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EFFECTS OF MAR MENOR BASIN ON THE ECOLOGICAL STATUS OF THE LAGOON

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1. Environmental status in the Mar Menor basin. Evolution, causes and consecuences

Economic activities in the basin and around the Mar Menor, especially the urban-tourist development in the vicinity of the lagoon and, more recently, the increase in intensive irrigation in the basin, have generated multiple processes of degradation in the lagoon, its associated wetlands and the environment of the Mar Menor area as a whole. These processes are briefly presented below.

After the historical problems of mining pollution and heavy metals, which continue to be present in the lagoon and in wetlands such as Lo Poyo (Alvarez Rogel, 2016, Muñoz-Vera and García, 2016, Jiménez Martínez et al, 2016), the widening and dredging of the communication channel between the lagoon and the Mediterranean (El Estacio) in the mid-70s produced deep changes in the temperature and salinity of the Mar Menor, facilitating the settlement of new species. The uncontrolled growth of tourism and the lack of planning and management with environmental criteria has caused serious impacts in the area of influence of the lagoon ahd has originated a high demand of resources.

One of the impacts generated by the urban-tourist development in the Mar Menor environment has been the production of a great volume of wastewater, part of which has been discharged into the lagoon until very recently, providing organic and nutrient pollution. Although improvements in sanitation and water treatment have greatly reduced urban discharges to the Mar Menor in recent years, some problems persist due to deficiencies in treatment infrastructure and sanitation networks, which are evident during summer and during episodes of large rainfall, when the capacity of the treatment plants is exceeded or breakages are generated that cause occasional spills to the lagoon.

Other problems that affect the Mar Menor include the construction of artificial beaches in typically lacustrine habitats (badly called beach regenerations, since the banks of the Mar Menor do not have natural presence of large accumulations of sand), the construction of seafront promenades and sport ports and the impacts of motorized nautical tourism, among others.

But undoubtedly the problem that has caused the very serious current crisis of the lagoon is the high input of nutrients into the lagoon. In the Mar Menor basin, with an extension of 1,236 km^2, irrigation agriculture has been progressively developed, initially based on the use of underground resources. Although up to three decades ago such exploitation has been quite limited, the arrival of the Tajo-Segura water transfer in 1979 implied a deep transformation of the basin, with a significant increase in irrigation. Work done with remote sensing has shown that only between 1988 and 2009 the irrigation of the basin increased from about 25,150 hectares to about 60,700 hectares, 141% more (Carreño Fructuoso, 2015). The transformation to irrigation has been reactivated in recent years, estimating the existence of between 15,000 and 20,000 hectares of irrigated lands outside the official figures.

Alongside the waters of the Tajo-Segura transfer, the use of groundwater has increased. Following the intense drought in 1995, the start-up of groundwater desalination plants began, leading to spills of brines with high concentrations of nutrients. Very recently, some resources from marine desalination have also been added (García Aróstegui et al., 2016).

This significant expansion of irrigation in the Mar Menor basin has greatly increased water flows and nutrients reaching the lagoon and its coastal wetlands through surface, subsurface and underground flows (Martínez-Fernández et al., 2005, Velasco et al., 2006, Carreño et al., 2008, Esteve et al., 2008, Martínez-Fernández et al., 2009). The increase in water flows has been confirmed by the rise in the piezometric levels of aquifers (Rodriguez Estrella, 2009, Aragon et al., 2009), as well as by the increase in the water table, periods of flooding and soil moisture in the wetlands of the Mar Menor (Álvarez-Rogel et al., 2007).

A particularly important flow is the direct entry of overland lows during episodes of heavy rainfall, such as the one that occurred in December 2016, when a large part of the accumulated agricultural pollution in the basin, together with a high sediment load, is loaded into the lagoon. The results obtained with simulation models (Martínez-Fernández et al, 2014, Esteve et al, 2016), point to the great importance of these heavy rainfall episodes in the total input of nutrients into the Mar Menor. These results are consistent with studies on pesticide entry to the lagoon, which show that more than 70% of the total input of pesticides to the Mar Menor occurs during flood events (Moreno González et al, 2013; León et al., 2016). Other available studies in the scientific literature also point to the great importance of flood events and heavy rains and their general washing of the basin on the total export of nutrients (David et al., 1997, Xue et al., 1998) .

The surfacel flows have high nitrogen and phosphorus contents, with nitrate concentration values that already reached 62 mg/l in the Albujón waterway in 1997, 85 mg/l in brines and 160 mg/l in some drainage channels (Martínez Fernández and Esteve Selma, 2003). In Rambla del Miedo, values exceeding 10 mg L^{-1} of P-PO4 have been found (Álvarez Rogel et al., 2006) and in Rambla de Miranda, values of 200 mg L^{-1} of total nitrogen have been reached and up to 2.5 mg L^{-1} of total phosphorus in Rambla de Miranda (González-Alcaraz et al., 2012). The agrarian pollutin has also reached the groundwater, which presents in the Quaternary aquifer values around 100 mg/l of nitrate in areas close to the lagoon and points with peaks exceeding 250 mg/l (Perez Ruzafa & Aragon, 2003).

The general status of the basin and the various compartments and water flows, and especially the high nitrate contents, led to the declaration in 2001 of the Campo de Cartagena as a Zone Vulnerable to Nitrate Pollution, in application of Directive 91/676 / CEE, although this declaration has not managed to control and reduce the high level of agricultural pollution and its impacts on the Mar Menor and associated wetlands.

2. River basin impacts on the lagoon. Export of nutrients and eutrophication in Mar Menor

Based on a dynamic simulation model on land use changes and their effects on nutrient flows in the Mar Menor basin (Martínez-Fernández et al, 2014; Esteve et al, 2016), the input values have been estimated. These values are in average around 1,000 tons of nitrogen per year in the period 2000-2005, with large fluctuations between 700 and 1,600 tons per year and around 240 tons per year of phosphorus. According to the estimates of the model, the contribution of urban discharges represents between 10 and 15% of the total input of nutrients to the lagoon. These results are consistent with many other studies, which agree that in watersheds with intensive agriculture most of the nutrients have a diffuse origin from agricultural uses (Jordan et al., 1997, Kronvang, 1999, Meissner et al., 2002; Lacroix et al., 2005). It has also been pointed out, in relation to the eutrophication of coastal zones, that the main source of nutrients in the affected areas, including coastal waters, is agriculture (Boesch & Brinsfield, 2000, Canton et al, 2012).

Regarding the nutrient export coefficients per hectare, the indicated values of total input to the Mar Menor correspond to an interannual average of around 8 kg N ha^{-1} $year^{-1}$, with fluctuations between 6 and 13 kg N ha^{-1} $year^{-1}$. These values are in ranges similar to those obtained in many other agricultural basins (Mattikalli and Richards, 1996, David et al., 1997, Jordan et al., 1997). The specific net contributions per hectare of irrigated land, considering the irrigated area in the Mar Menor basin in the period of 2000-2005, are at an annual average of around 18 kg N ha^{-1} $year^{-1}$, with fluctuations between 13 and 29 kg N ha^{-1} $year^{-1}$. These net export values from agrarian uses are also similar to those found in other cases of basin studies with intensive agriculture. Thus, agriculture is the main source of nitrogen in the coastal lagoon of Arcachon, France, with a net export of 28.5 kg N ha^{-1} $year^{-1}$ (Canton et al, 2012), while a broad revision of the Scientific literature, from more than 40 case studies in temperate climates, indicates ranges between 15 and 70 kg N ha^{-1} $year^{-1}$ of leaching and nitrogen transport in plains with intensive agricultural uses (Pärn et al, 2012).

On the other hand, the values of nitrogen input estimated with the dynamic model are consistent with the empirical data of nitrogen concentration of the main flows of the basin, which are between 28 and 60 mg/l of dissolved inorganic nitrogen (Lloret et al., 2005, Velasco et al., 2006, García Pintado et al, 2009, Serrano and Sironi, 2009, Álvarez Rogel et al., 2009) and with the estimated mean annual water input to the lagoon, which the basis of work by Senent Alonso et al., (2009), can be estimated between 37 and 45 Hm^3/year. These nitrogen concentration data and the estimates of the average annual discharge of water to the Mar Menor jointly provide an estimated average annual input of nitrogen to the lagoon located between 1,000 and 1,300 tons per year, similar to that obtained with the dynamic model.

The lagoon is also affected by flows of regulated and emerging organic pollutants, having detected the entry of some 70 organic pollutants through the Albujón waterway (Moreno González et al, 2013). An entry into the Mar Menor of about 18 kg per year of pesticides from agriculture and about 11 kg per year of other chemicals from urban spills and other anthropic sources has been estimated (León et al., 2016).

In short, as in many other basins with intensive agricultural uses, the irrigation of the Mar Menor basin is main cause responsible for the high flow of nutrients that has been affecting the Mar Menor lagoon for several decades. As in many other case studies, this high flow of nutrients is mainly responsible for the nutrient enrichment and eutrophication processes of aquatic ecosystems affected by such flows, including coastal lagoons and other coastal areas.

3. Effects on habitats and biodiversity. Associated wetlands and Mar Menor water birds

Part of the coastal wetlands associated with the Mar Menor have been characterized as coastal crypto-wetlands (Vidal-Abarca et al., 2003). In its inner bank, the Saladar de Lo Poyo, the Marina del Carmolí and Playa de la Hita are included. Following the typology of the Habitats Directive (92/43 / EEC), the salt steppe unit is 95% composed of habitat 1510 "Mediterranean salt steppes (*Limonietalia*)", of priority interest. The salt marsh unit is mostly made up of habitat 1420 (Mediterranean halophilic scrub and thermoatlantic, *Sarcocornetea fruticisi*), of community interest. Finally, the third community is composed of the reedbed (*Phragmites australis*), not included in the Directive.

The wetlands located in arid environments, as in the Mar Menor area, usually present hypersaline conditions and scarce water (cryptowetlands). These characteristics, on the one hand, are very vulnerable to hydrological changes and, on the other hand, give rise to a unique biodiversity that is considered rare in the European context. The values of the Mar Menor lagoon and its associated wetlands are endorsed by the existing protection status in the area: San Pedro del Pinatar Regional Park, Protected Landscape of Open Areas and Mar Menor Islands, designation of the Mar Menor and associated wetlands as Special Protection Area for Birds and Site of Community Importance), declaration of the Mar Menor and its surroundings as a Ramsar area (Wetland of International Importance of the Ramsar Convention) and ZEPIM area (Specially Protected Area of Importance for the Mediterranean).

