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ENVIRONMENT PROGRAMME
MEDITERRANEAN ACTION PLAN

5 May 2020
Original: Spanish

16th Meeting of the Compliance Committee of the Barcelona Convention and its Protocols

Teleconference, 16-18 June 2020

Agenda Item 7: Follow-up on previous Communication to the Compliance Committee under Paragraph 23.bis of the Procedures and Mechanisms on Compliance

Response from Spain to the Communication from Ecologistas en Acción de la Región Murciana (Spain)

UNEP/MAP
Athens, 2020

Note by the Secretariat

At the 15th Meeting of the Compliance Committee (Athens, Greece, 25-26 June 2019), the designated Rapporteur, Dr. Orr Karassin, presented her main findings and her draft preliminary decision on the admissibility of the communication from Ecologistas en Acción de la Región Murciana (EARM) (Spain), regarding the implementation of the Protocol concerning the Specially Protected Areas and Biological Diversity in the Mediterranean by Spain. The findings and the draft preliminary decision as tabled to the 15th Meeting of the Compliance Committee are presented as a reference document to this meeting (UNEP/MED CC. 15/10). The Compliance Committee welcomed the work of the Rapporteur, as presented in document UNEP/MED CC. 15/10, and on the basis of the Admissibility Criteria of Relevant Information Sources and Procedure under Paragraph 23.bis of the Procedures and Mechanisms on Compliance under the Barcelona Convention and its Protocols decided *"to confer admissibility of the communication from Ecologistas en Acción de la Región Murciana. Following the Admissibility Criteria, the Compliance Committee asked the Secretariat to make arrangements to proceed with the notification of the communication"* (UNEP/MED CC. 15/15,§24).

Following-up on the conclusion of the 15th Meeting of the Compliance Committee, Spain was notified of the admissibility of the communication from EARM (Spain) by the Compliance Committee, and as per paragraph 18 of the Admissibility Criteria, Spain was invited to submit written explanations or statements on the matter. The response from Spain to the communication from EARM is presented in this document, translated from the original in Spanish by the Secretariat. The response is made up of two reports: (1) a technical report from the Office of the Assistant Director for Natural Heritage and Climate Change of the Ministry of Ecological Transition and Demographic Challenge, and (2) a technical evaluation report of the current condition of Mar Menor by the Marine Environment Division of the Spanish Institute of Oceanography. Additional documentation submitted by Spain in support of its response is presented in document UNEP/MED CC. 16/Inf.6, which provides a courtesy translation from Spain of: (1) a synthesis report on the current status of Mar Menor and its causes in relation to nutrient contents and (2) a summary of the contents of the report entitled: *"Activities uses and pressures in the Mar Menor. Extract of the information available in the Levantine-Balearic marine demarcation and in the Mar Menor coastline protection plan (E.S.T. 2017-2020/66"*.

Action requested

The 16th Meeting of the Compliance Committee is expected to examine the communication from EARM in light of the response from Spain as presented in this document and conclude on action to take.

Región de Murcia
Consejería de Agua, Agricultura,
Ganadería, Pesca y Medio Ambiente

Dirección General de Medio Natural

N/Rfa: 2019_0262_AC3_MEN_INF	S/Rfa: 36818/3-12-2019
UNIDAD: DIRECCIÓN GENERAL DE MEDIO NATURAL	
ASUNTO: **Comunicación**	
DESTINATARIO: DIRECCIÓN GENERAL DE SOSTENIBILIDAD E LA COSTA Y DEL MAR (MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA)	

In response to your request for a report on the information presented by Ecologistas en acción de la Región Murciana at the fourteenth and fifteenth meetings of the Compliance Committee of the Barcelona Convention and its protocols, on the implementation of the protocol for specially protected areas of Mediterranean importance (SPAMI protocol) in the Autonomous Community of the Region of Murcia (which is of particular relevance to the situation of Mar Menor and to actions taken by the various responsible governments in that regard), we wish to inform you that the attached technical report, dated 30 January 2020, has been prepared by the Subdirección General de Patrimonio Natural y Cambio Climático (office of the assistant director for natural heritage and climate change), which falls under our office.

The report contains an evaluation of the work done by Dirección General del Medio Natural (the head office for the environment) and its jurisdictional scope, which excludes water management and agricultural activity.

It also contains a breakdown of current conservation regulations as represented in the integrated management plan for the protected areas of Mar Menor and the coastal margins of the Mediterranean Sea in the Region of Murcia, approved and published under decree no. 259/2019 of 10 October (Official Gazette of the Region of Murcia no. 298 of 27 December 2019) and the recent approval by the Consejo de Gobierno of the Region of Murcia of decree-law no. 2/2019 of 26 December on the integrated protection of Mar Menor.

Both regulations contain many measures for the protection and conservation of both the lagoon and the natural areas protected under the Natura 2000 network, which includes the special protected area of Mediterranean importance (SPAMI).

In addition, the report notes that in March 2019 an ordinary periodic review (audit) was conducted of the state of the SPAMI in the Region of Murcia, resulting in a score of 53 points out of a possible 66, an indication of high-level achievements in management and coordination.

Finally, it should be noted that the physical and chemical parameters of the lagoon of Mar Menor are continuously analysed and monitored and numerous studies are being conducted, including on its flora and fauna, sediments, hydrology and currents.

Región de Murcia
Consejería de Agua, Agricultura,
Ganadería, Pesca y Medio Ambiente

Dirección General de Medio Natural

The report is issued without prejudice to third-party and proprietary rights and does not represent a waiver of the obligation to obtain any other mandatory reports, permits or licenses related to the matter at hand.

The present document is issued pursuant to the authority and powers granted to Dirección General de Medio Natural under Consejo de Gobierno decree no. 173/2019 of 6 September, according to which the governing bodies of Consejería de Agua, Agricultura, Ganadería, Pesca y Medio Ambiente (the regional ministry of water, agriculture, livestock production, fisheries and the environment) were established, and pursuant to presidential decree no. 29/2019 of 31 July on the reorganization of the regional administration.

THE DIRECTOR-GENERAL FOR THE ENVIRONMENT
[Document signed digitally in the margin]

Fulgencio Perona Paños

Región de Murcia
Consejería de Agua, Agricultura, Ganadería, Pesca y Medio Ambiente
Dirección General de Medio Natural

Espacios Naturales
Región de Murcia

INFORME IT-01/FMT-01 Edic. 3	SubDG Patrimonio Natural y Cambio Climático: 2019_0262_AC3_MEN_INF
Asunto:	Comunicación presentada por Ecologistas en Acción de la Región de Murcia en la 14th y 15th Reunión del Comité para el cumplimiento del Convenio de Barcelona, sobre implementación del Protocolo sobre Áreas Especialmente Protegidas y Diversidad Biológica del Mediterráneo (ZEPIM).
Solicitante:	D.G. de Sostenibilidad de la Costa y del Mar (Ministerio para la transición Ecológica)

The Subdirección General de Patrimonio Natural y Cambio Climático (office of the assistant general director for natural heritage and climate change) received a request from the Director-General for Sustainability for the Coast and the Sea (Ministerio para la Transición Ecológica y Reto Demográfico, MITECO; Ministry of Ecological Transition and Demographic Challenge), national focal point for the Action Plan for the Protection of the Marine Environment and the Sustainable Development of the Coastal Areas of the Mediterranean (Barcelona Convention) for a report on the communication presented by Ecologistas en Acción de la Región Murciana at the fourteenth and fifteenth meetings of the Compliance Committee of the Barcelona Convention and its protocols on the implementation of the SPAMI protocol in that autonomous community.

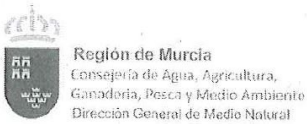
Two main claims can be identified in the text:

1. Since 2016, the lagoon of Mar Menor has been undergoing a process of eutrophication, and there is still no management plan for regulating the lagoon and the activities around it, in particular intensive farming using irrigation systems, which constitutes one of the sources of pressure in the area.

2. The various administrative entities responsible for water, agriculture, coastal regions, the environment and urban planning, all factors which affect the ecosystem of Mar Menor, have ignored the recommendations of Ecologistas en acción since they were presented in 2016. They have systematically legalized the use of illegal wells and desalination plants to allow for crop irrigation, with one third of those crops being illegal. Etc.

In response, first of all, Dirección General del Medio Natural (the head office for the environment) is actively working on the aspects that fall under its purview as a public entity, as established in Consejo de Gobierno decree no. 173/2019 of 6 September, under which the managing bodies of Consejería de Agua, Agricultura, Ganadería, Pesca y Medio Ambiente were established and began to exercise their authority and functions with respect to the planning and management of natural protected areas for the Natura 2000 network, natural habitats and forest fauna and flora, as well as for the promotion of the natural environment and combating climate change, representing the entity before Red de Autoridades Ambientales and regarding forestry policy, hunting and river fishing and the protection of forest wildlife.

