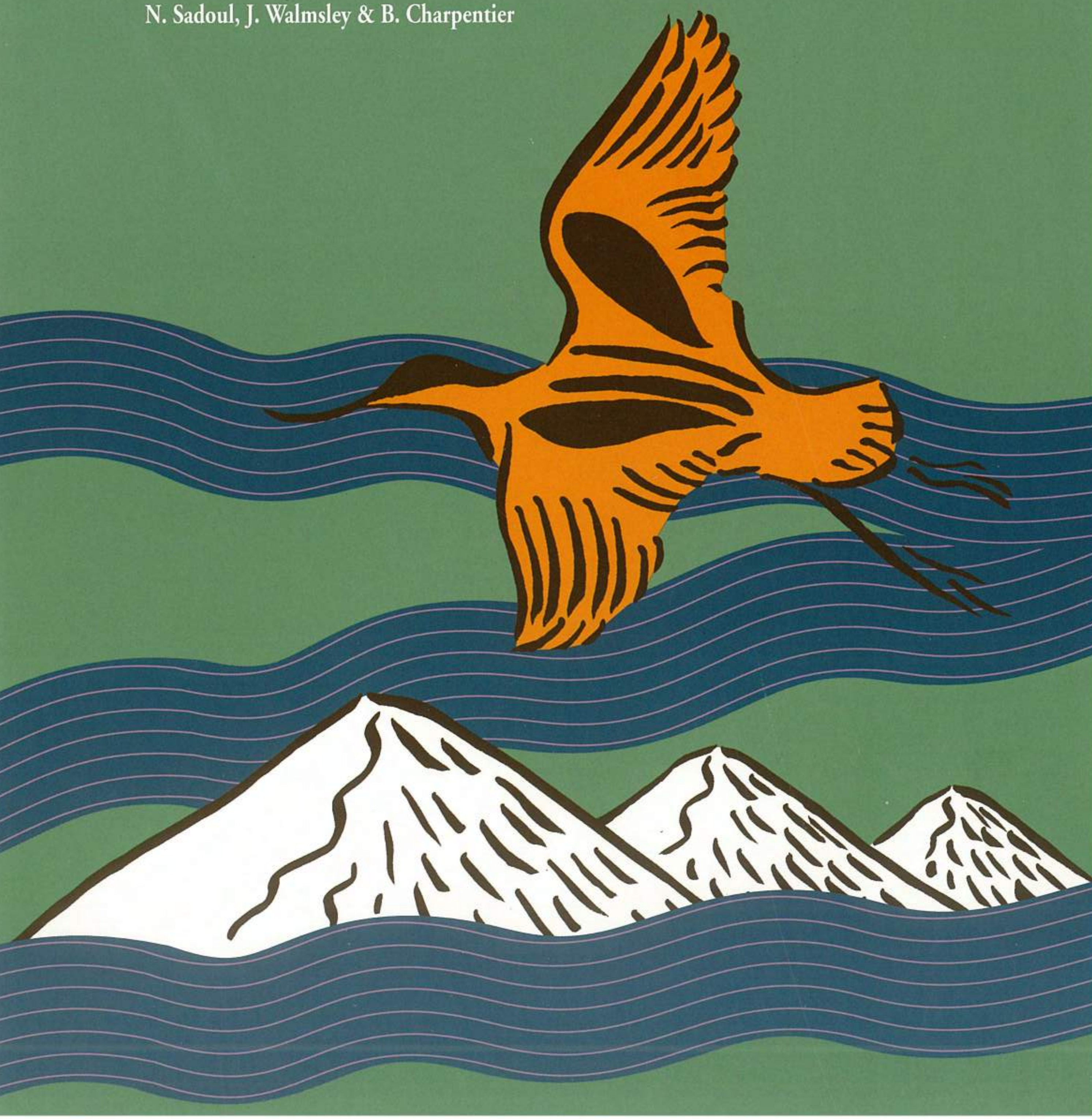
MedWet

Conservation of Mediterranean Wetlands

Salinas and nature conservation

N. Sadoul, J. Walmsley & B. Charpentier



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MedWet

The MedWet initiative

The Mediterranean basin is rich in wetlands of great ecological, social and economic value. Yet these important natural assets have been considerably degraded or destroyed, mainly during the 20th century. MedWet is a concerted long-term collaborative action, launched in Grado, Italy in 1991, to stop and reverse this loss and to ensure the wise use of wetlands throughout the Mediterranean.

The MedWet initiative is guided by the Mediterranean Wetlands Committee (MedCom), under the umbrella of the Ramsar Convention on Wetlands, which brings together 25 governments from the region, the European Commission, the Barcelona and Bern Conventions and international NGOs. It seeks partners and funds for implementing the Mediterranean Wetland Strategy, which includes conservation actions in wetlands of major importance in the region (especially Ramsar sites) and the promotion of national wetland policies, which take account of wetland values during the planning process. MedWet also provides a forum for regional exchange of experience at a technical level and publishes a range of wetland management tools with financial support from the European Union.

The concept of MedWet and its importance for promoting wise use of Mediterranean wetlands has been unanimously endorsed by the Contracting Parties to the Ramsar Convention on Wetlands.

The MedWet publication series

Wetlands are complex ecosystems, which increasingly require to be managed in order to maintain their wide range of functions and values. The central aim of the MedWet publication series is to improve the understanding of Mediterranean wetlands and the policy issues that surround them, and to make sound scientific and technical information available to those involved in their management.

Nicolas Sadoul, John G. Walmsley & Béatrice Charpentier, 1998
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4. Management of nest sites for Colonial Waterbirds
5. Wetlands and Water resources
6. Aquatic emergent Vegetation, Ecology and Management
7. Conservation of Freshwater Fish
8. Vegetation of temporary Marshes, Ecology and Management
9. Salinas and Nature Conservation

Conservation of Mediterranean Wetlands

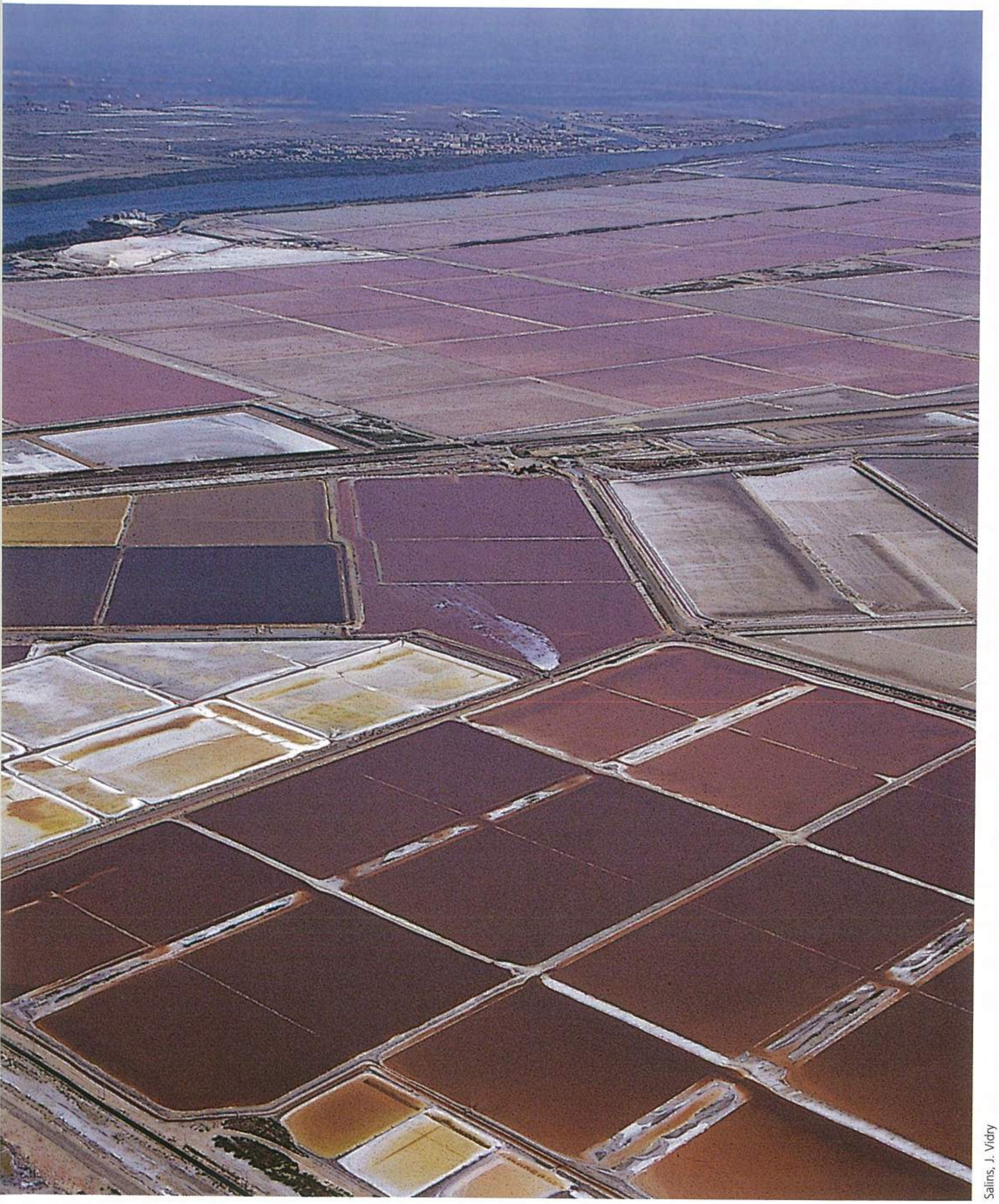
MedWet

Salinas and Nature Conservation

N. Sadoul, J.G. Walmsley and B. Charpentier

Number 9

Series editors : J. Skinner and A. J. Crivelli



Salins, J. Vidry

Preface

At the dawn of the 21st century few activities can claim to have been so intimately associated with people, and for so long, as salt production.

Both the daily requirement for dietary salt, essential for our well being, and the impact of salt production on the environment make it an important component of our bodies and our lifestyle.

The creeping urbanisation of our coasts has slowly colonised the Mediterranean shoreline. A few natural areas continue to resist, and the most remarkable are often those devoted to salt production. From ancient times this activity has naturally reconciled economics and environment and this forms a solid basis for its perennation.

Salt production creates a natural equilibrium from which it also benefits, and this is why salt producers struggle to maintain, as did their ancestors, a natural environment which is both the framework and the tool of their trade. The production of salt is simply a result of their ability to judiciously manage the water and the habitat, and this harmony is the true guarantee of the quality and quantity of the product.

Salt producers are above all active managers, and they protect the environment over the large surface areas covered by salt pans*. Water management is the true heart of their profession and this creates a unique ecosystem which also provides abundant food for waterbirds. In this respect salinity gradients, which are an inevitable consequence of this profession, promote biological diversity.

The Compagnie des Salins is committed to the environment, especially in the Camargue where regular collaboration with scientists, and especially with the Tour du Valat, is an example and a long term guarantee of quality.

This booklet, "Salines and Nature Conservation" bears witness to this constructive partnership. It demonstrates the existence of a common ground between its authors, and the salt producers. How could this be otherwise ? For them, nature is not only second nature but, more profoundly, the heart of their culture.

Gérard DUMONTEIL
Chief Executive
Groupe SALINS

An industrial salina seen from the air – Salin de Giraud, France.

** Refer to glossary, page 88*

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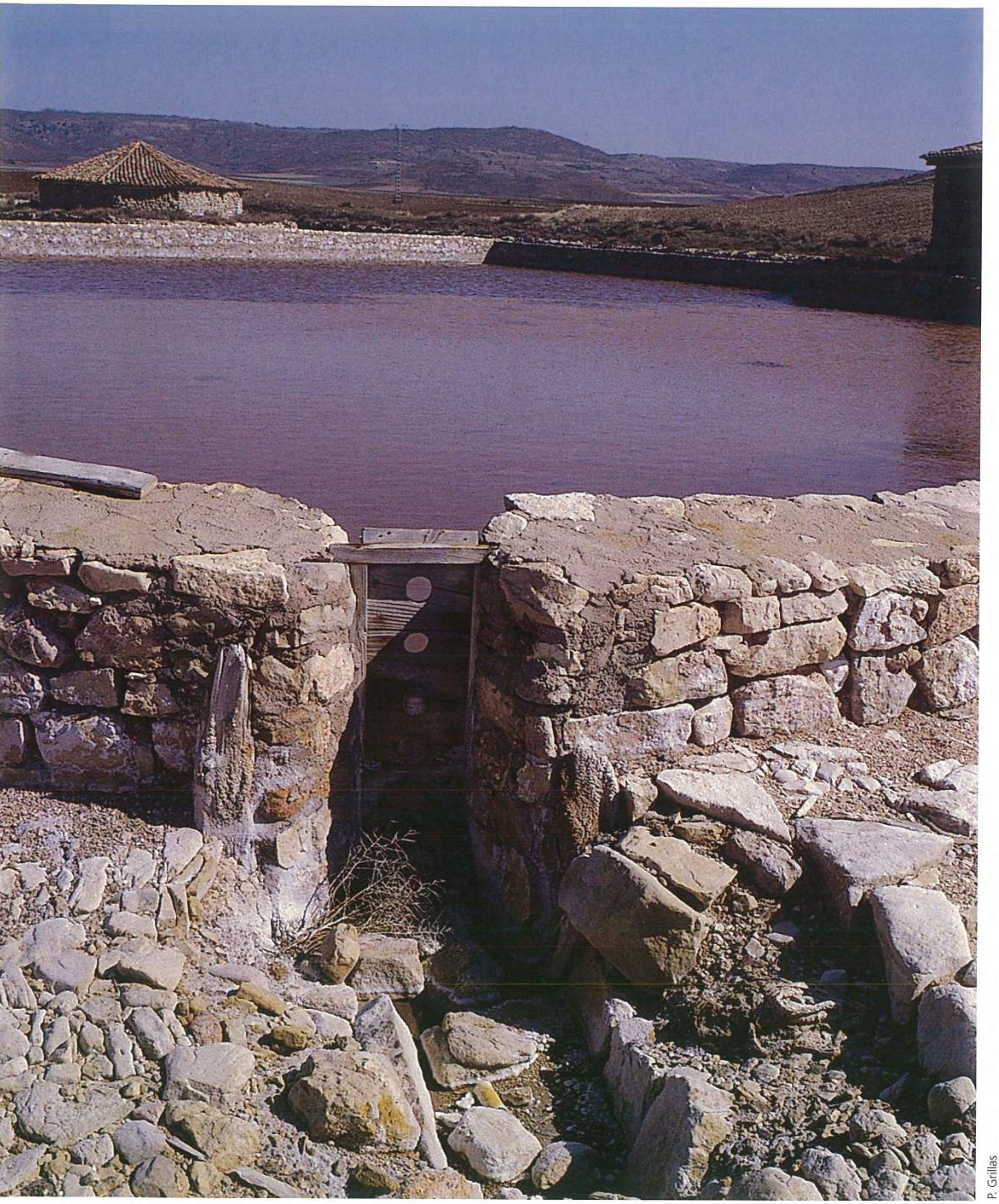


P. Grillas

Introduction

Wetlands are second only to tropical forests in their biological diversity and natural productivity. They are dynamic ecosystems with central roles in hydrological cycles, playing an important role in maintaining biodiversity, including waterbirds.

According to the Ramsar Convention*, wetlands are "areas of marsh, sphagnum* and peat bogs and natural or artificial water, temporary or permanent, where the water is stagnant or flowing, fresh, brackish or saline, including areas of sea water out to a depth of 6 m at low tide".

In the Mediterranean basin, the area they cover is difficult to estimate as it is constantly changing; it includes: coastal lagoons, about 6,500 km^2; lakes and natural marshes, 12,000 km^2; and up to 10,000 km^2 of artificial wetlands. The total area is the equivalent of Sicily or Albania[1].

Located for the most part next to lagoons and coastal dunes in the western Mediterranean, salinas are wetlands which have been marked by the hand of man, for economic reasons. This situation has generated a rather unattractive image, which is often unjustified. This may be why salinas are not well-known to the general public or even the scientific community. In contrast to lagoons, freshwater marshes, etc., there are several terms used for them: salt pans*, salines, salinas, or salt-works.

A salina near Madrid.

1 - See n° 1 in the same series

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. There is a close analogy with agriculture: an activity based on the harvesting of natural resources, which has gradually evolved into a modern efficient industry, to facilitate collection by man.

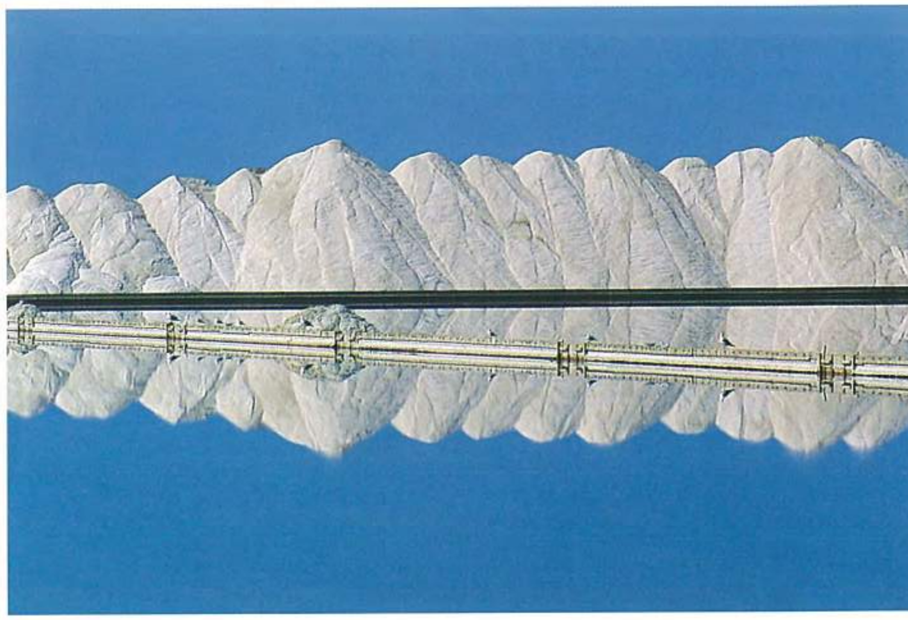
Salt production depends heavily on climate and its variations. With long, hot, dry summers the Mediterranean climate is particularly suitable. Salinas are found all around the world where this climate occurs, and within the Mediterranean basin this activity extends over 1,000 km^2. Today, within this area one can find primitive salinas, where little evaporation depressions have been dug out of the rock, as well as vast modern salinas where high performance technology is used for production.

Salinas, however, are not only sites of economic production. In contrast to preconceived ideas about salinas, they can be important sites for nature conservation. These heavily modified sites have become areas of high biological value supporting up to one hundred species of waterbirds, from 18 different families. Depending on their geographical location, surface area and management methods, they provide a range of habitats along the salinity* gradient for a variety of different species.

Some bird species, such as waders*, use them as feeding areas as mudflats emerge through the action of the wind on shallow basins and lagoons. This is a rare habitat in the Mediterranean because of the insignificant tides; other species find the tranquillity essential for much

Salins

Small wooded islands within the salinas are also of interest for fauna and flora.


E. Vialet

Harvested salt is stored in impressive piles in modern salinas.

needed rest, 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. Thus, they are a safe haven for large numbers of colonial bird species (Flamingo *Phoenicopterus ruber roseus*, Avocet *Recurvirostra avosetta*, Slender-billed gull *Larus genei*, etc.)

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.


Sal.

The History of salt in the Mediterranean

Due to favourable physical conditions, the Mediterranean basin has been a salt producing region since the beginning of humanity.

Salt has played a dominant role throughout history, providing political power to those who controlled its production, as well as influencing the landscape of this region.

Salt sellers from the 14th century. Italian manuscript. Bibliothèque nationale, Paris.

The Mediterranean and salt: an eternal alliance

Existing in considerable quantities and in various forms on the planet, salt is an essential mineral for man. Due to its physical characteristics, the Mediterranean basin is one of the regions where it has always been easy to produce salt.

From different sources

Salt obtained by evaporation represents only 20-30% of the world production.

Salt is found everywhere on earth. Sedimentary rocks contain large quantities of rock*salt. In Europe, in inland salinas of the east of France, the Swiss and Austrian Alps, and Lunebourg heath in Germany, this type of salt is first dissolved in water pumped underground; then, it is crystallised by evaporation from this brine*. In the Sahara, it is cut into blocks underground (Touadéni, Mali), or comes from saline water boiled dry (Niger). Washing out the ashes of plants grown on saline soils (Burundi), or ashes from saline peat (Netherlands, until Charles Quint stopped it), or from sand on beaches (the English Channel coast in Middle Ages, and Japan more recently) have enabled salt to be produced on a regular basis.

The ocean and seas constitute the principal source: if they were evaporated, the world would be covered with a layer of salt 37 metres thick. On first appearances, salt in the sea would seem the easiest source to exploit. Solar evaporation is not, however, without its problems. In Europe, the rainfall and relative lack of sunshine prevents salt production above 48° latitude; in Africa, the often abrupt coastline, and the tropical rains limit production to the shores of the Mediterranean and the desert; in many coastal parts of Asia, high rainfall is a constraint.

Favourable physical conditions

In the salinas of Salin de Giraud, Camargue, France, for example, the production of 1 million tons of salt uses free solar energy which is equivalent to 3 million tons of oil.