The increase in water flows as a result of the irrigation of the Mar Menor basin have caused significant alterations of the coastal wetlands of the Mar Menor. Remote sensing studies for the period 1984-2009 (Carreño et al., 2008, Carreño, 2015) show that during this period the area of saline steppe, of priority interest, has been reduced to less than half (from 243 to 100 ha), while the area of saltmarshes, of community interest, has doubled (from 69 to 142 ha) and finally the reedbed, without interest from the point of view of the Directive, has multiplied by more than five (from 29 to 165 ha). All these changes are correlated with the increase of irrigation in the basin with a delay of five years (Carreño et al, 2008, Carreño 2015) and with the distance of irrigation to the wetland (Martínez López et al, 2014, Martínez López et al, 2015) The net loss of salt steppe is very important, since it is the habitat with the highest interest from the point of view of the Directive. In addition, the saline steppe is a habitat with a total area in Spain of only 12,976 hectares, of which no more than 37% has a good state of conservation (Esteve and Calvo, 2000). The application of an index that values the interest of the communities from the point of view of the Habitat Directive, shows that the changes have meant a global reduction of 48% in the interest of the vegetation of the wetlands from the perspective of the Habitat Directive between 1984 and 2009 (Carreño et al, 2008), derived from the increase in water flows that affect them.

The changes have also affected the community of steppe passerines in the Marina del Carmolí (Robledano et al., 2010). The progressive reduction of the saline steppe induced by the increase of water flows to the Marina del Carmolí have led to a decline of the Alaudidae family, closely linked to the steppe habitat. This represents a loss of value from the point of view of the Birds Directive, as evidenced by the marked decline of the index based on that Directive. This decline is worrisome, given that the naturalistic values associated with the Alaudidae family are those that justify the designation of the Marina del Carmolí as Special Protection Area for birds. The hydrological alterations caused by the increase in irrigation in the Mar Menor basin are expressed in changes in other biological communities such as wandering coleoptera (Pardo et al., 2008). The changes in the Marina del Carmolí induced by the increase in water flows has been considered by the scientific communication services of the European Commission an emblematic example of the impacts of agriculture on wetlands and their conservation (Science for Environment Policy, 2010).

In relation to the waterbird communities of the Mar Menor, the increase of nutrients and their incorporation into trophic chains is associated with a succession in the lagoon bird community, with an initial phase of community diversification (consistent with the expected response to phenomena of enrichment in oligotrophic media), until reaching a maximum, but in the long term there is a simplification and trivialization of the bird community (Robledano et al 2011, Farinos et al, 2016). In the last phases, negative tendencies are evident, even disappearing in some cases, both of the species that have played the intermediate stages and of other genuine ones of the original hypersaline and oligotrophic environment (case of the *Mergus serrator*). Other species such as the great cormorant and the black-necked grebe show favorable demographic trends and end up dominating the community, which is interpreted in part as a response to local eutrophication. These changes are correlated with the increase of irrigation in the basin with a delay of two years (Robledano et al, 2011).

In short, the available studies and the long-term monitoring of coastal wetlands and their habitats and different biological communities, demonstrate the existence of important alterations derived from the increase of water and nutrient flows from the basin, caused by the great irrigation expansion. These alterations have negative effects on the naturalistic value of certain communities and components of biodiversity, especially worrying in the case of those specially involved in granting different protection status for the Mar Menor and its wetlands, as indicated in previous paragraphs.

4. Guidelines to prevent and minimize pressures. Precautionary and mitigation measures

The conservation of wetlands and lagoon systems such as the Mar Menor require, in an essential way, an integrated and sustainable planning and management of their basins. Facing the serious problems of the Mar Menor and in particular to reverse the current eutrophic state of the lagoon requires, among other measures, a drastic reduction in the entry of nutrients into the lagoon through the surface channels, groundwater flows, drainages, brine flows and flood events. This need is further reinforced by the declaration of the Mar Menor basin as a Area Vulnerable to Nitrate Pollution, the declaration of the lagoon as a Sensitive Area in application of the Urban Wastewater Directive (91/271 ECC) and the application of the Water Framework Directive (2000/60 EC), which requires to reach and maintain a good ecological status of the Mar Menor lagoon.

Specific studies aimed at assessing the preferences of the different social actors and the social acceptability of possible measures, show the willingness of citizens to pay for the improvement of the Mar Menor to the extent that the social benefits of such improvement exceed the costs of the measures (Perni et al., 2011, Martínez Paz et al., 2013). Likewise, the studies show the support of the different actors for environmental recovery measures in the basin, such as the rehabilitation of the Albujón channel (Perni and Martínez Paz, 2013).

It is necessary the coordination of all administrations, the involvement of the agricultural sector and the participation of citizens and different social actors, in order to propose a truly integrated strategy that simultaneously applies various measures at various spatial levels, from the scale of agricultural field to the whole basin:

1. Control and reorder the irrigated area in the Mar Menor basin, as well as the extraction of groundwater, the dislocation plants and the generation and pouring point of the brines.
2. Reduce agricultural pollution at source, with rigorous measures in application of the declaration of the Mar Menor Basin as a Area Vulnerable to Nitrate Pollution. These measures may include promoting the conversion to organic

farming, compulsory pretreatment of all brines (for example with small green filters) prior to the spill and that the greenhouses adopt closed cycle systems to avoid drainages rich in nutrients, something which is compulsory in some European countries.

3. Apply the extensive and experienced existing battery of measures based on nature based solutions (www.nwrm.eu), to reduce the flows of agricultural pollution thoroughout the basin. Among others, these measures include the establishment of hedges and vegetation strips between plots, the revegetation of channels and drainage networks or the creation of small water bodies with natural vegetation. These measures act as buffer-areas and traps for the retention of nutrients and other pollutants throughout the entire basin. As evidenced in the scientific literature, the reconfiguration of agrarian landscapes, incorporating wetlands, vegetation linked to drainage systems and the recovery of natural vegetation spots in connection with water flows, is key to maintain and improve the capacity of basins and fluvial plains to reduce pollution flows (Boesch & Brinsfield, 2000; Comín et al, in press). These components (wetlands, small bodies of water, vegetation associated to channels and drainage networks) can have a nutrient retention capacity that, according to a review of eleven study cases, would be between 66 and 89% (Pärn et al, 2012).

4. In the vicinity of the lagoon, to carry out actions to recover wetland surfaces, strengthening their nutrient retention capacity while maintaining their naturalistic values and conservation of biodiversity. The available data from the Mar Menor coastal wetlands (see, for example, Vidal-Abarca et al, 1998, Álvarez Rogel et al., 2005, González Alcaraz et al, 2011) show the high potential of these wetlands to remove and remove nutrients. contained in water flows. Other studies carried out in the Mar Menor case (Martínez-Paz et al, 2007, Perni and Martínez-Paz, 2013) indicate that the recovery of natural wetlands is also more cost-effective measure than other types of measures, such as reuse of drainages, given that the unit costs of the recovery of wetlands (euros per kg of removed nutrient) are around half of those corresponding to the reuse of drainages. These results are consistent with those obtained in other studies (Gren et al., 1997, Turner et al., 1999, Gustafson et al., 2000, Zanou et al., 2003, Lacroix et al., 2005, Elofsson, 2010; Trepel, 2010), which demonstrate that construction and especially the restoration of natural wetlands is an option with a high cost-effectiveness ratio to reduce diffuse pollution in agricultural watersheds. In addition, flood events, one of the main sources of nutrients to the lagoon, cannot be treated with hydraulic infrastructures, but their nutrient loads can be removed by means of the wetlands.

5. Monitoring and assessment of management measures

The integrated strategy described in the previous section needs the essential support of a good monitoring program; modeling tools for the analysis of the state of the system and the simulation of management options; the ex-ante evaluation for the selection of alternatives; the ex-post monitoring and evaluation of the measures and an adaptive management that guarantees the fulfillment of the expected objectives. These components should be made explicit and linked to the Integrated Management Plan for the protected areas of the Mar Menor and the Mediterranean Coastal Areas of the Region of Murcia. These components are briefly presented below.

1. It is essential to implement a monitoring program, both in relation to water flows and water quality at the surface, subsurface and underground levels in the

basin and in relation to the status of coastal wetlands and their various biophysical components.

2. It is also essential to have the appropriate modeling tools to quantify water and nutrient flows at the basin scale and to simulate the different management alternatives and measures in order to analyze their potential effects on the reduction of nutrient flows.

3. As established by the European Commission, a cost-effectiveness analysis of the different alternatives and management measures must be carried out, prior (ex-ante) to the selection of the alternatives finally adopted. Among the indicators to be used in this phase of selection of alternatives, efficiency indicators must be incorporated, specifically indicators of cost-effectiveness in relation to the removal of nutrients (kg of N and P removed per euro invested).

4. After the implementation of measures, a systematic monitoring and evaluation of such measures must be carried out (ex-post). The evaluation procedure must incorporate indicators of effectiveness, that is, indicators of the degree to which the expected objectives have been achieved, specifically indicators of the relative contribution of each measure to the reduction of the total input of nutrients to the lagoon.

5. An adaptive management must be applied, in order to guarantee the effectiveness of the measures to achieve the planned objectives. This adaptive cycle must allow to reorient and improve the effectiveness of the measures, in application of the best available knowledge. Specifically, adaptive management must continuously improve the effectiveness of measures to reduce the entry of nutrients into the Mar Menor.

References

Álvarez-Rogel J, Jiménez-Cárceles FJ, Egea C. 2006. Phosphorus and nitrogen content in the water of a coastal wetland in the Mar Menor lagoon (SE Spain): relationships with effluents from urban and agricultural areas. Water Air Soil Pollut, 173: 21–38.

Alvarez-Rogel, J., Jimenez-Carceles, F.J., Roca, M.J., Ortiz, R., 2007. Changes in soils and vegetation in a Mediterranean coastal salt marsh impacted by human activities. Estuarine, Coastal and Shelf Science 73: 510-526.

Álvarez-Rogel, J.; Jiménez-Cárceles, F.J.; Egea Nicolás, C.; María-Cervantes, A.; González-Alcaraz, M.N.; Párraga Aguado, I.; Conesa Alcaraz, H.M. 2009. Papel de los humedales costeros del Mar Menor en la depuración de aguas eutrofizadas: el caso de la Marina del Carmolí. En Cabezas & Senent (Eds): Mar Menor. Estado actual del conocimiento científico. Fundación Cluster-Instituto Euromediterráneo del agua. pp. 321-358

Alvarez-Rogel, J., González-Alcaraz, M.N.; Conesa Alcaraz, H.; Tercero Gómez, M.C.; Párraga-Aguado; I. María-Cervantes, I.; Jiménez-Cárceles, F.J. 2016. Eutrofización y contaminación por residuos mineros en humedales del Mar Menor: comprendiendo los procesos biogeoquímicos para plantear posibles actuaciones de manejo. En Leon, V.M y J.M. Bellido. Mar Menor: una laguna singular y sensible. Evaluación científica de su estado. Madrid, Instituto Español de Oceanografía, Ministerio de Economía y Competitividad. 414 p. Temas de Oceanografía, 9. ISBN 978-84-95877-55-0.

