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Biodiversity of Coastal Lagoon Ecosystems and Their Vulnerability to Global Change

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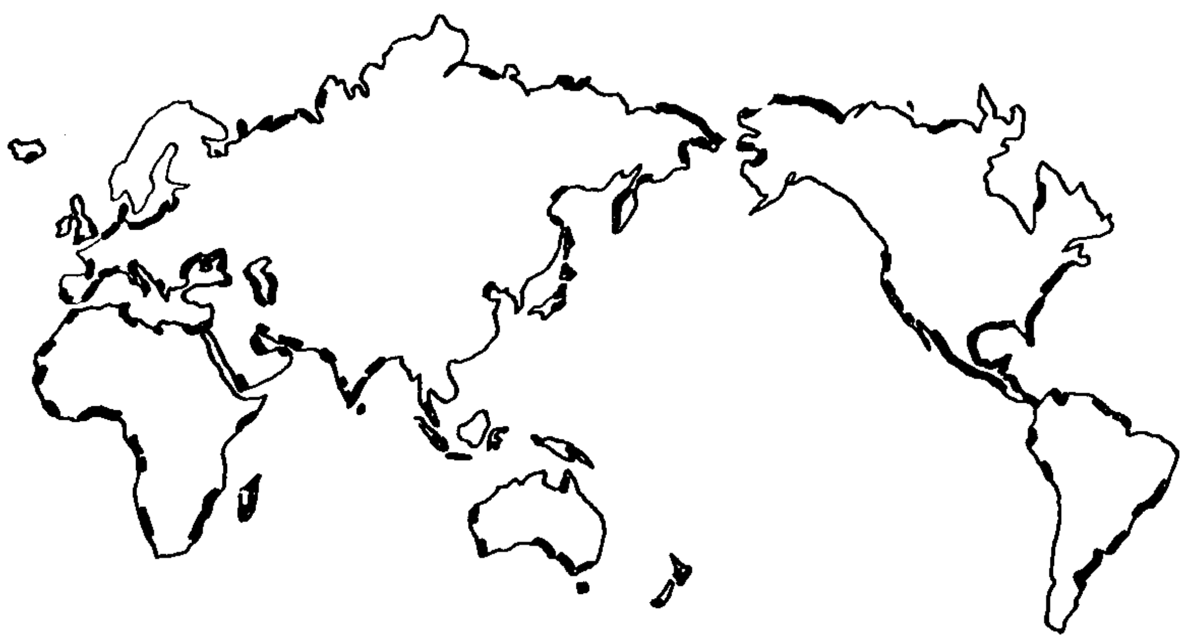
1. Introduction

In this chapter we define coastal lagoons according the definition proposed by Kjerfve (1994) as "shallow water bodies separated from the ocean by a barrier, connected at least intermittently to the ocean by one or more restricted inlets, and usually oriented shore-parallel". This definition is given in an introduction chapter of a multiauthor book edited by Kjerfve (1994). Nevertheless, in the scientific literature the term coastal lagoon is not always used. For example, in the North American ecological literature the term estuary has often been used rather than coastal lagoon for systems including "Laguna Madre", "Lake Pontchartrain" and "Waquoit Bay". In contrast, in the socio-historical context of Southwestern Europe, lagoons are well recognised and distinguished from estuaries as is shown by the vernacular languages that contain specific words for the coastal lagoons, their barriers and inlets. Thus, coastal lagoons are named "laguna" in Spanish and Italian, "lagoa" in Portuguese and "lagune" in French. However, the Spanish word "laguna" also refers to a relatively shallow freshwater lake system, and coastal lagoons are referred to as "lagunas costeras". In French, the word "lagon" refers to a marine water body that is separated from the open sea by a coral reef. Therefore, one has to be aware of possible confusions and different perceptions of coastal lagoons by different communities. Lagoon science is relatively young and had some difficulty of getting from the ground as was earlier highlighted in the classical book by Barnes (1980) titled "Coastal Lagoons; the natural history of a neglected habitat". Actually still today coastal lagoons in the tropical world have been poorly studied so far (Esteves et al., 2008). In Europe, nowadays a thriving community of lagoon scientists exists that joins together in biannual meetings since 2003 (European Coastal Lagoons Symposium, Eurolag), the latest (2011) has taken place in Aveiro, Portugal.
Coastal lagoon ecosystems are a particular type of estuarine systems where seawater mixes with fresh water from their continental catchments. These systems occupy about 12 % of the world coastlines (see Fig. 1). Salinities have been used since 1958 to classify the lagoons and other brackish or estuarine waters according the Venice system. Accordingly, a lagoon with salinities below 5 ppt is oligohaline; mesohaline waters have salinities between 5 and 18 ppt and polyhaline between 18 and 30 ppt. Lagoons with salinities above 30 ppt but below that of seawater are termed mixoeuhaline. Connections with the sea can be temporary or