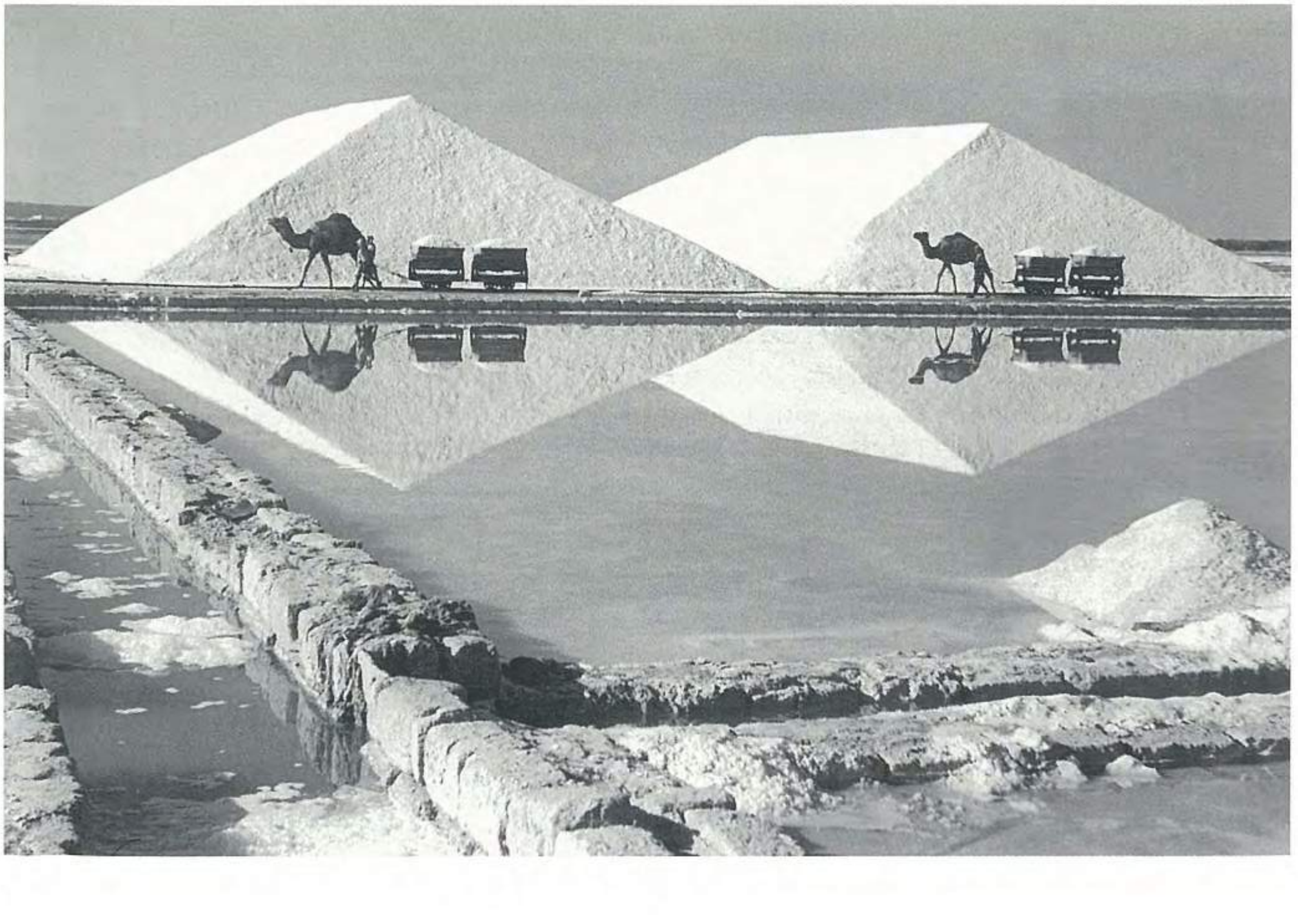
In the Mediterranean basin, low rainfall, high insolation (always more than 2,300 hours of sun) and a lot of wind together mean that evaporation is high during summer, which is an essential condition for salt production. Evaporation is equal to 2,900 km^3/year over the whole of the Mediterranean, equivalent to a layer of water about a metre deep. However, the period of production varies from one side of the Mediterranean to the other. To the north, it is limited to spring and summer, whereas in the south it occurs all through the year.

There are other parameters which also favour large harvests. For instance, the salinity of the Mediterranean is high, varying from 36 ‰ in the west to 39 ‰ in the east. The coastal relief is often suitable for the installation of salinas; 40 % of 46,000 km of the Mediterranean coastline is low-lying. Also, there are depressions close to the coast which are fed by saltwater intrusions.

Sites of local production

Salinas have been abundant in the Mediterranean for thousands of years. Apart from continental salinas of the semi-arid parts of the Iberian peninsula and salt lakes of the semi-desert areas, most of the salt, and the best quality, is produced from sea water in open salinas. Management and production is based on an equilibrium between surface area and evaporation of sea water which is pumped through lagoons, travelling over long distances through canal systems. Salinas have been developed on low-lying coasts, in particular where there are wetlands. The salt producer, following the example of the farmer, then has to decide on the right moment for the harvest, which will be more or less abundant depending on the conditions.

In the past, dromadaries were used to pull the salt wagons. Tunisia.



Salins, Cotusal

The organisation of salt production: from the Neolithic period to the Middle Ages

Production techniques and the salt routes developed very early on. Everything was organised for salt to provide an important revenue and to be an effective political instrument.

Salt in Antiquity

In the Mediterranean, the oldest salinas (5,000 B.C.) are Eygptian. From 2,000 B.C., the Hittites, the Hebrews and the Phoenicians developed salinas. The principle means of production were perfected, in particular the use of animal traction or wind power to move the wheels of the machines which raised, in the absence of tides, the sea water from the evaporation pans to the salt tables. The Phoenicians soon exported these methods to the western Mediterranean.

During the Roman Empire, in addition to the production of the Ostie salinas, Rome imported salt from the whole of the Mediterranean basin. A network of *viae salariae** was set up between Rome and Sicily, Spain, Cappadocia, the Crimea and Egypt. The fall of the Roman Empire coincided with the great invasions; so the production and trade in salt collapsed.

The salt barons

From 11th to 14th century, an increase in the salting of fish (herrings from the Baltic and the North Sea), linked to the increase of the European population and expansion of religious practice, encouraged the towns and states which owned salinas to expand their production. These booming salinas, can be divided into three groups: Venice, the coast of Languedoc and Provence in France, and the islands.

Until the 17th century religious practice increased the number of days of partial fasting to 166 days per year, increasing the demand for salted fish dramatically.

The salt trade added to the fortunes of Venice. It was based on the monopoly of the market in northern Italy and the Alps, and also on the take-over of the nearby salinas (Comacchio, Ravenna, and Cervia) which it neglected in favour of the large salinas from which it bought the majority of the salt. So it was able to import salt at a low price from Cyprus, Crete, Alexandria and Ibiza.

Along the south coast of France, until the 10th century, the salinas belonged to the powerful monasteries such as Saint-Victor; Marseilles owned the Hyères salinas, Maguelone exported its production from its own port. Then, the Princes, the "salt kings" *(domini salis)*, took over

Salins, R. Sprang

Tools for salt production, 18th century.

the salt at the expense of the Church. Owning the Hyères salinas and providing salt to the Alps as far as Lake Geneva, the Count of Provence, Charles d'Anjou, instituted the salt monopoly and the salt tax in 1259. But the King of France provided severe competition, in addition to the salinas of Narbonne, Béziers, Agde and Maguelone, he also owned important ones in Peccais. Political pressure, higher prices, inferior quality and the Black Plague (1348) all contributed to the decline of the salinas of Provence, which continued after the unification of Provence to the kingdom of France in 1481.

The Mediterranean islands also produce salt from Crete to the Balearics. The success of Sardinian salt, based on its exportation to the monastery of Saint-Victor, and then to Pisa, and to the administration of the salinas Regals de Cagliari by Aragon, collapsed after the island was ransacked. By the 15th century, production began to decline in the other islands – only Ibiza continues to play an important role.

Salt: object and instrument of politics

Since Antiquity, salt has been used in food, particularly for the production of *garum** and *allex**, and for the conservation of food (meat, fish, cheese), in animal food, curing skins, dying (for purple), ceramics, (whitening of clay), in perfume making, and medicines.

These multiple uses explain how the control of the supply of salt, throughout history provided effective political leverage.

This power was based partly on monopoly: this was held initially by Egypt and Rome, then by Venice and Genoa in the 11th century, and by the counties of Nice and Provence, and the kingdoms of Aragon (Ibiza), Naples and France (salinas of Peccais, near Aigues-Mortes) from the 12th century. Diplomacy reinforced the monopoly when salt was a political issue and an instrument for other objectives, either economic or military.

In the 19th century, the technical and administrative improvements in production have removed this element of political power from salt since it is now widely traded from many different sources.

The rise and fall of the power of salt

From the Renaissance to the industrial revolution, salt has been coveted by traders and by those in power in the Mediterranean and in Europe. Salt experienced a golden age which was lost by the modernisation of production methods and the development of world trade.

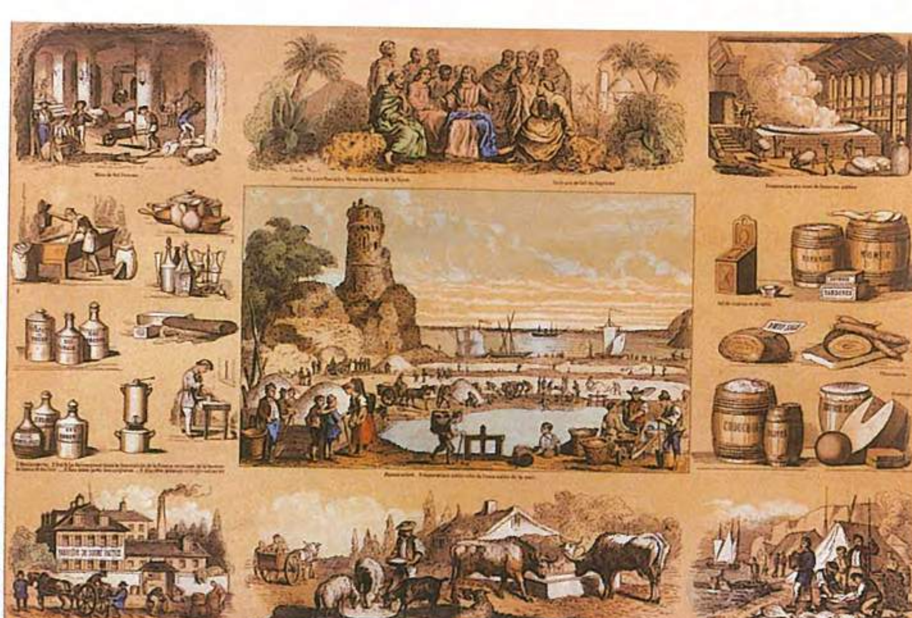
The advent of the traders

The traditional uses for salt are the same today. It is still essential in food for people, providing oligo-elements (iodide and fluoride) and preserving food. In farming, salt blocks provide oligo-elements as well as salt for animals, and in silage it controls the fermentation.

During the Renaissance, the international market in salt developed, dominated by a class of traders. It was linked to the development of towns and the demand from the fisheries of Newfoundland. The conjunction of the geography of salt production and the new political frontiers created four zones: the Mediterranean and its salinas, the Atlantic and "salt from the bay" of Bourgneuf produced by the English, the Baltic with salt from Lunebourg soon to be replaced by salt from the Atlantic which was cheaper, and Central Europe with rock salt from the Jura, France to Poland. There was competition between these zones as well as within them: the clash between the Venetian and the Genoan traders, eternal rivals, is one example.

Active and contrasted markets

The salt producers were spread over many states, small and large. In Genoa, the monopoly was held by Casa di San Giorgio, the most powerful financial institution in the West at the end of the Middle Ages. It imported salt through the ports of Savone, Finale and Albenga and sold it to the people of Milan. In Venice, the trade was carried out



Salins, R. Sprang

The different uses of salt illustrated in the 19th century.

through the "Salt office", which alone was authorised to sell the salt produced or imported; it made considerable profits.

The large states had to assure the availability of salt for internal consumption and for exportation; thus, the salt trade was a prerogative of power. In the south of France the salt had to transit through the king's store-houses, this was how he levied the salt tax. The taxes were so high that fraudulous actions began to take place to the extent that between 1423 and 1441, the revenue from the tax on the Rhone salt declined by half. When this was discovered, the King of France and the Count of Provence entrusted the "tirage" of Rhone salt to farmers. These people speculated and the salt tax became a way of getting rich

By sea or land: the salt routes

From the 10th century, in Europe and in the Mediterranean basin, salt routes, by sea and by land, began to develop.

Maritime transport used vessels in convoy, "salt fleets", to stand up to pirates. Venice, for example, supplied itself from Cyprus, Alexandria, Libya, Djerba, and Ibiza. This island, "the salt cellar of Europe", became the biggest producer of salt in the Mediterranean until 17th century, exporting as far as the Baltic. From the 15th century, cod fishing off the coast of Newfoundland increased; the vogue for stockfish* caught on in Italy, Spain, Portugal and the south of France where the cod fishermen exchanged their fish for local salt. In the 19th century, the new American states obtained their salt from Portugal and Tunisia.

By land, the salt went from tollhouse to tollhouse, at the speed of teams of mules and horses: at least 15 days between Aigues-Mortes and Tournon. The trip was expensive (in 1547, the cost of transport from Peccais salinas to Valence represented 48 % of the price of salt). Navigable rivers were also used: the Po for the salt from Comacchio, Italy, the Rhone for salt from Peccais and Provence, France. In 19th century the building of the railway and canals facilitated the transport of salt, and political unification (Italy, Germany) reduced the number of custom posts.

In North Africa, the salt produced was used locally, and exported to Europe. Caravans of thousands of camels took a variety of goods from the Mediterranean to the Saharan oases, providing fresh supplies for the interior of the continent. There, they were exchanged for salt from Mali and Niger. Further south, on the gulf of Guinea, the salt was were bartered for gold, ivory, slaves, etc., which were brought to the Mediterranean and then on to the Near East and Europe.

Today, world trade has completely changed the old routes: salt from Tunisia is used for keeping Norwegian roads from icing-up and that from the Camargue is used in water purification in American households.

quick to which the powerful people of the kingdom (Dukes of Condé, Richelieu, etc.) resorted to under false names. The salt trade not only made one's fortune; it served as a lever in markets for other goods (precious metals, spices, etc.). In the 15th century, in Switzerland and Savoie (France), the State took the place of the traders when the supply became irregular due to political vagaries and profit-seeking.

Today's salt: economy rules

From the 17th century, new production methods where introduced to put an end to the shortages, which frequently hit northern Europe. This destroyed the political power of salt. In 19th century, the steam engines for pumping sea water to the salt pans, improvements to the water circulation system within salinas and better use of the weather, led to the production of high quality salt in the Mediterranean and an increase in the surface area of salinas, with entire new salinas being established in Greece.

With industrialisation in the 19th century other uses for salt could be added to the multiple traditional ones, such as: preventing icing of the roads, industrial uses (cosmetics, dyeing, curing of animal skins, ceramics, etc.). In the chemical industry, electrolysis of salt solutions produced chlorine and soda. The former is used for the making of solvents, plastics, insecticides and bleach. The latter contributes to the making of sodium carbonate (for glass), extracting cellulose from wood, saponification and refining of aluminium.

The history of salinas in the south of France illustrates modernisation linked to the industrial revolution. To improve productivity, the salinas in Peccais were regrouped into one vast production unit, and the salinas of Giraud, the biggest in Europe (nearly 12,000 ha) were created. This all started at the end of 18th century when Nicolas Leblanc developed a production process for soda, using salt. In 1855, the Henri Merle chemical products company set up a soda production plant in the Gard. For this he required the raw material, salt.

Coastal lagoons were bought in the delta of the Rhone, a railway link between them was set up, a connection from there to Arles was established, and the industrial town of Salin de Giraud was built. Dynamic and efficient managers, merges of industrial groups, diversification of the demand, use of high technology (harvesting methods, computer-control of water movements), together with monitoring of water levels, density of the brine, and the weather: all these factors together increased salt production.

Established on low-lying coasts around the Mediterranean, the salinas produced salt of quality, which became the basis for an important trade which used the traditional land and sea trading routes. Jealously guarded for centuries because of its political role leverage, salt lost, with the arrival of modern technology, its strategic place in the world market. This change has had an impact on the Mediterranean landscape, of which the salinas are a component.

In the 1930's , salt was loaded by wheelbarrow. France.

"Faux saunier"*: fall out of high salt taxes

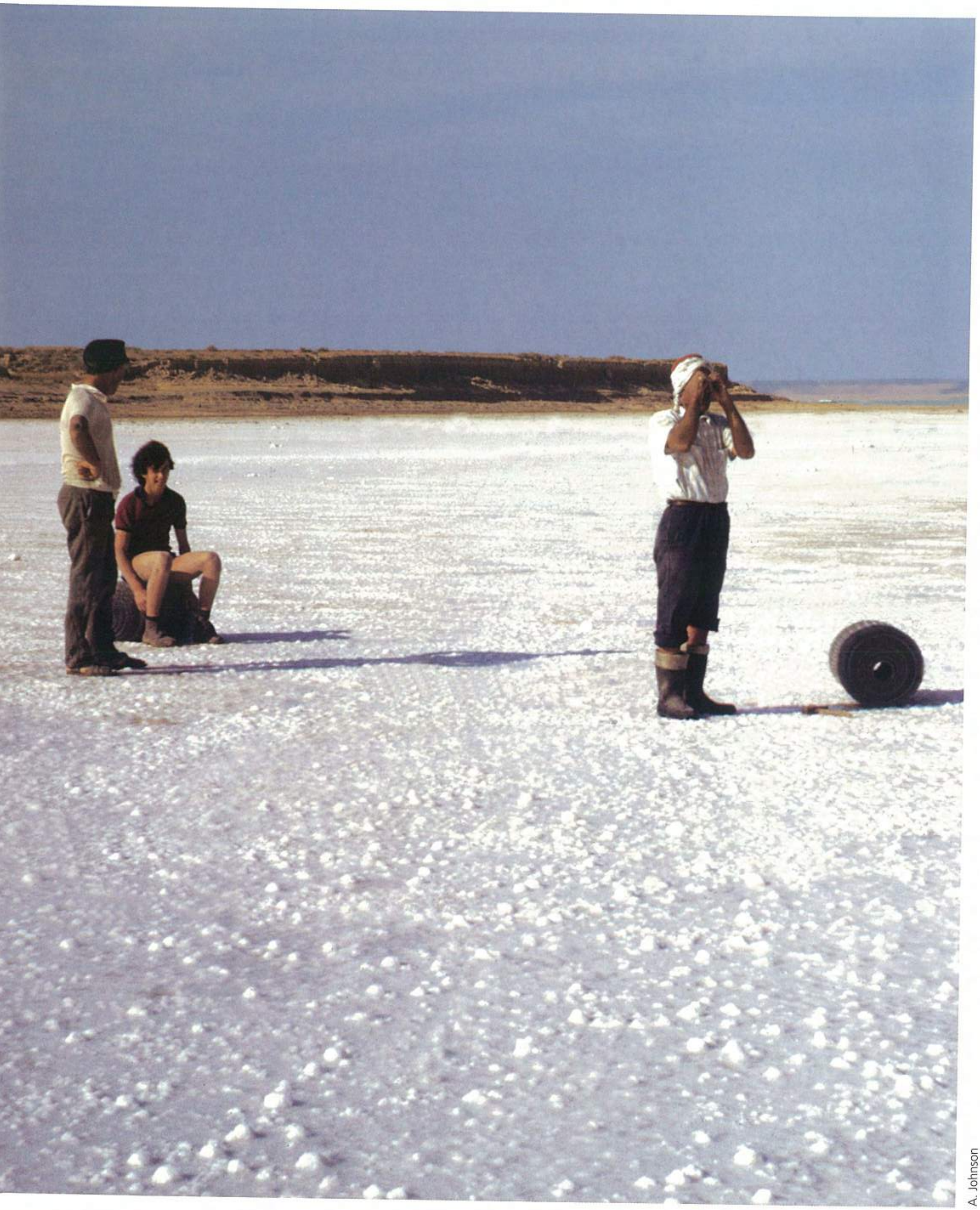
So high were the direct costs of salt production that prices became exorbitant. The salt producer, bonded by contract to an owner, hardly received more than a quarter of the revenue from his salina. He had to pay various costs, the best known (and the most detested) was the salt tax, inherited from the Arab administration of the Norman kingdom in Sicily.

At the end of Louis XIV's reign, the salt tax represented nearly 25 % of the State's revenues, generating social injustices towards the peasants and the urban poor who needed salt. These lead to the butchers' revolt of 1413.

The price of salt varied by a factor of twenty between provinces where salt taxes were heavy, and provinces where taxes were lower due to a more abundant supply. Salt producers and tax collectors became the target of people's anger, and smuggling became commonplace, sometimes with the complicity of the authorities.

For example, the agreements that obliged the Peccais salinas to deliver the necessary quantity of salt to the people of Savoie, as estimated by the Duke of Savoie's administration, were manipulated so that more salt was delivered than was needed. Since the salt tax in Savoie was lower than that of France, the surplus was re-exported to France by the "faux sauniers".

In Provence and Languedoc, this illicit behaviour was so frequent that, Henri IV had salinas he could not control flooded by an edict in 1596. In France, the Revolution ended this situation by halving the price of salt and abolishing the salt tax (it reappeared under the Directoire, which governed between 1795-99, and was only finally abolished in 1945). Venice ruined the smuggling by levelling the prices.



A. Johnson

Mediterranean salinas today

When chotts* and sebkhas* dry out in the summer they leave a thick layer of salt. Sebkha Sidi el Hani, Tunisia.

Throughout history, the Mediterranean coast has changed under the influence of people who developed numerous activities.

A large number of coastal lagoons were transformed into salinas, but the traditional form of salt production has greatly changed today.

Functioning salinas

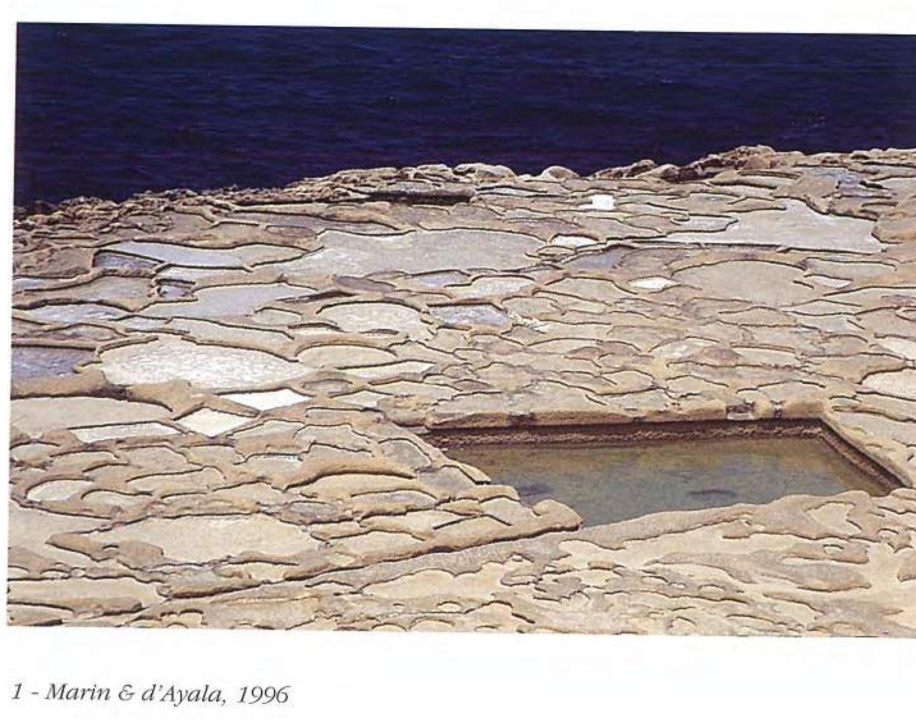
In addition to the primitive salinas which are now sometimes considered a part of the cultural heritage, the productive salinas of the Mediterranean are very diverse. However, the general modernisation of these salinas has removed the distinctive characteristics creating a standard salina landscape.