Compliance with the aforementioned SPAMI protocol for the Mar Menor region and the eastern Mediterranean area of the coast of the Region of Murcia falls within these competencies.



We clarify that water management and use and agriculture are not included within our jurisdictional framework.

Secondly, the lagoon of Mar Menor, an area that is included in the SPAMI, already has an **Integrated management plan for the protected areas of Mar Menor and the Mediterranean coastal margins of the Region of Murcia**, approved under and published in **decree no. 259/2019** of 10 October (Official Gazette of the Region of Murcia no. 298 of 27 December 2019).

The recently approved Consejo de Gobierno of the Region of Murcia **decree-law no. 02/2019 of 26 December on the integrated protection of Mar Menor** now joins the list of these enacted protective regulations.

Both regulations include numerous measures to protect and conserve both the lagoon and the protected natural areas and areas associated with the Natura 2000 network, which include the SPAMI.

Thirdly, in March 2019, an ordinary periodic review of the SPAMI (audit) was conducted in the Region of Murcia, resulting in a score of 53 points out of a possible 66, an indication of high-level achievements in management and coordination.

It was emphasized in the conclusions of the audit report that work should continue and initiatives such as the following should be taken:

--The creation of a map that would show the various protected areas within the SPAMI and approval of the Management Plan. This goal, as indicated above, was achieved with the approval and publication of decree no. 259/2019. The limits, description and map are set forth in volume IV, annex 6. A digital map is also available and may be viewed as part of this information.

--Together with the other jurisdictional administrations, a system of infrastructure should be established to treat and manage the waters that drain into Mar Menor.

On 6 September 2018, this public entity issued a report on the consultation on projects for rain water collection systems and storm tanks to prevent spills into Mar Menor, as follows:

- **EIA20180053:**

Project: Storm water treatment system for the wastewater treatment facility in Torre Pacheco (Murcia).

- **EIA20180056:**

Project: Rainwater collection system in Barrio de Los Pescadores de San Javier (Murcia).

- **EIA20180057:**

Project: Storm water collection system and tank in Islas Menores-Mar de Cristal. T.M. Cartagena

- **EIA20180058:**

Project: Storm water collection system and tank in Los Nietos. T.M. Cartagena.

- **EIA20180059:**

Project: North and south rainwater collection system and flow-through dam to reduce spillover into Mar Menor. T.M. San Javier

EIA20180063:

Project: Storm water collection system and tank in Los Cuarteros, T.M. San Pedro del Pinatar.

- **EIA20180064:**

Project: Storm water collection system and tank in Playa Honda T.M. Cartagena.

Some of these projects have been completed and others are under way.

Maintain and increase the monitoring and oversight of SPAMI parameters, even beyond Mar Menor and Cabo de Palos.

Although indeed currently, owing to the serious ecological imbalance of Mar Menor, many actions have focused on that area, other management and protection initiatives are being taken in other areas, including in the SPAMI and in the special protected area for birds (ZEPA) of Isla Grosa. An example of this is the push to award the 2020 tender for the service for environmental oversight and public use activities for the special protected area of Isla Grosa, among other projects.

Another example of a proposal for the management and conservation of another of the areas included in the SPAMI, specifically the submerged coastal margin of the Region of Murcia special conservation area (ZEC), is the proposal to increase the scope of protection of the Cabo de Palos-Islas Hormigas Marine Reserve, an initiative that is being undertaken jointly with other public entities with jurisdiction.

Finally, regarding the lagoon of Mar Menor, its physical and chemical parameters are continuously analysed and monitored, and numerous studies are being conducted on its flora and fauna, sediments, hydrology and currents, etc.

See https://www.canalmarmen.oers/web/cnaalmarmenor/ciencia.

In addition, various protocols for action are being established and implemented in an attempt to conserve the different species of threatened fauna in and around the lagoon, including urgent measures to protect the fan mussel (*pinna nobilis*).

In conclusion, this administration continues to work to comply with the aforementioned SPAMI protocol for the Mar Menor and eastern Mediterranean regions of the coast of the Region of Murcia.

Notwithstanding the aforegoing, we remain available to provide additional details on any matter of interest to you.

DOCUMENT SIGNED DIGITALLY IN THE MARGIN

LA TÉCNICO AMBIENTAL (ENVIRONMENTAL TECHNICIAN)
Signed: Alicia Montano Simón

Per: EL SUBDIRECTOR GENERAL DE PATRIMONIO NATURAL Y CAMBIO CLIMATICO (THE ASSISTANT GENERAL DIRECTOR OF NATURAL HERITAGE AND CLIMATE CHANGE)
Signed: J. Faustino Martínez Fernández

THE DIRECTOR-GENERAL FOR THE ENVIRONMENT

MINISTERIO
DE CIENCIA, INNOVACIÓN
Y UNIVERSIDADES

INSTITUTO ESPAÑOL
DE OCEANOGRAFÍA

MINISTRY OF SCIENCE, INNOVATION AND UNIVERSITIES **SPANISH INSTITUTE OF OCEANOGRAPHY**

TECHNICAL EVALUATION REPORT BY THE MARINE ENVIRONMENT DIVISION OF THE SPANISH INSTITUTE OF OCEANOGRAPHY [1]

SUBJECT	Report on the current condition of Mar Menor
Requesting body	Subdirección General para la Protección del Mar (Office of the Assistant Director General for the Protection of the Sea); Dirección General de Sostenibilidad de la Costa y del Mar (Office of the Director General for Sustainable Coasts and Seas); Ministerio para la Transición Ecológica (Ministry of Ecological Transition)
Date of request	22 October 2019

SUMMARY OF THE CURRENT CONDITION OF MAR MENOR AND ITS CAUSES

Understanding eutrophication

Eutrophication is a process of natural or human-induced enrichment with inorganic nutrients (nitrogen and phosphorus) that exceeds the critical self-regulation capacity of a given system with a balanced nutrient flow and cycle (Schramm & Nienhuis 1996). Hypertrophy refers to a situation in which, unless nutrient inputs are reduced, excess nutrients cause irreversible changes in aquatic communities.

The following are considered **primary effects** of eutrophication:

- Increased nutrient levels
- Phytoplankton blooms
- Decline or loss of perennial marine plant communities, which are replaced by fast-growing algae
- Reduction in the diversity of associated flora and fauna
- Short-lived algal blooms that can harm fishing or other activities (e.g., tourism)

[1] Referred to later in this document as SIO.

- Changes in the depth of distribution of benthic algae caused by reduced levels of light

The following are considered **secondary effects** of eutrophication:

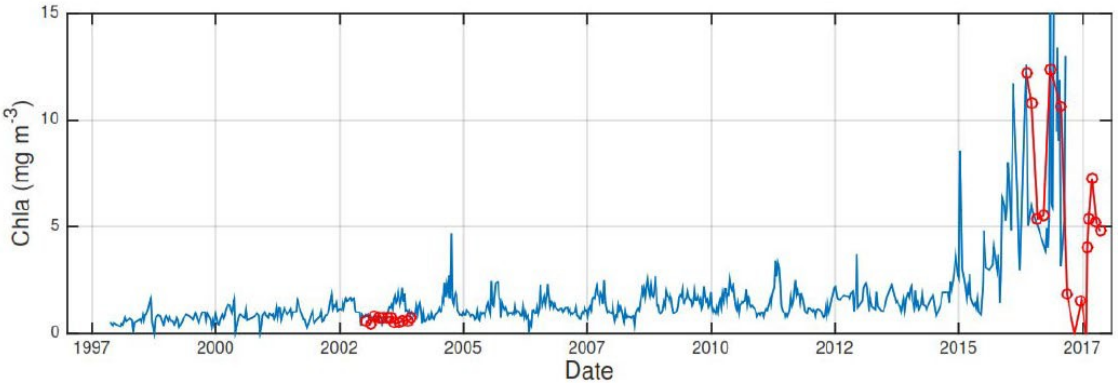
- Increase in plant biomass leads to an increase in particulate and dissolved organic matter
- Increase in the numbers of benthic filtering and detritivorous species
- Intensification of oxygen-consuming processes, leading to hypoxia and to the production of sulphides
- Decline in zooplankton and fish diversity

Unlike eutrophic systems, **oligotrophic** systems are poor in nutrients because of scant nutrient input, either because there is little input from the land, as is the case in arid and semi-arid Mediterranean coastal areas (such as in the southeast of the peninsula), or because there is little input of human origin. In these systems, the growth of phytoplankton is limited and the water is transparent, enabling permanent benthic plant communities to develop. This was the situation of Mar Menor in the 1950s, before urban and agricultural development.

