RGSA – Revista de Gestão Social e Ambiental
ISSN: 1981-982X
Submission date: 08/19/2024
Acceptance date: 10/21/2024
DOI: https://doi.org/10.24857/rgsa.v18n11-238
Organization: Interinstitutional Scientific Committee
Chief Editor: Ana Carolina Messias de Souza Ferreira da Costa
Assessment: Double Blind Review pelo SEER/OJS

ENVIRONMENTAL CRISIS IN THE MAR MENOR LAGOON (REGION OF MURCIA – SPAIN)

Encarnación Gil-Meseguer[1]
Miguel Borja Bernabé-Crespo[2]
José María Gómez-Gil[3]
José María Gómez-Espín[4]

ABSTRACT

Objective: The objective of this study is to gain insight into the causes of the environmental crisis that affects the Mar Menor ecosystem and its surroundings, as well as to propose measures for a new territorial model.

Theoretical Framework: It is based on the study of population growth in the Campo de Cartagena - Mar Menor region, as well as the different activities that take place there, especially focusing on regenerated water.

Method: The methodology adopted for this research includes regional geographic analysis for the management of the territory, with extensive field work and interviews with users of the Mar Menor; to conclude with a series of "zero discharge" proposals and cultural practices to mitigate the environmental crisis of the lagoon and its surroundings.

Results and Discussion: Agriculture, urban expansion, obsolescence of sanitation networks, and other activities such as stable livestock farming and mining waste hauling have caused anthropization of the Mar Menor with eutrophication phenomena. It is advisable to promote a bottom-up participatory process of citizens, reach agreements between Administrations, and harmonize the different land uses making them compatible with the good condition of the lagoon.

Research Implications: The practical and theoretical implications of this research are discussed, discussing the causes of the state of the lagoon and the uses of the catchment area.

Originality/Value: This study contributes to the literature by addressing a topic of interest and concern from a comprehensive perspective, considering causes and consequences, as well as possible solutions. The relevance and value of this research are evident in its geographical approach to human-natural environment relationships.

Keywords: Anoxia, Environmental Crisis, Eutrophication, Mar Menor, Region of Murcia, Southeast Spain.

CRISE AMBIENTAL NA LAGOA DO MAR MENOR (REGIÃO DE MÚRCIA – ESPANHA)

RESUMO

Objetivo: O objetivo deste estudo é conhecer as causas da crise ambiental que afeta o ecossistema do Mar Menor e a sua envolvente, bem como propor medidas para um novo modelo territorial.

Referencial Teórico: Baseia-se no estudo do crescimento populacional da região Campo de Cartagena - Mar Menor, bem como nas diversas atividades que aí decorrem, com especial enfoque na água regenerada.

[1] University of Murcia, Murcia, Spain. E-mail: encargil@um.es Orcid: https://orcid.org/0000-0002-4372-4127
[2] Autonomous University of Madrid, Madrid, Spain. E-mail: miguelb.bernabe@uam.es
Orcid: https://orcid.org/0000-0001-7269-3270
[3] University of Murcia, Murcia, Spain. E-mail: jm.gomezgil@um.es
Orcid: https://orcid.org/0000-0002-8848-3187
[4] University of Murcia, Murcia, Spain. E-mail: espin@um.es Orcid: https://orcid.org/0000-0001-7287-4952

Método: A metodologia adotada para esta pesquisa inclui a análise geográfica regional para a gestão do território, com um extenso trabalho de campo e entrevistas aos utilizadores do Mar Menor; concluir com uma série de propostas de "descarga zero" e práticas culturais para mitigar a crise ambiental da lagoa e da sua envolvente.

Resultados e Discussão: A agricultura, a expansão urbana, a obsolescência das redes de saneamento e outras actividades como a pecuária estável e o transporte de resíduos mineiros provocaram a antropização do Mar Menor com fenómenos de eutrofização. É aconselhável promover um processo participativo dos cidadãos de baixo para cima, chegar a acordos entre as administrações e harmonizar os diferentes usos do solo tornando-os compatíveis com o bom estado da lagoa.

Implicações da Pesquisa: São discutidas as implicações práticas e teóricas desta investigação, discutindo-se as causas do estado da charca e os usos da área de captação.

Originalidade/Valor: Este estudo contribui para a literatura ao abordar um tema de interesse e preocupação numa perspetiva abrangente, considerando causas e consequências, bem como possíveis soluções. A relevância e o valor desta investigação são evidentes na sua abordagem geográfica das relações homem-ambiente natural.

Palavras-chave: Anóxia, Crise Ambiental, Eutrofização, Mar Menor, Região De Múrcia, Sudeste De Espanha.

CRISIS AMBIENTAL EN LA LAGUNA DEL MAR MENOR (REGIÓN DE MURCIA – ESPAÑA)

RESUMEN

Objetivo: El objetivo de este estudio es acercarse al conocimiento de las causas de la crisis ambiental que afecta al ecosistema del Mar Menor y su entorno, así como proponer medidas para un nuevo modelo territorial.

Marco Teórico: Se basa en el estudio del crecimiento de la población en la comarca del Campo de Cartagena - Mar Menor, así como en las distintas actividades que tienen lugar en ella, incidiendo especialmente en el agua regenerada.

Método: La metodología adoptada para esta investigación comprende el análisis geográfico regional para la gestión del territorio, con amplio trabajo de campo y entrevistas a usuarios del Mar Menor; para concluir con una serie de propuestas de "vertido cero" y prácticas culturales para mitigar la crisis ambiental de la laguna y su entorno.

Resultados y Discusión: Agricultura, expansión urbanística, obsolescencia de las redes de saneamiento, y otras actividades como la ganadería estabulada y los arrastres de los estériles de la minería han provocado una antropización del Mar Menor con fenómenos de eutrofización. Es recomendable promover un proceso participativo de abajo hacia arriba de los ciudadanos, alcanzar acuerdos entre Administraciones, y armonizar los distintos usos del suelo haciéndolos compatibles con el buen estado de la laguna.

Implicaciones de la investigación: Se discuten las implicaciones prácticas y teóricas de esta investigación, discutiendo las causas del estado de la laguna y los usos de la cuenca vertiente.

Originalidad/Valor: Este estudio contribuye a la literatura al abordar un tema de interés y preocupación desde una óptica integral, considerando causas y consecuencias, a la vez que posibles soluciones. La relevancia y valor de esta investigación se evidencian en su enfoque geográfico de las relaciones ser humano - medio natural.

Palabras clave: Anoxia, Crisis Ambiental, Eutrofización, Mar Menor, Región De Murcia, Sureste de España.