Aragon, C.; Jiménez-Martínez, J. ; Gaqrcía-Aróstegui, J.L.; Hornero, J. 2009. Hidrogeología y recursos subterráneos en el área Campo de Cartagena-Mar Menor. En Cabezas & Senent (Eds): Mar Menor. Estado actual del conocimiento científico. Fundación Cluster-Instituto Euromediterráneo del agua. pp. 85-108.

Boesch, D.F; Brinsfield, R.B. 2000. Coastal eutrophication and agriculture: contributions and solutions. Biological Resource Management: connecting science and policy. 93-115.

Canton, M.; Anschutz, P.; Coynel, A.; Posenaere, P.; Auby, I.; Poirier, D. 2012. Nutrient export to an Eastern Atlantic coastal zone: first modeling+ and nitrogen mass balance. Biogeochemistry, 107: 361-377.

Carreño, M.F., Esteve, M.A., Martinez, J., Palazón, J.A. and Pardo, M.T. 2008. Habitat changes in coastal wetlands associated to hydrological changes in the watershed. Estuarine. Coastal and Shelf Science, 77, 475-483.

Carreño, M.F. 2015. Seguimiento de los cambios de usos y su influencia en las comunidades naturales en la cuenca del Mar Menor, 1988-2009, con el uso de SIG y Teledetección. Tesis Doctoral. Universidad de Murcia.

Comín, F.; Sánchez Pérez, J.M.; Español, C.; Carranza, F.; Sauvage, S.; Antigüedad, I.; Zabaleta, A. et al. Floodplan capacity to depollute water in relation to the structure of biological communities. Ecological Engineering (en prensa).

David, M. B., L. E. Gentry, D. A. Kovacic & K. M. Smith, 1997. Nitrogen balance in and export from an agricultural watershed. Journal of Environmental Quality 26: 1038–1048.

Elofsson K. 2010. Cost-effectiveness of the Baltic Sea action plan. Mar Policy, 34:1043–1050.

Esteve, M.A; Calvo, J.F. 2000. Conservación de la naturaleza y biodiversidad en la Región de Murcia. En: Calvo, J.F.; Esteve, M.A. y López Bermúdez, F. (Coord.). Biodiversidad. Contribución a su conocimiento y conservación en la Región de Murcia. Instituto del Agua y Medio Ambiente. Servicio de Publicaciones Universidad de Murcia.

Esteve, M.A.; Carreño, M.F.; Robledano, F.; Martínez-Fernández, J.; Miñano, J. 2008. Dynamics of coastal wetlands and land use changes in the watershed: implications for the biodiversity. In Raymundo E. Russo (Ed.): Wetlands: Ecology, Conservation and Restoration. Nova Science Publishers. New York. pp. 133-175.

Esteve Selma, M.A., Martínez Martínez, J.; Fitz, C.; Robledano, F.; Martínez Paz, J.M.; Carreño, M.F.; Guaita, N.; Martínez López, J.; Miñano, J. Conflictos ambientales derivados de la intensificación de los usos en la cuenca del Mar Menor: una aproximación interdisciplinar. pp. 79-112. En Leon, V.M y J.M. Bellido. Mar Menor: una laguna singular y sensible. Evaluación científica de su estado. Madrid, Instituto Español de Oceanografía, Ministerio de Economía y Competitividad. 414 p. Temas de Oceanografía, 9. ISBN 978-84-95877-55-0.

Farinós, P., F. Robledano, Ma F. Carreño. 2016. Las aves acuáticas del Mar Menor: respuesta al cambio ambiental a distintas escalas. En Leon, V.M y J.M. Bellido (Eds). Mar Menor: una laguna singular y sensible. Evaluación científica de su estado. Madrid, Instituto Español de Oceanografía, Ministerio de Economía y Competitividad. Temas de Oceanografía, 9. pp 213-240.

García Pintado, J.; Barberá, G.; Martínez-Mena, M.; Albaladejo, J.; Erena, M.; Castillo, V. 2009. Caracterización y evaluación de fuentes antrópicas de nutrientes transportados por la rambla del Albujón hacia el Mar Menor. In Cabezas & Senent (Eds): Mar Menor. Estado actual del conocimiento científico. Fundación Cluster-Instituto Euromediterráneo del agua. pp. 167-206.

García-Aróstegui, J.L., Jiménez-Martínez, J.; Baudron, P.; Hunink, J.; Contreras, S.; Candela, L. 2016. Las aguas subterráneas en el Campo de Cartagena-Mar Menor. En Leon, V.M y J.M. Bellido. Mar Menor: una laguna singular y sensible. Evaluación científica de su estado. Madrid, Instituto Español de Oceanografía, Ministerio de Economía y Competitividad. 414 p. Temas de Oceanografía, 9. ISBN 978-84-95877-55-0.

González-Alcaraz, M.N., Jiménez Cárceles, F.J., Egea, C., María-Cervantes, A., Párraga-Aguado, I., Álvarez-Rogel, J., Conesa, H.M. 2011. Papel de los humedales costeros del Mar Menor en la depuración de aguas eutrofizadas: el caso de la Marina del Carmolí, En: El Mar Menor. Estado actual del conocimiento científico. pp. 73-104. Instituto Euromediterráneo del Agua. Murcia.

González Alcaraz, M.N.; Egea, C., Jiménez-Cárceles ,F.J., Párraga, I., María-Cervantes, A., Delgado, M.J., Álvarez-Rogel, J. 2012. Storage of organic carbon, nitrogen and phosphorus in the soil-plant system of Phragmites australis stands from a eutrophicated Mediterranean salt marsh. Geoderma, 185-186: 61-72.

Gren, I.M., Elofsson, K, Jannke, P. 1997. Cost-effective nutrient reductions to the Baltic Sea. Environmental and Resource Economics 10, 341-362.

Gustafson, A., Fleischer, S., Joelsson, A. 2000. A catchment-oriented and cost-effective policy for water protection. 2000. Ecological Engineering 14, 419-427.

Jordan, E ; Correll, D ; Weller D. 1997. Effects of agriculture on Discharges of Nutrients from Coastal Plain Watersheds of Chesapeake Bay. Journal of Environmental Quality 26: 836-848.

Jiménez Martínez, J.; García-Aróstegui, J.L.; Hunnink, J.E.; Contreras, S.; Baudron, P.; Candela, L. 2016. The role of groundwter in highly human-modified hydrosystems: a review of impacts and mitigation options in the Campo de Cartagena-Mar Menor costal plain (SE Spain). Environmental Reviews, 24: 377-392.

Kronvang, B., Svendsen, L.M., Jensen, J.P., Dørge, J., 1999. “Scenario analysis of nutrient management at the river basin scale.” Hydrobiologia vol. 410, pp. 207–212.

Lacroix, A., Beaudoin, B., Makowsk, D. 2005. Agricultural water nonpoint pollution control under uncertainty and climate variability. Ecological Economics 53, 115– 127.

León, V., Moreno-González, R.; Campillo, J.A. 2016. Contaminantes orgánicos regulados y emergentes en el Mar Menor. En Leon, V.M y J.M. Bellido. Mar Menor: una laguna singular y sensible. Evaluación científica de su estado. Madrid, Instituto Español de Oceanografía, Ministerio de Economía y Competitividad. 414 p. Temas de Oceanografía, 9. ISBN 978-84-95877-55-0.

Lloret, J.; Marin, A.; Marin-Guirao, L.; Velasco, J. 2005. Changes in macrophytes distribution in a hypersaline coastal lagoon associated with the development of intensively irrigated agriculture. Ocean & Coastal Management, 48, 828-842.

Martínez Fernández, J. & M. A. Esteve Selma, 2003. El papel de las aguas subterráneas en la exportación de nutrientes de origen agrícola hacia la laguna del Mar Menor. In Fornés, J.M. & R. Llamas (eds), Conflictos entre el desarrollo de las aguas subterráneas y la conservación de los humedales: litoral mediterráneo. Ediciones Mundi-Prensa, Madrid, 191–213.

Martínez Fernández, J., Esteve, M.A., Robledano, F., Pardo, M.T., Carreño, M.F. 2005. Aquatic birds as bioindicators of trophic changes and ecosystem deterioration in the Mar Menor lagoon (SE Spain). Hydrobiologia, 550: 221-235.

Martínez-Fernández, J.; Esteve, M.A.; Carreño, M.F.; Palazón, J.A. 2009. Dynamics of land use change in the Mediterranean: implications for sustainability, land use planning and nature conservation. In Denman and Penrod (Eds): Land use policy. Nova Science Publishers. New York. pp. 101-143.

Martínez-Fernández, J.; Esteve-Selma, M.A; Martínez-Paz, J.M.; Carreño-Fructuoso, M.F.; Martínez-López, J.; Robledano, F.; Farinós, P. 2014. Trade-Offs Between Biodiversity Conservation and Nutrients Removal in Wetlands of Arid Intensive Agricultural Basins: The Mar Menor Case, Spain. En S. E. Jørgensen, N-B. Chang & F-L Xu (Eds.): Ecological Modelling and Engineering of Lakes and Wetlands. Developments in Environmental Modelling, Volume 26. pp. 275-310.

Martínez-López, J.; Carreño, M.F.; Palazón-Ferrando, J.A.; Martínez-Fernández, J.; Esteve, M.A. 2016. Remote sensing of plant communities as a tool for assessing the condition of semiarid Mediterranean saline wetlands in agricultural catchments. International Journal of Applied Earth Observation and Geoinformation, 26: 193-204.

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Martínez-López J., Martínez-Fernández J., Naimi B., Carreño M.F., Esteve M.A. 2015. An open-source spatio-dynamic wetland model of plant community responses to hydrological pressures. Ecological Modelling, 306: 326-333.

Martinez Paz, J.M.; Martinez Fernández, J.; Esteve Selma, M.A. 2007. Evaluación económica del tratamiento de drenajes agrícolas en el Mar Menor (SE España). Revista Española de Estudios Agrosociales y Pesqueros, 215/216. 211-231.

Martínez-Paz JM, Perni A, Martínez-Carrasco F. 2013. Assessment of the programme of measures for coastal lagoon environmental restoration using cost–benefit analysis. Eur Plan Stud, 21: 131–148.

Mattikalli, N; Richards, K. 1996. Estimation of Surface Water Quality Changes in Response to Land Use Change: Application of The Export Coefficient Model Using Remote Sensing and Geographical Information System. Journal of Environmental Management 48: 263–282.

Meissner, R., Seeger, J., Rupp, H., 2002. "Effects of agricultural land use changes on diffuse pollution of water resources." Irrigation and Drainage, vol. 51, pp. 119-127.

Moreno-González, R., Campillo, J.; García, V., León, V. M. 2013. Seasonal input of regulated and emerging organic pollutants through surface watercourses to a Mediterranean coastal lagoon. Chemosphere, 92, 247-257.