The terminology used is based on the method of production

Mediterranean coastal salinas can be characterised by the following criteria[1]:

- location (lagoon, delta, islands, etc.);
- physical characteristics and construction (primitive salinas, Phoenician type, Roman, etc.);
- water management (circulation by gravity, windmill, paddle wheel, diesel motors, electric pumps);
- harvesting methods (by hand, partial or complete mechanisation).

The salinas of the Mediterranean basin are highly diverse. To clarify this, we have used simple terminology based on the type of production, which has the advantage of taking into account all the Mediterranean salinas in production when this document went to press. There are four main types: primitive, rudimentary, traditional, and modern.



J. Walmsley

Depressions cut in the rocks collect spray and wash from winter storms. Gozo, Malta.

1 - Marin & d'Ayala, 1996

Primitive salinas

Several centuries before the Roman Empire, the primitive salinas were situated on the rocky coasts of islands exposed to the winds. They are made up of a mosaic of bowls cut out by hand in the rock, about 50-75 cm deep. They functioned best when the waves broke on the cliffs, and the spray fell into the little basins. When the weather was calm, crystals of salt formed naturally by evaporation and were collected by hand. The primitive salinas of Xweini, Gozo island, Malta are some of the few that are still in use. In response to interest in the site, particularly expressed by tourists, the Minister of the Environment has recognised their national heritage value and has agreed to conserve them for future generations.

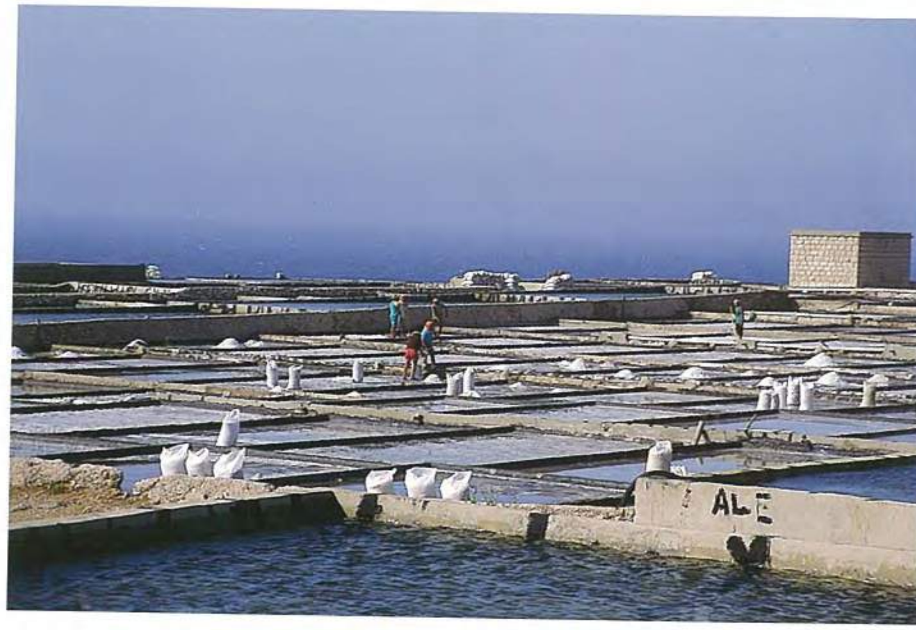
Rudimentary salinas

Rudimentary salinas are typical of North Africa and the Near East. Those found in the large lagoons close to the road Port-Saïd-Damiette in the Nile delta, are separated from the sea by a sandy bar. They mostly consist of a pan of less than 1 ha in surface area, and are about 1 m deep, the water levels being maintained even during the salt harvest.

When the saturation point is reached, the salt crystals precipitate and are gathered by hand. The salt, harvested all year round due to the high and relatively constant temperatures, is sold locally.

H. Schekkermann

Rudimentary salinas near Port Saïd, Egypt.



Traditional salinas near Efni, Lebanon.

X. Montbailliu

Traditional salinas

Found on low-lying coasts, particularly in wetlands, traditional salinas are made up of developed pans, linked by canals and dykes. Their extent, size, differences in altitude, and the means of circulating water depend on the number of people who work there. In some, windmills lift the water into the upper pans; today these have been replaced by electrical pumps or motorised paddle-wheels.

These salinas work in the same way as the modern salinas. When the right water-level is reached, the water is evaporated until saturation point is reached. Throughout evaporation, the crystallised salt is scraped off and turned over each day.

Continental salinas in Spain

In the interior of the Iberian peninsula, where the annual rainfall is less than 400 mm, small salinas have produced salt for centuries. This is produced by pumping salt water from marine sediments deposited during the last marine transgression during the Pleistocene*. In the *norias**, the donkeys and goats walk round in circles lifting the salt water to the surface. It is put into *calentadores** for evaporation. When saturation is reached the water is sent into the *cristalizadores**. Until recently, the salt was used for the salting of pork and fish; today it is used for roads. Few in number, the survival of these salinas are threatened, unless they are conserved for their heritage interest.

Extracted from the pans by rakes or spades, the salt is transported in wheel-barrows to the stocking point where it is covered by a roof of tiles (southern Italy) to prevent the rain from dissolving the piles of salt. In the last half century, a few of the biggest of these salinas have been modernised; pumps, machines and a small-gauge railway network have been installed, for example the salinas of Tourlida (south of Messolonghi in Greece).

Modern salinas

Most modern salinas are simply traditional salinas transformed over the past thirty years. The pans have been made bigger, dykes constructed and water management modified.

In spring, sea water is pumped into the pans with the largest evaporating surface area, which are dry in winter. Then, the water is circulated by pumps and sluice gates over tens, if not hundreds of kilometres until it reaches saturation point. It may take up to two years to reach the harvesting tables*.

Evaporation results in a progressive increase in the total salinity, from 32 g-150 g/l in lagoons with low salinity, to 150-200 g/l for medium salinity, and to 200-300 g/l for the pans with the highest salinity. The water is transferred to the harvesting tables when the salinity is higher than 300 g/l; sodium chloride precipitates and is deposited on the bottom.

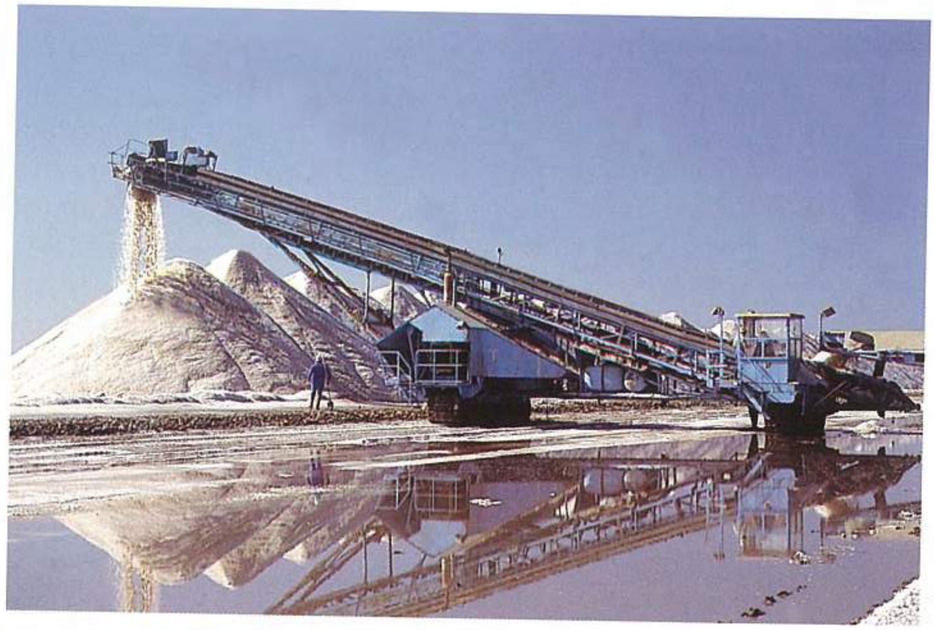
In the north of the Mediterranean, excess freshwater from strong rains is evacuated by canals to avoid the dilution of the brine. During the period of salt production, the weather forecasts are followed closely, particularly in August to set the date to stop pumping sea water.

Salt in semi-desert areas

The salt lakes, or chotts* and sebkhas*, in the semi-desert areas of North Africa and Turkey, are not technically salinas but can extend over thousands of hectares and produce salt, sometimes in large quantities. In winter, they are covered by shallow water. At the hottest point in the summer, when the temperatures are close to 40-50°C, they are huge areas of crystallised salt.

With a surface area of 800,000 ha, Djherid Chott in Tunisia is the largest temporary salt lake in North Africa. In Anatolia (Turkey), Tuz Golu Lake, which covers 164,200 ha, is a Ramsar site; partly dry in summer due to the strong evaporation, it provides a layer of salt about 30 cm thick. The salinas of this lake (Kaldirim, Kayacik, Yausan) produce c. 55 % of the national production[1].

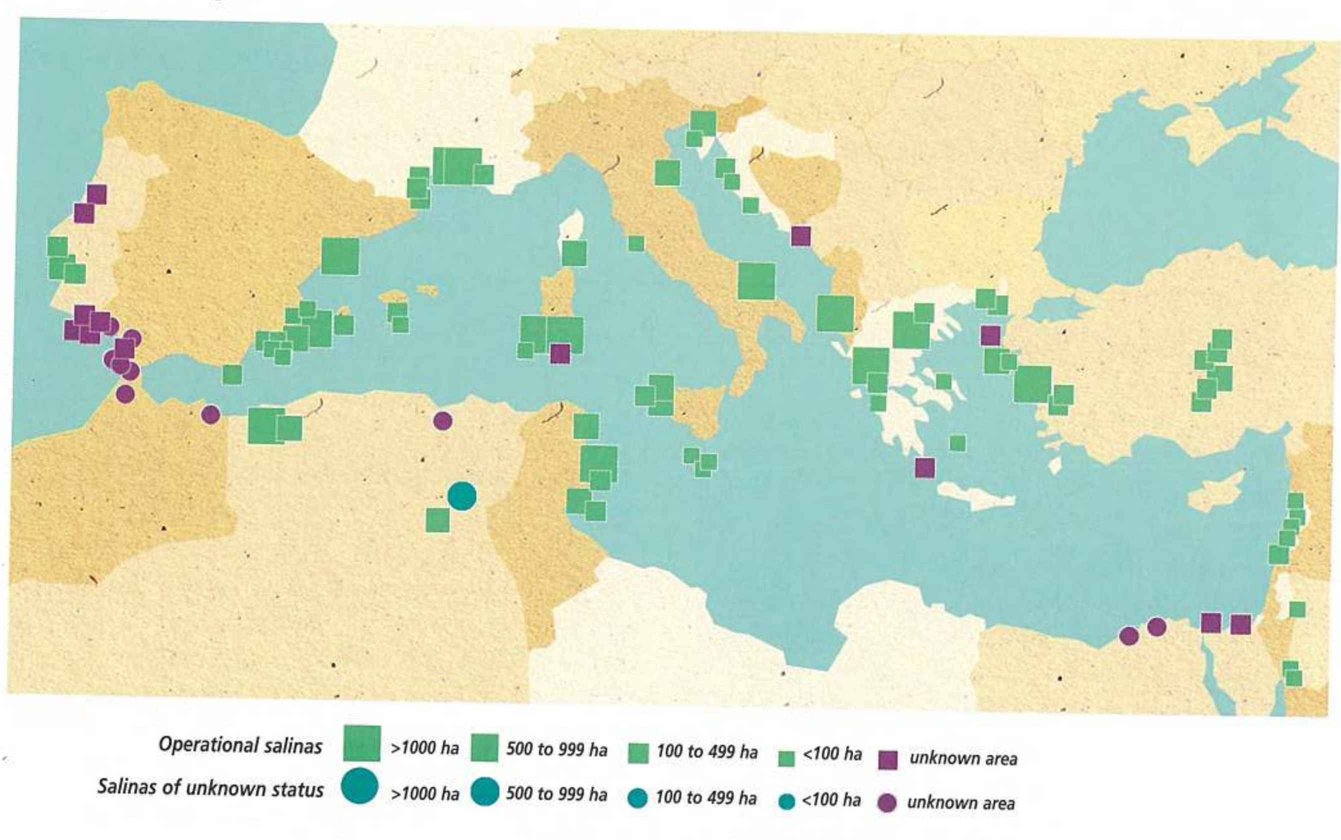
1 - Magnin & Yarar, 1997



Salin de Giraud, France.

The salt water which has not reached saturation is put into the deepest salt pans; in spring, it is returned to the system of evaporating pans to finish its cycle. Water of high salinity, stocked in winter reservoirs, is distributed over the harvesting tables starting at the beginning of the new production year.

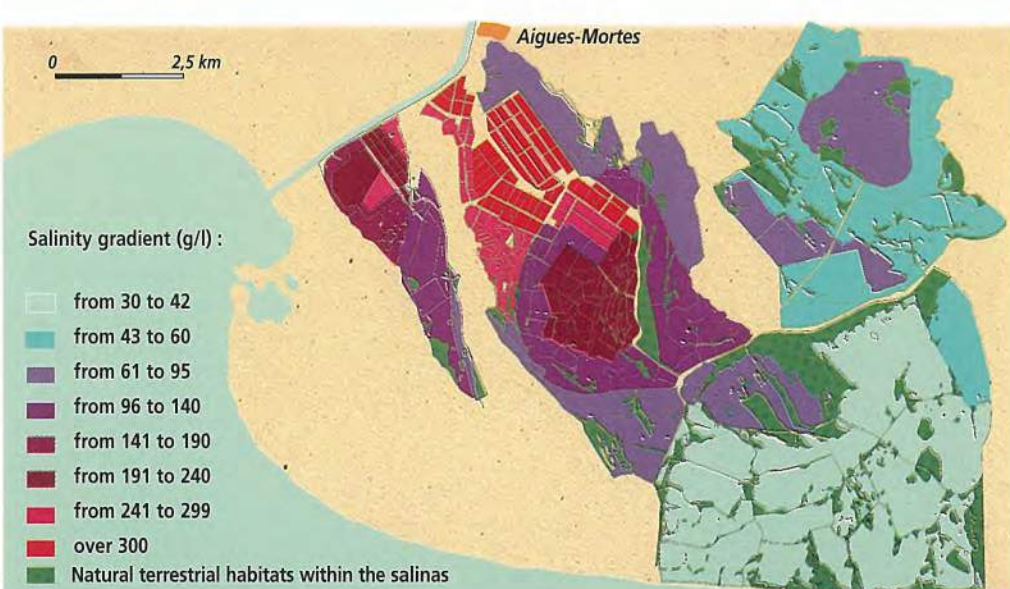
Salinas are distributed throughout the Mediterranean region.



Modern salinas of the Camargue

In the heart of the Camargue (France), a vast deltaic area created by the sediments from the River Rhone, are found the two biggest salinas in Europe. In the east, the salinas of Giraud are 12,000 ha of dykes, canals and salt pans, the smallest of which extend over 1-2 ha and the biggest are 1,000 ha. Created in the second half of the 19th century, to provide salt for the chemical industry, (particularly the production of soap in Marseilles), this salina quadrupled its size from 1953 by the dyking of coastal marshes and lagoons. In the west, the salinas of Aigues-Mortes have been worked since ancient times. Production increased progressively: seventeen small traditional salinas existed in the 17th century, then in the 19th century (1856), they amalgamated before the transformation in the demand for salt due to the arrival of the industrial era. These salinas today form a modern salina of almost 11,000 ha. These two salinas provide a series of landscapes, from the natural lagoons through to transformed man-made salt pans, levelled and dyked in, to those of high salinity. The differences between the two salinas are linked to the geomorphological history of the delta.

In the first salina situated in the old beds of the river Rhone, soils are dominated by silt and clay, only the coastal fringe has sand dunes. In the second, further from the Rhone, the sandy-silt has lead to the development of dunes, covered in umbrella pines, surrounding the lagoons. In addition to effective control of sea water, the circulation and density of brine, the successful functioning of the salina depends on weather conditions. Unfavourable in winter, these allow for only one harvest at the end of the summer. Sea defences are required to prevent the intrusion of sea water of a lower salinity. The coastal dykes reinforced by rocks have been built, and more recently, groynes have been installed to try and fix the sand and stabilise the line of dunes.



Map of Aigues-Mortes showing the increasing salinity gradient as water moves towards the harvesting tables.

Inactive salinas and transformed salinas

Inactive salinas are those which have not produced salt for at least forty years. There are two types of salinas, which can be distinguished by the state of the conservation of their infrastructure. Some of these salinas have been transformed so much that it is difficult to find any trace of them in the landscape.

Inactive salinas

The first salinas to be abandoned were the rudimentary and traditional ones; more recently, a few small modern salinas have also stopped production.

The economics of salt markets have led to the closure of a certain number of small salinas in the north of the Mediterranean. Depending on the market, the maintenance work on the dykes, the levelling of the pans, the cost of pumping and the mechanisation of the harvest has meant that they are no longer competitive with salt other than sea salt. Some salinas, inactive for 40 years, have buildings and a hydraulic system which have fallen largely into ruin. Others are used intermittently, for example the salinas of Hyères were not used between 1967 and 1982, they were then started up again until 1995. In contrast to the first salinas mentioned, these ones had preserved their infrastructure intact so it was easy to put it back into action. During the period of inactivity there is no water in the system. Rainfall does, however, flood the pans, but then evaporates.

Transformed salinas

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. As a result, some salinas have been transformed to provide space for other activities. These changes can lead to complete destruction of the site, or to the survival of only a few visible remains (dykes, posts, etc.). Transformation of the salinas for aquaculture is less destructive in terms of the landscape, and has increased rapidly over the past twenty years. The prices of purchase and maintenance are low and are covered by the sale of fish and subsidies from the European Union. Traditional aquaculture uses only part of the salina, so the appearance of the site is conserved, which is not the case with intensive aquaculture.

Mediterranean salinas

Although salt production occurs throughout the Mediterranean basin, it is on the northern edge that, paradoxically, the main production is found, together with the largest number of inactive salinas.

This data comes from a survey of information carried out by the authors, from the people mentioned in the acknowledgements. For several countries (Turkey, Italy, Portugal) the data from a number of salinas was summarised into one production area. Lebanon also has several small coastal salinas. Data for Syria and Libya are not available, so there may be more salinas than indicated here.

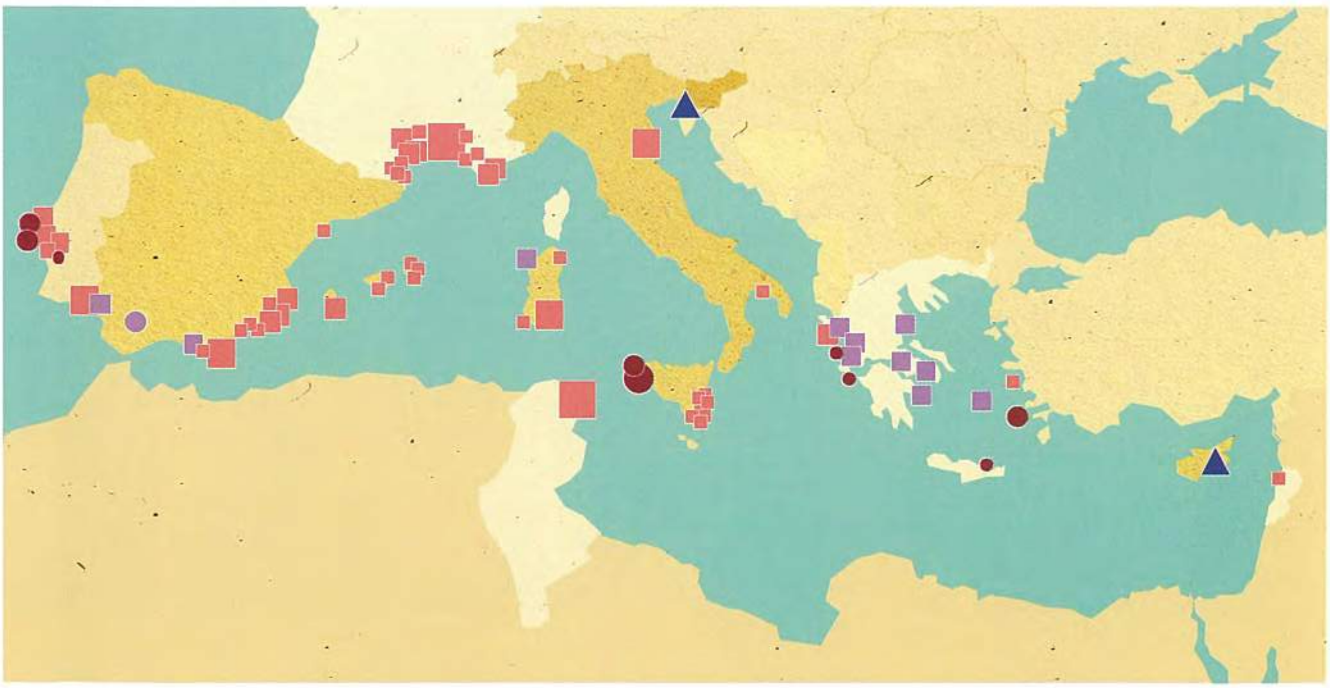
The geographical distribution of salinas

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.