RGSA adota a Licença de Atribuição CC BY do Creative Commons (https://creativecommons.org/licenses/by/4.0/).

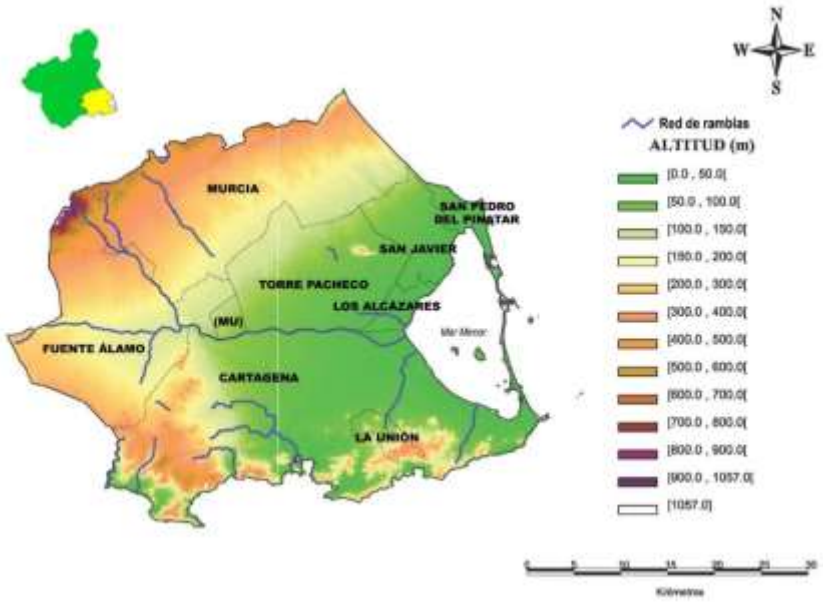
1 INTRODUCTION

Mar Menor, within the Region of Murcia (Spain), is the hypersaline, largest lagoon on the Spanish Mediterranean coast. It suffers from a disastrous ecologic situation which was anticipated by many scholars for years: Conesa and Jiménez-Cárceles (2007) warned about the discharge of enriched nutrient waters, sprawling urbanization and metal pollutans from mine exploitations, resulting in the eutrophication and algal blooms (Alcolea *et al.*, 2019). Its natural conditions have also changed, with an increase of the annual mean temperature, a decrease of the salinity value, in addition to the concentrations of nitrates and other compounds (Pérez-Ruzafa *et al.*, 2005; Velasco *et al.*, 2006; De Pascalis *et al.*, 2012; Erena *et al.*, 2019).

The study area is located in the Iberian Southeast, which is the territory between the Mediterranean coast that extends south of Cabo de La Nao (Alicante) to the north of Cabo de Gata (Almería), and the interior limit marked by the isohyet of 400 mm of precipitation and the isotherm of 16ºC of average annual temperature (Gil *et al.*, 2021, p. 119). The central part of this space corresponds to the Campo de Cartagena – Mar Menor Basin, which is a Neogene sedimentary basin that originated a coastal plain, whose unfilled part is occupied by the Mar Menor lagoon (Figure 1). Most of the territory flows into the local base level which is the Mar Menor – only to the west there is a sector draining directly into the Mediterranean through the Benipila rambla.

Figure 1

Campo de Cartagena – Mar Menor basin (Southeast of Spain).



The Mar Menor is a 135 km2 lagoon, with hypersaline and oligotropic waters, separated from the open sea (Mediterranean Sea) by a 22 km long false detritic-volcanic sandbar, which is called La Manga. These geographical features are linked to volcanic, eustatic, epirogenetic and neotectonic phenomena (Rodríguez, 2009, p.49). Inside the Mar Menor there are a series of volcanic islands: Mayor or Barón, Perdiguera, Ciervo, Sujeto and Rondela. The lagoon has a perimeter of about 73 km of shoreline. La Manga sandbar allows the flow of water between the Mar Menor and the Mediterranean through some water passages called golas, some of them natural (Ventorrillo and Charco) and some others artificial (Estacio and Marchamalo).

Taking advantage of the greater salinity of the waters of the Mar Menor, the traditional activity of obtaining salt was developed. There were several salt mines such as those of El Pinatar or Cotorillo, Los Narejos, Lo Poyo, Marchamalo and Córcolas. At present, only El Pinatar or Cotorillo salt flats remain active, also converted into the Salinas y Arenales de San Pedro Regional Park. Part of the Marchamalo salt flats, the oriental ones or Cabo de Palos (about 8 hectares), have been recovered thanks to biodiversity conservation projects. It is also intended to act on the 16 hectares of the western salt flats, between Vivero and Playa Honda. Nearby, but outside the Mar Menor, further south along the Mediterranean, are the Rasall salt flats in Calblanque (Gil *et al.*, 2010, p. 619).

The climatic conditions of the Campo de Cartagena-Mar Menor are characterized by a marked summer drought, which, due to the low rainfall coinciding with high temperatures (average rainfall barely exceeds 300 mm, while the average temperature exceeds 18ºC) is referred to as semi-arid climatic conditions (Gil & Gómez, 2014, p. 544). Hydrography is characterized by rambla-type courses, being the most significant the Fuente Álamo-Albujón rambla, which drains an area of 543 km2 and has a length of 42.3 km from the center of Fuente Álamo to the mouth of the Mar Menor. This course collects the surface runoff after heavy rainfall and the drainage of the groundwater that even comes to the surface by the action of the expansion of irrigation for the new agriculture that is practiced. It is estimated at more than 5 million cubic meters a year, the volume that the waters of the Albujón rambla contribute to the lagoon. This would be one of the causes of the decrease in salinity of the Mar Menor, which dropped from 57 g/L in 1957 (compared to 37 g/L in the Mediterranean) to only 41 g/L in 1989, although the hydrodynamic changes due to the renewal of water with the opening of artificial passages and especially after the dredging and widening of the Canal del Estacio in 1973, to make it navigable and build a marina, are the main causes (Pérez-Ruzafa *et al.*, 2009, p.23).

Since the 60s of the s. XX (when the Law of Centers and Areas of National Tourist Interest was enforced), La Manga del Mar Menor became a linear city, through its central axis

called "Gran Vía", where different building units gather, different residential areas which sometimes prevent access to the sea, with an anarchic arrangement of buildings (Morales, 2021, p. 464). More public facilities and the modernization of road and drainage infrastructures are also lacking.