Muñoz-Vera, A.; García, G. 2016. Influencia de los residuos mineros de la Sierra Minera de Cartagena-La Unión en la evolución de los sedimentos de la laguna costera Mar Menor. En Leon, V.M y J.M. Bellido. Mar Menor: una laguna singular y sensible. Evaluación científica de su estado. Madrid, Instituto Español de Oceanografía, Ministerio de Economía y Competitividad. 414 p. Temas de Oceanografía, 9. ISBN 978-84-95877-55-0.

Pardo, M. T., Esteve, M .A., Giménez, A., Martínez-Fernández, J., Carreño, M. F., Serrano, J. and Miñano, J. 2008. Assessment of the hydrological alterations on wandering beetle assemblages (coleoptera: Carabidae and Tenebrionidae) in coastal wetlands of arid mediterranean systems). Journal of Arid Environments, 72: 1803– 1810.

Pärn, J; Pinay, G.; Mander, U. 2012. Indicators of nutrients transport from agricultural catchments under temperate climate: A review. Ecological Indicators, 22: 412.

Pérez Ruzafa, A. & R. Aragón, 2003. Implicaciones de la gestión y el uso de las aguas subterráneas en el funcionamiento de la red trófica de una laguna costera. In Fornés, J. M. & R. Llamas (eds), Conflictos entre el desarrollo de las aguas subterráneas y la conservación de los humedales: litoral mediterráneo. Ediciones Mundi-Prensa. Madrid: 215–245.

Perni, A.; Martínez-Paz, J.M. 2013. A participatory approach for selecting cost-effective measures in the WFD context: The Mar Menor (SE Spain). Science of the Total Environment, 458–460: 303–311.

Perni, A.; Martínez-Carrasco, F.; Martínez-Paz, J.M. 2011. Economic valuation of coastal lagoon environmental restoration: Mar Menor (SE Spain). Ciencias Marinas, 37: 175-190.

Robledano F, Esteve M.A, Farinós P, Carreño M.F, Martínez J. 2010. Terrestrial birds as indicators of agricultural-induced changes and associated loss in conservation value of mediterranean wetlands. Ecological Indicators, 10: 274-286

Robledano, F., Esteve, M.A., Martínez-Fernández, J., Farinos, P. 2011. Determinants of wintering waterbird changes in a Mediterranean coastal lagoon affected by eutrophication. Ecological Indicators 11. 395-406.

Rodríguez Estrella, T. 2009. El Mar Menor: Geología y sus relaciones con las aguas subterráneas del continente. In Cabezas & Senent (Eds): Mar Menor. Estado actual del conocimiento científico. Fundación Cluster-Instituto Euromediterráneo del agua. pp. 47-84.

Science for Environment Policy. 2010. Irrigation threatening steppe birds in Mediterranean wetlands. Science for Environment Policy, News Alert Issue, 181. January 2010. European Commission DG Environment News Alert Service.

Senent Alonso, M.; Martínez Vicente, D.; Cabezas, F.; García Aróstegui, J.L.; Baudron, P. 2009. Aproximación mediante modelización matemática a la evaluación de las descargas del acuífero cuaternario del Campo de Cartagena al Mar Menor (Murcia). In Cabezas & Senent (Eds): Mar Menor. Estado actual del conocimiento científico. Fundación Cluster-Instituto Euromediterráneo del agua. pp. 109-130.

Serrano, J.F.; Sironi, J.S. 2009. Cuantificación y evolución de la carga contaminante de nutrientes y plaguicidas en aguas del Mar Menor y su relación con los aportes hídricos de la Rambla del Albujón y otros aportes subterráneos. In Cabezas & Senent (Eds): Mar Menor. Estado actual del conocimiento científico. Fundación Cluster-Instituto Euromediterráneo del agua. pp. 245-284.

Trepel M. 2010. Assessing the cost-effectiveness of the water purification function of wetlands for environmental planning. Ecol Complex, 7: 320–326.

Turner, K., Georgiou, S., Green, I.M., Wulff, F., Barret, S., Soderqviest, T., Bateman, I., Folke, C., Langaas, S., Zylicz, T, Maler, K.G., Markowska, A. 1999. Managing nutrient fluxes and pollution in the Baltic: an interdisciplinary simulation study. Ecological economics 30, 333-352.

Velasco, J.; LLoret, J.; Millan, A.; Marin, A.; Barahona, J.; Abellán, P.; Sánchez-Fernández, D. 2006. Nutrient and pajrticulate inputs into the Mar Menor lagoon (SE Spain) from an intensive agricultural watershed. Water, Air and Soil Pollution, 176: 37-56.

Vidal-Abarca, M.R.; Esteve, M.A.; Suárez, M.L.; Gómez, R.; Robledano, F.; Martinez, J.; Martínez, B. 1998. Análisis de viabilidad del uso de humedales para mitigar el efecto de los vertidos y drenajes agrícolas al Mar Menor. Informe técnico para la Confederación Hidrográfica del Segura. Murcia.

Vidal-Abarca, M.R., Esteve, M.A., Sua´rez, M.L. (Coordinadores), 2003. Los humedales de la Región de Murcia. Dirección General del Medio Natural. Consejería de Agricultura, Agua y Medio Ambiente de la Región de Murcia, Murcia, 50 pp.

Xue, Y., B. M. David, E. L. Gentry & D. A. Kovacic, 1998. Kinetics and modelling of dissolved phosphorus export from a tile-drained agricultural watershed. Journal of Environmental Quality 27: 917–922.

Zanou, B.; Kontogianni, A.; Skourtos, M. 2003. A classification approach of cost effective management measures for the improvement of watershed quality. Ocean & Coastal Management 46: 957-983.

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ECOLOGICAL STATUS OF MAR MENOR LAGOON. CAUSES AND CONSEQUENCES

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1. Present ecological status of Mar Menor lagoon and their consequences

The Mar Menor is an ecosystem of high ecological value, recognized by the designation of different protection status (Natural Park, RAMSAR wetland, Specially Protected Area of Importance for the Mediterranean - Convention of Barcelona-, Special Protection Area for Birds, Area of Importance for Conservation belonging to the Natura 2000 Network). These designations are based on the identification of characteristics and ecological processes that are its hallmark and make it a unique ecosystem, as recognized in all the scientific and technical documents that support its category.

The environmental state of the lagoon has been considered as relatively good until a few years ago, taking into account the main physico-chemical parameters, with relatively low values of nutrients or chlorophyll (0.76-5.61 mg m-3 of chlorophyll a), which seemed to indicate a relative oligotrophy of its waters (Gilabert, 2001a, Perez-Ruzafa et al., 2005, Lloret et al 2008). This fact also contrasted with other coastal lagoons, in which intense eutrophication processes were described, with high concentrations of nutrients and phytoplankton (Sfriso et al, 1987, De Casabiaca et al, 1997, Vicent et al, 2006, Komas et al. , 2001). But the low concentrations of nutrients did not indicate the absence of eutrophication, it is evident that the enormous biomass of *Caulerpa prolifera*, can play an important role both in the uptake of nutrients from the water column and in sediment retention (Palomo et al. , 2004, Boyer and Fong, 2005). What happened in the lagoon coincides with the process described by numerous authors and specifically in the model proposed by McGlathery et al (2007) for shallow bays or lagoons. In a situation prior to the entry of nutrients, the photic zone extends to the bottom, and the benthos, which is originally dominated by phanerogams, in a first phase of eutrophication, is replaced by blooms of fast-growing macroalgae. While in extreme situations, in a stage of high eutrophication the system is dominated by phytoplankton, the grasslands disappear due to the limited availability of light (Figure 1) and the death of the entire benthic community causes processes of anoxia in the sediment.

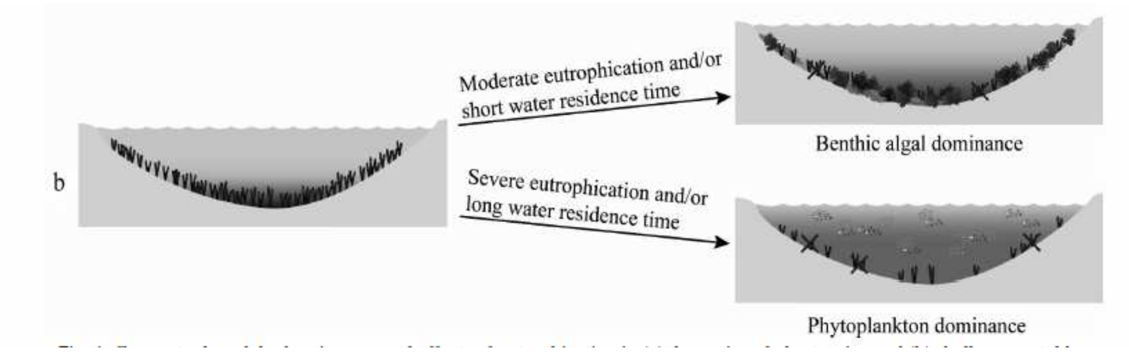

Figure 1: Conceptual model showing the effects generated by moderate eutrophication and severe eutrophication in shallow coastal lagoons, according to McGlathery et al (2007).

The coverage of 91.7% of the bottom of the lagoon and high biomass values reached by *Caulerpa prolifera* (Lloret et al, 2008), showed the importance of benthic production in the Mar Menor, compared to other Mediterranean lagoons (Laugier et al., 1999, Bennet et al., 2000;, 2002, Agostini et al., 2003, Curiel et al., 2004). As demonstrated by Terrados and Ros (1991), *Caulerpa prolifera* became the primary producer of the Mar Menor lagoon. The production of this algae was associated with a significant absorption of nitrogen and phosphorus nutrients from the water column. The excess of nutrients from agricultural activity and wastewater was partially eliminated from the water column and stored in the benthos, due to the action of the macroalgae in line with what was observed in other estuarine systems (Grall and Chauvaud, 2002; and Fong, 2005). This noticeable control of the system by the benthos can explain the low concentrations of nutrients and phytoplankton described in the lagoon for years, which favoured the clarity of its waters. In turn, this fact coincides with the observations of Valiela et al. (1997), who argued that water quality is much better in shallow systems dominated by macrophytes than in systems dominated by phytoplankton, based on similar nutrient loads.

The results of Lloret et al (2008) estimated that the area at that time of *C. prolifera* was capable of retaining up to 3,988 tons of N and 420 tons of P per year, when in those years the emission estimates were between 1,000 and 1,300 tons of N per year and 178 tons of P per year (Velasco et al., 2006, García Pintado et al, 2009, Serrano and Sironi, 2009, Alvarez Rogel et al, 2009). On the other hand, nutrient concentrations in the Mar Menor lagoon have increased in recent decades as predicted by different publications (Pérez-Ruzafa et al., 1991, 2002, 2005, Velasco et al, 2006).

