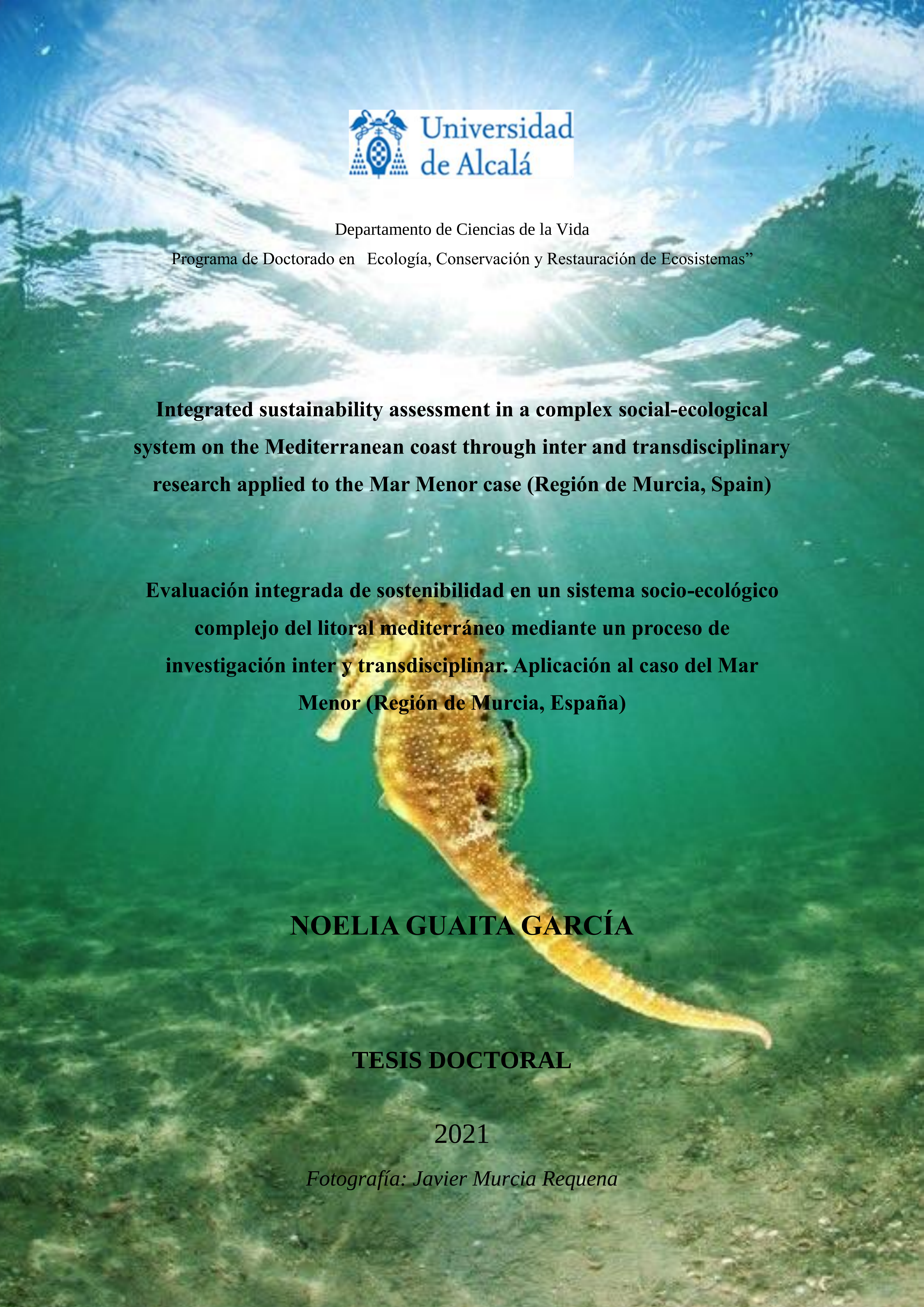

Departamento de Ciencias de la Vida

Programa de Doctorado en Ecología, Conservación y Restauración de Ecosistemas”

Integrated sustainability assessment in a complex social-ecological system on the Mediterranean coast through inter and transdisciplinary research applied to the Mar Menor case (Región de Murcia, Spain)

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NOELIA GUAITA GARCÍA

TESIS DOCTORAL

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Fotografía: Javier Murcia Requena

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Tesis doctoral presentada por:

NOELIA GUAITA GARCÍA

Directora:

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Co-director:

Dr. H. Carl Fitz

Tutor:

Dr. Antonio Gómez Sal

Alcalá de Henares, 2021

Dña. **Julia Martínez Fernández**, Doctora en Biología por la Universidad de Murcia y Directora Técnica de la Fundación Nueva Cultura del Agua,

INFORMA que la Tesis Doctoral titulada "Evaluación integrada de sostenibilidad en un sistema socio-ecológico complejo del litoral mediterráneo mediante un proceso de investigación inter y transdisciplinar. Aplicación al caso del Mar Menor (Región de Murcia, España)" ha sido realizada por Dña. **Noelia Guaita García** bajo su dirección y asesoramiento, y reúne todos los requisitos científicos de originalidad y rigor metodológicos para proceder a la lectura y defensa pública ante un tribunal.

Alcalá de Henares, 15 de abril de 2021

Julia Martínez

Dra. Julia Martínez Fernández

DIRECTORA DE LA TESIS

Universidad de Alcalá

D. **H. Carl Fitz**, Doctor en Ecología por la Universidad de Georgia (USA) y Profesor asistente en la University of South Florida (USA),

INFORMA que la Tesis Doctoral titulada "Integrated sustainability assessment in a complex social-ecological system on the Mediterranean coast through inter and transdisciplinary research applied to the Mar Menor case (Región de Murcia, Spain)" ha sido realizada por Dña. **Noelia Guaita García** bajo su co-dirección y asesoramiento, y reúne todos los requisitos científicos de originalidad y rigor metodológicos para proceder a la lectura y defensa pública ante un tribunal.

Alcalá de Henares, 22 de abril de 2021

Dr. H. Carl Fitz
CO-DIRECTOR DE LA TESIS

Universidad de Alcalá

En mi calidad de **Tutor** de la presente Tesis Doctoral, tengo el gusto de **INFORMAR**, que la memoria elaborada por Dña. **Noelia Guaita García** para optar al título de Doctor, dentro del Programa de Doctorado en "Ecología, Conservación y Restauración de Ecosistemas" y titulada *"Evaluación integrada de sostenibilidad en un sistema socio-ecológico complejo del litoral mediterráneo mediante un proceso de investigación inter y transdisciplinar. Aplicación al caso del Mar Menor (Región de Murcia, España)"*, reúne los aspectos formales, metodológicos, contenidos y requisitos de calidad necesarios para su presentación y defensa como tesis doctoral en la Universidad de Alcalá.

En Alcalá de Henares, 25 abril de 2021

Antonio Gómez Sal
Catedrático de Ecología

A mi familia, con todo mi amor

“Caminante, son tus huellas
el camino y nada más;
Caminante, no hay camino,
se hace camino al andar.
Al andar se hace el camino,
y al volver la vista atrás
se ve la senda que nunca
se ha de volver a pisar.
Caminante no hay camino
sino estelas en la mar”.
Antonio Machado

Agradecimientos

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ÍNDICE

Resumen

El objetivo general de esta tesis es analizar y evaluar la sostenibilidad en el sistema socio-ecológico del Mar Menor (SSEMM) (SE, España) mediante un enfoque metodológico integral, sistémico y participativo, para atender las problemáticas que lo amenazan, apoyar los procesos de toma de decisión y contribuir en su gestión y transición hacia la sostenibilidad.

Con esta finalidad se desarrolló un modelo cualitativo integral e interdisciplinar, como base para elaborar un diagnóstico sintético del SSEMM. Este modelo contribuyó a comprender las interrelaciones ambientales y socioecológicas que afectan al estado de este sistema socioecológico, lo que facilita una visión global de su problemática a la comunidad local y a los distintos actores implicados. Para completar este diagnóstico con una óptica de trabajo transdisciplinar se realizó una encuesta a la comunidad local y se llevaron a cabo entrevistas a los actores implicados en el SSEMM, con el fin de conocer sus valoraciones y preferencias. Distintos análisis estadísticos de los resultados obtenidos arrojaron luz sobre sus percepciones en relación a las presiones y los impactos de los principales cambios de uso del suelo (intensificación agraria de la cuenca y desarrollo urbano-turístico del entorno del Mar Menor) y las posibles medidas a adoptar para mejorar la situación actual de degradación ambiental y específicamente para recuperar el estado ecológico de la laguna del Mar Menor. Fruto de este trabajo inter y transdisciplinar, se definieron los objetivos específicos de sostenibilidad para el SSEMM y se desarrolló un sistema de indicadores en base a un enfoque sistémico, en el que participaron un conjunto de expertos de distintas disciplinas. El sistema de indicadores y sus resultados constituye una herramienta de interés para la evaluación de los avances y retrocesos hacia los objetivos definidos y para actualizar el diagnóstico de la sostenibilidad del Mar Menor, realizando un seguimiento en el tiempo a través de dicho sistema de indicadores.

Posteriormente, tras la realización del diagnóstico, se propuso entender la configuración de la gobernanza en el SSEMM y analizar las respuestas o soluciones propuestas públicamente por los grupos de actores implicados en su gestión. Este trabajo contribuyó a conocer las condiciones de la gobernanza actual y a identificar los retos a los que se enfrenta la gobernanza ambiental en el SSEMM.

Los resultados de esta tesis revelan que el SSEMM se sitúa en un momento avanzado de la fase de aceptación y formulación de un consenso en el diagnóstico del problema y sus causas (fase aún no culminada), pero todavía existe desacuerdo en torno a las medidas de gestión a aplicar. Tanto la comunidad local encuestada, como los actores y expertos entrevistados coinciden con el diagnóstico que la comunidad científica ha venido realizando en las últimas décadas. Estos grupos

perciben una crisis ecológica, apuntando a la agricultura como la causa principal del deterioro de la laguna del Mar Menor. Esta crisis, a su vez, acarrea impactos sociales y económicos importantes para la población del SSEMM, en cuanto a pérdida de calidad de vida y disminución progresiva de oportunidades socioeconómicas ligadas a la menor funcionalidad del propio sistema. El problema es fundamentalmente de gestión, de gobernabilidad del SSEMM, con políticas poco eficaces, eficientes y coherentes y formas de hacer política poco informadas, participadas y transparentes, lo que ha conducido a la situación actual en la que se encuentra el SSEMM.

Estos resultados permiten concluir que para hacer frente a la situación de degradación ambiental del SSEMM es necesario un enfoque más integrador que tenga en cuenta la complejidad del sistema, la pluralidad del conocimiento y la participación activa de la ciudadanía, como esta tesis propone. En este sentido, se espera que los resultados de esta tesis sirvan de apoyo en los procesos de toma de decisiones que se lleven a cabo en un futuro en el SSEMM, contribuyendo así a su transición hacia la sostenibilidad.

Palabras clave: Sistema socio-ecológico, sostenibilidad, participación pública, indicadores, gobernanza ambiental, enfoque integral, Mar Menor.

Abstract

The general objective of this thesis is to analyze and evaluate the sustainability in the socio-ecological system of the Mar Menor (SESMM) (SE, Spain) through an integral, systemic and participatory methodological approach, to address the problems that threaten it, support the decision-making processes and contribute to its management and transition towards sustainability.

For this purpose, an integral and interdisciplinary qualitative model was developed, as a basis for preparing a synthetic diagnosis of the SESMM. This model contributed to understand the environmental and socio-ecological interrelationships that affect the state of this socio-ecological system, which facilitates a global vision of its problems for the local community and the different stakeholders involved. To complete this diagnosis with a transdisciplinary work perspective, a survey was carried out with the local community and interviews were carried out with the stakeholders involved in the SESMM, in order to know their evaluations and preferences. Different statistical analyzes of the results showed their perceptions in relation to the pressures and impacts of the main land use changes (agrarian intensification in the sub-basin and urban-tourist development around of the Mar Menor) and pointed to the possible measures to be taken to improve the current situation of environmental degradation and, specifically, to recover the ecological status of the Mar Menor lagoon. As a result of this inter and transdisciplinary work, the specific sustainability objectives for the SESMM were defined and a system of indicators was developed based on a systemic approach, in which a group of experts from different disciplines participated. The system of indicators and its results is a useful tool for evaluating progress and setbacks towards the defined objectives and for updating the diagnosis of the sustainability of the Mar Menor, monitoring over time through the system of indicators.

Subsequently, after conducting the diagnosis, it was proposed to understand the configuration of governance in the SESMM and analyze the responses or solutions publicly proposed by the groups of stakeholders involved in its management. This work contributed to understanding the current governance conditions and identifying the challenges faced by environmental governance in the SESMM.

The results of this thesis reveal that the SESMM is at an advanced stage in the phase of acceptance and formulation of a consensus in the diagnosis of the problem and its causes (phase not yet completed), but there is still disagreement regarding the measures of management to apply. Both the local community surveyed, as well as the stakeholders and experts interviewed, coincide with the diagnosis that the scientific community has been making in recent decades. These groups perceive an ecological crisis, pointing to agriculture as the main cause of the deterioration of the Mar Menor lagoon. This crisis, in turn, has important social and economic impacts for the population of the SESMM, in terms of loss of quality of life and progressive decrease in socioeconomic opportunities linked to the lower functionality of the system. The problem is fundamentally of management, of governance of the SESMM, with ineffective, inefficient and incoherent policies and ways of doing politics that are poorly informed, with poor participation and transparency, which has led to the current situation in the SESMM.

These results allow the conclusions of this thesis, that to face the situation of environmental degradation of the SESMM, it is necessary to have a more integrative approach that takes into account the complexity of the system, the plurality of knowledge and the active participation of citizens. In this sense, it is expected that the results of this thesis serve as support in the decision-making processes that are carried out in the future in the SESMM, and thus contribute to its transition towards sustainability.

Keywords: Socio-ecological system, sustainability, public participation, indicators, environmental governance, integral approach, Mar Menor.

INTRODUCCIÓN, MARCO TEÓRICO Y METODOLÓGICO

Capítulo 1.

Introducción

Caballito de hocico largo adulto (*Hippocampus guttulatus*)

Adult seahorse (*Hippocampus guttulatus*)

Fotografía: Javier Murcia Requena

1. Introducción

1.1. Presentación

Ante el significativo y acelerado proceso de cambio global en el que nos encontramos inmersos, el análisis de los sistemas socio-ecológicos (SSE) es de vital importancia para entender las relaciones e interacciones entre la sociedad y los ecosistemas (Ojima et al. 1994; Hurtt et al. 2011). La necesidad de integrar las ciencias sociales y biofísicas para la identificación de problemas y posibles soluciones futuras para un desarrollo sostenible ha sido ampliamente reconocida (Binder et al. 2013; Fischer et al. 2015).

Aunque cada vez es mayor el conocimiento de las interdependencias de las dimensiones social, económica y ambiental, en la práctica estas dimensiones han sido generalmente tratadas de modo independiente en la gestión de los SSE, lo que ha dado lugar a la aplicación de políticas y medidas inadecuadas. Las dimensiones de la sostenibilidad han de ser consideradas en un enfoque integral ya que los enfoques sectoriales, tradicionalmente usados para la gestión de los SSE, no han dado buenos resultados en términos de sostenibilidad (Bell y Morse 1999; Mirchi et al. 2012).

La revisión de la literatura científica sobre el análisis y gestión de los SSE recoge cómo la complejidad de los procesos de planificación, así como los acelerados cambios ambientales, requieren una evaluación permanente y participativa en la gestión (Xue et al, 2015; Megdal et al, 2017; Sterling et al. 2017). Esta evaluación exige valorar la sostenibilidad del SSE y el estado de la calidad de vida de quienes los habitan. Desde la Cumbre mundial de la Tierra celebrada en Brasil en 1992 han surgido diferentes herramientas y enfoques metodológicos para evaluar la sostenibilidad a nivel mundial y en concreto en los SSE (Saldivar et al. 2002; Gallopín 2006; Böhringer & Jochem 2007; Singh et al. 2009, 2012).

Los indicadores de sostenibilidad son, por ejemplo, una herramienta que permite reducir la complejidad de los procesos que representan, facilitando la elaboración de diagnósticos y su seguimiento en el tiempo, la comunicación con el conjunto de actores y partes interesadas y la utilización del mejor conocimiento disponible como base para la toma de decisiones y los procesos de participación pública (Lotze-Campen 2008; Singh et al. 2012; Poveda and Lipsett 2014). Sin embargo, las complejas interrelaciones con la mayoría de sistemas naturales y actividades humanas generan una dificultad añadida para su análisis integral. Los catálogos de indicadores no son siempre igualmente eficaces en relación con los objetivos señalados (Reed et al. 2006; Levrel et al. 2009; Kajikawa et al. 2011). En este sentido, será necesario utilizar enfoques metodologicos que permitan seleccionar y definir indicadores que se ajusten a los objetivos específicos de sostenibilidad de cada SSE (Martínez et al. 2016).

Además de los indicadores, en el analisis de los SSE se precisa utilizar herramientas prospectivas que exploren los efectos a medio y largo plazo en cualquiera de las variables del sistema bajo diferentes escenarios. Los modelos de simulación dinámica ofrecen muchas ventajas para ello, ya que permiten conceptualizar las complejas interrelaciones que se dan en los SSE, facilitando su comprensión y seguimiento (Martínez-Moyano y Richardson 2013; Kelly 2013, Tenza et al. 2017) y a su vez nos ayudan a facilitar los procesos de toma de decisiones en materia de sostenibilidad, valorando la evolución futura del sistema e indicadores integrados bajo distintos escenarios o alternativas (Banos-Gonzalez et al. 2015).

En definitiva, la gestión de los SSE requiere herramientas metodológicas con un enfoque inter y trans-disciplinar que 1) diagnostiquen el SSE con una visión holística y sistémica, 2) monitoreen la sostenibilidad y la dinámica del SSE mediante indicadores ajustados a los objetivos específicos del SSE y 3) faciliten la evaluación de diferentes opciones de gestión y planificación sostenible de cara a una transición hacia la sostenibilidad.

En este contexto, esta tesis, cuyos objetivos concretos se tratarán más adelante, se centra en comprender la estructura y dinámica socio-ecológica del sistema socio-ecológico del Mar Menor (SSEMM) situado en el sureste de España, analizando la sostenibilidad de la laguna del Mar Menor, sus humedales periféricos y la subcuenca hidrográfica vertiente, los actores que interactúan con tales sistemas y las instituciones implicadas en su gestión. Se aplicará para ello un enfoque metodológico inter y transdisciplinar para el entendimiento integral del SSEMM, con el fin de vincular el conocimiento científico con el de otros sectores no académicos y contribuir a construir alternativas sostenibles para su gestión.

1.2. El sistema socio-ecológico del Mar Menor. Interés científico y socioambiental

El SSEMM, situado en la Región de Murcia (SE, España) es un área de una enorme riqueza ambiental, económica y social. Su clima, ubicación, geografía y entorno natural tan singular ha propiciado que el Mar Menor sea conocido y valorado tanto a nivel nacional como internacional. Debido a su indudable importancia, ha sido objeto de múltiples estudios e informes de carácter científico, social, cultural e institucional.

En el SSEMM conviven varios usos y actividades económicas simultáneamente que dan lugar a numerosas presiones humanas, causantes a su vez de graves impactos en el SSE. Hoy es un espacio alterado y más vulnerable, lo que pone en riesgo su singularidad y sostenibilidad en el medio y largo plazo.

Esta situación ha despertado por un lado un interés científico por continuar mejorando el conocimiento sobre la dinámica y funcionamiento de la laguna del Mar Menor, sus humedales periféricos y su subcuenca hidrográfica vertiente y, por otro lado, una preocupación de toda la sociedad, que demanda acciones y medidas, hasta ahora insuficientes, con el objetivo de recuperar y salvaguardar los valores del SSEMM, no solo por la importancia de los ecosistemas y especies que alberga sino por constituir la base del desarrollo socioeconómico de este territorio y por el vínculo existente con los habitantes de su entorno y por el aporte de bienes y servicios que les presta. Esta tesis pretende contribuir a avanzar hacia un conocimiento integral y sistémico del SSEMM, que incorpore las visiones de los distintos actores implicados y de la población local, con el fin de conseguir una gestión adecuada y asegurar su sostenibilidad ambiental, social y económica en el medio y largo plazo.

Las razones para seleccionar y abordar las diferentes cuestiones mencionadas utilizando como caso de estudio el SSEMM son las siguientes.

El SSEMM, por su ubicación en el litoral mediterráneo, representa bien las principales dinámicas socioeconómicas del territorio a escala mundial, como son los cambios de uso del suelo (Paerl 2010; Sekovski et al. 2012; Newton & Weichselgartner 2014), las tendencias a la concentración de la población en la banda costera (Burke et al. 2001; Creel 2003; Airoldi & Beck 2007) y las implicaciones de todo ello en relación con la propia sostenibilidad, en este caso, de la subcuenca hidrográfica vertiente y los ecosistemas de la laguna del Mar Menor y los humedales perífericos. A ello se une que la zona del Mar Menor es una zona con un alto valor ecológico y naturalístico por la laguna del Mar Menor y los humedales periféricos (Vidal et al. 2003; Esteve et al. 2016), reconocidos por varias figuras de protección internacional, nacional y regional (Espacios Naturales Protegidos, Zona de Especial Protección para las Aves, Zona Especialmente Protegida de Importancia para el Mediterráneo, Lugar de Importancia Comunitaria, Humedal de Importancia Internacional del Convenio Ramsar). A pesar de todas estas figuras de protección, está sometido a unas altas presiones derivadas de las actividades antropogénicas con trascendentales consecuencias ecológicas (crisis eutrófica), económicas, sociales, políticas e institucionales.

Por otra parte, se ha seleccionado como escala de análisis la de cuenca (subcuenca) hidrográfica, en lugar de otras posibilidades como ámbitos administrativos, porque la cuenca resulta idónea para integrar los recursos naturales, especialmente el agua. Los efectos directos y sobre todo indirectos de los cambios de uso del suelo pueden no ser tan obvios dependiendo de la escala espacial del análisis, ya que hay efectos indirectos de los cambios de uso que solo se revelan a escala de cuenca (Skuras et al. 2014). Por ejemplo, algunos cambios de uso alteran los flujos hídricos y esto genera efectos indirectos sobre otros componentes, como los ecosistemas acuáticos, los espacios naturales, el mantenimiento de los humedales o la biodiversidad (Guaita et al. 2020), como claramente ejemplifica el caso del Mar Menor.

Un tercer factor de interés en el Mar Menor y su entorno como zona de estudio es su elevada vulnerabilidad al cambio climático (Moreno 2005; Ciscar et al. 2014; Cramer et al. 2018). Los escenarios más plausibles en España apuntan a un incremento progresivo de la temperatura, una disminución de las precipitaciones y, sobre todo, una disminución de la escorrentía a lo largo del siglo XXI, tendencias que se acelerarán a partir de mediados de siglo en el caso de escenarios de emisiones globales más altas. Además, estas reducciones serán mayores en el tercio sur peninsular, donde se sitúa el SSEMM, con reducciones superiores al 30% en el escenario de emisiones altas y en torno al 20% en el escenario de emisiones bajas (VVAA 2007). Algunos estudios recientes señalan que el ámbito más amenazado por el cambio climático en España es La Manga del Mar Menor, por la potencial subida del nivel del mar (Jiménez et al. 2016). El Plan Nacional de Adaptación al Cambio Climático señala que el cambio climático podría provocar un aumento de 50 cm del nivel del agua en el Mediterráneo en esta zona en un plazo de 20 a 50 años.

Son muchas las investigaciones científicas realizadas hasta el momento (2021) en el SSEMM y que han abordado diferentes aspectos, como por ejemplo, la evolución histórica de los usos del suelo y sus efectos (Martínez-Fernández et al. 2013; Carreño 2015), la exportación de nutrientes hacia la laguna costera del Mar menor (Martínez-Fernández y Esteve Selma 2005, Velasco et al. 2006; García Pintado et al. 2009, Martínez-Fernández et al. 2005, 2014, 2017); los suelos y vegetación de los humedales periféricos a la laguna del Mar Menor (Alvarez-Rogel et al. 2007); las opciones de gestión de los drenajes agrícolas (Martínez-Fernández et al. 2007) y su evaluación económica (Martínez Paz et al. 2007); los servicios ecosistémicos de los humedales (Martínez-Fernández et al. 2014); así como los cambios en los hábitat de los humedales (Carreño et al. 2008, Esteve et al. 2008) y en distintas comunidades biológicas (Pardo et al. 2008; Robledano et al. 2010 y 2011), o estudios sobre los efectos del cambio climático (Jiménez et al. 2016), entre otros.

Sin embargo, a pesar de los muchos estudios científicos dirigidos a distintos aspectos sectoriales del SSEMM, no se han abordado trabajos que, además de un enfoque metodológico integral y sistémico, incorpore la óptica transdisciplinar y participativa para la comprensión conjunta de su dinámica y abordar sus problemas de sostenibilidad en el marco del actual proceso de cambio global, buscando estrategias y marcos conceptuales que contribuyan a la transición hacia la sostenibilidad del sistema.

En este contexto, en el marco de esta tesis se plantean las siguientes preguntas de investigación:

1. ¿Cuáles son los métodos y enfoques más apropiados para evaluar el cambio global, específicamente los cambios de uso del suelo y sus implicaciones para la sostenibilidad en los SSE?
2. ¿Cuáles son los principales factores ambientales, sociales y económicos implicados en la dinámica del SSEMM?
3. ¿Cuál es la percepción que tiene la comunidad local en relación a la situación actual de degradación ambiental del SSEMM?
4. ¿Quiénes son los actores que interactúan con los ecosistemas y recursos naturales del SSEMM y cuáles son sus principales percepciones?
5. ¿Cómo evaluar los avances y retrocesos en relación con los objetivos de sostenibilidad del SSEMM?
6. ¿Cúal es el modelo de gobernanza para la gestión del SSEMM y cúales son las respuestas abordadas?

Para responder a estas preguntas, en esta tesis se plantean los siguientes objetivos.

1.3. Objetivos

El **objetivo general** de esta tesis es analizar y evaluar la sostenibilidad en el SSEMM mediante un enfoque metodológico integral, sistémico y participativo (inter y transdisciplinar) para atender las problemáticas que lo amenazan, apoyar los procesos de toma de decision y contribuir en su gestión y transición hacia la sostenibilidad. Para ello se plantean los siguientes **objetivos específicos** que podrían dar algunas respuestas a las preguntas de investigación planteadas.

1. Evaluar el estado del arte en el uso de modelos y escenarios en los sistemas socio-ecológicos en relación con el cambio global, específicamente con los cambios de uso del suelo y el cambio climático.
2. Construir un modelo cualitativo que sintetice, desde una perspectiva integral, los principales factores implicados en el estado ambiental del SSEMM como diagnóstico sintético del SSEMM y su sostenibilidad.

3. Conocer la percepción de la población del entorno del Mar Menor acerca de las presiones, los impactos y las posibles medidas a adoptar para mejorar la situación actual del SSEMM y específicamente el estado ecológico de la laguna.
4. Analizar los actores asociados al SSEMM mediante una metodología participativa para poder identificarlos, caracterizarlos y conocer sus preferencias sobre posibles soluciones o medidas de gestión para la restauración ambiental del Mar Menor.
5. Desarrollar un sistema de indicadores para evaluar la sostenibilidad en el SSEMM, así como los avances y retrocesos hacia los objetivos de sostenibilidad del mismo.
6. Analizar la dinámica de gobernanza y participación comunitaria en la gestión de los recursos naturales y ecosistemas del SSEMM.

1.4. Estructura de la tesis

La presente tesis doctoral está dividida en capítulos agrupados en tres bloques:

- Introducción, marco teórico y metodológico
- Resultados
- Conclusiones y futuras líneas de investigación

El primer bloque consta de tres capítulos. El capítulo 1 tiene carácter introductorio, y en él se describe una presentación inicial de este trabajo, así como el interés científico y socio ambiental, la justificación de esta investigación, los objetivos que responden a las preguntas de investigación planteadas y la estructura de la investigación. En el capítulo 2 se ha desarrollado un marco teórico y conceptual para ayudar al lector a comprender algunos conceptos y la problemática de la cuestión. Para ello se han desarrollado los siguientes aspectos teóricos que trascienden a lo largo de la tesis: *Sostenibilidad de los sistemas socio-ecológicos*, *Los procesos de participación pública en la gestión de los sistemas socio-ecológicos, Herramientas para analizar la sostenibilidad y la gestión adaptativa al cambio global en los sistemas socio-ecológicos y Gobernanza ambiental.* En el capítulo 3 se expone la metodología general seguida para elaborar esta tesis.

El segundo bloque consta de cinco capítulos (capítulos 4, 5, 6, 7 y 8) los cuales abordan los objetivos específicos planteados. A continuación, se describen los capítulos del 4 al 8.

El capítulo 4 aborda los dos primeros objetivos y se estructura en dos subcapítulos (4.1 y 4.2). El subcapítulo 4.1 se presenta en formato de artículo científico en inglés. En él se hace una revisión de la literatura científica a lo largo de un periodo de 25 años para evaluar el estado del arte en el uso de modelos y escenarios en los sistemas socio-ecológicos en relación con el cambio global,

específicamente con los cambios de uso del suelo y el cambio climático. Los resultados contribuyeron a 1) tener un mejor conocimiento de los métodos, enfoques y aplicaciones en el uso de modelos y escenarios ambientales como herramientas predictivas en la gestión de los SSE y 2) sirvieron de base para plantear otras preguntas de investigación abordadas en la tesis y priorizar algunas de las cuestiones relacionadas con la construcción de modelos. Todo ello condujo a plantear el segundo objetivo específico recogido en el subcapítulo 4.2. Este subcapítulo se presenta en inglés y aborda el desarrollo de un modelo cualitativo con un enfoque integral como base para elaborar un diagnóstico sintético del SSEMM. En primer lugar, se hace una breve descripción de las características biofísicas y socioeconómicas más relevantes del SSEMM y en segundo lugar se presenta un diagnóstico sintético del SSEMM donde se describe la metodología seguida para el desarrollo del modelo y los resultados. Este trabajo contribuyó a comprender las interrelaciones ambientales y socioecológicas que afectan al estado del SSEMM y facilitar una visión global de la problemática del Mar Menor a los distintos actores implicados y a la comunidad local.
El subcapítulo 4.1. ha sido publicado en la revista *Sustainability* como Guaita García et al. 2020.

En el capítulo 5 se analiza la percepción de la comunidad local en la zona del Mar Menor a través de la realización de una encuesta sobre las causas, consecuencias y posibles soluciones a los problemas actuales, especialmente la crisis eutrófica en la laguna del Mar Menor. Los datos recopilados fueron analizados mediante estadística descriptiva y análisis de componentes principales. El propósito de este capítulo fue reflexionar acerca de la importancia que reviste el análisis de la percepción social en el marco de la evaluación de la sostenibilidad y el diseño de estrategias de gestión en los SSE. Los resultados de este trabajo contribuyeron al diagnóstico integral y el modelo conceptual presentado en el capítulo 4 (apartado 4.2), a identificar algunos de los principales grupos de actores sociales asociados al SSEMM y sus preferencias, analizados posteriormente en el capítulo 6 y a definir los objetivos específicos de sostenibilidad del SSEMM en el capítulo 7. Este capítulo se presenta en formato de artículo científico en inglés y ha sido publicado en la revista *Environment, Development and Sustainability* como Guaita García et al. 2020.

En el capítulo 6 se analizan los actores implicados, interesados y afectados por la situación de degradación ambiental del SSEMM a través de un conjunto de entrevistas que han permitido su identificación y caracterización, así como conocer sus preferencias sobre posibles soluciones o medidas de gestión. Los datos recopilados fueron analizados con análisis de conglomerados jerárquico y técnicas de elicitación de expertos. Los resultados de este capítulo contribuyeron a conocer los intereses y preferencias de los actores, así como los consensos y conflictos establecidos entre ellos para priorizar medidas de gestión. Estos resultados también contribuyeron a la definición de los objetivos específicos de sostenibilidad para el SSEMM en el capítulo 7. Este capítulo se presenta en formato de artículo científico en inglés y ha sido enviado a la revista *Environmental Development*.

En el capítulo 7 se desarrolla una metodología para realizar un seguimiento de la sostenibilidad en el SSEMM a través de un sistema de indicadores ambientales, sociales, económicos e institucionales. La selección del conjunto de indicadores se hizo en base a un enfoque sistémico y al diálogo multidisciplinar con un conjunto de expertos de distintas áreas, siguiendo las siguientes etapas: 1) definición de los objetivos específicos de sostenibilidad del SSEMM; 2) selección y definición de un conjunto de indicadores de sostenibilidad relevantes para el caso del SSEMM y 3) validación del sistema final de indicadores mediante consulta a un amplio conjunto de expertos de distintas disciplinas. La caracterización del sistema de indicadores contribuyó a conocer el estado de la información disponible y la viabilidad para su cálculo futuro. Este capítulo se presenta en formato de artículo científico en inglés.

En el capítulo 8 se analizan el modelo de gobernanza, las políticas públicas relativas al Mar Menor elaboradas o implementadas, así como los procesos participativos y las acciones colectivas en torno a los recursos naturales y ecosistemas del SSEMM. Para ello se propuso entender la configuración de la gobernanza en el SSEMM y analizar las respuestas o soluciones propuestas públicamente por los grupos de actores implicados en la gestión del SSEMM. Los resultados de este capítulo contribuyeron a conocer las condiciones de la gobernanza actual y definir los retos a los que se enfrenta la gobernanza ambiental en el SSEMM. Este capítulo se presenta en formato de artículo científico en inglés y ha sido enviado a la revista *Local perception*.

En el tercer bloque se desarrolla el capítulo 9 en inglés y español, donde se muestran las principales conclusiones derivadas de esta tesis y se detalla las futuras líneas de investigación a partir de este trabajo.

Finalmente, en el apartado de apéndices se encuentra la documentación complementaria para abordar cada uno de los capítulos de resultados. El Apéndice I presenta la estructura y contenido de la encuesta realizada a la comunidad local del entorno del Mar Menor. En el Apéndice II y III se incluyen la estructura y contenido de las entrevistas realizadas a los expertos y a los actores sociales. El Apéndice IV recoge de manera informativa la caracterización de los actores y su relación con el SSEMM. Finalmente, el Apéndice V incluye el contenido de la consulta realizada a los expertos para validar el sistema de indicadores de sostenibilidad y el Apéndice VI recoge el marco normativo más relevante del SSEMM.