The fundamental and majority tourism is seasonal in the summer months (especially July and August), clearly seen in the water consumption of residents' associations in La Manga. Two thirds of the annual water consumption is made in the months of July-August and September-October. As an example, two neighborhood communities can serve, one from each municipality. In the case of the 'Km 2 community' (in the municipality of Cartagena) with 192 homes, in two 12-storey blocks; and the 'Km 6 community' (in the municipality of San Javier) with 163 homes, in four blocks of eight heights. Both have a communal swimming pool, car parks, sports courts and landscaped spaces, which consume water. More than 50% of annual water was consumed in the months of July-August by the community of residents of La Manga-Cartagena (52.94%) in the year 2021, and more than 40% in that of La Manga-San Javier (41.05%).

In the case of La Manga and nearby settlements such as Cabo de Palos, Cala Reona, Los Belones, Las Barracas, Playa Honda, Mar de Cristal, etc., permanent population living all year round (registered) is almost 12,000 inhabitants, although it increases to more than 250,000 residents in the months of July and August (with the occupation of second homes, accommodation in apartments and hotels, placing caravans in the "Camping Caravaning", etc.). The population of this Costa Cálida area multiplies by 20 in the summer months.

2 METHODOLOGY

The aim of this study is to get to know the causes of the environmental crisis that affects the ecosystem of the Mar Menor and its surroundings, as well as to propose measures for a new territorial model. Regional-geographic analysis methodology allows the study of environment-human relations in areas such as the Southeast of Spain. The entire Campo de Cartagena-Mar Menor basin constitutes the study area, assuming that the environmental crisis of the Mar Menor will be overcome with corrective measures both in its surroundings and in the lagoon. The basin of more than 1,550 km2 is administratively composed by eight municipalities: Cartagena, La Unión, Fuente Álamo, Torre Pacheco, Los Alcázares, San Javier, San Pedro; and part of Murcia (9 districts of Campo de Murcia).

The data for the analysis of the territorial system has been collected from the three

administrations: State, Autonomous and Local. In the case of temperature and precipitation data, from the State Meteorological Agency (AEMET); those for water purification of the Wastewater Sanitation Entity of the Region of Murcia (ESAMUR); those of water capacities and phreatic of the Segura Hydrographic Confederation (CHS); and water for irrigation, according to origin, from irrigation communities such as IC Arco Sur-Mar Menor and IC Campo de Cartagena.

Work phases include the bibliographic and press review, extensive field work with the collection of data and the interviews with users of the Mar Menor region, and photo interpretation, mapping and diagnosis of the status of the lagoon and its surroundings (SWOT matrix). Qualitative and quantitative research was developed in order to present proposals for land use planning (analysis - diagnosis - prognosis) that allow improving the processes (relationships between geographic space-society) of the current territorial model.

3 RESULTS

The geographical area of Campo de Cartagena-Mar Menor amounts to more than 160,000 hectares, almost 15% of the area of the Region of Murcia (14.26%). Most of them are rural landscapes (including irrigated land with more than 56,000 hectares). The urban and industrial spaces, and the transport networks are close to 50,000 hectares (Gil & Gómez, 2014, p. 544). The population, as of 01-01-2024, was 391,360 inhabitants; that is, a quarter of the regional population (25.21%). It should be considered the floating population of the months of July and August in the surroundings of the Mar Menor (especially in La Manga) as it would exceed half a million people, in the summer, in the area of the Campo de Cartagena-Mar Menor Basin.

The Mar Menor and its surroundings represent the largest tourist destination on the Costa Cálida. Of the tourist municipalities on the coast of the Region of Murcia (San Pedro del Pinatar, San Javier, Los Alcázares, Cartagena, Mazarrón and Águilas), those of San Javier and Cartagena are the ones that presented the highest consumption of drinking water per person in 2020 and day (312 l/day in San Javier and 293 l/day in Cartagena), with high rates of seasonality in this consumption (5.60 in the ratio of the highest and lowest month of consumption in La Manga (San Javier) and 4.61 in La Manga (Cartagena), which forces the supply and sanitation networks to be oversized (Bernabé-Crespo, Gil-Meseguer & Gómez-Espín, 2022, p. 306).

Human settlement and agricultural activity have been linked to the presence of water points in the territory: collection, accumulation and distribution of water from springs to the places of consumption and irrigation. The exploitation of aquifers in the Campo de Cartagena

(with a multitude of wells) and the water distribution networks of the Mancomunidad de Canales del Taibilla (MCT) and the Tajo-Segura Post-Transfer (TTS), have allowed the supply of the population and the development of activities such as tourism and irrigated agriculture. In recent decades they have been completed with water plants resulting from desalination and regeneration of purified waste (Bernabé-Crespo *et al.*, 2021, p. 24).

Within circular economy, it is the reuse of wastewater and drainage in irrigation communities such as IC Arco Sur-Mar Menor (3,030 hectares of irrigable area and 74 community members) and the IC Campo de Cartagena (42,435 hectares of irrigable area and 9,699 community members). The reuse of wastewater once treated is widespread in Spain (among the top of the European Union), especially in Autonomous Communities such as the Region of Murcia (more than 90%). Recycled water that must meet the quality criteria set out in Royal Decree 1620/2007 and in European Regulation 2020/741, which establishes the minimum requirements that treated urban water must meet for its application in agricultural irrigation. In the IC Arco Sur-Mar Menor tertiary production, after treatment of purified wastewater and drainage (drainage system of vertical wells-pits associated with horizontal wells-galleries, parallel to the southeastern shore of the lagoon), allowed the recovery of the almost 3/4 of the raw water once regenerated at the irrigation community plant (Table 1).

Table 1

Tertiary production in the IC Arco Sur-Mar Menor.*

Year	Raw water from STP and drainage (m^3)	Tertiary production (m^3)	Percentage Tertiary production / Raw water (%)
2008	1,002,550	751,876	75.00
2009	1,596,400	1,197,311	75.00
2010	2,582,765	1,937,049	75.00
2011	3,932,105	2,046,826	52.05
2012	3,432,084	2,088,781	60.86
2013	4,415,756	3,169,890	71.79
2014	4,231,620	3,318,320	78.42
2015	4,238,506	2,971,903	70.12
2016	4,057,389	2,655,233	63.58
2017	4,842,801	3,318,320	68.52
2018	3,542,736	2,652,773	74.83
2019	3,787,170	2,817,282	74.39
2020	363,817	250,301	68.80

(*) Since 2020, it was not possible to produce tertiary as the brine outfall to the sea is broken. Source: IC Arco Sur Mar Menor.

Recycled water accounted for more than 2/3 of the irrigation volume, but in recent years this number decreased and the IC had to compensate with water from the Escombreras

desalination plant (Table 2). Precisely when these infrastructures would be more interesting and it would be necessary to modernize facilities and processes to overcome the environmental crisis of the lagoon. In 2022, the use of water produced by the Escombreras desalination plant has even been made more difficult (by the Administration), compromising crops in the C.R. from Arco Sur-Mar Menor.