permanent through tidal inlets (see definition above by Kjerfve). This implies that tides are propagated in the lagoon when the inlets are open and tidal ranges in lagoon may range from <10 cm to 3 to 4 m. Tidal range has been used to define adjectives for coastal ecosystems including lagoon, i.e. microtidal (< 2m), mesotidal (2-4 m) and macrotidal (4-6 m). Coastal lagoons are particularly abundant along the coastlines of enclosed seas like the Mediterranean and Baltic Seas, which are both microtidal. In some lagoons, evaporation temporarily or permanently exceeds fresh water inflow and these lagoons become more saline (hyperhaline according the Venice system) than the adjacent sea. In other cases, the salinity of lagoons can drop tremendously during periods when fresh water input is high and exchanges with the sea are restricted. Such conditions can vary drastically during an annual cycle and because most lagoons are rather shallow, the water column salinities and temperatures often vary to a high extent. The term poikilohalinity is sometimes used to characterise the highly fluctuating salinity conditions that are so characteristic for many lagoons.



= barrier/lagoonal coastalines

Fig. 1. World distribution of barrier and lagoonal coastlines. Reproduced from Barnes (1980), Coastal Lagoons, Fig. 1.1 on page 2, with kind permission of Cambridge University Press.

2. Lagoon formation and creation of ecotones, biodiversity patterns

On a geological scale coastal lagoons are ephemeral ecosystems that change form and dimensions in time and space due to natural processes. This dynamic behaviour of coastal lagoons is nicely expressed in the title "Shifting Sands" a book on the coastal lagoons in Maryland, USA (Dennison et al., 2009). Most lagoons have been formed during periods of sea-level rise, so-called transgression periods. A first type of lagoons develops when the rising sea invades a relatively flat coastal plane and when a barrier is formed from marine sediments that separates the shallow water body from the sea (see Fig. 2A). When the barrier is attached to firm land it is called a "lido" or a "spit". However, tidal inlets often interrupt the barrier and a stretch of barrier separated by two inlets on either side is called a barrier island. A second type of lagoon forms from a classical estuary, when a barrier is subject to longshore drift that deviates the estuary from its original course and creates a large area of lagoonal environment (see Fig. 2B). The classical example is the triangular shaped Bassin d'Arcachon (De Wit, 2008). A third type is formed in coastal deltas, like in the Camargue region the delta of the Rhone (e.g. Etang de Vaccares) or in the Ebro, Po and Nile deltas. A fourth type is formed in more accidentated regions, e.g. by invasion of the sea in glacier vallies (Fjord type) or by tectonic processes. These latter lagoons can be rather deep while most of the other types are relatively shallow. In the Languedoc-Roussillon region in S. France (along the Gulf of Lions), 12 of 18 lagoons have a mean depth < 1 m and four between 1-2 m depth. Only the Thau lagoon, which is also the largest in this region (75 km^2), has an average depth of 4.5 m with deeper basins with around 10 m depth.