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Capítulo 2.
Marco teórico y conceptual

Nacra (*Pinna nobilis*)

Noble pen Shell (*Pinna nobilis*)

Fotografía: Javier Murcia Requena

2. Marco teórico y conceptual

2.1. Sostenibilidad de los sistemas socio-ecológicos

El incremento de la interdependencia entre el sistema humano y el sistema ecológico en el marco del cambio global, hace surgir la necesidad de analizar y entender las interacciones entre las actividades humanas y los recursos naturales, que lleva a definir como unidad apropiada de análisis y gestión los SSE (Audouin et al. 2013; Fischer et al. 2015). Berkes y Folke (1998) señalan que los sistemas sociales y los sistemas naturales están estrechamente vinculados a nivel multi-escalar y que la delimitación exclusiva de un ecosistema o de un sistema social resulta arbitraria y artificial.

La Ciencia de la Sostenibilidad surge precisamente al inicio del siglo XXI para comprender el sistema cada vez más complejo constituido por las sociedades humanas y los sistemas naturales con los que interactúan y hacer así posible el tratamiento sistémico de problemas que se potencian mutuamente. Para la resolución de estos problemas la Ciencia de la Sostenibilidad propone aproximaciones interdisciplinarias, transdisciplinarias, la pluralidad de conocimiento y la participación activa de la ciudadanía a fin de hacer possible la transición hacia la sostenibilidad. En este sentido la gestión de las interacciones entre la naturaleza y la sociedad requiere nuevos marcos de análisis basados en una perspectiva holística, sistémica e integradora.

Según Berkes y Folke (1998), el término de SSE se utiliza para referirnos, precisamente, a ese concepto holístico, sistémico e integrador del ser humano en la naturaleza. Se entiende que un SSE es un sistema complejo y adaptativo en el que distintos componentes culturales, políticos, sociales, económicos, ecológicos y tecnológicos están interactuando y cuyas interacciones se ajustan y autoorganizan a través del tiempo (Costanza y Jorgensen 2002; Jassen y Ostrom 2006; Resilience Alliance 2010). Este abordaje desde los SSE permitirá construir formas alternativas de interacción entre la sociedad y los ecosistemas hacia la sostenibilidad.

En los SSE abiertos existen influencias y dependencias entre y hacia los elementos de los subsistemas: biofísico, social, económico y cultural, lo cual se manifiesta en una dinámica de comportamiento que es compleja y que obliga a analizarla con un enfoque integral y sistémico (Berkes et al. 2000; Gallopín 2001; García 2008). Este enfoque facilita un mejor conocimiento de la estructura y función del SSE en términos de definir sus elementos y las relaciones entre ellos (Farhad 2012). Además, permite analizar y evaluar factores involucrados desde diversos escenarios (administrativos, económicos, naturales, socio-culturales, etc.). Por otra parte, ofrece un marco conceptual dentro del cual los contenidos de las ciencias biofísicas y sociales pueden integrarse de manera lógica. El enfoque sistémico, a su vez, permite reconocer las interrelaciones de los diferentes elementos del sistema dentro de fronteras establecidas.

Los estudios de caso de este tipo de sistemas son clave para entender su funcionamiento y, sobre todo, para atender las problemáticas específicas que los amenazan, como los cambios de uso del suelo y el cambio climático. Desde la perspectiva de la ciencia de la sostenibilidad, la gestión de los SSE se considera un factor crucial para impulsar la sostenibilidad global. A pesar de la importancia de estos sistemas, la mayor parte de los estudios existentes sobre SSE permanecen en el plano teórico y conceptual, lo que dificulta su aplicación práctica (Tenza 2017).

2.2. Los procesos participativos en la gestión de los sistemas socio-ecológicos

Los enfoques participativos son clave para el estudio de los SSE (Gadgil et al.1993; Beckerand Ghimire 2003; Lunas-Reyes y Andersen 2003; Tengö y Belfrage 2004), especialmente cuando se tiene como objetivo contribuir en la transición de estos sistemas hacia la sostenibilidad.

Varios autores han destacado la necesidad de los enfoques participativos para mejorar la toma de decisiones en la gestión de los SSE (Reed 2008; Ban et al. 2013). Este tipo de enfoques, también conocido como 'de abajo a arriba', ha tenido una evolución notable a lo largo del tiempo, y pese a que no siempre se ha denominado de la misma manera, en la mayoría de los casos se presenta como un elemento eficaz en el desarrollo de democracias locales (Kok 2007).

Los enfoques participativos se basan en la implicación directa de todos los actores (sociales, económicos, gubernamentales) asociados a un SSE en las diferentes fases de procesos de planificación en general, y de la gestión de recursos naturales en particular. Las decisiones estratégicas en un territorio concreto, no pueden prescindir del conocimiento y percepciones de los diferentes grupos de actores locales que operan en ese ámbito (Comino et al. 2016). La gestión sostenible de los recursos naturales no se puede alcanzar sin la implicación de la comunidad afectada. Por esta razón se debe promover el establecimiento y construcción de diálogos, confianza, cooperación y reconciliaciones mediante el intercambio de información, percepciones, necesidades, visiones y, en términos más generales, el conocimiento implícito y explícito de los actores clave sobre la realidad que les afecta (Prell et al. 2009; Hauck et al. 2016).

Freeman (1984) define los actores clave o stakeholders, como aquellos individuos o grupos que afectan o son afectados por una decisión o acción. En los últimos años el análisis de actores está creciendo en la gestión ambiental y de recursos naturales, como consecuencia de sociedades más democráticas que demandan mayor participación ciudadana en la formulación y desarrollo de políticas públicas (Reed 2008). Este análisis de actores surge como una forma de responder al desafío de integrar múltiples intereses y objetivos para el análisis, formulación y desarrollo de políticas y prácticas (Grimble y Wellard 1997). El propósito del análisis y mapeo de actores es identificar a los actores clave que componen una determinada estructura social, identificar los roles que cumplen dentro de un determinado contexto territorial y analizar la posición relativa que cada actor posee dentro de la estructura social, en función de sus intereses e influencias (Lienert et al. 2013).

Algunas de las herramientas y técnicas de investigación social más comunes aplicadas para llevar a cabo los procesos de participación pública son: entrevistas, encuestas, mapeo de actores y talleres participativos o asambleas. Es crucial seleccionar las herramientas y los enfoques participativos más apropiados para cada contexto específico y objetivo (Villarmor et al. 2014). Por ello, a través de la combinación de varios métodos participativos, como son las encuestas, entrevistas en profundidad y los talleres de trabajo, se obtiene información de diferente índole que enriquece la investigación y permite un acercamiento contrastado y más adecuado a la realidad de los SSE. Además, estas técnicas de investigación social en muchos casos son una fuente de información cuantitativa y semi-cuantitativa, de calidad que complementa a las técnicas más convencionales en la investigación científica (Huntington 2000; Anadón et al. 2009; Pérez et al. 2012; Parry and Peres 2015).

Todas estas técnicas de investigación social y participación de la comunidad local son fundamentales para sumergirse en la realidad del SSE bajo estudio, así como conocer las aspiraciones, necesidades y conflictos de las comunidades locales e iniciar una relación de confianza mutua con los actores locales. Para finalmente buscar el consenso sobre alternativas y soluciones, y tomar las decisiones sobre cuestiones que afectan directamente a las comunidades locales de una manera efectiva (Reed 2008).

Integrar y reconocer diversos tipos de conocimiento y valores de los diferentes actores contribuirá a un mejor entendimiento de las dinámicas y procesos de los SSE, así como a facilitar la toma de decisiones en cuestiones relativas a la gestión del territorio (Palomo et al. 2011; Hanspach et al. 2014; Balvanera et al. 2017).

2.3. Herramientas para analizar la sostenibilidad y la gestión adaptativa al cambio global en los sistemas socio-ecológicos

El concepto de sostenibilidad o desarrollo sostenible aparece por primera vez en el Informe Brundtland (también titulado "Nuestro futuro común") elaborado y publicado por Naciones

Unidas en el año 1987, donde se define como “el desarrollo que satisface las necesidades del presente sin comprometer la capacidad de las futuras generaciones para satisfacer sus propias necesidades” (Brundtland 1987). Todo ello garantizando un equilibrio entre la protección del medio ambiente, el bienestar social y el crecimiento económico.

Desde el año 1992, donde la comunidad internacional se reunió en Río de Janeiro (Brasil) para discutir los medios para poner en práctica el desarrollo sostenible, han surgido diferentes herramientas y enfoques metodológicos para evaluar la sostenibilidad a nivel mundial y en concreto en los SSE (Saldivar et al. 2002; Gallopín 2006; Böhringer & Jochem 2007; Singh et al. 2009, 2012).

Los **indicadores** son una de estas herramientas que nos ayuda a cuantificar, entender y simplificar realidades complejas, facilitando la elaboración de diagnósticos de sostenibilidad y su comunicación con el conjunto de actores (Lotze-Campen 2008; Singh et al. 2012; Poveda and Lipsett 2014). La Organización para la Cooperación y Desarrollo Económico (OCDE 1993) considera que un indicador es un parámetro o un valor derivado de otros parámetros, dirigido a proveer información y descripción del estado de un fenómeno. Según Guttman et al. (2004), los indicadores toman sentido al considerarlos como un sistema. Cualquier sistema de indicadores busca de alguna forma organizar la información disponible para proporcionar claridad en un asunto específico o un problema planteado en la sociedad. Como señala Antequera (2005) su utilidad depende mucho del contexto particular, y sólo serán útiles si encajan en el modelo conceptual y pueden relacionarse entre sí (Guttman et al., 2004). Los indicadores además, contribuyen a fortalecer y sustentar las decisiones de manera informada para impulsar el desarrollo en una determinada región. En este sentido, el uso de indicadores que contribuyan a valorar la fragilidad de un SSE y demostrar, cuantificar y evaluar la magnitud de estos cambios puede ser de utilidad socioeconómica, y de política regional (Chirino et al. 2008).

En los procesos de gestión y toma de decisiones de los SSE se está reconociendo que además de la importancia de indicadores para elaborar un diagnóstico integral de los procesos y problemas actuales son necesarias estimaciones razonables acerca de la evolución esperable de tales procesos y problemas bajo distintas condiciones futuras (Martínez-Moyano y Richardson 2013; Guaita et al. 2020). Los sistemas complejos y cambiantes como los SSE distan de exhibir comportamientos lineales, por lo que las tendencias pasadas no pueden ser extrapoladas directamente en el futuro, excepto para periodos de tiempo muy corto. Por ello es necesario un conocimiento profundo de las causas que determinan la dinámica del SSE y utilizar herramientas de simulación capaces de tener en cuenta las interacciones entre los factores clave de los subsistemas socioeconómico y ambiental, con el fin de explorar las consecuencias a largo plazo. Como herramientas prospectivas podemos destacar la definición de escenarios de futuro y su exploración a través de modelos de simulación y la integración dinámica de indicadores.

Los **modelos de simulación dinámica** describen la estructura de un sistema a través de los principales factores e interacciones, lo que permite la simulación de su comportamiento dinámico (Martínez-Moyano y Richardson 2013; Kelly 2013). Los modelos dinámicos (Jorgensen y Bendoricchio 2001; Brinsmead 2005) permiten tener en cuenta las interrelaciones entre los distintos factores tanto ambientales como socioeconómicos, simular distintos escenarios y evaluar en qué medida los cambios previsibles pueden afectar a los distintos componentes de un sistema o a su sostenibilidad (Voinov y Shugart 2013). El proceso de construcción de este tipo de modelos se divide en tres grandes etapas: la conceptualización del sistema, la elaboración y validación del modelo cuantitativo, y la exploración de escenarios de gestión. Los modelos de simulación dinámica representan una herramienta muy valiosa en gestión sostenible participativa, por facilitar la comunicación entre el ámbito científico-técnico, el de los gestores y el de los agentes sociales, por su capacidad para visualizar diagnósticos y tendencias de forma comprensible para no expertos, por su capacidad para integrar los indicadores de sostenibilidad y por incorporar una perspectiva a largo plazo.

Los **escenarios de futuro** no representan, necesariamente, lo que se espera que ocurra en el futuro, sino que describen caminos alternativos hacia un futuro posible apoyado en hipótesis razonables que ayudan a comprender lo que puede ocurrir (Wollenberg et al. 2001). Un escenario no es ni una predicción ni una previsión, sino que debe entenderse como una descripción coherente, internamente consistente y verosímil de un posible estado futuro del mundo (Nakicenovic et al. 2000). Aunque no existe un marco metodológico común, se considera que un buen escenario debe apoyarse en buenos datos y ofrecer un análisis comparativo fiable. Para ello es necesario la implicación de diferentes partes sociales interesadas y desarrollar escenarios participativos que contribuyan a tender puentes entre la comunidad científica, gobernantes, empresas y ciudadanos, así como aumentar la relevancia y legitimidad del escenario (Patel et al. 2007; Reed et al. 2013).

Varios estudios demuestran (Banos et al. 2015, Tenza et al. 2017) como el análisis de escenarios futuros a través de los modelos de simulación y la integración dinámica de indicadores es de gran utilidad para 1) identificar los escenarios bajo los cuales el SSE de interés es más vulnerable, 2) anticipar los efectos previsibles de diferentes estrategias de gestión y 3) determinar, utilizando los indicadores de sostenibilidad integrados en el propio modelo, las opciones que mejor contribuyen a una mayor sostenibilidad ambiental, económica y social.

2.4. Gobernanza ambiental

La gobernanza ambiental fue reconocida en el programa de Naciones Unidas para el Medio Ambiente (PNUMA) de 2000 y 2002 como un elemento a valorar para enjuiciar la calidad democrática de las naciones. Este avance se enmarcó en los trabajos preparatorios de la Cumbre sobre Desarrollo Sostenible, también conocida como Río+10 (Johannesburgo 2002). El contenido del principio número 10 en la declaración final de la conferencia fue relativo a la gobernanza ambiental, y se expresaba del modo siguiente: *"El mejor modo de tratar las cuestiones ambientales es con la participación de todos los ciudadanos interesados, en el nivel que corresponda. En el plano nacional, toda persona deberá tener acceso adecuado a la información sobre el medio ambiente de que dispongan las autoridades públicas, incluida la información sobre los materiales y las actividades que encierran peligro en sus comunidades, así como la oportunidad de participar en los procesos de adopción de decisiones. Los Estados deberán facilitar y fomentar la sensibilización y la participación de la población poniendo la información a disposición de todos. Deberá proporcionarse acceso efectivo a los procedimientos judiciales y administrativos, entre éstos el resarcimiento de daños y los recursos pertinentes".*

En este sentido, el concepto de gobernanza parte de una visión integral, en la que intervienen no solo las condiciones biofísicas, sino que a su vez reconoce los sistemas que interactúan en ella. La cooperación entre todos los actores que repercuten en el medio ambiente es fundamental para lograr una gobernanza eficaz que nos pueda ayudar en la solución a los conflictos de gestión ambiental y en la transición hacia la sostenibilidad. Desde entonces el concepto de gobernanza ambiental se ha abordado de varias maneras, por ejemplo como: "el conjunto de procesos e instituciones legales y políticos que, incluyendo normas valores, comportamientos y modalidades organizativas, permite que los ciudadanos, las organizaciones y movimientos sociales y los diversos grupos de interés, articulen sus intereses, medien sus diferencias y ejerzan sus derechos y obligaciones en relación al acceso y usos de los recursos naturales (Ojeda 2005)". Para Delgado, Bachman y Oñate (2007), la gobernanza ambiental se refiere a los procesos de toma de decisiones en relación con bienes públicos en los que intervienen el Estado, las empresas y la sociedad civil, que tienen que ver con el establecimiento de marcos regulatorios para la conservación, los limites y las restricciones sobre el uso de los recursos naturales y los ecosistemas.

La gobernanza se diferencia de otros conceptos tales como gobierno o gobernabilidad porque conlleva implícita la necesidad de generar un desarrollo participativo y reflejar los intereses sociales en la forma en que se toman las decisiones en los distintos ámbitos. Según SEO/Birdlife, la gobernanza incorpora dentro del concepto del buen funcionamiento de los gobiernos la necesidad de fomentar y aceptar la participación, la implicación, la vigilancia y hasta la crítica de la sociedad en los procesos gubernamentales y parlamentarios, de facilitar los cauces adecuados y de no solo escuchar, sino también de actuar en consecuencia. Esto implica necesariamente que los ciudadanos tengan acceso a la información y los procesos de toma de decisiones y participen en los procesos de debate, diseño y aprobación de las políticas y normas.

En el marco de análisis de los SSE, muchos de los servicios que prestan los ecosistemas son recursos comunes con mútiples actores que compiten por su uso, lo que a menudo genera conflictos entre ellos y su gestión. La solución tradicional a los conflictos en la gestión de los SSE ha sido delegar toda la responsabilidad en el gobierno. Según varios autores (Ostrom 1990; Holling y Meffe 1996) este enfoque de gestión centralizada es poco eficaz por la inflexibilidad y la falta de ajuste ante la complejidad de los procesos socio-ecológicos. Todo ello ha llevado recientemente al establecimiento de estructuras de gobernanza con mútiples actores, involucrados en la problemática socio-ecológica del sistema (Echevery y Vieira 2019). Según Ostrom (1990) no existe nadie mejor para gestionar sosteniblemente un recurso de uso común que los propios implicados. Existe suficiente evidencia que indica que el avance en la conservación exitosa y sostenibilidad de los sistemas ecológicos depende de la integración de los diferentes grupos gubernamentales y no gubernamentales, locales y externos, de alguna manera involucrados o interesados en la gestión de los SSE (Ostrom 1990; Özesmi y Özesmi 2003; Prell et al. 2009; Bodin y Prell 2011). En este sentido, la gobernanza ambiental es clave para alcanzar el desarrollo sostenible en los SSE.

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Capítulo 3.

Marco metodológico general

Anguila (*Anguilla anguilla*)

Eal (*Anguilla anguilla*)

Fotografía: Javier Murcia Requena

3. Marco metodológico general

En este capítulo se describe la metodología utilizada para dar respuesta a las preguntas planteadas en esta tesis, describiendo las fases de elaboración, los métodos y fuentes de recogida de información y los métodos de análisis.

La metodología se ha desarrollado de manera paralela al progreso de la investigación para la consecución de los objetivos específicos. De este modo pueden distinguirse seis etapas de desarrollo metodológico, las cuales se han organizado de manera general en dos fases diferenciadas: una fase de carácter exploratorio en torno al marco teórico sobre el análisis y la evaluación de la sostenibilidad en los SSE y una segunda fase de métodos empírico-analíticos para la búsqueda y obtención de datos y su correspondiente análisis, incluyendo tanto enfoques cualitativos como cuantitativos (análisis estadísticos).

A continuación, se describe la secuencia metodológica seguida para la formulación de las preguntas planteadas y para el alcance de los objetivos general y específicos de la tesis.

3.1. Enfoque metodológico general y fases de elaboración

En una fase inicial se optó por realizar un amplio ejercicio exploratorio sobre las herramientas metodológicas para abordar uno de los componentes del cambio global, concretamente los cambios de uso del suelo y sus posibles interacciones con el cambio climático, sus impactos a diferentes escalas (global, regional, local), así como el uso de modelos, escenarios y otros instrumentos para analizar sus implicaciones sobre la sostenibilidad. Tras dicha exploración de la literatura científica se planteó la necesidad de trasladar algunos aspectos de dicha revisión al análisis de los SSE y formular la primera pregunta planteada: ¿Cuáles son los métodos y enfoques más apropiados para evaluar el cambio global, específicamente los cambios de uso del suelo y sus implicaciones para la sostenibilidad en los SSE?

Para ello se realizó una detallada revisión de la literatura científica a lo largo de un periodo de 25 años (1995-2019) sobre el uso de modelos y escenarios ambientales (cambios de usos del suelo y cambio climático) aplicados al análisis y evaluación de sostenibilidad de los SSE.

Es importante señalar que no todos los resultados de este trabajo de revisión de la literatura científica condujeron a plantear el resto de preguntas de investigación ya que alguna de las preocupaciones iniciales de la investigación redujo su grado de atención en pro de la concentración hacia otras. Por otra parte, algunos de los resultados generados por dicho trabajo de revisión de la literatura científica contribuyeron además a priorizar algunas de las cuestiones que del mismo se derivaron como, por ejemplo, el enfoque metodológico para responder a la segunda pregunta planteada: ¿Cuáles son los principales factores ambientales, sociales y económicos implicados en la dinámica del SSEMM?

Para abordar esta segunda cuestión se priorizó el desarrollo de un modelo cualitativo con un enfoque integral que incorporara las dimensiones y factores clave. La construcción de modelos de simulación dinámica sobre la sostenibilidad en los SSE consta de varias fases que se agrupan en dos etapas, una primera etapa de conceptualización y modelado cualitativo y una segunda etapa de modelado cuantitativo, la cual puede realizarse a través de distintas técnicas de modelización, como la dinámica de sistemas (Forrester 1994; Meadows et al. 1972; Sterman 2000; Martínez-Moyano and Richardson 2013), entre otras herramientas. Desde esta base conceptual, en este trabajo se abordó la primera etapa, de modelización cualitativa.

El diagnóstico realizado con el modelo cualitativo, desde la óptica de un trabajo interdisciplinar, sirvió para diseñar el contenido de una encuesta dirigida a la comunidad local y responder así a la tercera pregunta planteada en esta tesis: ¿Cuál es la percepción que tiene la comunidad local en relación a la situación actual de degradación ambiental del SSEMM?

La encuesta se sitúa también en línea con otro de los resultados emergentes de la revisión de la literatura científica que abordó la primera pregunta de investigación, acerca de la importancia de promover enfoques transdisciplinares, con las perspectivas de los distintos actores, en el análisis y la gestión de los SSE. En la encuesta se plantearon 23 preguntas dirigidas a conocer la percepción de la comunidad local en relación a los principales cambios de uso del suelo que han tenido lugar en la subcuenca del Mar Menor y sus impactos, así como sus preferencias sobre un conjunto de posibles soluciones en el SSEMM.

La encuesta, además de ofrecer una amplia información sobre la opinión de la población local en relación al SSEMM, aportó también mucha información de interés sobre los perfiles de los encuestados, incluyendo, su profesión y principal actividad económica. Esta información dio unas primeras indicaciones acerca de la identificación de los principales grupos de actores sociales asociados al SSEMM y acerca de sus preferencias. Esto condujo al planteamiento de la cuarta pregunta: ¿Quiénes son los actores que interactúan con los ecosistemas y recursos naturales del SSEMM y cuáles son sus percepciones?

Continuando con un método de trabajo transdisciplinar, se realizaron catorce entrevistas a representantes de los grupos de actores identificados. Estas entrevistas aportaron información de sus intereses y preferencias sobre un conjunto de medidas de gestión.

Los resultados obtenidos con las fases metodológicas y respuestas a las preguntas señaladas desde una óptica de trabajo interdisciplinar y transdisciplinar, permitieron definir los objetivos específicos de sostenibilidad para el SSEMM y plantear las dos últimas preguntas de investigación: ¿Cómo evaluar los avances y retrocesos en relación con los objetivos de sostenibilidad del SSEMM?, ¿Cúal es el modelo de gobernanza para la gestión del SSEMM y cúales son las respuestas abordadas?

Para evaluar los avances y retrocesos hacia dichos objetivos se definió un sistema de indicadores en base a un enfoque integral y sistémico en el que participaron un conjunto de expertos de distintas disciplinas. Posteriormente se caracterizó el sistema de indicadores en base a la información disponible para conocer la viabilidad de cálculo. El sistema de indicadores constituyó una herramienta de interés para la evaluación y seguimiento de la sostenibilidad y de la distancia entre la situación presente y la deseada, lo que condujo a la última pregunta de investigación, en torno al modelo de gobernanza y las respuestas que se plantean en la gestión del SSEMM para resolver los retos pendientes.

La figura 3.1 presenta las fases metodológicas seguidas y sus relaciones con los distintos capítulos de la tesis.

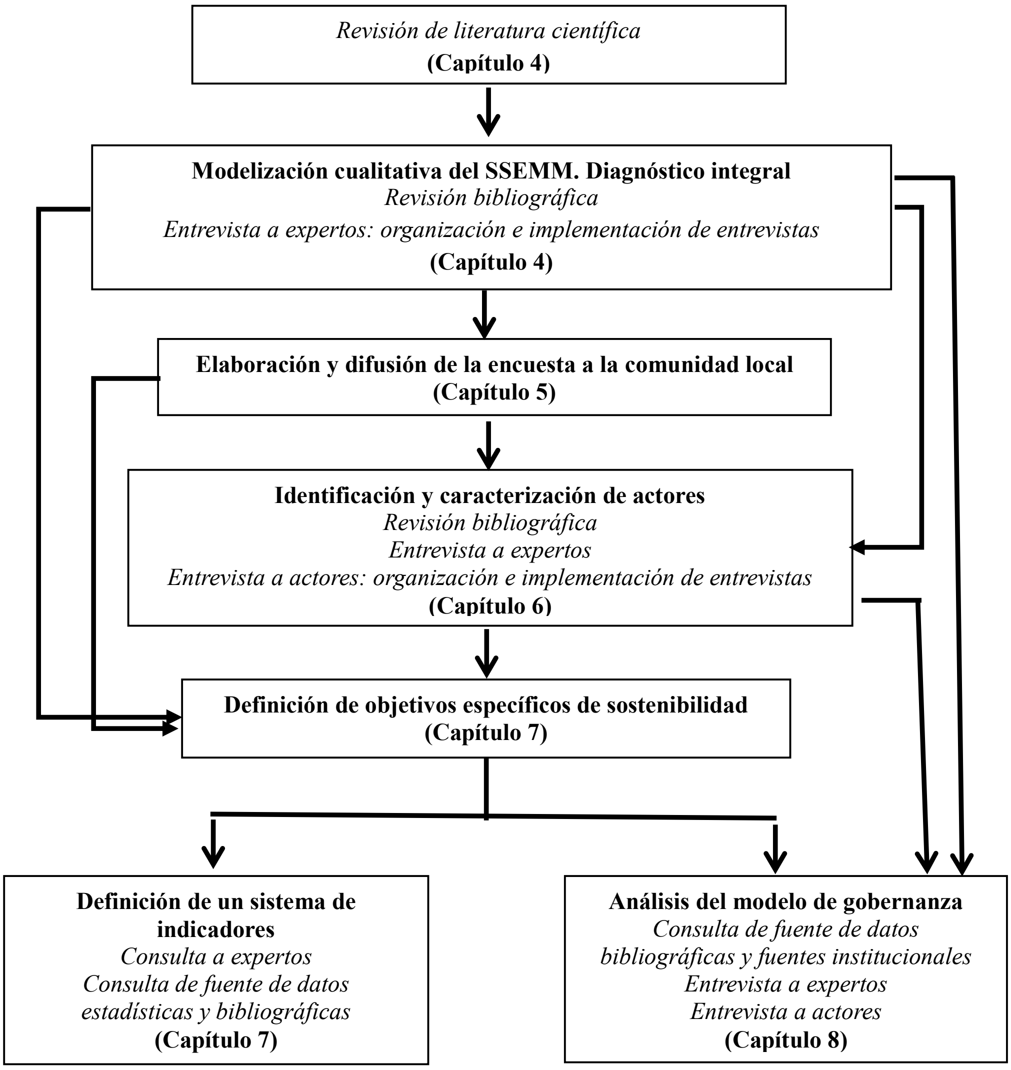

Figura 3.1. Fase de elaboración de la tesis doctoral.

3.2. Herramientas metodológicas

Los métodos empleados para afrontar todas estas tareas se encuentran reflejados en el apartado de metodología de cada uno de los capítulos de resultados. No obstante, a continuación, se presenta brevemente las diferentes herramientas metodológicas utilizadas.

El modelo cualitativo se construyó utilizando el marco metodológico FPEIR (fuerzas motrices, presión, estado, impacto, respuesta) (EEA 1999, tomado de la iniciativa de la OCDE 1993) para primero, describir la narrativa del modelo conceptual y segundo, construir un diagrama causal mediante el software Vensim (Ventana System 2011), con las variables socio-ecológicas más importantes del sistema, así como sus principales relaciones, interacciones y realimentaciones. La complejidad de estos sistemas emerge de relaciones no lineales entre componentes y la existencia de bucles de realimentación (circuitos cerrados de relaciones causa-efecto entre variables)

(Vennix 1996) lo que justifica que la definición del modelo vaya más allá de los esquemas lineales FPEIR.

Para su diseño las fuentes de información que se utilizaron fueron una amplia revisión bibliográfica de publicaciones científicas y técnicas del área de estudio, las cuales se especifican en el capítulo correspondiente y veinte entrevistas estructuradas a expertos de diferentes disciplinas en las dimensiones ambiental, social, económica e institucional. A través de este método de entrevistas se recogió la opinión de expertos importantes en la gestión del SSEMM sobre los principales procesos ecológicos, sociales, económicos e institucionales que están ocurriendo en el SSEMM. Las entrevistas se realizaron durante los meses de enero a abril de 2017 y los entrevistados fueron contactados en persona, por teléfono y por correo electrónico. La entrevista empleada para este trabajo se expone en el Apéndice II.

En cuanto a la encuesta elaborada a la comunidad local en el año 2017, el tipo de muestreo fue aleatorio simple y se dirigió a diferentes sectores de la población mayor de 18 años en el entorno del Mar Menor y a organismos implicados en las actividades y gestión del SSEMM. El cuestionario se sometió a una prueba piloto con un grupo de 35 personas entre estudiantes de la Universidad de Murcia y miembros la plataforma ciudadana Pacto por el Mar Menor, para determinar si las preguntas habían sido correctamente comprendidas por la población y si la duración de la encuesta era adecuada o excesiva.

Para analizar los datos de la encuesta se utilizó el software estadístico R (R Core Team, 2019). Se realizaron analisis bivariantes y se aplicó la prueba no paramétrica chi-cuadrado de Pearson (X^2) o el test exacto de Fisher (Agresti 1992), se realizaron análisis de componentes principales (ACP) (Wold, Esbensen and Geladi 1987) y representaciones biplot (Kassambara and Mundt 2019). El cuestionario empleado para este trabajo se expone en el Apéndice I.

Para el proceso de identificación y caracterización de los actores se utilizaron las veinte entrevistas a expertos previamente mencionadas, en la que también se abordaba una pregunta sobre cual eran los principales actores clave y sus intereses en el SSEMM. También se realizó una revisión bibliográfica de artículos científicos e informes técnicos relacionados con el área de estudio, los cuales se detallan en su capítulo correspondiente, con el fin de verificar y completar en su caso la identificación de actores. Se revisaron también otras fuentes de información como la Estrategia de Gestión Integrada de Zonas Costeras en el Mar Menor y su entorno (2018).

Además, se realizaron catorce entrevistas estructuradas a representantes de cada grupo de actores identificados (Apéndice III). Estas entrevistas se realizaron durante los meses de enero y febrero de 2019, y aportaron información sobre la percepción de los actores sobre la situación actual del SSEMM y sus preferencias respecto al conjunto de medidas de gestión que se habían propuesto en la encuesta a la comunidad local. Para realizar la entrevista los representantes de cada grupo de actor social asociados al SSEMM fueron designados por sus entidades correspondientes y contactados por correo electrónico, teléfono y en persona.

Para analizar los datos y poder comparar las preferencias de los actores con las de la comunidad local, se utilizó la técnica de elicitación de expertos (O'Hagan 2019), donde cada actor, en base a su conocimiento e intereses, actualizó las calificaciones de acuerdo a su nivel de importancia en una escala de 0 a 100. Para el análisis de los conflictos y consensos se utilizaron dos análisis de conglomerados jerárquico, empleando la distancia euclidiana y el método Ward (Murtagh y Legendre 2014).

También, entre las fuentes utilizadas para la consecución de los objetivos específicos se encuentran las fuentes bibliográficas y las fuentes de datos estadísticos, las cuales quedan especificadas en cada uno de los capítulos de resultados. No obstante, cabe destacar algunas de las fuentes que han sido fundamentales para la elaboración de esta tesis, así como para abordar las dos últimas preguntas planteadas en relación al sistema de indicadores y el análisis del sistema de gobernanza, en particular: el Centro Regional de Estadística de Murcia para datos estadísticos de sectores económicos y de población, el Canal del Mar Menor de la Consejería de Agua, Agricultura, Ganadería, Pesca y Medio Ambiente para datos sobre las propiedades físicas, químicas y biológicas de la laguna del Mar Menor, la Confederación Hidrográfica del Segura para datos de la subcuenca hidrográfica vertiente, el Instituto Español de Oceanografía (IEO) para datos del estado ecológico de la laguna, así como el Instituto de Turismo de la Región de Murcia (ITRM) y el Servicio Regional de Empleo y Formación (SREF), entre otros.

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RESULTADOS

Chapter 4.
Models and scenarios in the analysis of social-ecological systems. A qualitative modeling application in the Mar Menor social-ecological system.

Flamenco (*Phoenicopterus ruber*) en las salinas de San Pedro del Pinatar

Flamingo (*Phoenicopterus ruber*) in Salt Marshes of San Pedro del Pinatar

Fotografía: Javier Murcia Requena

4. Models and scenarios in the analysis of social-ecological systems. A qualitative modeling application in the Mar Menor social-ecological system.

This chapter presents the results that contribute to answering the first two questions posed in this thesis. First, in section 4.1., a review of the scientific literature over 25 years is presented to evaluate the state of the art in the use of models and scenarios in socio-ecological systems in relation to global change, specifically with land use change. This scientific review yields interesting results that serve as the basis for posing other research questions addressed throughout this thesis. Among the results found, that are detailed below, it should be noted that despite the progress that has been made in the construction of models of land use change in socio-ecological systems, such as watersheds and similar scales, more integrated approaches through models that incorporate biophysical and socioeconomic factors are required. This finding contributes to the second objective: to build a qualitative model that synthesizes, from an integral perspective, the main factors involved in the environmental state of the SESMM as a synthetic diagnosis of the SESMM and its sustainability.

From this conceptual base, in section 4.2., the results of the development of a socio-ecological conceptual model are exposed, which allows to elaborate a diagnosis that approaches to establish not only the situation and the environmental state of the SESMM, but also the socioeconomic factors that most influence its environmental status in order to understand the structure of the system considered as an organized totality to communicate it to the local community and other stakeholders associated with the SESMM.