Table 2

Reclaimed water and desalinated water in IC Arco Sur-Mar Menor.

Year	Reclaimed (m^3)	Reclaimed (%)	Desalination (m^3)	Desalination (%)	Total (m^3)
2017	3,318,320	75.09	1,101,039	24.91	4,419,359
2018	2,652,778	58.64	1,871,297	41.36	4,524,075
2019	2,817,282	61.91	1,733,277	38.09	4,550,559
2020	250,501	8.82	2,591,012	91.18	2,841,513
2021	0	0	1,558,486	100.00	1,558,486
2022	0	0	569,199	100.00	569,199
2023	0	0	1,467,994	100.00	1,467,994

Source: IC Arco Sur Mar Menor.

In the IC Campo de Cartagena, the participation (%) of reuse and drainage is lower than in the IC Arco Sur-Mar Menor, since it has more a more diverse offer of resources (Segura Basin, Tajo-Segura Transfer, etc.), but they are also forced to turn to desalination (Escombreras and Torrevieja desalination plants). In the future they could recover, at the "El Mojón" plant, part of the water that will have to be extracted from the Quaternary aquifer (Table 3). The Escombreras desalination plant plans to allocate more than 20 hm3/year for agriculture and livestock use.

Table 3

Participation of reclaimed water and desalinated water in the consumption of water for irrigation of the IC Campo de Cartagena.

Hydrological Year	Reclaimed (m^3)	Reclaimed (%)	Desalination (m^3)	Desalination (%)	Total (m^3)
2015/16	5,454,273	8.09	17,753,097	26.34	67,407,703
2016/17	7,648,877	14.91	9,726,894	18.96	51,304,971
2017/18	7,375,673	11.81	13,845,990	22.17	62,450,471
2018/19	8,021,479	9.84	17,558,398	21.55	81,490,530
2019/20	7,029,416	9.09	11,906,020	15.41	77,300,785
2020/21	8,262,686	8.76	21,668,299	22.96	94,369,137
2021/22	4,835,762	5.51	24,254,651	27.66	87,674,233
2022/23	5,186,589	6.41	34,562,299	42.71	80,927,356

Source: IC Campo de Cartagena.

The hydrogeological system of the Campo de Cartagena-Mar Menor basin is a multilayer system made up of deep confined aquifers (Triassic, Tortonian, Messinian and Pliocene) and a shallow free aquifer (Quaternary). The latter is the one that has received the most agrochemical contaminants and its discharge contributes to the environmental degradation of the lagoon (especially eutrophication).

In the 80s of the 20th century, Professor Martín José Lillo Carpio, in his doctoral thesis, pointed out some changes that would alter the Mar Menor: such as mining waste from the mountains near the basin, which once dragged by the waters of intense rains affected the vegetal colonization of the lagoon and its surroundings; the urban planning plans approved for the centers of national tourist interest in 1966 and 1968 that meant a multitude of constructions for the surroundings of the Mar Menor, such as the lake city in the place occupied by the Vivero fish farm or that of Veneziola on the old Charco fishery, or the "Tomás Maestre" Marina on the Estacio fishery (Lillo, 1978-79, p. 47-48). Spaces of geological interest such as the Calnegre volcanism have been left under the multitude of constructions erected for urban development.

One of the causes of the deterioration of the Mar Menor lagoon is attributed to the sewage network (obsolete and incomplete). Law 3/1987 on the Protection and Harmonization of Uses of the Mar Menor, contemplated a Sanitation Plan that would avoid news such as those of the Diario La Verdad of 06/01/1982 "Some beaches of the Mar Menor contaminated" and of 08/16/1983 "The Mar Menor, on its way to being a sewer". In the Campo de Cartagena-Mar Menor region, Sewage Treatment Plants (STPs) have been installed for more than thirty years. Out of a total of 25 STPs in the region, those of Cabezo Beaza and Mar Menor-Sur stand out for their treatment capacity. The first collects and treats wastewater from the town of Cartagena, and the second from La Manga and surroundings.

In recent years these plants treated more than 25.4 million cubic meters/year, which means 22.80% of the entire volume treated in the Region of Murcia. The length of the waste collection network reaches more than 2,000 km of main sewage (Abellán, 2019, p. 183). The renewal of the network is urgent, expanding the connection to all residential areas, and also modernizing the treatments in the STPs. Treated wastewater is granted for use within circular economy to different users (Table 4). More than 20 hm3/year of the STP near the Mar Menor are destined for agricultural use.

Table 4

Main uses of reclaimed water in STP of Mar Menor's surroundings.

Number in the register of water	Intake point and municipality	Volume (m^3/year)	Use
4252	STP Mar Menor Sur (Cartagena)	4,864,120	Agriculture
6877	STP Urb. Inmogolf (Belones, Cartagena)	310,650	Golf and gardening
6188	STP Cabezo Beaza (Cartagena)	9,367,843	Agriculture
5354	STP San Javier	300,651	Golf Roda Golf
5355	STP San Javier	500,000	Agriculture
5497	STP San Javier	2,394,730	Agriculture
6433	STP La Unión	650,000	Agriculture
7132	STP La Aljorra (Cartagena)	630,000	Agriculture
7133	STP La Aljorra (Cartagena)	270,000	Agriculture
5083	STP Los Alcázares	168,953	Municipal gardening
4835	STP Los Alcázares	155,000	Golf Torre de Rame
6175	STP Los Alcázares	2,611,141	Agriculture
8473	STP San Pedro del Pinatar	2,430,000	Agriculture

Source: Environmental Information of the CHS Water Quality Area (11/05/2022).

Heavy and intense rainfall generate floods in the river courses and flooding in the lower parts of the basin. From the analysis of recent years (2012-2020), the episode with the highest volume of precipitation occurred after DANA on September 12, 2019. That day is the one with the most observatories with records greater than 60 mm/24 hours (15 stations) in the Region of Murcia (Gómez *et al.*, 2021, p. 900). In the recently created station 7019B of San Javier/La Manga 320.6 mm were registered. The existence of these surface runoffs collected in the sewage network leads us to think that current purification studies need to be done according to sewersheds, that is, the surface that discharges into a STP (Bernabé-Crespo, Olcina & Lahora, 2022). It is also necessary to consider the creation of storm tanks to collect the first cloudy after heavy rains and the treatment of these waters that carry contaminated soil both from the important fertilization of the fields and that of streets and communication routes.