Recent changes to the marine lagoon ecosystem

For decades, nutrients (mainly nitrates, but also phosphates and ammonia) and organic matter have been flowing into Mar Menor, forcing the formerly oligotrophic system into a eutrophic state. ***Chlorophyll a*** is considered a macro-descriptor of the degree of development of phytoplankton communities, and therefore of the degree of oligotrophy or eutrophy. Generally, under normal circumstances, a higher level of chlorophyll a is the result of more nutrients in the environment. The following graph shows the changes in levels of **chlorophyll a** in the waters of Mar Menor from the end of the 1990s until 2017 (blue line, figure 1).

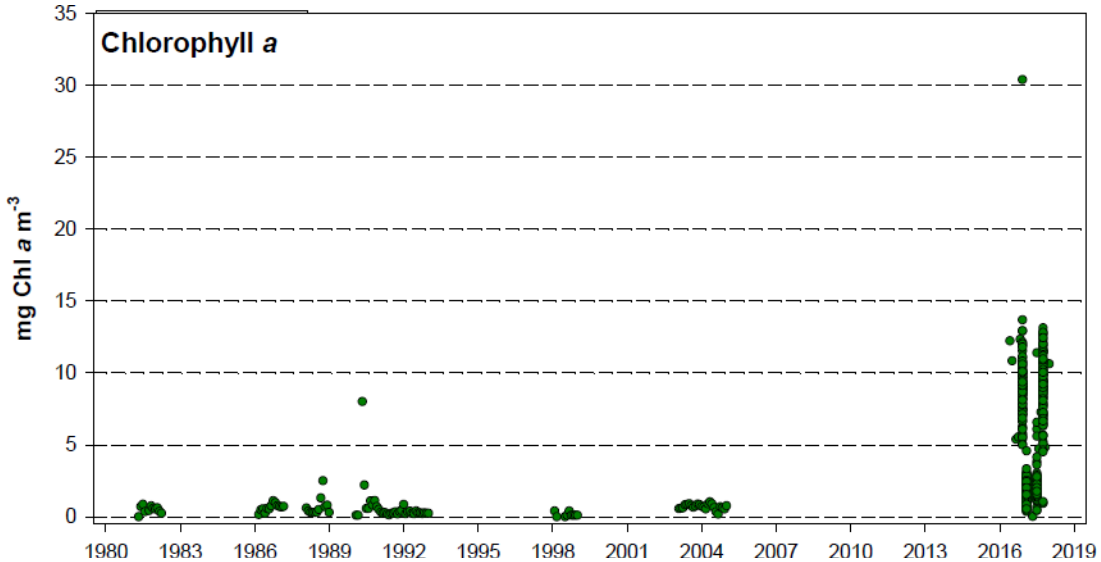
Figure 1.



The blue line represents chlorophyll, obtained through spectral analysis of satellite images, and the red dots and lines are the chlorophyll numbers directly obtained from water samples and measured by spectrophotometry (SIO, MMEM project). Source: prepared by Eugenio Fraile Nuez (SIO) from satellite imagery for Belando et al. (2019).

It can be seen that levels of chlorophyll a were very low before 2015 and were characteristic of an oligotrophic system. Figure 2 shows the average levels of chlorophyll a found by SIO in different projects at different times. Over this period, levels in excess of 1.5 mg m^{-3} were very rarely seen, and the average was 0.6±0.82 1.5 mg m^{-3}.

Figure 2. Average chlorophyll-a readings obtained between 1981 and 2018 from water samples using spectrophotometry. Source: prepared by Jesús Mercado, Oceanography Centre of Málaga (SIO) from a variety of sources.



Between 2000 and 2010, changes to levels of chlorophyll a were already being observed that pointed to a risk of eutrophication. It was in the third quarter of 2015, however, that the level of chlorophyll a shot up because of phytoplankton growth, and the water became murky and

green (the so-called Mar Menor eutrophication crisis of 2016). Light ceased to penetrate to the bottom for a long time (over 9 months; Belando et al., 2019), and as a consequence, 85 per cent of the vegetation of Mar Menor (10,843 ha) disappeared, as shown in figure 3.

Figure 3. High-precision map of the communities of benthic macrophytes of Mar Menor, taken before the eutrophication crisis (2014) and after (2016 and 2017). Source: Belando et al. (2019), SIO.

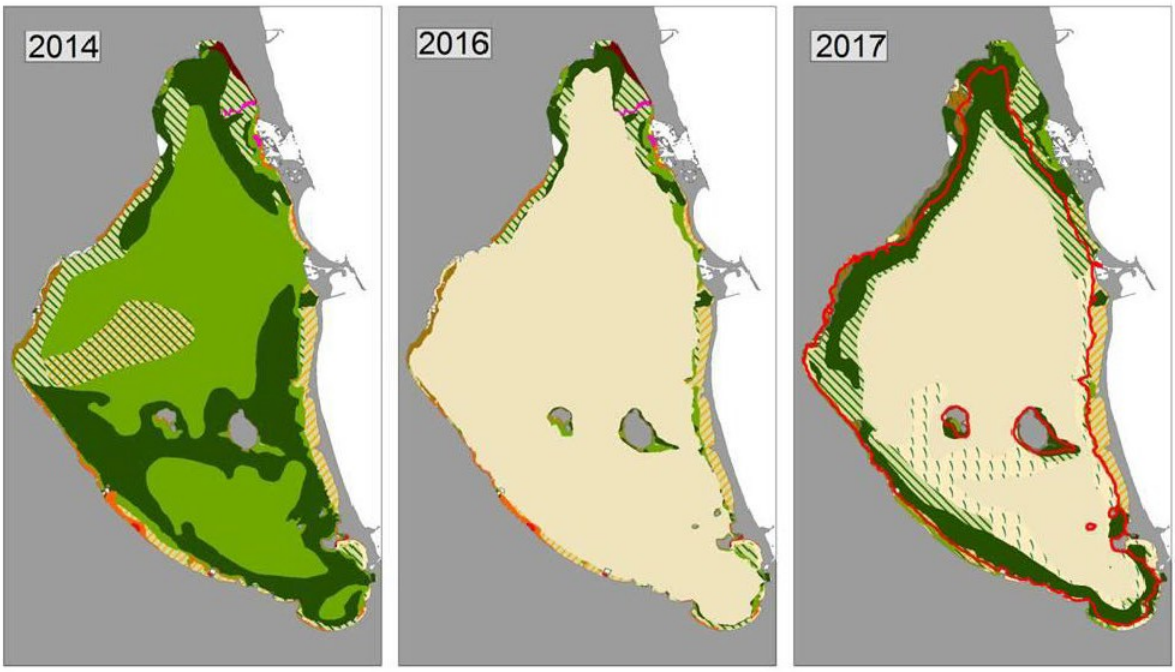
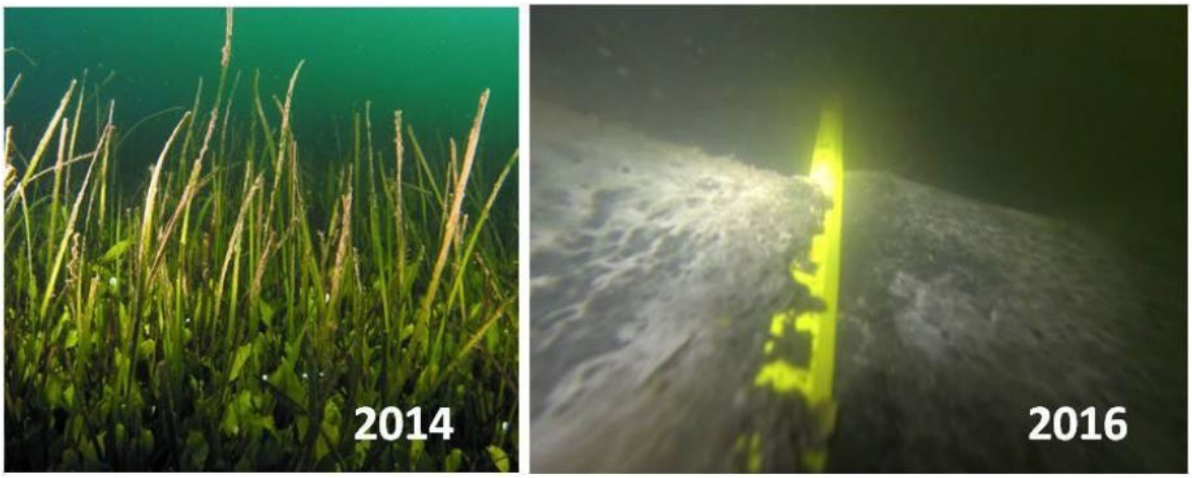


Figure 4 shows the condition of the bottom in 2014, before the massive phytoplankton growth event, completely populated by vegetation, and then its condition in 2016 after the death of the vegetation on the bottom. Both of the images shown in figure 4 were taken in the same location.

