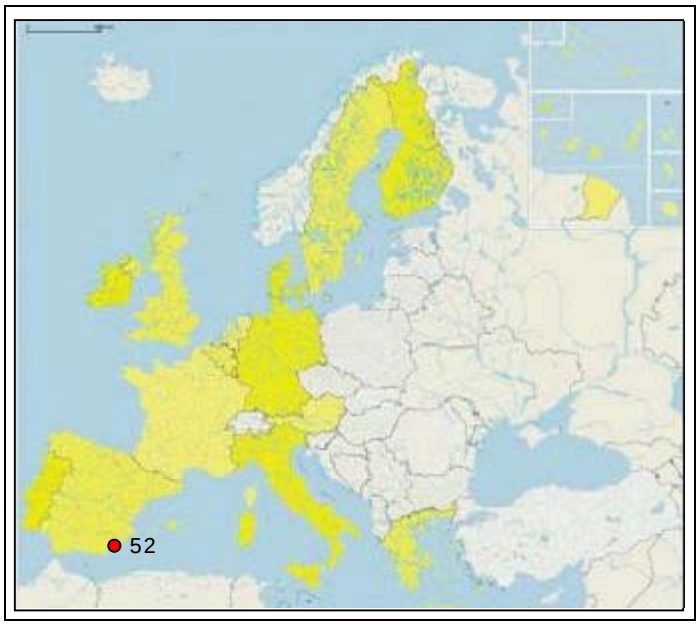
MAR MENOR
(SPAIN)



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1. GENERAL DESCRIPTION OF THE AREA

The Mar Menor is a hypersaline coastal lagoon of 135 Km^2 in surface area, located at the SE of the Iberian Peninsula, between the parallels 37º 38' and 37º 50' North latitude and the meridians 0º 43' and 0º 57' West longitude. The mean depth is 3 to 4 m, and the maximum depth is over 6 m. Such characteristics made the Mare Menor one of the bigger coastal lagoons from Europe and the Mediterranean. A sandy bar, called La Manga with 22 km of long, acts as a barrier between the lagoon and the Mediterranean Sea. It is crossed by five, more or less functional, channels or "*golas*". (Perez-Ruzafa, 1996).

Fig. 1: Location of the Mar Menor lagoon area.

Fig. 2: Aerial view of the Mar Menor

1.1 Physical process level

1.1.1 Classification

- General: Coastal lagoon, sandy beaches
- CORINE: Coastal lagoon
- Coastal guide: coastal plain, soft rock and hard rock. Natural habitats: sandy beaches and coastal lagoon. Catchment's area: Mediterranean. Microtidal range.

1.1.2 Geology

The Mar Menor basin borders the anticline of Torrevieja to the north and the Cartagena mountain range to the south. The lagoon is in a coastal depression, which is contained by a wider coastal plain called Campo de Cartagena. This plain gently slopes from 200m to sea level. The coastal plain and the Campo de Cartagena form a homogeneous plain of material from Quaternary, which is occasionally interrupted by volcanic outcrops (The islands of the Mar Menor, the Carmolí). The continental shore is occupied by an extensive sedimentary covert from Quaternary, which is formed by black and red silts.

La Manga is represented as a superficial, sandy barrier, determined by wave force and sediment contributions from longshore drifts, built on a substrate of diverse lithology, which connects Cabo de Palos with the Mójon Coast (Lillo, 1979). The neogene support outcrops in the southern third of La Manga, while elsewhere there is a predominance of Quaternary sediment. The volcanism of the Calnegre (43m) and the Calblanque is from the late Premiocene.

The origins and evolution of the Mar Menor were highly influenced by changing levels of the sea occurring since the Tortoniense, the volcanic activity that took place during the Pliocene and formed the small hills and islands in the Mar Menor basin (Figure 3), and the Quaternary compressive system that contributed to the displacement towards the land of the sandy barriers enclosing the Mar Menor. (Díaz del Río, 1990) (Figure 4). It is considered that quaternary glaciation and deglaciation were the most important elements in the formation of the coast, along with neotectonics, which moved the coastline backwards. This movement and the contribution of sediment on the successive barriers led to the present configuration.