Surface runoff has been favored by the sealing of soils by urbanization works and the expansion of transport and communication networks. Some studies evaluate it in more than 15% of the surface of Campo de Cartagena-Mar Menor (Romero *et al.*, 2017, p. 521). The agricultural practices of intensive agriculture with tasks such as pulverizing the soil to facilitate horticultural machining planting, generate a large amount of fine material ready to be washed away after the rains, with the consequent loss of fertile soil and the accumulation of sediment in the lagoon.

There is an agreement to prevent the dragging of soil and water contaminated by nitrates and heavy metals from reaching the Mar Menor and the Mediterranean. For this, it will be

necessary to order the small watersheds, especially that of the Fuente Álamo or Albujón rambla, with cultural practices such as the terracing of sub-arid slopes (Hernández & Morales, 2013, p. 107) and with the diversion of rainwater concentrated in courses of the rambla type, through networks of channels that lead this stormwater to irrigate drylands (alfait irrigation) (Gil *et al.*, 2021, p. 121). Retentions and diversions, to accumulate them in ponds and storm tanks, to mitigate the floods that occur after heavy and intense, torrential rains, as in the DANA episodes of September 2019 (Bernabé-Crespo *et al.*, 2020, p. 428). Some farmers have established small reservoirs to collect and store rainwater, which undergoes a decantation process before being used for irrigation. They have also created hedges of vegetation in order to retain runoff and prevent soil loss. Tillage practices are being changed to replant and till according to contour lines, and thus avoid erosion. It is necessary to provide aid to the owners of the land, to maintain the dry-stone walls which support the terraces to retain water and soil; to replenish flood water diversion dams and to revitalize the inlet systems that direct the turbid to the terraces for assisted rainfed practices. As well as the reconstruction and maintenance of the cisterns of the Campo de Cartagena-Mar Menor that made it possible to cope with droughts (Gil *et al.*, 2020, p. 107). Stabled livestock causes a large amount of slurry (which accumulates in more than 300 ponds) and also manure, in whose management it is necessary to avoid an increase in the passage of nitrates into the aquifer. Especially to the Quaternary aquifer, which is the most superficial, a free aquifer composed of gravel, sand and clay, which is saturated and with a high nitrate load (more than 150 mg/L). CHS calculated that this aquifer received, in 2020, more than 1,575 tons of nitrates.

In order to avoid excess nitrates in the aquifer, water is being pumped from the mouth of the Rambla del Albujón, which concentrates surface runoff and outcrops from the high water table. According to the CHS more than 2.1 million cubic meters/year are pumped. The C.R. del Campo de Cartagena indicates that with the pumping of Los Narejos and El Mojón, 4 million cubic meters could be exceeded. On the southern shore, a whole network of drainages (pitches and galleries) allows capturing the subalveous runoff from the surroundings of the lagoon, and they were pumped to the IC Arco Sur-Mar Menor for further desalination and denitrification. To the west is the North Collector, within the set of infrastructures to achieve "zero discharge", which involves building 55 kilometers of pipes-drain, pumping stations and a brine outfall to the Mediterranean. About 12 hm3/year could be avoided to discharge, which is the volume of the current emission from the aquifer to the lagoon. Since March 2021, the pumping of the Rambla del Albuijón has been stopped; the CHS has not carried out the necessary repairs or expansion.

The contribution of nutrients and organic matter to the lagoon is the main cause of eutrophication, which generates an excess of phytoplankton (due to less light input that lowers photosynthesis and oxygen availability). For the generation of this phytoplankton, phosphorus is also necessary, which enters the lagoon through human discharges (breakages and overflows of the sanitation network, direct discharges from residences outside the network, leaks from cesspools, etc.). The Ingenio Foundation, in May 2022, indicated some areas of the Mar Menor that had high levels of phosphorus, E.coli and ammonium, and attributed them to the poor state of the sanitation network and the lack of connection in some urbanizations.

4 DISCUSSION

The poor state of the aquifer and the lagoon is attributed to intensive irrigation agriculture that has contaminated the aquifer, and subsequently the lagoon where it ends up. Techniques such as bioremediation are proposed to reduce the organic load and nitrates in irrigation (the experiences of drains and bacteria in this bioremediation are positive), and 5% of the surface of each farm can be used to create and maintain nutrient reduction systems as contemplated by Law 1/2018, of February 7. This would comply with Directive 91/676/EEC, which recommended not applying water with a nitrate concentration greater than 50 mg/L.

In the "zero discharge" agreements, the measures to reduce the contamination of the Quaternary aquifer stand out. But while that is achieved, to prevent these flows from reaching the Mar Menor, according to Alcolea *et al.* (2019) groundwater pumping should be considered. This is in order to drain a large part of the aquifer, lowering the water table at least the first ten meters, with a system of catchment wells and a network of drains and pipes that carry the water laden with nitrates to the desalination and denitrification plant that IC El Arco Sur -Mar Menor has in the southeast sector (next to Cabo de Palos-Cartagena) and the IC Campo de Cartagena has in the northeast (El Mojón-San Javier). From these sites, through submarine outfalls, the waste is diluted to more than 2 km from the coast, while the denitrified product waters can be used for irrigation. The objective is to reduce nutrient discharges, which are variable and occur through the drainage network, which collects rainwater pipes, direct discharges of groundwater from the Quaternary aquifer, and others (Álvarez-Rogel *et al.*, 2020). The restoration of wetlands is also a strategic action, since the marshes act as a filter to reduce the concentrations of nutrients, so it would be convenient to avoid the channeling of water beds (Álvarez-Rogel *et al.*, 2006). That is the reason why Martínez-Paz (2007), who argues that it would be more cost-effective measure rather than intercepting runoff and its treating in a desalination plant.

There seems to be a debate about the causes of the environmental crisis in the Mar Menor, as the Central and Autonomous administrations do not reach agreements on the competences of each one and on the measures to be carried out to overcome the crisis. What it is greatly spread is a social clamor for the poor state of the lagoon with slogans like "We must save the Mar Menor", which has reached the press and other media. Even a study of Velasco *et al.* (2018) showed that more than 60% of respondents would accept an annual fee to ensure its conservations and a sustainable ecosystem use. The analysis of the title pages and other pieces of news of the regional newspapers of La Opinion and La Verdad, seem to reflect this social malaise, and there is awareness of applying "zero discharge" for the recovery of the Mar Menor, and even giving it greater legal prominence that facilitates his defense. Some of the most notable include: 08/01/1980. La Verdad. *"They want to save the Mar Menor. The Ministry and the Secretary of State will carry out a study to combat the deterioration of the Mar Menor*". As of writing, more than 42 years ago it was already evident the poor environmental condition of Mar Menor. On 06/01/1982, journal La Verdad headlined *"Some beaches of the Mar Menor contaminated. It is due to serious flaws in the Sanitation Infrastructure Plan, according to a study".* This was the first time that beaches were visibly polluted, 40 years ago. On 08/16/1983, the same newspaper La Verdad wrote *"The Mar Menor, on its way to being a sewer. The pesticides and chemical fertilizers that reach its waters can double these years",* warning about the upcoming disaster.