4.1. Environmental scenario analysis on natural and social-ecological systems: A review of methods, approaches and applications *

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Abstract

Scenario analysis is a useful tool to facilitate discussions about the main trends of future change and to promote the understanding of global environmental changes implications on relevant aspects of sustainability. In this paper, we reviewed 294 articles published between 1995–2019, to evaluate the state of the art use of models and scenarios to investigate the effects of land use change and climate change on natural and social-ecological systems. Our review focuses on three issues. The first explores the extent to which the environmental dynamics of land use and climate change were jointly analyzed and the spatial scales associated with such integrated studies. The second explores the modelling methodologies and approaches used in the scenario analysis. The third explores the methods for developing or building scenarios. Results show that in most predictions there is little integration of key drivers of change. We find most forecasting studies use a sectoral modelling approach through dynamic spatially distributed models. Most articles do not apply a participatory approach in the development of scenarios. Based on this review, we conclude that there are some gaps in how scenario analysis on natural and social-ecological systems are conducted. These gaps pose a challenge for the use of models and scenarios as predictive tools in decision-making processes in the context of global change.

Keywords: climate change; land use change; models; scenarios; sustainability; watersheds.

4.1.1. Introduction

In recent decades, changes in land use and climate have had major impacts on the environment at local, regional and global scales [1–5]. The high rate of land use change and climate change are now one of the most important environmental problems on regional to global scales [2,6–8]. Both processes operate simultaneously, with feedbacks at varying spatial and temporal scales.

Given this significant and accelerated process of global change, the need arises to analyze and understand the interactions between human activities and natural resources [2], which leads to the definition of social-ecological systems as a unit of analysis and management. Berkes and Folke (1998) [9] point out that social systems and natural systems are linked at a multi-scale level and that the exclusive delimitation of an ecosystem or the resulting social system is arbitrary and artificial. Janssen and Ostrom (2006) [10] define social-ecological systems as complex adaptive systems in which social and bio-geophysical agents are interacting through multiple spatial-temporal scales. This approach from social-ecological systems will allow to build alternative ways of interaction between society and ecosystems towards sustainability.

Case studies of these types of systems, such as watersheds, are key to understand their functionality and to address the specific problems that threaten them, such as land use change and climate change. This requires a thorough understanding of the causes that determine land use and climate change and the use of simulation tools capable of taking into account the interactions among key factors of socioeconomic and environmental subsystems. This will allow us to explore the consequences in the medium and long-term in aspects relevant to sustainability such as water resources, biodiversity or nature conservation policies. However, the effects of land use change on water resources may not be as obvious, depending on the spatial scale of analysis.

In recent years, advances in research and understanding have led to increased attention to the importance of future scenarios of land use change [11–13], with simulation models [14–17] helping in the analysis of environmental responses.

Scenarios of land use change make possible to explore potential futures and their environmental consequences, as well as potential solutions to environmental problems and thus support decision-making [18]. A scenario is a creative, visionary tool that can support planning for a desired future as well as the preparation for possible undesirable events [19]. Scenarios are best developed not by researchers alone but with stakeholder participation. However, there are many successful and high-profile scenarios that have been developed with little participation from stakeholders [20,21]. Participatory approaches offer a chance to discuss, negotiate, and reach agreement [22,23].

The involvement of stakeholders in designing land use scenarios helps to identify acceptable land use alternatives by reflecting local preferences in land use decisions [24]. It facilitates the understanding of the multifaceted nature of land use issues from the perspective of stakeholders who are directly affected by land use decisions, but with usually limited participation in science and policy discourses [25]. However, development of land use change scenarios which are spatially explicit and detailed remains a complex challenge. In this regard, we ask the extent to which the literature has progressed in emphasizing these topics, and the extent to which there appear to be demonstrable advances in the understanding of the importance of interactions of changes in land use and climate.

We made a review of the recent scientific literature to address the following questions related to our understanding of socio-ecological responses to future scenarios of land use change:

1. In the evaluations of socio-ecological responses, to what extent were the environmental dynamics of land use change and climate change analyzed jointly in each study, and generally what were the spatial scales associated with such integrated studies? To what extent was a

direct or implied synergistic effect considered between both of these two environmental dynamics in those studies?
2. What were the modelling methodologies and approaches used in the scenario analysis?
3. What were the methods used for developing or building scenarios?

4.1.2. Materials and Methods

This review used international publications that were included in the Web of Knowledge encompassing the 25 years period, from 1995–2019. The type of publications includes articles in journals that are published by a publishing company or organization and have undergone peer-review.

The search, through the Web of Science database integrated into the source Web of Knowledge, has been conducted through a first search based on the following key words: "Land use model" ($n = 423$), "Land use change model" ($n = 168$), "Land use simulation model" ($n = 23$). This search identified a total of 614 articles, which were successively screened based on their titles, keywords, and abstracts. In order to select the articles according with the aim of this review, we adopted an additional filter for each key word based on the topic "scenarios", which reduced the list of articles to 231, the rest of articles were excluded because they were considered out of the scope of this review.

We did a second search based on the following key words: "Land use change scenarios" ($n = 273$) and "Land use and climate change scenarios" ($n = 32$) that give access to all publications containing those words in their title, abstract and/or keywords in the article. That search identified a total of 305 publications. Duplicated publications were removed and a total of 294 peer review journals were screened as a result of the combination of the two searches.

Most peer review were published in the categories of environmental sciences, ecology and water resources.

For the data analysis based on the aims of the paper, a publication summary was elaborated including the following attributes:
1. Year of publication.
2. Classification of study areas by country.
3. Spatial scale of analysis. We classified the publications according to two different spatial scales of analysis: watersheds and other spatial scales. The publications defined as watersheds were those whose areas of study referred to a region of land within which water flows down

into a specified body such as a river, lake, sea or ocean. We included in the classification of watersheds areas of study such as a basin, river basin, watershed, river catchment and catchment. The publications defined as other spatial scales were those whose areas of study referred from local to global levels (e.g., cities, islands, countries, states, earth system).

4. If land use change and climate change are both jointly analyzed.
5. If the possible synergistic effect between land use change and climate change is analyzed.
6. Methodologies applied to analyze climate change scenarios. The applied methodology has been classified into two groups: global climate models (GCM) and regional climate models (RCM), which increase the resolution of the GCM in a small or limited area of interest.
7. Methodologies applied to analyze land-use change scenarios. The applied methodology has been classified into four groups of models: (1) non-spatial statistical models, (2) spatial statistical models (e.g., Geographic Information System (GIS)), (3) aggregated dynamic models and (4) dynamic spatially distributed models.
8. If the methodologies applied to analyze land use change scenarios do or do not analyze effects on hydrological dynamics.
9. If the methodologies applied to analyze land use change scenarios do or do not analyze effects on nutrient dynamics.
10. If the methodologies applied to analyze land use change scenarios do or do not analyze other environmental effects different to the effects on hydrological dynamics and nutrient dynamics, such as effects on the biodiversity and in the ecosystem services.
11. Land use change scenarios methods. We classified the articles according to two approaches [26,27]: researcher-driven processes and participatory processes. Researcher-driven approaches are experts-driven scenario development. A participatory approach in the scenario development is a process in which stakeholders, frequently guided by researchers, are engaged in a highly collaborative process and develop a leadership role within some or all stages of a scenario development process to investigate alternative futures.

The analysis and assessment of this review focused on a comparative study of all these attributes in articles using the social-ecological system of watershed as spatial scale, versus articles using other different spatial scales of analysis.

4.1.3. Results

Of the 294 articles that were found to include scenario analysis of land use change, nearly half (49%) analyzed the changes at watershed scale. These articles focusing on watersheds are relatively recent, especially when considering the joint study of land use change with climate change and/or analysis of the synergistic effect of both processes (Fig. 4.1). In the last decade of the analyzed period, 79% of the articles on land use change scenarios in watersheds were published. More than half of the publications also discussed the climate change (72%). The synergistic effect of both processes (80%) were published in the last six years (2014–2019). The data indicate that recent advances in research and/or changing research priorities may provide more complete knowledge about the likely trajectories of land use change under different scenarios and their synergistic effect with climate change at a watershed scale.

Only 47% of these articles of land use change at the watershed scale also analyzed the process of climate change. In this group, most cases applied regionalized climate change scenarios (68%) compared to global scenarios (32%), possibly due to the increasing availability of regionalized scenarios. Of articles at the watershed scale that also address climate change, more than half (52%) analyzed the synergistic effect between the two processes of global change. Moreover, the evolution over time of these group of articles is rising, although there is a small recession in the last two years (2018 and 2019) (Fig. 4.1).

As for the methodology applied to analyze scenarios of land use changes in watersheds, dynamic spatially distributed models were used more often than spatial statistical models (Table 4.1). Among the dynamic spatially distributed models the most used were the hydrological models (83%). Specifically, the SWAT model was used in 28% of the reviewed articles. The consideration or lack thereof of climate change did not significantly alter the overall distribution of applied methodological approaches (Table 4.1).

Moreover, in order to know the methodological approach of the models (sectoral or integrated approach), we identified what kind of land use change effects were considered in the reviewed papers, including effects on hydrological dynamics, nutrient dynamics and other different potential environmental effects that may affect the sustainability of the watershed socio-ecological system. Most papers evaluated the hydrological dynamics effects (75%), and there was less frequent analysis of the effects on the dynamics of nutrients (26%) and other environmental attributes (28%), mainly the loss of biodiversity and ecosystem services. Again, the consideration or lack thereof of climate change did not substantially alter the type of analyzed effects.

Most of these publications (86%) evaluated these impacts in the watershed with a sectoral (hydro-ecological discipline) approach. The percentage of articles analyzing the hydrological dynamics effects without considering other possible effects in the watershed were 67%, although the analysis of the effects on the dynamics of the nutrients in the watershed was accompanied by the study of the hydrological dynamics effects in most cases (65%), especially when taking into account the synergistic effect of climate change (91%). Moreover, the study of other environmental effects was accompanied by the study of the hydrological dynamic effects in the 35% of the articles. The analysis of hydrological and nutrient dynamics effects along with other different environmental effects in the watershed was studied in just 2% of the publications, where the watershed was analyzed as a social-ecological system.

These results indicated that there were few integrated approaches, and the analyses were focused primarily on the hydrological dynamics effects of the watershed, versus an integrated and more interdisciplinary approach.

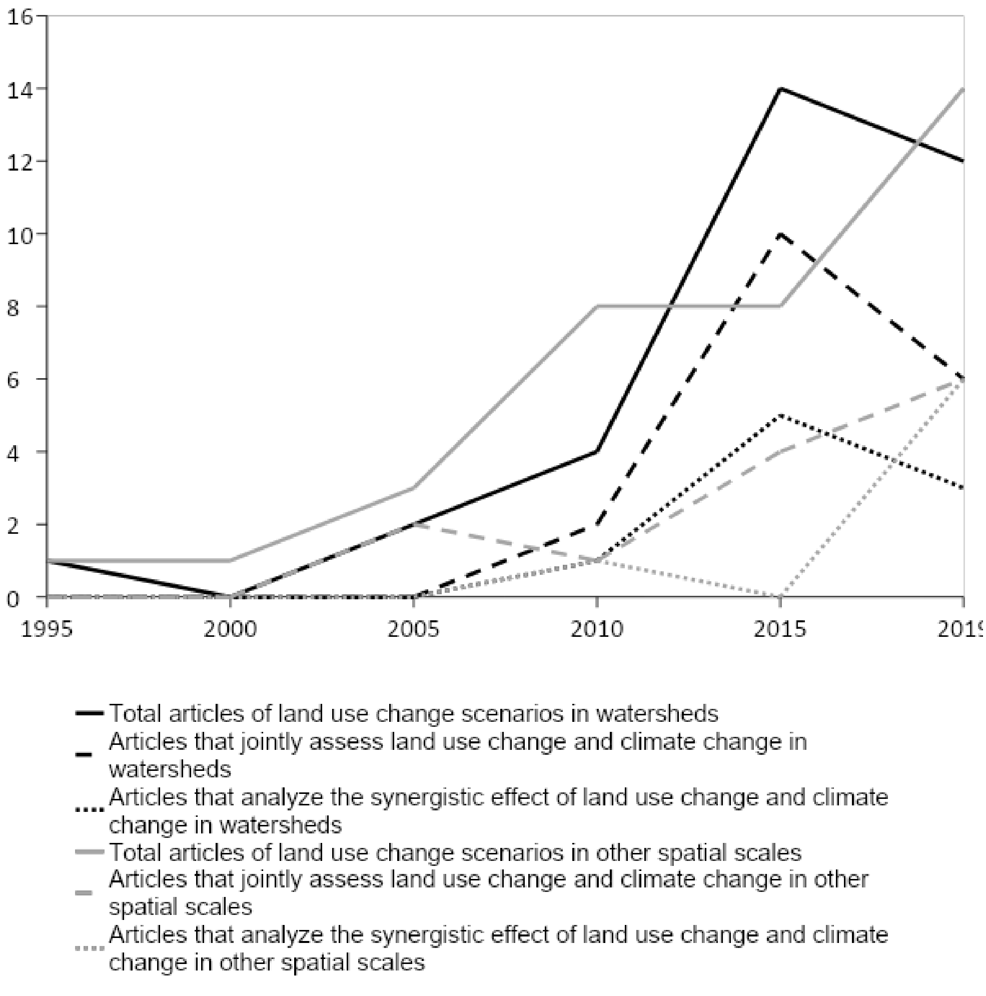

Figure 4.1. Number of publications in the analysis of land use change scenarios. 1995–2019.

Table 4.1. Models classification applied in the analysis of land use change scenarios in watersheds.

Models Classification	Number of Total Articles in Watersheds	Number of Articles of Land Use Change and Climate Change Jointly Analyzed in Watersheds	Number of Articles of Synergistic Effects of Land Use Change and Climate Change in Watersheds
Non-spatial statistical model	4	0	0
Spatial statistical model (e.g., GIS)	14	5	5
Aggregated dynamic model	0	0	0
Dynamic spatially distributed model	119	59	30
Other methodologies	6	3	0
Total	143	67	35

The articles that have analyzed land use changes scenarios in other spatial scales were placed together on a percentage slightly higher to that of watershed (51% of the 294 reviewed publications). More than 50% (specifically, 53%) of these articles were also published in the period 2014–2019 (Fig. 4.1).

Notably, only 28% of these articles analyzed the process of climate change, a much lower percentage than in the case of watersheds (47%). Moreover, only 48% of these cases used regionalized climate change scenarios. Just as in watersheds, 67% of the publications that took into account both processes of global change, were published in the last six years, from 2014 to 2019 (Fig. 4.1). The study of the synergistic effect of land use change and climate change was discussed only in seventeen studies (39%) and 81% of these studies were published in the last four years (2016–2019) (Fig. 4.1).

In relation to the methodology used in the analysis of scenarios in other spatial scales, it is noteworthy that although the dynamic spatially-distributed models remained the most common method, their use was not as major as in the case of the analysis of land use change scenarios in watersheds (Table 4.1). The spatial statistical models rose to 59% in the articles analyzing the synergistic effects of land use change and climate change (Table 4.2).

Unlike the analysis of land use change scenarios in watersheds, most of these publications in other spatial scales assessed other environmental effects (87%) compared to the effects of hydrological dynamics (9%) and nutrients (3%). The consideration or lack thereof of climate change did not substantially alter the type of effects analyzed. The approach for the analysis of scenarios in other spatial scales was totally sectorial and cases studies were not analyzed within the social-ecological framework. Overall, 95% of articles studying other environmental effects on scenario analysis did not take into account the effects on the hydrological dynamics and nutrients.

The participation of stakeholders in the process of building land use change scenarios was only collected in twelve articles (Table 4.3) and 50% of these articles have been published recently in the last four years (2016–2019). Most of the articles (95%) developed land use scenarios with researcher-driven approaches [4,28–33], where the experts drove scenario development with an objective of providing rigorous descriptions of plausible futures, including details that are well supported by available science.

Table 4.2. Models classification applied in the analysis of land use change scenarios in other spatial scales to watershed.

Models Classification	Number of Total Articles in Other Spatial Scales to Watershed	Number of Articles of Land Use Change and Climate Change Jointly Analyzed in Other Spatial Scales to Watershed	Number of Articles of Synergistic Effects of Land Use Change and Climate Change in Other Spatial Scales to Watershed
Non-spatial statistical model	26	4	0
Spatial statistical model (e.g., GIS)	26	11	10
Aggregated dynamic model	1	0	0
Dynamic spatially distributed model	72	24	7
Other methodologies	26	4	0
Total	151	43	17

Table 4.3. Articles with a participatory approach in the land use change scenarios development.

References	Spatial Scale	Land Use Change and Climate Change Jointly Analy-zed	Synergis-tic Effect of Land Use Change and Climate Change	Methodolo-gy to Study LUC	Effects on Hydrologi-cal Dynamic	Effects on Nutrients Dynamic	Other Environ-mental Effects
Mancosu, E. et al. 2014 [34]	Catch-ment	YES	NO	Dynamic spatially distributed models	YES	NO	NO
Harmáckov á, Z.V. and Vacka, D. 2015 [18]	Basin	NO	NO	Dynamic spatially distributed models	NO	YES	YES
Ronfort, C. et al. 2011 [35]	Water-shed	NO	NO	Dynamic spatially distributed models	YES	NO	NO
Rickebusch, S. et al. 2011 [36]	Regional	NO	NO	Spatial statistical model	NO	NO	YES
Castella, J.C., Verburg, P.H. 2007 [37]	Local	NO	NO	Dynamic spatially distributed models	NO	NO	YES

van Noordwijk, M. et al. 2001 [38]	Local	NO	NO	Dynamic spatially distributed models	NO	NO	YES
Kim, Y.S. et al. 2018 [39]	Local	NO	NO	Dynamic spatially distributed models	YES	NO	YES
Lippe, M. et al. 2017 [40]	Local	NO	NO	Dynamic spatially distributed models	NO	NO	YES
Sherrouse, B.C. et al. 2017 [41]	Local	NO	NO	Spatial statistical model	NO	NO	YES
Benini, L. et al. 2016 [42]	Basin	YES	YES	Dynamic spatially distributed models	YES	NO	NO
Trisurat, Y. et al. 2016 [43]	Water-shed	YES	NO	Dynamic spatially distributed models	YES	NO	NO
Min, F. et al. 2016 [44]	Water-shed	YES	NO	Dynamic spatially distributed models	YES	YES	NO

4.1.4. Discussion

The interest of current studies of land use change, beyond a mere descriptive representation in form of maps analysis, focuses on a more dynamic modeling for understanding the past, monitoring the current situation, and predicting future trajectories [45,46]. The review conducted confirms this and shows that there are numerous models of land use that allow us to explore the dynamics of changes and analyze future scenarios that may be useful to support land use planning and policy development [15,47,48]. In the following subsections, we return to the questions posed in the Introduction.

1. Extent to Which the Environmental Dynamics of Land Use and Climate Change Were Analyzed Jointly and Spatial Scales Associated with Such Integrated Studies.

The results of the review show that although many papers have analyzed the dynamics and influence of land use change, e.g., [34,49–51] or climate change, e.g., [52–55] on a particular natural or social-ecological system, the papers that jointly assess both environmental processes are less frequent and very recent (past decade, Fig. 4.1), particularly those that analyze its synergistic effect, e.g., [4,33,56–58]. The evolution of the number of articles on land use change over time has had an upward trend in the past two decades (Fig. 4.1) and more than half of the articles that also take into account climate change analysis have been published in just the last six years of the analyzed period (Fig. 4.1) [33,59]. Therefore, this joint assessment is still fairly recent in spite of scientific reports, such as the Science plan of the Global Land Project [60], which in 2005 highlighted its importance for the sustainable management of social-ecological systems. The scientific literature in this review has demonstrated that the combined effect is much greater than the individual effects, with examples in water resources and the hydrological dynamics. Publications such as Chung, E.S. et al. 2011 [61]; Lopez-Moreno, L.I. et al. 2013 [62] and Mehdi, B. et al. 2015 [3] made the case that the environmental synergistic impact of both environmental processes is much greater than the sum of individual impacts.

The joint study of land use change and climate change varies according to the spatial scale of analysis. In watersheds, it has been taken into account in almost half of the reviewed articles (Fig. 4.1), and half of these also assess the synergistic effect of both environmental processes, especially on the hydrological dynamics and water resources of the watershed [3,29,33,63,64]. When analysis is made in other spatial scales, the analysis with climate change only constitutes a quarter of the reviewed articles. Of those articles, the interaction and the synergistic effect of both environmental processes is evaluated in 39% of the articles [32,33,65–67]. As already noted in [68], the synergies between land use change and climate change are insufficiently addressed. Moreover, recent publications emphasize the importance of assessing the synergistic effect of both, climate and land use change processes at sub-global scales [4,32,33,62].

On the other hand, watersheds are a perfect example of a socio-ecological system [69,70] dynamic, open and complex, in which its biophysical components are combined with the characteristics of economic systems, and the demographic patterns and sociocultural dynamics of the population that inhabits them. To address the inherent complexity of SES, an integral approach is required [71]. However, despite the increasing acknowledgment of the need for holistic approaches, the results in this review point out that their application in real socio-ecological systems is less frequent than would be desirable.

In relation to the scale of analysis, land use changes have direct effects on important components of sustainability, such as the connectivity of natural areas or biodiversity within the territory/landscape, attributes which can be studied at multiple spatial scales [66,67]. However, relative to a territorial analysis using administrative boundaries as study unit, the application of ecological and other functional criteria as units of analysis, within watersheds, promotes the integration of goods and services produced by ecosystems [72–74]. Apparently for this general reason, watersheds were the dominant spatial scale of analysis, used in nearly half of the reviewed articles (Figure 1). Although in the last two years (2018 and 2019) the analysis of watersheds decreased lightly, we can point out that the watershed is considered the most successful spatial scale for integrated management of natural resources, especially water [75]. In this regard, it should be noted that only a small percentage of reviewed publications in other spatial scales analyze the effects of land use changes on water resources, corresponding, in some cases, with islands [76,77], possibly because the islands are also units with well-defined natural limits and where land use change effects can be easily recognized in the whole system, including water resources [78,79].

However, using the watershed as a spatial scale and as a social-ecological system not only allows addressing resources such as water and land within an optimum geographical context, but also provides a spatial framework for the integration of relevant biophysical aspects with socio-economic aspects [18,80]. In fact, the analysis of land use change and all the direct and indirect effects that result may not be so obvious depending on the spatial scale of the analysis.

There are indirect effects of land use change that are only disclosed at a watershed scale [81]. Indeed, among the direct effects of land use change are included the alteration of water flows, alteration which in turn results in indirect effects on other components such as aquatic ecosystems, natural spaces, maintaining wetlands or biodiversity. For example, cases studies such as the Mar Menor social-ecological system (SE, Spain) show how land use changes, particularly the increased irrigation in the watershed, have increased water and nutrient flows into the Mar Menor lagoon and its wetlands. This high input of nutrients into the lagoon has caused serious ecological impacts on the species and habitats, the loss of the traditional transparency of the waters, and important damages to the tourist quality and other ecosystem services [81–84].

These indirect effects are barely addressed by our reviewed scientific literature, although we can highlight the work of Santos, R.M.B. et al. 2015 [57], which uses a range of scenarios to evaluate the impact of land use and change and climate change on the conservation of a species, the mollusc *Margaritifera margaritifera*, which depends on specific river flows and depth conditions. Instead, most of the case studies of our reviewed scientific literature analyze the direct effects, such as the hydrological ones, but not the indirect effects that these hydrological effects cause on other components such as the biodiversity. Therefore, the indirect impacts remain underestimated or not considered.

Furthermore, the analysis of watersheds as a social-ecological system implies having an integrated knowledge of the relationships between its natural and social components. Farhad, 2012 [85] points out that only a multidisciplinary analysis can jointly conceive these different natural and social aspects, focusing not only on the components of the system, but also on their relationships, interactions and feedbacks, thus having a deeper understanding of the system. Interactions in social-ecological systems are continuously changing due to feedbacks and internal or external factors (e.g., land use change and climate change), taking place across different temporal and spatial scales, making social-ecological systems highly dynamic systems [10]. The approach of the analysis of watershed in this review confirms that the holistic approach and its application in social-ecological systems has not been applied in most cases. Among the difficulties behind this, the need for a new conceptual perspective concerning the relationships between science and the management of real social-ecological systems, as well as the lack of tools to manage the inherent complexity of such systems, should be emphasized. However, to manage complex socio-ecological systems using partial approaches or linear causal thinking may provide unrealistic or, at least, questionable results [86].

2. Modeling Methodologies and Approaches Used in the Scenario Analysis.

In relation to the methodology, there are differences depending on the spatial scale of analysis. The analysis of land use change scenarios at the watershed scale is made with dynamic spatially distributed modeling in more than 80% of the articles (Table 4.1). Among these models, hydrological models are the most used, particularly the SWAT model (Soil and Water Assessment Tools), because of the wide variety of environmental conditions that may be applied [64,68]. In other spatial scales, dynamic spatially distributed models remain the most common, but not as common as watersheds, also spatial statistical models (e.g., GIS) are often applied (Table 4.2). The approach of dynamic spatially distributed models is generally sectoral (discipline-specific) in any of the spatial scales, especially in the different spatial scales to watersheds. In watersheds, this approach focuses on the effects that land use change has on the hydrological functioning of the watershed, such as water flows [45,87,88] and nutrients [89,90], which in turn translate into changes on different subsystems of the watershed (drainage, aquifers, wetlands, river, lake or final receiving system of water flows).

In publications focusing on different spatial scales to the watershed, the sectoral approach focuses on other environmental effects such as loss of biodiversity and ecosystem services [51,91,92]. The trend in the use of dynamic spatially distributed models has been rising throughout the analyzed period, principally within the last decade. The use of dynamic spatially-distributed models that integrate across disciplines is increasingly recognized to be an informative approach to best understand and evaluate trends of socio-ecological dynamics under a range of future scenarios, with examples of such research/modeling goals in the Everglades, USA, watershed [93], and more broadly with respect to the integration of social and ecological processes across a range of scales to better simulate land use changes in general [94]. While NRC 2014 [94] provides a comprehensive suite of recommendations, we note that their review did not explicitly address the range of uncertainties and complexities associated with climate change.

Dynamic models, unlike statistical models, can conceptualize the complex interrelationships that characterize social-ecological systems and to facilitate their understanding and monitoring [95,96]. Furthermore, dynamic spatially distributed models with integrated approaches have the advantage of being able to integrate different processes, scales, variables, and the possibility of generating configurations with stakeholders within the framework of participatory modeling processes [88]. This becomes a potential for interdisciplinary planning and management processes in SES, particularly for the support decision-making processes at the local level. However, in this review, we can highlight few cases using dynamic spatially distributed models for integrated approaches [57,97–100].

3. Methods for Developing or Building Scenarios.

Regarding the development of land use change scenarios, some studies [23,101,102] point out that scenario planning in environmental research and the management of natural resources has become more participatory. However, in this review, just 4% of the articles apply a participatory approach in the development of land use scenarios [18,43].

In many articles of this review, scenario creation is expert- and/or model-driven, and researchers make the case for their utility to end users [33,45]. This is problematic in a case with high stakes and high uncertainty, as with land use [24]. Westervelt, J. et al. 2011 [103] point out that decision makers often prefer their own judgment to model results, highlighting the need for a model to be transparent and simple. However, using a participatory approach can partly relieve this issue. Stakeholder and public participation legitimize the process and justifies the use of the outcomes for planning and decision-making [23]. Reed et al. 2013 [104] point out that participatory scenario development has the potential to make scenarios more relevant to stakeholder needs and priorities, extend the range of scenarios developed, develop more detailed and precise scenarios through the integration of local and scientific knowledge and move beyond scenario development to facilitate adaptation to future change.

A key issue in scenario-building methods is the integration of stakeholder-derived qualitative data (typically in the form of a storyline) into models that require quantitative data to produce the final output [105]. Still, these participatory approaches are rarely spatially explicit, making them difficult to apply. Walz et al. 2007 [106] point out several drawbacks and limitations of stakeholder participation in scenario development. For example, local knowledge is not always sufficiently robust or detailed enough to provide information about relationships between system components, necessary for scenario quantification. Reed et al. 2013 [104] highlight that effective stakeholder participation in scenario development is likely to take extra time and resources, requiring integrating diverse types of knowledge, and the success of this participation is likely to depend on the quality of the process design and effective representation of stakeholder interests.

All these limitations could explain the low percentage of land use scenarios with participatory approach in this review. Therefore, Booth et al. 2016 [107] and Mallampalli et al. 2016 [108] highlight that applications of land-use scenario processes are still in the early stages of learning how to effectively combine stakeholder and scientific (model-based) inputs. Participatory scenario development still requires greater systematic monitoring and evaluation to assess its impact on the promotion of collective action for transitions to sustainability and the adaptation to global environmental change and its challenges [101]. However, involving stakeholders in scenario development can bring significant benefits to both stakeholders and researchers, leading to the development of more consistent and robust scenarios.

4. Recommendations for the Future.

Based on results from this review we identify the following issues that we think need to be addressed in the study of land use change scenarios on natural and social-ecological systems: (1) to work in the complex interface of ecological and social systems, which is where policies concerning land use are developed. In turn, this involves integrating the social and natural sciences, and there is a growing agreement that transdisciplinary research is a key approach in facing environmental challenges. Hence, there is a need to expand the boundaries of the studied cases towards the social-ecological systems, (2) to integrate multiple processes and driving forces such as climate change, operating at different spatio-temporal scales, (3) to develop models to apply integrated approaches incorporating biophysical and socioeconomic factors and (4) to promote participatory approaches in the scenario development, integrating both types of knowledge, scientific and local. Progress in these deficiencies could improve the use of predictive tools in decision-making processes to contribute to sustainability goals.

4.1.5. Conclusions

In recent decades, there has been a breakthrough in the development of models to simulate land use change at different spatial scales and under different future scenarios, covering issues such as the expansion of agriculture, abandonment of farmland, deforestation, as well as growth and urban sprawl, among others. However, the papers that assess land use change jointly with climate change are less frequent and very recent, particularly those that analyze their synergistic effect.

Land use change and climate change are two main components of global environmental change that must be analyzed jointly. Recent research confirms and emphasizes the importance of assessing the synergistic effect of both processes, since it has been demonstrated that the combined effect is much greater than the individual effects. This issue is still insufficiently addressed by the reviewed scientific literature, although an upward trend has recently observed in the number of publications, with some variation depending on the spatial scale of analysis.

The results presented also confirm that the analysis of land use change and its direct and indirect resulting effects may not be as obvious, depending on the spatial scale of analysis. The direct effects of the connectivity of protected natural areas and biodiversity within the territory/landscape can be analyzed at a variety of spatial scales, whereas the direct effect on water resources and the indirect effects they generate on other important components of sustainability, such as aquatic ecosystems, natural areas, maintenance of wetlands, biodiversity and ecosystem services, are only revealed at the watershed scale. In addition, watersheds are social-ecological systems that offer two other advantages: they favor the integration of goods and services produced by ecosystems and provide a spatial framework for the integration of relevant biophysical aspects with socio-economic aspects.

From our review, we saw that a common methodology used to analyze land use change scenarios and their impacts on different territorial units is that of dynamic spatially distributed models.

Overall, the models use a sectoral approach, focusing primarily on the study of hydrological dynamics, in the case of watersheds, and other possible environmental effects, such as loss of biodiversity, in the case of other different spatial scales. In this regard, it is necessary to promote more integrated approaches through models incorporating biophysical and socioeconomic factors and also to take into account land use change, climate change and their synergies. The development and application of methodologies for integrated modeling will certainly help develop such a systemic integrated knowledge of the territory. This will facilitate the understanding of the implications of land use changes not only in the functionality of the watershed, but also in other aspects of sustainability.

Finally, in spite of the fact that the literature reviewed does not show many articles with a participatory approach in land use change scenario development, this approach can be a useful and powerful tool to facilitate the sustainable management, because such approaches draw on multiple sources of knowledge to accurately describe complex social-ecological processes and because stakeholder participation can yield more effective and resilient decisions. Active involvement of the wider stakeholder community can play a crucial function in the better consideration of problems by identifying different stakeholder perspectives, provide an active learning arena for all those involved, and offer the interactive basis necessary for generating joined-up thinking.

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4.2. The social-ecological system of the Mar Menor. A qualitative modeling as a basis for developing an integrated diagnosis

The study of cases in which there are interactions between humans and nature, such as the SESMM, is of special importance for the observation and modeling of sustainability, due to the impacts that anthropogenic activities generate on the environment (Paolini 2013). In this sense, tools such as dynamic simulation models often have a first stage of conceptualization and qualitative modeling, then a second stage of quantitative modeling that is specific to the SES dynamics (Forrester 1994; Meadows et al. 1972; Sterman 2000; Martínez-Moyano and Richardson 2013). Such an approach allows conceptualizing the complex interrelationships that occur in SES, facilitating their understanding and monitoring (Martínez-Moyano and Richardson 2013; Kelly et al. 2013).

However, the review of the scientific literature previously carried out indicates that the modeling of SES with an integrated approach, that explicitly considers land use changes or management decisions, remains insufficiently addressed (Nemec & Raudsepp-Hearne 2013; Guaita et al. 2020); this is an equally pending challenge in the case of the integrated dynamics of Mediterranean basins (Martínez Fernández et al. 2013). Although in this sense, the effort of the European Coastal research project initiated in 2018 (Horizon 2020 program) deserves special attention, because of the development of dynamic models by economic sectors in collaboration with stakeholders to improve rural-coastal synergies and decision-making in different SES of the EU.

Based on that background, this work prioritizes the development of a qualitative socio-ecological model that has an integrated approach, versus more complex/involved quantitative modeling, in order to: 1) understand the environmental and socio-ecological interrelationships that affect the state of the SESMM, and 2) provide a synthetic, but integral, broad-scale vision of the Mar Menor problem to the different stakeholders and the local community. A description of the main biophysical and socioeconomic features of the SESMM, as well as the applied methodology for the elaboration of the diagnosis and results are detailed below.

4.2.1. The Mar Menor socio-ecological system. Main biophysical and socioeconomic characteristics

The Mar Menor is located in the Region de Murcia (SE, Spain) (Fig. 4.2) and it is the largest and most unique coastal lagoon in the western Mediterranean, as well as a biodiversity *hotspot* (León and Bellido 2016; Giménez and Gomaríz 2013). The Mar Menor and its surroundings have been considered as a social ecological system (SES) (Folke et al. 2003). According to this concept, social and natural systems are strongly interconnected due to the historical co-evolution between them. In the Mediterranean context, human societies have shaped nature for thousands of years and in turn nature has shaped the development of human societies (Grove and Rackham 2003). We understand the Mar Menor and its surroundings as a set of social processes deeply interconnected with the ecosystems from which it obtains a multitude of natural resources and services. When we talk about the Mar Menor social ecological system (SESMM) we refer to a spatial entity whose limits are defined by biophysical and social criteria. The biophysical limits are marked by the ecosystem of the coastal lagoon, the surrounding wetlands and the hydrographic sub-basin, which together offer a variety of natural resources and ecosystem services to society (León and Bellido 2016; Mar Menor Scientific Advisory Committee 2017).