The main salt production

Of 168 known sites of salinas in 18 Mediterranean countries, there is information available for 165 – 90 productive, 64 inactive, 11 transformed. The main salinas are found in the centre and north of the Mediterranean region.

Many small salinas have been taken out of production or transformed for aquaculture.



Inactive salinas — *>1000 ha* — *500 to 999 ha* — *100 to 499 ha* — *<100 ha* — *Unknown area*

Salinas converted to aquaculture — *>1000 ha* — *500 to 999 ha* — *100 to 499 ha* — *<100 ha* — *Unknown area* — *Nature reserve in salinas*

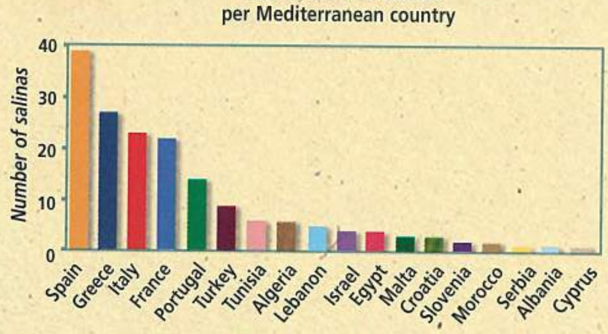
Of the 90 active salinas, 75 % are located in the countries in the centre and north of the Mediterranean. Spain, Greece, Italy, France and Portugal hold 77 % of the salinas in the Mediterranean; followed by Turkey, Algeria and Tunisia.

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

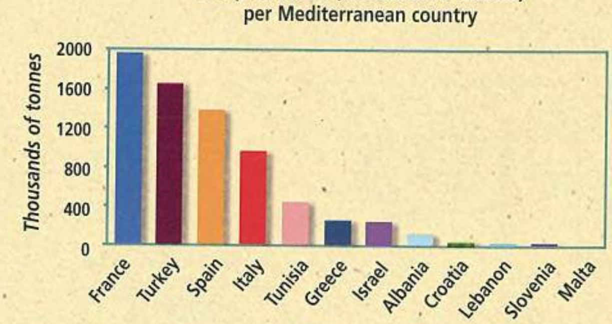
The annual production of salt in the Mediterranean is about 7 million tons. France is the highest producer with about 1.5 million tons, followed by Turkey, Spain and Italy. These four countries produce 84 % of Mediterranean salt. Production is, thus, concentrated in a small number countries (and salinas): for example Greece, which has more salinas than France, has a smaller surface area and a lower production of salt.

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

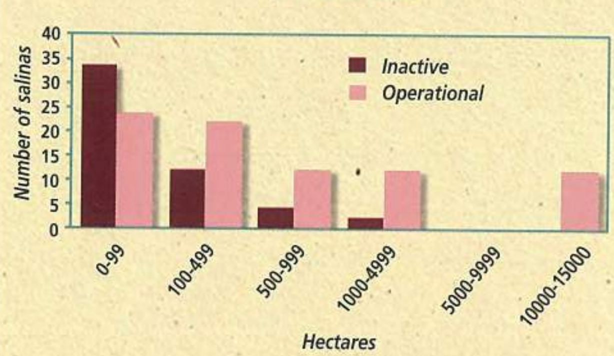
Total number of salinas per Mediterranean country



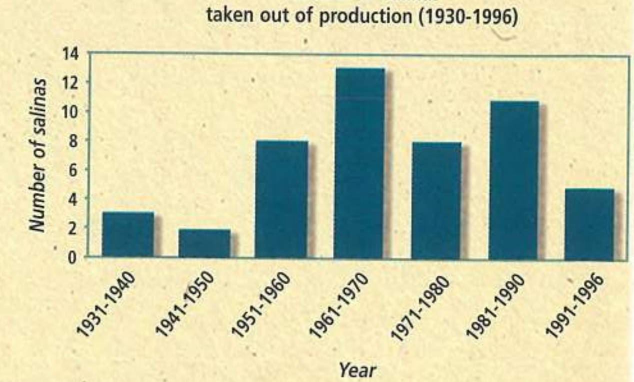
Salt production (thousands of tonnes) per Mediterranean country



The number of salinas of different areas



Number of salinas taken out of production (1930-1996)

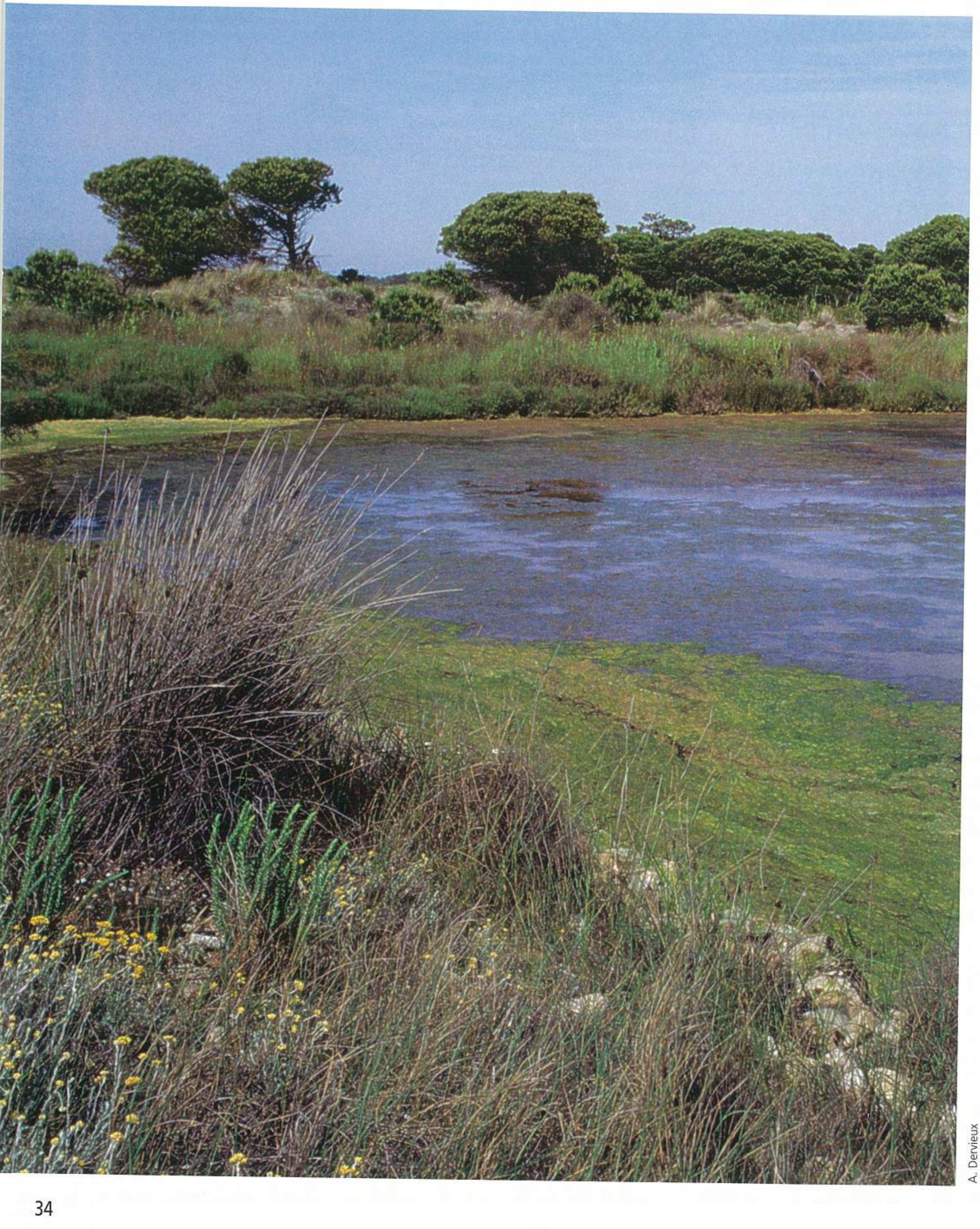


The abandoned salinas at Cruzhina, Portugal, are excellent breeding and feeding habitats for water birds.

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.

Of the 64 which became inactive, 83 % covered a surface area of only 9,230 ha. It was particularly in Portugal, Sicily and Greece that salinas were transformed into fish farms: 6 of 8 recent fish farms have a surface area of 457 ha. A few salinas have acquired nature reserve status: one in Cyprus, for example covers 450 ha.

Mediterranean salinas are very diverse. Productive salinas, essentially traditional and modern salinas, are concentrated on the northern coast. As for the abandoned salinas, new vocations await them, in particular the possibility of being transformed into nature reserves due to their biological richness.



A. Dervieux

Biological richness of salinas

Salinas are biologically rich despite being artificial habitats. This is partly because they are wetlands, but also because human interventions ensure the circulation of water. In addition, they are relatively undisturbed habitats.

Situated in the coastal zone, between land and sea, they are shallow, stable wetland habitats, despite the unpredictable Mediterranean climate which often varies greatly from year to year.

Salinas may also hold important terrestrial habitats. Aigues-Mortes, France.

The cause of the biological richness of salinas

Salinas are relatively simple habitats made up of shallow lagoons and pans. They provide a gradient of salinity and a degree of artificialisation: they are separated from one another, yet remain interconnected and function in a similar way.

The principal ecological factors

The animal and plant species in salinas vary geographically. The Shelduck *Tadorna tadorna* of the western Mediterranean is replaced in Greece by Ruddy shelduck *Tadorna ferruginea.* The diversification of habitats in salinas, and the richness of their plant and animal communities, are strongly linked to the size of the salina. This also influences three principal ecological factors: isolation (due to the compartmentalisation within the salina), the water regime and the salinity gradient.

The influence of isolation

Generally, the first salt pans are in connection with the sea. Their biological richness, however, is lower than that of the sea. Within the same pan, the zonation of marine organisms is on a gradient between the section closest to the arrival of sea water, the richest, to the poorest which is the furthest away.

J. Roché

The shape of the basins determines water circulation. Here, algae accumulates where the water stagnates. Aigues Mortes, France.

The degree of confinement is defined as the time required for the turnover of the marine components, or the time taken for them to reach a particular point.

In Camargue, for example, annual temperatures at a depth of 40-60 cm vary from -6°C to +33°C.

The origin of this variation in the biological diversity has several causes. The first is the water for the salina (sea, lagoon, etc.), but the degree of isolation, although difficult to define precisely, plays an undeniable role. The large daily variations of water temperature (up to 14°C in summer), pH and dissolved oxygen are considerable in comparison to those in the sea, a much larger and more stable habitat.

The method of bringing water into the salina also has an influence, mainly on the populations of fish. If water flows in through a channel using the movement of the tides and wind, or paddle-wheels, marine species can enter. In contrast, in modern salinas powerful pumps[1] allow only the larvae of fish, Gilt-head seabream *Sparus auratus* for example, which grow more rapidly than in the sea. These fish, however, generally cannot return to the sea to reproduce.

The influence of the water regime

Depending on their exposure and depth, lagoons may have areas of mud temporarily exposed by the wind, similar to intertidal* zones which are important feeding habitats for waders.

Modern salinas ensure that the autumn and winter rains do not reduce the concentration of the brine, which is stocked in deep lagoons. The substrate of other salt pans is then exposed. The area of the dried-out salinas is not good habitat, until the following production season, for species that do not have a resistant form or are intolerant of desiccation: macrophytes *(Althenia filiformis)*, chironomids *Chironomus salinarius*, worms, molluscs and fish.

J. Walmsley

Salinas are an important staging point for migratory waterbirds. Mediterranean waders and terns.

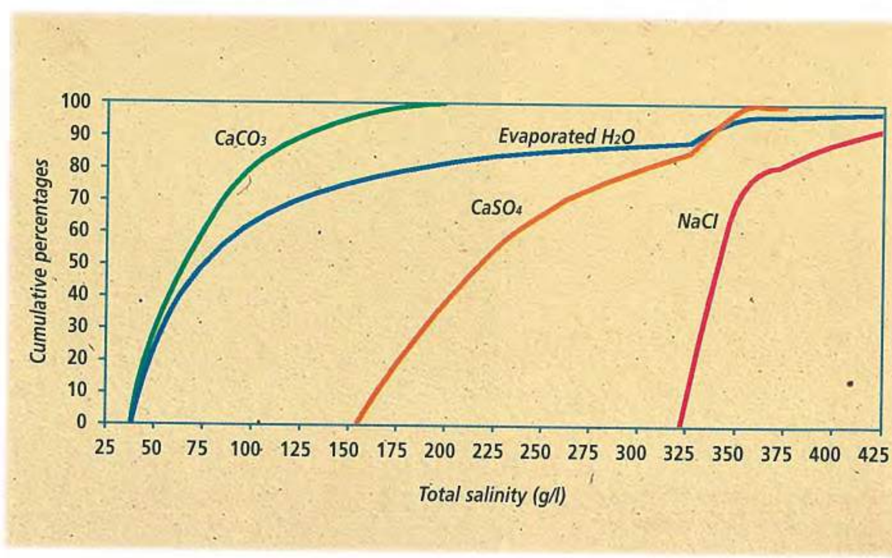
1 - 15m³/s for an annual volume of nearly 80 million m³ in the salinas of Giraud

The influence of salinity gradient

The preponderant determinant of the diversity of species is the salinity. In contrast to lagoons, the main salinity gradient in salinas occurs not in time, but in space. The species-richness of each salt pan 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 salt pan is from the sea-water pump. These chemical variations are physiological constraints for colonising marine organisms.

From 70 g/l salinity, carbonates and borates of calcium, and ferric compounds begin to precipitate. They are found in small quantities, and thus do not leave a significant deposit. The major change comes at a salinity of 150 g/l; gypsum (calcium sulphate) forms a crust on the sediment, of up to 10 cm deep in some years. This barrier between the substrate and the water adds to the effects of the changing ionic composition of water, blocking the development of a number of organisms. Finally, sodium chloride precipitates on the harvesting tables, where the salinity is around 320 g/l.



The salts contained in sea water crystallise at different salinities, and water evaporation is initially rapid before tailing off. After Usiglio, 1849

The biological richness of salinas

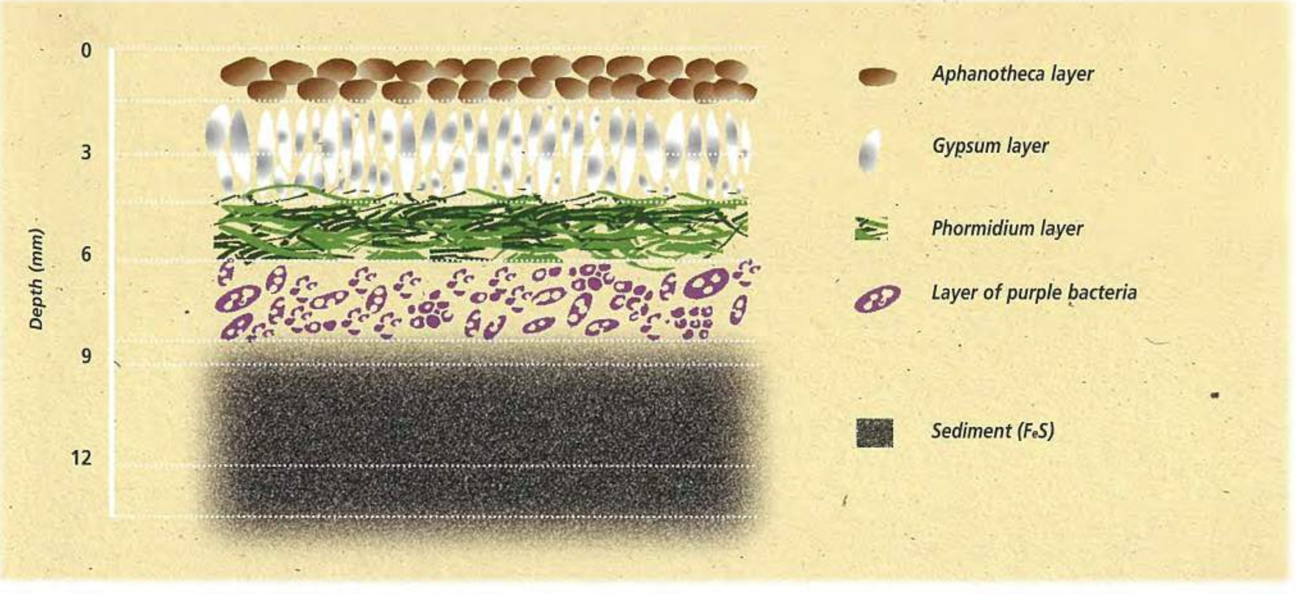
Among the animal and plant communities which characterise salinas and which can tolerate the gradients of salinity and humidity, two groups stand out by their productivity: unicellular organisms and aquatic invertebrates. They are essential elements of the food chain which provide food for high densities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

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.

In salinity of up to 130 g/l diatoms and blue-green bacteria dominate. The distribution of the blue-green bacteria *Lyngbya estuarii* is limited to temporary lakes and areas cleared by the wind; in permanent water they seem to be controlled by predation by the gastropod *Hydrobia acuta.* Carpets of blue-green bacteria *(Microcoleus chthonoplastes,* for example), although they are several centimetres thick whatever the water depth and the water regime, develop best between 55-150 g/l salinity.

Laminated microbial mats are most extensive in basins of 70-140 g/l. The underlying sediment lacks oxygen. After Caumette et al., 1994.



From 150 g/l, the precipitation of gypsum modifies the community. The lamella structure characteristic of hypersaline habitats is due to the vertical gradient in oxygen content and light, both of which decline with depth. The layering is as follows: a brown layer of blue-green bacteria, of the group *Aphanothece* which creates a strong photosynthetic activity; a crust of gypsum which if pierced lets off a strong smell of hydrogen sulphide (H_2S) and beneath which low oxygen contents and low light reduce photosynthetic activity, aerobic by day and anaerobic by night; a green layer of blue-green filamentous bacteria of *Phormidium* and a layer of purple sulphurous bacteria of *Chromatium* and *Thiocapsa* 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. They create the red colour of the water in the most concentrated salt pans.

Aquatic and terrestrial plants

The plant communities are composed only of species which are very tolerant of salt.

Emergent aquatic plants do not grow in salinas, as the salinity exceeds their levels of tolerance[1]. Abandoned salinas, however, flooded by rainwater or managed with freshwater as hunting marshes have emergent plants of slightly brackish marshes, such as *Scirpus sp. (S. lacustris, S. littoralis, S. maritimus)* and rushes *(Juncus gerardi, J. maritimus)* and plants of freshwater marshes, such as reeds *(Phragmites australis).*

Exposed by the winds, the edges of the shallow lagoons are colonised by annual species of coastal marshes: annual salicornia *(Salicornia europea)* and seablites *(Suaeda sp., Salsola sp.).* When the salinity goes above 40 g/l, these plants grow only on dykes or islands where succulent, perennial plants from the sansouire* grow, *Arthrocnemum fructicosum, A. glaucum, Halimione portulacoïdes.* Their distribution is a function of soil salinity and the protection they manage to find from salt spray.

The soil and the location also influence the distribution of colonising species on the higher ground, which is very dry. Plants such as Marram grass *Ammophila arenaria,* Stinking everlasting *Heliochrysum stoechas, Anthemis maritima,* Sea spurge *Euphorbia paralias, Erianthus ravennae,* Sea daffodil, *Pancratium maritimum* and *Crucianella maritima* occur on the dunes separating the salinas from the sea or on the fixed dunes.

1 - See n° 6 in the same series

Biological richness of salinas

On the most stabilised areas, forest communities of Umbrella pine *Pinus pinea* and Maritime pine *P. pinaster*, associated with Juniper bushes *Juniperus spp.* and Phillyrea *Phillyrea angustifolia* bring diversity to the landscapes.

There are not many species of submerged macrophytes, and they are absent from lagoons with salinity higher than 70 g/l, and are rare in those that are dried out in winter. The most abundant are species of Ruppia, such as *Ruppia maritima* and *R. cirrhosa* which can form large beds; *Althenia filiformis* and *Lamprothamnium papulosum* are rare. These beds of submerged macrophytes are an important food resource for invertebrates and herbivorous birds, such as Wigeon *Anas penelope*; they also provide shelter for fish. With an annual biomass of 85-150 g/m^2 of dry matter, their productivity is relatively low compared to that of freshwater macrophytes[1].

When the salinity is close to 70 g/l, green algae can be very abundant. *Chaetomorpha spp.* and *Cladophora sp.* form carpets on the sediment in shallow areas; *Chaetomorpha linum*, whose filaments of 30-60 cm are not fixed to the substrate do not require much light. *Enteromorpha spp.* form flat tubes and like habitats rich in nitrates. In summer, the algae build up large floating carpets that pile up on lagoon edges with the wind. Their decomposition causes deoxygenation of the water, and as a result eliminates the local aquatic fauna. In contrast, invertebrates such as chironomids *Halocladius varians* do well in these conditions.

Salins, J.F. Dejonghe

Spring flowering in the salinas.

1 - Verhoeven, 1980

Aquatic invertebrates

Aquatic invertebrates occur in all salinas. No one species is present everywhere, and their distribution depends on water salinity. 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 two important physical and chemical reactions occur: the precipitation of carbonates, and gypsum. When the salinity is 70 g/l *Eurytemora velox, Gammarus inaequicaudata* and *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.

The distribution of invertebrates within a lagoon is highly clumped, and varies greatly through time: a species may be absent one day, and abundant a few days later.

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.

Other predators, *Thinophilus achilleus* and *Potamonectes cerisyi* colonises very salty lagoons feeding on brine shrimps *Artemia sp.* At high salinities where few species live, species richness of the lagoons varies little from year to year, particularly when they are used as winter reservoirs. Three species resist very high salinity, (>280 g/l): *Thinophilus achilleus*, salt fly *Ephydra bivittata* and brine shrimps. The densities of the last two species are highest at concentrations above 150 g/l because of the small number of predators around. On the other hand, at salinities lower than 70 g/l, despite their tolerance of a wide range of salinity densities of *Thinophilus achilleus* and *Ephydra bivittata* are very low due to predation by fish.

These community structures change in wet years, when the lagoons are filled by winter rain; the salinity is then much lower than during the summer. Freshwater species, such as the hemipteran *Sigara lateralis* then mix with species of marine origin, such as the copepod *Harpacticus littoralis*.

Although the two year study of the salinas of Giraud showed the presence of twenty five taxa (thirty four species), these aquatic invertebrates occur at relatively low densities compared to other salty habitats. The salinas are an oligotrophic* system.