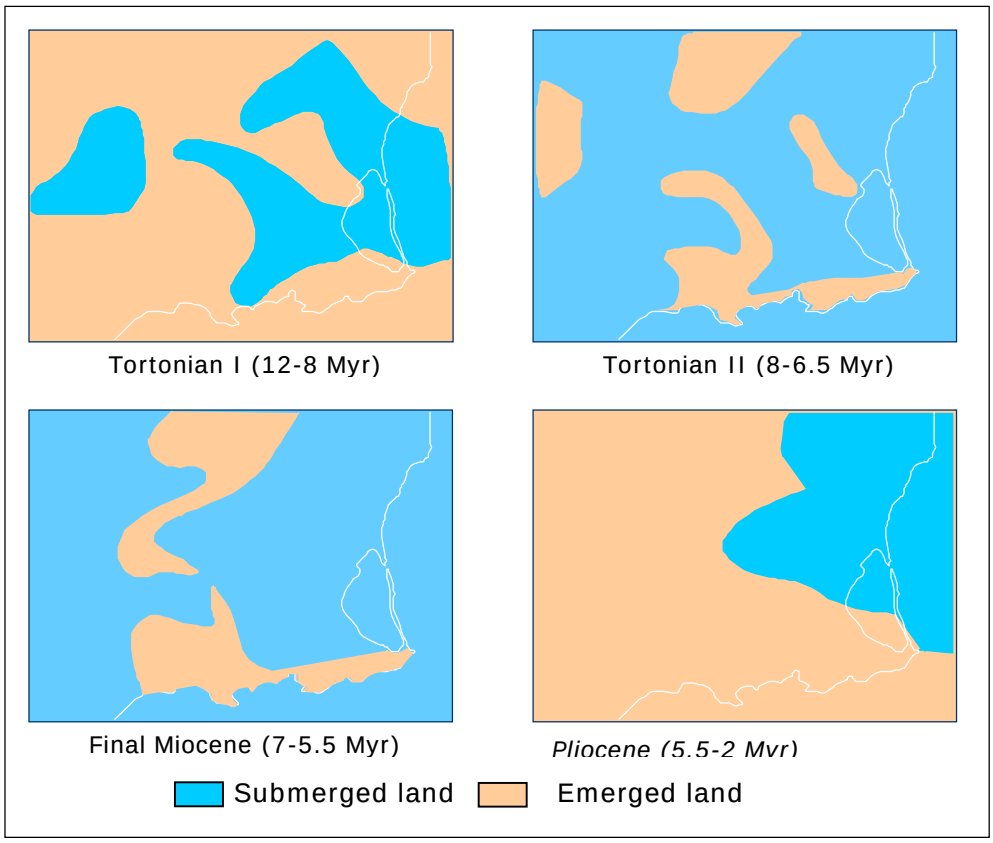


Fig. 3: Genesis of the Mar Menor (Modification of Fernández, J.C., 1986).

Fig. 4: Geomorphological diagram of the different evolutive episodes of closing barriers of the Mar Menor (Modification of Díaz del Río, 1990).

The seabed of the Mar Menor bottoms is covered by three sediment categories, according to granulometric composition: mud, sand and that constituted by terrestrial clays. Muddy seabeds cover the whole central area of the basin and there are shallow seabeds where there is low hydrodynamism. Sandy seabeds, with a sand content of up to 89%, are located on the margins of the basin and in the bays around the islands. (Pérez-Ruzafa, 1996).

1.1.3 Coastal morphology

As mentioned earlier, the Mar Menor is a coastal lagoon created by a sequence of consecutive oscillations of the sea level that occurred in the Quaternary. It is located at the bottom of a river basin bordered by mountains that enclose the Campo de Cartagena, which is a vast plain of 1440 km^2 with a low inclination to the southeast. The contribution of continental water is made up of six watercourses, which are dry most of the year and contribute to the natural process of filling the Mar Menor (Diaz del Rio, 1990).

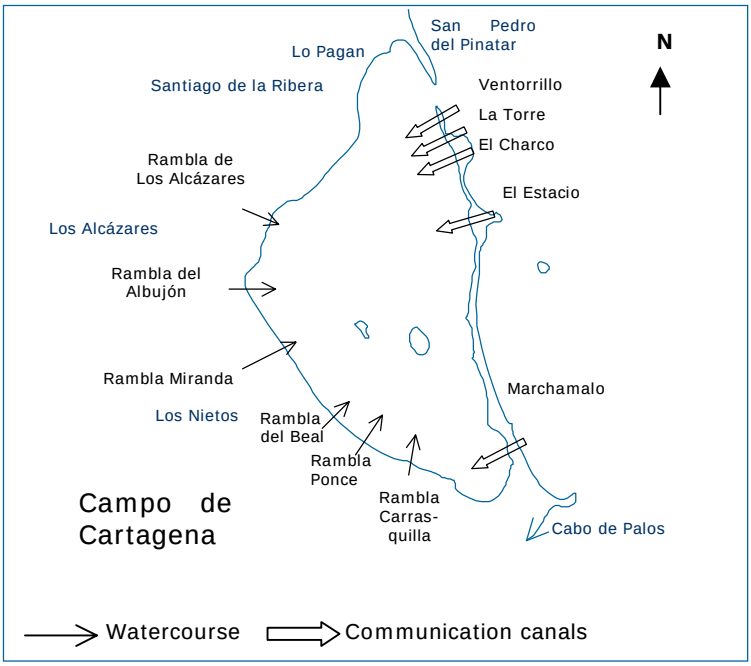


Fig. 5: Diagram of watercourses flowing into the Mar Menor and communication canals between the lagoon and Mediterranean Sea.

In relation to this, the most outstanding geomorphological elements determining the dynamics of the lagoon are:

The sand barrier

Enclosing the Mar Menor (La Manga) and the channels or *golas* that determine the entrances from the Mediterranean Sea and its hydrography and confinement. La Manga of the Mar Menor is a sand barrier that extends along the coast for 20 km in a NNW-SSE direction and which is 100-900m wide. The barrier has three natural discontinuities, which link both seas (Marchamalo, southern channel; the Encañizadas of the Ventorrillo and the Torre, northern channel; the channel of the Estacio, center channel).

There are two different geomorphological sectors. The first, which is between San Pedro del Pinatar and the cape of El Estacio, is characterized by its slightly winding coastal profile with a morpho-depositional genesis base. The southern section, lies between the aforementioned El Estacio and the Palos Cape, with a slightly curved coastal profile, concave outside waters,

with a regular coastline, which is only altered by the volcanic outcrops of El Calnegre (Díaz del Río 1993).

Fig. 6: The 'Estacio' channel.

Fig. 7: Northern interchange channel.

The sandy band next to the shore, in the Mediterranean band, is of a variable width that oscillates between 30 and 150 m (Figures 8 and 9). Its minimum expression is on the opposite shore (Figure 10 and 11). Moreover, the dunes that make up La Manga, highly important systems for the maintenance of the sedimentary body, have now practically been destroyed., A programme of dune protection and restoration has only been initiated at the northern extreme, inside the Regional Park of the saltworks (figure 9).