The lagoon has an area of 135 km^2, a capacity of 580 hm^3 and a maximum depth of around 7 m. It is a lagoon almost closed by a strip of sand 20 km long and between 100 and 1,200 m wide called La Manga del Mar Menor, with a restricted connection with the Mediterranean Sea through some small natural channels or gullies. In its perimeter it has 73 km of coastline. Inside the lagoon there are five volcanic islands, two of them classified as Major Islands: Perdiguera and Barón Islands, located in the central area of the lagoon and three of them considered the Minor Islands: Rondella, del Sujeto and del Ciervo, located in a grouped way in the southern part of the lagoon. All of them are protected and integrate five scenic landmarks of exceptional interest. The shallow depth of the lagoon causes temperature changes to be poorly dampened and directly dependent on weather conditions. These sudden and drastic changes in temperature mean that it only allows the life and reproduction of a few fish species, although of great abundance, such as mullet, bream and magres (Ballester et al. 2003). The species that have shaped and structured the submerged landscape are euryhaline (tolerant to changes in salinity) and eurythermes (tolerant to changes in temperature). In the lagoon there are also several vulnerable fish, bivalve, and plant species protected at national and international level such as the fartet (*Aphanius iberus*), the nacra (*Pinna nobilis*), the seahorse (*Hippocampus guttulatus*), and other relevant ones such as the seagrass meadows (*Cymodocea nodosa* and *Rupia cirrhosa*) (Robledano et al. 2003 and Martínez et al. 2003). Species such as *Mergus serrator* or *Tadorna* are representatives of the aquatic birds (Esteve and Robledano 2003).

The ecological value of the lagoon and its surrounding wetlands has been recognized by several protection entities at regional, national and international levels: San Pedro del Pinatar Regional Park, Protected Landscape of Open Spaces and Mar Menor Islands, ZEPA (Zone of Special Protection for Birds), SCI (Site of Community Importance), Ramsar area (Wetland of International Importance of the Ramsar Convention) and ZEPIM (Specially Protected Area of

Importance for the Mediterranean). The wetlands surrounding the lagoon are typified as littoral crypto-wetlands (Saladar de Punta de Lomas, Saladar de lo Poyo, Marina del Carmolí), wetlands with active salt flats and micro-tidal marshes (Humedal de las Salinas de Marchamalo, Humedal de las Salinas de San Pedro del Pinatar) (Vidal et al. 2003). These wetlands cover an area of approximately 1,000 hectares with high biodiversity (Robledano et al. 2010). The location of the wetlands between the watershed and the lagoon plays an important environmental role in the retention and elimination of nutrients, which contributes to reducing their entry into the lagoon, thus reducing the risk of eutrophication (Esteve et al. 2008, 2016). Located in an arid environment, these wetlands experience conditions of hypersalinity and limited overland sheet flow, which makes them very vulnerable to hydrologic changes, while giving rise to a unique biodiversity and are considered rare in the European context.

The Mar Menor watershed has an area of 1,270 km^2 and is drained by a set of 20 ephemeral watercourses locally called “ramblas” that flow into the Mar Menor lagoon (Fig 4.2). The area has an arid Mediterranean climate characterized by mild and dry conditions. Rainfall is very scarce and does not exceed 300 mm per year in much of the territory, with a great interannual variation. As in other Mediterranean basins, precipitation occurs in autumn and winter in a torrential manner (David et al. 1997; Xue et al. 1998), which makes the ramblas that discharge into the lagoon mostly dry during the year, but flow with great intensity during these episodes of rain. The average annual temperature is 15 ° C to 17 ° C (Martínez et al. 2003).

The social limits of the SESMM are marked by those municipal entities whose economy depends directly or indirectly on these ecosystems. For this purpose, the municipalities of San Pedro del Pinatar, San Javier, Los Alcázares, Torre Pacheco, Cartagena, Fuente Álamo and La Unión, belonging to the areas of Campo de Cartagena and Mar Menor are identified. These municipalities increased to a combined total of 357,266 inhabitants in 2017. The demographic evolution of the SESMM shows, until a few years ago, a clear growth trend, which is explained in certain stages by vegetative growth and in others by the influx of immigrants. Between 1950 and 2017 the population has more than doubled, from 158,000 to more than 350,000 inhabitants. Especially noteworthy are some cases such as those of San Pedro del Pinatar, which multiplied its population almost 5 times in the same period of time, or those of San Javier and Torre Pacheco, whose inhabitants increased more than three times (Integrated Management Strategy of the Zones Coastal of the Socio-Ecological System of the Mar Menor and its surroundings, 2020).

The SESMM has had changes in its landscape since the Middle Ages due to the presence of human activity and over the past centuries has supported numerous economic activities such as fishing, rain fed agriculture and the salt industry. These activities have had a clear setback in the last century due to the appearance of new human activities and more intensive exploitation of the environment. Currently, the main uses and activities happening in the SSEMM are intensive irrigated agriculture, urban-tourism development, and some fishing activity.

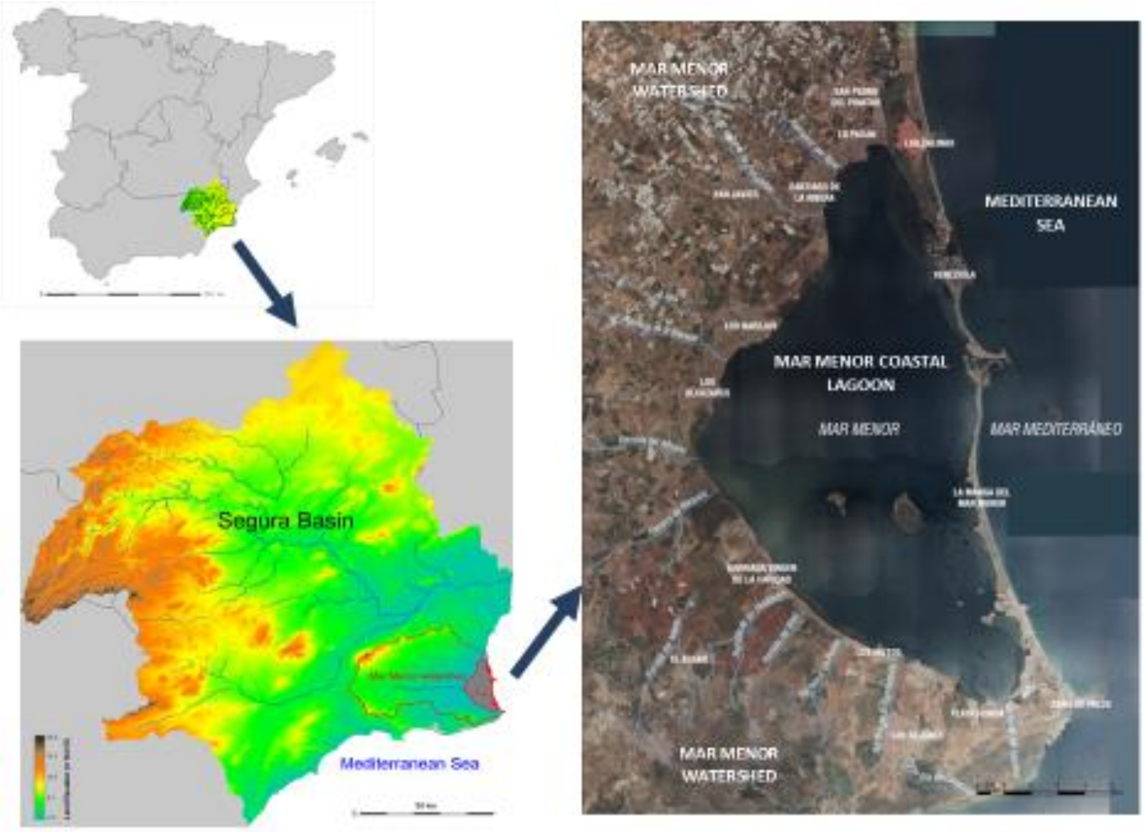


Figure 4.2. Location of the SESMM. Source: Own elaboration from the image obtained from the National Geographic Institute.

4.2.2. Methodology

Towards those objectives, we reviewed a range of scientific and technical publications in the study area (bibliographic review, including Martínez-Fernández et al. 2009; Carreño 2015; Esteve Selma et al. 2016; Vidal et al. 2003; León and Bellido 2016 and Mar Menor Scientific Advisory Committee 2017), and from January-April 2017 we conducted twenty structured interviews with scientific-technical experts from environmental, social, economic and institutional disciplines (Appendix II).

For the development of the model, we used the DPSIR (driving forces, pressure, state, impact, response) methodological framework (EEA 1999, taken from the OECD initiative, 1993). This model is a powerful tool for analyzing the interrelationships between socio-economic dynamics and environmental impacts that affect sustainability. This approach takes into account the *driving forces*, which exert different *pressures* on the environment and the environmental and natural resources, altering their initial *state*. The change in the *state* translates into an *impact* when a deterioration of ecosystems, resources and associated uses and services is perceived. Society can activate a *response* to these impacts, trying to correct the negative trends detected. This response can be directed to correct the driving forces, reduce the resulting pressures, or mitigate or adapter to impacts.

The DPSIR model was applied to describe the narrative of the conceptual model and build a qualitative model of the SESMM using the Vensim software (Ventana System 2011), incorporating the most important socio-ecological variables of the system, as well as their main interactions. Among other results, the structure of the model revealed the existence of different feedback loops that govern the behavior of the system. Although the model incorporates a high interaction between all the variables and sectors, the analysis focused on three different sectors:1) urban-tourist development, 2) intensive irrigated agriculture (both sectors which constitute the main uses and activities developed in the SESMM), and 3) the ecological status of the lagoon. Figure 4.3 explains how the complexity of these systems emerges from non-linear relationships between components and the existence of feedback loops (closed circuits of cause-effect relationships between variables) (Vennix 1996), which justifies that the definition of the model goes further of the linear DPSIR schemes.

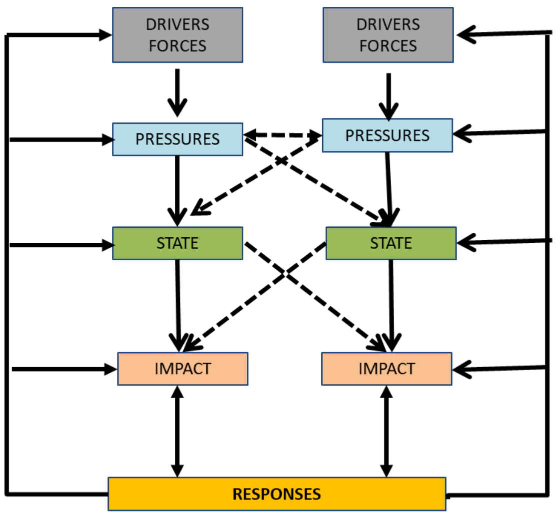


Figure 4.3. Conceptual framework which describes the relationships within the components of the DPSIR scheme.

4.2.3. Results

The complexities of the SESMM were described at several levels using the DPSIR framework. The initial, high-level, summary shows that there are a large number of variables (or factors) associated with the complete problem. Figure 4.4 presents those factors identified as main driving forces, pressures, state and impacts in the SESMM.

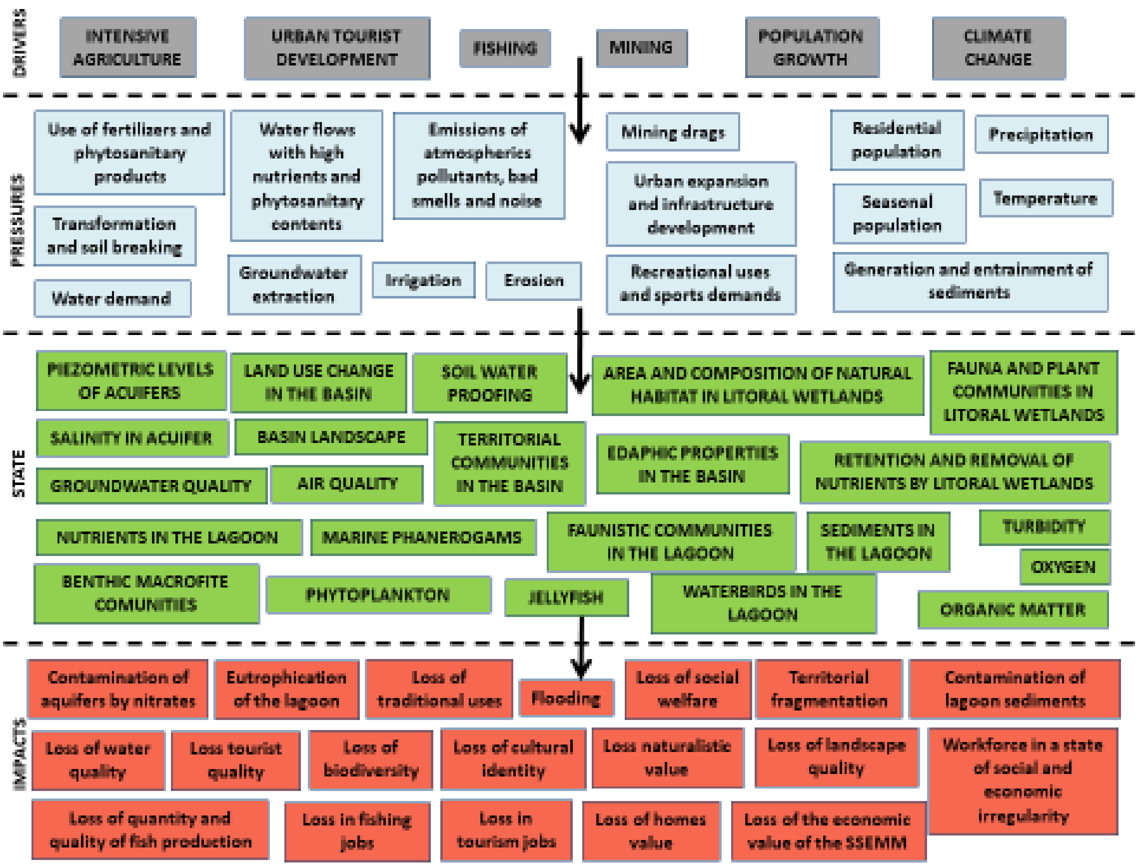
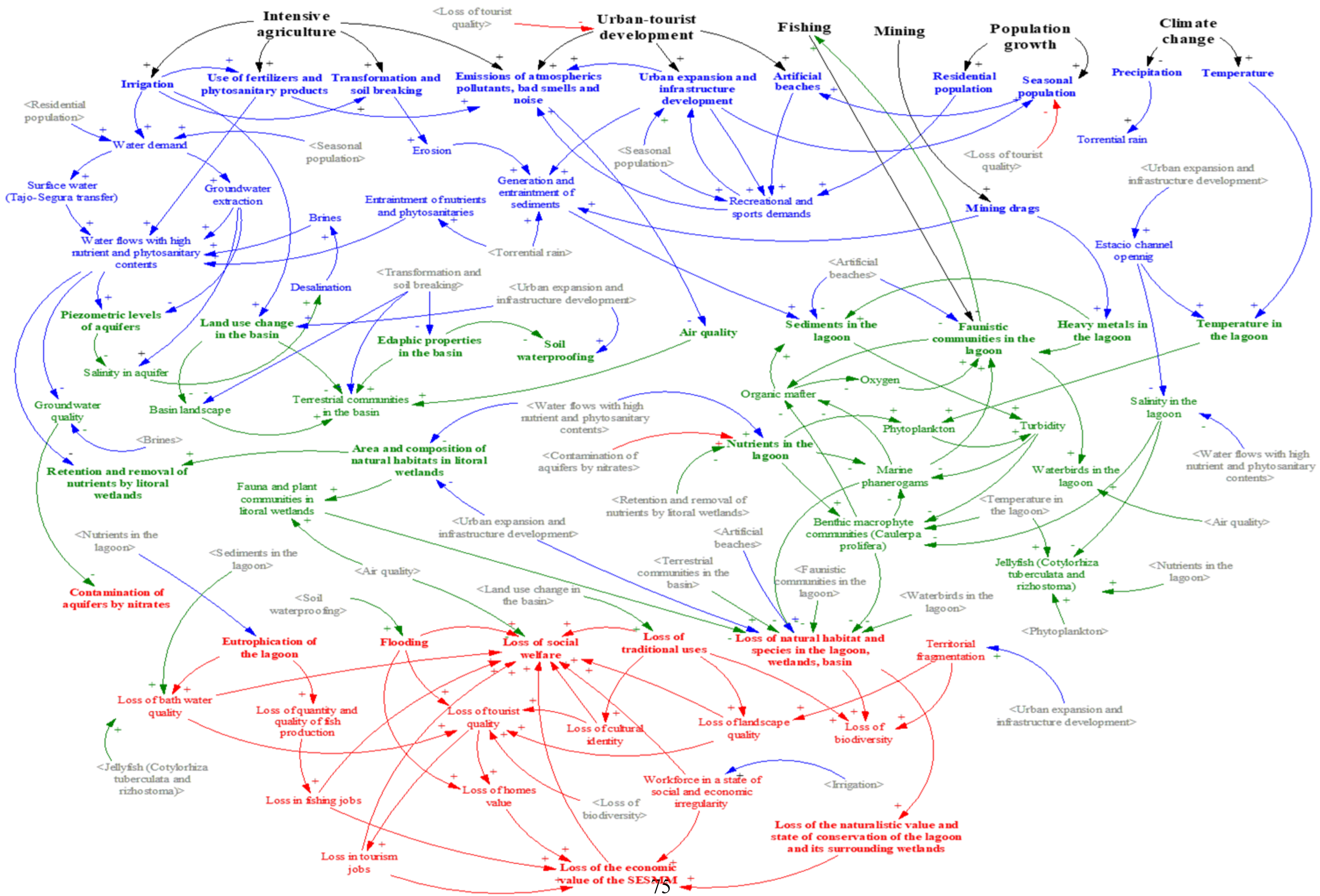


Figure 4.4. Socio-ecological system model for the Mar Menor (SESMM) within the DPSIR conceptual framework.

The qualitative interactions among these factors were formulated from the extensive prior (bibliographic and interview) research, and summarized in the overall conceptual model of Figure 4.5, showing the different relationships and interactions among these factors. There are a large number of factors that interact in a complex fashion, and clearly would be best understood by evaluating subsets of the overall model. Thus, following this broad graphical conceptual model overview, a detailed synthetic (text and graphical) diagnosis of the three model sectors (urban-tourist development, intensive irrigated agriculture and ecological status) of the SESMM is presented.

Figure 4.5. Conceptual model of the SESMM overall, with the main socioeconomic and environmental factors involved in its dynamics and the interrelationships between such factors. In addition, the nature of each of these factors is identified according to the DPSIR scheme, distinguishing the driving forces (black), pressures (blue), state (green) and impacts (red).


Intensive agriculture
Urban-tourist development
Fishing
Mining
Population growth
Climate change
Irrigation
Use of fertilizers and phytosanitary products
Transformation and soil breaking
Emissions of atmospherics pollutants, bad smells and noise
Urban expansion and infrastructure development
Artificial beaches
Residential population
Seasonal population
Precipitation
Temperature
Water demand
Erosion
Torrential rain
Surface water (Tajo-Segura transfer)
Groundwater extraction
Generation and entraintment of sediments
Recreational and sports demands
Mining drags
Brines
Entraintment of nutrients and phytosanitaries
Water flows with high nutrient and phytosanitary contents
Estacio channel opennig
Desalination
Piezometric levels of aquifers
Land use change in the basin
Edaphic properties in the basin
Soil waterproofing
Air quality
Sediments in the lagoon
Faunistic communities in the lagoon
Heavy metals in the lagoon
Temperature in the lagoon
Salinity in aquifer
Terrestrial communities in the basin
Basin landscape
Groundwater quality
Organic matter
Oxygen
Phytoplankton
Turbidity
Salinity in the lagoon
Nutrients in the lagoon
Marine phanerogams
Waterbirds in the lagoon
Retention and removal of nutrients by litoral wetlands
Area and composition of natural habitats in litoral wetlands
Fauna and plant communities in litoral wetlands
Benthic macrophyte communities (Caulerpa prolifera)
Jellyfish (Cotylorhiza tuberculata and rizhostoma)
Contamination of aquifers by nitrates
Eutrophication of the lagoon
Flooding
Loss of social welfare
Loss of traditional uses
Loss of natural habitat and species in the lagoon, wetlands, basin
Territorial fragmentation
Loss of bath water quality
Loss of quantity and quality of fish production
Loss of tourist quality
Loss of cultural identity
Loss of landscape quality
Loss of biodiversity
Loss in fishing jobs
Loss of homes value
Workforce in a state of social and economic irregularity
Loss of the naturalistic value and state of conservation of the lagoon and its surrounding wetlands
Loss in tourism jobs
Loss of the economic value of the SESMM

Urban-tourist development sector

The tourist sector is one of the main economic activities of the SESMM in terms of job creation and GDP (11% in 2017) (García-Ayllón 2018). The urban and tourist expansion experienced since the 60s and 70s has given rise to a great artificialization of the lagoon environment. An increase in the coastal urban occupation of the lagoon (150 m from the coastline), including the whole of La Manga del Mar Menor, has been estimated by 199% between 1956 and 1981 (Mar Menor Scientific Advisory Committee 2017). In recent years it has suffered a new urban boom, rapidly expanding the occupied area (López Morell et al. 2005) (Fig. 4.6).

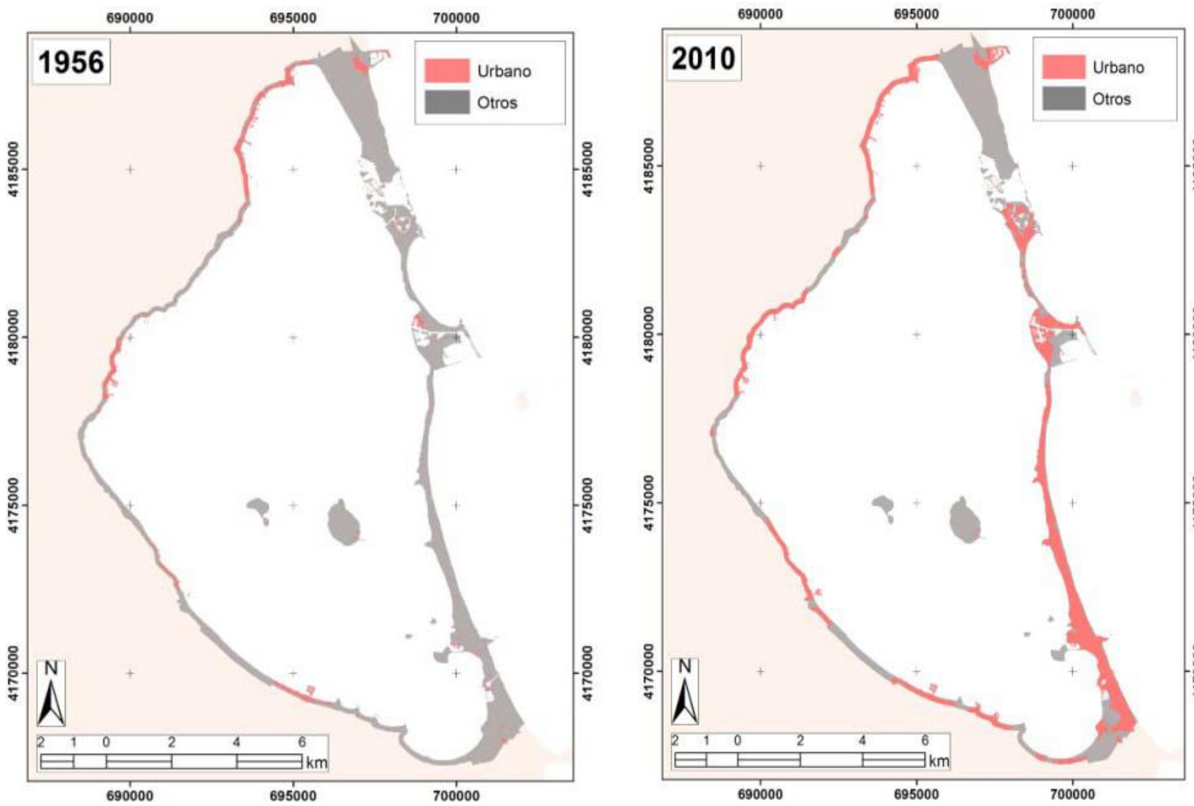


Figure 4.6. Surface of the coastline (150 m from the coastline) for the entire Mar Menor plus the entire La Manga del Mar Menor, highlighting urban use and others, which include: Courses and water surfaces, Road infrastructures, Matorral and/or herbaceous and/or rocky areas, coastal defense and protection works, beaches and dunes, marinas, urbanized surfaces, agricultural uses and coastal wetlands. Made from aerial photographs from 1956 and 2010 (Gomaríz and Giménez 2017) (Mar Menor Scientific Advisory Committee 2017).

The Mar Menor Scientific Advisory Committee (2017) pointed out that the number of ports per kilometer of coastline in the lagoon is almost five times higher than that of the Balearic Islands and the number of moorings per kilometer of coastline is only surpassed by the coast of Barcelona, being seven times higher than that of the Granada coast and five times higher than that of the Balearic Islands. In the Mar Menor lagoon there are twelve ports, which represent 60% of the total number in the Region of Murcia, when the coastline that occupies the Mar Menor lagoon, is only a small fraction of the total coastline in the autonomous community (Martínez et al. 2003). These data show that there is a clearly excessive burden on port infrastructure.

Related to the ports, the model includes the variable the *opening of the Estacio canal*, as it is one of the actions that has had the greatest impact on the lagoon. The expansion of the Estacio canal in 1969, up to 30 meters wide and 5 meters deep to make it navigable, turned this natural connection into the largest communication channel between the Mar Menor and the Mediterranean Sea. This produced an increase in the renewal rates of the water, reducing salinity and moderating the extreme temperature fluctuations of the lagoon (Mas 1994), allowing the ingress of new colonizing species (below sections), in a process of “mediterraneisation” (Mar Menor Scientific Advisory Committee 2017). Other infrastructures on the lagoon coast related to tourist activity include 41 breakwaters, 7 channeling dikes, 12 intertidal land occupations, 4 longitudinal defense structures, 4 exempt dikes, 1 margin protection work and 15 artificial beaches (Management Plan Integral of the Protected Spaces of the Mar Menor and the Mediterranean Coastal Strip of the Murcia Region, Ministry of Water, Agriculture and Environment Region of Murcia, 2016).

Regarding the demographic dynamics, the model includes the variables of the *resident population* and the *seasonal population*. It is important to point out that tourist activity is based in second home tourism. All of this has led to an increase in temporary residents mainly of national origin (77% in 2018), although in recent years a large population of foreigners (23% in 2018) has also settled, mainly Europeans (80% of the foreign population) (Tourism balance of the Region of Murcia, 2018). This has caused a proliferation of medium-low quality tourist-residential developments, with a marked environmental deterioration, with negative effects even for the tourism activity itself and its future development in the medium and long term. The processes of buying a home for a second residence act as an element of attraction for the population in summer, which conditions the supply of services and infrastructures in a short period of time, being practically abandoned during the rest of the year. Added to this tourist displacement is the opening of the coastline to global migratory flows of unskilled labor and the reinforcement of a tourist pattern based above all on the residential model. As in many other coastal ecosystems (Ciriquián et al. 2018), tourism acts as the main engine of urban development.

The *seasonal population*, which has exerted strong pressure on the lagoon and coastal wetlands, is particularly high in La Manga del Mar Menor. The carrying capacity of La Manga del Mar Menor is estimated at around 30.000 people, and in the summer months it can reach 100.000 (Morales 2013). The area of La Manga del Mar Menor is distributed mainly between the municipalities of Cartagena, with 27% of the territory, and the municipality of San Javier, with 67%. According to the cadastre data, the municipality of San Javier presents the highest index, within the autonomous community, of urban units built in relation to the number of inhabitants, with a value of 1,88, doubling that of more important municipalities such as Murcia (0,98) or Cartagena (0,87). Regarding the intensity of occupation of the space, the municipalities of San Pedro del Pinatar and San Javier are in second and third place at the regional level, with 1.286 and 788 urban units per km^2, respectively. These values indicate the degree of urbanization to which they are subjected. Regarding second homes promoted by tourist demand, the cadastre values also show that in the municipality of San Javier a large area has been dedicated to the construction of second homes (77,4%), with a total of 23.276 homes of this type (Morales 2013). The forecasts prior to the eutrophic crisis of the Mar Menor estimated the construction of 150.000 homes for the following years (General Directorate of Transport, Coasts and Ports of the Ministry of Development, Public Works and Land Management, 2014).

The artificialization of the lagoon environment has caused notable environmental impacts due to pressures such as the construction along La Manga del Mar Menor and the northern and western inner shore of the lagoon, construction of ports, dredging, promenades, breakwaters and transport infrastructures, mainly. In the model (Fig. 4.7), all these pressures are reflected in the variable *urban expansion and infrastructure development*, which along with the creation of *artificial beaches* generate other important pressures, such as *uncontrolled recreational and sports use* (motorized navigation, overcrowding of free spaces, etc.) as well as the increase in the volume of *emissions of air pollutants and noise*, also due to the increase in road traffic due to *urban expansion and infrastructure development.* The model includes several feedback loops in which the variables of *seasonal population*, *urban expansion and infrastructure development*, *uncontrolled recreational and sports use,* and the creation of *artificial beaches* are involved. The factors involved in these loops are mutually reinforcing, driving their continued increase. Another of the pressures to highlight is the *generation of sludge and sediments* due to the rupture of the hydrodynamics lagoon by infrastructures such as breakwaters and ports.

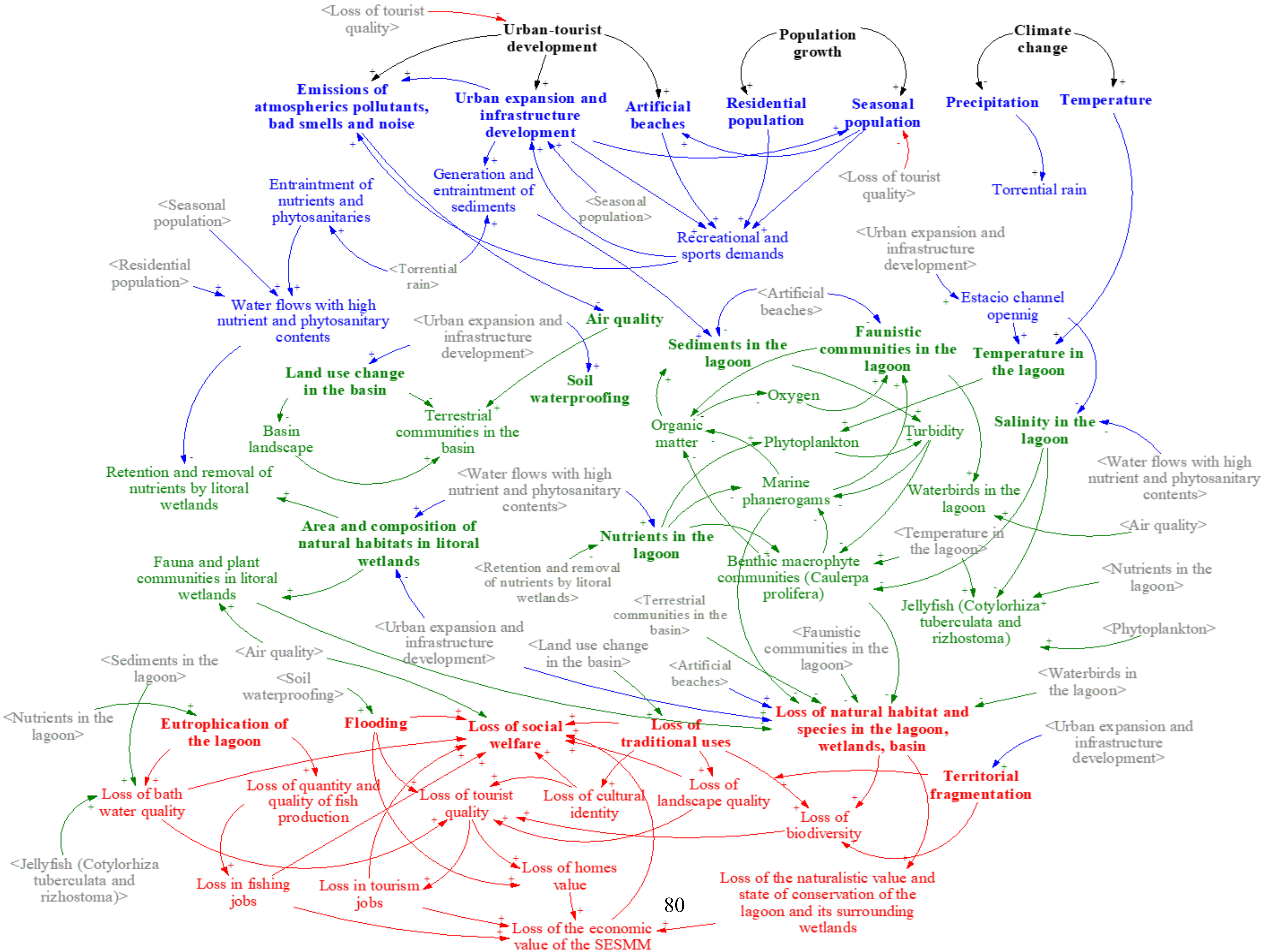
One of the main pressures of population growth was the discharge of untreated wastewater for many years, contributing to the lagoon significant amounts of phosphorus and other pollutants such as drugs, organic pollutants, surfactants and personal hygiene products, among others (Mar Menor Scientific Advisory Committee 2017). The construction and start-up of new treatment plants has allowed this pressure to be largely controlled today (2020), with certain exceptions due to breakdowns and other incidents. Although the entry of nutrients from urban origin only represents around 15% of the total (Esteve Selma et al. 2016; Martínez-Fernández et al. 2013), their role in previous decades could have been significant.