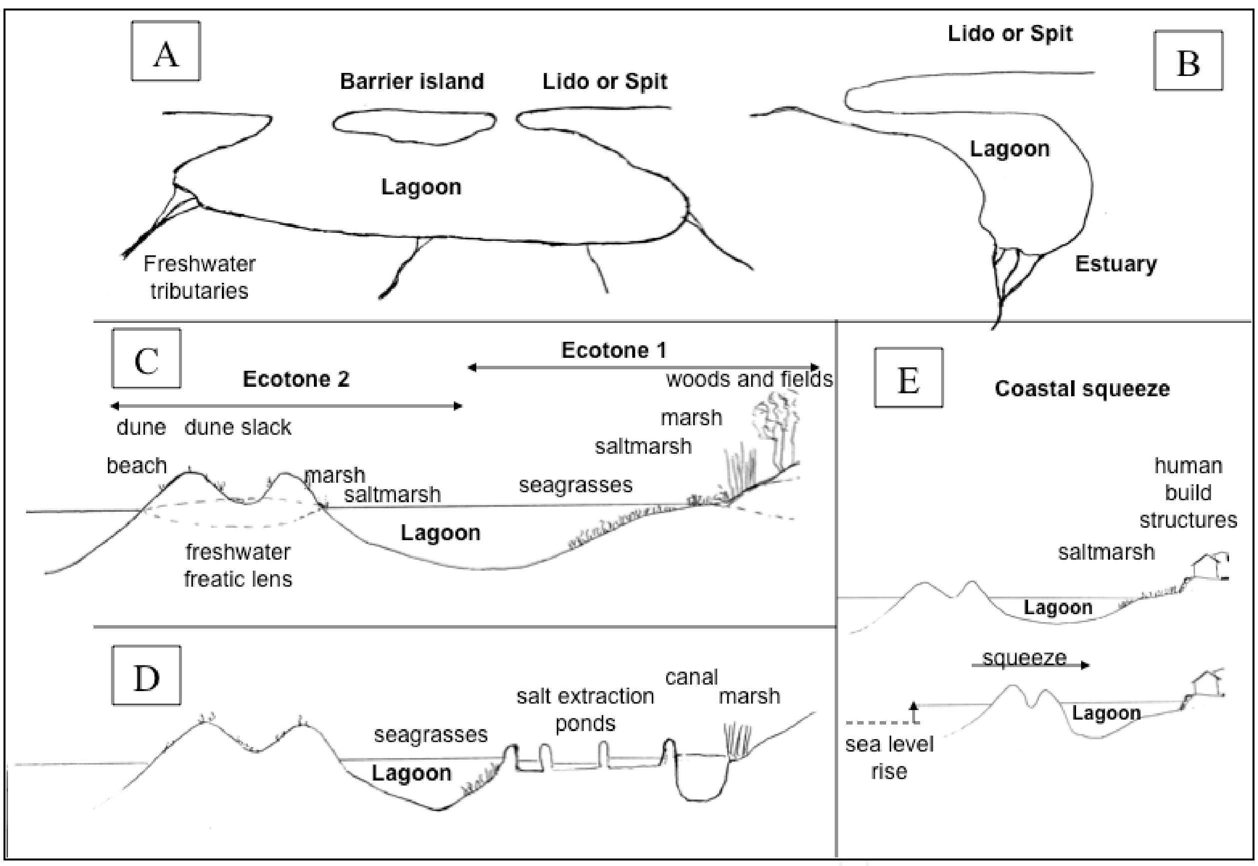


Fig. 2. A: Map of classical lagoon formed during sealevel rise by submersion of a coastal plain and formation of barrier (lido and barrier islands) from marine sediments. B: Bar built estuary evolved in a coastal lagoon. The longshore drift is oriented from right to left and has created a lido or spit that separates a lagoon from the sea. C: Ecotones in classical lagoons (cf. A). D: creation of salt extraction ponds in a coastal lagoon. The original ecotone (1) has been destroyed by creation of a canal to intercept freshwater runoff, while a new ecotone has been created. E: Effect of coastal squeeze in a lagoon where the inner shore is fixed by hard human structures. Sea level rise induces landward movement of the barrier and loss of the fringent salt marshes.

The lagoons existing nowadays are therefore relatively young ecosystems most of which have been formed during the Holocene transgression and particularly between 5,000 and 1,000 years BP. Barnes (1980) mentions that a typical lifetime can be 1,000 years for a coastal lagoon, but it seems that several lagoons have longer life spans. The Curonion lagoon on the Baltic Sea is the largest coastal lagoon in Europe (1540 km^2) and was formed since 5,000 years ago, while some Mediterranean lagoons existed since Roman times and other have been formed during the medieval period. For highly mobile species like fishes and birds, the lagoons systems are connected, because both easily migrate from one lagoon to the other through the sea and air, respectively. In contrast, for smaller size species with more restricted dispersion, a coastal lagoon can represent a geographically isolated environment. Hence, a major question is if the short geological lifetime of lagoons allows sufficient time for the evolution of novel species through geographic isolation? So far, this aspect remains poorly studied and perhaps endemic species specific to certain lagoons can be found in the future among micro-organisms and small benthic fauna like nematods (Esteves et al, 2008).

As highlighted before, the water body of coastal lagoons can be exposed to very strong fluctuations of salinities due to seasonal variations of precipitation and evaporation. In addition, in the shallow environments, the seasonal fluctuations of temperatures are often more pronounced than in the adjacent sea. This may present stressing conditions for many aquatic species and as a result, the biodiversity is often lower than can be found in comparable albeit more moderately fluctuating coastal environments. However, some species have clearly evolved from marine species to cope with the lagoonal fluctuations through radiative evolution. When the lagoon-adapted species and its evolutionary relative are morphologically very similar they are considered sibling species (Barnes, 1980). For example, *Cerastoderma glaucum*, the cockle of temperate coastal lagoons is the sibling species of *Cerastoderma edule*. Not surprisingly, *C. glaucum* has a higher tolerance range both for salinities and temperatures than *C. edule*. Three different species of *Hydrobia* snails exist, i.e. *H. ulvae*, *H. neglecta* and *H. ventrosa*. All three species are very similar as they are of similar size, attain the same age and feed on the same food and only differ by their salinity ranges (Barnes et al., 1980). Their distribution patterns corresponded to their salinity ranges of optimal growth, with *H. ulvae* occupying the open coastal environments and *H. neglecta* and *H. ventrosa* occupying the lagoonal environments of lower salinities in Danish coastal lagoons, which could be explained by a trade-off between salinity optima and resource competition (Fenchel and Kofoed, 1976). The zooplankton of the lagoon also comprise characteristic lagoon species that hardly occur in the adjacent sea including: *Acartia latisetosa, Acartia margalefi, Acartia tonsa, Calinipeda aquaedulcis*. Typical phytoplankton species in the lagoon are *Skeletonema costatum, Cyclotella* spp., *Amphora* sp. (a pennate benthic species), and typical foraminifera in the benthos include *Ammonia beccarii, Cribrononion granosum, Haynesina paucilocula* (Guerzoni and Tagliapietra, 2006).