Fig. 8: Central beaches of La Manga.

Fig. 9: Beaches of San Pedro del Pinatar with dune system under protection.

On the Mediterranean coast, there are rocky seabeds, some covered and some not by algae, which form a barrier located between 100 and 200 metres away from the shore. That barrier, of variable height of around –1.5m, has a sounding line of less than –1m at many points, with some outcrops. Rocky seabeds extend to approximately –20m, which means around 3,000 m from the shore. Its mean inclination is about 6.7 ‰ . Only a few holes filled by sand appear on this platform. (Salinera Española S.A.1986)

Fig. 10: Road built in the Mar Menor shore of La Manga.

Fig. 11: The Mar Menor shore of La Manga with seawall construction.

Continental shore

Stretching from Lo Pagán village to Playa Honda. This whole coastal section was somewhat modified by man through the construction of marinas and groins, beach regeneration and sand extraction from the sea bed. Nonetheless, different units can be recognized, such us marsh and beach deposits, along with sedimentary continental units, which are in direct contact with marine waters. For that reason, a variable coastal profile has originated; land beaches (continental contribution) are combined with sandy beaches (coastal drift deposits), inserting salt marshes and alluvial deltas, which correspond to a fluvial system formed by six watercourses or *ramblas*. (Díaz del Río, 1993)

Fig. 12: Continental shore of the Mar Menor, where land limits directly with the lagoon.

Fig. 13: Sandy, regenerated beaches of the continental shore of the Mar Menor.

Islands and volcanic outcrops

Constitute the only rocky substrate. In the interior of the Mar Menor, there are five islands: *Barón*, *Perdiguera*, *Redonda*, *Ciervo* and *Sujeto*, apart from the Galera, which is an outcropped reef. In the Mediterranean Sea, there is the *Grossa Island* and the *Farallón*, and another non-outcropped reef called La Laja.

Underwater area of the Mar Menor

The distribution of the islands and their own bathymetry means the Mar Menor can de divided into two sub-basins. The northern basin is bigger than the southern one, having more morphological diversity and a more active hydrodynamic regime. (Díaz del Río, 1993). The maximum depth is reached in a reduced place located at the NW extreme of Barón Island, with a bathymetric of 7.2 m, but all the seabeds are between 5 and 6 m deep.

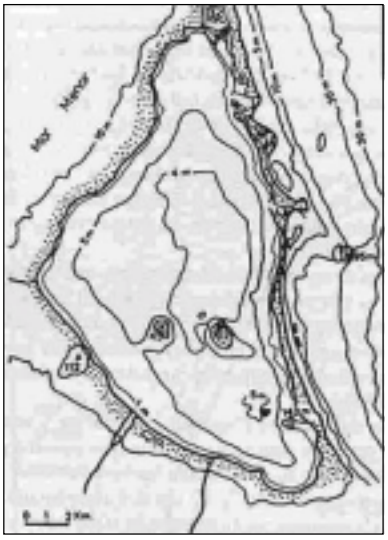


Fig. 14: Bathimetry of the Mar Menor (Lillo, 1979).

1.1.4 Physical processes

Erosion factors include mainly natural driving forces - winds, storms, waves and a rise in sea level. La Manga was created by marine currents and the effect of the wind and waves.

The wind is the main factor influencing sediment transport in this area. Prevailing winds in the area are from the East component, mainly from the ENE and E, that with NE and ESE winds, represent more than 30% of the annual total. Next in importance are the winds from W. From May to October the winds from the first quadrant dominates (known as *levantes*), meanwhile, from November to April SW, WSW and W winds dominate. The annual mean velocities of the weakes winds (W and WSW) range between 9 and 12 km/h and for the strongest (NE, ENE, SSW AND SW) range between 18 and 26 km/h. (Pérez-Ruzafa, 1996).

The fact that the most frequent winds are also those of a higher intensity makes their activity more evident than that of others. Therefore the ENE, E and SW and WSW winds, and exceptionally NW winds, exert the greatest influence on the waves and the water dynamic in the lagoon (Figure 15)

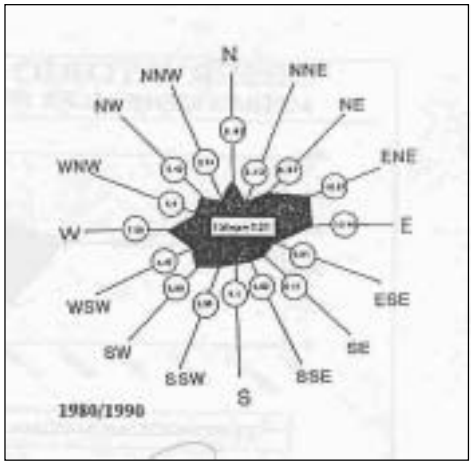


Fig. 15: Wind yearly distribution (1980-90) (Mas 1994).