The pressures of urban-tourist development, mainly *urban expansion and infrastructure development*, have also generated changes in the state of various factors in watershed, leading to *land use changes* that, among other effects, have led to greater *waterproofing soil*, a change in the traditional *landscape of the watershed* and an alteration of its *terrestrial communities*. Also noteworthy are some changes in the state of surrounding wetlands, specifically in the *area and composition of natural habitats*, which have affected the *plant and wildlife community* of these wetlands (Fig. 4.7).

Regarding the lagoon ecosystem, *urban expansion and infrastructure development*, specifically the *opening of the Estacio canal*, has generated a decrease in salinity values and a moderation of temperature extremes, thus initiating a first alteration of the aquatic community. According to Pérez Ruzafa et al. (1991, 2002), the *temperature in the lagoon* increased from 7ºC to 10ºC in winter and from 29ºC to 32ºC in summer and the *salinity in the lagoon* went from 48,5-53,4 ups to 42-47 ups. These changes allowed the settlement of new species in the lagoon, in the "mediterraneisation" (Mar Menor Scientific Advisory Committee 2017) of their communities.

The development of coastal infrastructures, such as ports, has altered sedimentary dynamics and contributed to the generation of *sediments in the lagoon*. On the other hand, for the creation of *artificial beaches*, dredging has been carried out to extract sediments from the bottom of the lagoon, which has caused a change in the original state of their natural habitats. It should be noted the extraction carried was out in the 1980s at the bottom of the lagoon (Belando et al. 2017; IEO 2020).

Figure 4.7. Conceptual model of the SESMM: Subset of Urban-tourist development sector in the SESMM. Some factors-feedbacks are expanded from the SESMM Conceptual model (CM): Overall (Fig. 4.5), while others are omitted for simplicity of presentation here. In addition, the nature of each of these factors is identified according to the DPSIR scheme, distinguishing the driving forces (black), pressures (blue), state (green) and impacts (red).


<Loss of tourist quality>
Urban-tourist development
Population growth
Climate change
Emissions of atmospheric pollutants, bad smells and noise
Urban expansion and infrastructure development
Artificial beaches
Residential population
Seasonal population
Precipitation
Temperature
Generation and entraintment of sediments
<Seasonal population>
<Loss of tourist quality>
Torrential rain
Entraintment of nutrients and phytosanitaries
<Seasonal population>
Recreational and sports demands
<Urban expansion and infrastructure development>
<Residential population>
<Torrential rain>
Water flows with high nutrient and phytosanitary contents
<Artificial beaches>
Estacio channel opennig
<Urban expansion and infrastructure development>
Air quality
Sediments in the lagoon
Faunistic communities in the lagoon
Temperature in the lagoon
Land use change in the basin
Soil waterproofing
Oxygen
Terrestrial communities in the basin
Organic matter
Turbidity
Salinity in the lagoon
Basin landscape
Phytoplankton
<Water flows with high nutrient and phytosanitary contents>
Retention and removal of nutrients by litoral wetlands
<Water flows with high nutrient and phytosanitary contents>
Marine phanerogams
Waterbirds in the lagoon
Area and composition of natural habitats in litoral wetlands
Nutrients in the lagoon
<Air quality>
<Temperature in the lagoon>
<Retention and removal of nutrients by litoral wetlands>
Benthic macrophyte communities (Caulerpa prolifera)
Fauna and plant communities in litoral wetlands
<Nutrients in the lagoon>
<Terrestrial communities in the basin>
Jellyfish (Cotylorhiza tuberculata and rizhostoma)
<Urban expansion and infrastructure development>
<Faunistic communities in the lagoon>
<Phytoplankton>
<Land use change in the basin>
<Air quality>
<Sediments in the lagoon>
<Artificial beaches>
<Waterbirds in the lagoon>
<Soil waterproofing>
Loss of natural habitat and species in the lagoon, wetlands, basin
<Nutrients in the lagoon>
Eutrophication of the lagoon
Flooding
Loss of social welfare
Loss of traditional uses
<Urban expansion and infrastructure development>
Territorial fragmentation
Loss of bath water quality
Loss of quantity and quality of fish production
Loss of tourist quality
Loss of cultural identity
Loss of landscape quality
Loss of biodiversity
<Jellyfish (Cotylorhiza tuberculata and rizhostoma)>
Loss in fishing jobs
Loss in tourism jobs
Loss of homes value
Loss of the naturalistic value and state of conservation of the lagoon and its surrounding wetlands
Loss of the economic value of the SESMM

Intensive irrigated agricultural sector

The intensive irrigated agricultural activity is one of the main driving forces of the SESMM. The number of contracts in 2017 in the agricultural sector represented 69,8% of the total contracts in the entire SSEMM (Regional Employment and Training Service, 2017). The total number of workers linked to the agricultural sector and the agri-food industry in the watershed, which basically coincides with the called Campo de Cartagena, amounted to 41.500 people in 2017 (Comunidad de regantes del Campo de Cartagena 2017). In the municipalities of Cartagena, San Javier, Torre Pacheco and Fuente Álamo between 50% and 80% of the work contracts were carried out in the agricultural sector (General Social Security Treasury, 2017). The weight of the economic activity in the area was 5,5% of GDP in 2017 (García-Ayllón 2018).

Since the early 1980s there has been a *land use change* that has led to a profound transformation of the traditional landscapes and natural habitats of the watershed (Fig. 4.8). The expansion of the *irrigated area*, over the previous rain fed crops and with the clearing of areas of natural vegetation (Martínez-Fernández & Esteve Selva 2005; Carreño 2015), is one of the main pressures that affect the SESMM. Between 1988 and 2009, the *irrigated area* increased by 141%, (Carreño 2015) reaching 60,700 ha in 2009. This transformation was driven by the arrival of the *Tajo-Segura transfer* in 1979, technological advances in agriculture and socioeconomic changes, given the great profitability differential between rainfed and irrigated crops (Martínez and Esteve 2000; Carreño 2015). More than 80% of the total area of the Mar Menor watershed is dedicated to agriculture, especially horticultural crops (lettuce, broccoli, melon and others), citrus (oranges and lemons) and greenhouse crops (pepper) (Mar Menor Scientific Advisory Committee 2017). The two main irrigation communities in the Mar Menor watershed are Campo de Cartagena, which has 9,506 community members, and Arco Sur, with 149 community members.

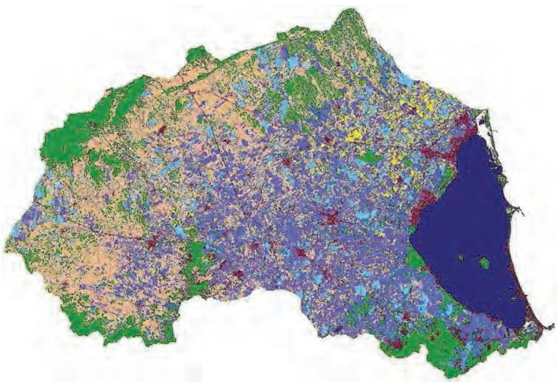


Figure 4.8. Main land uses in the Mar Menor watershed. Green: natural areas; Blue: irrigated outdoors; Yellow: greenhouses; Cream: dry; Garnet: urban areas and infrastructure. Source: Carreño, 2015.

These crops require a great *water demand*, mainly from the *Tajo-Segura transfer* and the *groundwater extraction*. The irrigated areas located outside of the irrigation area of the transfer have mainly groundwater, but it is also used in the perimeters of the *Tajo-Segura transfer*, especially when the volumes transferred are small. In addition, certain volumes from the reuse of wastewater and marine desalination are also used in the watershed.

One of the main pressures of intensive irrigation is the high *use of fertilizers and phytosanitary products*. Irrigation has led to *contamination of aquifers by nitrates* (Martínez and Esteve 2003; Velasco et al. 2006). According to the Geological Mining Institute, the Quaternary aquifer presents values higher than 200 mg/l, which gives an idea of the magnitude of the problem, since the limit value established by the Nitrates Directive (91/676/EEC) is 50 mg/l. Part of the extracted groundwater undergoes a *desalination* process due to the high salinity of the aquifers, a process that generates a reject *brine* with a high nitrate content, because the desalination process concentrates in the *brines* the nitrates present in groundwater.

The *brines* have been uncontrollably dumped into watercourses or injected into wells in the Quaternary aquifer. Irrigation surpluses and *brines* have contributed to an increase in *water flows with high nutrient and phytosanitary content* and to an increase in *piezometric levels* of the hydrogeological unit of Campo de Cartagena (Rodríguez 2009; Aragón et al. 2009). These pressures as represented in the model (Fig. 4.9) generate a feedback loop.

In recent decades, the entry of water flows into the lagoon has taken place through different surface flows (watercourses, urban wastewater outfalls, brine pipes, drainage channels, large avenues) and underground (direct contribution from the Quaternary aquifer). These water flows incorporate a high load of nutrients and other pollutants, whose entrance to the lagoon shows strong interannual fluctuations, increasing considerably during episodes of *torrential rains*.

In the lagoon, estimates based on a dynamic model (Martínez-Fernández et al. 2013, Esteve Selma et al. 2016), suggest that agricultural activity in the Mar Menor watershed would be responsible for around 85% of the total input of nutrients to the lagoon. The high load of nutrients (with values that exceed 100 mg/l of nitrate and in some cases 200 mg/l) and suspended particles (Martínez-Fernández & Esteve-Selma 2005; Velasco et al. 2006), in addition to a large number of organic pollutants commonly used in intensive agriculture, among which phytosanitary products stand out, it has caused alterations in lagoon communities that are summarized below.

Regarding contamination by pesticides, the concentrations of these substances in the flows that reach the lagoon vary seasonally in both quantity and quality, with a predominance of insecticides and herbicides in spring and summer and of fungicides in autumn and winter (Moreno-González et al. 2013; León et al. 2016). Herbicides and pesticides inhibit the growth *phanerogams* such as *Cymodocea nodosa* and *Ruppia cirrhosa* of the lagoon (Marín-Guirao et al. 2005).

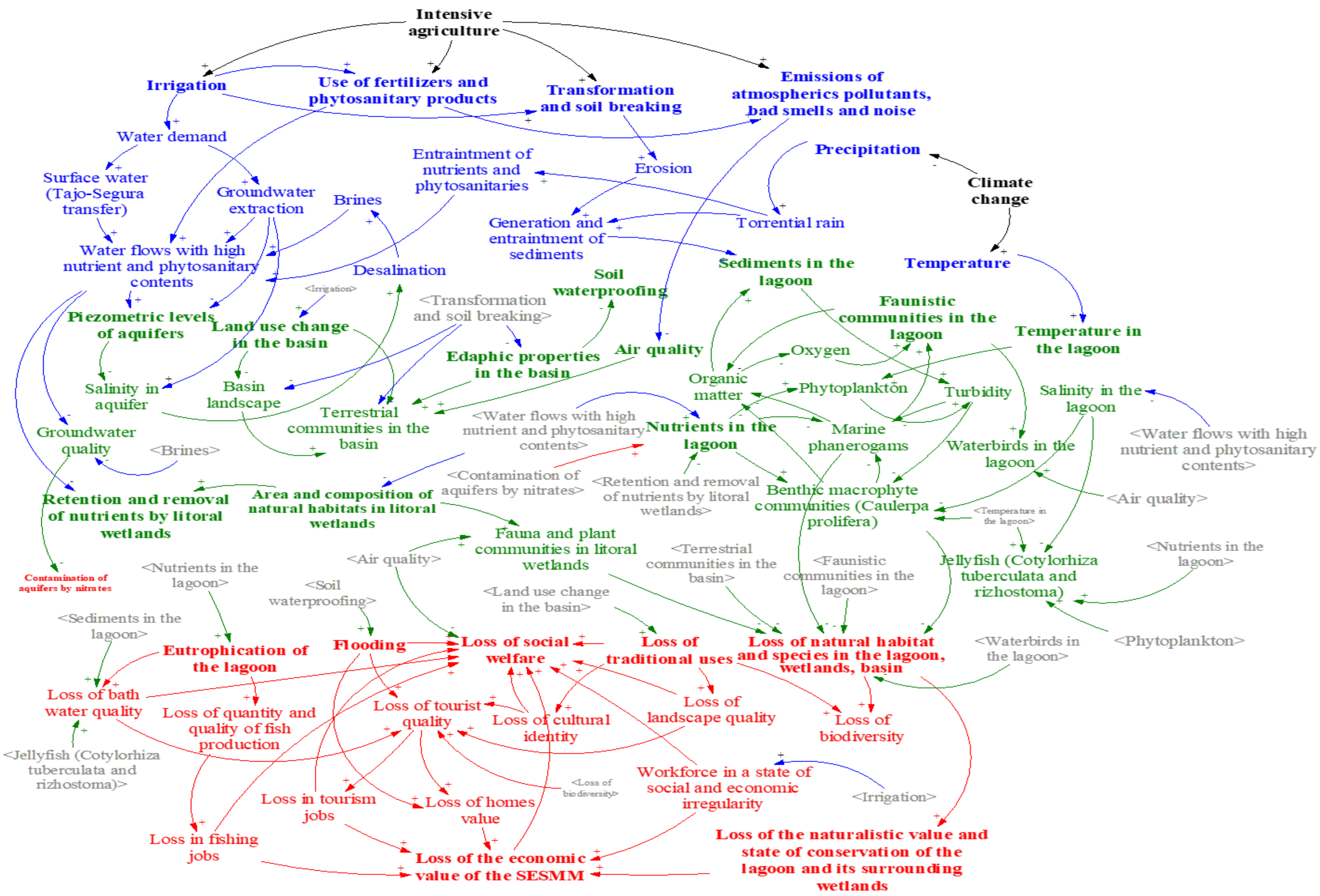
On the other hand, intensive irrigation production systems, without the soil retention practices present in traditional agricultural uses, favor *erosion* and the entry of *sediments* into the Mar Menor. These pressures are contributing to increase the *turbidity* in the water of the lagoon due to the contribution of *sediments*, in addition to affecting the filter feeders and the ichthyofauna (Ruiz et al. 2020).

In the watershed, irrigation also generates significant pressures (Fig. 4.9). The *clearing and transformation of the soil* from traditional drylands or areas occupied by natural vegetation to expand irrigation, has contributed to the change in the *landscape of the watershed*, affecting its *terrestrial communities*, to which are added the edaphic and topography alterations generated by these intensive production systems.

The increase in *water flows with high nutrient and phytosanitary content* entering into the wetlands has altered their initial state. Several works (Alvarez-Rogel et al. 2007; Tercero et al. 2015, 2016) point out the degradation suffered by these wetlands as a consequence of the increase in water flows, which alter the water-saline balance and in turn affect biodiversity (*plant and fauna communities*) (Pardo et al. Carreño et al. 2008; Esteve et al. 2008; Martínez-Fernández et al. 2009) and their most unique habitats, such as the saline steppes (Carreño et al. 2008) and steppe birds (Robledano et al. 2010).

Finally, it should be noted that the irrigation of Campo de Cartagena constitutes an agri-productivity model that is based in part on factors such as the low-skilled labor and the labor precariousness. The Regional Employment and Training Service in Region de Murcia indicates that the number of contracts in the agricultural sector in 2017 represented 69,8% of the total contracts in the SESMM. On the other hand, of the total contracts executed, 96,3% were temporary and the remaining 4% were permanent. Regarding the contracts according to nationality, more than half (58,6%) were contracts with people from outside the EU, 38,5% with Spanish citizens and 2,8% with EU citizens.

Figure 4.9. Conceptual model of the SESMM: Subset of Intensive irrigated agriculture sector in the SESMM. Some factors-feedbacks are expanded from the SESMM CM: Overall (Fig. 4.5), while others are omitted for simplicity of presentation here. In addition, the nature of each of these factors is identified according to the DPSIR scheme, distinguishing the driving forces (black), pressures (blue), state (green) and impacts (red).



Intensive agriculture
Irrigation
Use of fertilizers and phytosanitary products
Transformation and soil breaking
Emissions of atmospherics pollutants, bad smells and noise
Water demand
Surface water (Tajo-Segura transfer)
Groundwater extraction
Brines
Entraintment of nutrients and phytosanitaries
Erosion
Precipitation
Climate change
Generation and entraintment of sediments
Torrential rain
Water flows with high nutrient and phytosanitary contents
Desalination
Sediments in the lagoon
Temperature
<Irrigation>
Soil waterproofing
<Transformation and soil breaking>
Faunistic communities in the lagoon
Piezometric levels of aquifers
Land use change in the basin
Temperature in the lagoon
Edaphic properties in the basin
Air quality
Oxygen
Salinity in aquifer
Basin landscape
Organic matter
Phytoplankton
Turbidity
Salinity in the lagoon
Terrestrial communities in the basin
<Water flows with high nutrient and phytosanitary contents>
Nutrients in the lagoon
Marine phanerogams
Groundwater quality
<Brines>
Waterbirds in the lagoon
<Water flows with high nutrient and phytosanitary contents>
<Contamination of aquifers by nitrates>
<Retention and removal of nutrients by litoral wetlands>
Benthic macrophyte communities (Caulerpa prolifera)
<Air quality>
Retention and removal of nutrients by litoral wetlands
Area and composition of natural habitats in litoral wetlands
<Temperature in the lagoon>
Fauna and plant communities in litoral wetlands
<Terrestrial communities in the basin>
<Faunistic communities in the lagoon>
<Nutrients in the lagoon>
Jellyfish (Cotylorhiza tuberculata and rizhostoma)
<Air quality>
Contamination of aquifers by nitrates
<Nutrients in the lagoon>
<Soil waterproofing>
<Land use change in the basin>
<Sediments in the lagoon>
Eutrophication of the lagoon
Flooding
Loss of social welfare
Loss of traditional uses
Loss of natural habitat and species in the lagoon, wetlands, basin
<Waterbirds in the lagoon>
<Phytoplankton>
Loss of bath water quality
Loss of quantity and quality of fish production
Loss of tourist quality
Loss of cultural identity
Loss of landscape quality
Loss of biodiversity
<Jellyfish (Cotylorhiza tuberculata and rizhostoma)>
Workforce in a state of social and economic irregularity
<Loss of biodiversity>
<Irrigation>
Loss in tourism jobs
Loss of homes value
Loss in fishing jobs
Loss of the economic value of the SESMM
Loss of the naturalistic value and state of conservation of the lagoon and its surrounding wetlands

Ecological status of the lagoon

The main pressures that affect the ecological status of the Mar Menor lagoon (Fig. 4.11) correspond in the first place to the contribution of nutrients from intensive irrigated agricultural activity and urban wastewater (currently practically suppressed, except for episodes of rains and occasional discharges) and secondly with the tourist coastal infrastructures carried out since the sixties (land filling, opening and widening of communication channels with the sea, urban development and associated discharges, construction of ports, etc.) (García-Ayllón 2018), which have already been described in the previous sections.

Until the 1970s, the Mar Menor was an oligotrophic lagoon, the primary production was mainly benthic, with the phanerogam *Cymodocea nodosa* being the main macrophyte. During the first years of the 1980s, after the *opening of the Estacio canal*, the significant increase in the exchange rates of water with the Mediterranean caused the "Mediterraneanization" of the lagoon noted above. These changes allowed the entry and settlement of Mediterranean species such as the *Caulerpa prolifera* and the entry of non-native species such as the *Cotylorhiza tuberculata* and *Rhizostoma pulmo* jellyfish. Towards the beginning of the 1990s, a dense meadow of the invasive macroalgae *Caulerpa prolifera* covered 80% of the seabeds (Pérez-Ruzafa et al. 1989), restricting the phanerogam *Cymodocea nodosa* to more or less reduced spots in shallow areas. The high benthic biomass of macrophytes contrasted with the low *phytoplankton* density (Ros and Miracle 1984) and the oligotrophy of the waters (Gilabert 2001), which allowed maintaining a high transparency in the water column.

A key factor for the encroachment of *Caulerpa prolifera*, as well as for the proliferation of *jellyfish*, which became a serious problem for tourism since the mid-1990s, was the continuous supply of *nutrients*. This increased nutrient loading was initially from the urban wastewater in the 60s and 70s, and then in the late eighties was mainly from intensive irrigated agricultural activity, which through the following decades through the present has expanded greatly. For several decades the excess *nutrients* have been being rapidly taken up and stored by the benthic community. This explains why, despite the massive influx of *nutrients* from the watershed, low concentrations of *nutrients* and *phytoplankton* were observed in the water column for years; and therefore the water would show remarkable transparency, except for occasional episodes limited spatially and temporally.

As of the second half of 2015, the waters of the Mar Menor experienced a drastic change due to a massive proliferation of *phytoplankton* in the entire lagoon, reaching a state of serious *eutrophication* (Aguilar et al. 2016). This bloom process was activated by excess *nutrients* in the water column coupled with abnormally high winter temperatures, which led to an explosive growth of single-celled algae. This situation was popularly baptized with the name of "green soup" in the spring of 2016. The high cell concentration prevented the passage of light to areas with depths of more than three meters, which caused the death of the benthic vegetation from this light limitation. A study by the Spanish Institute of Oceanography presented in 2016 showed a loss of 85% of the initial extension of seagrass beds in the Mar Menor (Fig. 4.10), which in turn caused the death of numerous organisms that depend on it (Martínez et al. 2017; Mar Menor Scientific Advisory Committee 2017). The resulting excess of detritus led to the proliferation of decomposing microorganisms, whose respiration in turn practically depleted the available *oxygen* in the water column. The lack of *oxygen* destroyed a good part of the *faunal communities* that live both in the water column and in the benthos, aggravating the excess of *organic matter* and subsequent hypoxia (even anoxic states) and leading to a state close to the collapse.

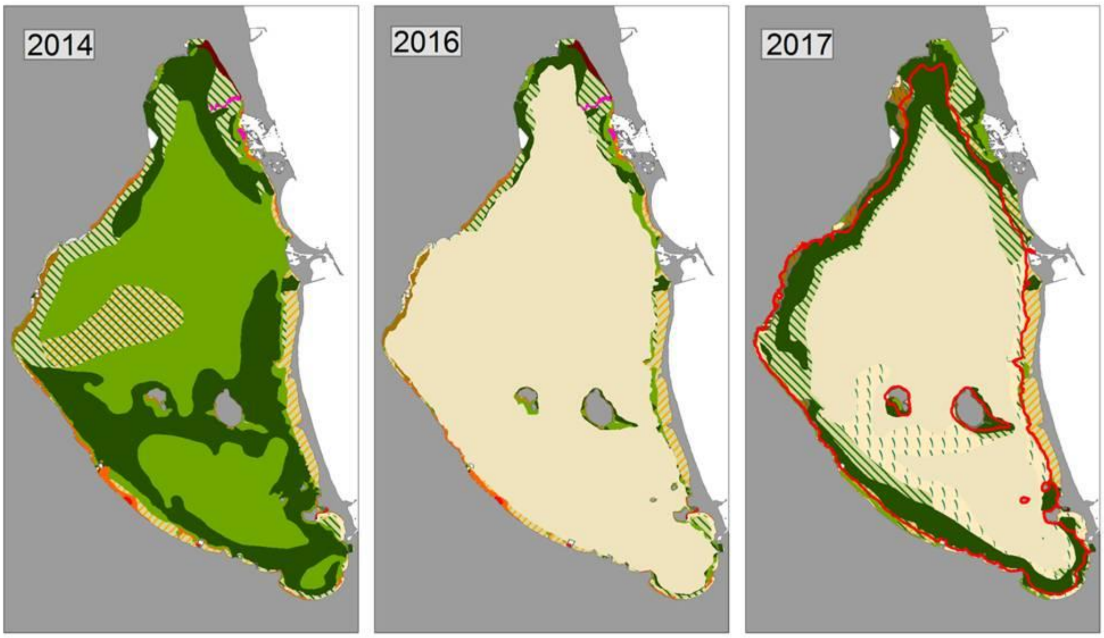


Figure 4.10. Distribution of seagrass beds in the Mar Menor before and after the eutrophic crisis. Legend: *Cymodocea nodosa* (organge), *Caulerpa prolifera* (dark green), mixed meadow *Cymodocea nodosa-Caulerpa prolifera* (green), *Ruppia cirrhosa* (pink) and silty unvegetated bottoms (yellow). The red line showed in the 2017 map correspond to the maximum depth limit of macrophytes on that year. Source: Belando et al. 2019.

After the collapse of the ecosystem in 2016, the already deteriorated state has been aggravated by the *runoff of nutrients and phytosanitary products* and the *runoff of sediments* due to *torrential rains* such as DANA (Spanish acronym for a western Mediterranean meteorological phenomenon) that took place in September 2019 (Ruiz et al. 2020), which caused the entry into the lagoon of a significant volume of floodwaters. The massive entry of *nutrients* accumulated in the Campo de Cartagena into the lagoon during the DANA episode was estimated between 500 and 1.000 tons of nitrates, 35 tons of ammonium, and more than 100 tons of phosphates (Ruiz et al. 2020). These *nutrient* inputs accelerated the eutrophic process in the surface waters. The absence of *oxygen* and the presence of sulfides toxic to fauna, caused the death of all the sessile benthic organisms and the massive movement to the surface of all mobile fauna. Some 9.000 hectares of the lagoon bottom were lost again (Ruiz et al. 2020).

Eutrophication has led to a deep ecological degradation in the Mar Menor that is becoming chronic, and is now an unstable ecosystem and vulnerable to multiple factors such as DANA events (Ruiz et al. 2020).

Impacts

All these changes in the upland watershed, wetlands and lagoon are linked spatially and temporally, and have led to various impacts on the entire SESMM (Fig. 4.11). In the case of the upland watershed, the main impacts have been incorporated into the qualitative model through the following variables: *contamination of aquifers by nitrates*, increased risk of *flooding*, which, in turn, has contributed to a *loss in the home values*, *territory fragmentation*, *loss of traditional uses* and *loss of natural habitats and species*. These impacts in turn generate *loss of biodiversity*, *loss of landscape quality* and *loss of cultural identity*.

It should be noted that the irrigation in the upland watershed constitutes an agri-productivity model that is based in part on factors such as the low-skilled labor and the labor precariousness, as is noted above, which has generated a *labor in a state of social and economic irregularity*.

In the case of wetlands, the *loss of natural habitats and species* and their effects on the *biodiversity and naturalistic value* of wetlands stands out.

Regarding the the *loss of natural habitats and species,* Carreño el al. (2008) pointed out that in the 1984-2009 period the vegetation surface occupied by salt steppes, of priority interest according to Directive 92/43/EC on the conservation of natural habitats and of wild fauna and flora, was reduced to less than half (from 243 ha to 100 ha), while the area of salt marshes, of community interest in the Directive, increased from 69 ha to 142 ha. According to the same study by Carreño et al. (2008), the application of an index that assesses the interest of communities from the point of view of the Habitat Directive, shows that the changes have led to a global reduction of 48% in the interest of wetland vegetation from the perspective of the Habitat Directive between

1984 and 2009. Robledano et al. (2010) point out that these changes in the wetlands have also affected the community of steppe passerines in the Marina del Carmolí wetland. Between 1984 and 2008, the *Alaudidae* family, linked to the steppe habitat, shows a significant decrease.

In the lagoon, the continuous contributions of *nutrients*, mainly from upland watershed agricultural activity and to a lesser extent from urban wastewater, have produced a chain of state changes in the lagoon, highlighting the alterations in the physical-chemical parameters of the water, in the sediments, benthic vegetation, phytoplankton, the population of jellyfish and the singular fauna species such as the fartet (*Aphanius iberus*), the nacra (*Pinna nobilis*) and the seahorse (*Hippocampus guttulatus*). All of this has led to two primary impacts: the *loss of natural habitats and unique species* in the lagoon and *eutrophication*.

Regarding the state of the lagoon habitats, in 2014 according to studies carried out by the IEO and ANSE, it was indicated that *Cymodocea nodosa* occupied 54% of the surface of the lagoon bottom, *Caulerpa prolifera* occupied 87% of the lagoon surface and *Rupia cirrhosa* 1,08% of the lagoon surface. In 2016, these same sources confirmed that as a consequence of the eutrophic crisis, 85% of the entire area occupied by benthic vegetation at the bottom of the Mar Menor lagoon was lost, and the remaining 15% was in the shallower parts. The IEO data indicated that in 2019 *Caulerpa prolifera* reoccupied the same surface than in 2014, but the same did not happen for *Rupia cirrhosa* and *Cymodocea nodosa* (Ruiz et al. 2020).

Regarding the most unique species of the lagoon, the population evolution of the seahorse (*Hippocampus guttulatus*) was reduced by 99% in just the last 8 years (period 2012-2020). This situation is similar to the population of nacras, *pinna nobilis*, which went from being distributed in 57,4% of the lagoon surface in 2014 to a mortality of 94% in 2017 (Ruiz et al. 2020). Giménez-Casalduero et al. (2020) pointed out that the rate of decline increased since 2016, possibly as a consequence of the environmental collpase of the laggon.

But other secondary impacts derive from these impacts. In the case of the *loss of natural habitats and species*, they generate *loss of biodiversity* and *loss of the naturalistic value and state of conservation of the lagoon*. In this sense, according to the IEO, the decline of these species (*Hippocampus guttulatus and pinna nobilis*) in recent years indicates a very worrying situation from the point of view of conservation.

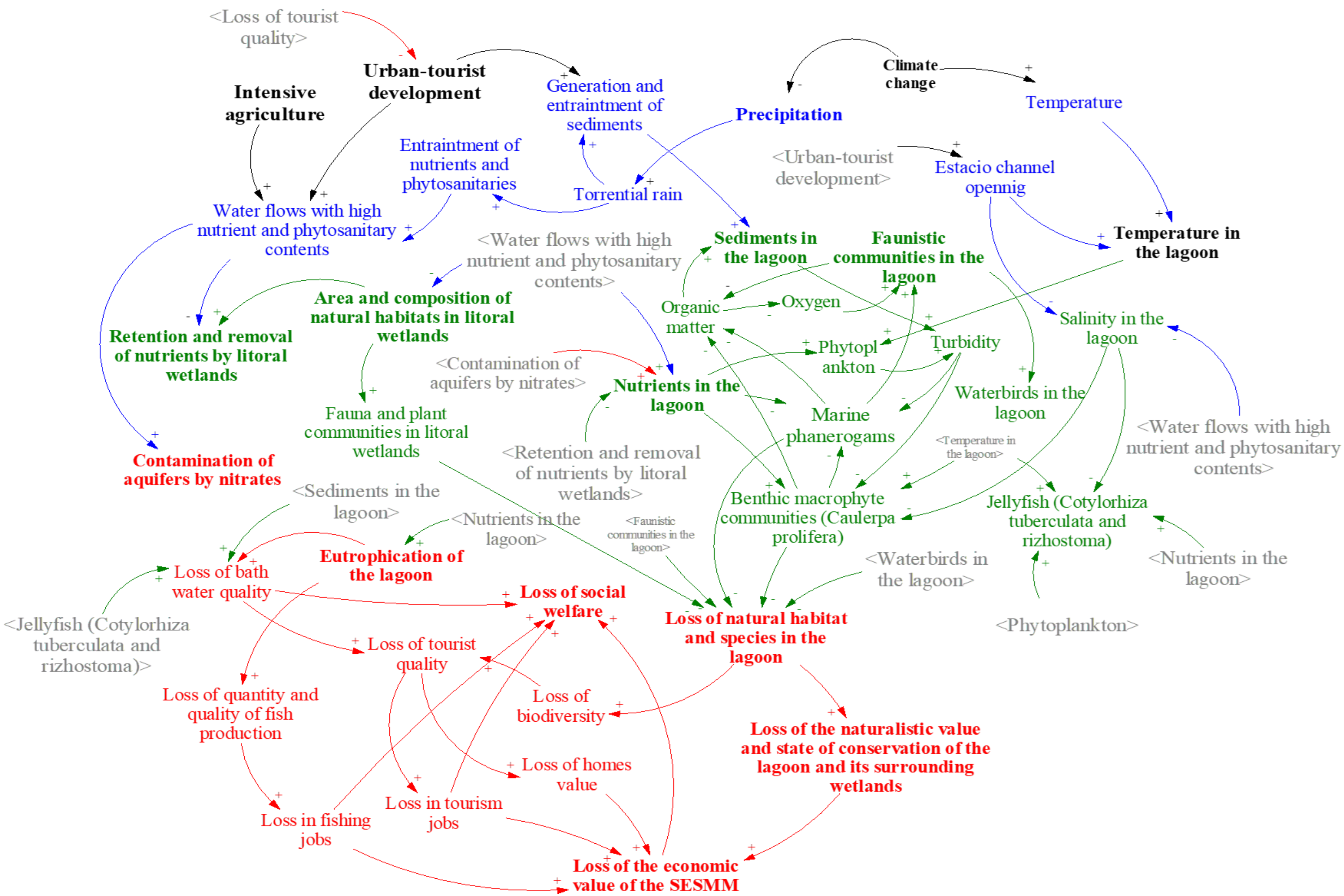
In the case of *eutrophication*, data on chlorophyll-a and nutrients (nitrogen and phosphorus) from 1980 to 2019 confirm the eutrophic situation of the lagoon since 2016. According to the Oceanographic Center of Murcia, of the Spanish Institute of Oceanography (IEO), from 1980 to

2010 chlorophyll-a increased by 0,38 mg/m^3 per decade. From 2012, this trend continued to increase, reaching in 2016, maximum values higher than 20 mg/m^3. And although in 2018 the chlorophyll-a values were similar to those of 2016, in 2019 it progressively increased until reaching an average concentration of 50,01 mg/m^3 (or 50 µg/l) (Ruiz et al. 2020). The nutrient evolution data recorded by the IEO indicate that for the period 1980-2019, the average monthly concentration of nitrates was less than 1µM until 1990, but from on this date, maximum concentrations higher than 8µM were reached. Between 2016 and 2019, some peaks of concentrations higher than 10 µM were obtained.

The *eutrophication* gives rise to many other impacts, such as the *loss of water quality*, which in turn translates into a *loss in tourism quality*. One of the indicators of this is that, since the second half of 2015, after reaching a state of serious *eutrophication* in the Mar Menor, the number of (consumer-desired) blue flags awarded to the beaches of the coast was reduced (Asociación de educación ambiental y del consumidor, 2020). This *loss of tourism quality* also implies a *loss of employment in the tourism sector* and a reduction in the residential *homes value*, with cascading effects on the economic contribution of this sector to the SESMM. A recent study (Aparicio 2020) indicates that the continuous and growing loss of profitability of hotels, restaurants and shops, as well as the decrease in the number of tourists, have meant the loss of 311,2 million euros (28,3 million euros annually) from 2008 to early 2020. *Eutrophication* also led to some loss in the *quantity and quality of fishery resources*, at least during some period, with negative consequences on *fisheries employment*.