It is therefore evident the transcendental role that the macrophyte has played in the control of the quality of the waters of the lagoon, avoiding for years that the nutrients activate explosive growths of phytoplankton, as happened in year 2016. The high levels of nutrients from anthropic activities, urban discharges in the 60s and in the last decades the intense agricultural activity in the Mar Menor basin, are the ***cause*** of the important growth of *C. Prolifera* and the proliferation of jellyfish as indicators of trophic alteration of the instability of the parameters of the lagoon (Pérez-Ruzafa et al., 2002). These events must be interpreted as part of the process of eutrophication that occurred in the Mar Menor. If we compare the increase in the coverage of *C Prolifera* with the urban occupation of the lagoon's coastline (Figure 2), we can derive a direct relationship between both. The absence, in the first years of the urban occupation, of sanitation networks caused urban waste to enter the lagoon, which favoured the growth of the macrophyte in a process of moderate eutrophication.

Eutrophication is a process caused by the enrichment of water by the supply of nutrients, especially nitrogen and/or phosphorus compounds, which lead to the accelerated growth of primary production and biomass of algae, to undesirable disturbances to organisms and to the degradation of water quality. The consequences of eutrophication are undesirable if they significantly degrade the health of ecosystems and/or the sustainable provision of goods and services. (Ferreira et al, 2010)

From the second half of 2015, the waters of the Mar Menor experienced a drastic change in its quality, due to a massive proliferation of phytoplankton. The cell abundances estimated for the majority of phytoplankton species were considered very high, surpassing in most of cases million cells per liter, which is a level considered to determine the existence of an Algal Harmful Harm Event (FAN) and reaching values of total concentration of up to 250,000,000 cells/liter. The presence of harmful species such as *Cylindrotheca closterium* caused conflicts in the fishing sector due to the production of mucilage (Aguilar and Giménez Casalduero, 2016, Aguilar et al, 2016). At this point the lagoon reached a stage of severe eutrophication and an "environmental collapse", the excess of nutrients caused an explosive growth of unicellular algae that gave the water the greenish color of the spring of 2016. The high cell concentration prevented that light reach the deep zones of the lagoon, preventing the photosynthesis in such zones. The vegetation below the new photic threshold dies, as does an important fraction of phytoplankton, due to the limitation in the availability of light and the depletion of nutrients caused by the exponential algae growth. In the bottom, all the dead organic matter decomposes due to the bacterial activity, which consumes oxygen (situation that coincides with the specific data taken by the regional goverment of Murcia throughout summer of 2016). The absence of oxygen caused the massive death of the benthic organisms (molluscs, polychaetes, etc.), a situation evidenced by the work presented by the Spanish Oceanography Institute in 2016. This work also showed the death of large filter feeders such as *Pinna nobilis.* The death of these individuals of *P. nobilis* is worrying because they had not been affected by the serious epidemic of *Haplosporidium sp*, which has affected all Mediterranean populations of *P. nobilis*, probably because the high salinity of the lagoon prevented this epidemic event). Moreover, the species with little mobility, such as the seahorse (*Hippocampus guttulatus*), saw their populations drastically reduced and the survivors were relegated to specific areas of the lagoon's coast during the summer months of 2016.

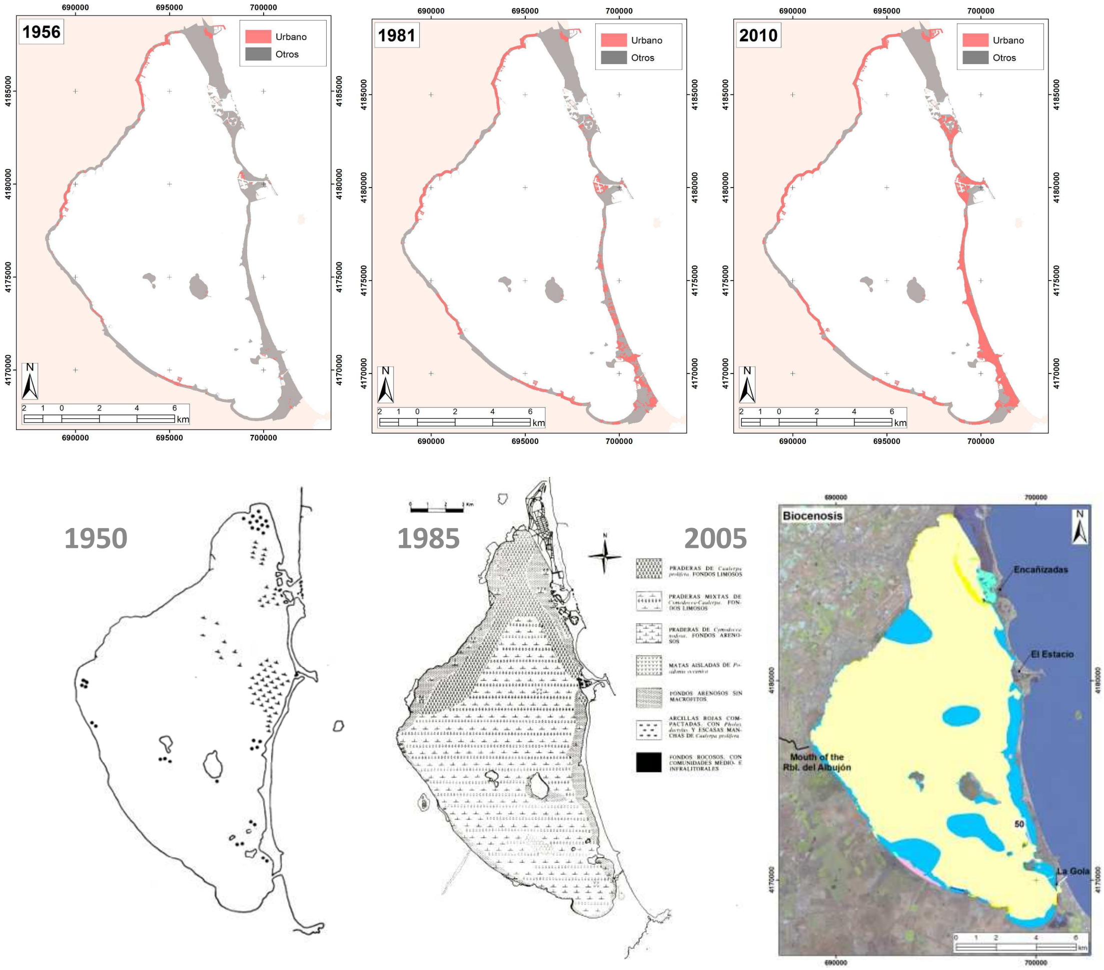

Figure 2: Upper images: Surface of the coastal strip (150 m from the coastline) for the entire Mar Menor plus the entire Manga del Mar Menor, highlighting urban and other use, including Courses and water surfaces, Road infrastructures, Scrub and / or grass and / or rocky, Defense and coastal protection works, Beaches and dunes, Marinas, Urbanized surfaces, Agricultural uses, Coastal wetlands, from the aerial photographs of 1956 (7% occupancy), 1981 (21% occupation) and 2010 (40% occupation) (Gomaríz and Giménez-Casalduero, 2017).

The vegetation maps made by the Spanish Institute of Oceanography in September and October 2016 (IEO, 2016) (Figure 3), showed a loss of 85% of the initial extension of Mar Menor seagrass beds. The 15% survivor was concentrated in the shallower and lighter parts of the lagoon, above 2-3 meters depth.

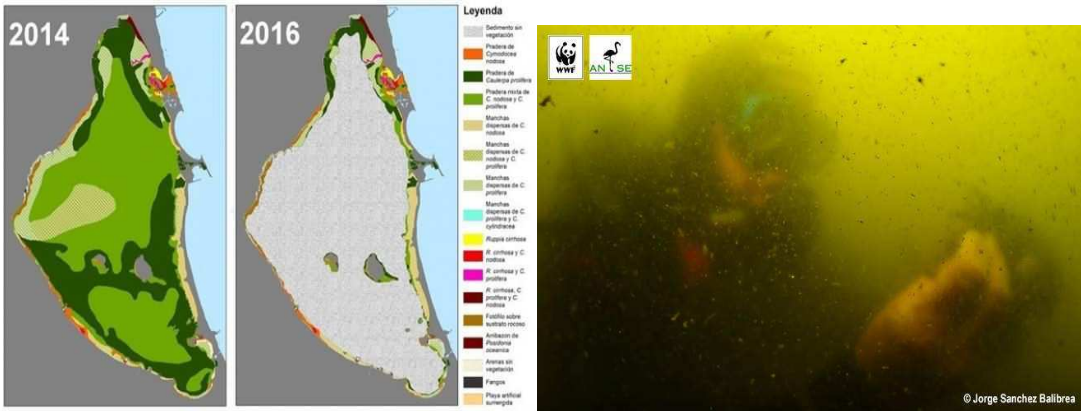

Figure 3: Images presented by the Spanish Institute of Oceanography (IEO) and the Association of Naturalists of the Southeast (ANSE) in November 2016. Map before (2014) and after (2016) the process of environmental collapse, regarding the distribution of the marine prairies in Mar Menor.

The decomposition of all this benthonic biomass has caused anoxia and acidification of the sediments, detecting pH values of up to 6.95, with redox potentials close to -400 and concentrations of organic matter higher than 20%. These conditions limit the community of infauna to the dominance of nematodes and to the polychaete families which are typical of very eutrophic sedimentary communities, such as paraonids, maldanids and capitellids. During the second half of 2017 it has been observed in shallow areas a certain recovery of the prairie of *C. prolifera* and an extraordinary growth of filtering serpulid polychaetes, probably dominated by P*omatoceros triqueter*, in response to the high availability of organic matter in suspension. These worms with calcares tubes generate micro-recife structures (figure 4) that change the texture of the sediment.

All these changes represent an important alteration in the lagoon ecosystem status, with consequences not yet evaluated in biodiversity, economic sectors such as fisheries and tourism and civil society, but which are already having visible effects.

Figure 4: Photograph of micro-recifes structure formed by the congregation of polyprints serpulidos. © R. Canales Cáceres

2. Identification and typology of impacts in Mar Menor lagoon and effects on habitats

The area of the Mar Menor and its entire area of influence is characterized by a great socio-economic dynamics, with a convergence of activities such as agriculture, tourism, fishing, old mining exploitations, etc. These activities constitute driving forces generating pressures which have generated impacts for decades. The socioeconomic changes in the lagoon and its area of influence in recent years have caused a decrease in environmental quality and the loss of both natural and cultural values as well as traditional uses. The following is a summary of the impacts on the ecosystem generated by the most relevant sectors, specifically the agricultural sector, the fishing sector, the extractive industry and finally the urban, tourism and recreational sectors, totally interconnected among themselves in the study area.

The alterations produced by mining over the natural environment cover a wide spectrum of environmental problems. Derived from old mining activities in the Cartagena-La Union hills, it should be highlighted the presence of large deposits of mining wastes, caused by the washing of minerals (García, 2004). These mining wastes have generated risk of landslides and problems of air, soil and water pollution due to the spread of fine particles of silica and metal sulfides (Conesa and Jiménez-Carceles, 2007).