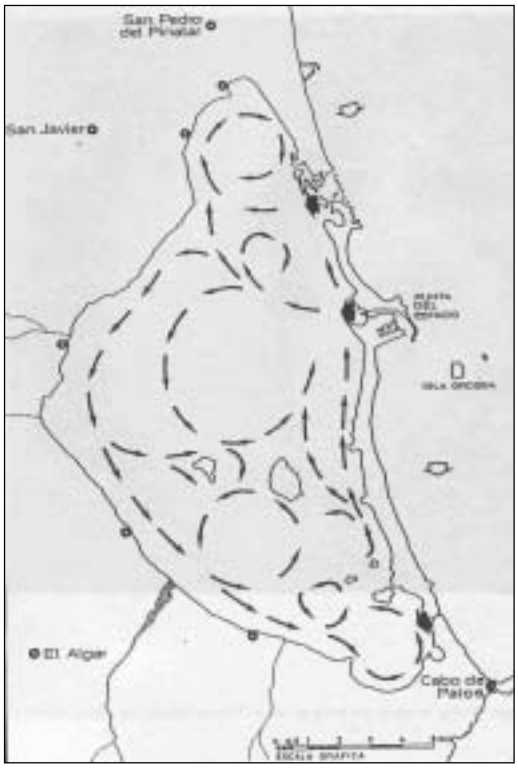


Fig. 16: Model proposed of interior currents of Mar Menor (Díaz Río 1990).

The La Manga beaches on the Mediterranean shore are submitted to two wind regimes going in opposite directions. Thus, sand is displaced from one to the other, in relation to the wind, constantly modifying the profile of the beach. However, weak natural dynamics affect continental shores. Only torrential watercourses are relevant when they suddenly bring a large volume of detritic material to the system, which forms extensive deltas that later, due to the effects of the wind, are redistributed into the underwater perimeter of the Mar Menor (Díaz del Río, 1990).

The wind is considerably important in terms of wave formation and the generation of currents. There is generally southward sediment transport on the Mediterranean coast. At the same time, the wind is partly responsible for the interchanges of water between the Mar Menor and the Mediterranean Sea, actively intervening in internal water circulation. Furthermore, in the interior of the lagoon, the 15 km fetch (N-S) justifies few waves.

The location of the islands, as mentioned earlier, causes a division into two basins separated by a line that joins the Carmolí, Perdiguera Island and Baron Island. The hydrodynamic regime, shown in figure 1.16, was more active up until the extension of the Estacio canal The northern basin is considerably larger than the southern one, its sedimentary deposits are more morphologically diverse, and has a more active hydrodynamic regime caused by the construction of the Estacio Canal.

The section of La Manga beaches is considerably oriented to the east, the direction that corresponds to the maximum fetch. The eastern fetch for this zone coincides with the channel that separates the island of Sardinia from Tunisia. This orientation suggests that the result of swell activity can reduce transport. (Salinera Española S.A. 1986)

Sea Level Rise

In the near future, where it seems foreseeable that there will be a significant increase in sea level due to climatic change, the equilibrium could break between filling and the relative rise in sea level of the coastal lagoons.
Decreasing rains in the region, in coherence with the rise in average temperature, estimated between 0.6 and 0.8 ºC in the last century, involves a parallel increase in the average sea level evaluated at 0.55 mm/year during the last century. The modification of the sea level will lead to important consequences for low coasts such as the Mar Menor, in which the backward movement of the coast is ranked at around a meter per centimetre of rise in sea level. (Mas, 1994).

1.1.5 Erosion

The Mar Menor lagoon is an accumulation coast dominated by sedimentation rather than erosion, although in some specific places erosive phenomena are quite evident, emphasizing the full exterior of La Manga.

Inputs of sediment

The sands that form sediment in La Manga originate from: (Díaz del Río, 1993):

- Water courses: the contribution of the Segura river has been estimated at an approximate volume of 80.000 m^3, although in recent years this value has fallen due to the damming of the river (San Jaume, 1985). Other lesser rivers are: Nacimiento and Seco along with a few ramblas.
- Erosion of old infracoastal relieves or river deposits that have been transported toward more distant zones and that are subsequently remobilised.
- Sediments of organic origin, derived from the destruction of fauna and marine flora.

The sediment of the Mar Menor is terrestrial in origin, mostly contributed by the torrential watercourses flowing into it. The value estimated is around 20.000m^3 per year (Sanjaume, 1985).

Causes of erosion

Initially, La Manga was formed by dunes. However, current land urbanization has stopped natural dynamics and led to a lack of sediment. Obstruction of longshore coast by San Pedro del Pinatar Port (1954), which supposes an obstacle for longshore transport, impedes the arrival of sediment to the whole system of La Manga.

The enlargement and deepening of the 'El Estacio' channel for the construction of a harbour and a navigable channel have led to many impacts apart from the aggravation of the erosion problem. The channel is currently 1800m long (between both mouths), with a variable width that oscillates between 16 m and 130m. The extension of the channel has deeply affected the sedimentary nature of the lagoon, permitting the massive entrance of water and sediment. (Díaz del Río, 1993).

Fig. 17: The Estacio canal.

Fig. 18: The Pedro del Pinatar Port.

The aforementioned rocky crest, which is parallel to the coast, has a stabilizing effect on the beach. On the one hand, the smooth platform causes refraction of the waves, so that large storms reach the submerged beach with the crest in parallel to the isobath and therefore with a scarce longitudinal component. On the other hand, the existence of the barrier produces, apart from limitng the height of waves, the contention of the beach, diminishing or impeding the transportation of sand towards the high sea. (Salinera Española S.A. 1986).

1.2 Socio-economic aspects

1.2.1 Population rate

The Mar Menor has experienced varying changes over the last 40 years. From being a practically uninhabited place, with only a few families of fishermen living permanently on its shores, there is now a large human presence, above all in the months of summer. Its towns were created as a result of its proximity to the cities of Murcia and Cartagena. Some 700,000 people have their permanent residence within less than fifty kilometres of this sea. La Manga was uninhabited until the year 1960 and it was the property of a family that exploited a fishing art called *encañizadas*. It developed into an excellent tourist resort. These circumstances made La Manga a unique natural spot, in these 40 years it has become an intolerable place that in summer comes to have 300,000 inhabitants.