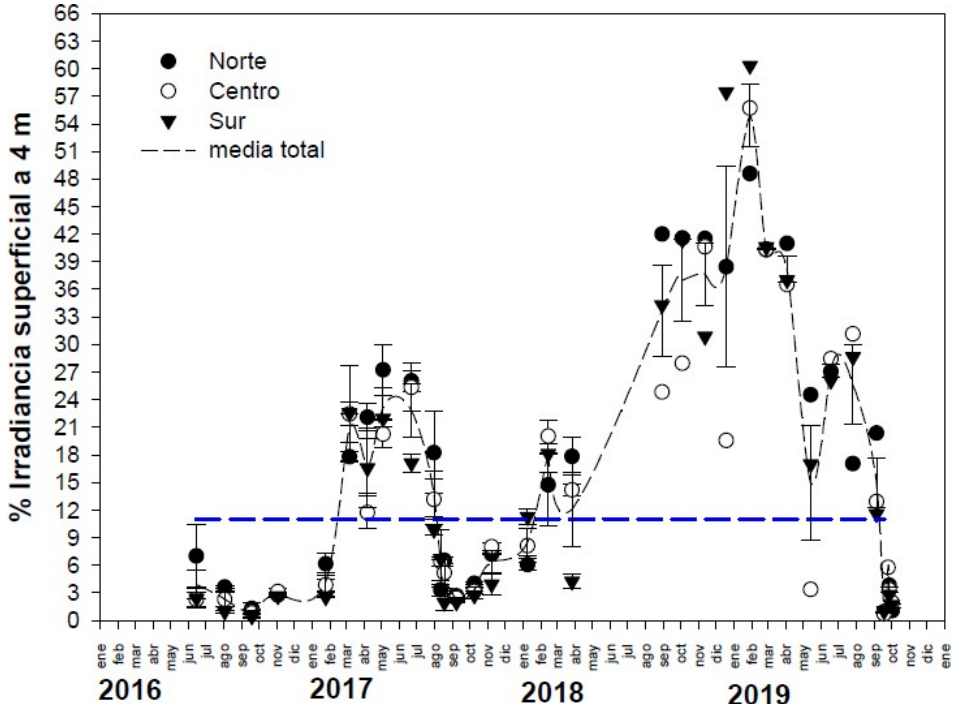
Figure 4. Communities of *cymodocea nodosa* and *caulerpa prolifera* at a depth of 5 m in 2014 (left) and an image of the same place taken during sampling in 2016. Source: Belando et al. (2019), SIO.



This episode consisted of the death and decomposition of huge amounts of vegetable biomass (in the order of 20,000 tons), which in turn contained significant amounts of nitrogen and phosphorus that were re-released into the environment. Furthermore, when the vegetation disappeared, the sediment was exposed, promoting the release of the nutrients stored in the sediment into the water column. The sediment is one of the reservoirs of nutrients and organic matter of the lagoon ecosystem, as recently demonstrated in a study carried out by Álvarez Rogel et al. (2019).

Beginning in 2017, episodes of murky water alternated with episodes of clear water (see figure 5), a situation that enabled chlorophyte *caulerpa prolifera* to regain some of the surface lost in 2016 (38.9 per cent; figure 3).

Figure 5. Amount of light that penetrates to a depth of 4 meters compared with the amount of light at the surface.



Between January and August 2017 and through most of 2018, light levels recovered and exceeded the critical levels required for the growth of benthic vegetation (dotted blue line). Since the beginning of 2019, the waters have shown an almost constant trend towards turbidity and, beginning in the summer of 2019, the levels of light at the bottom decreased to well below the critical level. Source: MMEM Project, SIO.

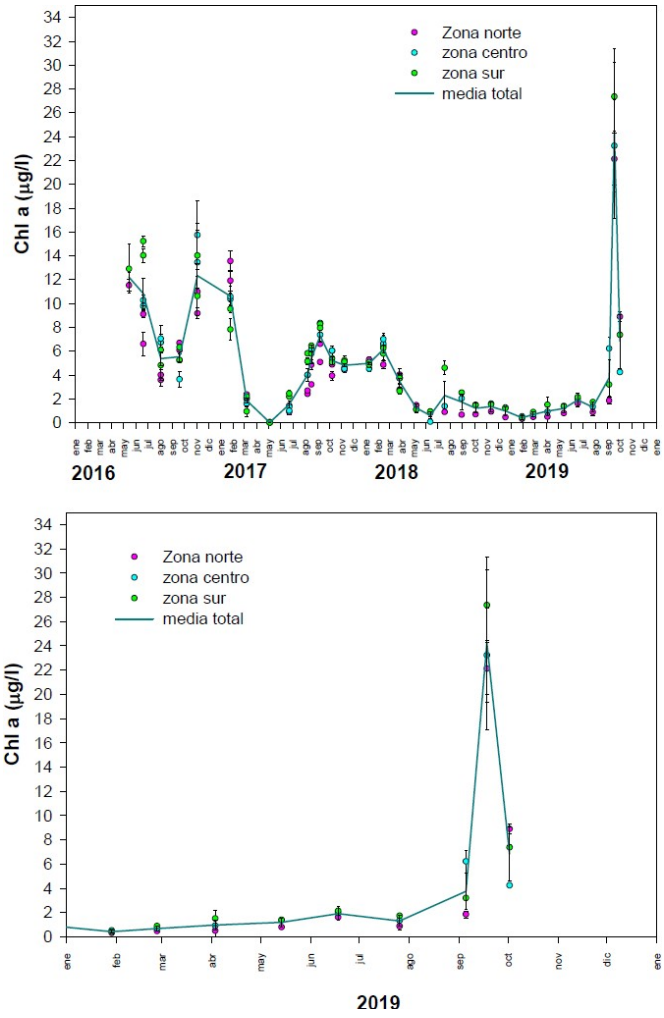
[text from image above]

North
Centre
South
Total average [end of text from image]
Y axis: Percentage of surface irradiance at 4 m
X axis: Year

In 2018, Mar Menor once again reached the levels of transparency that had prevailed before the event in 2016 (figure 5), which in some circles was interpreted as a recovery of the ecological condition of Mar Menor. Nevertheless, some members of the scientific community, including researchers from SIO, the University of Murcia, the University of Alicante, CEBAS-CSIC, the Technical University of Cartagena and our organization, consider that ***the scientific evidence and the actual circumstances do not support a diagnosis of recovery.*** In fact, in 2019 the concentration of chlorophyll in the water column ***increased progressively until it reached levels in the range of those observed in 2015–2016.*** This became obvious at the end of August

2019, just before the extreme precipitation event caused by an isolated depression at high levels, known by its acronym in Spanish as the DANA, as shown in figure 6.

Figure 6. Change in chlorophyll a during the period 2016–2019 (above) and details of changes thereto in 2019 (below). Source: DMMEM Project, SIO.



[text from image above]

Northern area
Central area
Southern area
Total average [end of text from image]

After the DANA, chlorophyll levels surged until they reached levels that were higher than the 2016 maximum levels, which has been attributed to the massive inputs of nitrogen and phosphorus associated with inflows of water and sediment coming from the land, in particular from the farmland around Campo de Cartagena. The chlorophyll levels decreased a few days

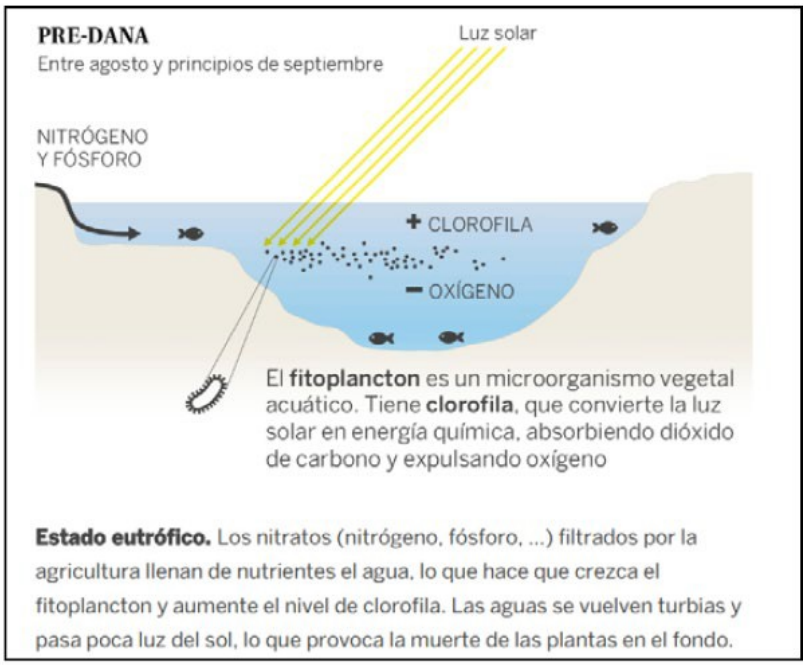
later, and now they have gone up again and are back in the range of the levels that were measured in 2016.