These are the oldest pieces of news, but this process kept on worsening until 2016, when contamination reached a critical point. On 05/28/2016, newspaper La Verdad entitled "The Mar Menor is dying" for another time, after years of a more stable situation. On 04/05/2019, La Verdad announced that "The Confederation closes 300 desalination plants since the Mar Menor crisis", and on 10/23/2019, the same journal wrote "The CHS identifies 1600 ha of illegal irrigation in the Mar Menor". These findings were followed by sanctions, as newspaper La Opinión disclosed on 09/12/2020: "Sanctions for the illegal use of water in the Mar Menor skyrocket: The Ministry increases the number of files to almost 300 and the area used doubles when it exceeds 2,150 ha. 186 illegal desalination plants are sealed in Campo de Cartagena". Social pressure made political authorities act to try to prevent more disastrous events. Thus, on 09/14/2021, La Opinion reported "The Regional Assembly gives the green light to the prohibition of using nitrogenous fertilizers. Government and opposition discuss again the competence to act on illegal irrigation and discharges into the Mar Menor", and on 03/10/2021, La Verdad communicated "The Plan of Uses of the Mar Menor will establish an ecological corridor and will limit the urbanizations".

There have been no agreements between the political groups to apply a specific regulation that achieves the integral protection of the Mar Menor. Despite having one of the first territorial planning laws in Spain, such as Regional Law 3/1987, on the Protection and Harmonization of Uses of the Mar Menor, which covered the Mar Menor and its surroundings in an integrated manner, in order to enable compatibility between development and conservation of the lagoon ecosystem. The Land Law of the Region of Murcia, approved in 2001, repealed it. The most recent Law 13/2015, of March 30, on territorial and urban planning of the Region of Murcia, has not been able to achieve this integration between the uses and the lagoon either. The changes in the national governments and the lack of political will in both administrations, did not allow to carry out a Plan of Harmonization of Uses.

In addition to these laws, others contemplate in a very sectoral way some aspects of landscape and biodiversity are contemplated in a very sectoral way for the protection and management of the coastline. Thus, Law 7/1995, on the Protection of Wild Fauna, declared the Wild Fauna Protection Area "Mar Menor and associated Wetlands". The development of the Natura 2000 Network (Habitats Directive 92/43/CEE and Birds Directive 2009/147/CEE) included several of these spaces in Special Protection Areas for Birds and Special Conservation Areas. At the international level, the Convention for the protection of wetlands, celebrated in Ramsar (Iran) in 1971, had included the Mar Menor as a wetland of international relevance and in 2001 (Barcelona Convention) as a Specially Protected Area of Interest for the Mediterranean.

In the last years, the situations of environmental crisis, which the Mar Menor and its surroundings have gone through, have generated a series of Laws, Decree-Laws and Resolutions that have barely been developed, and not all of their measures have been applied. Some of them are: Law 1/2018, of February 7, on urgent measures to guarantee environmental sustainability in the surroundings of the Mar Menor; the Resolution of September 4, 2019 of the General Directorate of Biodiversity and Environmental Quality, which formulates the environmental impact statement of the Project Analysis of solutions for the objective of zero discharge to the Mar Menor from Campo de Cartagena (Murcia) (BOE, nº 222, Thursday, September 26, 2019); Decree-Law 2/2019, of December 26, on the Comprehensive Protection of the Mar Menor (BORM, No. 298, of 12-27-2019). As well as Law 3/2020, of July 27, on the Recovery and Protection of the Mar Menor (BOE, 08-15-2020). We hope that the development of all these regulations will allow this comprehensive approach to the lagoon and its surroundings.

In the diagnostic phase, a SWOT matrix has been prepared on the state of the Mar Menor and its surroundings, weaknesses, threats, strengths and opportunities are as follows:

Weaknesses: - Scarcity of own water resources. – Competition for water between different uses. – Losses in supply and sanitation networks. – Lack of regulations for comprehensive management of the Mar Menor and its surroundings. - Soil losses due to torrential runoff. – Excessive seasonality in tourist occupation.

Threats: - Decrease or suppression of the volumes of the Tagus-Segura Transfer. – Increased cost of energy for purification and desalination processes. – Lack of investments for the renewal of drainage and sanitation networks. – Eutrophication and anoxia in the Mar Menor due to discharges.

Strengths: -Adequate water management by organizations such as the MCT. – Good light and wind conditions for tourism (sun hours) and water sports (sailing). – Availability of technology, capacity for innovation and research in irrigation, purification, desalination. - Tourist accommodation (hotels) of good quality.

Opportunities: - Financing from the European Union (NextgenerationEU) for investments in recovery and resilience after COVID19 that could expand and renew sanitation and drainage networks. -New functionalities in the use of rainwater to deal with droughts and floods.

As Conesa and Jiménez-Cárceles (2007) point out, changes to a more environmentally friendly agriculture are needed, including a lesser use of fertilizers and a monitoring of agricultural water discharge. These authors add that "the role of the salt marshes as green filters should be considered, and therefore, these areas should be protected from urban development" (Conesa & Jiménez-Cárceles, 2007, p. 847), what renders to the conception of a new legislation regarding territorial model.

A sanctioning regime is being prepared for illegal irrigation and for excessive application of fertilizers. According to CHS, more than 43,000 hectares are authorized for irrigation, but there are more than 8,000 hectares that at some point have been irrigated without having a concession, so files have been opened and they are instructed to return to other crop system. It is proposed to reduce the use of fertilizers in agriculture (especially inorganic or synthetic nitrogen) in zone 1 of the Mar Menor, which covers some 11,000 hectares. In this area near the Mar Menor, the use of fertilizers would be totally prohibited in the next two years and it would be reduced in zones 2 and 3, the furthest from the Mar Menor.

Recently (June 2024) the ecologist Angel Pérez Ruzafa and the hydrogeologist Tomás Rodriguez Estrella pointed out that it is advisable to lower the level of the Quaternary aquifer, at least 6 to 10 meters, which would prevent waters with excess nitrates from passing or flowing into the Mar Menor. To do this, the exploitation (pumping) of boreholes and wells would have

to be authorized and the extracted water would be taken to the El Mojón desalination plant of the Campo de Cartagena Irrigation Community, and the brine would be thrown into the Mediterranean through the emissaries of San Pedro del Pinatar's desalination plants. Research can help reduce these brines, as is the case with the Arco Sur-Mar Menor Irrigation Community that participates in the "LIFE DESIROWS" Project aimed at eliminating liquid waste (brine), reducing it to solid (ZDL, Zero Liquid Discharge). In this way, most of the contaminants are eliminated through reverse osmosis, along with other treatments for removing metals, organic matter and divalent ions. Finally, a Sodium Chloride product of high concentration and purity is obtained that can be marketed.