The following table shows the evolution of the population of the main municipalities of the Mar Menor in the last decade.

Table 1: Evolution of the population of the Mar Menor from 1991 to 2000 (Rosique, 2000).

Municipality	1991	1992	1993	1994	1995	1996	1998	1999	2000
Los Alcázares	3.683	3.827	4.183	4.456	4.779	5.501	6.134	-	8.400
Cartagena	168.023	169.536	176.139	179.659	180.553	170.483	175.628	-	-
San Javier	14.696	14.947	16.120	16.816	17.282	16.773	17.523	-	19.774
San Pedro del Pinatar	12.057	12.220	13.076	13.597	13.916	13.644	14.487	15.237	-

1.2.2 Major functions of the coastal zone

Since ancient times, the Mar Menor has been an economic source and has been subjected to continuous transformations. The human activities developed close to the lagoon include: salt mining, agriculture, fishery, industry, tourism and recreation, urbanisation and military uses. This conjunction of many interests and uses made the Mar Menor the target of all type of aggressions during its recent history (land reclamation, the opening or deepening and extending channels, mining, urban and agricultural wastes, urban development, building sporting harbours, artificial beaches creation, etc) (Pérez-Ruzafa, 1996).

- **Agriculture and Farming**: the 'Campo de Cartagena' plain is a hydrogeological unit used for agricultural purposes. The river basins in the region of Murcia were originally conditioned by sporadic and torrential rainfall. Nonetheless, in 1979 the Tajo-Segura transfer was produced, which caused an important change in the area's agricultural production, increasing irrigated cultivation, and intensifying the use of fertilizers and agricultural phytosanitary products. At present, in the Campo de Cartagena plain there is a cultivated area of 144,000 ha. The location of the surrounding mountains determines the fact that most of the watercourses discharge into the southern half of the lagoon. That means that all agricultural waste discharges into the lagoon leading to a proliferation of nitrophilic algae. This phenomenon, along with urban and tourism expansion, which also discharge wastes into the lagoon, are changing the oligotrophic character of the Mar Menor, whose waters have always had a low content of nutrients and low primary productivity. Furthermore, such modifications of the lagoon's ecosystems by pesticides and wastes have led to an increase in the jellyfish population, which is a disturbance for tourists in summer.

Fig. 19: Agricultural land in the continental shore of the Mar Menor.

Fig. 20: Algae proliferation close to the bathing waters.

- **Fishing:** since ancient times, fishing has been an important human activity in this region, but it has been greatly influenced by environmental changes to the lagoon. A traditional system, used for most of the 20th century, *las encañizadas,* has now disappeared. *Encañizadas* consist of a complex labyrinth of canes and woods that catch fish as they come into the lagoon from the Mediterranean Sea. Nonetheless, increasing urban and tourism pressure diminished the importance of the *encañizadas* due to the extension of the communications between the lagoon and the Mediterranean Sea, until 1985 when this system was totally eliminated.

- **Industry:** an important mining industry was established on Cartagena Mountain to extract heavy metals (Pb, Zn, Cd, Mn, etc). Its heavy metallic sediment waste flowed down through the Beal and Carrasquilla watercourses and into the Mar Menor. Since the 1950's, pressure groups successfully stopped such discharge into the Mar Menor, which was deviated southwards to Portman Bay to cause major new environmental impacts. Salt mining is one of the oldest activities developed in the Mar Menor area. It is developed in the municipality of San Pedro del Pinatar and in Cabo de Palos, in the northern and southern extremes of the Mar Menor. Nowadays, this activity is under pressure of disappearing as occurred with traditional fishing. Urban development and land speculation have endangered this economic activity that has co-existed with natural systems since ancient times.

- **Tourism:** this activity is the basic motor of the local economy. Nonetheless, the natural attributes that have attracted tourism since the early 19th century have started to disappear with the progressive saturation of coastal tourism. From the 1960's until now, a tourism explosion has led to an overcrowding of the coastline. Tourism, which is of a seasonal nature, mostly comes from Murcia region (53.9%) with the rest coming from other parts of Spain (36.1%) and from foreign countries (10%). (M.J. ROSIQUE, 2000).

Fig. 21: First construction in La Manga, in 1964 (Benedicto & Olmos , 1995).

Fig. 22: Actual view of the urbanization of La Manga.

- **Urbanization:** the aforementioned demand for tourism has led to uncontrolled urban growth, with the construction of marinas and a proliferation of coastal settlements. Construction of the Mar Menor sand barrier started in 1968. The tourist construction rate was extremely high up until the 1980's, but it has since slowed down, though not stopped. There are problems with the overexploitation of natural resources, such as water consumption which has led to saline intrusion in the coastal aquifer. There are not enough purifying-plants or basic infrastructures for sanitary purposes, which has led to urban discharge. Urbanization on the dune system and boulevard constructions, which has interfered with coastal dynamics, is one of the main causes of coastal erosion.

- **Military:** many military activities have been developed on the shore of the Mar Menor. In the section between Los Nietos and Los Urrutias, this activity has prevented urbanization in the area, as terrains were expropriated for these uses and now form part of the protected areas of Mar Menor Wetlands.

Fig. 23: View of saltworks in San Pedro del Pinatar

- **Ships and Ports:** a relevant activity linked to the tourism is the construction of marinas. In the Mar Menor case, the development of harbours has been disproportionate, almost each village have its own marina, reaching a density close to 2 ports by 10 km, and some of them are separated by less than 800m. (Pérez-Ruzafa, 1996). Building of Marinas has effects directly on coastal dynamics.