Because of the fresh water brought in by the DANA, the water column became stratified and a superficial layer that was less saline was formed, reducing the atmospheric oxygen transfer towards the deepest parts of the water column. At the same time, the high turbidity of the water drastically decreased the amount of light reaching the bottom of the lagoon (figure 5), preventing the production of oxygen by benthic vegetation through photosynthesis. All of these factors contributed to creating a layer of deep water, beginning at a depth of 3 m, in which the oxygen has been almost completely depleted, causing the death of the living beings that dwell on the bottom of the lagoon and the massive outmigration of organisms of every species towards shallower areas of the lagoon. This episode is described in the attached document: **Interim report on the evolution of the impacts of the DANA on Mar Menor**

On Saturday, 12 October, as a result of the easterly winds, a portion of this ***deep, anoxic layer came to the surface*** at the platform at the extreme northern edge of the lagoon, triggering extreme anoxia and releasing the products of anaerobic metabolic processes that had accumulated in the deep waters, such as dissolved sulphides and hydrogen sulfide gas, which are toxic to many animals and plants. Both the lack of oxygen and the sulphides formed during anaerobic respiration processes would have contributed to the death of all of the fauna present in a broad swath of the northern part of the lagoon.

According to the available data, the anoxic layer at the bottom has become considerably thinner, and oxygen levels are beginning to recover in most of the water column, especially in the central and southern parts of the basin. The northern area is where there is still a residual layer of anoxic water.

The following diagram provides an informative summary of the process described beginning in August 2019, based on the data gathered by SIO and other institutions beginning in August 2019 (source: El País infographic, adapted from information provided by JM Ruiz of SIO):



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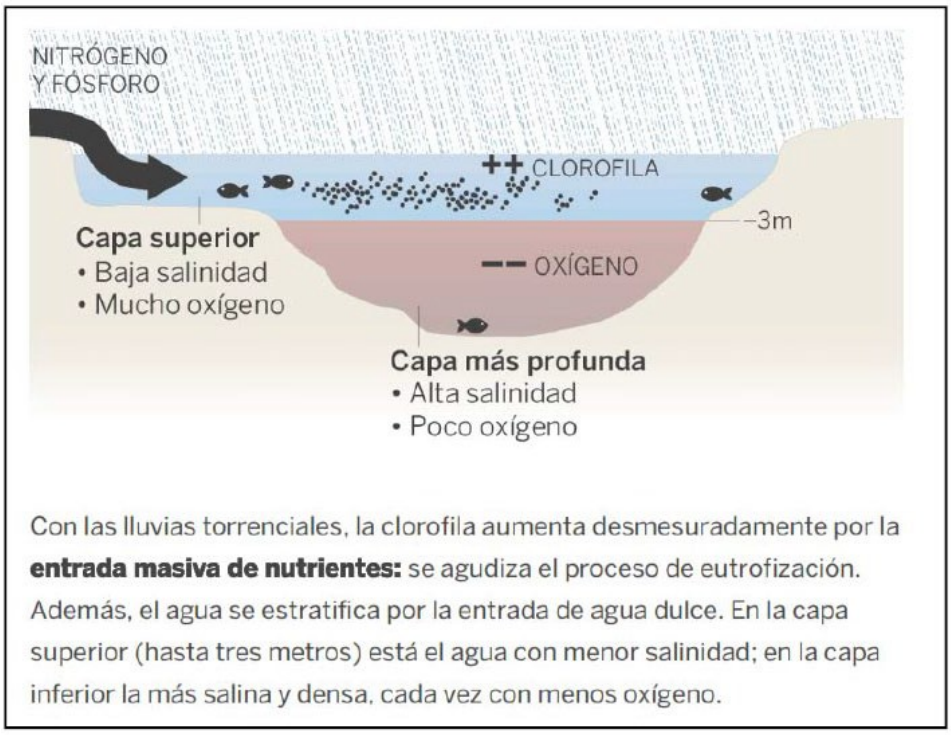
BEFORE DANA

Between August and the beginning of September.
Sunlight
NITROGEN AND PHOSPHORUS
+ CHLOROPHYLL
- OXYGEN

Phytoplankton is an aquatic plant microorganism. It has **chlorophyll**, which converts sunlight into chemical energy, absorbing carbon dioxide and releasing oxygen.

Eutrophic state. Nitrates (nitrogen, phosphorus, etc.) that filter through due to agricultural activity fill the water with nutrients, which causes plankton to grow and increases the level of chlorophyll. The water becomes murky and little sunlight gets through, causing the plants on the bottom to die. [End of text from image]

DANA. From 9 to 14 September:



[text from image above]

NITROGEN AND PHOSPHORUS

++CHLOROPHYLL

--OXYGEN

Upper layer

- Low salinity
- Abundant oxygen

Deeper layer

- High salinity
- Little oxygen

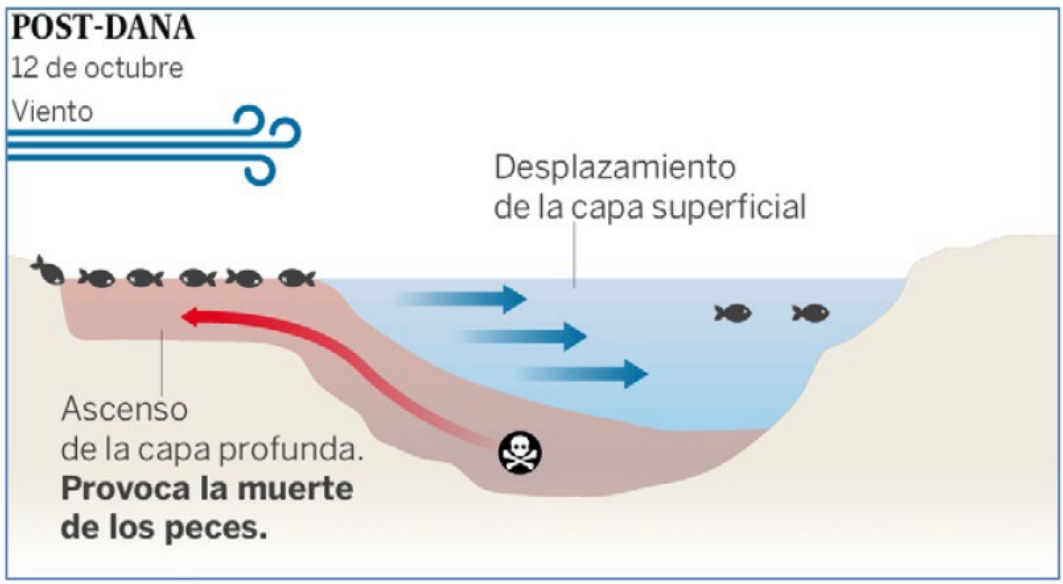
With the torrential rain, chlorophyll levels shoot up because of the **massive inflow of nutrients**: the process of eutrophication intensifies. In addition, the water stratifies because of the fresh water that flows into the lagoon. In the upper layer (down to a depth of 3 m), the water is less saline; in the lower layer, the water is denser with high salinity levels and an ever-decreasing oxygen content. [End of text from image]

AFTER DANA

[text from image above]

End of September – beginning of October

Over two or three weeks, the anticyclonic weather conditions are very stable. **In the lower layer, organisms die because they lack oxygen** and fish and crustaceans flee to the upper layer. Toxic compounds, sulphides for example, become increasingly concentrated on the bottom as well, the result of anaerobic metabolic processes. [End of text from image]



[text from image above]

AFTER DANA

12 October

Wind

The upper layer shifts

The lower layer rises up.

This causes the fish to die. [End of text from image]

The wind moves the water from the shoreline towards the centre of the lagoon, allowing the **anoxic layer** that had remained on the bottom **to rise to the top**. This layer of water lacking in oxygen and containing sulphides is what **kills all of the fish and crustaceans** that it touches, which had taken refuge in the upper layer.