The mean density of the bivalve *Cardium glaucum*, for example, is 31-1,525 individuals/m^2 in comparison to 430-6,070 individual/m^2 in the nearest mesohaline* lagoons. The maximum density of *Hydrobia acutais* is 18,000 individuals/m^2 in winter in permanent lagoons, in comparison to 50,000 individuals/m^2 for a similar species *(H. ulvae)* on intertidal flats in England at the same season. Only brine shrimps have similar densities as analogous habitats, i.e. 16,000 individuals/m^2.

The species present vary with the geographical position of the salinas. For example at the salina of Atlit (Israel) molluscs absent from Salin de Giraud occur, such as *Paludinella littorina, Siphonaria krracheensis* and *Pirenella conica*, an indian-pacific species[1].

In the first lagoons, where salinities are similar to that of the sea, the invertebrate species are limited to euryhaline* species. For there to be crustacea like *Crangon crangon* and *Carcinus mediterraneus* or the polychaete worm, *Nereis diversicolor*, these must immigrate from the sea. The limiting factors for the life cycles of invertebrates are the daily temperature range in the water and desiccation. Desiccation in dried-out lagoons in winter has a significant impact: to resist this the mollusc *Hydrobia acuta*, the copepod *Cletocamptus retrogressus* and the beetle *Berosus spinosus* dig themselves into the sediment whereas the copepods *Canuella perplexa* and *Laophonte setosa*, and the amphipod *Gammarus inaequicaudata*, do not have a resistant stage and disappear.

Brine shrimp: a natural and economic resource[2]

Found only in salt water, temporary or permanent, brine shrimps, of which there are six species or super-species, are phyllopod crustacea with a world-wide distribution, except Antarctica. *Artemia tunisiana*, an endemic species of the Mediterranean, limited to south of 40° latitude, is found in abundance and *Artemia parthenogenetica*, a European species is found all over the region. With a productivity higher than all other invertebrates in the salinas, they are a key link in the food chain. Their population dynamics vary at different salinities and temperatures. Their density increases up to a salinity of 240 ‰, and then declines, and in the salinas in the north of the Mediterranean brine shrimps over-winter as cysts*[3]. From March onwards, the increase in temperature and the rain stimulate hatching, and at least five generations succeed each other during the summer. The rapid succession of the different phases of development (about fifteen days) explains the incredible productivity of brine shrimps whose densities can be greater than 100,000 individuals/m^3 in optimal conditions.

Salins

***Artemia* the main food resource for most waterbirds.**

At the end of May, the extinction of the phytoplankton bloom, which is the food for brine shrimps, reduces population growth and the first cysts begin to appear.

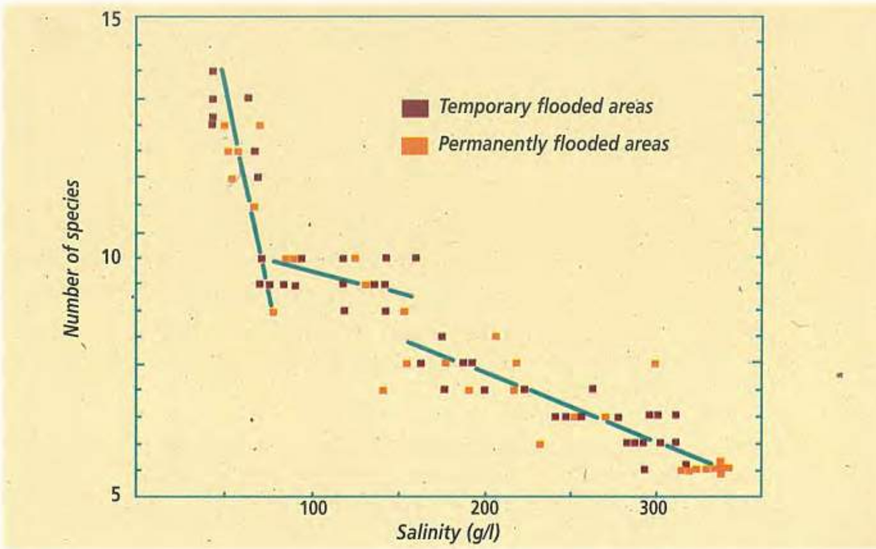
Eaten by many waterbirds (Flamingo, Avocet, etc.) the brine shrimps contribute to the diversity of birds in salinas. Currently, raising of brine shrimps under controlled conditions is not economically viable, their commercialisation for aquaria and aquaculture, which began in USA in 1950, makes good use of their productivity. In 1988, the World Aquaculture Society estimated the world production of brine shrimp cysts at 250 tons/year.

1 - Ortal, 1997
2 - Browne et al., 1991
3 - Browne, 1988
4 - MacDonald & Browne, 1989

Their presence in the spring is due to recolonisation from permanent lagoons. Molluscs survive by closing their operculum. The dipteran *Chironomus salinarius* and the copepod *Neocyclops salinarum* become more tolerant to salinity with a decline in the water temperature in winter.

List of invertebrates recorded in the Salin de Giraud according to mean salinity g/l (min-max). Britton & Johnson, 1987.

Family	Species	Summer	Dry winter	Wet winter
Turbellaria				
	• *Macrostomum appendiculatum*	91 (40-166)	81 (25-153)	57 (25-117)
	• *Monocelis lineata*	-	-	41 (31-52)
Nematoda				
	• Unidentified	113 (40-284)	97 (25-200)	63 (25-141)
Annelida				
Oligochaeta				
	• *Tubificidae* unidentified	46 (40-54)	-	45 (30-86)
Polychaeta				
	• *Nereis diversicolor*	49 (40-63)	119	34 (26-41)
	• *Spionidae* unidentified	-	-	28 (25-31)
Mollusca				
Lamellibranchiata				
	• *Abra ovata*	52 (40-63)	68 (46-111)	50 (30-70)
	• *Cardium glaucum*	51 (40-66)	62 (45-111)	47 (26-70)
Prosobranchiata				
	• *Hydrobia acuta*	54 (40-84)	81 (46-143)	84 (30-89)
Crustacea				
Decapoda				
	• *Carcinus mediterraneus*	49 (40-52)	-	31
	• *Crangon crangon*	55 (40-66)	-	-
Mysidacea				
	• Unidentified		40	-
Amphipoda				
	• *Corophium sp.*	-	-	39 (26-52)
	• *Gammarus inaequicaudata*	51 (40-68)	-	33 (25-31)
Anostraca				
	• *Artemia sp.*	211 (68-320)	-	91 (39-104)
Ostracoda				
	• *Cyprideis littoralis*	56 (40-84)	90 (46-143)	48 (25-89)
Copepoda				
	• *Calanipeda aquae-dulcis*	-	-	25
	• *Canuella perplexa*	46 (40-54)	-	41 (27-54)
	• *Cletocamptus retrogressus*	99 (40-207)	90 (22-217)	61 (25-134)
	• *Eurytemora velox*	48 (40-64)	-	42 (40-56)
	• *Harpacticus littoralis*	-	-	39 (30-52)
	• *Laophonte setosa*	40	-	39 (30-52)
	• *Metis ignea*	45 (40-54)	67 (46-89)	32 (27-40)
	• *Neocyclops salinarum*	50 (40-66)	95 (59-119)	53 (25-100)
	• *Copepoda* unidentified	-	-	41 (30-52)
Insecta				
Hemiptera				
	• *Sigara lateralis*	-	-	59
Coleoptera				
	• *Anacaena bipustulata*	63 (50-74)	-	-
	• *Berosus spinosus*	88 (40-152)	95 (22-160)	44 (25-59)
	• *Potamonectes cerisyi*	115 (40-284)	85 (22-160)	52 (25-89)
Diptera				
	• *Chironomus salinarius*	58 (36-63)	78 (46-119)	61 (40-89)
	• *Halocladius varians*	84 (40-152)	75 (18-143)	60 (25-122)
	• *Halocladius stagnorum*	?	-	-
	• *Ephydra bivittata*	176 (40-284)	94 (84-147)	86 (25-162)
	• *Ephydra glauca*	?	-	-
	• *Thinophilus achilleus*	163 (50-287)	94 (22-218)	71 (25-161)



The number of species able to survive declines rapidly as salinity increases. Britton & Johnson, 1987.

Family	Species	Family	Species
Clupeidae		**Serranidae**	
	• *Sardina pilchardus*		• *Dicentrarchus labrax*
Anguillidae			
	• *Anguilla anguilla*	**Sparidae**	
Belonidae			• *Sparus auratus*
	• *Belone belone*		• *Sargus rondeletti*
Syngnathidae			• *Sargus annularis*
	• *Syngnathus abaster*	**Gobiidae**	
	• *Syngnathus acus*		• *Pomatoschistus sp.*
Mugilidae			• *Gobius sp.*
	• *Mugil cephalus*	**Pleuronectidae**	
	• *Mugil ramada*		• *Platichthys flesus*
	• *Mugil auratus*	**Soleidae**	
Atherinidae			• *Solea vulgaris*
	• *Atherina boyeri*		

List of fishes recorded at Salin de Giraud, France Britton & Johnson, 1987.

Fish in the salinas

Atherines *Atherina spp.*, mullets *Mugil spp.* and killifish *Aphanius spp.*, mostly juveniles use salinas up to a salinity of 70-80 g/l. In the Mediterranean, the most abundant fish, *Aphanius fasciatus*, is very euryhaline*.
A study carried out in Messolonghi (Greece) showed that the population of *Aphanius* resident in the salinas had a shorter life-span, a slower growth rate and a higher mortality than if they were in two large neighbouring lagoons with a salinity (10-24 g/l) that was lower than the salinas (19-80 g/l). The temperature in these salinas reaches 39°C in July, which is close to the lethal temperature for this species, in the lagoons it is never higher than 29°C. Generally speaking, salinas are marginal habitats for fish.

1 - *Leonardos et al., 1996*

Birds[1]

In degraded coastlines, salinas are habitats which are relatively undisturbed, diverse and biologically productive. They are important for biodiversity and have heritage value, and thus represent an important capital for the conservation of birds in the Mediterranean. In 1997, the Audouin's gull *Larus audouinii* endemic to the Mediterranean basin, has about 50 colonies with a total of more than 19,000 pairs[2]. The Ebro delta (Spain) is the main breeding area with about 11,700 pairs; the Trinitat salinas are today essential for this species because 70 % of the population is concentrated there. A few isolated pairs also use the Sardinian salinas.

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. This partially explains why bird diversity of a salina on an urbanised coastline (e.g. Hyères, France) is lower than that of a salina found in the heart of biologically rich areas such as the deltas of the Rhone, Ebro, Po, Evros or at Thyna (Gulf of Gabès, Tunisia).

Slender-billed gulls are increasing in the Mediterranean region and colonise mainly salinas

J. Walmsley

1 - See species table, page 86
2 - Audouin's gull Action Plan, Melissa, Spain, 1997

The value of the salinas for birds

As there has never been any measure of the impact of the transformation of a wetland into a salina, the value of salinas for birds can be evaluated only by comparison with similar habitats.

In the Camargue there are two characteristic types of marine lagoon habitats: the salinas and the lower lagoons of the Vacarrès. This area has been dyked in, and consists of a large lagoon, a mosaic of temporary lagoons and salt marshes* with a hydrological regime which varies between years. These habitats are within two protected areas where disturbance is low, as in the salinas.

Monitoring over the past 40 years, together with a questionnaire to ornithologists has enabled a rough estimate of the abundance of breeding birds. Of the hundred and three breeding species in the Camargue, sixty nest in the lagoon-marine zone. Half of them have a comparable abundance in the two habitats, however 16 of them are more numerous in the salinas.

The lower lagoons hold small numbers of eleven birds of freshwater or slightly brackish habitats which do not occur in the salinas, such as Moorhen *Gallinula chloropus* and Reed bunting *Emberiza schoeniclus.*

The salinas hold nine species not found in the lagoons due to the lack of appropriate nesting sites: old buildings for the Ring-neck dove *Streptopelia decaocto*, cliffs for European bee-eater *Merops apiaster*, breeding islands for flamingos.

J. Roché

The Yellow Wagtail *Motacilla flava* is a common breeder in salinas.

Two species are common in the lower lagoons: Spectacled warbler *Sylvia conspicillata* in the large area of *Salicornia spp.,* and Nightingale *Luscinia megarhynchos* in the areas with scrub.

The salinas seem to be more important for six species of waterbirds (shelduck and waders) due to their requirements for specific feeding and breeding sites.

Ten to fifteen of the most abundant species in the salinas are Charadriiforms, and nine of them are colonial.

This illustrates the great richness of the salinas for birds. It is comparable with similar types of habitats. However, this is a one-off study which does not yet take account of long term variations, or the importance of habitat dynamics on community structure[1]. It appears that each site has certain specific characteristics, such as the presence of a shrub layer, which cause the differences in the bird communities, so the results cannot be generalised to other areas.

1 - See chapter "Management of birds and salinas", pages 60-63.

Feeding areas for waterbirds

Resource partitioning between bird species using the salinas as feeding sites contributes to their diversity. Birds may be herbivores, fish-eaters, or invertebrate feeders; they exploit the whole of the water column, their different morphologies being adapted to different hunting techniques.

Available and accessible food

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.

Each species looks for lagoons with a salinity which will allow their food resource to develop. However, the niche it occupies depends on its morphology and its feeding method. 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. Predation by waders is maximal in water 0-18 cm deep.

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

The beaks and legs of birds are adapted to feeding in different water depths. Drawing by Serge Nicolle.

fish in turbid water. This segregation linked to space and the food requirements leads to resource partitioning, and explains the diversity of the bird communities in the salinas.

Herbivorous birds

Herbivorous birds, (geese, duck and coot), are not common because there is little emergent vegetation. However, the Coot *Fulica atra* feeds principally on blue-green algae, Wigeon and Mallard *Anas platyrhynchos* feed on *Ruppia*. In winter, groups of several thousand duck gather, and if they are not disturbed by hunting, use the salinas as a roost*, flying out to feeding areas, mostly neighbouring freshwater marshes, at dusk.

Fish-eating birds

Among the birds which feed on fish, there is a distinction between purely fish-eating species and generalists. The former, principally northern species occur in the salinas in winter or on migration, are not very abundant and use the least salty lagoons. These include the Great-crested grebe *Podiceps cristatus*, Red-breasted merganser *Mergus serrator*, and Cormorant *Phalacrocorax carbo*.

In the eastern Mediterranean, the Pygmy cormorant *Phalacrocorax pygmeus*, White pelican *Pelecanus onocrotalus* and Dalmatian pelican *P. crispus* often use salinas as a resting area.

Cormorant roosts of several hundreds of individuals occur on islands in French salinas. The cormorants fish in the morning in freshwater and brackish marshes. Excellent swimmers, they catch their prey more easily when the water is clear and shallow.

Purely fish-eating birds, Common tern *Sterna hirundo* and Little tern *S. albifrons* spot the fish as they fly over the water, and then dive. In addition to areas where water is flowing, like near the pumps or between two lagoons, where they catch their prey by hovering overhead, they feed a certain distance from the shore.

The Sandwich tern *Sterna sandvicensis* breed in the salinas, but feed out at sea on pelagic fish (sardine *Sardina pilchardus*, anchovy *Engraulis encrasicolus*, etc.) The presence of these birds in the salinas is linked to the neighbouring marine fish resources.

Herons

Little egrets *Egretta garzetta* are solitary hunters of crustacea and coleoptera larvae, amphibians, and fish in freshwater marshes. They form groups of several tens of individuals when the lagoons are emptied, snatching up the trapped fish. A nasal gland enables the bird to get rid of excess salt. Most of the other herons (Squacco heron *Ardeola ralloides*, Night heron *Nycticorax nycticorax*, Purple heron *Ardea purpurea*), do not have this anatomical feature and are therefore absent from the salinas.

In contrast to Little egret, Grey heron *Ardea cinerea* catch quite large prey, for example, mullet 30 cm long. The heron family use stealth for fishing: with their long legs they pace up and down in shallow waters or on the edge of lagoons. The Little egret is, however, capable of fishing in turbid water, disturbing the fish with their feet.


Salins, J.F. Dejonghe

The Little egret feeds on fish and shrimps in the salinas.

The tree-nesting herons breed in salinas when there are trees, such as pines on the coast[1]. The size of a colony depends also on the presence of freshwater or brackish marshes nearby, whose production of food organisms complements that of salinas.

The generalist fish-eating birds change their diets and feeding habitats in relation to the availability of their prey. Opportunists, gulls, such as Slender-billed gull, adapt their methods to the situation: diving like terns, walking in shallow water like herons, scraping the bottom with its beak to catch fish stuck in the mud.; their own special technique is swimming, and then dipping the head or the body into the water to catch fish.

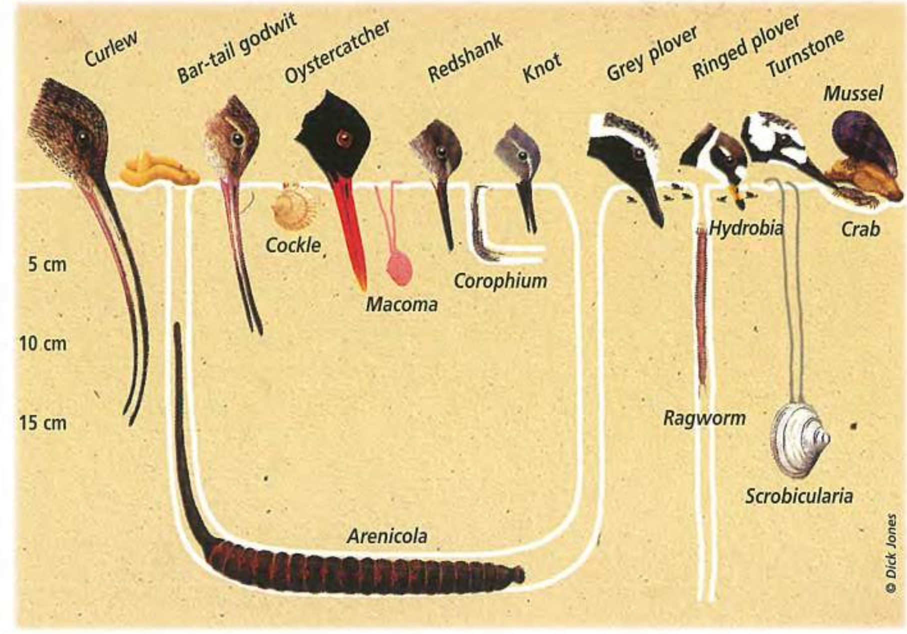
Invertebrate-eating birds

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. This is the case for 26 of 33 wader species that are most common in the western Mediterranean, for example 40-50 % of 25,000 wintering waders in Cadiz Bay (S.W. Spain) use the salinas[2]. The other species are typically found in steppe habitats (Dotterel *Eudromias morinellus*, Stone curlew *Burhinus oedicnemus*), freshwater marshes (Wood sandpiper *Tringa glareola*, Pratincole *Glareola pratincola*, Common snipe *Gallinago gallinago)*, or grasslands (Lapwing *Vanellus vanellus)*.

1 - See n°4 in the same series
2 - Perez-Hurtado, 1995

The distribution of birds looking for food in the salinas reflects the distribution of the invertebrates constituting their diet. The shape and the length of the beak, and the length of the legs are adaptations to capture their preferred prey. These specificities are the basis of the hunting techniques of the different species, and they allow the different waders to feed together in a group with only limited competition. Feeding on bivalves *Cardium sp.*, Oystercatcher *Haematopus ostralegus* share the pans of low salinity with Bar-tailed godwit *Limosa lapponica*, Curlew *Numenius arquata* and Whimbrel *N. phaeopus*, which use their long beaks to extract worms from the mud. Like Grey plover *Pluvialis squatarola*, they also feed on molluscs, decapods and young crabs.

The majority of waders use lagoons of medium salinity, but the availability of prey controls their feeding and movements. Thus, in winter, the disappearance of brine shrimps causes them to move to the pans with the lowest concentration of salt. Dunlin *Calidris alpina* is specialised on beetles and Little stint *C. minuta* on chironomids. They have a similar method of capturing their prey, based on a tactile sense at the base of their beak. This method is also used by Avocets which swing their beak from side to side at the surface of the water; however its long legs enable it to use deeper water. In contrast, plovers and Black-winged stilt *Himantopus himantopus* catch their prey visually.



The length of each bird's bill is adapted to catching different prey items in the mud. After Dick Jones[1]

1 - Goss-Custard, 1975

Salins

Avocets take their young to nearby feeding grounds as soon as they hatch.

The flamingo is a filter feeder, using its tongue like a pump to draw water in and out at a rate of twenty times a second. The lamella structure of the edge of its beak acts as a sieve and keeps back prey varying in size from 0.1-10 mm. Its ability to eliminate salt through its nostrils enables it to use the whole salinity range. This filtering mechanism is so efficient that it provides enough food for this large bird, which has to eat about 10 % of its body weight each day, the equivalent of 32,000 larvae of *Ephydra* or 135,000 brine shrimp. Five thousand flamingos feeding in the Camargue salinas require 1.4 tons of invertebrates per day. The shelduck uses the same method of filtering, but is less efficient.

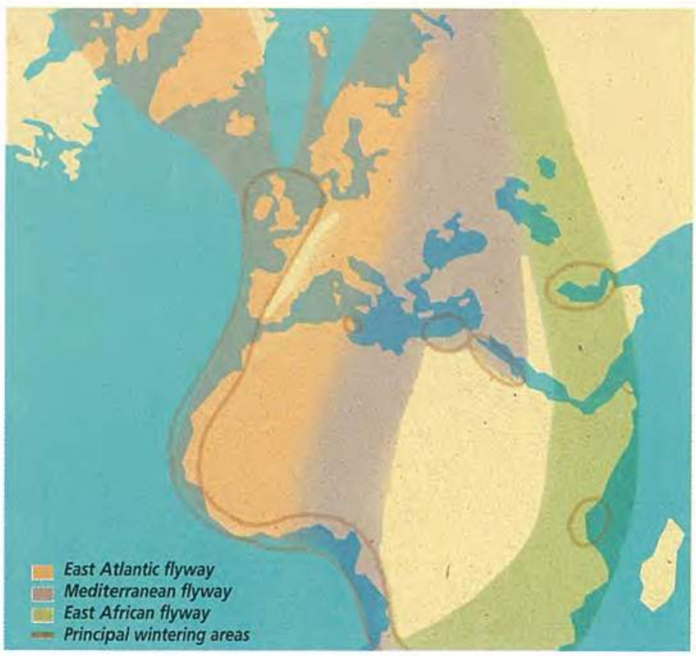
The gulls, like Black-headed gull *Larus ridibundus*, Little gull *Larus minutus*, and Slender-billed gull are also great consumers of invertebrates, in particular brine shrimps. They catch them whilst swimming, pecking at the surface of the water. This method is used by one wader family only, phalaropes, of which the main species in the Mediterranean, although still rare, is Red-necked phalarope *Phalaropus lobatus*. Gulls, flamingos, shelducks and waders also benefit from the wind when it accumulates the invertebrates on the edges of the pans. Black tern *Chlidonias niger* use the salinas during migration, catching invertebrates at the water surface.