The discussion arises whether the contamination is due to agricultural practices or to the lack, insufficiency and poor functioning of the sanitation network. The Ingenio Foundation suggests that the appearance of phosphates and other products is due more to an insufficient and outdated (more than 25 years) sanitation network. The Sanitation and Wastewater Purification Entity of the Region of Murcia (ESAMUR) indicates that in times of copious rains of high intensity per hour, the rainwater and turbid waters overflow the capacity of the STPs. Therefore, storm tanks are being created to collect this water and subsequently purify it in the STPs. The Department of Water and Environment of the Autonomous Community of the Region of Murcia has prepared an investment plan (more than 250 million euros) in the area of the Mar Menor, with the aim of changing the sanitation networks that present leaks, in order to modernize some STPs, replace brine emissaries to the Mediterranean, etc. The Segura Hydrographic Confederation (CHS), dependent on the Ministry for the Ecological Transition and the Demographic Challenge (MITECO), is also preparing projects to prevent the surpluses from the treatment plants (after heavy rains) from reaching the Mar Menor, for this purpose the surpluses are piped in order to discharge into the Mediterranean through the San Pedro del Pinatar outfall.

5 CONCLUSION

All administrations, ecologists, users, neighbors, etc. agree that the environmental crisis cannot be solved by acting only on the lagoon – it is necessary to act on the entire Campo de Cartagena-Mar Menor basin, ordering the territory and harmonizing the different uses, in order to improve the quality of life in the lagoon and its surroundings.

Among the emergency measures to alleviate the areas of anoxia, especially in the southeastern quadrant of the lagoon, the CARM proposes the dredging of the Marchamalo water

passage (former Gola de la Constancia, opened in 1775 to create a fishery for the Congregation of the Hospital and Santa Caridad of Cartagena). Other years dredging has been carried out, with a depth of less than 1 meter, and has allowed the flow between Mar Menor and the Mediterranean Sea. A report from the Spanish Institute of Oceanography indicates that it could affect the nacra (Pinna nobilis), an endemic Mediterranean mollusk that has reduced its number in the Mar Menor.

The Order of October 29, 2019 of the Regional Office of Water, Agriculture, Livestock, Fisheries and the Environment of the Region of Murcia (BORM, 254, November 4, 2019) prioritizes the research subareas for the financing of research that helps to overcome the environmental crisis of the lagoon and its surroundings. Among those related to agricultural uses, the following stand out: Good agricultural practices, agri-environmental measures, good livestock practices, manure and purine control, etc. Among those related to water masses: connectivity of aquifers-Mar Menor, nutrients and heavy metals in water, contamination and salinization of aquifers, water parameters for bathing, water purification, desalination, etc. Among those related to land use planning: Rainwater and sewage networks, hydrographic basins and their recovery, eutrophication mitigation technologies, public and tourist infrastructures; harbors, docks, and pontoons; landscape studies, local development policies, etc. In short, studies and research that allow the environmental sustainability of the Mar Menor and its surroundings.

It is also necessary to act on other uses such as tourism, avoid the total urbanization of the riverbanks, open spaces must be left (the city councils must advance urban moratoriums); we must reduce the excess of docks, pontoons, and berths; reconsider the number of marinas and the state of their surroundings; reduce motor boating and facilitate sports that use wind for energy.

The Segura Hydrographic Confederation (CHS) has planned actions in ramblas such as La Maraña, Miedo, Beal, etc. As the Campo de Cartagena-Mar Menor basin is an internal basin in the Region of Murcia, these actions could be assumed and managed by the Autonomous Community of the Region of Murcia; leaving the maintenance of the quality of the aquifer and the water mass of the Mar Menor to the CHS, since these water masses are part of the Segura Hydrographic Demarcation. European Next Generation funds must be invested (more than 600 million euros) to carry out the expansion and modernization of the sanitation network and the drainage systems (storm tanks, tertiary in all the STPs, separate network of rainwater and residuals, apply studies of residual basins, etc.). It is advisable to promote a bottom-up participatory process of citizens (users, residents, social agents, etc.). Agreement between the

Administrations (State, Regional, Local) is necessary, with political will to harmonize the different uses and apply cultural practices, with the aim of overcoming the environmental crisis of the Mar Menor and its surroundings. Harmonizing the different uses includes allowing precision irrigation agriculture that would maintain the jobs associated with this fruit and vegetable production and distribution activity, and controlling the growth of tourist urbanization, making them always compatible with a good state of the lagoon.

REFERENCES

Abellán Soler, M. (2019). "Actuaciones para evitar la contaminación procedente de aguas residuales urbanas". Una mirada global sobre el Mar Menor. DM Diego Marín. Murcia. 179-191.

Alcolea, A.; Contreras, S.; Hunink, J. E.; García-Aróstegui, J. L.; Jiménez-Martínez, J. (2019). Hydrogeological modelling for the watershed management of the Mar Menor coastal lagoon (Spain). Science of the Total Environment 663, 901–914. https://doi.org/10.1016/j.scitotenv.2019.01.375

Álvarez-Rogel, J.; Barberá, G. G.; Maxwell, B.; Guerrero-Brotons, M.; Díaz-García, C.; Martínez-Sánchez, J. J.; Sallent, A.; Martínez-Ródenas, J.; González-Alcaraz, M. N.; Jiménez-Cárceles, F. J.; Tercero, C.; Gómez, R. (2020). The case of Mar Menor eutrophication: State of the art and description of tested Nature-Based Solutions. Ecological Engineering 158, 106086. https://doi.org/10.1016/j.ecoleng.2020.106086

Álvarez-Rogel, J.; Jiménez-Cárceles, F. J.; 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, and Soil Pollution, 173, 21–38. DOI: 10.1007/s11270-006-9020-6

Bernabé-Crespo, M. B.; Gil Meseguer, E; Gómez Espín, J. Mª. (2020): "Recientes episodios de lluvias e inundaciones en el litoral de la región de Murcia". En López Ortiz, M.I.; Melgarejo Moreno, J. (Eds.). Riesgo de inundación en España, análisis y soluciones para la generación de territorios resilientes. 419-430. Universitat d'Alacant. Ayuntamiento de Orihuela. ISBN: 978-84-1302-091-4.