The pollution of surface waters is due to the effects caused by runoff and leakage, which have reached the lagoon. The waste containing heavy metals reaches the Mar Menor through the drainage systems, mainly through the Rambla del Beal channel (CARM, 2003, Marín-Guirao, 2005, Velasco et al., 2006). Simonneau (1973) estimated the inflow of about 25 million tons of mining sediments into the lagoon. There are different studies that highlight the high concentrations of heavy metals, both in the lagoon and in the vicinity, due to the old mining activities, (De León et al, 1982, Álvarez-Rogel et al., 2004, Jiménez-Cárceles et al. , 2006, García and Muñoz-Vera, 2015, Muñoz-Vera and García, 2016). The studied concentrations of Pb, Zn and Cd in the lagoon sediment surpass the thresholds that some European legislations proposed as requiring cleaning activities (VBBo, 1998 and MHSPE, 2000). Metal uptake was also studied in macrophytes such as *Cymodocea nodosa*, *Caulerpa prolifera* and *Ruppia cirrhosa* and the consequences in organisms wer also assessed (Sanchiz et al., 2000, Marín-Guirao et al., 2005a and Marín-Guirao et al., 2005b) . The bioaccumulation of heavy metals in organisms and the transference in trophic chains is one of the important impacts suffered by the lagoon.

In recent studies it has been measured in the marine sediment near to the mouth of the Beal channel, values well above the legal limits: Lead> 9000 mg / kg; Zinc> 6000 mg / kg; , Ace, Cadmium ≈ 20 mg / kg and Copper> 150 mg / kg (Figure 5, Table 1).

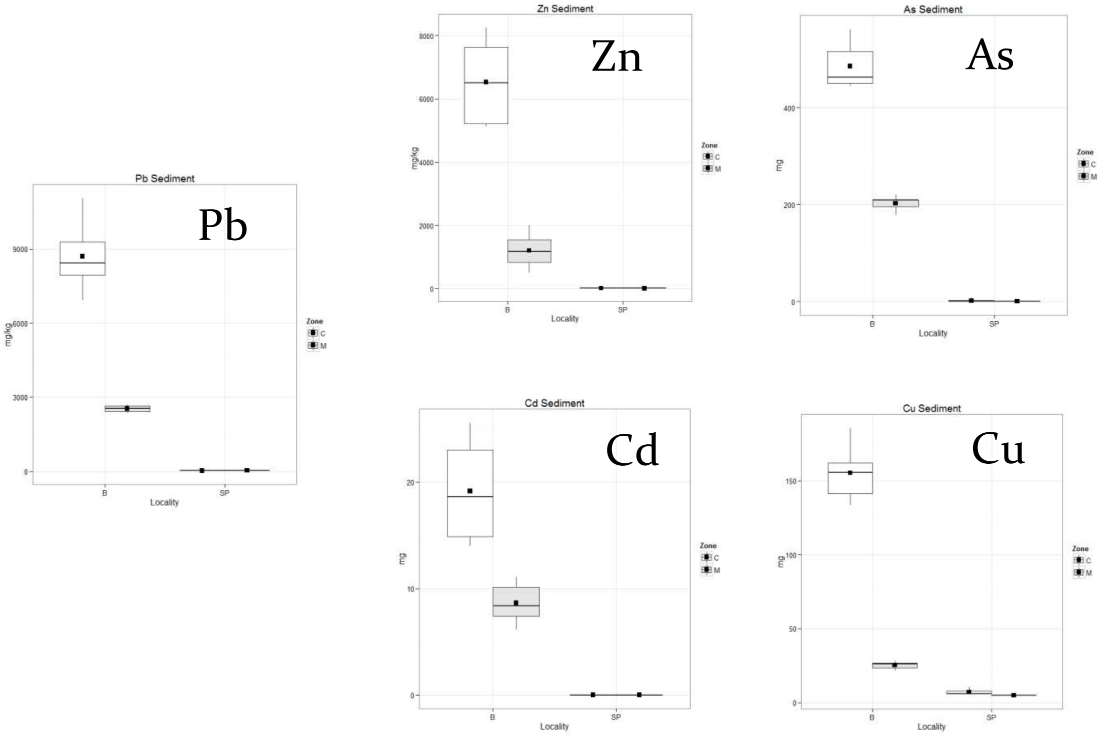

Figure 5. Concentrations of Lead, Zinc, Arsenic, Cadmium and Copper, in sediments from San Pedro del Pinatar (northern area of Mar Menor lagoon) and in sediments from the mouth of Rambla del Beal channel (southern area of Mar Menor lagoon) in mg/Kg of sediment.

	Europe		Turkey		Spain	
Element	Netherland[1]	Denmark[1]	Contaminated	Extrem.-contaminated	Murcia	Andalucia
Fe	-	-	-	-	-	-
Pb	> 530	> 400	150	600	77	350
Zn	> 720	> 1000	500	3000	51	700
As	> 55	> 20	-	-	-	52
Cu	> 190	> 500	100	500	49	250
Cd	> 12	> 5	5	20	0.2	5

Table 1: Concentration values established for soils by the legislation of different European countries (mg/kg) (Serrano et al, under review)

The tourist development has focused, basically, on the littoral area around the lagoon. It began, in the early twentieth century, with the use of the laggon as a spa, limited to the existing traditional population centers. From the 60s, the great urban and tourist transformation began. It has been estimated a 199% increase in the urban occupation of the coastal area around the lagoon (150 m from the coastline, including the entire La Manga) between 1956 and 1981 (own data). In recent years there has been a new urban boom, exponentially expanding the occupied area. (Lopez Morell et al., 2005). The uncontrolled growth of tourism and, above all, the lack of planning and management with integrated environmental criteria, have caused serious impacts in the area of influence of the lagoon and, at the same time, have originated a great demand for resources and high generation of waste with a marked seasonal character.

Sports, recreational and tourist activities exert unequal pressures on the lagoon. The nautical activities associated with the tourist sector represent a risk for the lagoon habitats. The character of closed system of the Mar Menor exacerbates the problem of pollution by hydrocarbons and other pollutants associated with the nautical activity.

Imposex phenomena have been detected in gastropods in studies conducted in the lagoon (García, 1996). This effect, widely documented, is a consequence of pollution by TBT. In addition to the polluting effect, the nautical activity entails other alterations such as noise, that can affect the fauna (mainly birds in breeding season).

A total of 10 sports ports have been developed in the lagoon. The recreational navigation is the third motivation for the tourist visit, according to the survey on the behavior of demand in 2002 (CTOT, 2002). In the Mar Menor yacht clubs, there are more than 5,000 members registered. The number of ports per kilometer of coastline in the lagoon is almost five times higher than that of the Balearic Islands. The number of moorings per km of coastline is only exceeded by those found on the Barcelona coast of Barcelona and is seven times higher than that of Granada coast and five times higher than that of the Balearic Islands. These data show that there is an excessive burden of port infrastructures that need an urgent plan of port management, based on a serious study of carrying capacity, looking for the least aggressive infrastructures for the lagoon ecosystems and the normal functioning of the Mar Menor sedimentary and hydrodynamic dynamics.

The isolation of the Mar Menor from the Mediterranean, together with the extreme environmental conditions (lack of water supply, thermal stress, high evapotranspiration, high salinity, etc.) generated in the lagoon a series of communities dominated by euryhaline and euriterma species, which constitute unusual landscapes with respect to the nearby Mediterranean areas. In addition, environmental stress and confinement favour the appearance of specific lagoon morphotypes and a certain genetic variability, increasing their uniqueness (Gonzalez Wagüemert, 2006). The widening and dredging of the Estacio channel in 1976, up to 30 meters wide and 5 meters deep, produced profound changes in hydrodynamics, biological communities and lagoon fisheries production, with important socioeconomic repercussions. By modifying the rates of water renewal, the physico-chemical conditions changed, reducing salinity and smoothing the extreme temperatures with the consequent repercussions on the lagoon biocenosis (Perez-Ruzafa et al, 1991).

The trend of these physicochemical parameters to reach values close to those of the Mediterranean has caused the entry of new species, multiplying by two the number of molluscs and fish during the last 15 years. Some of these new species act as invaders, competing with the autochthonous ones and, consequently, transforming the submerged landscape and generating a loss of singularity. The jellyfish *Cotylorhiza tuberculata* (Macri, 1778) and *Rhizostoma Pulmo* (Macri, 1778) are seasonal species from the Mediterranean (Gili, 1985, Prieto et al., 2010). From the 90's, massive proliferations began to emerge (EUROGEL, 2004, Fuentes et al., 2011). The jellyfish plagues generated a problem in the tourist sector, although, at the level of the system dynamics, they should be considered, more than a problem, as a causal event, a consequence of the growing eutrophication of the lagoon. These events have caused important impacts, not only environmental but also socioeconomic ones and directly affect the tourism sector.

Due to its physiological characteristics, it is highly probable that the entrance of the referred jellyfish species is associated to the salinity drop. Its main colonization route is through the Estacio channel and its growth is due to the high availability of nutrients and therefore the high availability of plankton in the water. The work done with *C. tuberculata* in the area (Prieto et al., 2010, Astorga et al., 2012) suggests that symbiotic *zooxanthellae* do not seem to contribute significantly to the energy balance of the jellyfish, so it would have to be reconsidered the function of "nutrient filter" that have been assuming for years. On the other hand, the factor that controls the massive proliferation of the population is temperature. The ctenophore *Mnemiopsis leidy* (Agassiz, 1865) appeared in the form of dense swarms in 2012 (Marambio et al., 2013). Its population has declined in recent years, although it is expected that new episodes of massive proliferation will occur when the optimal conditions for the species are reached (Giménez Casalduero et al, 2016).

Numerous species have been incorporated into the lagoon attached to the hulls of the vessels through the Estacio channel, such as the *Amphibalanus amphitrite* (Darwin, 1854), which is considered an invader in the Mediterranean (Molnar et al., 2008), the sponge *Haliclona oculata* (Linnaeus, 1759) or the ascidia S*tyela canopus* (Savigny, 1816), among others (Gonzalez-Carrión, 2015). Among the species considered invasive or with a high potential for this consideration, it should be mentioned the annelids *Branchiomma bairdi* (McIntosh, 1885) and the Korean *Perinereis linea* (Treadwell, 1936), the mollusks *Fulvia fragilis* (Forsskål in Niehbur, 1775), the *Bursatella leachii* (Blainville 1817) or the blue crab (*Callinectes sapidus*, Rathbun).

The urban expansion in the area of influence of the lagoon is mainly associated with tourism. The increase in land occupation has led to the disappearance of natural habitats and unique ecosystems such as dunes and coastal lagoons, salt marshes, etc. The occupation of land in the areas of influence of the Public Domain has repercussions on the increase in the associated natural risks (flood due to elevation of marine waters or floods, coastal erosion, climate change, etc.).