Causes of the ecological crisis of Mar Menor

Since the 1980s, Mar Menor has been receiving large quantities of **nutrients coming mainly from the agricultural activity in Campo de Cartagena**, where the irrigated surface area in the basin increased between 1988 and 2009 from 21,150 ha to more than 55,000 ha, according to studies performed using remote sensing. The shift towards the use of irrigation has continued since 2009. The continuous inflow of these nutrients is considered a crucial factor in triggering the eutrophication crisis of 2016. The mass death of benthic vegetation constitutes a massive contribution of organic matter and nutrients to the bottom of the lagoon, which causes a spike in microbial activity in the sediment and causes it to become largely anoxic. This is how nutrients released by the sediment itself (especially phosphorous and ammonia), due to the process of mineralization of the accumulated organic matter, are added to the external inputs of nutrients ***from the basin*** that are received by the water column. This problem worsens with acute episodes of inflow, especially from the DANA in September.

The profound degradation of Mar Menor was caused by the process of eutrophication due to excess nutrients, degradation that already existed before the DANA and that was worsened by the nutrients flushed out by the DANA: preliminary estimates based on samples gathered during the event show that between 35 and 60 tons of nitrates, 25 and 45 tons of ammonia and more than 100 tons of phosphates entered its waters. Therefore, the problem cannot be attributed solely to the fresh water that has washed into the lagoon (promoting the anoxification of the bottom; this was the cause of the latest mass mortality event of marine organisms); rather, the problem is the result of what was carried into the lagoon with that water, which is the "fuel" for the process of eutrophication and which joins the organic matter and nutrients that have accumulated over decades in the marine sediment and subterranean waters. In fact, as recalled by Asociación Meteorológica del Sureste (the meteorological association of the southeast), rain-gauge data shows that the accumulated precipitation during

the flood of November 1987 was one third more than the precipitation that fell during this year's DANA, in spite of which there were no mass mortality events in the lagoon at the time or during many other historic flooding events. Testimony from local fishermen confirms that the water turbidity caused by the surge of 1987 had disappeared within approximately one week. The DANA and the easterly winds caused this mass of deep water to come to the surface in the northern part of the lagoon, causing a mass die-off of many species, probably because of the toxic product of anaerobic decomposition. This type of severe event could recur. **Eutrophication has caused a profound and increasingly chronic decline in Mar Menor and has made the lagoon critically vulnerable to factors that are many and varied (the DANA is not the only example), which at any moment could trigger acute die-off episodes.**

The recovery of Mar Menor will be a ***long and very complex*** process, because even if no more nutrients enter the basin, the release of nutrients from internal reservoirs (i.e. sediment, subterranean water) could continue for quite some time, and the timeline for the reversal of nutrient levels remains unknown, even if all existing input ceases now (years or decades).

Therefore, the first step to recovery for the ecosystem is to halt the flow of nutrients using prevention measures at the source, to enable the basin to retain and eliminate the nutrients itself through a variety of nature-based measures, including the restoration of natural wetland areas around the lagoon and the creation of artificial wetlands or other systems that are capable of holding back and purifying the run-off and effluent generated in the region. Wetlands are also the only systems capable of holding back and eliminating a good part of the nutrients that accumulate when flooding occurs, which will be ever more frequent due to climate change. In that sense, the measures prioritized in Proyecto Vertido Cero should be reviewed, as their main actions are oriented along other lines.

Madrid, 28 October 2019

Spanish Institute of Oceanography

MINISTERIO
DE CIENCIA, INNOVACIÓN
Y UNIVERSIDADES

INSTITUTO ESPAÑOL
DE OCEANOGRAFÍA

ANNEX

Interim report on the evolution of the impacts of the DANA on Mar Menor

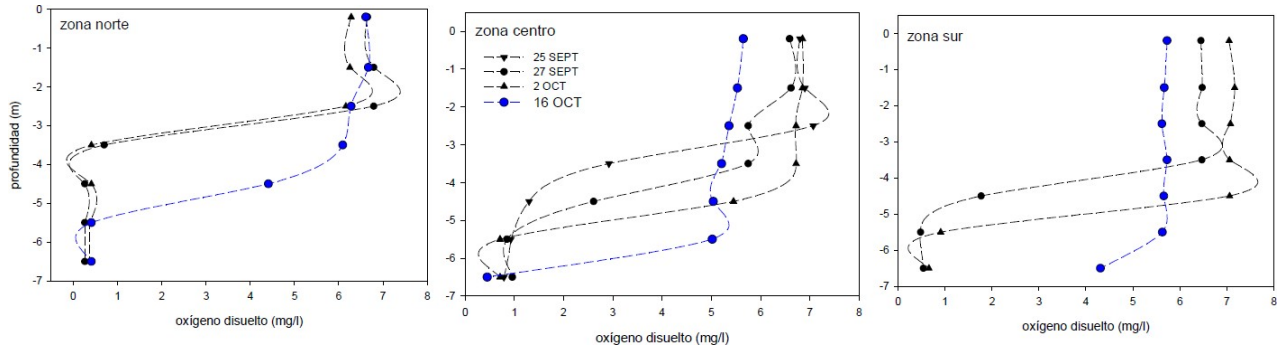
A summary is provided of the results of a series of samples taken on 25 and 27 September and on 2 and 16 October to evaluate the effects of the inflows of fresh water to Mar Menor after the DANA. Average values have been determined for temperature, salinity, dissolved oxygen, pH, chlorophyll a, PAR irradiance, turbidity and particulate matter (total organic and inorganic: not shown in this report, to be provided soon) at the stations in the lagoon used by SIO for monthly monitoring, as shown in the following figure:

Figure 1: Location of the monitoring stations of IEO in the northern area (A), the central area (B) and the southern area (C).

Stratification of the water column and anoxia

In the following figures, average values for temperature, salinity, pH and oxygen are shown along the bathymetric gradient.

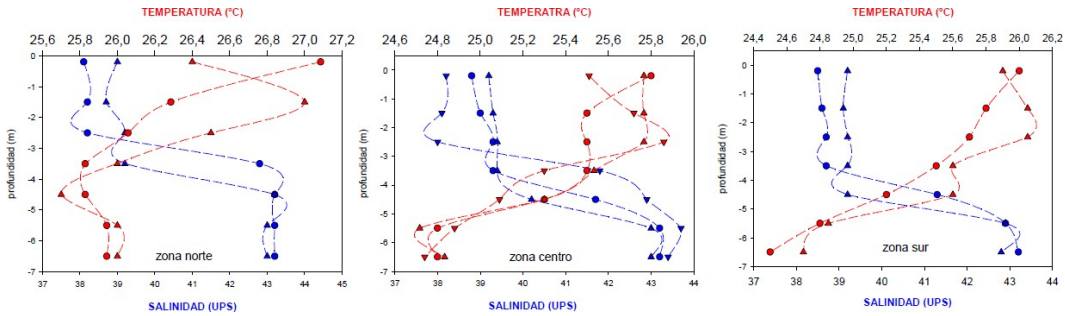
Figure 2. Vertical profile of dissolved oxygen on 25 September (inverted triangles), 27 September (circles), 2 October (triangles) and 16 October (blue circles).



[text inside figure 2 image]

Northern area	Central area	Southern area
Y axis: Depth (m)		
X axis: Dissolved oxygen (mg/l)		

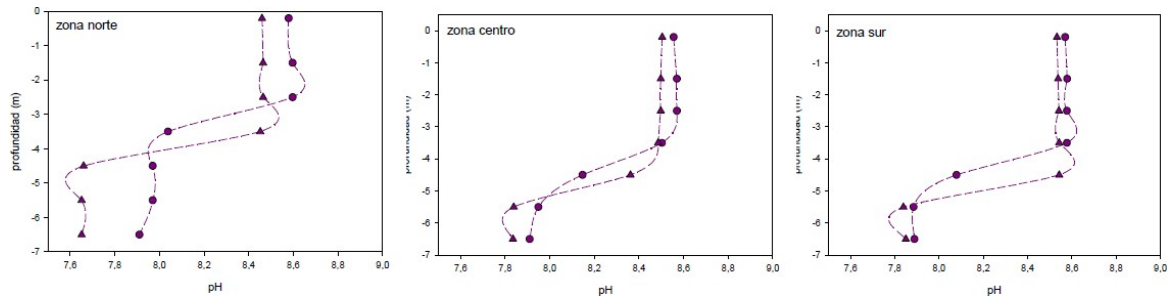
Figure 3. Vertical profile for temperature and salinity on 25 September (inverted triangles), 27 September (circles) and 2 October (triangles).