Finally, all these impacts affect the driving force of urban-tourism development and, along with the impacts on fishing and on the residential homes value, they imply a *loss of the economic value of the entire SESMM*, as well as of *social welfare*.

Figure 4.11. Conceptual model of the SESMM: Subset of Ecological status in the SESMM. Some factors-feedbacks are expanded from the SESMM CM: Overall (Fig. 4.5), while others are omitted for simplicity of presentation here. In addition, the nature of each of these factors is identified according to the DPSIR scheme, distinguishing the driving forces (black), pressures (blue), state (green) and impacts (red).



<Loss of tourist quality>
Urban-tourist development
Intensive agriculture
Generation and entraintment of sediments
Climate change
Precipitation
Temperature
Entraintment of nutrients and phytosanitaries
Torrential rain
<Urban-tourist development>
Estacio channel opennig
Water flows with high nutrient and phytosanitary contents
<Water flows with high nutrient and phytosanitary contents>
Sediments in the lagoon
Faunistic communities in the lagoon
Temperature in the lagoon
Area and composition of natural habitats in litoral wetlands
Retention and removal of nutrients by litoral wetlands
Organic matter
Oxygen
Salinity in the lagoon
Phytoplankton
Turbidity
<Contamination of aquifers by nitrates>
Nutrients in the lagoon
Waterbirds in the lagoon
Fauna and plant communities in litoral wetlands
Marine phanerogams
<Water flows with high nutrient and phytosanitary contents>
<Retention and removal of nutrients by litoral wetlands>
<Temperature in the lagoon>
Contamination of aquifers by nitrates
<Sediments in the lagoon>
Benthic macrophyte communities (Caulerpa prolifera)
Jellyfish (Cotylorhiza tuberculata and rizhostoma)
<Nutrients in the lagoon>
<Faunistic communities in the lagoon>
Eutrophication of the lagoon
Loss of bath water quality
<Waterbirds in the lagoon>
<Nutrients in the lagoon>
Loss of social welfare
Loss of natural habitat and species in the lagoon
<Phytoplankton>
<Jellyfish (Cotylorhiza tuberculata and rizhostoma)>
Loss of tourist quality
Loss of biodiversity
Loss of quantity and quality of fish production
Loss of the naturalistic value and state of conservation of the lagoon and its surrounding wetlands
Loss of homes value
Loss in tourism jobs
Loss in fishing jobs
Loss of the economic value of the SESMM

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Chapter 5.

Local perceptions regarding a social–ecological system of the mediterranean coast: the Mar Menor (Región de Murcia, Spain)

Humedal de Lo Poyo

Lo Poyo wetland

5. Local perceptions regarding a social–ecological system of the mediterranean coast: the Mar Menor (Región de Murcia, Spain) *

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Abstract

The social–ecological system of the Mar Menor located in southeastern Spain is facing serious environmental degradation which is generating important economic and social impacts. This article analyzes the local community perception in the Mar Menor area about the causes, consequences and possible solutions to current problems, especially the eutrophic crisis in the Mar Menor lagoon. For this research, a survey based on a questionnaire was conducted in 2017 and answered by 498 people. The collected data were analyzed using descriptive statistics and principal component analysis. Results showed significant diferences among the groups of respondents, according to their profession and main economic activity, but the results also point to an important consensus in the group of respondents. It is worth noting that the broad consensus was that agricultural activities are the main causes of the entry of nutrients into the lagoon, and the respondents indicated that the priority should be given to measures to reduce nutrient inputs. This consensus, which is very diferent from the results obtained in previous studies, represents a very recent change of perception in relation to the role of agriculture in the Mar Menor. However, the broad consensus in the diagnosis of the current problem is not refected in the varying opinions regarding the possible solutions or management options. Survey responses regarding solutions varied greatly across groups: There were important diferences between (a) the respondents' perceptions of the best solutions, and (b) the main management practices undertaken by the public administration at this point. This fnding highlights a potential confict that should be considered in any decision-making processes.

Keywords: Social–ecological system; Agrarian pollution; Coastal lagoon; Social perceptions; Sustainability.

5.1. Introduction

The analysis and management of social–ecological systems (SES) are of vital importance to understand the relationships and interactions between society and ecosystems (Holling et al. 1998; Berkes and Folke 1998; Audouin et al. 2013; Fischer et al. 2015). The scientific literature raises several attributes necessary to carry out the practice of SES management. Among the SES management attributes most commonly mentioned and developed (Challenger et al. 2014) are: the interdisciplinary approach, incorporate knowledge of the local population, mainstreaming, efective governance, adaptive monitoring and co-management, the use of indicators of sustainability and social participation.

Stakeholder's knowledge and perception about the natural environment and about some of its components are aspects of great importance for the integral management of a región and, especially, for the conservation and sustainable use of its biodiversity (Challenger et al. 2014; Delgado-Serrano et al. 2015). The interdependence between the ecological components and the multiplicity of users at the SES level requires that all stakeholders know the functionality of the system and participate in the design and implementation of management practices. In this sense, participatory governance processes require a good stakeholder analysis (Yang 2014; Comino et al. 2016), especially in cases of complex socio-environmental conficts, as happens in the socio-ecological system of the Mar Menor (SESMM) located in the Mediterranean coast (SE Spain).

The main economic uses in the SESMM are the urban-tourist development and agrarian activity, although some fshing activity is maintained in the lagoon. The frst two activities have involved the entry of nutrients into the lagoon, although with diferent relative efects, as the nutrient inputs from urban uses have been signifcantly reduced by the improvement in the wastewater treatment and its reuse, while the input from agricultural practices has continued to grow due to the expansion of irrigated areas following the arrival of the Tajo-Segura transfer in 1979. This large increase in water transfers to the Campo de Cartagena watershed increased water and nutrient flows to the lagoon and its wetlands (Martínez Fernández et al. 2005, 2014, 2017; Esteve et al. 2008, 2016; Carreño et al. 2008; Carreño 2015). Estimates indicated that the agricultural nutrient inputs represent about 85% of the total into the lagoon (Martínez-Fernández et al. 2014; Esteve Selma et al. 2016).

This high input of nutrients into the lagoon is the main reason why, in the middle of 2016, the current eutrophic crisis emerged abruptly with serious ecological impacts on the species and habitats, the loss of the traditional transparency of the waters and important damages to the tourist quality and other ecosystem services. In addition, this (Esteve Selma et al. 2016; Carreño 2015; Martínez Fernández et al. 2005) can lead to a "domino" effect, whereby many of the economic activities that the lagoon directly supports will lead to job losses and associated impacts.

The scientifc literature includes the study of other coastal lagoons with similar pressures to the Mar Menor such as Salton Sea (USA), the Thau lagoon (France) or La Mar Chica, also called Nador (Morocco) (Glenn et al. 1999; Caillaud 2017; García-Ayllón 2017). Specifcally, Salton Sea and the Thau lagoon have sufered serious environmental impacts that have required large recovery plans and complex integrated management.

Although in recent years there has been an attempt to manage the SESMM from a holistic perspective, sectoral visions have predominated so far, and it has not been managed from a systemic and integral approach (García-Ayllón 2018, 2019). Failure to comply with current regulations, lack of coordination and the absence of efective measures to prevent and address the multiple problems of the SESMM, and in particular the eutrophication of Mar Menor waters, have caused a serious confict that has spread to the diferent spheres: environmental, social, economic, political and institutional (Comité de Asesoramiento Científco del Mar Menor 2017).

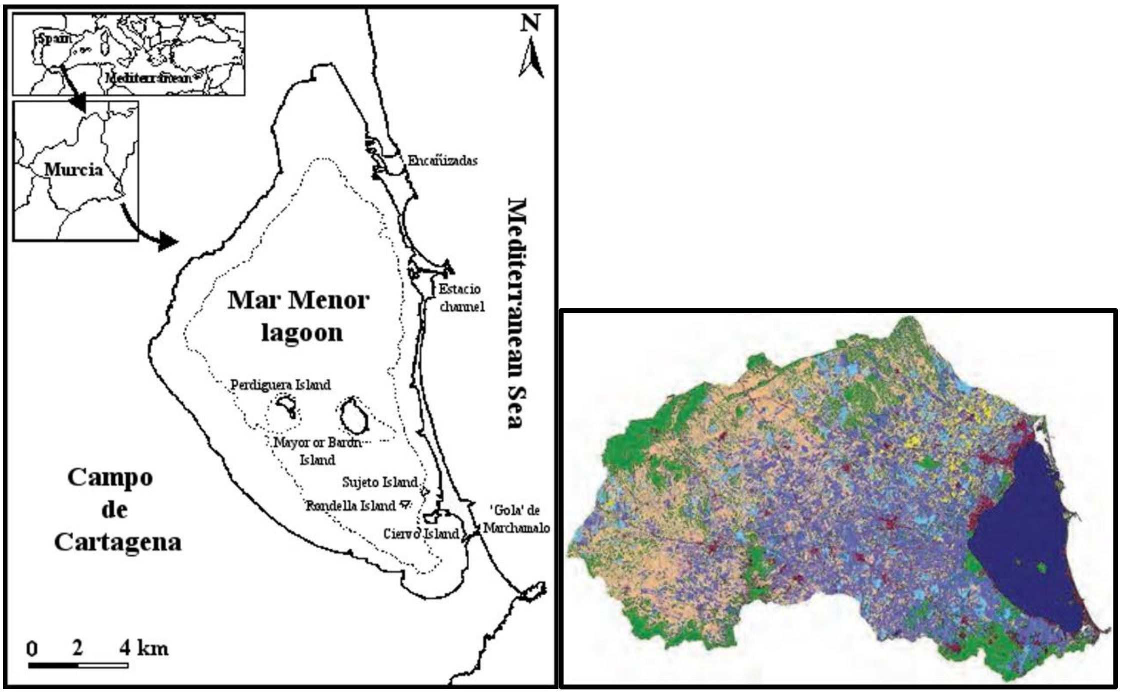
Along with the scientifc and technical diagnosis that have been made in recent years in the SESMM (Esteve et al. 2008, 2016; Martínez-Fernández et al. 2014, 2017; León and Bellido 2016; Comité de Asesoramiento Científco del Mar Menor 2017), it is also necessary to understand the social perception in the study area. Thus, we view management practices with an integrated approach, taking into account the key stakeholders' involvement, including the local community, with the common objective of improving the environmental and socioeconomic situation of the SESMM.

This article aims to contribute to a better understanding of the local community perception in the Mar Menor area through the completion of a survey, in order to identify their perceptions about pressures, impacts and possible management practices to improve the current status of SESMM and specifcally the ecological status of the lagoon.

5.2. Study area

The SESMM, located in the east of the Region of Murcia (SE Spain), includes the Mar Menor lagoon, the surrounding wetlands and the Campo de Cartagena watershed (Fig. 5.1). The lagoon is separated from the Mediterranean Sea by an ancient sandy bar that is 22 km long and varies between 100 and 900 m wide, crossed by five very shallow channels that connect the lagoon to the Mediterranean Sea; some of these natural cuts have been widened to allow the passage of boats between the lagoon and sea. This coastal lagoon, the largest in the Western Mediterranean, covers an approximate area of 135 km^2 and has a volume of 610 hm^3, with a maximum depth of 7 m and a mean depth of 4.5 m. The low rainfall which does not exceed 300 mm per year in much of the region and the high temperatures (annual mean of 17 °C) determine a water deficit (difference between precipitation and evapotranspiration) around 600 mm/m^2 per year, which has favored the hypersaline nature of the lagoon's waters. Another of its unique characteristics has been its oligotrophic character until a few years ago (Comité de Asesoramiento Científco del Mar Menor 2017).

Wetlands that surround the lagoon are typified as littoral crypto-wetlands, coastal salt-pans and micromareal salt marshes (Vidal-Abarca et al. 2003), with total cover of approximately 1000 hectares, and with a high biodiversity. Due to the high natural value, the lagoon and surrounding wetlands have led to the creation of multiple regional, national and international protection declarations.



A) B)

Figure 5.1. A) Location of the SESMM. B) The SESMM, made up of the lagoon and its watershed. The main uses of the watershed are indicated. Green: natural; blue: outdoor irrigation; yellow: greenhouses; cream: dry; garnet: urban and infrastructures. Source: Carreño 2015.

The Campo de Cartagena watershed has an area of 1270 km^2 and is drained by more than 20 ephemeral watercourses locally called "ramblas" that flow into the Mar Menor lagoon. The population of this study area is 357,266 inhabitants in 2017. The main uses and activities in the watershed are intensive irrigation agriculture (especially of horticultural crops (lettuce, broccoli, melon and others), citrus fruits (oranges and lemons) and greenhouse crops) and urban-tourist development. The Campo de Cartagena watershed has suffered significant changes during the last few decades due to the presence of human activity. But it is after the start-up of the frst irrigation system using subterranean water, and later with the Tajo-Segura surface water canal transfer in 1979, when these changes are most evident. Data from Carreño (2015) indicate that between 1988 and 2009, the irrigation of the watershed increased by 141%, going from 25,150 ha to 60,700 ha. Currently (2020), the Campo de Cartagena watershed is one of the most competitive areas in Europe in fruit and vegetable production. These crops have needed to be competitive, large amounts of water coming mainly from the Tajo-Segura transfer, from the pumping of groundwater and more recently from desalinated water (from brackish groundwater and very recently also from desalination marine), whose rejection brine has been poured uncontrollably into channels or injected into wells in the upper aquifer itself, with the consequent environmental impact of contamination that this entails in the medium and long term due to the high nitrate content (Martínez Fernández and Esteve Selma 2000; Velasco et al. 2006). These crops have also needed strong fertilizer and phytosanitary inputs, and the development of the long-distance road transport network (and its associated greenhouse gas emissions), as well as a workforce in a state of social and economic irregularity. An especially relevant impact of the agricultural activity in the Mar Menor lagoon is the discharge of the efuents loaded with nutrients, surpluses of intensive fertilization which is causing an acute process of eutrophication of the waters (Martínez Fernández et al. 2005, 2014, 2017; Velasco et al. 2006; Esteve et al. 2008, 2016; Carreño et al. 2008; Carreño 2015). Another important efect of the agricultural activity is the transformation and breakage of soils.

On the other hand, since the 1960–1970s, urban-tourism and second-home development have led to the increase in temporary residents (local, national or international), including increases in services associated with such increased development of urban areas and infrastructure such as the construction of roads, ports (such as the Canal del Estacio), boardwalks, dikes, beach regeneration and riverbed occupancy. All this has exerted a strong ecological pressure on the Mar Menor lagoon and its surrounding wetlands, which have finally negatively impacted the water quality of the lagoon and its associated biodiversity. Ultimately, these negative impacts lead to decreased goods and services that the system provides to society, with a wide range of negative social and economic impacts (Conesa and Jiménez-Cárceles 2007). For example, activities such as tourism, fishing or recreational diving are already seeing the consequences of the loss of bathing water quality (due to the loss of traditional water transparency) and marine biodiversity. This reduction in biodiversity and ecosystem services of the lagoon, especially as a result of the ecological collapse caused by the eutrophic crisis that has been sufering since 2016, has a negative impact on both the ecological and economic and social value of the coastal ecosystem (Martínez Fernández and Esteve Selma 2020).

Regarding the political and legislative measures that have been approved or applied for the SESMM, it is worth highlighting the numerous protection figures: San Pedro del Pinatar Regional Park, Protected Landscape of Open Spaces and Mar Menor Islands, declaration of the Mar Menor and surrounding wetlands such as ZEPA (Special Protection Area for Birds) and SCI (Site of Community Importance), Ramsar list of wetlands (Wetland of International Importance of the Ramsar Convention) and ZEPIM (Specially Protected Area of Mediterranean Importance). Also a broad European, state and regional regulations, such as the declaration in 2001 of the Campo de Cartagena watershed as a Vulnerable Zone in application of the Nitrates Directive (91/676 ECC), the declaration of the lagoon as a Sensitive Area in application of the Urban Wastewater Directive (91/271 ECC) and the application of the Water Framework Directive (2000/60 EC), which obliges to achieve and maintain The Good State of all water bodies, Law 1/2018, of February 7, on urgent measures to ensure environmental sustainability in the Mar Menor environment, the Integrated Management Plan for the protected areas in the Mar Menor and the strip of the Mediterranean coast of the Region of Murcia or the Strategy of integrated management of coastal areas of the socio-ecological system of the Mar Menor and its surroundings, among others.

5.3. Methodology

A survey was conducted with 23 questions with categorical and dichotomous type responses. The questions of the survey were distributed in five blocks: (1) urban-tourist development, (2) agrarian activities, (3) the state of the Mar Menor lagoon, (4) environmental values and ecosystem services and (5) metadata (Appendix I).

The type of sampling was simple random sampling, and the survey was directed to different sectors of the population over 18 years of age in the Mar Menor area and to organizations involved in the activities and management of the SESMM. The questionnaire was subjected to a pilot test with a group of 35 people among students of the University of Murcia and members of the Pacto por el Mar Menor citizen platform, to determine whether the questions had been correctly understood by the population and whether the duration of the survey was excessive.

Considering that the size of the population in the study area is greater than 100,000 inhabitants, for a confidence level of 95% and assuming a margin of error of ±5%, it was necessary to have a sample size of approximately 400 respondents. A total of 498 people responded during the months of February to May 2017. The survey was sent and answered by email in order to have a greater difusion, participation and representativeness of the local community.

As part of the survey metadata, respondents were classifed into ten groups according to their profession and main economic activity: (1) public administration (12%), (2) agricultural sector (8%), (3) tourism sector-Services (5%), (4) tourism sector-Hotels and restaurants (4%), (5) fisheries sector (1%), (6) construction and real estate development sector (2%), (7) industry sector (8%), (8) academic sector (professor or researcher) (17%), (9) students (21%) and (10) others (liberal professions, retirees and other occupations) (22%). In total, 60% of the people who answered the survey were men and 40% women, with an age range between 21 and 74 years old and with a level of higher education (university and postgraduate) in 80% of cases. Regarding the respondent's relationship with the Mar Menor, half of the people who responded to the survey were regular visitors to the Mar Menor, 30% residents and 20% sporadic visitors. Half of the people who answered the survey participated in some type of association, mainly those related to the environment and the other half were not associated with any association.

The data were analyzed using the statistical software R (R Core Team 2019). For the analysis of the questions on the perceptions related to pressures (Q1, Q2, Q7, Q8), state (Q14, Q15_1, Q15_2, Q15_3, Q16, Q18), impacts (Q9, Q11, Q20, Q21_1, Q21_2, Q21_3, Q21_4, Q22, Q23_1, Q23_2, Q23_3, Q23_4) and responses (Q5, Q19) (Appendix I), a bivariate analysis was carried out by means of contingency tables on two nominal variables: on the one hand, profession and main activity economic and on the other the answers of the respondents to the questions on the pressures, state and the impacts in the SESMM. Pearson's Chi-square nonparametric test (X^2) or Fisher's exact test (Agresti 1992) was applied, depending on the case, according to the observed frequencies, applying the Monte Carlo simulation of the *p* values to determine whether the answers to the questions depended on the profession and main economic activity group of each surveyed individual.

For the analysis of the questions referring to the solutions or possible management measures to be adopted (Q6 and Q12), the respondents were asked to order ten possible measures to improve urban-tourist development (Q6_1, Q6_2, Q6_3, Q6_4, Q6_5, Q6_6, Q6_7, Q6_8, Q6_9 and Q6_10) and nine measures to limit the entry of nutrients into the Mar Menor lagoon (Q12_1, Q12_2, Q12_3, Q12_4, Q12_5, Q12_6, Q12_7, Q12_8 and Q12_9) (Appendix I), with the option that each respondent could also reject those measures that they did not consider of interest by assigning that measure the value 0.

First, a principal component analysis (PCA) (Wold et al. 1987) was carried out considering each of the two questions according to the average value obtained in the group of respondents according to their profession and main economic activity, with the aim of grouping the diferent groups of measures and see which were more related to each other. Secondly, we made biplot representations (Kassambara and Mundt 2019) to know the relationship between each of the variables or management measures, regarding the groups of respondents according to their profession and main economic activity. Third, we established an order of preference for management measures according to the average value of the respondents.

The analysis of results was based on the classifcation of respondents according to their profession and main economic activity, because the classifcation of respondents according to other variables, such as age, gender or place of residence, did not give rise to significant diferences of opinion. On the other hand, some of the main stakeholders associated with SESMM are identifed by their main economic activity, so that the results of the survey according to said variable allow a first approximation to their perceptions. It should be noted that the active population for each of the groups of respondents classified according to their profession and main economic activity, is diferent and in some cases unknown and difcult to calculate, which explains the level of participation proportionally higher in those groups of respondents with a higher active population. In this sense, although the survey is not stratified, in the answers where majority consensus is obtained, the results can be considered representative of the population.

The validation of the fnal data of the survey was verifed through 20 interviews with scientific–technical experts from diferent disciplines in the environmental, social, economic and institutional dimensions.

5.4. Results

5.4.1. Social perceptions about the pressures in the SESMM

Most of the respondents (86.2%) considered that the urban-tourist development in the Mar Menor area is too crowded (Q1) with a position in favor of greater urban-tourist development in the tourism sector (hotels and restaurants) and in the construction sector compared to the rest of the groups. The respondents assessed the current tourist quality between regular and bad (75.2% between both qualifcations) (Q2). 52.3% of the tourism sector dedicated to the hotels and restaurants assessed the quality of tourism between acceptable and good, unlike the consensus established by the rest of the groups of respondents about the regular and bad tourist quality.

Almost half of the respondents (47.1%) considered agriculture as a relatively important economic sector, although it does not generate the greatest economic wealth of the Mar Menor area and around a quarter of the respondents considered that irrigation does not contribute signifcantly to the richness of the study area. The other quarter of the respondents considered that agriculture is an essential sector for the economy of the Mar Menor area. This assessment of the agricultural activity in terms of its economic importance in the SESMM (Q7) was assessed in one way or another depending on the group of respondents according to their profession and main economic activity (Table 5.1). In addition to the expected greater support for the economic importance of agriculture within the agricultural sector (64.3%), the results showed a divergent behavior between the construction and tourism sectors: while 50% of respondents from the construction sector considered agriculture as essential, in the tourism sector this percentage did not reach a quarter of the number of respondents.

Almost half of the respondents (44.1%) considered that the agricultural activity is controlled by large companies that create scarce and precarious employment, while 37.2% thought that it generates many jobs, but the employment is not high quality nor with a guarantee of longevity. Only 18.7% considered that irrigated agriculture is very important because of the quantity and quality of employment it generates, and that irrigation is a guarantee of present and future opportunities for the surrounding population. The answers to the social importance of the agrarian activity in the SESMM (Q8) depended on the group of respondents according to their profession and main economic activity (Table 5.1).

Only the agricultural sector had more than 50% support of the option that irrigated agriculture is very important for the quantity and quality of employment it generates and that irrigation is a guarantee of present and future for the surrounding population, expressing an opinion contrary and statistically signifcantly different compared to the rest of the groups.

5.4.2. Social perceptions about the state and impacts in the Mar Menor lagoon

Regarding the assessment of the environmental impacts caused by intensive agriculture (Q9), the majority of respondents (97.6%) considered that agriculture is mainly responsible for the eutrophic state of the lagoon, and more than half (58.7%) thought that the agrarian sector should assume its share of co-responsibility, as in the application of the polluter pays principle. Significant diferences were found according to the groups of respondents by economic activity (Table 5.1). Within the agricultural sector, this attribution of responsibility is the lowest, but it reaches the substantial proportion of 38%, followed by construction (50%) and by the rest of the sectors which reached values higher than 50%.

Among the main effects of irrigated agriculture on the Mar Menor lagoon and its surroundings (Q10), the most noted were: pollution by pesticides and fertilizers, negative efects on other sectors such as tourism (tourism quality), degradation of the landscape, and negative effects on recreational and leisure uses of the Mar Menor lagoon. Given this situation, almost all respondents (98.6%) thought that the entry of nutrients into the lagoon should be limited (Q11), and no signifcant statistical differences were found among the groups of respondents (Table 5.1).

Table 5.1. *P* values for independence test between the groups of respondents according to their profession and main economic activity and the variables corresponding to questions Q1, Q2, Q5, Q7, Q8, Q9, Q11, Q14, Q15_1, Q15_2, Q15_3, Q16, Q18, Q19, Q20, Q21_1, Q21_2, Q21_3, Q21_4, Q22, Q23_1, Q23_2, Q23_3 and Q23_4.

Questions	P-value
Q1	0.00001
Q2	0.00081
Q5	0.31784
Q7	0.00001
Q8	0.00005
Q9	0.04346
Q11	0.05787
Q14	0.00004
Q15_1	0.04638
Q15_2	0.13361
Q15_3	0.00001
Q16	0.00023
Q18	0.00014
Q19	0.00002
Q20	0.97149
Q21_1	0.0386
Q21_2	0.34849
Q21_3	0.00034
Q21_4	0.00341
Q22	0.13825
Q23_1	0.02632
Q23_2	0.32163
Q23_3	0.0051
Q23_4	0.15617

Almost all respondents (99%) felt that the Mar Menor lagoon has important environmental values and ecosystem services (Q20); therefore, no differences were found among the groups of respondents. The most relevant environmental values and ecosystem services (Q21) in order of importance were the conservation of the biodiversity of the lagoon and its associated wetlands, fishing production, cultural identity and quality of life, and the recreational and tourist aspect. A total of 98.8% of respondents perceived that these environmental values and ecosystem services are threatened (Q22), there being no differences between the groups of respondents (Table 5.1).

A total of 91.3% of respondents felt that the water quality of the lagoon is no longer good (Q14). The answer to this question depended on the profession and main economic activity of the respondent (Table 5.1), so that, construction and tourism sectors (Hotels and restaurants and Services) reached the highest percentages of those who believe that the water quality of the lagoon is good despite specifc episodes of pollution (40%, 20% and 24%, respectively, values much higher than the other groups of respondents). Agricultural discharges were considered the main causes of pollution in the lagoon (Q15), without differences of opinion between groups reaching the level of statistical significance (Table 5.1).

Regarding attribution of responsibilities (Q16), most of the respondents (83.5%) thought that the main responsibility for nutrient pollution is the regional administration (Ministry of Water, Agriculture and Environment) and state administration (Confederación Hidrográfica del Segura), due to its insuficient control and monitoring of agricultural activity and water use, although some of the respondents also pointed to other responsible parties such as farmers and even agricultural advisory technicians. The answer to this question was varied significantly depending on the group of respondents (Table 5.1). It should be noted that the respondents belonging to the public administration also expressed the majority opinion (86%) that they are the main responsible for nutrient pollution.

In addition, most respondents (81.6%) felt that climate change could worsen the state of the lagoon (Q18). Although this opinion is majority in all groups, signifcant differences were found, with that opinion being less expressed by the tourism sector (Table 5.1).

5.4.3. Preferences on management measures in the SESMM

5.4.3.1. Management measures on urban-tourist development

A total of 95.5% of the respondents considered it necessary to take urgent measures to improve urban-tourist quality (Q5), and there were no significant statistical differences between the groups of respondents (Table 5.1). According to the PCA in Table 5.2, it was observed that the frst two components explained the variability of the variables corresponding to the measures related to urban-tourist development (Q6).

Table 5.2. Contribution of each component of the PCA to the total variance explained for the management measures to improve urban-tourist development in the SESMM.

	Eigenvalue	**Percentage of variance**	**Cumulative percentage of variance**
Component 1	4.648947e+00	4.648947e+01	46.48947
Component 2	3.138831e+00	3.138831e+01	77.87779
Component 3	8.944562e-01	8.944562e+00	86.82235
Component 4	6.026995e-01	6.026995e+00	92.84934
Component 5	3.264989e-01	3.264989e+00	96.11433
Component 6	2.349651e-01	2.349651e+00	98.46398
Component 7	1.204169e-01	1.204169e+00	99.66815
Component 8	2.664344e-02	2.664344e-01	99.93459
Component 9	6.520653e-03	6.520653e-02	99.99979
Component 10	2.055888e-05	2.055888e-04	100.00000

The frst two main components collected a cumulative total variance of 77.9%. It was observed that the measurements Q6_7, Q6_4, Q6_6, Q6_3 and Q6_2 are the best represented in the frst component (PC1) (Fig. 5.2). These measures are those related to sustainable mobility and the management and protection of natural protected areas and areas that allow construction, as well as two types of measures that are negatively correlated and that most of the respondents wanted to reject and not carry out (Q6_4 and Q6_3). This set of measures, according to the quality of their representation in the PC1, was:

• Improve the public transport network (Q6_7).
• Do not make a greater offer of second homes Q6_4).
• Improve the bike lane and the spaces adapted for walking and sports (Q6_6).
• Do not carry out more hotel construction (Q6_3).
• Improve the management and protection of the natural areas around the Mar Menor, coastal wetlands and free areas of buildings (Q6_2).

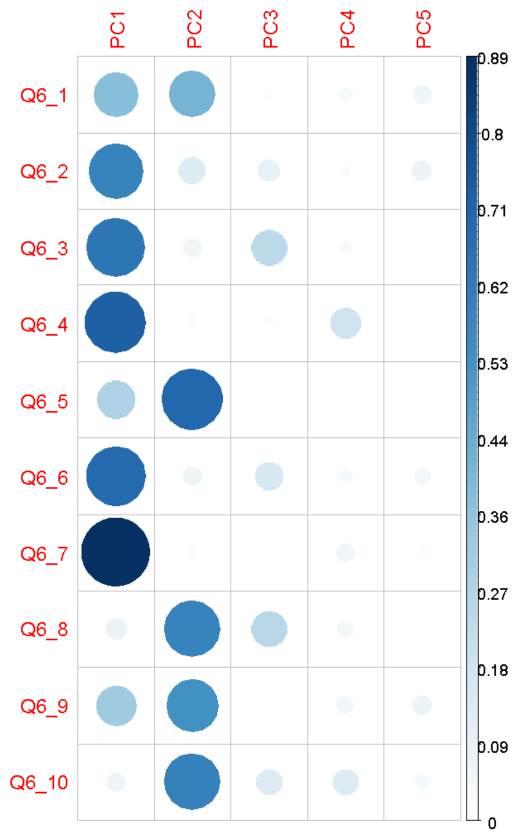


Figure 5.2. Weight of the variables (management measures to improve the urban-tourist development in the SESMM) in the frst five main components.

On the other hand, the measurements Q6_5, Q6_10, Q6_8, Q6_9 and Q6_1 contributed most weight to the second component (PC2) (Fig. 5.2). This second group of measures had a very high positive correlation with the measures related to the improvement of the public infrastructure already built and the urban moratorium:

• To remodel built buildings for an improvement of tourist image (Q6_5).
• Improvement of parking areas (Q6_10).
• Improvement of the infrastructure for road traffic (Q6_8).
• Improvement of accessibility to urbanizations and beaches (Q6_9).
• Urban moratorium (Q6_1).

The biplot presented in Fig. 5.3 showed the relationship between each of the variables or management measures studied, with respect to the average score of the groups of respondents. It was observed that the management measures Q6_10, Q6_8 and Q6_5 are related, and the representatives of the administration were the group of respondents that acquired a closer position to carry out these measures. On the other hand, the management measures Q6_6 and Q6_7 are also related to each other and the people who are in the services of the tourism sector (TouristS) were the ones that had the greatest preference for these management options. It should be noted that respondents engaged in fishing had a greater affinity with management measures Q6_2 and Q6_1.

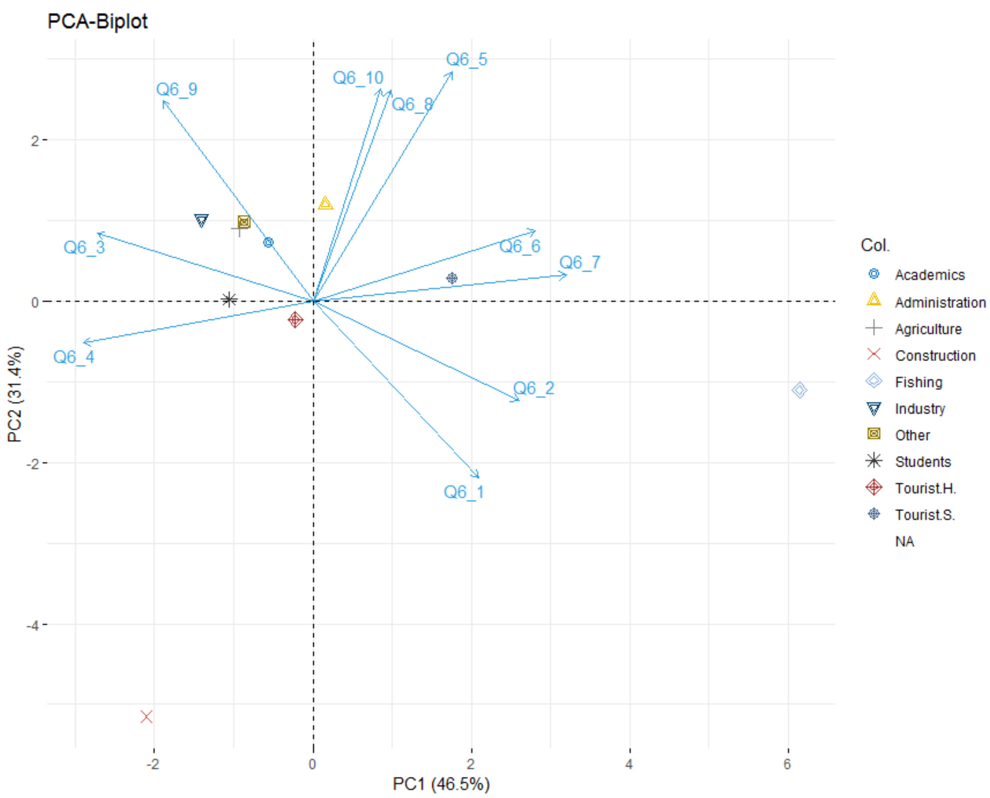


Figure 5.3. Biplot for the management measures to improve the urban-tourist development of the SESMM and the groups of respondents in the study according to their profession and main economic activity.

The order of preference according to the level of importance of the management measures to improve urban-tourist development of the Mar Menor area, established according to the average value of the respondents, was:

1. Do not make a greater offer of second homes (Q6_4).
2. Improve the public transport network (Q6_7).
3. Remodeling built buildings for an improvement of tourist image (Q6_5).
4. Improvement of parking areas (Q6_10).
5. Improve the bike lane and the spaces adapted for walking and sports (Q6_6).
6. Improvement of accessibility to urbanizations and beaches (Q6_9).
7. Improve the management and protection of natural areas around the Mar Menor, coastal wetlands and free areas of buildings (Q6_2).
8. Urban Moratorium (Q6_1).
9. Improvement of the infrastructure for road traffic (Q6_8).
10. Do not carry out a greater construction of hotels (Q6_3).