The importance of salinas for migratory birds

Migration is the reason why the number of birds using salinas vary so much through the seasons.

Some species are found only at certain times of year, such as Dunlin in winter or Common tern and Little tern which winter on the west African coast. Others like Knot *Calidris canutus* and Sanderling *C. alba* use the salinas only as a stop-over during migration. Other species like Flamingo are present all year, although part of the population winters further south. The populations of Black-headed gull, Avocet, and Redshank *Tringa totanus* increase as populations to the north of Europe move south.

Waders use two routes to migrate south across the Mediterranean[1]. Three million birds from northern Europe, western Siberia, Greenland and northern Canada migrate southwards to West Africa and the gulf of Guinea. The main passage of these birds is down the Atlantic coast to Africa, although some may cross the eastern Mediterranean. The second route is Mediterranean and takes birds from central Europe and Siberia to overwinter between Angola and Ghana, and Egypt and the Red sea. Nearly 500,000 birds, however, spend the winter on mudflats of the intertidal zone of the Mediterranean sea. The Mediterranean, apart from rare exceptions like the Gulf of Gabès with 250,000 birds, has few intertidal zones because of the small tides. The salinas, therefore, play an important role, providing replacement habitats when the bottoms of the salt pans are exposed. For wintering birds like the long distance migratory species they are a major stop-over point for rest and reconstitution of fat reserves.



Three distinct "flyways" link the waders' arctic breeding areas with temperate and tropical coastal wintering areas. After Smit & Piersma, 1989.

1 - *Smit & Piersma, 1989*

Breeding areas for waterbirds

The choice of the breeding site is essential for successful breeding, chosen without care, it can lead to the abandonment or the destruction of the clutch[1]. There are two major constraints: a suitable site for the construction of a nest and feeding areas close by.

The choice of a nest site forces birds to limit their movements around this fixed point. The breeding strategy of each species controls their distribution in the salina.

Solitary pairs

Ducks and certain waders nest as solitary pairs. They build their nest on dykes in the salinas or on islands inaccessible to mammalian predators (rats, dogs, cats or foxes), even though their discreet behaviour and camouflaged nests are already good protection. Mallard, Red-headed pochard *Netta rufina* and Redshank make their nests beneath salicornia or in the grass.

These solitary pairs, which do not feed their young, nest close to feeding sites to which they take their young soon after hatching. Oystercatchers are an exception.

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. This strategy has important consequences with specialised predators around. In the salinas of Giraud, up to 90 % of the nests can be predated by weasels *Mustela nivalis* or by crows *Corvus corone.*

J. Walmsley

In the Mediterranean region Shelduck occur mainly in salinas.

1 - See n° 4 in the same series.

Colonies

Other birds form colonies, like flamingos which can have up to 10,000 pairs, particularly in the salinas. Here human disturbance is low compared to the lagoons, which are used by people for numerous activities. As they are very visible, particularly since their social behaviour is accompanied by noisy calling, they look for sites inaccessible by terrestrial predators, against which they have no defence[1]. Islands are also preferred by gulls and terns.

A combination of three factors make the islands inaccessible: water depth, distance from the dyke and the salinity. The depth reduces access by predators, walking or swimming. With low salinities, foxes *Vulpes vulpes* for example will not go across to the island if they have to swim more than 150 m. On the other hand, if it can reach the site on foot, the distance is not important. In water with salinity higher than 100 g/l, depth is the controlling factor. 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. Thus in very salty lagoons, colonies can establish themselves only a few metres from the edge.

The Mediterranean population of Shelduck[2]

There are two principal populations of shelduck. Estimated at 250,00 birds, those of north-west Europe are essentially coastal, whereas the Asiatic population, south-east of the Black Sea and the Caspian Sea, (100,000 individuals) live on inland salt lakes. Recent studies have shown that the west Mediterranean population of 5-10,000 individuals uses salinas and coastal lagoons and therefore has a discontinuous distribution.

The Shelduck place their nests either in the shelter of vegetation or in rabbit holes. In summer, the adults accompany the young, grouped in a crèche, to areas rich in brine shrimp, which is the basic food whilst they are young. In winter, as there is no longer any brine shrimp the shelduck feed on the carpets of blue-green algae *(Microcoleus chthonoplastes).*

At the end of the breeding season, adult Mediterranean shelduck migrate to the Wadden sea (Germany) They are joined by those of north-west Europe and moult. Incapable of flying during this period, they shelter from terrestrial predators on huge mudflats rich in food. Once the moult is finished, in November, the Mediterranean shelduck move south again: the trip, through the Rhone and Rhine valleys, is more than 2,500 km.

1 - See n° 4 in the same series.
2- Walmsley, 1987

Terns frequently breed on the beaches of the islands - the preferred habitat of Avocets and Slender-billed gulls

These birds living on islands do not have the same habitat requirements, which enables them to form mixed colonies. The Black-headed gull uses *Salicornia* plants to build its nest, whereas the Mediterranean gull *Larus melanocephalus* lays its eggs in holes in more open vegetation. Terns prefer areas free of vegetation with a loose substrate, in which it scrapes a dip for its eggs; they can also nest on a bed of sea-purslane.

In contrast, the flamingo colonies are very dense and their large size prevents the installation of other birds except a few isolated pairs, on their island which is often devoid of vegetation.

Yellow-legged herring gulls *Larus cachinnans* also nest essentially in monospecific colonies. This predator of eggs and chicks of other species, and even its own, is avoided by other birds.

Large colonies require rich feeding habitats. Like all waders, avocets nest close to feeding habitats in order to be able to move their chicks there easily. The diversity of its diet allows it to nest alongside pans that are either not very saline or very saline. Chicks of other colonial species are fed at the nest. The choice of the breeding site depends on the distance to the feeding habitat, and is influenced by the size of the birds and 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.

Terns bring back fish in their beaks to the colonies, which are often situated close to the coast where they feed. The smallest tern, Little tern, travels 5-10 km whereas the largest, Sandwich Tern, can go more than 20 km. Some species, Mediterranean gull or Gull-billed tern *Sterna nilotica*, for example, prefer freshwater marshes, rice-fields and abandoned land, so their colonies are situated near these habitats. The Mediterranean gull travels several tens of kilometres to feeding sites and feeds its chicks on regurgitated food, whereas the Gull-billed tern brings back fish in its beak, and feeds closer to the colony.

Flamingos, salina birds par excellence

In the Mediterranean, the distribution of flamingos coincides with that of salinas because they are totally adapted to this habitat. It is not bothered by water depth (its long legs enable it to use many of the lagoons, and it can swim), or salinity. The salinas which are not dried out are full of invertebrates all year round, so there is ample food for a bird of this size, and other species without there being competition. In winter, when the brine shrimp disappear, the flamingos in the north of the Mediterranean use the pans of medium salinity to feed on chironomid larvae, tubificid worms, small molluscs and cysts of brine shrimps.

Biological richness of salinas

A. Johnson

Flamingos breeding on dykes of the old salinas at Fuente de Piedra, Spain, will fly 150 km to feed in the Marismas of the Guadalquivir.

Nearly all the nesting colonies of flamingos in the Mediterranean basin have been established in active salinas (salinas of Giraud, Camargue; Trinitat in the Ebro delta; Camalti near Izmir) or inactive ones (Molentargius, Sardinia); the inland lagoon of Fuente de Piedra (Andalousia), with its salina developments, is the second largest breeding site for flamingos in the Mediterranean. When part of this lagoon was transformed into a salina, dykes were built. With the abandonment of the salinas in 1950's, these dykes were so eroded that they became islands, which are occupied by breeding birds in wet years. The same occurred in the salinas of Molentargius, when they were abandoned because of pollution by waste water.

The regular presence of water in a salina makes it a stable habitat, almost ideal for many species. In the long term, however, the islands disappear by wind erosion, and trampling by flamingos, which build mud piles with their beaks for nests. Thus, an island occupied in May by flamingos has totally changed by July.

Confinement*, the water regime, and the salinity gradient in the salinas all depend on human actions. Linked with the geographical situation, these three ecological factors control the biological richness of these salina habitats. The numerous unicellular organisms, invertebrates and plants ensure the dynamics, enabling the presence of a diverse avifauna of which the flamingo, because of its perfect adaptation to the habitat, can be considered the flagship species.

J. Walmsley

Management of birds and salinas

The salinas offer a mosaic of feeding and breeding habitats for birds, strongly influenced by the water management.

Traditionally powered by steam, the water wheels which used to move water through the canal network are today increasingly rare.

Despite conditions which are favourable overall, some factors limit breeding birds: these differ between active and inactive salinas.

Limiting factors for birds breeding in active salinas

The biological advantages and disadvantages of salinas compared to the original natural habitat are difficult to estimate. These salina systems are certainly important at a regional level: nonetheless their limitations become clear as time passes.

The impact of landscape dynamics on nesting conditions

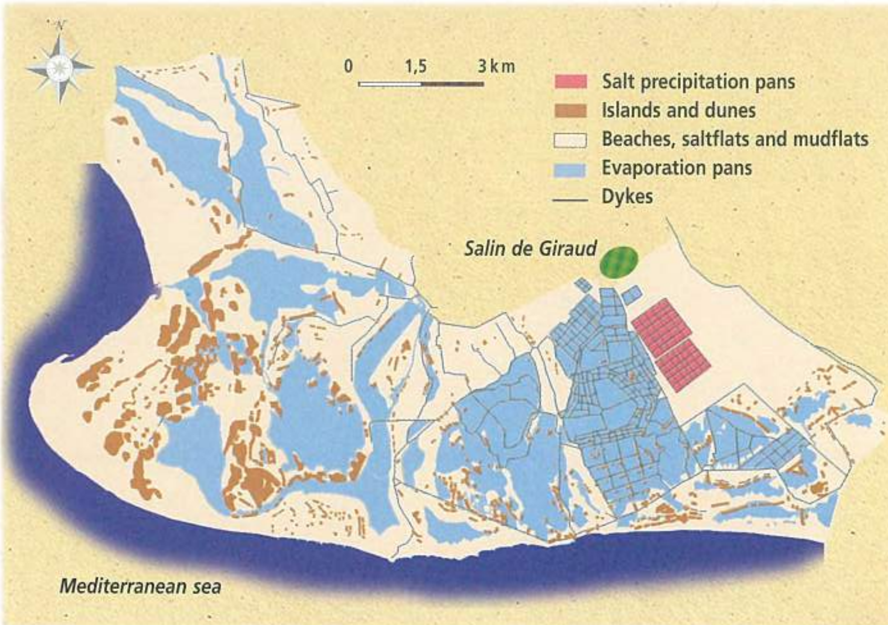
The salinas of the Camargue (Aigues-Mortes and Giraud) are important breeding sites for colonial waterbirds. Since 1956, the numbers of breeding colonial charadriiforms (gulls, terns and avocets) have been monitored.

The resulting database, unique in the Mediterranean region, has shown the impact of the landscape on the nesting of these species[1].

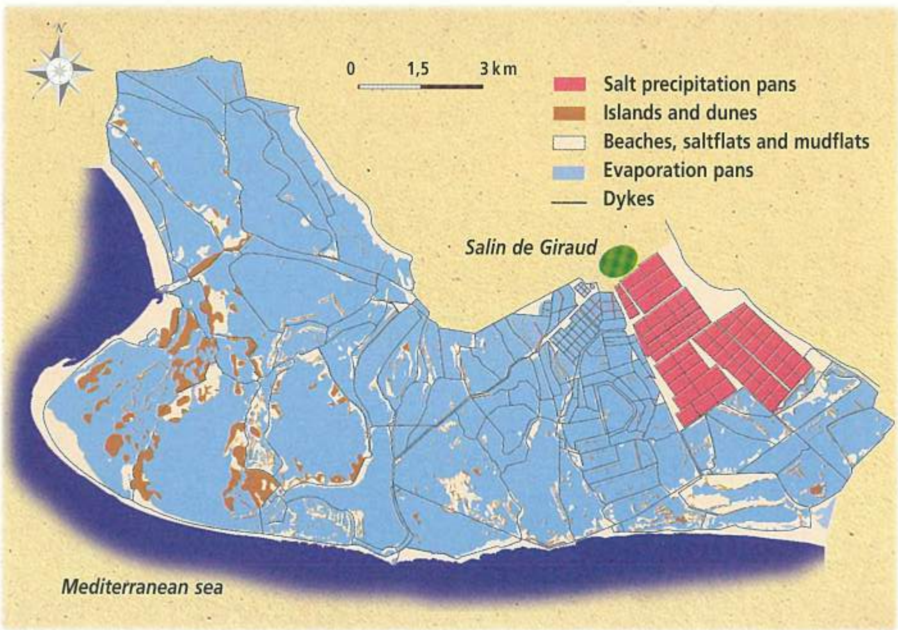
Before 1953, the coastal fringe, today occupied by the salinas of Giraud was made up of natural lagoons and sansouire where the flooding conditions varied, depending on the rains and intrusions of sea water. The breeding season usually coincided with the drying out of the area. The landscape was unstable due to the processes of erosion and accretion: after the dyking of the delta at the end of 19th century, the relief of the landscape continued changing although at a much slower rate, unpredictably creating islands and destroying them. Only the 2,800 ha of salinas provided stable water conditions.

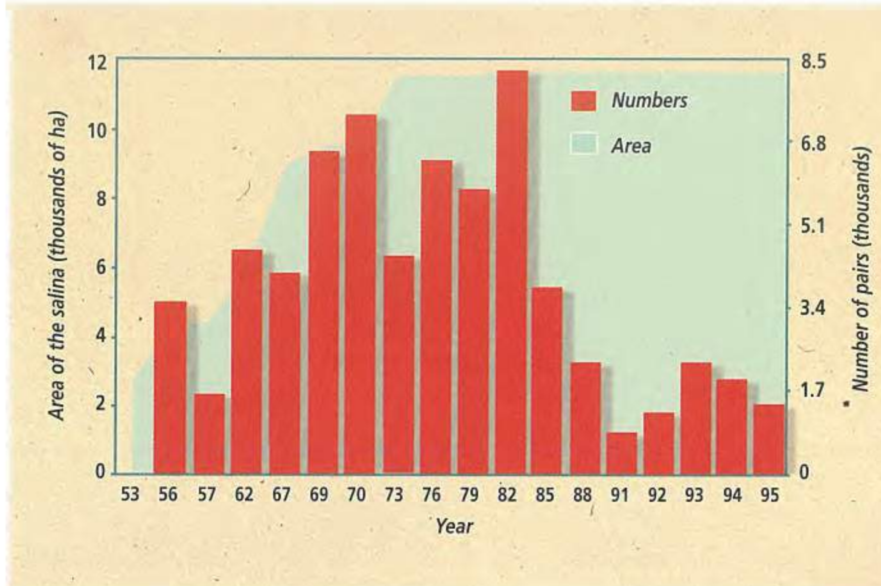
From 1953-1973, the area of the salinas had quadrupled. Dyking of the natural depressions transformed them into pans, and putting water into these pans during the breeding season the islets, old dunes and levées became isolated. The earth-works and levelling of the pans led to the creation of artificial islets, but also the destruction of natural islets (e.g. by levelling the lagoons to increase the evaporation surfaces). In addition, protective dykes have been built and dune systems reinforced in order to ensure effective sea defence. These dyked-in salt pans function hydrologically in exactly the opposite way to the original, natural lagoons; the water levels are predictable and stable. In two hundred years, the expansion of the salinas has modified the landscape as much as natural dynamic processes like storms and floods of the Rhone.

1 - Sadoul, 1996



The expansion of the salina between 1944 (above) and 1994 (below) has substantially modified the landscape of Salin de Giraud. After Sadoul, 1996





The relationship between area of the salinas and the number of breeding colonial charadriiformes, Salin de Giraud, 1953-1995. After Sadoul, 1996.

The variations in the bird colonies

The small charadriiforms (gulls, terns, avocet) responded rapidly to the changes in the salinas. The old islets, degraded by erosion, were abandoned and the newly developed areas colonised. The numbers of birds increased and the expansion of the salinas appears to have been beneficial for their nesting.

The increase in waste tips and the development of trawling has allowed the population of Yellow-legged herring gull to increase considerably along the French coast. This species colonises islets in the salinas where the stable water levels allow regular breeding. Herring gulls are aggressive and occupy these sites to the detriment of other species, which are pushed out and must colonise new islets as the salinas expand.

From 1973, however, the growth of the salinas had finished, new islets were no longer created. The smallest islets had disappeared because of erosion whereas the bigger ones progressively were colonised by herring gulls. Given this situation, the small charadriiforms had no alternative to leaving the salinas or to colonising unsuitable sites. Their numbers declined sharply. Today the surviving colonies are found on dykes, where predators and human disturbance are the main causes of low breeding success. Monitoring of breeding success in 1993 and 1994 has showed that none of the colonies produce enough young to maintain themselves.

Management of birds and salinas

Water management: a limiting factor in the medium term

The history of the colonisation of the Camargue salinas by birds indicates the limiting factors for their breeding which need to be addressed by management. In the long term, the modification of the functioning of the habitats has different consequences for the species depending on their breeding strategies.

Water management may influence the richness of the feeding habitats, but the stabilisation and predictability of the water levels have negative effects. Permanent summer flooding results in erosion of the islets, which are no longer being replaced naturally. The predictability of the water levels encourages species which like stabile habitats (Yellow-legged herring gull) in favour of species adapted to unstable habitats. In the long term, the stability of the salina habitat causes a decrease in the diversity of the bird communities.

In the Chott Djerid in Tunisia, flamingos and slender-billed gulls breed only in years with heavy rain, when the islets are isolated. Although breeding does not occur each year in these natural wetlands, the variable conditions they provide allow some breeding over long term periods. In contrast, the stability of the water level in the salinas allows birds to install each year but threatens breeding success in the long term.

This situation is repeated in all the salinas along the French coastline, and probably in most of the Mediterranean salinas where the Yellow-billed herring gull populations are expanding. Only in places where this species is rarely present are colonies of other species able to function well.

J. Walmsley

Water in modern salinas is pumped by powerful electric pumps.

Management of breeding sites in active salinas

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 herring gull. However, the conservation of the salina landscape and keeping management costs down remains a priority.

The construction and restoration of sites[1]

Isolated from predators, the artificial islets must provide sufficient areas for the colonies. The relief and the substrate should allow the eggs to be sheltered from storms and spray.

An experiment in the salinas of Giraud provide a useful example. In 1994, sixteen islets of clay, a total area of 450 m^2, bare and degraded by erosion, were used by a mixed colony of Common terns, Avocets and Black-headed gulls. Only a few tern chicks were fledged.

In January 1995, these islets were restored with the help of the CSME[2] to create one islet of 1,600 m^2. 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 Avocets had installed, closely followed by Slender-billed gulls, Common terns, Little terns and Black-headed gulls (respectively 44 %, 99 %, 33 %, 66 %, and 5 % of the breeding pairs in

A. Johnson

Bringing in gravel or sand helps colonial waterbirds to breed on islands of compacted mud.

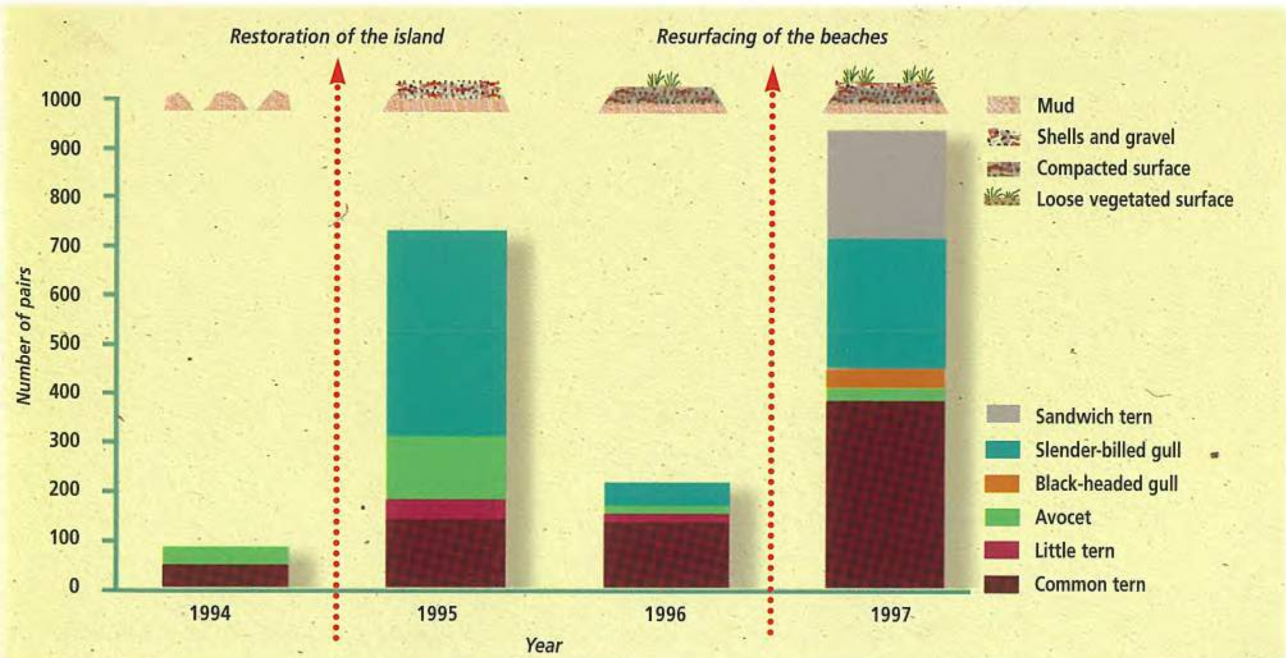
1 - Buckley & Buckley
2 - Compagnie des Salins du Midi et des Salines de l'Est

The predictability of the water levels due to management for the salinas is the reason why Yellow-legged herring gulls monopolise the islets as breeding sites. Management of the sites based on control of water levels, which is needed to maintain the isolation of the islets, could restore variability in the annual flooding conditions of certain lagoons. This type of water management, which would be difficult in active salinas, would be suitable for inactive salinas. It has not yet been tested in the field.

the salinas). The Slender-billed gulls formed four groups on four of the gravelled beaches; the other species used the remaining beaches and the peripheral clay areas. Breeding success was low for the Avocets, only two pairs fledged young, perhaps due to predation of the chicks by Yellow-legged herring gulls. The 138 pairs of Common terns produced between 0.5 and 1 chick per pair; this result is without doubt attributed to the nests being on clay and the eggs suffering heavy losses. About 400 Slender-billed gull chicks were fledged. The Black-headed gulls installed themselves late and in small numbers due to the absence of vegetation, and the eggs never actually reached hatching.