The demand for infrastructure frequently conflicts with the conservation of the lagoon. The actions of dredging and filling land for the generation of new beaches in a lacustrine environment which by definition does not have large beaches, together with the construction of seafront promenades and ports, linked to the urban expansion, have led to the modification of the characteristics of lagoon bottoms and associated communities. On the other hand, the increase in infrastructures and the occupation of the Public Domain also cause an alteration of the hydrographic basin, increasing the natural risks, mainly the floods and their consequent increase in sedimentary contributions, nutrients, fresh water, etc. It will affect all the communities in the receiving areas, as has been observed with the recent episodes of heavy rainfall.

The Campo de Cartagena or Mar Menor basin, from which the lagoon receives both surface and underground waters, underwent a transformation in the agricultural use of its soils with the arrival in 1979 of the Tajo-Segura water transfer, which irrigated 41,254 hectares of previously rainfed land. The entrance into the basin of external water contributions has caused an important change in land use, suffering a transformation from rainfed areas to irrigated lands, with the consequent increase in water flows. This transformation has affected the landscapes and associated species.

The intensification of agriculture caused significant effects in the lagoon. The replacement of traditional rainfed agriculture with intensive agriculture led to a substantial transformation of the landscape, with the elimination and degradation of terrestrial habitats, as well as structural deficiencies in the layout and size of the agricultural drainage network (Carreño Fructuoso, 2015). All this contributes to the natural risk of floods and generates an alteration in the hydrographic basin, whose direct consequence is the water imbalance in the wetlands. This imbalance promotes the replacement of typical species in favour of opportunist ones. The increase in the water flows increases the sedimentary contributions into the lagoon and, consequently, the turbidity, diminishing the radiations of available light for the fital community. In addition, the existence of a higher number of particles in suspension affects the filtering organisms and the ichthyofauna (the fish do not support high levels of particles in suspension in the water, since it causes them to clog the gills and death by asphyxia) (DOER, 2000, Engel-Sørensen and Skyt, 2001).

The increase in irrigated agriculture in the Mar Menor basin causes a growing need for water resources, which has led to an intense overexploitation of aquifers and salinization of groundwater by marine intrusion. All this entails the need to desalinate the groundwater for use in agriculture, a process that generates brine residues with high levels of nitrates (Martínez and Esteve, 2002, Velasco et al, 2006). These residues end up in the drainage network, affecting the wetlands (Martínez Fernández et al, 2005, Velasco et al., 2006, Carreño et al., 2008, Esteve et al., 2008, Martínez Fernández et al, 2009) and , later, entering into the lagoon, favouring the eutrophication process. On the other hand, fertilizers and phytosanitary products (mainly chemical fertilizers and pesticides), used for the increase of agricultural productivity are, in part, leached and transported by the runoff water into the lagoon. Fertilizers transformed into nutrients have generated a process of trophic imbalance and the eutrophication of the lagoon, oligotrophic in its origin, causing a significant loss of singularity and the destruction of 85% of the prairies of the lagoon, as explained above.

The effect of the phytosanitary products on the lagoon and marine communities is not well understood. However, the entry of about 70 organic pollutants has been detected through the Albujón channel (Moreno Gonzalez et al, 2013), about 18 kg per year of pesticides from agriculture and around 11kg per year of drugs from urban spills (León et al, 2016). Studies conducted in other environments point to algae, crustaceans and molluscs as groups especially sensitive to this type of compounds. Herbicides and pesticides inhibit the growth of lagoon phanerogams such as *Cymodocea nodosa*, *Zostera noltii* and *Ruppia sp*. (Marin-Guirao et al., 2005).

There are a series of typically lagoon species. They are protected, key or emblematic species due to ecological or cultural reasons which are currently threatened. The key species are those important for the entire lagoon health. Some of them are the basis of the ecosystemic landscape, since they are the main structural species, such as *Cystoseira amantacea var. strictae* in the rocky habitats or the phanerogams *Cymodocea nodosa* and *Ruppia cirrhosa* which form the most emblematic landscape of the lagoon sedimentary bottoms. The euryhaline and eurithermal environment of the lagoon restricts the presence of many species, so the existence of some emblematic invertebrates give it an added value, such as the sponges *Tethya aurantium* and *Tethya citrina* or the mollusks *Pholas dactylus*.

The presence of *Pinna nobilis* should be treated as a specific case, since it is one of the hundreds of species that were introduced into the lagoon as a response to the Mediterraneización and, therefore, it is important to diagnose the current populations and their evolution in the lagoon. Some of the most emblematic species of the lagoon include the horse *Hippocampus guttulatus* or the fartet *Aphanius (= Lebias) iberus*, currently under great pressure and with evident falls in its population. There are also species in the lagoon of great importance for the fishery, such as shrimp (*Penaeus kerathurus*), with evidence of drastic population falls, as in the previous species, probably in this case associated with the loss of habitats and increased pollution.

The diversity and stability of the fish community is a good indicator of the stability of the ecosystem. In the lagoon, habitats and benthic communities provide shelter and food resources to adults and juveniles of many species. After the events of the past year, a loss of size and quality of the individuals has been detected, which the fishermen attribute to the lack of food resources, associated with the processes of anoxia that have occurred. A loss of confidence in the product has also been detected (http://www.laopiniondemurcia.es/comunidad/2016/12/27/murcia-temporal--pescadores-avisan/793584.html)

The Mar Menor lagoon is an area of great importance as a food and breeding area for birds. The presence of piscivorous fish is also a good indicator of the state of health of the lagoon, as they are important predators in the lagoon and all impacts that disturb their potential prey (including changes in salinity, nutrient inputs, pollution or fishing pressure) will affect them drastically (Davis et al, 2005, Ortiz, 2011).

The current situation of the Mar Menor urgently demands actions from an integral approach, with the ultimate goal of conserving and replenishing the natural capital and ecosystem services of the lagoon. The challenge presented with the objective of recovering the degraded lagoon ecosystem is a complex management process that implies a deep understanding of biological and environmental interactions.

References

Agostini, S, B. Marchand, G. Pergent. 2003. Temporal and spatial changes of seagrass meadows in a Mediterranean coastal lagoon. Oceanologica Acta, 25 (2003), pp. 297–302

Aguilar, J. y Giménez Casalduero, F. (2016) . Análisis de muestras de agua del Mar Menor-Murcia (febrero de 2016)

Aguilar, J. Giménez Casalduero, F., Ramos, AA, y Mas, J. (2016) . Evaluación del estado y composición de la Comunidad Fitoplanctónica de las aguas del Mar Menor, Murcia (mayo de 2016). https://rua.ua.es/dspace/bitstream/10045/57169/2/Mar_Menor_Mayo_2016.pdf

Álvarez-Rogel, J.; Jiménez-Cárceles, F.J.; Egea Nicolás, C.; María-Cervantes, A.; González-Alcaraz, M.N.; Párraga Aguado, I.; Conesa Alcaraz, H.M. 2009. Papel de los humedales costeros del Mar Menor en la depuración de aguas eutrofizadas: el caso de la Marina del Carmolí. En Cabezas & Senent (Eds): Mar Menor. Estado actual del conocimiento científico. Fundación Cluster-Instituto Euromediterráneo del agua. pp. 321-35

Álvarez-Rogel, J., Ramos-Aparicio, M.J. Delgado-Iniesta, M.J, Arnaldos-Lozano, R. 2004. Metals in soils and above-ground biomass of plants from a salt marsh polluted by mine wastes in the coast of the Mar Menor Lagoon, SE Spain. Fresenius Environmental Bulletin, 13, pp. 274–278

Astorga, D, Ruiz,J , Prieto, L. 2012. Ecological aspects of early life stages of *Cotylorhiza tuberculata* (Scyphozoa: Rhizostomae) affecting its pelagic population success. Hydrobiology 690: 141-155

Belando, M.D., García Muñoz, R. Ramos segura, A., Franco Navarro, I., García Moreno, P., Ruiz, J.M. Distribución y abundancia de las praderas de macrófitos bentónicos y las poblaciones de nacra (Pinna nobilis) en el Mar Menor. Informe del instituto Español de Oceanografía y ka Asociación de Naturalistas del Sureste, Murcia 60 pp

Boyer, K. E., & Fong, P. (2005). Macroalgal-mediated transfers of water column nitrogen to intertidal sediments and salt marsh plants. *Journal of Experimental Marine Biology and Ecology*, *321*(1), 59-69.

CARM (Comunidad Autónoma de la Región de Murcia), 2003a. Programa de gestión integrada del litoral del Mar Menor y su zona de influencia. Documento técnico de la Consejería de Industria y Medio Ambiente, Murcia, Spain

Carreño, M.F. 2015. Seguimiento de los cambios de usos y su influencia en las comunidades naturales en la cuenca del Mar Menor, 1988-2009, con el uso de SIG y Teledetección. Tesis Doctoral. Universidad de Murcia Departament de Ciències del Mar i Biologia Aplicada Departamento de Ciencias del Mar y Biología Aplicada

Conesa, H. M., y Jiménez-Cárceles, F. J. (2007). The Mar Menor lagoon (SE Spain): a singular natural ecosystem threatened by human activities. *Marine pollution bulletin*, *54*(7), 839-849.

Consejería de Turismo y Ordenación del Territorio de la Región de Murcia. (CTOT). 2002. Turismo de la Región de Murcia. Revisión y actualización del Inventario Regional de Zonas Húmedas.

Curiel, D. A. Rismondo, G. Bellemo, M. Marzocchi. Macroalgal biomass and species variations in the Lagoon of Venice (Northern Adriatic Sea, Italy): 1981–1998. Scientia Marina, 68 (2004), pp. 57–67

Davis, S.M. Childres, D.L., Lorenz, J.J., Wanless, H.R., Hopkins, T.E. 2005. A conceptual modelo f ecological interactions in the mangrove estuaries of the Florida Everglades. Wetlands 25: 832-842.

De León, A.R., Guerrero, J., Faraco, F. 1982. Evolution of the pollution of the coastal lagoon of Mar Menor. VI Journées Étud. Pollutions. C.I.E.S.M. 355.

EUROGEL 2004 European gelatinous zooplankton: Mechanisms behind jellyfish blooms and their ecological and socio-economic effects. Annual report no 2 to European community, Section 3, 38 pp

De Casabianca, M. L., Laugier, T., & Marinho-Soriano, E. (1997). Seasonal changes of nutrients in water and sediment in a Mediterranean lagoon with shellfish farming activity (Thau Lagoon, France). *ICES Journal of Marine Science: Journal du Conseil*, *54*(5), 905-916.