Thus, while the large fluctuations in lagoons result in lower biodiversity of aquatic organisms in the water body and its associated sediments, at the landscape level the picture becomes a bit different. The lagoons, their barrier islands, coastal spits and their peripheral wetlands provide ecotones which creates highly diversified habitats that support a high level of biodiversity (see Fig. 2).

A first ecotone runs perpendicularly to the inner shoreline of the lagoon from terrestrial ecosystems like woods and fields- through freshwater marshes and swamps, brackish vegetation, salt marshes with halophytes and finally submerged aquatic vegetation in the lagoons (see Fig. 2C). The terrestrial aquatic interface is particularly important for amphibian species that have suffered important declines in recent times (see e.g. Dennison, 2009). But, this ecotone is also home for many interesting bird and plant species. Reed (*Phragmites australis*) often forms extensive stands in the surrounding coastal lagoons and this species is capable to grow upto 10-15 ppt salinity and can occasionally tolerate higher values. The reed stands often form where freshwater inputs from surface flow or upwelling chase the more saline water from the lagoon. In the case of temperate oligohaline lagoons, reed belts often present the dominant shoreline vegetation. In more brackish or saline lagoons, the area close to the shore is occupied by fringing belts of halophyte vegetation. Halophytes are flowering plants or Magnoliophyta (formerly Angiosperms) that have specific adaptations to live in saline soils. The aerial parts of the halophytes can be submerged temporarily in saline water due to tidal immersion. Some species, like *Salicornia* can withstand very frequent submersion while others are submerged less frequently and occur higher in the littoral zone. In tropical areas, i.e. where winter temperatures of the water column are above 20 °C, the fringing vegetation is formed by mangrove forests. Mangrove trees are dicotyledonous Magnoliophyta, and there are about 55 species of them described. Mangrove swamps occur along the shore of lagoons and also occupy the intertidal marshes along the estuaries and open coastal shoreline. The mangroves of the Indo-Pacific domain are rather rich in species, while the Atlantic domain comprises much less mangrove species. The mangrove forests represent home for important biodiversity, particularly including invertebrates and bird species.

The Magnoliophyta comprise between 250,000 to 400,000 species among which a very minor proportion has reinvaded the marine environments. The 55 species of mangrove trees are able to develop in waterlogged saline soils and withstand frequent or almost permanent inundation and form really swamps. These trees also have specific adaptations to cope with the anoxic and strongly reducing conditions in the soil and also produce viviparous propagules that can float and disperse by the sea.

Within the lagoon, aquatic Magnoliophyta occur fully in the water column with their roots in the sediments and stems and leaves submerged in the water. In oligohaline conditions condition, the pondweed *Potamogeton pectinatus* L. can proliferate and form dense meadows. *Ruppia maritima* and *Ruppia cirrhosa* typically occur in meso and polyhaline conditions and the latter even has a very high salinity range and can even tolerate hyperhaline conditions. Nonetheless, the *Potamogeton* and the *Ruppia* species are often not considered as the seagrasses *sensu stricto*. Seagrasses are aquatic plants that have really invaded the marine waters and comprise about 50 species worldwide. These are monocotyledonous Magnoliophyta that occur wordwide in tropic and temperate environments upto the Arctic. These plants are only absent in Antarctica. In the Mediterranean lagoons seagrasses comprise three species namely *Zostera noltii*, *Zostera marina* and *Cymodocea nodosa*. These submerged aquatic plants are particularly vulnerable to eutrophication and these plants have suffered dramatic losses and degradation during the last four decades (e.g. De Wit et al. 2001). The seagrass species can be considered as ecosystem engineers as they provide the physical habitat for a rich fauna and play also major role in biogeochemical processes thus contributing to high water quality in coastal lagoons. Seagrasses also provide an important food source for herbivorous avifauna and particularly for goose species. In the Bassin d'Arcachon coastal lagoon, upto 45,000 brent geese overwinter that feed on the intertidal seagrass meadows. The root system of the seagrasses is adapted to the anoxic interstitial water of the sediments as it has a lacunal gas transport system that allows to release oxygen from the roots. In addition, roots often excrete organic compounds. This has a very strong impact on the biodiversity of microbes in the rhizosphere of these plants. Hence, all these phenomena explain why the presence of seagrasses enhances biodiversity through many positive facilitative ecological interactions among species.