[text inside figure 3 image]

TEMPERATURE (Celsius) Y axis:
Depth (m)
X axis: Salinity (UPS)

Figure 4. Vertical profile for pH on 25 September (inverted triangles), 27 September (circles) and 2 October (triangles).



[text inside figure 4 image]

Northern area	Central area	Southern area
Y axis: Depth (m)		
X axis: pH		

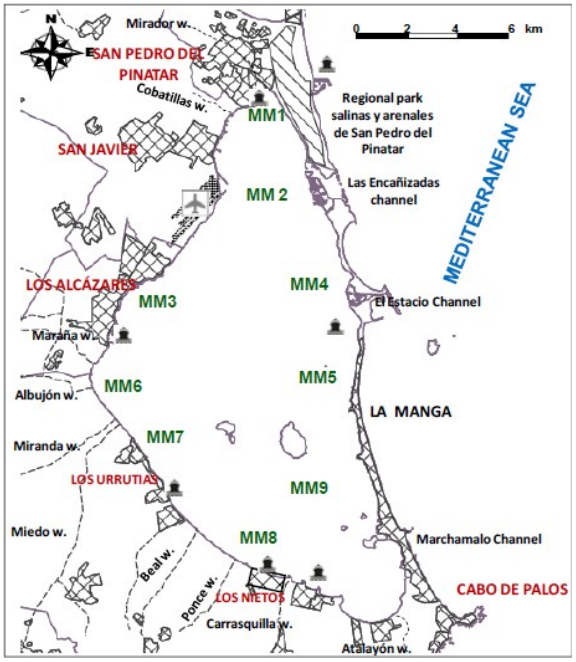
As found in this and other data (Servicio de Pesca y Acuicultura, Consejo Administrativo de la Región de Murcia [fishing and aquaculture service of the regional government of Murcia]), there is a clear vertical stratification, which, when it began the beginning (25 September) was differentiated into a superficial layer (0–3 m) with lower salinity (38-39 ups) that is also 1.2 degrees warmer, and another layer underneath it (3-6.5 m) with markedly higher salinity, around 43 ups. Obviously, the first layer corresponds to the mixture of continental water with the surface water of Mar Menor, and the second corresponds to the mass of saline water that predates the run-off from the flood, which has only mixed in a little. Most significantly, the especially severe anoxia is in this deep layer, with average figures for oxygen that are lower than 2 mg/l, the critical threshold after which sub-lethal and lethal effects are seen in most benthic and demersal marine species. A reduction of seven tenths of 1 pH has been observed when comparing the water on the bottom with the surface water, meaning that the bottom is more acidic.

The atmospheric conditions during the period in which this sampling took place and the lack of water exchange with the Mediterranean have stabilized the stratification of the water column, also therefore stabilizing the effects of the anoxia on the bottom of the lagoon from a depth of 3 m down. However, as the observation period advances, a reduction in the thickness of the deeply anoxic layer of water has been noted, while the surface layer has become thicker, especially in the central and southern regions. On 16 October, this trend towards the dissolution of the anoxic layer was confirmed as was the recovery of the oxygen levels in the upper area (see figure 2).

Sampling carried out by the pollution team of SIO in Murcia on 17 and 18 October, in a broader network of stations for the PLAS-MED Project (figure 4), confirmed the aforementioned findings. The data yielded by this sampling also demonstrate the low redox potential of the sediment,

which indicates that it is severely anoxic. These levels of anoxia are significantly lower than those obtained during previous sampling, before the DANA (around -200 mV).

Figure 4. Distribution of the sampling stations for the PLAS-MED Project. Table of average values for dissolved oxygen in the water column and for sediment redox potential on 17 and 18 October 2019. Source: SIO Pollution and Biological Effects Team, Oceanographic Centre of Murcia.



Estacion	Oxxigeno disuelto (mg/L) superficie	fondo	Eh sedimento mV
MM1	6,7	6,7	-422
MM2	7,01	4,24	-419
MM3	4,75	4,28	-356
MM4	3,82	3,58	-417
MM5	3,56	3,67	-426
MM6	8,15	7,28	-131
MM7	6,38	6,42	-135
MM8	7,53	7,33	-303
MM9	6,19	5,72	-422

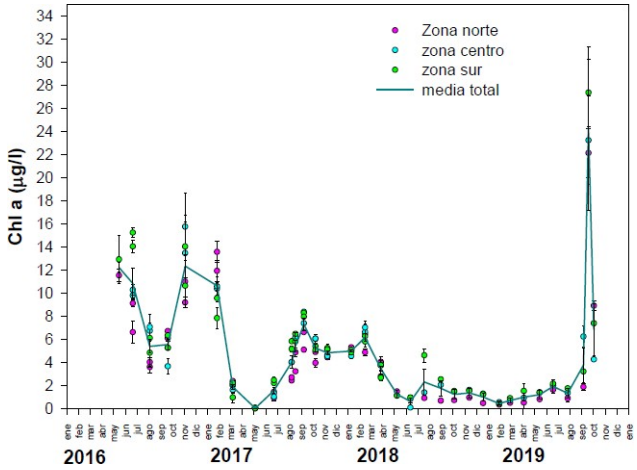
Station	Dissolved oxygen (mg/L) Surface	Bottom	Sediment EH mV

Figure 4. Distribution of the sampling stations for the PLAS-MED project. Table of average values for dissolved oxygen in the water column and redox potential of sediment on 17 and 18 October 2019. Source: Pollution and Biological Effects Team of SIO, Oceanographic Centre of Murcia.

Chlorophyll a

Figures 5 and 6 show the time series of this variable since 2016.

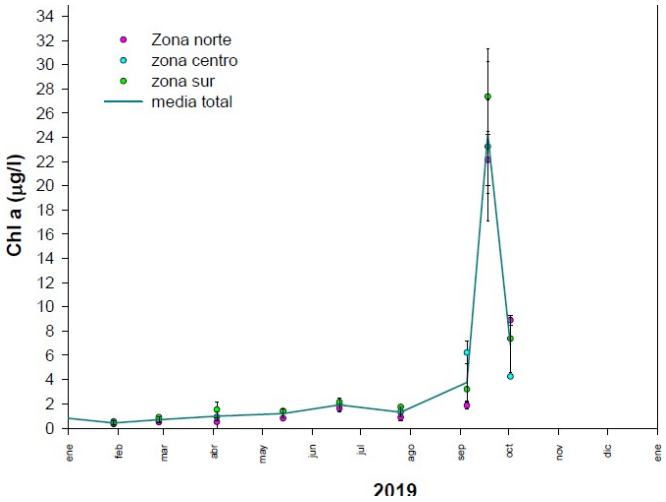
Figure 5. Change in the amount of chlorophyll a in Mar Menor since 2016. Method used: spectrophotometry



Northern region
Central region
Southern region Total average

Y axis: Chl a (µg/L)
X axis: year

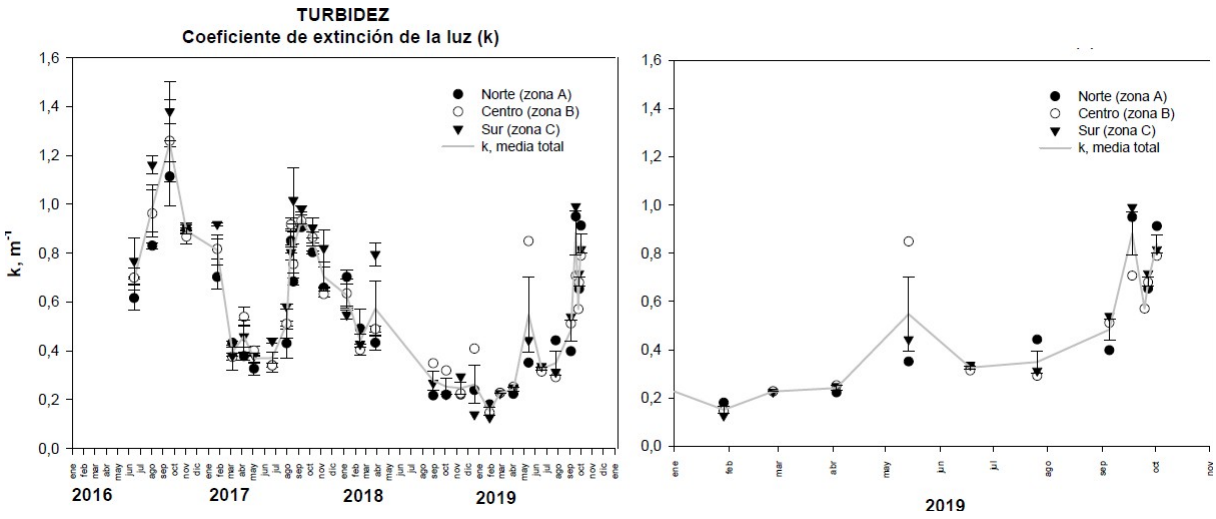
Figure 6. Details of the change in the amount of chlorophyll a (chl a) in Mar Menor in 2019



The levels that were reached after the DANA varied on average between 22 and 27 µg/L of chl a, and were visibly higher than the average values in autumn 2016 (8-20 µg/L of chl a) (Fig. 6). According to data from Fisheries Services, these values decreased considerably within a few days, and according to our data, until 2 October, average values were between 4 and 8 µg/L of chl a, with the highest values corresponding to the northern and southern areas (figure 7). These numbers are very similar to the figures already being recorded in Mar Menor **before** the DANA (figure 7), in keeping with an

increasing and almost constant trend since February. Sampling done on 16 October yielded values that were between 10 and 30 µg/l of chl a.