Fig. 24: Marina of Lo Pagan.

Fig. 25: Island port in Los Nietos.

- **Transport:** tourism development has involved the construction of new roads. One of these runs along La Manga. There is one road that joins La Manga with Ciervo Island, taking advantage of a natural process of tombolization. Furthermore, the Murcia regional airport is also located close to the continental shore of the Mar Menor. Furthermore, the airport of Murcia region is also located close to the continental shore of the Mar Menor.

- **Protected areas:** in 1994, the Mar Menor was considered part of the Ramsar list (Convention on Wetlands) with 15,000 ha designated as wetlands of international interest. This is due to the high natural value of the area and its many species of birds. It was recently proposed that it should be a Specially Protected Area of Mediterranean Importance (SPAMI) under the Convention for the Protection of the Marine Environment in the Coastal Region of the Mediterranean. Furthermore, the Mar Menor includes several nationally designated sites:

Regional Park of "Salinas y Arenales de San Pedro del Pinatar"

A good example of the transformation of an ancient coastal lagoon into saltworks, which are still in use. It has a surface area of 856 ha and there are also interesting sedimentary coastal formations and dune systems. Furthermore, 836.99 ha were designated as a Special Area for Conservation in 1998, under Directives for Birds. There are many projects in progress in this area, one of which aims to protect the dune system through the replanting of the dunes and the construction of passages.

Fig. 26: Flora recuperation in Regional Park of San Pedro del Pinatar.

Fig. 27: Dune stabilization in the Regional Park of San Pedro del Pinatar.

Part of the Regional Park of "Calblanque, Monte de las Cenizas y Peña del Águila"

It is located in the eastern part of the Mar Menor and has 2,822.45 ha of varied geologic structures and materials.

Protected Landscape of "Open Spaces of the Mar Menor"

1,186 ha of the the Mar Menor shore are designated to this, which includes several natural enclaves of wetland ecosystems of major interest.

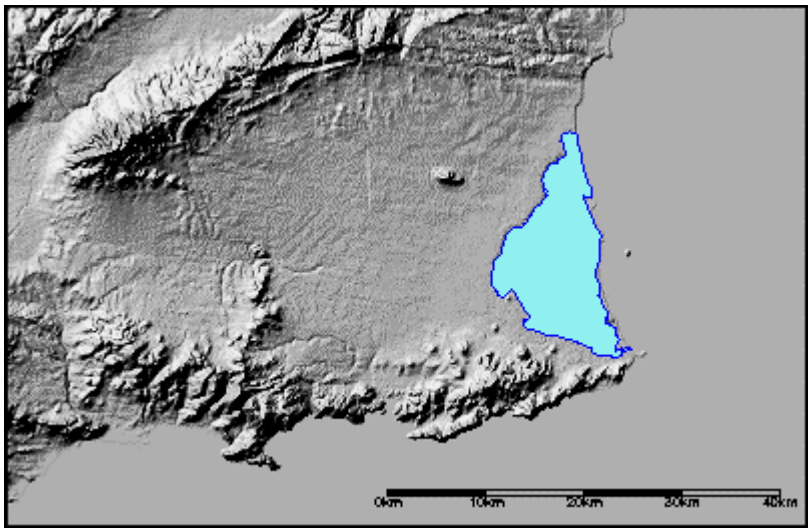


Fig. 28: Area Covered by RAMSAR designation (http://www.mma.es/ramsar).

1.2.3 Land use

The following figure is a representative diagram of the main land uses across the area of the pilot site. A wide variety of uses can be observed, which implies a great deal of pressures on the environment and constant conflicts between the different uses. Traditional uses such as salt mining and fishing are losing ground now that they are confronted by the constant growth of tourism and urbanization.

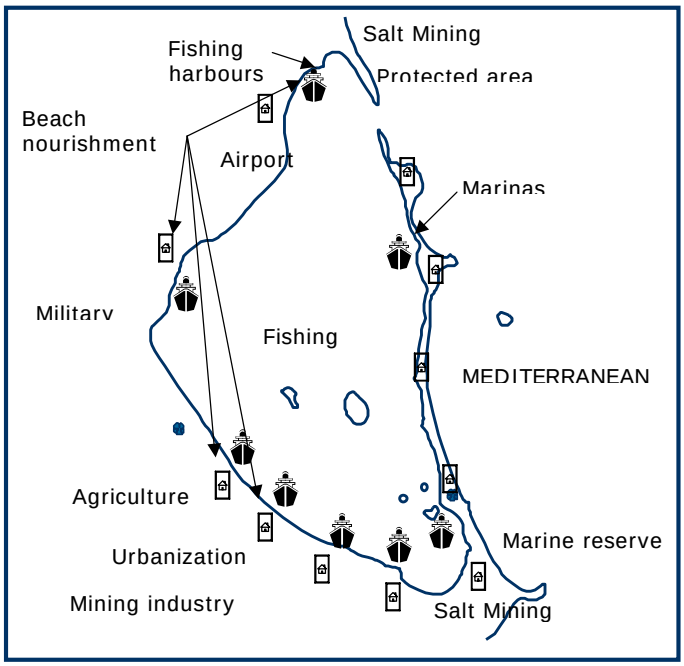


Fig. 29: Main uses and activities developed in the Mar Menor area. (modification of Perez-Ruzafa, 1996).