5.4.3.2. Management measures on the water quality of the Mar Menor lagoon

Although most respondents chose to reduce the input of nutrients to improve the water quality status of the lagoon (72.6%), some groups of respondents also supported other options (Q19), with different preferences according to the group of respondents (Table 5.1). In the agricultural sector, almost half of the respondents chose diferent measures, the expansion of communication channels of the lagoon with the Mediterranean (23.8%) and intervention measures within the lagoon (11.9%). In the construction sector, these two other measures received the support of 30% and 10% of the respondents, respectively. In the sector of public administration, although 65.5% of respondents chose to eliminate or reduce the entry of nutrients, 27.3% considered the application of measures inside the lagoon.

Within the specific measures to reduce the entry of nutrients into the lagoon, the PCA allowed the identifcation and grouping of two groups of measures: those related to the control of pressures and those related to nature-based solutions (PC1), and other measures less related with solving the problem at source (PC2).

Table 5.3 presents the percentage of variance explained by each main component. It was observed that the frst two components explain a large part of the variability of the variables under study and that the cumulative variance percentage reached 79.8%. In addition, Fig. 5.4 indicates that the measurements Q12_4, Q12_2, Q12_3, Q12_8, Q12_1, Q12_5 and Q12_9 are those of greater weight in the frst component. It should be noted that measure Q12_5 was rejected by most respondents who preferred not to consider it. The set of these measures, according to the quality of their representation in the PC1, was:

• Establish and monitor the application of maximum fertilizer input values (Q12_4).
• Elimination of irregular uptake of groundwater (Q12_2).
• Require that each desalinator includes a brine treatment (Q12_3).
• Apply natural measures of water and nutrient retention at plot scale and in the watershed (e.g., green hedges, small ponds, etc.) (Q12_8).
• Reduce the irrigated area (Q12_1).
• Do not collect the brines and pour them directly into the Mediterranean Sea (Q12_5).
• Recover and enhance the lost surface of natural wetland in the periphery of the lagoon (Q12_9).

For its part, management measures Q12_7 and Q12_6 were well represented in the second component:

• Build a green flter to treat the flow of the Albujón watercourse (Q12_7).
• Collect the brines and part of the flows of the waters of the "ramblas" and after their dislocation, pour their reject flow into the Mediterranean Sea (Q12_6).

Table 5.3. Contribution of each PCA component to the total variance explained for management measures to limit the entry of nutrients into the Mar Menor lagoon.

	Eigenvalue	Percentage of variance	Cumulative Percentage of variance
Component 1	5.742676140	63.80751266	63.80751
Component 2	1.443675028	16.04083364	79.84835
Component 3	0.844636518	9.38485020	89.23320
Component 4	0.419507002	4.66118891	93.89439
Component 5	0.321633412	3.57370458	97.46809
Component 6	0.122616230	1.36240256	98.83049
Component 7	0.081287470	0.90319411	99.73369
Component 8	0.018313137	0.20347930	99.93717
Component 9	0.005655063	0.06283403	100.00000

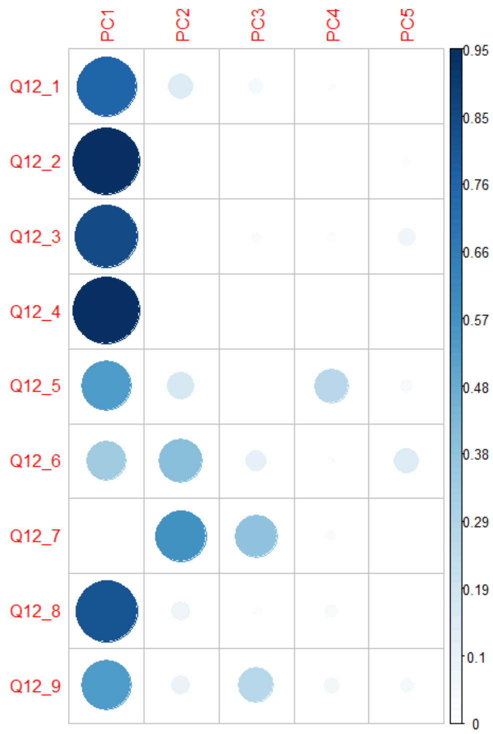


Figure 5.4. Weight of the variables (management measures to limit the entry of nutrients in the Mar Menor lagoon) into the first five main components.

Figure 5.5 presents the biplot representation for management measures to limit the entry of nutrients into the Mar Menor lagoon, with respect to the average score of the groups of respondents involved in the study. It was observed that management measures Q12_6 and Q12_1 are related, and the representatives of the administration were the group of respondents who point to them. In addition, management measures Q12_2 and Q12_4 are also related to each other, and the people surveyed who belong to the fishing sector were those who agreed with these options. It should be noted that the representatives of the construction sector, the tourism sector and the academic sector were all similar with respect to preferences associated with the management measure Q12_7.

The order of preference according to the level of importance of the management measures to limit the entry of nutrients into the Mar Menor lagoon, established according to the average value of the respondents, was:

1. Reduce the irrigated area (Q12_1).
2. Require that each desalinator includes a brine treatment (Q12_3).
3. Elimination of irregular uptake of groundwater (Q12_2).
4. Recover and enhance the lost surface of natural wetland in the periphery of the lagoon (Q12_9).
5. Apply natural measures of water and nutrient retention at plot scale and in the watershed (e.g., green hedges, small ponds, etc.) (Q12_8).

6. Establish and monitor the application of maximum values of fertilizer contribution (Q12_4).
7. Build a green filter to treat the flow of the Albujón watercourse (Q12_7).
8. Do not collect the brines and pour them directly into the Mediterranean Sea (Q12_5).
9. Collect the brines and part of the flows of the waters of the "ramblas," and after their dislocation, pour their reject flow into the Mediterranean Sea (Q12_6).

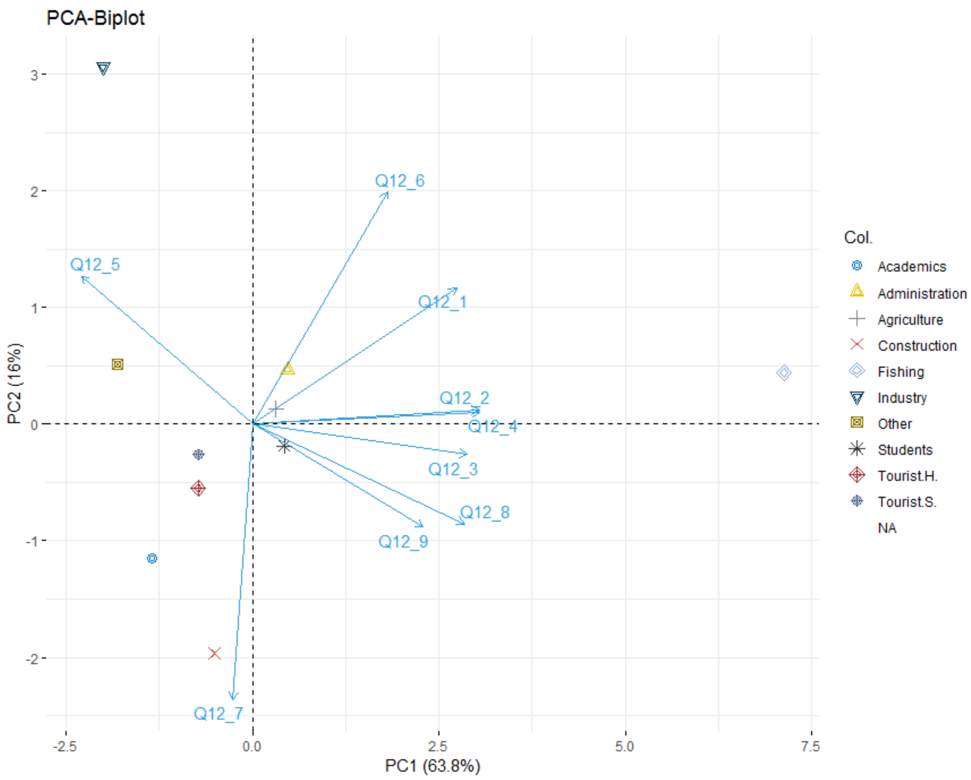


Figure 5.5. Biplot for management measures to limit the entry of nutrients into the Mar Menor lagoon and the groups of respondents in the study according to their profession and main economic activity.

5.5. Discussion and conclusions

The results confrmed that the general perception of the surveyed groups regarding the pressures, state and impacts of the main uses and activities in the SESMM coincides with the diagnosis that the scientifc–technical community has been making in recent decades (Martínez-Fernández et al. 2014; Esteve Selma et al. 2016; Comité de Asesoramiento Científico del Mar Menor 2017; Martínez Fernández et al. 2017). In this sense, there seems to be a certain consensus in the diagnosis of the problem, but that consensus does not fully translate into responses or management measures. Regarding such potential response measures, there are greater differences among the groups of respondents, and also between the perceptions of the respondents and the main measures that have been carried out or are currently envisaged by the public administration. This evolution closely follows the life-cycle curve of environmental policies. This theory explains how the degree of disagreement and the political weight of the different phases of an environmental policy change. According to this theory, environmental problems go through an initial stage in which the disagreement is very high and includes the recognition of the existence of the problem itself. This stage gives way to other phases in which the disagreement is giving way to acceptance and formulation, where consensus is first reached in the diagnosis but there is still disagreement about the measures to be applied, until the final stages of implementation and control (Nebel and Wright 1999) when the consensus also covers the measures.

There are statistically significant relationships among the different groups of respondents that vary according to their profession and main economic activity, and the groups vary in their perception of urban-tourist development and its impacts, agricultural activities and their impacts and the state of the Mar Menor lagoon. It refects the existence of different interests, expectations and values in the different groups of respondents, as expected, which in turn is partly reflected in the responses obtained. Thus, as expected, the agricultural sector considers mainly that its activity is essential for the economic development of SESMM. Likewise, within the agricultural sector more than half consider that agricultural activity is very important because of the quantity and quality of employment it generates; while in most other groups of respondents, they consider either such employment to be not of quality, or without future guarantees, or that the employment is controlled by large companies that create scarce and insecure employment. In the same way, continuing with the more or less expected results, regarding the measures to limit the entry of nutrients into the Mar Menor lagoon, the priority position of the representatives of the public administration is to collect the brines and, after treatment and denitrification, pour them into the Mediterranean Sea, line of work in which, precisely, several actions of the regional government are framed (BOE 2019).

However, some of the results are striking and less obvious, such as diferences of opinion within the tourism sector, comparing those engaged in the hotels and restaurants to those working in the service sector. Specifcally, half of the former favored greater urban-tourist development and valued the quality of tourism to be between acceptable and good. The service sector, on the other hand, thought that the urban-tourist development surrounding the Mar Menor lagoon is too crowded, and they valued the current tourism quality between regular and bad, which was similar to the rest of the groups of respondents. Other studies (Aledo et al. 2007; Gaja 2008) also confrm how the model of urban-tourist development in the Mar Menor area and in other areas of the Mediterranean coast, has not generated a quality tourism structure and has also brought negative environmental consequences (Romero Díaz et al. 2011; Pérez Morales et al. 2016).

It should also be noted that a quarter of the tourism sector as a whole perceived that the lagoon's water quality is good despite the fact that there are specific episodes of pollution and that they do not believe that climate change affects its state, a view contrary to most of the rest of the groups surveyed, as well as the latest studies on climate change in the Region of Murcia and particularly in the Mar Menor (García-Ayllón and Miralles 2014; Martínez-Graña et al. 2018). The National Climate Change Adaptation Plan points out that La Manga del Mar Menor will be one of the areas most threatened by the sea level rise (OECC, MIMAM 2006).

It is important to point out that with regard to management measures to improve urban-tourist development, the fishing sector took a closer position to improve the management and protection of the natural areas around the Mar Menor, coastal wetlands and free zones of buildings, as well as the urban moratorium. The representatives of the administration were closer to the second group of management measures, measures that were related to the improvement of the infrastructures already built, while people working in the service sector (TouristS) gave more priority to the measures related to sustainable mobility such as improving the bike lane and the spaces adapted for walking and sports, as well as improving the public transport network.

However, what is more remarkable is the existence of important consensus, among all the groups of respondents, regardless of their profession and main economic activity. These basic consensuses, some of them certainly not expected, can be summarized as follows: (a) They believe it is necessary to apply improvements in urban-tourist development; (b) consider that the entry of nutrients into the Mar Menor lagoon should be limited; (c) think that the main cause of pollution in the Mar Menor lagoon is agriculture; (d) consider that the Mar Menor lagoon has relevant environmental values and ecosystem services and (e) believe that such values and services are threatened (Table 5.1).

Regarding the consensus about the urban-tourist sector, the best supported measures to improve the urban-tourist development of the SESMM were those related to sustainable mobility. It is also important to highlight a majority consensus on the part of all the respondents to not apply the measures that promoted new urban developments, such as a greater construction of second residences, and instead to focus more on the remodeling of existing buildings. This perception is analogous to findings of recent studies on the environmental and socioeconomic effects of the "urban sprawl" in the Mediterranean coast of Spain, where Region of Murcia is located (Romero Díaz and Pérez Morales 2017; Pérez Morales et al. 2015; Docampo Calvo 2011). In a less priority position than the previous ones, the urban moratorium was also supported. Although in February 2017, the Regional Assembly approved a motion in favor of an urban moratorium, its approval was controversial and was not implemented (and it was approved with the vote against the party in the regional government). It should be noted that the regional government has not adopted legislative initiatives to improve urbanism in the SESMM, despite the fact that the Autonomous Community has suficient powers in this area to lead, in collaboration with the municipalities involved, the necessary control of urban-tourist development in the SESMM. There are current (2019) measures that the regional government proposes to carry out, or have been carried out, to improve the urban-tourist development in the SESMM. For the most part, they are far from the group of priority measures proposed by the respondents in this study, and that derive from this study, a result which shows the existence of clear differences between what the regional government is doing or proposes to do in this area and what the population really wants. In this sense, the results of the survey point to a divergence between the preferences of the local community and the policies promoted by the regional government.

Continuing with the elements of consensus, it is striking to see the widespread recognition of agriculture as the main cause of pollution in the lagoon, since until recently there was no such consensus on the role of intensive irrigation. Thus, studies carried out in the previous decade (Martínez-Paz et al. 2005) showed that most of the local community and stakeholders in the Mar Menor area considered the improvement in wastewater management to be much more important than actions in the agrarian feld. This perception is possibly based on the greater visibility of pollution by wastewater with respect to the difuse agricultural pollution. The correct identifcation of the main origin of the contamination detected in our results could be due to the continuous work of dissemination carried out from the scientific feld and from different environmental organizations and, above all, to the great impact in the population that the eutrophic crisis generated in 2016. The magnitude of the change, with the drastic transformation of the traditional transparent waters of the Mar Menor into the so-called green soup, broke the inertia of perception, invalidated the explanatory mechanisms that until then had been working and allowed the dissemination of the causes of problem made from scientific felds would receive the echo and the necessary public attention.

The change in this general perception, and the correct identifcation of agrarian activities as the main source of pollution in the lagoon, could support the idea that, although the specific interests of the different groups of respondents contribute to shaping the opinions of the same (Rickson 1985), the degree of knowledge that we have about the processes of the basin and the lagoon (which is significantly greater at the present time as a result of the eutrophic crisis) is also an important factor when explaining the local perceptions and changes over the long term. Regarding the priority measures to limit the entry of nutrients into the Mar Menor, most respondents preferred the application of measures related to the control of pressures such as reducing the irrigated area, forcing each desalinator to include a brine treatment or the elimination of irregular uptake of groundwater. On the other hand, they also expressed support for those related to nature-based solutions, such as the recovery of wetlands and natural water retention measures, in the line of the results obtained by other works (Martínez-Paz et al. 2013; Perni and Martínez-Paz 2013). They also rejected the measure of collecting the brines and dumping them directly into the Mediterranean Sea. It is striking the consensus around the rejection of this management measure since it is a measure that has been proposed on different occasions. This rejection of the direct discharge to the Mediterranean could be explained, on the one hand, by the increase in environmental awareness about the impacts in the Mediterranean Sea and, on the other, by the ecological collapse of the Mar Menor lagoon, which perhaps has been visualized as an example of what could also happen in the Mediterranean.

It should be noted that some of these measures, such as the application of natural measures to retain water and nutrients at the scale of the plot and in the basin, are also included in Law 1/2018 on urgent measures to guarantee environmental sustainability in the Mar Menor area. This law, approved by the Regional Assembly in February 2018, focuses on measures in the agrarian field, including the obligation to devote 5% of the area of agricultural land to hedges, revegetation with wild species and similar actions. It also establishes the obligatory nature of soil conservation practices and runoff control. The approval of this law was also very controversial (it was approved with the vote against the party in the regional government and with strong opposition from the agrarian sector) and it is not being applied; however, the results of this work show that a good part of the measures included in the aforementioned Law 1/2018 have broad support from the respondents. Again, this points to divergent positions between the measures that the majority supports the population and those that have greater support and priority for the regional government. The results obtained also show the social acceptability of some measures (recovery of wetlands) whose environmental and economic viability has been widely established by other studies, which show that the construction and especially the restoration of wetlands is an option with a high cost-efectiveness to reduce difuse pollution in agricultural watersheds (Gren et al. 1997; Zanou et al. 2003; Lacroix et al. 2005, Elofsson 2010; Trepel 2010).

The need to apply measures to limit the entry of nutrients into the Mar Menor lagoon is also reinforced by the legal obligations arising from the declaration in 2001 of the Campo de Cartagena watershed as a Vulnerable Zone in application of the Nitrates Directive (91/676/ECC), of the declaration of the lagoon as a Sensitive Area in application of the Urban Wastewater Directive (91/271/ECC) and of the application of the Water Framework Directive (2000/60/EC), which requires reaching and maintaining the Good Condition of all water bodies.

To conclude, the results of this work reveal that the local community of the SESMM perceives an ecological crisis that brings a crisis and important social impacts for the population of the study area in terms of loss of quality of life and progressive decrease in socioeconomic opportunities linked to the lower functionality of the system. The crisis is fundamentally of management, of governance of the SESMM, with little effective, efficient and coherent policies and little informed, participatory and transparent ways of doing politics, which has allowed the SESMM to arrive at the current situation. This has generated a high social concern that so far has not been well attended by those responsible for the management of this SES.

According to the scientific community (Comité de Asesoramiento Científico del Mar Menor 2017; Ruiz Fernández et al. 2019), the main key actions that must be taken to promote the desired changes are: to stop the entry of sediments and nutrients with prevention measures at source, improving the techniques and efficiency of agricultural fertilization, applying different solutions based on nature and recovering the surfaces of natural wetlands located on the periphery of the lagoon, the only systems capable of retaining and eliminating a good part of the sediments and nutrients transported during the food events. To this must be added the elimination of irregular irrigation, compliance with current European, state and regional regulations [e.g., the Nitrates Directive (91/676 ECC) and the Water Framework Directive (2000/60 EC)], as well as not promoting new urban developments. Publicizing the impacts of excessive urban development in the Mar Menor where massive construction has been promoted for its tourist exploitation could help not to make the same mistakes in other similar characteristic lagoons, such as the coastal lagoon of Nador or Mar Chica (NE, Morocco), an area in a state of incipient development with traditional activities such as agriculture and fishing, but where there are development plans as a national and international tourist center (Raji et al. 2013). It should be noted that these actions are in line with what the population proposes in this work, but instead are far from the planned actions by the regional government.

The cost of not acting and managing the SESMM with an integral and holistic approach could be very high from an economic, social, ecological and public health point of view and lead us to situations such as Salton Sea, the largest lagoon in California (USA) (Upadhyay et al. 2013). The contamination by agricultural spills and an unbridled urban planning for decades has led to an ecological deterioration of this lagoon, with enormous ecological and socio-economic consequences, as well as on public health in the area and that currently the Californian government does not know how to solve (Bradley and Yanega 2018; Marshall 2017). The traditional solution to management conflicts in the SES has been to delegate all responsibility to the government. However, there is evidence that centralized and vertical style management approaches are inappropriate due to their infexibility and lack of adjustment to the complexity of socio-ecological processes (Jassen and Ostrom 2006; Ostrom 1990; Holling and Mefe 1996).

In this regard, several authors have highlighted the need for participatory approaches to improve decision-making in the management of SES and contribute to the transition of these systems toward sustainability (Reed 2008; Ban and Mills 2013). The sustainable management of natural resources cannot be achieved without the involvement of the afected community, so other alternative governance approaches to centralized management such as co-management are required. Therefore, an aspect of great relevance for future work is the identifcation and characterization of the key stakeholders and their interests in the SESMM, in order to formulate consensus alternatives (Mumtas and Wichien 2013; Purnomo et al. 2017). For this reason, the establishment and construction of dialogues, trust and cooperation processes should be promoted through the exchange of information, perceptions, needs, visions and the implicit and explicit knowledge of the key stakeholders (Prell et al. 2009; Hauck et al. 2016).

This article supports the widely accepted vision by other authors (Sodhi et al. 2009; Castro et al. 2011; Perni and Martínez-Paz 2013) that local knowledge must be explicitly taken into account for the successful management of complex socio-ecological systems such as the Mar Menor. The analysis of stakeholders, together with the knowledge of the local community perceptions that this work exposes, would allow to support and improve the selection, efficiency and effectiveness of the policies and projects that are carried out in the future in the management of the SESMM.

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Chapter 6.

Stakeholder analysis and priorization of management measures for a sustainable development in the social–ecological system of the Mar Menor (SE, Spain)

Humedal de Marina del Carmolí

Marina del Carmolí wetland

6. Stakeholder analysis and prioritization of management measures for a sustainable development in the social-ecological system of the Mar Menor (SE, Spain) *

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Abstract

The effects caused by agricultural and urban activities over the last decades have led the social-ecological system of the Mar Menor to an environmental degradation that compromises the ecosystem services it offers to society. This article describes a stakeholder analysis through a participatory methodology where dialogue has been essential to identify, characterize and know their preferences about possible solutions or management measures for the restoration of the social-ecological system. Results showed that the objectives, interests and needs of the seven stakeholder groups identified are contradictory. Results also showed that, at least in the initial phase of facing the design and implementation of a deliberative participation process, it appears difficult to reach consensus regarding the prioritization of measures. It may be a challenge to both to improve urban tourism development and to limit the entry of nutrients into the Mar Menor coastal lagoon. But results point to an important consensus such as the prioritization of reducing the irrigated area. This consensus, which is different from the results obtained in previous studies, represents a very recent change of opinion regarding the role of agriculture in the Mar Menor. Stakeholder participants who collaborated in this article can be positive influences in the design and implementation of a deliberative participation process, given that they can act as intermediaries to generate consensus. Therefore, the results of this stakeholder analysis can contribute to guiding future deliberative participation processes.

Keywords: Environmental degradation; Management measures; Mar Menor; Participatory process; Social-ecological system; Stakeholder.

6.1. Introduction

6.1.1. Social-ecological systems and the role of the stakeholders

The concept of the social-ecological system (SES) has generated a growing consensus among scientific disciplines, regarding its usefulness as a framework to understand the relationships between natural and social integrated systems, in the search for more sustainable guidelines for development (Binder et al. 2013; Fischer et al. 2015). The concept of SES is born as part of a new paradigm due to the concern of different researchers, from different disciplines, for the conservation of biodiversity and for the proper functioning of ecosystems and life support systems on the planet (Liu et al. 2007, Balvanera et al. 2017). Janssen and Ostrom (2006) define SES as complex adaptive systems in which social and biogeophysical agents are interacting through multiple spatial-temporal scales.

Participatory processes are key factors for the study of SES (Gadgil et al. 1993; Becker and Ghimire 2003; Lunas-Reyes and Andersen 2003; Tengö and Belfrage 2004), especially when it is aimed at contributing to the taking decision-making for sustainability (Reed 2008; Ban et al. 2013). Participatory approaches facilitate the direct involvement of the stakeholders associated with a SES in the different phases of the planning processes and the management of natural resources, promoting the construction of dialogues and cooperation between the stakeholders (Prell et al. 2009; Hauck et al. 2016).

Stakeholder analysis allows a better understanding of SES, identifying key actors and evaluating their interests in that system (Prell et al. 2009; Hauck and Col 2016; Young et al. 2013), in addition to being a process to support decision-making and strategy formulation (Yang 2014; Delgado-Serrano et al. 2015). The identification of the key actors, their representativeness and legitimacy is decisive to implement an adequate governance process and thus successfully contribute to conflict resolution (Comino et al. 2016). Integrating and recognizing different types of knowledge and the values of the different stakeholders will contribute to a better understanding of the dynamics and processes of SES, as well as facilitating decision-making (Palomo et al. 2011; Hanspach et al. 2014; Villamor et al. 2014; Balvanera et al. 2017).

A stakeholder is defined as "any group or individual that can affect or be affected by a decision or action" (Freeman 1984). The scientific literature includes several practical methods for the analysis of stakeholders such as surveys, interviews, participatory workshops, map of interest and influence, brainstorming, analysis of decision networks, among others (Bourne and Walke 2008; Dente 2014). Stakeholder analysis is applied in differnt fields (Friedman and Miles 2006). It is increasingly used in natural resource management (Reed et al. 2009; Knontogianni et al. 2012), and in understanding SES (Rietbergen and Narayan 1998; Koanda 2006) and strategic decision-making, especially in complex SES, such as the social-ecological system of the Mar Menor (SESMM).

The SESMM (SE, Spain) deals with an environmental collapse that is already assuming significant social and economic costs to the local community, who is demanding new development initiatives to get out of the social and economic situation caused by the environmental degradation of the area (Conesa and Jimenez 2007; García-Ayllón 2017). A different development is necessary, a development that internalizes the environmental dimension in order that the population of this social-ecological system has a future in a medium-long term (Scientific Advisory Committee of the Mar Menor 2017; Ruiz et al. 2019). This situation requires the urgent search for management measures with an integrated approach based on the best available knowledge and taking into account the stakeholders opinion involved in the system with the common objective of improving the environmental and socioeconomic situation. But who are these stakeholders? Who do they represent? What are their roles? What strategies do they have? What are their perspectives? What is their relationship between them? This article aims to present a stakeholder analysis in the SESMM, through a participatory methodology where dialogue has been essential to answer the questions asked and know their interests. To achieve these goals, we: 1) identified and characterized the stakeholders associated with the SESMM in order to know their perceptions and interests; 2) evaluated their preferences regarding management measures for the restoration of the system and 3) analyzed the consensus and/or conflicts established between them over solutions or management measures.

6.1.2. The Social-ecological System of the Mar Menor. Keys to the problem

The SESMM, in Southeastern Spain (Fig. 6.1), is an area with a sub-desert Mediterranean climate, characterized by high temperatures (average annual temperature of 15 ºC to 17ºC) and low rainfall (around 300 mm per year). Its location, geography, and unique natural environment have made it known and valued both nationally and internationally (Martínez et al. 2003). The SES includes the Mar Menor lagoon, the surrounding wetlands and the Mar Menor watershed. The population of the seven municipalities fully or partially integrated in the watershed (San Pedro del Pinatar, San Javier, Los Alcázares, Torre Pacheco, Cartagena, Fuente Álamo and La Unión) amounts to 357,266 inhabitants in 2017. The local government of these municipalities along with the Ministry of Water, Agriculture, Livestock and Fisheries (regional government) and the Segura Hydrographic Confederation (national government) are the main government institutions.

The main uses and economic activities in the SESMM are agrarian activity, urban-tourist development, and some fishing activity. The Scientific Advisory Committee of the Mar Menor (2017) highlights that these activities have operated as driving forces generating pressures and impacts on the SESMM for decades, which has induced environmental deterioration and the loss of natural and cultural values, as well as traditional uses and exploitation (Esteve et al. 2008, 2016; Martínez et al. 2014, 2017; León and Bellido 2016).

The urban-tourist development started in the 1960s. Most of the activity was on the watershed coastline, mainly in La Manga del Mar Menor, with second homes in a proliferation of tourist developments. These were generally medium-low quality residential, with a high environmental deterioration and negative effects even for tourism itself, including its future development in the medium and long term (Scientific Advisory Committee of the Mar Menor 2017). Added to this tourist displacement is the opening of the coastline to global migratory flows of unskilled labor and the reinforcement of a tourist pattern based above all on the residential model, with a consolidated summer population. That population is fundamentally of national origin and of great loyalty (Romero and Perez 2017), although in recent years a large population of foreigner's community has also settled. The population in summer season is estimated to reach half a million people (Verdiell et al. 2013; García-Ayllón 2016). Consequently, one of the first pressures was the discharge of urban wastewater that historically affected the water quality of the lagoon in the summer due to breakage or overloading of the treatment infrastructures. These waters were discharged untreated, especially during the busy summer season (García-Ayllón 2016). This problem, persistent for many years, currently (2020) is partially controlled by the construction and start-up of new treatment plants, with the exception of specific situations due to the breakdown of any installation.

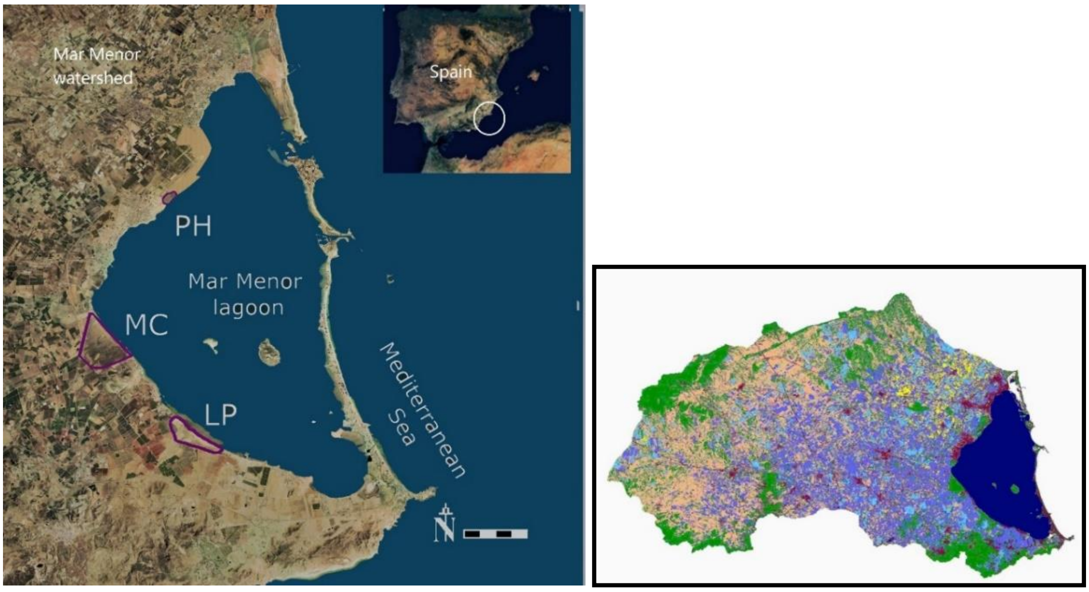
At the same time, tourism has demanded infrastructures such as the construction of roads, ports, dikes, boardwalks and beach regeneration that are often accompanied by environmental impacts. Other relevant effects include those generated by the opening of the Estacio canal (port) in 1973 to make it navigable. This infrastructure increased the water connection between the lagoon and the Mediterranean Sea, which caused a reduction in the lagoon's salinity, as well as a tempering of the range of temperatures inside the lagoon. These modifications of the physicochemical conditions have induced profound changes in the communities and lagoon dynamics (Scientific Advisory Committee of the Mar Menor 2017).

It should be noted that in the Mar Menor lagoon there are twelve ports, which represent 45% of the total number in the Region of Murcia, when the coastline that the Mar Menor lagoon occupies is only a small fraction of the total coastline in the autonomous community (Martínez et al. 2003). Also, 50% of the hotel beds on the coast and 64% of the total supply of apartments are in the Mar Menor. The speculative pressure along with the excessive buildability and the absence of a true urban planning has greatly exceeded the capacity of reception of the territory (García Sánchez and García Garay 2003).

But the degradation of the SESMM is mainly determined by an uncontrolled development of the agricultural sector and the agri-food industry in the entire watershed, especially since the conversion of dry land to irrigation with the arrival of water from the Tajo-Segura Transfer in 1979, technological advances in agriculture and socio-economic changes, all driven by the great differential in profitability between rainfed and irrigated crops (Martínez and Esteve 2000; Carreño 2015). More than 80% of the total area of the Mar Menor watershed is dedicated to the intensive irrigated agriculture (mainly horticultural crops, citrus and greenhouses supporting these other crops) (Carreño 2015), because of the high demand of these crops in water, land and fertilizer. The agriculture sector has two very different groups: the farmer who manages his own land, and the large companies, both national and international, that rent the land to the owner of the land and exploit it by hiring labor, for the subsequent export of the products to Europe.

Estimates indicated that the agricultural nutrient inputs represent around 85% of the total loading into the lagoon (Martínez et al. 2014; Esteve et al. 2016) which is causing an acute process of eutrophication of the waters (Martínez et al. 2005, 2014, 2017; Velasco et al. 2006; Esteve et al. 2008, 2016, Carreño 2008; Carreño 2015; Ruiz et al. 2019). It should also be noted that another of the impacts of agricultural activity is nitrate contamination of aquifers. The Quaternary aquifer contained nitrate concentrations above 200 mg/l (Scientific Advisory Committee of the Mar Menor 2017) which gives an idea of the magnitude of the problem, since the limit value established by the Nitrate Directive (91/676/EEC) is 50 mg/l. Also, this type of intensive agriculture modifies the soil, changes the slopes, and plans it in order to increase the efficiency of its farming machinery. The loss of the traditional soil retention mechanisms favors erosion and the massive entry of materials and solid waste into the Mar Menor, contributing to increase the turbidity of water in episodes of heavy precipitation, due to sediment entrainment (Scientific Advisory Committee of the Mar Menor 2017).