Figure 7. Change in the light extinction coefficient between 2016 (left) and 2019 (right).



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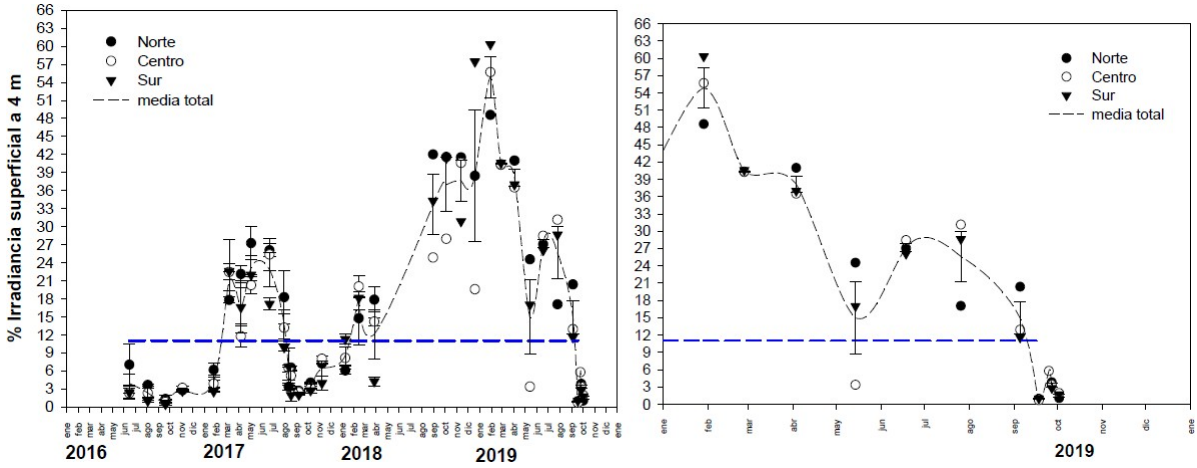
TURBIDITY
Light extinction coefficient (k)
North (Zone A)
Centre (Zone B)
South (Zone C)
Total average

PAR irradiance and turbidity

Figure 7 shows the change in the average values of the light extinction coefficient (k, m^{-1}) or turbidity obtained from vertical irradiance PAR profiles by measuring with the LiCor LI192 submersible light sensor. Figure 8 shows the average values of PAR irradiance that reaches the bottom (4 m), expressed as a percentage of the total amount of light that travels through the surface of the water (%I_0).

Figure 8. Change in the percentage of PAR irradiance that reaches the bottom compared to the amount measured at the surface between 2016 (left) and 2019 (right). The dotted blue line indicates 10 per cent I_0, which is the critical level for benthic macrophytes.



[text inside figure 8 image]

North

Centre

South

Total average

Y axis: Percentage of surface irradiance at 4 m

X axis: Year

After the DANA, the turbidity of Mar Menor increased significantly to average values of between 0.7 and 0.99 m^{-1}, levels that are lower than those recorded in 2016 during the extreme eutrophication event (up to 1.37 m^{-1}). Although with some variation, these values held steady until 2 October, at a level somewhat above the level recorded in Mar Menor before the DANA. During the period prior to the DANA, turbidity increased almost continuously from February 2019 on, just as chlorophyll had. In terms of PAR irradiance, the same trend is much clearer, and by May, levels close to the critical level for benthic vegetation had already been reached. After the DANA, these values tumble down to extremely low average values (1–2 per cent I_0), well below the requirements for the activity and survival of marine vegetation and very similar to the numbers recorded during episodes of phytoplankton growth in 2016 and 2017.

Comments on flora and fauna

Scuba divers who dove down to the sampling stations and other areas of Mar Menor beginning on 25 September found that a mass mortality event had affected the majority of species and communities on the bottom of the lagoon in areas located at depths of 3–4 m or more, depending on the part of the lagoon. A bathymetric survey of the lagoon proves that this represents an area and a volume in the order of 80 per cent of the lagoon.

In most areas, *caulerpa prolifera* was dead or dying (measurements of chlorophyll fluorescence taken to evaluate photosynthesis confirm this) and sea cucumbers were dead and disembowelled. Numerous specimens of gastropods of the genus *hexaplex* were still alive and active. At the beginning, the bivalves appeared to be weakened, but in later dives all had died and were open, displaying their dead bodies that had not yet begun to decompose; some gobies were also seen alive during the first dives, among them *pomatoschistus*, but during the final visits there were no longer any alive, although their dead bodies could be seen; anemones and tube polychaetes that had apparently been alive at first were all found dead a few days later.

In the shallowest areas, massive concentrations of shrimp and fish were observed (especially gobies and blennies, but also juvenile *symphodus*, *syngnathus* and others), not only in areas adjacent to the coastline, but also in areas far away in the middle of the lagoon, swimming erratically and slowly in the first two meters of water, something completely unusual and out of place.

All these observations are gathered in geo-referenced videos that can be requested and viewed by anyone.

According to the specialized literature, both the stunning and disorientation are symptoms of the stress typically caused by lack of oxygen, which drives organisms that are able to escape to seek out oxygenated areas. Those that cannot escape within a given time period end up dying, especially where concentrations are lower than 2 mg/L and depending on the species. Therefore, the severe anoxia described above can be considered one of the main causes of the lethal and sub-lethal effects described and observed by scientists and citizens in many parts of the lagoon.

Mass mortality event of 12 October 2019

In the early morning of 12 October, the waters in the northern part of Mar Menor were grey and milky and there was a strong odour of rot. Measurements taken on 12 and 13 October by SIO confirmed that the waters were completely anoxic (values below 1 mg/L) and had negative redox potential (-200 to -400 mV). These characteristics and other data obtained in the area over the same period by other organizations (Polytechnic University of Cartagena and Servicio de Pesca y Acuicultura) indicated that the waters were very anoxic, with elevated concentrations of sulphides, meaning that they were highly toxic to marine life.

In fact, in the area, thousands of dead animals of all species and sizes were found on the beaches in the morning, an unprecedented event in Mar Menor.

All of the data pointed to the water from the deep, anoxic layer in the northern region of Mar Menor having risen up, probably pushed by the north-easterly winds that had appeared the day before. Because of the characteristics of the water and the vastness of the area covered by the mass of greyish, anoxic water (which could easily be differentiated by the naked eye), the
possibility that some substance had been dumped locally was not considered, and that was confirmed by the data provided by the technicians of local and regional governments.

Preliminary conclusions

- The stratification of the water column was quite stable for about four weeks, leading to almost all of oxygen in the deepest areas of Mar Menor being exhausted beginning at the isobath of 3–4 m, which implies that the phenomenon affected a breadth (and volume) that was very significant, on the order of 80 per cent.

- This episode of extremely severe and protracted anoxia is the main cause of death of almost all the benthic communities below a depth of 3–4 m, and of the mass migrations of some demersal species, whose most extreme and severe expression was observed on 12 October because of the deep waters rising up to the superficial areas in the extreme north of the lagoon.

- There is now a clear trend toward the thinning of the deep, anoxic layer, and it is now relegated to an expanse in the northern region. Currently, the oxygen levels in the lagoon have been re-established, although phytoplankton biomass is in a phase of robust growth, as indicated by recent data (up to 16 October).

- The effects of the phytoplankton growth and turbidity on the availability of light for macrophyte communities are critical, and if those effects persist, the surface area occupied by macrophytes could recede once again.

- The DANA has noticeably worsened the state of the ecology of Mar Menor and is responsible for the mass mortality event of marine organisms, but before that episode, a very clear trend towards a new episode of eutrophication had already been recorded, and that is the real cause of the deterioration of Mar Menor.

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