1.2.4 Assessment of capital at risk

Obstruction of the runoff waters and watercourses by buildings is the main reason for the major damage caused by flooding. As rainfall is so irregular and given that there are no permanent watercourses in the zone, the sediment dragged by the water is deposited in successive phases before reaching the Mar Menor. Afterwards, when there is high rainfall and the water flows at extreme strengths and speeds, this sediment is suddenly introduced into the interior of the lagoon. This plays a role in the natural filling process, along with the contribution of marine sediments originating from coastal drift.

Fig. 30: Episode of flooding in Los Alcazares (Benedicto J.F., Olmos F.J. 1995).

On the Mediterranean shore of La Manga, the reduction of the surface area of the beach has led to the flooding of the basements of some of the buildings located along the seafront during storms. In the future, if the predicted rise in sea level occurs, coastal erosion will endanger all of La Manga and the infrastructure and human capital developed upon it.

Fig. 31: Flood occurred in Los Alcázares, 3 de octubre de 1953 (Tiana, "La Verdad" diary).

2. PROBLEM DESCRIPTION

2.1 Eroding sites

The Mar Menor responds to an erosion-accumulation dynamic, therefore different phenomena can be described on a local scale:

Erosion

On the shore of the Mediterranean Sea, the external part of La Manga, a general regression of the beach has been observed. A volcanic crest extends in parallel along the coast, 200m from the Mediterranean and –2m deep, which protects La Manga from the erosive effect of the most powerful waves. It has been observed that where this outcrop is interrupted greater erosion is produced on the beaches in front of it.

On the shore of the Mar Menor, the internal part of La Manga, a regression has been observed because wind transportation, which feeds the zone, has been broken by the urbanization and the process of making the dune system more rigid.

Fig. 32: Mar Menor shore of La Manga with the road construction on it.

Fig. 33: Groin construction to stop sand losses in the Mar Menor shore of La Manga.

Accumulation

The Northern part the Mar Menor is characterized by its accumulation processes, the mud-filling process that is starting to be a problem for tourist activity. Diaz del Rio et al. (1990) estimate a sedimentary velocity of 1.2 mm/yr and 2.0 mm/yr for the last 80,000 years. Only by natural mechanisms, without human intervention, can the system fill itself for the next 6,000 to 8,000 years.

2.2 Impacts

The negative impacts of trends in erosion-sedimentation are:

- The salt mining industry located in San Pedro del Pinar is directly affected by coastal erosion. After the construction in 1954 of the groin in San Pedro del Pinar Port a considerable retreat of beaches has been observed to the south (La Barraca Quemada and La Llana). Saltworks located just behind those beaches are invaded by seawater in storms, which damages salt production.

- Changes in the ecological status of the Mar Menor, having direct consequences on fishing activities. In 1978, Estacio canal was extended which provoke a bigger water interchange between two water systems. The increase water exchange with the neighbouring Mediterranean sea has brought about a process of "mediterranization" both o the waters and the biota of the Mar Menor. As for its waters, there has been an important decrease in the salinity, a smoothing of the more extreme temperatures, which influence on the growth and expansion of Caulerpa *prolifera* meadows (Pérez-Ruzafa, 1996 Before the extension of the Estacio canal, salinity of up to 52.34 ‰ was registered, compared with 42.7 ‰ - 47 ‰ in recent times. The temperature range has also decreased. (Díaz del Río & Somoza, 1990; Mas 1994). Furthermore, sediment transport dynamics have been altered, which has intensified the filling process of the lagoon.

- The impacts of coastal erosion on tourism are not not evident quite yet. For the moment, as mentioned earlier, only a few houses have suffered from flooding in isolated storm incidents. Nonetheless, in the future increasing damage to the infrastructures located in La Manga can be expected, and new protective measures would have to be developed.

3. SOLUTIONS / MEASURES

3.1 Policy options

There is no a real, active policy concerning coastal erosion. Regarding the few interventions performed (beach nourishment and construction of groins), the main policy option has been to “Hold the Line”, as promoted by public administration, commonly on a national level.

3.2 Strategy

3.2.1 Approach related to the problem

The strategy followed in order to protect infrastructure from beach erosion has combined soft and hard measures. On the one hand, beach nourishment has been highlighted as the main technical measure to be adopted. But on the other, groins have been used to keep sand nourished in its place and reduce erosion trends. It is important to point out that most of the nourishment performed on the continental shore of the Mar Menor is aimed at the creation of new beaches in a place where there was originally no morphology of sandy beaches. The main goal of these interventions was to try to attract more tourism.

3.3 Technical measures

3.3.1 Type of measures/ technical details

Renourishment of the seafront of the villages located on the continental shore of the Mar Menor in 1988

Initially, the Mar Menor had no beaches except for some deltas caused seasonally by the outlet of the watercourse, which produced sediment accumulations. To promote tourism, authorities opted to create new beach surfaces with sediment from the bottom of the lagoon. At the same time, groins were built to avoid sand loss on the new beaches caused by soft coastal drifts.

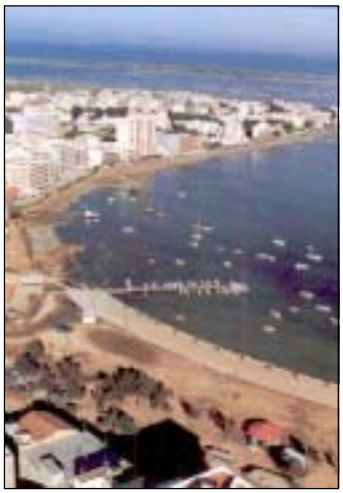
This activity, which has continuously taken place over the last decade, has implied a total of 270,275 m^2 of land reclaimed from the sea, with a contribution of 640,456 m3, most of this coming from dredges in the same lagoon (Mas, 1995).