Another ecotone is the one that runs perpendicular to the coast, from the open sea across the lido or barrier island and into the lagoon (see Fig. 2C). The lido often comprises a sandy beach on the marine side and dune systems. Although in some cases the lido or barrier island also comprise single beds and bedrocks may crop up above the surface. The dune is home for a typical xerophilic vegetation (i.e., adapted to low water availability). However, water from rain, which percolates easily through the sand, may accumulate on top of the marine water and build up to a freshwater lens in the dune system. Such a freshwater lens emerges on the surface in the dune slack where rich vegetation may develop for example including *Parnassia palustris* and the marsh orchid *Epipactus palustris*. The lido and barrier islands may also be exposed to marine intrusion and salt spray. As a result, the marshes on the lido may represent a mosaic of different salinities ranging from freshwater in the slacks and outwelling zones to brackish where it mixes with the seawater and finally to seawater salinities along the beaches. The interior of the lido or barrier island may present an interesting ecotone ranging from the dry dune through outwelling areas and saltmarshes fringing the lagoon.

Coastal lagoons often comprise a mosaic landscape with larger water masses of more or less homogenous salinity in the center, while pronounced and fluctuating salinity gradients occur along its borders. Furthermore, this hydrodynamic heterogeneity gives rise to a large spectrum of sediment types. The higher intertidal and supratidal is characterised by saltmarshes with a sometimes extremely complex mosaic structure when the lagoon comprises a sinuous coastline and many islands (e.g. lagoon of Venice). This extreme complexity and mosaic landscape contribute to creating many ecotones and maintaining a very high biodiversity. A third major ecotone may exist in the lagoon as a strong estuarine salinity gradient ranging from seawater salinities close to the grau or tidal inlet to freshwater close to the inflow of the river tributaries. This allows marine, brackish and freshwater species to coexist in the lagoon, albeit in different habitats. Finally, lagoons often show gradients of water renewal, which can be expressed by its reciprocal, i.e., the water residence time. Water residence times are short close to the tidal inlets and the freshwater tributaries as the water colum is frequently diluted by incoming water from the sea and land, respectively. In some more confined corners of the lagoon, the water residence time can increase dramatically. These more confined areas are particularly sensitive to eutrophication and development of dystrophic crises.

On a global scale, for the different taxonomic animal and plant groups one can often observe a latitudinal gradient with the highest biodiversity in the tropics and a decreasing biodiversity trend with increasing latitudes. Such a pattern has been confirmed for the seagrasses. Thus in the Arctic, only one species may occur in lagoons (*Zostera marina*), and seagrass stands in the tropics may comprise upto 5 species, while Mediterranean lagoons are intermediate with two or three species (Duarte, 2001). The coastal zones of the Malaysian peninsula, Indochina and the Indonesian archipelago represent a hot spot of biodiversity both for seagrass species and mangrove tree species. However, for the rest of the taxonomic groups in lagoons such latitudinal gradients have not been documented for coastal lagoons, probably because detailed records of biodiversity are rare for tropical lagoons (Esteves et al., 2008).

Productivity in coastal lagoons ranges from a poor 10 g C m^{-2} $year^{-1}$ to a very high value of 7,000 g C m^{-2} $year^{-1}$. The high productivity can be positive for sustaining biodiversity if there is an efficient trophic transfer. The fluctuating salinities are often a constraint and source of stress for a number of animal species. However, the relatively calm conditions and the high productivity of the lagoons are advantageous. As a result, many fish and invertebrate species have evolved a life cycle, which consists of spawning in the open sea where salinities are more constant and migration of juveniles into the lagoon where they can grow up and benefit from the calm conditions. The adults migrate back to the sea in autumn. Thus, lagoons can be considered as a nursery for many fish and invertebrate species and coastal fisheries clearly benefits from this nursery function. In general, coastal lagoons are rich in invertebrate species, e.g., the relatively small Thau lagoon (75 km^2) in S France is home for about 100 mollusc species of the 500 found in the Mediterranean Sea (Maxant and Quignard, 2005).

The primary productivity of the Magnoliophyte communities comprises both the plant material and the associated epiphytes. The epiphytes are often grazed by small invertebrates like snails *Gibbula* spp. and *Hydrobia* spp. (see above) and by small crustaceans and oligochaetes. Brent goose (see above) and other herbivorous waterfowl may directly feed on the leaves and stems of seagrass species. In general, lagoons can be very important for waterfowl, because it both sustains the herbivorous species as well as those that feed on small benthic invertebrates and on fishes. Thus, lagoons are often important for migrating waterfowl. Despite the fact, that waterfowl can feed on the plant material of the seagrasses it is generally believed that most of this material is not consumed as it is rather recalcitrant, may accumulate in sediments as refractory material and enters finally in a more slowly operating detritus food chain. However, in addition to the herbivorous bird species, seagrasses can be consumed by aquatic animals. A spectacular example are the Dugongs (*Dugong dugon*), large (upto 3 m length) marine herbivorous mammals (Mamifera) of the sirenian order that occur along the East coast of Africa, South Asia, the Indonesian archipelago and northern Australia. In temperate lagoons, seagrasses can be grazed by sea urchins (*Paracentrotus lividus*).