Ferreira, J.G., Andersen, J.H., Borja, A., Bricker, S.B., Camp, J., Cardoso da Silva, M., Garcés, E., Heiskanen, A.S., Humborg, C., Ignatiades, L., Lancelot, C., Menesguen, A., Tett, P., Hoepffner, N., Claussen, U., 2010. Marine Strategy Framework Directive e Task Group 5 Report Eutrophication. EUR 24338 EN e Joint Research Centre. Office for Official Publications of the European Communities, Luxembourg, pp. 49

Fuentes, V., Straehler-Pohl, I, Atienza, D., Franco, I., Tilves, U., Gentile, M., Acevedo, M. Olariaga, M. Gili, J.M. 2011. Life cycle of the jellyfish Rhizostoma pulmo (Scyphozoa: Rhizostomeae) and its distribution, seasonality and inter-annual variability along the Catalan coast and the Mar Menor (Spain, NW Mediterranean). Marine Biology 158: 2247-226

García, B. 1996. Estudio sobre niveles y efectos del tributilo de estaño en la laguna costera del Mar Menor. JACUMAR. http://www.magrama.gob.es/ es/pesca/temas/ acuicultura/ capitulo_11.p.n.murcia_tcm7-7252.pdf

García, G., y Muñoz-Vera, A. (2015). Characterization and evolution of the sediments of a Mediterranean coastal lagoon located next to a former mining area. *Marine pollution bulletin*, *100*(1), 249-263.

García-García, C., 2004. Impacto y riesgo medioambiental en los residuos minerometalúrgicos de la Sierra de Cartagena-La Unión, Ph.D. Thesis. Universidad Politécnica de Cartagena, Cartagena, Spain.

García Pintado, J.; Barberá, G.; Martínez-Mena, M.; Albaladejo, J.; Erena, M.; Castillo, V. 2009. Caracterización y evaluación de fuentes antrópicas de nutrientes transportados por la rambla del Albujón hacia el Mar Menor. In Cabezas & Senent (Eds): Mar Menor. Estado actual del conocimiento científico. Fundación Cluster-Instituto Euromediterráneo del agua. pp. 167-206.

Gimenez-Casalduero, F., Ramos-Esplá, A. A., Izquierdo Muñoz, A., Gomariz Castillo, F. J., Martínez Hernández, F. J., y González-Carrión, F. (2016). Invertebrados marinos alóctonos en el Mar Menor. En: León y Bellido (ed) Mar Menor: Una laguna singular y sensible. Evaluación científica de su estado. Instituto Español de Oceanografía pp. 341 Departament de Ciències del Mar i Biologia Aplicada Departamento de Ciencias del Mar y Biología Aplicada

Gonzalez Carrión, F. 2015. Fouling en cascos de embarcaciones deportivas en el Mar Menor y Santa Pola. Trabajo Fin de Grado. Facultad de Ciencias Universidad de Alicante.

González-Wangüemert, M., Giménez-Casalduero, F., & Pérez-Ruzafa, A. (2006). Genetic differentiation of Elysia timida (Risso, 1818) populations in the Southwest Mediterranean and Mar Menor coastal lagoon. *Biochemical Systematics and Ecology*, *34*(6), 514-527.

Grall, J. Y Chauvaud, L. 2002. Marine eutrophication and benthos: the need for new approaches and concepts. Global Change Biology, 8 (2002), pp. 813–830

Jiménez-Cárceles, C. Egea, A.B. Rodríguez-Caparrós, O.A. Barbosa, M.J. Delgado, R. Ortiz, J. Álvarez-

Rogel. 2006. Contents of nitrogen, ammonium, phosphorus, pesticides and heavy metals, in a salt marsh in the coast of the Mar Menor lagoon (SE Spain). Fresenius Environmental Bulletin, 15, pp. 370–378

K.A. Kormas, A. Nicoladou, S. Reizopoulou. 2001. Temporal variations of nutrients, chlorophyll *a* and particulate matter in three coastal lagoons of Amvrakikos Gulf (Ionian Sea, Greece). Marine Ecology, 22, pp. 201–213

Laugier, V. Rigollet, M.L. Casabianca. 1999. Seasonal dynamics in mixed eelgrass beds, *Zostera marina* L. and *Z. noltii* Hornem., in a Mediterranean Coastal lagoon (Thau lagoon, France). Aquatic Botany, 63, pp. 51–69

León, V., Moreno-González, R.; Campillo, J.A. 2016. Contaminantes orgánicos regulados y emergentes en el Mar Menor. En Leon, V.M y J.M. Bellido. Mar Menor: una laguna singular y sensible. Evaluación científica de su estado. Madrid, Instituto Español de Oceanografía, Ministerio de Economía y Competitividad. 414 p. Temas de Oceanografía, 9. ISBN 978-84-95877-55-0.

Lopez-Morell, M.A, Pedreño, A. Baños, P. 2005. Génesis y trayectorias del desarrollo turístico del entorno del Mar Menor. VIII Congreso de la Asociación Española de Historia Económica. Santiago de Compostela.

Lloret, J; Marín, A; Marín-Guirao, L. 2008. "Is coastal lagoon eutrophication likely to be aggravated by global climate change?" *Estuarine Coastal and Shelf Science* 78(2): 403-412

Marambio, M., Franco, I., Purcell, J.E., Canepa, A. Guerrero, E. Fuentes, V., 2013. Aggregations of the invasive ctenophore Mnemiopsis leidyi in a hypersaline environment, the Mar Menorlagoon (NW Mediterranean). Aquatic invasion 8: 243-248

Marín-Guirao, L., Cesar, A., Marín, A., Vita, R. 2005a. Establishing the ecological quality status of soft-bottom mining-impacted coastal water bodies in the scope of the Water Framework Directive. Marine Pollution Bulletin, 50 (2005), pp. 374–387

Marín-Guirao, L., Cesar, A., Marín, A., Vita, R. 2005b. Valoración de la contaminación por metales en los sedimentos de la laguna costera del Mar Menor (SE de España): Distribución de metales, toxicidad, bioacumulación y estructura de las comunidades bentónicas. Ciencias Marinas 31: 413-428.

Martínez Fernández, J. & M. A. Esteve Selma, 2003. El papel de las aguas subterráneas en la exportación de nutrientes de origen agrícola hacia la laguna del Mar Menor. In Fornés, J.M. & R. Llamas (eds), Conflictos entre el desarrollo de las aguas subterráneas y la conservación de los humedales: litoral mediterráneo. Ediciones Mundi-Prensa, Madrid, 191–213.

Moreno-González, R., Campillo, J.; García, V., León, V. M. 2013. Seasonal input of regulated and emerging organic pollutants through surface watercourses to a Mediterranean coastal lagoon. Chemosphere, 92, 247-257. Departament de Ciències del Mar i Biologia Aplicada Departamento de Ciencias del Mar y Biología Aplicada

Muñoz-Vera, A. y García, G. 2016. Capítulo 12. Influencia de los residuos mineros de la Sierra minera de Cartagena- La Unión en la evolución de los sedimentos de la laguna costera Mar Menor. En Las aguas subterráneas en el Campo de Cartagena-Mar Menor. En: León y Bellido (ed) Mar Menor: Una laguna singular y sensible. Evaluación científica de su estado. Instituto Español de Oceanografía pp. 271-290.

Ortiz, A. 2011. Análisis espacio-temporal de la comunidad de aves piscívoras del Mar Menor. Proyecto final MAGEM. Universidad de Alicante.

Palomo, L., Clavero, V., Izquierdo, J. J., Avilés, A., Becerra, J., & Niell, F. X. (2004). Influence of macrophytes on sediment phosphorus accumulation in a eutrophic estuary (Palmones River, Southern Spain). *Aquatic Botany*, *80*(2), 103-113.

Pérez-Ruzafa, A., Aragón, R., 2002. Implicaciones de la gestión y el uso de las aguas subterráneas en el funcionamiento de la red trófica de una laguna costera. In: Fundación Marcelino Botín, Ediciones Mundi-Prensa (Eds.), Conflictos entre el desarrollo de las aguas subterráneas y la conservación de los humedales: litoral mediterráneo, Madrid, pp. 215–245.

Pérez-Ruzafa, C. Marcos-Diego, D. Ros. 1991. Environmental and biological changes related to recent human activities in the Mar Menor (SE of Spain). Marine Pollution Bulletin, 23, pp. 747–751

Pérez-Ruzafa, A. J. Gilabert, J.M. Gutiérrez, A.I. Fernández, C. Marcos, S. Sabah. 2002. Evidence of a planktonic food web response to changes in nutrient input dynamics in the Mar Menor coastal lagoon, Spain. Hydrobiologia, 475/476, pp. 359–369

Pérez-Ruzafa, A., A.I. Fernández, C. Marcos, J. Gilabert, J.I. Quispe-Becerra, J.A. García-Charton. 2005. Spatial and temporal variations of hydrological conditions, nutrients and chlorophyll *a* in a Mediterranean coastal lagoon (Mar Menor, Spain). Hydrobiologia, 550, pp. 11–27

Prieto, L., Astorga, D., Navarro, G., Ruiz, J., 2010. Environmental control of phase transition and polyp survival of a massive-outbreaker jellyfish. PLoS ONE 5 (11), 1-10.

Sanchiz, C., García-Carrascosa, A.M., Pastor, A. 2000. Heavy metal contens in sofá-bottom marine macrophytes and sediments along the mediterranean coast of Spain. Marine Ecology, 21 (1), pp. 1–16

Serrano, J.F.; Sironi, J.S. 2009. Cuantificación y evolución de la carga contaminante de nutrientes y plaguicidas en aguas del Mar Menor y su relación con los aportes hídricos de la Rambla del Albujón y otros aportes subterráneos. In Cabezas & Senent (Eds): Mar Menor. Estado actual del conocimiento científico. Fundación Cluster-Instituto Euromediterráneo del agua. pp. 245-284.

Sfriso, A., Marcomini, A., & Pavoni, B. (1987). Relationships between macroalgal biomass and nutrient concentrations in a hypertrophic area of the Venice Lagoon. *Marine Environmental Research*, *22*(4), 297-312.

Simonneau, J. 1973. Mar Menor evolution sedimentologique récente du remplissage.PhD. Thesis, Universite' de Toulousse. 172 pp.

Terrados, J. y Ros, J.D. 1991. Production dynamics in a macrophyte-dominated ecosystem: The Mar Menor coastal lagoon (SE Spain), Oecologia aquatica 10: 255.

Valiela, I, J. McClelland, J. Hauxwell, P.J. Behr, D. Hersh, K. Foreman. 1997. Macroalgal blooms in shallow estuaries: control and ecophysiological and ecosystem consequences. Limnology and Oceanography, 42 (1997), pp. 1105–1118 Departament de Ciències del Mar i Biologia Aplicada Departamento de Ciencias del Mar y Biología Aplicada

Velasco, J.; LLoret, J.; Millan, A.; Marin, A.; Barahona, J.; Abellán, P.; Sánchez-Fernández, D. 2006. Nutrient and pajrticulate inputs into the Mar Menor lagoon (SE Spain) from an intensive agricultural watershed. Water, Air and Soil Pollution, 176: 37-56.

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