Table 2: Compliance between sand contribution and beach surface gained in the last decade.

LOCATION	LAND EMERGED GAINED (m2)	SAND CONTRIBUTION (m3)
Villananitos	12.300	36.200
Punta Brava	34.875	95.196
Los Alcázares	122.100	202.236
Los Nietos	42.000	96.901
La Ribera-Lo Pagán	59.000	209.923



Figs. 34, 35, 36: Views of the renourished beaches in the continental shore of The Mar Menor.

Figs. 37 & 38: Before and after views of beach nourishment in San Pedro del Pinatar (MOPT, 1993).

Renourishment of Galua Beach in 1996-1997

A 2 km section of coast was nourished with terrestrial sand, extracted from a quarry located in the Palos Cape. This intervention has been considered as a failure because the sand contributed is disappearing very quickly.

Nourishment of the beach sheltered by Palos Cape in 1991

The resultant beach was 50-60m wide. Furthermore, a groin was built to protect the beach and avoid sand loss. Contributed sand came from quarries close to Murcia. For the moment, there is no proposed solution for the beaches suffering from erosion in the Mediterranean section, because continuous beach nourishment is not possible as there are extensive posidonia meadows in front of them. Therefore, major beach nourishment in these beaches would imply the destruction of the posidonia, which is fortunately under protection. Some experts believe that the aforementioned rocky bottom could be a positive factor in the maintenance of sand regenerated on the beach.

3.3.2 Costs

There is no data available.

4. EFFECTS AND LESSONS LEARNT

4.1 Effects related to erosion

Uncontrolled development has induced installation of structures to retain sediments, new beach creation, maritime walks, dredging for the extraction of sands etc. Lack of proportion between these works and lagoon hydrodynamic has lead to important alteration of sediment transport and water circulation. (Perez-Ruzafa, 1996) The example of the Estacio canal, which was dredged from 0.5 to 4 m deep to build a marina and provide a navigable canal.

The beach nourishment process on the continental shore of the Mar Menor, which included dredging, sand discharge and deposition of sediment in the marine media, has physical effects (increase in the turbidity of the column water, destruction of bentonic fauna, and possible changes in the granulometry), chemical effects (high organic concentrations of material that produce anoxia, contamination by heavy metals) and biological effects (growth of algae production and of opportunistic species) (PEREZ RUZAFA, 1988)

The lack of any coherent, urban development planning of the physiographic character of the environment has led to the destruction of the dune system as result of the excessive density of building and channel modification. All of this has broken the dynamic equilibrium of the barrier, the destruction of which can be expected in the not too distant future. (Díaz del Río, 1993)

The sand nourishment carried out in 1996/7 in order to break the erosive processes on the Galua Beach, did not have the expected results. It is considered that the efficacy was rather limited. On the one hand, the type of sands contributed was inadequate. On the other, the fact that this technique was not was not combined with another, that of stopping the original problem from persisting. This only supposed a temporary solution to the problem.

4.2 Effects related to socio-economic aspects

In coastal lagoons, human activities and developments include fisheries, aquacutlure, tourist and recreational, scientific and educational. In spite of this, lagoonal ecosystems are also used as receptacles for wastes, which cause accelerated degradation of these systems (Barnes, 1980, Paskoff, 1985),

Farming, deforestation, ploughing and mining activity in the Portman mountains, which until 1950 discharged its waste watercourses to the Mar Menor, the growth of irrigation in agricultural works, the increase in tourism and uncontrolled urban development, etc., have led to increases in the sedimentation rates of the lagoon, which go from 30mm/century to 30 cm/century, going in 100 years from a surface area of 185km^2 to 135,76km^2 . (Perez Ruzafa et al. 1987).

4.3 Relation with ICZM

The Mar Menor has been marked by the political absence of ICZM practices, which is verified by an environmental diagnosis and by the tendencies observed, which will mark the next years of the development of the lagoon, if preventive measures are not considered.

Nonetheless, part of the local society is reclaiming the protection of the Mar Menor. In response, the elaboration of Indicative Plans for Coastal Uses, Protection and Harmonization of Uses of the Mar Menor, specific designations for protected areas and evaluations of the environmental impact have been elaborated. Nonetheless, there is a lack of any real integrated approach and urban-planning excesses are still permitted.

For instance, there is a project in progress that is in the hands of La Confederación Hidrográfica del Segura regarding the collection and reuse of the irrigation waters of the Campo de Cartagena, previously subjected to desalination. . This project plans to collect and reuse for irrigation 10,000 m^3/day, extendible to 15,000m^3. This project would manage to withdraw 600 Tm/year of nitrogen, which is 10% of the total nitrogen of agricultural origin and 6% of the sulphur. (M.J. ROSIQUE, 2000).

The Mar Menor and its area of influence are currently being proposed as a pilot site for the CAMP (Coastal Area Management Programme) promoted by PAP/RAC (Priority Action Programme), which is aimed at the implementation of practical coastal management projects in selected Mediterranean coastal areas, applying Integrated Coastal Area Management (ICAM) as a major tool.

4.4 Conclusions

Different designations conferred to the Mar Menor area prove its high natural values and the need to improve its integrated coastal management and make different uses compatible, which are presently causing major damage to the environment.

Coastal sediment-erosion dynamics, emerging as a new threat to this fragile environment, demand an active policy in two directions. On the one hand, the erosion of La Manga will continue if technical solutions are not implemented and urban pressure reduced. On the other, the sinking process will continue to accelerate if there is no integrated management of the entire basin.

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