In conclusion, while brackish environments and particularly environments characterised by strongly fluctuating salinities are not prone to support very high biodiversity levels due to stress for many animal and plant species, it is remarkable that the lagoon environments are very important for biodiversity. But, it is important to consider the biodiversity at the landscape level. Hence, biodiversity is sustained by several factors: 1) the encounter of marine and continental flora and fauna, 2) the creation of many ecotones that run pronouncedly from dry to wet and from freshwater to (hyper) saline, 3) the presence of ecosystem engineers like the seagrasses that create specific habitats, 4) the mosaic structure of lagoons. The high productivity can be an asset for biodiversity if there is an efficient trophic transfer. However, increased eutrophication, and nutrient (N, P) overenrichment, which increases productivity, have often a negative impact on biodiversity as it has detrimental impacts on the seagrass meadows (e.g., De Wit et al., 2001, De Wit et al., 2005) and may disrupt food chains by creating dystrophic crisis in lagoons.

3. Some examples of interactions between humans and lagoons

Figure 3 is a photograph of a wall-painting representing the town of La Palma (Languedoc region, S. France) in the 13th century. It nicely shows the presence and activities of humans in the lagoon and its surrounding and gives a hint to the benefits people have obtained from lagoons. There is also substantial agricultural activity in the surrounding which certainly impacted the lagoon ecosystem, albeit to a much lesser extent than today (low fertilisation intensity and no pesticides used). The main activities in the lagoons were sailing, fishing and salt extraction. As can be seen on the photograph, salt ponds have been created as artificial structures. These have been managed to create and maintain a salinity gradient ranging from the salinity of the lagoon up to NaCl saturating conditions. Along this gradient interesting environments can be observed. The number of aquatic animal species decreases with increasing salinity and aquatic vegetation becomes simplified. From 70 g/L to 200 g/L the bottoms of the salt evaporation ponds are covered with so-called microbial mats, which are interesting stratified communities built by cyanobacteria that are very similar to stromatolites. At higher salinities an extremely eukaryotic halopilic algae *Dunaliella salina* and extremely halophilic archaea bloom in the water column colouring it orange and purple-red respectively (De Wit and Grimalt, 1992). In contrast, it was often necessary to protect these artificial pond system against intrusion of fresh water from continental runoff (see Fig. 2D). Therefore, in between the original shore of the lagoon and the salt extraction ponds, often a canal has been created to intercept the freshwater runoff and prevent it from flowing into the salt ponds. This way, the original ecotone across freshwater and salt marshes into the lagoon has been destroyed and a new ecotone has been created. While the high salinities result in lower biodiversity, it can be argued that the creation of the salt-evaporation ponds have resulted in habitat diversification allowing the original halophilic communities to coexist in the landscape with the interesting lagoonal biocoenoses, albeit at the expense of the earlier existing ecotone.