In 1996, part of the material deposited the previous year was blown away, no further work was done, the remains of the shells and gravel being encrusted in the clay were not available as nest building material, so the numbers declined. During the 1996-97 winter, more shells were deposited on the beaches. In the following breeding season, birds returned in large numbers together with a new species, Sandwich tern. By now the vegetation cover had increased which contributed to the increase in the numbers of Black-headed gulls – 30 pairs nested.

Improvement of nesting beaches has a positive effect on breeding gulls and terns. (Tour du Valat data).



Management of feeding and breeding sites in inactive salinas

The biological value of inactive salinas should not be forgotten. However, the maintenance and improvement of their characteristics as feeding and breeding sites require different management to that carried out in active salinas.

Unused salinas, sites for bird conservation

Unused salinas offer an enormous potential for the conservation of birds in the Mediterranean.

The geographical distribution of these biologically interesting zones compensates for the fragmentation of natural wetlands by providing stop-over points during migration, and wintering habitat. Their disappearance would increase the isloation of natural wetlands, making exchange between populations difficult. This is very important in the western Mediterranean, where the human pressure is greatest, and where there are many inactive salinas.

Their advantage over active salinas is the possibility of managing the water levels for conservation. This can be approached from two complementary angles: improving feeding for birds, and providing good breeding sites.

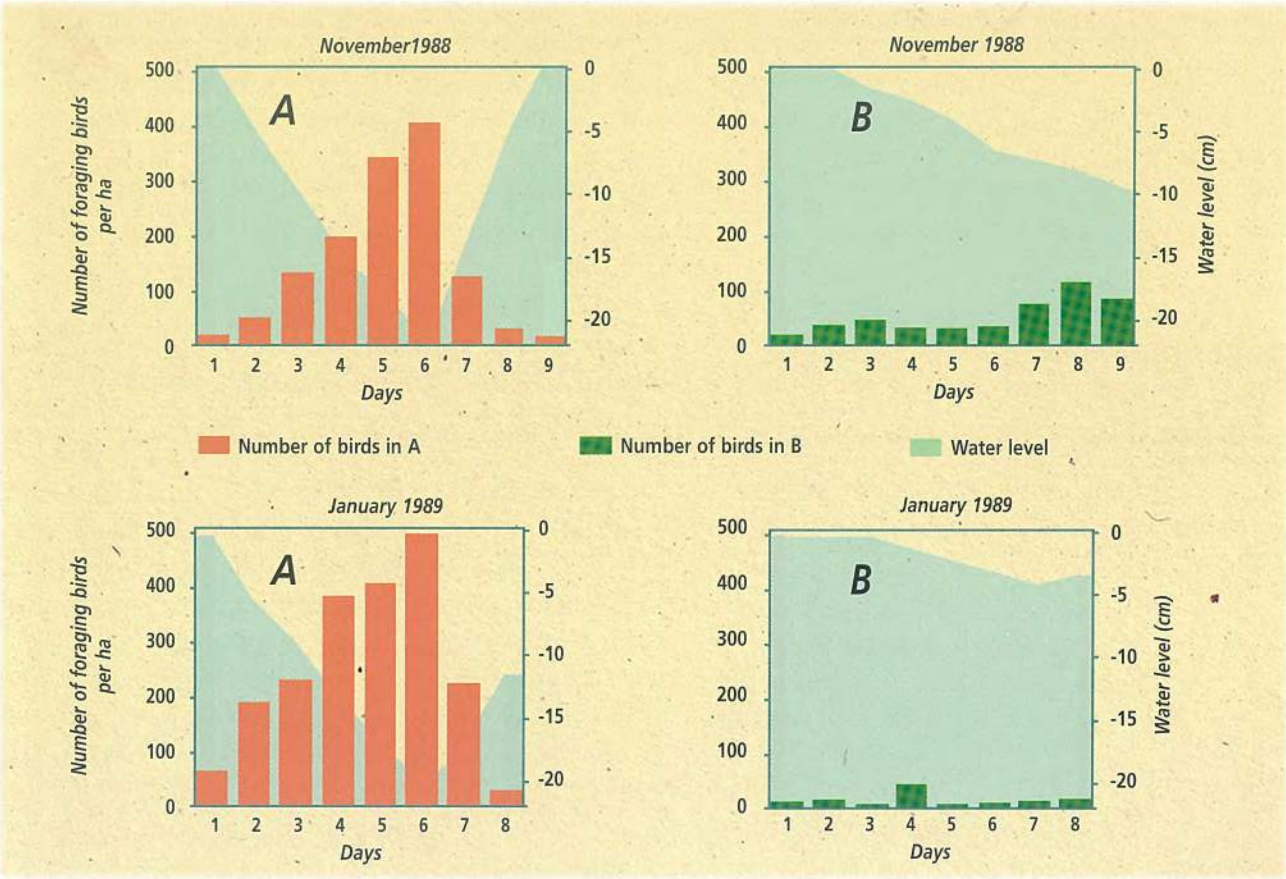
Management of food resources

Management of water in the unused salinas should imitate that of active salinas in order to guarantee high productivity from the habitat. The carrying capacity of a salina can thus be increased by varying the water levels.

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 isolated preventing an increase in concentration, either by pumping the brine back into the sea, or by bringing in more sea water. In relation to the active salinas, the carrying capacity of birds would be greater. This management would depend on the technical and financial potential at each salina; further harvesting of salt would not be possible.

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[1] were carried out in the salinas of Berg River (South Africa) during the wintering period for waders (southern hemisphere's summer). The water level in a salt pan of 11.3 ha was lowered by 20 cm in December, January and March exposing 7 ha of mudflats. The impact of this management on the waders, calculated from ten daily minimum counts during 6-10 days, was compared with the management of a neighbouring

1 - Vélasquez, 1992



Fluctuations in water levels affect densities of foraging wading birds. Salinas of Berg river, South Africa. After Velasquez, 1992.

pan of 15 ha where the water level was maintained. The waders responded rapidly to the lowering of the water level; in six days the density of birds feeding went from 19 to 404 per hectare, and 70-500 in December and January respectively. No significant modification was seen in the number of waders in the control. The reaction was particularly noticeable with the birds arriving on migration in December, due to their high energy requirements in comparison to the residents.

The lowering of the water level of the experimental pan pushed the salinity from 27 g/l to almost 50 g/l, which led to the disappearance of amphipods (mean density in December - 24,400 individuals/m^2) and an increase in chironomid larvae (mean of 2,800 larvae/m^2 in December against 12,700 in March). This may explain why the species did not show the same response to the lowering of the water level across the season. In December, the increase of Greenshank *Tringa nebularia*, which feeds on amphipods, was exponential until January when it became linear and almost zero in March. The Curlew sandpiper *Calidris ferruginea* fed mostly on polychaete worms in the mudflats at low tide in January and March and responded only in a linear manner to the lowering of the water level. In contrast, the numbers of Ruff

Philomachus pugnax and Ringed plover *Charadrius hiaticula* increased in the experimental zone because they eat chironomids. For small waders, such as Little stint the response was strong, in each period, because the maximum water levels made their food inaccessible.

It is also possible to favour the production of chironomid larvae, a key element in the diet of water birds, particularly waders.

In favourable flooding and temperature conditions, the colonising capacity of chironomids after drying out and the rapid turn over rate of generations explains the high production in disturbed or temporary habitats. In addition, by killing the vegetation, the drying out favours the development of chironomids, which are mostly detritovores. Water management must take these factors into account and adapt them to the cycles of the different species present[1]. The lowering of the water levels at the beginning of spring, on the one hand increases the accessibility of the food resources to the birds, and on the other leads to the death of the algae. From the end of April, when the water temperature is above 12°C, rapid flooding of the lagoons encourages a proliferation of chironomids (first peak hatching). Maintaining the flooding until August guarantees an optimal development (second peak hatching). The water levels can then be lowered during the autumn migration of waders. Flooding in early October results in a third peak, essential because the last generations contribute to the production of individuals for the following season. The maintenance of flooding throughout winter guarantees their survival[2].

Management of nesting sites

The management of water levels has been used to control vegetation, to encourage the production of invertebrates or fish, and the use by birds of their food resources. Until recently water management has not been used to reduce competition between species by the regulation of access to nesting sites. A site accessible to terrestrial predators is unsuitable for breeding colonial birds. Successive flooding, but at different periods, of a series of lagoons can favour the breeding of species such as small charadriiforms, and prevents the installation of Yellow-legged herring gulls.

This management has the advantage of restoring some instability to these habitats, an important element in the structure of the communities, on a coastline which is more and more developed and stabilised.
It can become part of a multi-site management programme where each inactive salina, even the smallest, is an element in a network of these habitats.

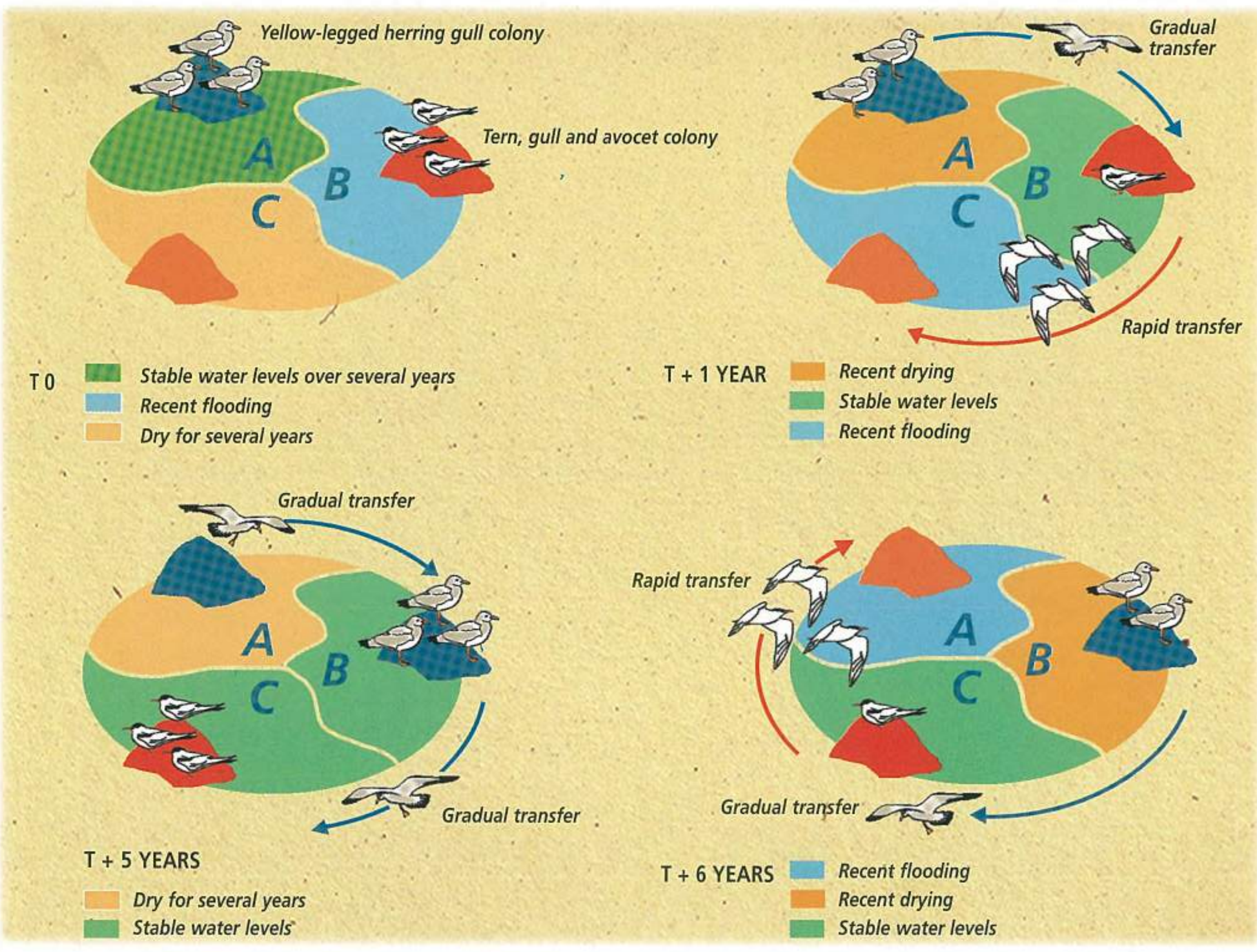
Today conservation efforts, must apply the principles of sustainable development in order to have some chance of success. Collaboration between salt producers, with their socio-economic constraints, and biologists with the environmental constraints, can allow the emergence of an effective conservation policy covering all salinas. Experimentation

1 - Rehfish, 1994
2 - Tourenq, 1975

and the success of the management proposed here imply medium and long term monitoring, in order to allow management to adapt as the data come in, and to provide tools that can be applied elsewhere.

Water management for salt production is at the root of the richness of these habitats, but it also induces limits, such as erosion of islets, or the stability of water levels, which favours a major predator, the Yellow-legged herring gull. These factors lead to a decline in the diversity of birds in the salinas: specific management measures to reconcile contradictory imperatives are then necessary.

By manipulating water levels each year, breeding of small colonial waterbirds can be favoured at the expenses of Yellow-legged herring gulls.



E. Vialet

Conservation of salinas

Mediterranean salinas are vital wetlands for the conservation of water birds.

These habitats, whose functioning is linked to salt production, are in danger of losing their biological and cultural values due to changing economics driven by world trade and competing land-uses.

Salins de Giraud, France.

The economic context of salt production

Salinas are functional wetlands, with both biological and cultural values. Their fragile balance, however, is linked to salt production and, therefore, to a market which is subject to competition from terrestrially-produced salt and world trade.

The difficulties facing active salinas

To remain competitive in the world market, salinas are being modernised. Large number of manual workers have been replaced by heavy machines, windmills and steam pumps have given place to motors and electric pumps, which require little maintenance. This change, induced principally by the cost of labour in western Europe, has reduced the wardening of salinas. Because of their position on populated coastlines, this has led to increased disturbance for the birds.

Sediments quickly fill channels and pans, particularly in the pans where gypsum is precipitated. This causes problems for water circulation but clearing out these sediments can be costly. The carrying capacity for birds, for feeding and breeding, is reduced by the reduction of the flooded areas, and also because the islets are then connected to the land.

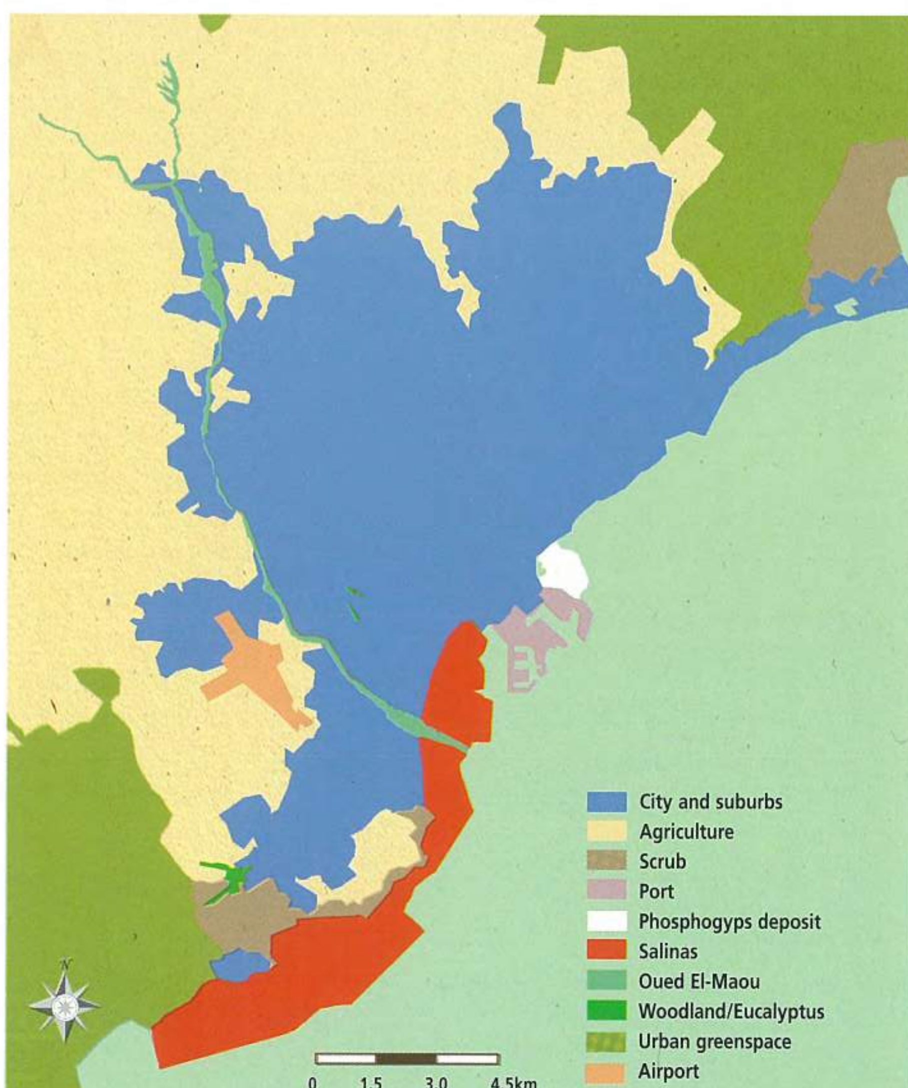
Sometimes large conurbations situated along the coast or on rivers, can pollute the surrounding waters due to inefficient sewage systems. This can affect salinas which take their water from lagoons with polluted water. The risk of contamination for the salt can be such that the salinas may have to close down, as in Molentargius and Quartu in Sardinia.

The consequences of abandoning salt production

Some salinas in the Mediterranean have begun a process of winding down their operations, in view of partial or complete closures. Only a few have been restarted in the last few years, like the one on Limnos (Greece). Without water circulating this leads to an immediate loss of biological richness of the salina; without any intervention, the biological richness will be as occasional as the rains.

A number of active salinas (54 %) have become integrated into the urban and industrial tissue of the coastline, which has been increasing since the beginning of 1960's, for example Ibiza, Sfax (Tunisia) and in Sicily. The closing down of salinas is due to excessive pressure of competition from other activities to use this space. Between 1985 and 1990, more than 7,000 ha of inactive salinas were reclassified[1] in the planning system as urban, industrial, port, airport, or tourist zones.

In Portugal, Spain, Sičily and particularly in Greece, the salinas are being reconverted into economically viable aquaculture farms[2]. Although aquaculture does not destroy the salina landscape, the development and functioning of the production systems leads to a major loss in biological diversity: fish-eating birds are excluded by dissuasive systems.



The salinas at Sfax, Tunisia, have gradually become enclosed by industry and the suburbs of this expanding city Blue plan, 1997.

1 - Marin & d'Ayala, 1996
2 - See n° 3 in the same series.

What alternatives for salinas?

Today it is fully accepted that the heritage value of the salinas, biological and cultural, results from the production of salt. Faced with the need to be economically viable, salinas are closing at an alarming rate. Subsidies from the European Union with the aim of maintaining rural landscapes is one solution.

Salinas in activity

The biological value of active salinas shows that production and biodiversity conservation are not incompatible. The threats to salt production vary according to local development policies and the degree of resistance to world competition.

Production units belonging to small private companies are the most threatened. Governement support, such as reduced taxes on salt production, could contribute to maintaining their viability.

All the same, whether they be small or large, private or state-owned, the salinas could benefit from international aid for management actions aimed at biological conservation. Agri-environmental measures[1] developed by the European Union could be applied to salt production particularly because in certain countries like France, it is legally an agricultural activity. These different methods of financial compensation[2] are aimed at helping the agricultural uses of land while taking into account the protection and improvement of the environment.

These measures are also aimed at encouraging management for public access and leisure, and appear well-adapted for salinas which could play an important role; since they offer a real potential for education by providing in natura the history of salt and its production.

Salt in the world

From 1950 to 1996, the world production of salt increased strongly, growing from 48.1 to 250 millon tons[3], spread quantitatively as follows:
Central and North America: 33.2 %;
Asia and Pacific: 29.1 %;
Western Europe: 19.7 %;
Central and Eastern Europe: 10.6 %;
South America: 10 %;
Africa - 1.8 %.

In Europe, its qualitative distribution[4] is as follows: in brine: 42.8 %; salt produced by boiling: 24.7 %; rock salt: 17.4 %; sea salt: 12.2 %; salt of mixed origin: 2.9 %.

It is used in several sectors[5]:
chemical industry: 44 %;
salting roads in winter: 34 %;
human consumption - 10 %;
diverse industries (including agriculture and water softening): 5 %.

1 - Art. 21-24 of regulation CE n°2328/91 of 06.08.91
2 - Art. 1 of regulation CE n°2078/92 of 30.06.92
3 - US Bureau of Mines, 1997
4 - European Salt Producers Association
5 - Comité des Salinas de France, 1997

A natural and cultural heritage, as interesting in the summer as in the winter, with an infrastructure of dykes enabling access to areas unknown to the public, their proximity to large coastal cities, are great advantages for the development of an activity which would guarantee the tranquillity of the birds. It could, in addition, create employment in the form of specialised guides.

J. Walmsley

Harvesting of *Artemia* for the aquarium trade is a potential source of revenue for salinas.