Bernabé-Crespo, M. B.; Gil, E.; Gómez, J. Mª. (2022). El consumo de agua potable en los municipios turísticos del litoral de la Región de Murcia. Cuadernos de Turismo, 49, 289–313. https://doi.org/10.6018/turismo.521921

Bernabé-Crespo, M. B.; Gómez Espín, J. Mª., Tudela Navarro, M. L. (2021): "Gestión del abastecimiento de agua en una región semiárida: análisis del consumo de agua potable en el Campo de Cartagena-Mar Menor, Sureste de España: 2010-2019". Boletín de la Asociación de Geógrafos Españoles (BAGE), 88, marzo 2021, 1-34. eISSN: 2605-3322.

Bernabé-Crespo, M. B.; Olcina, J.; Lahora, A. (2022). Examining the implementation of potable water reuse in sewersheds of Southeastern Spain. Urban Water Journal, 19 (6), 629-640. https://doi.org/10.1080/1573062X.2022.2069043

Conesa, H. M.; Jiménez-Cárceles, F. J. (2007). The Mar Menor lagoon (SE Spain): A singular natural ecosystem threatened by human activities. Marine Pollution Bulletin 54, 839–849.

De Pascalis, F.; Pérez-Ruzafa, A.; Gilabert, J.; Marcos, C.; Umgiesser, G. (2012). Climate change response of the Mar Menor coastal lagoon (Spain) using a hydrodynamic finite element model. Estuarine, Coastal and Shelf Science, 114, 118-129. https://doi.org/10.1016/j.ecss.2011.12.002

Erena, M., Domínguez, J. A.; Aguado-Giménez, F.; Soria, J.; García-Galiano, S. (2019). "Monitoring Coastal Lagoon Water Quality through Remote Sensing: The Mar Menor as a Case Study" Water 11 (7), 1468. https://doi.org/10.3390/w11071468

Gil Guirado, S.; Gil Meseguer, E.; Gómez Espín, J. Mª. (2010): "El territorio, un bien que conviene ordenar: las salinas del litoral e interior de la Región de Murcia". Cuadernos Geográficos, 47 (2010-2), 611-635. ISSN: 0210-5462.

Gil Meseguer, E.; Bernabé Crespo, M. B.; Gómez Espín, J. Mª. (2020): "Resiliencia en el consumo de agua por parte de abastecimientos y regadíos ante las sequías en el Sureste de España". Cuadernos de Geografía, 104, 107-130. Universidad de Valencia. ISSN: 0210-086X DOI: doi.org/ 10.7203/CGUV.104.16328

Gil Meseguer, E.; Bernabé-Crespo, M. B.; Gómez Espín, J. Mª. (2021): "Prácticas culturales de ordenación del territorio ante la crisis climática en el Sureste de la Península Ibérica". En Mora, J.; Castro, J.; Garrido, J. (coordinadores). Planificación Regional: paisaje y patrimonio. 117-132. Pamplona. Editorial Aranzadi, S.A.U. ISBN: 978-84-1390-856-4.

Gil Meseguer, E.; Gómez Espín, J. Mª (2014): "Los paisajes rurales del Campo de Cartagena-Mar Menor. Del riego itinerante a la factoría bajo cubierta" En Atlas de los paisajes agrarios de España. Tomo II. 543-552. MAGRAMA. Madrid. ISBN:978-84-491-1381-9.

Gómez Espín, J. Mª.; Gil Meseguer, E.; Bernabé-Crespo, M. B. (2021): "Infraestructuras de saneamiento y drenaje para adaptación a sucesos extremos de sequías e inundaciones en la Cuenca del Campo de Cartagena-Mar Menor". En Melgarejo, J.; López, I., y Fernández, P. (Editores). Inundaciones y sequías. Análisis multidisciplinar para mitigar el impacto de los fenómenos climáticos extremos. 897-907. Universitat d´Alacant. ISBN:978-84-1302-138-6.

Hernández Hernández, Mª.; Morales Gil, A. (2013): "Los aprovechamientos tradicionales de las aguas turbias en los piedemontes del Sureste de la península Ibérica: Estado actual en tierras alicantinas". Boletín de la Asociación de Geógrafos Españoles, nº 63. 105-123. ISSN: 0212-9426.

Lillo Carpio, M.J. (1978/79): "Geomorfología litoral del Mar Menor". Papeles del Departamento de Geografía, 8. 9-48. Murcia, Universidad de Murcia.

Martínez-Paz, J. M.; Martínez, J.; Esteve, 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, 211-232.

Morales Yago, F.J. (2021): "La Manga del Mar Menor (Murcia): De un espacio natural privilegiado hacia una transformación urbana, anárquica y especulativa". En Mora, J.;

Castro, J.; Garrido, J. (coordinadores). Planificación Regional: paisaje y patrimonio. 453-477. Pamplona. Editorial Aranzadi, S.A.U. ISBN: 978-84-1390-856-4.

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

Pérez-Ruzafa, A.; Marcos, C.; Pérez-Ruzafa, I.M. (2009):"30 años de estudios en la laguna costera del Mar Menor: de la descripción del ecosistema a la comprensión de los procesos y la solución de los problemas ambientales". El Mar Menor. Estado actual del conocimiento científico.17-46. Murcia. Fundación Instituto Euromediterráneo del Agua. ISBN: 978-84-9363-26-8-7.

Rodríguez Estrella, T. (2009): "El Mar Menor: Geología y sus relaciones con las aguas subterráneas del continente". El Mar Menor. Estado actual del conocimiento científico. 47-84. Murcia. Fundación Instituto Euromediterráneo del Agua. ISBN: 978-84-9363-26-8-7.

Romero Díaz, A.; Caballero Pedraza; A.; Pérez Morales, A. (2017): "Expansión urbana y turismo en la Comarca del Campo de Cartagena-Mar Menor (Murcia). Impacto del sellado del suelo". Cuadernos de Turismo, nº 39. 521-546. ISSN: 1139-7861.

Velasco, J., Lloret, J., Millan, A.; Marín, A.; Barahona, J.; Abellán, P.; Sánchez-Fernández, D. (2006). Nutrient And Particulate Inputs Into The Mar Menor Lagoon (SE Spain) From An Intensive Agricultural Watershed. Water Air Soil Pollut 176, 37–56. https://doi.org/10.1007/s11270-006-2859-8

Velasco, A. M.; Pérez-Ruzafa, A.; Martínez-Paz, J. M.; Marcos, C. (2018). Ecosystem services and main environmental risks in a coastal lagoon (Mar Menor, Murcia, SE Spain): The public perception. Journal for Nature Conservation, 43, 180-189. https://doi.org/10.1016/j.jnc.2017.11.002