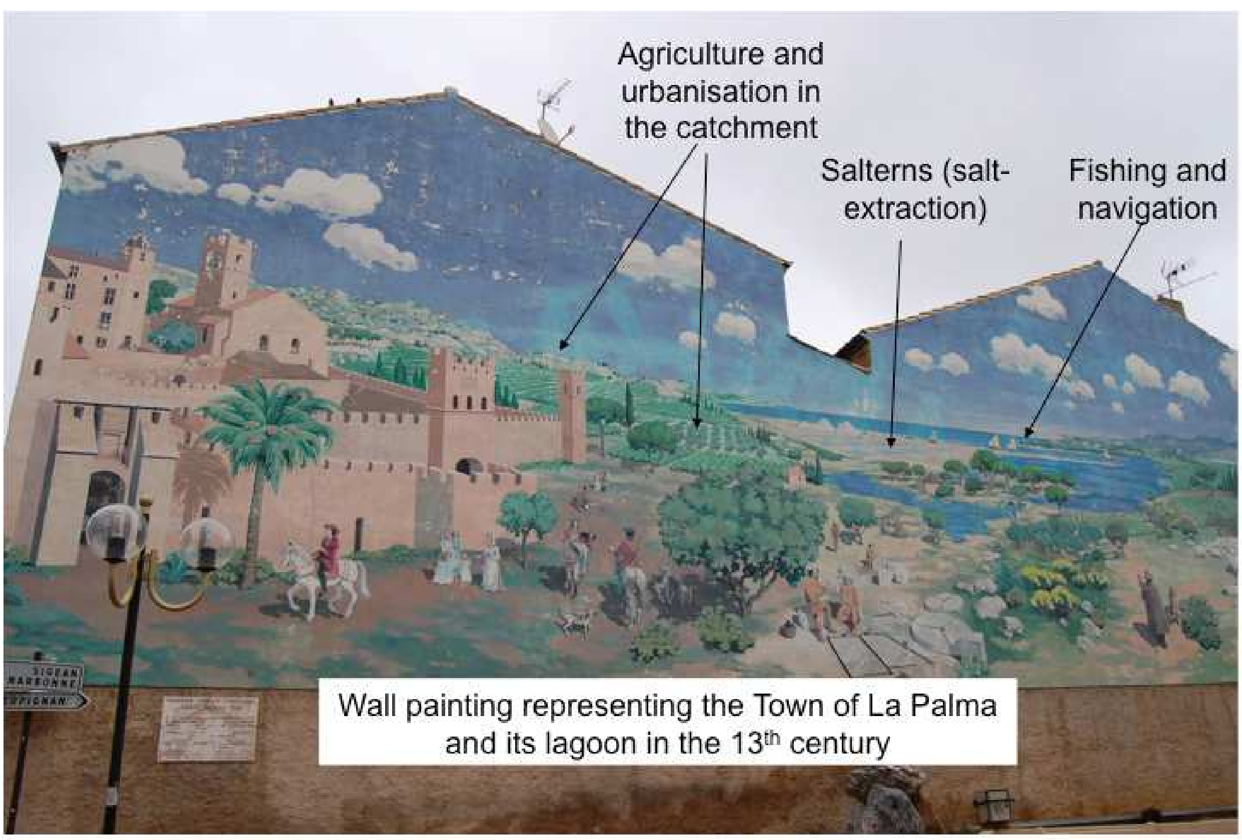


Fig. 3. Photograph of a wall painting in the Small town of La Palma, Languedoc, S. France (by Rutger de Wit).

Second, humans have tended to overexploit the natural resources in coastal lagoons. In general this has resulted in decreasing biodiversity that has become particularly dramatic since the 1950's. In many cases, the oysters where highly appreciated and have been overexploited and been depleted very early (Lotze et al., 2006) and often one or to centuries before the major dramatic biodiversity losses. In the 19th century this stimulated some entrepreneurial people to develop oyster farming in coastal lagoons as an alternative. Oysters were already farmed in the Gulf of Naples during Roman times. Initially the farmers used the autochthonous species, which in the Mediterranean and European Atlantic region was *Ostrea edulis*. However, in many cases diseases have decimated the stocks and this led to replacement by allochthonous species. The introduction of oyster farming raises the following questions: 1) Have the ecological roles of the natural populations of *Ostrea edulis* been replaced by the introduction and development of oyster farming?; 2) How should we evaluate the successive replacements by exotic species in oyster farming?; 3) Are oysters a sentinel for undesired environmental changes?; and 4) Does the socio-economic group of the oyster farmers positively contribute to the maintenance of biodiversity and ecosystem functions? Several of these questions are addressed in De Wit et al. (2011).

With the allochthonous oyster species humans also introduced undesired alien species. Currently, the Etang the Thau lagoon has about 20 % of alien macroalgal species, most originating from the Japanese coastal and marine environments, and therefore, the algal biodiversity in Thau has been characterised as a Japanese garden (Boudouresque et al., 2011). Most of them have been introduced with the foreign oysters. Some macroalgal species have become invasive and modify the local biodiversity patterns. Another animal alien species that causes many problems in mesohaline lagoons is *Ficopomatus enigmaticus* is a tube worm (Polychaeta) of 4-25 mm length that builds and lives within a carbonate tube (Grillas et al., 2006), which was first noticed in northern France in 1921. The accumulation of these carbonate tubing's results in recifs of several dm to a m height comparable to coral-like encrustation. The origin of this species is not clear and it has been suggested that it is originally an Australian species. It occurs in waters of variable salinity in temperate or warm temperate areas of both northern and southern hemispheres, and it was possibly introduced from Australia. Its preferred habitat is brackish water as found in estuaries and mesohaline lagoons. It is probable that it arrived while being transported on ships hulls or on commercial mollusc shells.