Aquaculture and birds

There are two types of aquaculture. Traditional fish farms (Portugal) which have kept the initial structure of the salina. Only one part is managed for fish production and the water depth is generally more than 1 m; the other pans, where the depth is often less than 0.15 m is used by birds.

In intensive fish farms, the dykes are devoid of vegetation, and the pans have abrupt sides which means that the water levels are controlled precisely. The initial salinas are transformed and their depth varies between 1-1.5 m, making feeding by birds difficult.

They are often good feeding sites only when the pans are empty and the pan bottom becomes accessible[1]. The value of these salinas in terms of nesting is almost zero.

In Portugal, for example, 69 % of the breeding black-winged stilts are found in salinas in or out of activity, only 3 % use traditional fish farms, and 0 % intensive fish farms.

In the Tagus estuary, the density of this species declines from 2-3 pairs/10 ha in the salinas, to 0.7 pairs in the salinas transformed for traditional fish farming.

1 - Perez-Hurtado, 1995

J. Walmsley

Urbanisation of the shoreline causes salinas to disappear.

A compromise between production and protection: co-operation between the CSME and the Station biologique de la Tour du Valat

For several tens of years in the Camargue, the CSME has been working with the Station biologique de la Tour du Valat in order to conserve the biological value of the salinas. Various actions have been carried out to protect the breeding colony of the flamingos, such as the periodic restoration of the breeding island.

Currently, faced with the disappearance of the breeding islands of the colonial charadriiforms, the CSME propose, with the Tour du Valat, to prepare a strategy of restoration work and management of the breeding sites. This will allow experimental tests of different types of management, specific to the salinas, in order to apply them elsewhere in the long term. This interdisciplinary partnership brings together professional salt producers, biologists, civil and water engineers, making it possible to optimise environmental management within Mediterranean salinas.

The development of substitution activities

The absence of salt production in the inactive salinas leads, in addition to their decrease in biological value, to their transformation into other economic activities which degrade them. It is therefore urgent either to protect them by buying out the owners, or to propose a type of development which aims at guaranteeing their role in bird conservation in the Mediterranean.

Mediterranean salinas: different means of protection

The natural and cultural heritage values of Mediterranean salinas and their importance for waterbird conservation are not yet sufficiently taken into account within institutional and conservation structures. Although they are not protected by any specific legal or financial measure, the situation has been improving over the past few years.

At a world level, UNESCO's programme "Man and Biosphere" has developed a network of biosphere reserves. This label can apply to any area which already has legal protection, and can help the site to find funds for ecosystem and genetic resource conservation, education and maintenance of traditional activities. In France, the Camargue became a biosphere reserve in 1977.

The heritage value of the Mediterranean salinas in the European Union is demonstrated by the fact that "more than 75 % of these areas are currently under some form of special protection, either urban or by specific legal measures for conservation"[1].

The European Wild Dirds Directive 79/409/EEC requires Special Protected Areas to be designed, the ecological value of these sites must be maintained; they include the salinas of Ibiza and Formentera (Balearic Islands) and Margherita of Savoia (Italy).
Within the framework of the European Habitats Directive of 92/43/EEC, an inventory of sites of European importance for terrestrial and aquatic habitats, as well as threatened species of fauna and flora is being prepared. The objective is to preserve biodiversity by the conservation of natural habitats. "The pans and lagoons of the salinas... where they are the result of the transformation of an old natural lagoon or an old salt marsh and are only lightly affected by the salt production" are part of the priority habitats. In the long term, these habitats will be part of the Natura 2000 network.

At the national level, salinas are often included in extensive protected areas: national parks, nature reserves, etc. In France the list of sites of national importance for fauna and flora shows the biological richness of a number of Mediterranean sites including the salinas, which in the long term should be covered by legal protective measures. Town and country planning can be an effective means of protection: for example the Loi "littoral", 3 January 1986 (France), dealing with coastal planning, conservation and development of the coastline; identifying the natural habitats to be conserved, is gradually being applied.

The river basin management strategy of the Agence Rhône-Méditerranée-Corse, identified an area of the Mediterranean coastline and broke it up into fifty homogeneous sections, including salinas; conservation actions are planned to deal with the large numbers of visitors, eutrophication, and to reduce urban and industrial pollution[2].

1 - Marin & d'Ayala, 1996
2 - Comité de Bassin, RMC, 1995

The biological value of the inactive salinas can be restored and even improved. In the south-east of Spain, the salinas of del Saladar, filled only by rainfall, each year holds five times fewer waders than the inactive salinas of Murtula, which is four times as small, but a film of water is maintained artificially. The density of waders is higher than that of the modern salina close to Sanat Pola. However, there is no difference in numbers during the breeding period[1].

In unused salinas, the main problem is the lack of economic activity to finance the management and functioning of the water system. In Portugal or south-west Spain, the tides control the water levels in the inactive salinas. In the Mediterranean, most of the pans can only be filled by pumping in water. The more extensive the salina is, the more costly is water circulation. Adequate management cannot therefore be done by a NGO alone, as it requires financial support.

The European Union agri-environmental measures could be applied because article 1 says that these subsidies are to "encourage the maintenance of abandoned agricultural and forestry land where necessary for ecological reasons, natural or fire risks and prevent risks linked to the depopulation of agricultural regions".

Although the impact of the closure of salinas on the sea defences is not a current problem, other risks such as botulism are already occurring in inactive salinas (Lion salina, Etang de Berre, France). Integration of these salinas into a conservation structure (Regional Park, nature reserve) can be the means to protect them in the long term. Such a project is being studied in Cadiz Bay (Spain) and the Languedoc-Rousillon (France). The development of adjacent activities, involving the willingness of the relevant actors, can lead to auto-financing.

1 - Robledano Aymerich, 1995

An example of development: Secovlje salinas in Piran Bay (Slovenia)[1]

Secovlje salinas, 738 ha, are the third largest salinas of the eastern side of the Adriatic sea. Probably created a thousand years ago, they became very innovative during the 19th century, combining the pleasant climate with the medicinal effect of the mud the region has become a holiday destination.

In the 1960's, following the high production costs, the salt activity declined. Between 1962 and 1995, the available jobs dropped by 85.5 %, from 165 to 24, within the Piran region.

During 1970's and 1980's, mass tourism developed with the construction of hotels, marinas and an airport. Today, only 263.5 ha are used for salt production, the harvest is done by temporary staff (retired people, students, odd job people).

Published in 1976, an inventory of the exceptional natural heritage of Slovenia stipulated the need to designate the Secovlje salinas as a protected area. Considered as one of the two most important wetlands in Slovenia it has been designated an Important Bird Area in 1980.

In 1990, a government decree recognised their local and national value for: conservation, scientific research, education and culture; this was the reason for the creation of the Secovlje Salina Landscape Park. Salt production is essential for the conservation of the site. In the abandoned section, four nature reserves have been established. The development of new activities (tourism, aquaculture, etc.) is planned on the condition that these activities do not disturb the natural balance. In 1991-1995, about 6,000 visitors/year were received and two pans were restored to show the public how salt is produced. In 1993, the designation of the site as a Ramsar* site demonstrated its status as an internationally important wetland.

Despite these measures, the conflict between different activities persists. A strategy for the development of the site has been proposed, taking into account the conservation objectives. Based on the co-ordination of interests and the integration of activities, it suggests the continuation of salt production as the solution to the conservation of the natural and cultural heritage value of the site.

The Secovlje salinas in Slovenia.

T. Salathé

1 - Beltram, 1996

The need for good information

The value of Mediterranean salinas for nature is that they constitute a network of wetlands for birds. The actors have organised themselves into a network, based on the exchange of experiences and the complementarity of different actions within salinas around the Mediterranean.

Acquiring knowledge

Salinas remain a relatively unknown habitat, particularly in terms of development and management. It is, therefore, urgent to establish a network to promote the exchange of knowledge on work being done in a number of sites in the Mediterranean. The aim is to help conciliate salt production with nature conservation and the maintenance of salt production in small salinas.

For the first time, a workshop was organised in 1996 in Olhão (Portugal) by the Ecology department of Cadiz University and the Portuguese Society for the study of birds (SPEA). There were three main themes of work: carry out an inventory of the salinas in the Mediterranean which would indicate the status and threats to them and their birds; information is needed about management of salinas, whether they are in activity or not, or transformed; develop a research programme designed to define the impact of water management on invertebrate populations, estimate the benefit for birds using the salinas on migration, indicate the breeding status of the birds as a function of environmental factors related to management and the protected status of the salinas[1].

The Mediterranean network groups together different actors, conservationists and salt producers, in order to take account of the socio-economic and conservation values within the framework of sustainable development. It helps with communication and exchange of information and experiences between sites and puts in place integrated management of bird populations, making use of the potentialities of a network of sites.

Development of institutional actions

The importance of salinas, for nature conservation and cultural interest, was recognised during an international conference "Nature and workmanship: artificial wetlands, threatened coastal areas in the Mediterranean". Organised by INSULA[2], with the participation of DG XI of the European Commission and UNESCO, it was held in Paris in 1997. The recommendations of the meeting were that information, public awareness and transfert of experiences were needed for actions in favour of salinas.

1 - Anonyme, 1996
2 - International Scientific Council for Island Development

The future of salinas and conservation

The future of the Mediterranean salinas heritage value depends on salt production. With the closure of salinas for salt production, the need is for innovative ideas, such as the extension of the European Union agri-environmental measures to salinas, the creation of other activities in the framework of management sharing between partners, who have had no contact with each other until now, and the development of a network of information between different actors in the world of salt production.

Organising field visits to remaining sites increases awareness of their importance. Here, at Carloforte in Sardinia.

J. Walmsley

The salinas of Cabo de Gata (Spain)[1]

Cabo de Gata salinas are situated in a "Natural Park"; the different management plans consider that continuation of the salt production is a guarantee for the maintenance of the ecological and cultural value of the site.

In 1987, an agreement was signed about the "collaboration for the protection of existing natural resources in the Cabo de Gata salinas"; it constitutes a model of co-operation and shared management of a natural habitat between public administration and the salt industry.

1 - Marin & d'Ayala, 1996 ; Castro Nogueira, 1993

Salins

Conclusion

The specific geographical conditions, warm, dry climate, low-lying coasts over half of the coastline, high salinity sea water, combine to explain the early development of salt production in the Mediterranean basin.

Production methods have changed over the centuries. Gradually the salina landscape has became integrated into the coastal landscape, to the point that it is now an integral part of the cultural heritage. A network of salt trading routes, *viae salariae*, extended across seas, oceans and continents. Huge numbers of people were involved, including salt producers, farmers, and "faux sauniers". A salt policy was developed with the leaders of the Church and the "lords of salt" who used this

Salt crystals.

element as a means of gaining power. The salt industry developed with traders, inventors and modern ideas. Today, world trade and the worries of economic viability has diminished the importance of this natural resource.

Beyond these economic and cultural aspects, salinas, which can be thought of as artificial wetlands, constitute an important biological heritage in the heart of a region where the pressure of human activity is intense. They act as a refuge for birds, a quiet resting, feeding and/or breeding place.

The main interest of salinas is in the water management, which is the basis of their economic interest, salt production. The important points of this management are the maintenance of water levels in periods which are naturally, and/or normally dry, the gradient of confinement and salinity, and the stability through time of the different cycles. These different factors has led to the development of a mosaic of habitats where the productivity of unicellular organisms and invertebrates, the main food of waterbirds, is particularly high.

The high predictability, however, that results from this management is in contrast to the natural instability of coastal wetlands and this can produce limiting factors for the breeding of birds: severe erosion of islets without creating others; Yellow-legged herring gulls which prefer stable conditions become a serious competitor and predator, tending to replace the other colonial species, which have a higher biodiversity value. The management of salinas for salt production can thus reduce biodiversity of birds, which is the basis of the biological richness of salinas. This decline is seen only over the long term.

J. Walmsley

Salinas are critical sites for the breeding of colonial waterbirds.

Conclusion

A. Johnson

The Oualidia salinas in Morocco are classified as a "Site of Biological Importance".

Today, salinas are at a turning point in their history. Facing numerous constraints, some of the salinas, for the most part in the north of the Mediterranean, have become or are becoming inactive. The biological richness of salinas disappears quickly in the absence of adequate water management. 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. The application of sustainable development proposed by UNCED (Rio 1992)[1], at the scale of the Mediterranean basin should lead to a systematic approach to the problem of the future of the salinas. Natural constraints and economic objectives should be harmonised, and innovative measures should be found, whether they be biological, institutional, legal, financial or educational, for the conservation of the natural and cultural heritage of Mediterranean salinas.

1 - United Nations Conference on Environment and Development.

List of bird species frequenting Mediterranean salinas

Family	Species	Eastern Med.	Period	Frequency	Activity
Podicipedidae					
	• *Tachybaptus ruficollis*		M W	+	F R
	• *Podiceps cristatus*		M W	++	F R
	• *Podiceps nigricollis*		M W	++	F R
	• *Podiceps griseigena*	*	W	+	F R
Phalacrocoracidae					
	• *Phalacrocorax carbo*		M W	++	f R
	• *Phalacrocorax pygmeus*	*	M W	+	f R
Pelecanidae					
	• *Pelecanus crispus*	*	Y	+	R
	• *Pelecanus onocrotalus*	*	M W	+	R
Ardeidae					
	• *Ardea cinerea*		Y	++	n f R
	• *Ardea purpurea*		M	+	R
	• *Egretta garzetta*		Y	++	N F R
	• *Egretta alba*		M W	++	f R
	• *Ardeola ralloides*		M	+	R
	• *Bubulcus ibis*		Y	++	n R
	• *Nycticorax nycticorax*		M	+	R
	• *Ixobrychus minutus*		M	+	R
	• *Botaurus stellaris*		M	+	R
Ciconiidae					
	• *Ciconia ciconia*		M	+	f R
	• *Ciconia nigra*		M	+	f R
Threskiornithidae					
	• *Plegadis falcinellus*		M	+(+)	f r
	• *Platalea leucorodia*		M W	++	F R
Phoenicopteridae					
	• *Phoenicopterus ruber*		Y	++	N F R
Anatidae					
	• *Cygnus olor*		M W	+	R
	• *Anser anser*		W	+	R
	• *Anser fabalis*		W	+	R
	• *Anser albifrons*	*	W	+	R
	• *Tadorna ferruginea*	*	Y	+	n f R
	• *Tadorna tadorna*		Y	++	N F R
	• *Anas strepera*		Y	+	n f R
	• *Anas platyrhynchos*		Y	++	N f R
	• *Anas querquedula*		M	+	f R
	• *Anas clypeata*		M W	++	f R
	• *Anas acuta*		M W	++	f R
	• *Anas crecca*		M W	+	f R
	• *Anas penelope*		M W	++	f R
	• *Aythya ferina*		M W	+	f R
	• *Aythya fuligula*		M W	+	f R
	• *Netta rufina*		Y	++	N f R
	• *Oxyura leucocephala*		M W	+	f R
	• *Mergus serrator*		M W	++	F R
	• *Mergus albellus*	*	M W	+	F R
Rallidae					
	• *Rallus aquaticus*		Y	++	n F R
	• *Gallinula chloropus*		Y	++	n F R
	• *Fulica atra*		M W	++	F R
Haematopodidae					
	• *Haematopus ostralegus*		Y	++	N F R
Recurvirostridae					
	• *Recurvirostra avosetta*		Y	++	N F R
	• *Himantopus himantopus*		Y	++	N F R
Burhinidae					
	• *Burhinus oedicnemus*		S M	++	n F R
	• *Glareola pratincola*		S M	++	n f R
	• *Glareola nordmanni*	*	M	++	f R
Charadriidae					
	• *Vanellus vanellus*		Y	+	n F R
	• *Charadrius alexandrinus*		Y	++	N F R
	• *Charadrius dubius*		S M	++	n F R

Family	Species	Eastern Med.	Period	Frequency	Activity
Glareolidae					
	• *Charadrius hiaticula*		M W	++	F R
	• *Charadrius asiaticus*	*	M	++	F R
	• *Charadrius leschenaultii*	*	M W	++	F R
	• *Charadrius pecuarius*	*	Y	++	N F R
	• *Pluvialis apricaria*		M W	+(+)	F R
	• *Pluvialis squatarola*		Y	++	F R
	• *Hoplopterus spinosus*	*	Y	++	N F R
Scolopacidae					
	• *Calidris alba*		M W	++	F R
	• *Calidris alpina*		Y	++	F R
	• *Calidris canutus*		M W	++	F R
	• *Calidris ferruginea*		M W	++	F R
	• *Calidris minuta*		M W	++	F R
	• *Calidris temminckii*		M W	++	F R
	• *Limicola falcinellus*		M	++	F R
	• *Philomachus pugnax*		M W	++	F R
	• *Limosa lapponica*		M W	++	F R
	• *Limosa limosa*		Y	++	F R
	• *Numenius arquata*		Y	++	F R
	• *Numenius phaeopus*		M	++	F R
	• *Tringa cinereus*		M (W)	+(+)	F R
	• *Tringa erythropus*		M W	++	F R
	• *Tringa glareola*		M	+(+)	f R
	• *Tringa nebularia*		M W	++	F R
	• *Tringa ochropus*		M W	+(+)	f R
	• *Tringa stagnatilis*		M W	++	F R
	• *Tringa totanus*		Y	++	N F R
	• *Actitis hypoleucos*		M W	++	F R
	• *Arenaria interpres*		M W	++	F R
	• *Gallinago gallinago*		M W	++	f R
Phalaropidae					
	• *Phalaropus fulicarius*		M	+	F R
	• *Phalaropus lobatus*		M	++	F R
	• *Phalaropus tricolor*		M W	+	F R
Stercorariidae					
	• *Stercorarius parasiticus*		M	+	R
Laridae					
	• *Larus cachinnans*		Y	++	N f R
	• *Larus melanocephalus*		Y	++	N R
	• *Larus ridibundus*		Y	++	N f R
	• *Larus genei*		Y	++	N F R
	• *Larus armenicus*	*	M W	++	f R
	• *Larus audouinii*		Y	++	N R
	• *Larus canus*		W	+	f R
	• *Larus fuscus*		M W	++	f R
	• *Larus ichthyaetus*	*	M W	+	R
	• *Larus minutus*		M	++	F R
	• *Chlidonias hybrida*		M W	+	f r
	• *Chlidonias niger*		M	++	F R
	• *Chlidonias leucopterus*		M	+(+)	F R
	• *Sterna nilotica*		S M	++	N f R
	• *Sterna hirundo*		S M	++	N F R
	• *Sterna sandvicensis*		Y	++	N R
	• *Sterna albifrons*		S M	++	N F R
	• *Sterna bengalensis*		S M	+	n R
	• *Sterna caspia*		M W	++	F R
	• *Sterna dougallii*		M	+	f R
	• *Sterna paradisaea*		M	+	f R

Eastern Med.: * = species found only east of a line drawn between Albania (east) and Tunisia (west).
Période:
M = during migration (spring or autumn),
W = winter,
S = summer,
Y = year round.

Frequency:
+ = rare;
++ = regular;
+(+) = rare or regular according to locality.
Activity:
N,n = nesting;
F,f = feeding;
R,r = resting.
A capital or small letter indicates a principal or secondary activity.

Glossary

Allex: a roman sauce made from fermented fish.

Brine: a strong solution of salt and water.

Calentadore: basin or pan (Spain).

Chott: seasonal salt lake.

Confinement: the degree of restriction of (water) movement.

Cristallizadore: see “harvesting table”.

Cysts: a dormant stage protected by a thick membrane.

Euryhaline: ability to tolerate a wide range of salinities.

Faux-saunier: smuggler of salt.

Garum: see “allex”.

Harvesting table: small, levelled pan, usually square, where the crystallised salt is harvested.

Intertidal (zone): area lying between the high and low tide marks.

Mesohaline: salinities close to that of sea-water.

Noria: a water wheel or chain with buckets attached for raising water from a stream or well. Usually powered by animal traction.

Oligotrophic: poor in nutrients.

Pleistocene: first epoch of the Quaternary period.

Ramsar (Convention): intergovernemental treaty concerning wetlands of international importance. Signed in Ramsar, Iran in 1971.

Rock salt: salt of terrestrial origin, mined underground.

Roost: a place where birds sleep or nest.

Salinity : the total concentration of soluble salts.

Salt marshes: an area of marshy ground intermittently flooded with salt water, or where the soil contains salt.

Salt pan: a shallow basin used to concentrate sea-water and precipitate salt.

Sansouire: deltaic wetland habitats typical of the Camargue and dominated by halophytic vegetation.

Sebhka: semi-permanent salt lake.

Sphagnum: mosses of the genus *Sphagnum*

Stockfish: dried cod

***Viae salariae*:** the "salt roads" of Roman times.

Wader: wading birds of the order Charadriiformes.

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Station Biologique de la Tour du Valat

The term "wetlands" includes a wide range of different habitats, including deltas, lagoons, marshes, lakes and riverine forests. All play an essential role in the water cycle and support a rich diversity of flora and fauna. Wetlands also provide important benefits to people: reducing flooding, improving water quality, providing recreation areas, water supply, fish, game and other natural resources.

Today these areas are threatened. If their destruction continues, the benefits for mankind and for nature will be lost. The importance of their conservation is therefore of critical concern even beyond the protection of endangered species and natural habitats.

In this context, Tour du Valat has adopted the mission ***"to halt the loss and degradation of Mediterranean wetlands and to restore them".***

Research

Any effective policy for nature conservation requires scientific understanding based on rigorous research. Within this framework, Tour du Valat has established an interdisciplinary research programme on the functioning of wetland systems, especially reedbeds and temporary marshes. Long term studies are also undertaken on key species, wetland restoration and agro-environmental measures (ricefields and grazing).

Management

Experiments are undertaken on the Tour du Valat estate (2500 ha) in the centre of the Camargue. Tour du Valat also manages the Vigueirat marshes, a property belonging to the Conservatoire du littoral, at the request of the municipality. This site provides an excellent case study for integrated management.

Conservation

Tour du Valat helps disseminate and apply the information obtained by researchers and wetland managers through management planning for Mediterranean wetlands, training programmes, consultancies, support to regional and national strategies promoting the wise use of wetland resources, and the publishing of booklets on technical subjects.

Tour du Valat Biological Station was created in 1954 by Dr Luc Hoffmann. It is a private non-profit organisation, managed by the Fondation Sansouire. A team of around 80 people undertakes scientific activities, management of the estate, and the implementation of conservation activities.

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