4. Lagoons and global change

Coastal lagoons are formed during periods of transgression under conditions of sea-level rise. However, the current rate of sealevel rise is much faster than observed in geological periods. This poses the question of the vulnerability of the lagoons. For example, rising sealevels and increasing erosion of lido's and barrier islands may result in complete disappearance of the lagoon at the land and seascape level, as the lagoon may be converted to an open bay. In other cases, the lido and the water body of the lagoon may move inward and a lagoonal setting remains possible in the future. Inward moving of lagoons is a natural phenomenon during periods of seawater level rise. However it depends a lot on the geomorphological and physical conditions in the land and seascape. Inward moving is often hampered by man-made structures to protect the land from erosion and and/or flooding and by urbanisation of the shoreline both at the seaside and interior shore of the lagoon. A nice example of this phenomenon is given in the book by Dennison et al. (2009) for Ocean city located on the barrier island Fenwick Island that separates the Isle of Wight Bay lagoon from the Atlantic ocean (Maryland, USA). Because of the heavy urbanisation the position of Fenwick Island has been fixed in space, but this is an uncomfortable situation as the area suffers from heavy erosion and occasionally from submersion by the sea during extreme high tides and storm events. In contrast, Assateague island, a non-urbanised barrier island located just to the south of Ocean city has moved about 600 m to the west (inland) since 1942. Assateague island and the lagoon Sinepuxent bay still comprise beautiful ecotones and all the natural aspects of lagoons although some modifications occur because Ocean city reduces the natural sand transport in the Northern part of Assateague island. This shows how natural systems have the capacity to adapt to relative sealevel rise which about 30 cm during the last 100 years and is expected to rise another 60-90 cm by 2100 (Dennison et al., 2009).

In general the interior shore of the lagoon also moves inland with relative sealevel rise. However, man-made structures can severely limit this inland migration (see Fig. 2E). As a first result, the lagoon is often losing many of the fringent saltmarshes and wetlands with a rising sea due to submersion and incorporation into the lagoon. Often, no new wetlands are created as humans often use the potentially remaining land for agriculture or housing. In addition, natural structures like cliffs may also limit the inward move of lagoons in some specific landscapes. Thus, the surfaces of coastal landscape surface in general and coastal lagoons in particular may become reduced by squeezing between an inward advancing shoreline and fixed boundary inland, a phenomenon referred to as coastal squeeze (Doody, 2004).

The shallow coastal lagoons may be particularly susceptible to increased temperatures and increased UV radiation, which are predicted to increase in 2100 by about 3 °C and 20%, respectively with respect to the current situation. This may have important consequences on the pelagic wood web (e.g., Vidussi et al., 2011). In addition, temperature changes may modify distribution patterns. For example, the seagrass *Zostera marina* has its southern distribution limit in the Mediterranean Sea. Thus, questions arises if *Zostera marina* will disappear from the Mediterranean lagoons and such a disappearance may have dramatic impacts on biodiversity, as this species is an important ecosystem engineer. Another aspect is that it is most important that lagoons have a high connectivity among them to allow species to migrate and accommodate to new geographic distributions that are compatible with the climate change. In contrast, very isolated lagoons are at higher risk as they may loose species and have low probabilities to be invaded by foreign species that are adapted to the new climatic conditions.

Finally an important aspect of global change in the marine environment is ocean acidification. Seawater used to have a pH of 8.2 and currently this has already decreased to 8.1 and a further decrease is expected to 7.9 by about 2011. While such a pH shift seems minor it may have important consequences in marine ecology, as this acidification is detrimental for calcifying organisms like some small algae, the coccolithophores, and shell-forming bivalves. However, shallow coastal lagoons with calcareous sediments like in the Languedoc region of S. France, will have the capacity to buffer the acidification.

$$CaCO_3 + H^+ \rightarrow HCO_3^- + Ca^{2+} \quad (1)$$

Equation 1 gives the chemical reaction for this dissolution. Bicarbonate is the predominant form of the carbonate equilibrium at pH around 8; hence the dissolution will consume protons and buffer the ocean acidification in shallow lagoons.

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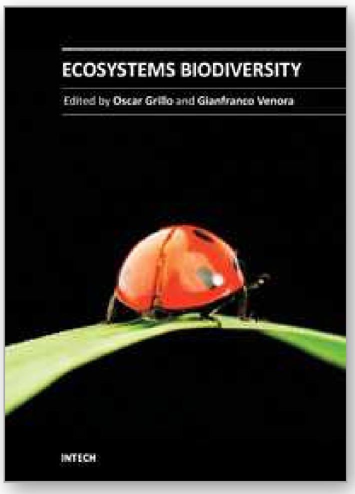

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Ecosystems can be considered as dynamic and interactive clusters made up of plants, animals and micro-organism communities. Inevitably, mankind is an integral part of each ecosystem and as such enjoys all its provided benefits. Driven by the increasing necessity to preserve the ecosystem productivity, several ecological studies have been conducted in the last few years, highlighting the current state in which our planet is, and focusing on future perspectives. This book contains comprehensive overviews and original studies focused on hazard analysis and evaluation of ecological variables affecting species diversity, richness and distribution, in order to identify the best management strategies to face and solve the conservation problems.