The continued input of nutrients into the Mar Menor lagoon in recent decades, associated mostly with agriculture and secondly with urban-tourist development, along with the increase in winter temperatures due to climate change, has meant that since mid-2015 the lagoon has entered into a eutrophication process with a notable deterioration in the quality of the waters of the Mar Menor (Scientific Advisory Committee of the Mar Menor 2017). This led to a significant loss of the biodiversity of the Mar Menor, which has numerous regional, national and international protection designations: San Pedro del Pinatar Regional Park, Protected Landscape of Open Spaces and Mar Menor Islands, declaration of the Mar Menor and surrounding wetlands such as ZEPA (Special Protection Area for Birds) and SCI (Site of Community Importance), declaration of the Mar Menor and its surroundings as a Ramsar area (Wetland of International Importance of the Ramsar Convention) and ZEPIM (Specially Protected Area of MediterraneanImportance). Such biodiversity losses lead to a “domino” effect whereby many of the economic activities that the lagoon directly supports will lead to job losses and associated impacts. This phenomenon has motivated a strong social alarm that has given rise to multiple acts of protest, and the local community and stakeholders groups have demanded compliance with current regulations and effective management measures which consider all the stakeholders involved. We used a range of participatory methods to evaluate characteristics of these stakeholders' preferences for possible solutions to the SESMM problems.



A) **B)**

Figure 6.1. A) Location of the SESMM. B) Mar Menor watershed and coastal lagoon and the main land uses (Green: natural; blue: outdoor irrigation; yellow: greenhouses; cream: dry; garnet: urban and infrastructures). Source: Carreño 2015.

6.2. Methodology

The methodological approach of this research was carried out in three steps: 1) identification and characterization of stakeholders; 2) stakeholders' preferences on possible management measures to improve urban-tourist development and limit the entry of nutrients into the Mar Menor lagoon; and 3) analysis of conflicts and consensus among stakeholders on possible management measures for the restoration of the system.

6.2.1. Identification and characterization of stakeholders

For the identification and characterization of stakeholders, 20 structured interviews were conducted with scientific-technical experts from different disciplines in the environmental, social, economic and institutional dimensions during the months of January to April 2017 (Appendix II). The structure of the interview was as follows: first, a block of five questions was carried out in order to know their opinion on the main ecological, social and economic processes that are taking place in the SESMM, and the solutions or management measures that, as experts, they would apply to restore the system and identify the main stakeholders and their interests. Next, a second block was made on the characteristics of the respondents, such as their scientific-technical area of experience and knowledge of the SESMM and their personal relationship with the Mar Menor. To conduct the interview, the experts were contacted by email and in person.

In order to complete the stakeholders map, a bibliographic review of scientific articles was carried out (for example, Martínez et al. 2009; Carreño 2015; Esteve et al. 2016) and technical reports (such as Vidal et al. 2003; León and Bellido 2016; Scientific Advisory Committee of the Mar Menor 2017, among others) related to the study area, in order to verify and complete, where appropriate, the identification of stakeholders. The Integrated Management Strategy for Coastal Zones in the Mar Menor and its surroundings (2018) was also reviewed, in the preparation of which a process of citizen participation in the SESMM was carried out. The aim of all this was to answer the questions of identification of key stakeholders: Who are the stakeholders involved in the use and activities carried out in the SESMM? Who are the stakeholders or potential beneficiaries of the ecosystem services of the SESMM? Who can be the most affected stakeholders by the situation of degradation of the SESMM? And who has information, knowledge, and experience about the degradation of the SESMM and its functioning as a system?

To guide the characterization process of the stakeholders, the questions and attributes collected in Tables 6.1 and 6.2 were formulated and completed with the information given by the experts in relation to what each stakeholder is, does, perceives and proposes as solutions or responses regarding the situation of environmental degradation in the SESMM. Tables 6.1 and 6.2 show the information that was obtained on the position of the stakeholder and his relationship with the SES.

Table 6.1. Identification and characterization of stakeholders.

Stakeholders	Who are they?	What do they do?	What do they perceive?	What do they propose?

Table 6.2. Relationship of the stakeholders with the SES.

Stakeholders	Relationship to SES and its degradation	Main interest of the stakeholder	Main relationships between the stakeholders

6.2.2. Stakeholders preferences on possible management measures in the SESMM

During the months of January and February 2019, 14 structured interviews were conducted (Appendix III) with representatives of each stakeholder group previously identified, with the aim of knowing their perception of the current status of the SESMM and their preferences regarding

1) ten management measures to improve the urban-tourist development of the Mar Menor area and 2) nine management measures to limit the entry of nutrients into the lagoon. The measures proposed were derived from the study carried out in Guaita et al. (2020), where a survey was carried out with the local community to find out the social perception about pressures, impacts and possible management practices to improve the current status of SESMM. That Guaita et al. 2020 survey had 23 questions distributed in five blocks: 1) urban-tourist development, 2) agricultural activities, 3) state of the Mar Menor lagoon, 4) environmental values and ecosystem services and 5) metadata. It was answered by 498 people by email during the months of February to May 2017. As part of those past (Guaita et al. 2020) survey results, an order of preference was obtained for the performance of management measures to 1) improve the urban-tourist development of the Mar Menor area and to 2) limit the entry of nutrients into the lagoon, according to the average value of respondents.

For our study's stakeholder preference (2019) interview, this order of preferences by the local community was given to the representatives of each group of stakeholders for us to learn their assessment and preferences through the interview. Each stakeholder, based on their knowledge and interests, updated the ratings according to their level of importance on a scale of 0 to 100. This technique is known as expert elicitation (O'Hagan 2019), where the interest lies in estimating unknown parameters or values through the prior beliefs of experts. Each stakeholder or expert updates the ratings obtained in the survey, considering a high degree of certainty in each of their responses and allowing them to update their responses as many times as necessary until they are satisfied with their statements. Finally, the opinion of the stakeholders was compared with the opinion of the local community surveyed in Guaita et al. (2020).

To carry out the interview, the representatives of each group of stakeholders associated with the SESMM were contacted by email, telephone and in person. The election of the representatives of each group of stakeholders, previously identified by the experts, was made first, based on the availability and willingness of the stakeholder to participate and, secondly, based on the most representative position within the entities who had greater decision-making capacity and influence in each of the stakeholder groups. Lastly, the entity itself appointed its own representative (Table 6.3).

Table 6.3. Representatives of each stakeholder group in the SESMM.

Stakeholder groups	Name of the stakeholder
NGOs, citizen platform	Ecologistas en acción (NGO)

	Asociación de naturalistas del sureste (NGO)
	Citizen platform "Pacto por el Mar Menor"
Academic sector	PhD in Sociology
	PhD in Biology
	PhD in Economics
Fishing sector	Fishermen's guilds of San Pedro del Pinatar and Cartagena
Construction and real state sector	Regional federation of construction entrepreneurs of Murcia (FRECOM)
Tourist sector	Association of hotels and tourist accommodations of the Costa Cálida (HOSTETUR)
	Mar Menor nautical station
Agricultural sector	Agricultural cooperative societies Murcia federation (FECAMUR)
	Coordinator of farming associations (COAG)
Public administration	Office of socioeconomic promotion of environment of the Autonomous Community of Murcia (OISMA)
	Ministry of Water, Agriculture, Livestock, Fishing and Environment (CARM)

6.2.3. Analysis of conflicts and consensus among stakeholders on possible management measures for the restoration of the system

For the analysis of the conflicts and consensuses among stakeholders regarding their preferences for the management measures to restore the system, two hierarchical cluster analyzes were performed, using the Euclidean distance and the Ward method (Murtagh and Legendre 2014). This multivariate technique, through the representation of two dendrograms, allowed each of the stakeholders to be classified into clusters with similar opinions. The results for each cluster in relation to the preference order of possible management measures were represented by the median, in order to avoid bias introduced by extreme values. Finally, the opinion of the representatives of each stakeholder group was compared with the opinion of the corresponding group of respondents, according to the profession and main economic activity of each respondent, obtained in the survey to the local community in Guaita et al. (2020).

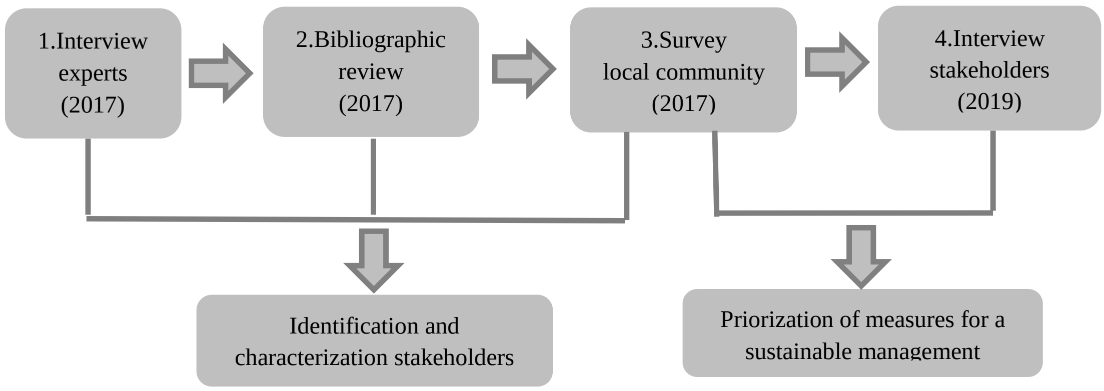


Figure 6.2. Sequence of the iterative process for the analysis of the stakeholders.

6.3. Results

6.3.1. Identification and characterization of stakeholders

We identified seven stakeholder groups who were involved, interested, or affected by the status of environmental degradation of the SESMM. These were classified into the following categories: (1) public administration, (2) agricultural sector, (3) tourist sector, (4) fishing sector, (5) construction and real estate sector, (6) academic sector and (7) citizen platforms, neighborhood associations and NGOs.

The agricultural sector, the tourism sector and the construction and real estate sector were identified as the groups of stakeholders that generated the current status of environmental degradation due to their uses and activities carried out in the SESMM; the fishing sector was identified as an affected sector and recipient of the current status of environmental degradation; citizen platforms, neighborhood associations and NGOs were the group of stakeholders that showed the greatest interest in solving the identified problems and in the desire to participate in the solution by disseminating information to society, denouncing environmental illegalities and lobbying to government entities for compliance with current regulations. Finally, the academic sector and the public administration were identified as the groups of stakeholders that have the scientific-technical knowledge and competence, respectively, in relation to the current environmental status and future management.

The results of the characterization of stakeholders are shown in Table 6.4 (Appendix IV). Furthermore, in Table 6.5, the following attributes were identified: 1) Relationship with the SES and its degradation, 2) Main interest of the stakeholder and 3) Main relationships between the stakeholders (Appendix IV). Those detailed results served as the organizational basis for understanding their (stakeholders') preferences below.

6.3.2. Stakeholders preferences on possible management measures in the SESMM

The resulting all-stakeholder preferences (D1-D10) regarding the management measures to improve the urban-tourist development of the Mar Menor area is shown in Fig. 6.3, showing a wide range of magnitude in preferences. The order of preference, from highest to lowest, is:

1. Do not make a greater offer of second homes (D1).
2. Improve the management and protection of natural areas around the Mar Menor, coastal wetlands and free areas of buildings (D7).
3. Urban moratorium (D8).
4. Improve the public transport network (D2).
5. Remodeling built buildings for an improvement of tourist image (D3).
6. Improvement of parking areas (D4).
7. Improve the bike lane and the spaces adapted for walking and sports (D5).
8. Do not carry out a greater construction of hotels (D10).
9. Improvement of the infrastructure for road traffic (D9).
10. Improvement of accessibility to urbanizations and beaches (D6).

These results indicated that, unlike the data obtained in the survey by the local community (Guaita et al. 2020), the stakeholders gave higher priority to the urban moratorium (D8) and to improving the management and protection of the natural areas (D7) rather than the various actions on sustainable mobility (e.g., D2 and D5)

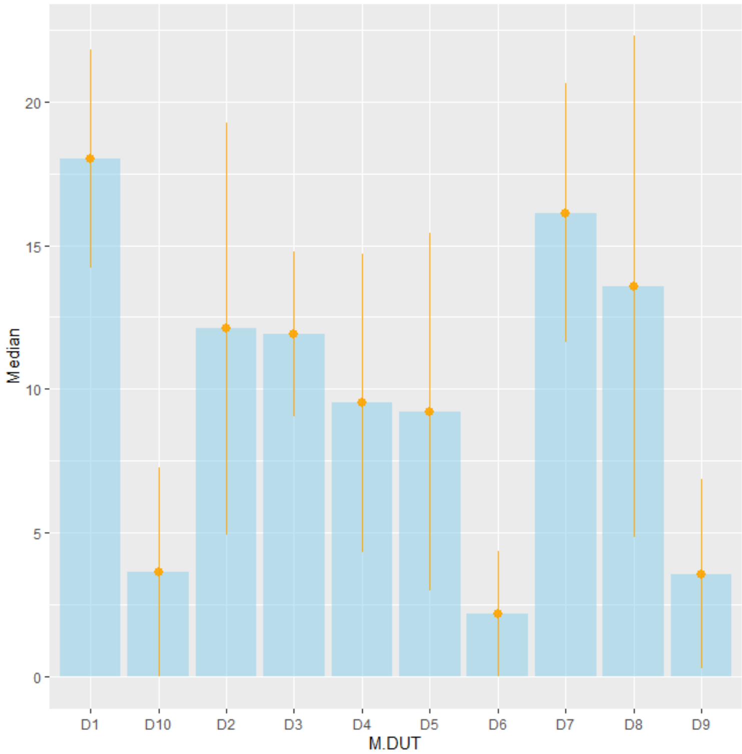


Figure 6.3. Barplot error for the median (%) of the assessment of all the stakeholders, regarding management measures to improve urban-tourist development (M.DUT).

The resulting all-stakeholder preferences (L1-L9) regarding the management measures to limit the entry of nutrients to the Mar Menor lagoon is shown in Fig. 6.4. The order of preference, from highest to lowest, is:

1. Reduce the irrigated area (L1).
2. Elimination of irregular uptake of groundwater (L3).
3. Require that each desalinator includes a brine treatment (L2).
4. Establish and monitor the application of maximum values of fertilizer contribution (L6).
5. Recover and enhance the lost surface of natural wetland in the periphery of the lagoon (L4).
6. Apply natural measures of water and nutrient retention at plot scale and in the watershed (L5).
7. Build a green filter to treat the flow of the Albujón watercourse (L7).
8. Do not collect the brines and pour them directly into the Mediterranean Sea (L8).
9. Collect the brines and part of the flows of the waters of the "ramblas" and after their dislocation and denitrification pour their reject flow into the Mediterranean Sea (L9).

This order of preferences of all the stakeholders coincided with that established by the local community in the survey in Guaita et al. (2020), only that the stakeholders considered it a marginally higher priority to establish and monitor the application of maximum values of fertilizer contribution (L6) before the processes to recover and enhance the lost surface of natural wetland in the periphery of the lagoon (L4) and apply natural measures of water and nutrient retention at plot scale and in the watershed (L5). While those were marginal differences, both the stakeholders and the local community had dramatically lower preference for the processes associated with brine processing (L8, L9).

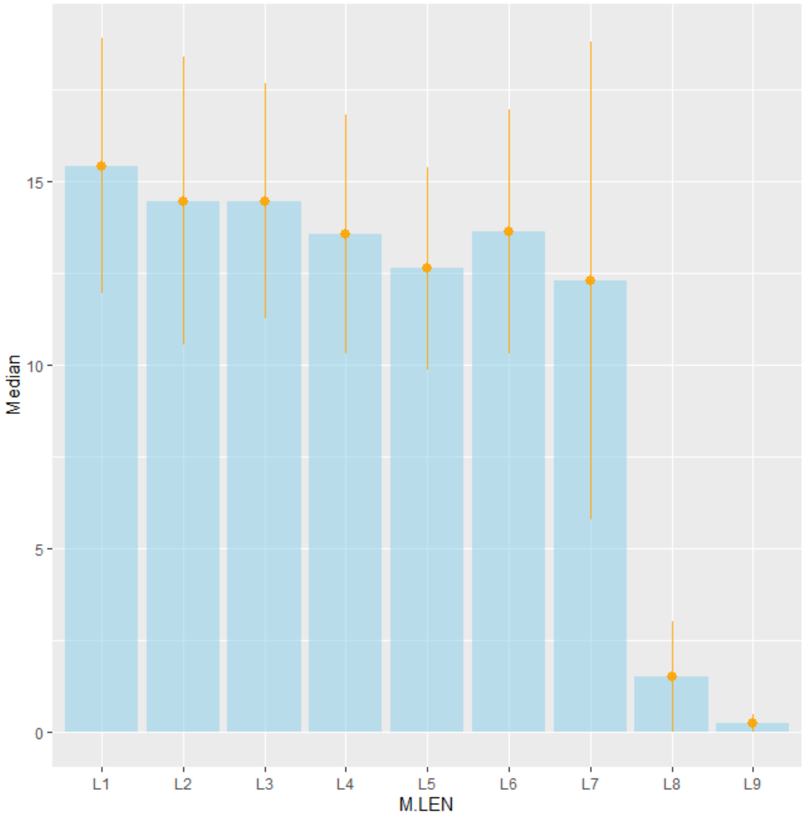


Figure 6.4. Barplot error for the median (%) of the assessment of all the stakeholders, regarding management measures to limit the entry of nutrients into the Mar Menor lagoon (M.LEN).

6.3.3. Analysis of conflicts and consensus among stakeholders on possible management measures for the restoration of the system

The hierarchical cluster analysis grouped the stakeholders into three groups according to the similarity in the responses they gave to order their preferences for management measures to improve urban-tourist development in the SESMM (Fig. 6.5). Cluster 1, formed by the stakeholders representing the construction sector and the tourism sector dedicated to services, considered that the priority measures would be to improve the bike lane and the spaces adapted for walking and sports (D5), improve the management and protection of natural areas around the Mar Menor, coastal wetlands and free areas of buildings (D7), remodeling built buildings for an improvement of tourist image (D3) and improve the public transport network (D2) (Fig. 6.6). Cluster 2 formed by the stakeholders representing the fishing sector, the public administration sector, the NGO sector and citizen platform, and two of the three actors representing the academic sector, gave preference to the measures of do not make a greater offer of second homes (D1), improve the management and protection of natural areas around the Mar Menor, coastal wetlands and free areas of buildings (D7) and the urban moratorium (D8) (Fig. 6.6). And thirdly, the cluster formed by the tourism sector dedicated to hotels and restaurants, the agricultural sector, the local community and an actor from the academic sector, who in their order of preference also placed in the first two positions, do not make a greater offer of second homes (D1) and improve the management and protection of natural areas around the Mar Menor, coastal wetlands and free areas of buildings (D7) (Fig. 6.6).

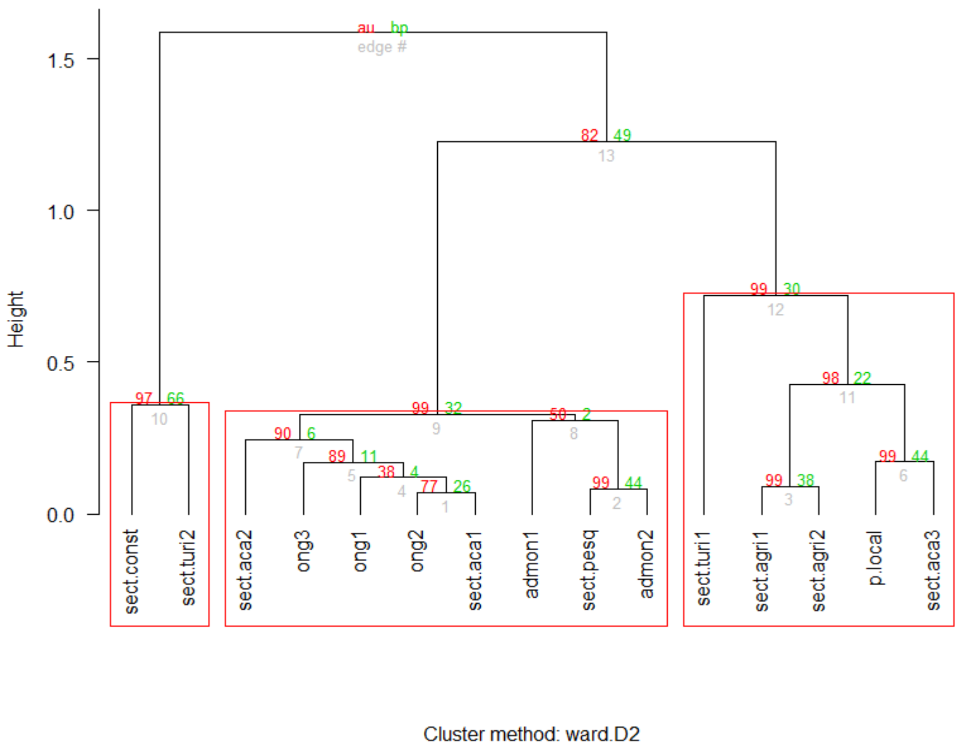


Figure 6.5. Dendrogram for the stakeholder's preferences for management measures to improve tourist-urban development, highlighting the final clusters (red boxes).

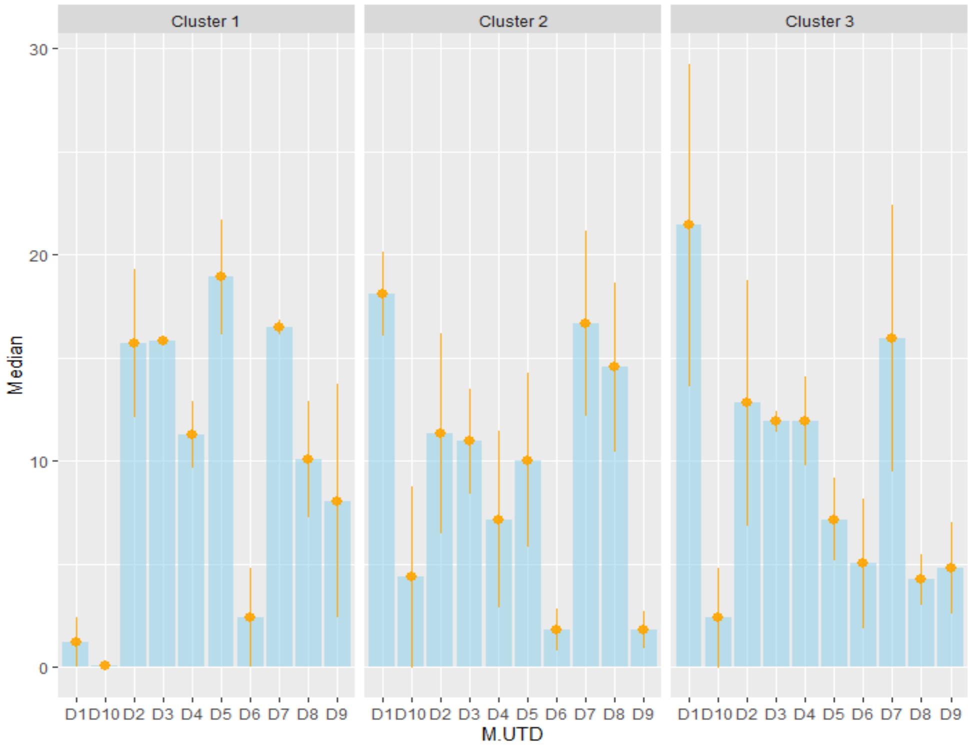


Figure 6.6. Barplot error for the median (%) of the assessment of the stakeholders in cluster 1, cluster 2 and cluster 3 regarding management measures to improve urban-tourist development (M.UTD).

The comparative analysis of the representatives of each stakeholder group in this study, with the opinion of the respondents (classified in groups according to their profession and main economic activity) in the survey to the local community in Guaita et al. (2020), showed that only the stakeholder representing the fishing sector agreed with the opinion given by the respondents who belongs to that economic sector, regarding management measures to improve urban-tourist development. On the other hand, the stakeholders in this study representing to the public administration, the tourism sector dedicated to hotels and restaurants and the agricultural sector in this study, are the ones that most differed in their preferences for management measures with the respondents in the survey to the local community in Guaita et al. (2020) corresponding to their respective fields work. It should be noted that the stakeholders in the academic sector, the construction sector and the tourism sector dedicated to services, partially agreed with the groups of respondents classified under these professions in the preferences of some measures such as, urban moratorium (D8), remodeling built buildings for an improvement of tourist image (D3) and improve the bike lane and the spaces adapted for walking and sports (D5).

Regarding the measures to limit the entry of nutrients to the Mar Menor lagoon, the hierarchical cluster analysis distinguished between two clusters based on the similarity in the responses that the stakeholders gave to order their preferences (Fig. 6.7). Cluster 1 formed by the agricultural sector, the fishing sector and the tourism sector dedicated to hotels and restaurants, considered that the highest priority measures would be to reduce the irrigated area (L1), collect the brines and part of the flows of the waters of the "ramblas" and after their dislocation and denitrification pour their reject flow into the Mediterranean Sea (L9), recover and enhance the lost surface of natural wetland in the periphery of the lagoon (L4), establish and monitor the application of maximum values of fertilizer contribution (L6) and build a green filter to treat the flow of the Albujón watercourse (L7) (Fig. 6.8). And the rest of the groups of stakeholders who thought that the priority measures were to reduce the irrigated area (L1), require that each desalinator includes a brine treatment (L2), elimination of irregular uptake of groundwater (L3), establish and monitor the application of maximum values of fertilizer contribution (L6), recover and enhance the lost surface of natural wetland in the periphery of the lagoon (L4) (Fig. 6.8).

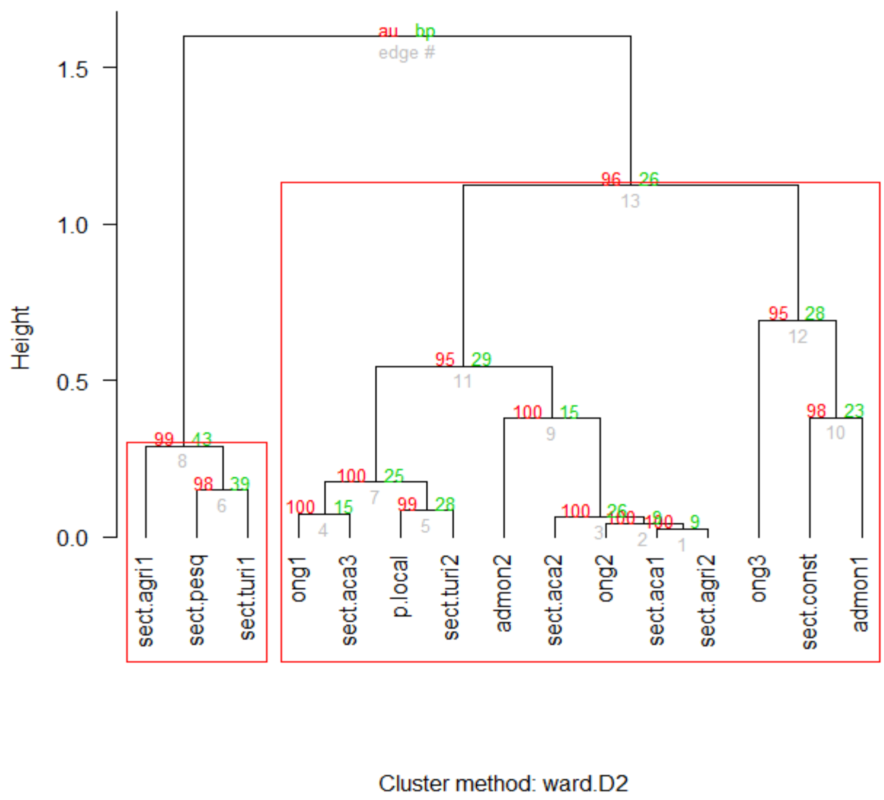


Figure 6.7. Dendrogram for the stakeholder's preferences on management measures to limit the entry of nutrients into the Mar Menor lagoon, highlighting the final clusters (red boxes).

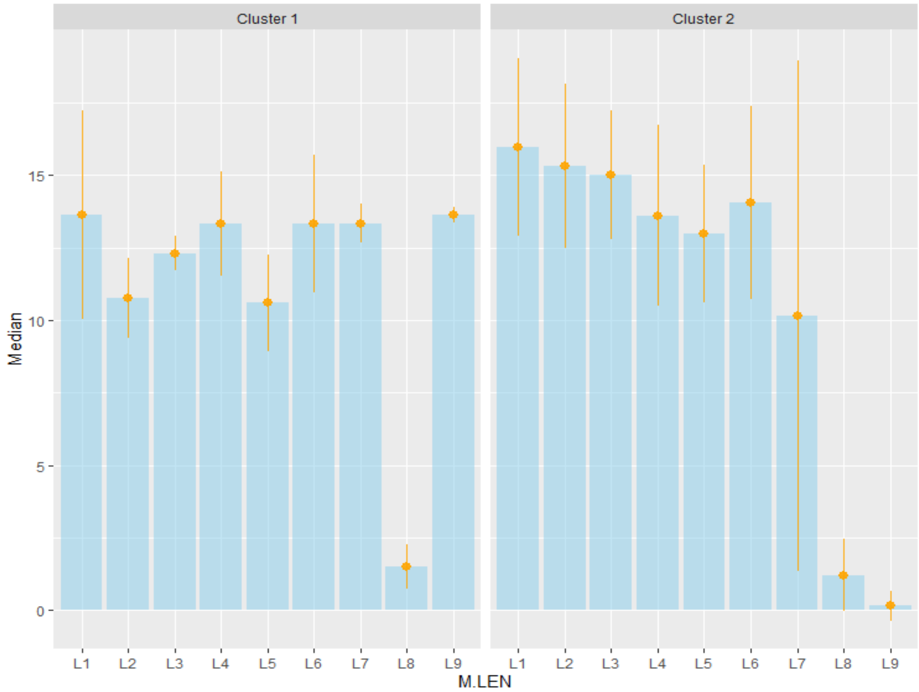


Figure 6.8. Barplot error for the median (%) of the assessment of the stakeholders in cluster 1 and cluster 2 regarding management measures to limit the entry of nutrients into the Mar Menor lagoon (M.LEN).

The analysis of the degree of coincidence of each stakeholder in this study with the respondents (classified in groups according to their profession and main economic activity) in the survey to the local community in Guaita et al. (2020), on measures to limit the entry of nutrients into the lagoon, showed that only the stakeholder in the fishing sector agreed with the opinion given by the corresponding group of respondents. The stakeholders representing the agricultural sector and the tourism sector dedicated to hotels and restaurants only agreed with those of the groups of respondents from their respective professional fields in two measures: collect the brines and part of the flows of the waters of the "ramblas" and after their dislocation and denitrification pour their reject flow into the Mediterranean Sea (L9) and establish and monitor the application of maximum values of fertilizer contribution (L6). Likewise, the opinion of the stakeholders in the administration sector, the academic sector, the construction sector and the tourism sector dedicated to services only agreed with those surveyed whose profession or main economic activity belonged to the respective sectors in to establish and monitor the application of maximum values of fertilizer contribution (L6). It should be noted that in the cases of the administration sector and in the tourism sector dedicated to services, the stakeholders also agreed with the corresponding groups of respondents in the measures of elimination of irregular uptake of groundwater (L3) and in recover and enhance the lost surface of natural wetland in the periphery of the lagoon (L4), respectively.

6.4. Discussion and conclusions

The objectives, interests and needs of the stakeholder groups identified are contradictory. The governmental institutions corresponding to the public administration (national, regional and local) have the objective of establishing policies for the management of the territory, of the uses and activities that take place in it, as well as the conservation of the environment of the SESMM. However, the results point out that, according to the interviews with experts, at this point in time those institutions have shown a lack of coordination to adopt the necessary management measures and to comply with current national and European regulations. Different scientific and technical studies also confirm these results (Martínez and Esteve 2020; Ruiz et al. 2019; Perni and Martínez-Paz 2013). This poor coordination, along with other factors, has led to a lack of governance, which ultimately translates into weak government action, in which action only begins after the problem has already had a significant socio-ecological impact. This situation is repeated in the management of other social-ecological systems with high ecological value such as Doñana (Spain) (García Novo and Marín 2005; Palomo et al. 2011) or the Everglades (USA) (Estenoz and Bush 2015; Atisa 2020) where there are two opposite positions, conservation and developmentalism.

Interviews with experts indicated that stakeholder groups belonging to the economic sectors of agriculture, construction and tourism seek to maximize the benefit in their respective economic activities. All this agrees with recent investigations that document the environmental, social and economic impacts of these economic activities (Esteve et al. 2016; Romero and Pérez 2017; García-Ayllón 2019; Ruiz et al. 2019; Martínez and Esteve 2020). These three stakeholder groups have an important influence on the SESMM society and economy, as well as on local and regional political groups. According to interviews with experts, the tourism sector calls for a clean Mar Menor and focuses on urgently demanding solutions from the administration and points to the agricultural sector as being most responsible for the status of environmental degradation. For its part, the agricultural sector has taken a very important step in recognizing its responsibility for the deterioration of the lagoon and the watershed, although they do not believe that they are the only ones responsible, mainly holding the administration responsible, who according to them has ignored all their demands for improvement of desalination facilities and their own practices. This finding confirms an important change of perception within the agrarian sector that so far had not occurred and that seems to confirm the hypothesis that what the stakeholders think does not depend only on their own interests but also on the degree of knowledge of the problem (Guaita et al. 2020). On the contrary, the scientific literature includes some examples of social-ecological systems such as the Everglades (USA) where despite the fact that said SES has been immersed in an ecological restoration project since 2000, the funding and progress on restoration has been slow, with a range of stakeholder priorities and scientific uncertainties (Sklar et al. 2005).

The interviews with the experts also highlight that the active protest pressure by the social, neighborhood and environmental movements since the end of 2015 (and which has been constant in the media) has demanded political responsibility. All this has contributed to increasing the level of awareness by civil society to the state of the SESMM, which may have contributed to this change of perception within the surrounding population (Guaita et al. 2020) and some of the stakeholders involved in the SESMM. However, despite this recognition and interest in helping to improve the environmental situation of the lagoon, the experts point out that the agricultural sector considers that the solutions should not affect the reconversion of their activities, being reluctant to change current cultivation practices. This poses a potential threat to the approach of a sustainable management model in the SES. The Scientific Advisory Committee of the Mar Menor 2017; Martínez et al. 2017; Ruiz et al. 2019, among others, point out that the agricultural management model in the Mar Menor must be modified to guarantee the sustainability of the SES.

Interview results with the experts also highlight that, because the construction and real estate development sector has been relatively inactive in recent years, it appears that the most proximate responsibility for the state of environmental degradation in the SESMM is the agricultural and tourist sectors. Similarly, the fishing sector identifies both of those sectors as mainly responsible for eutrophication in the lagoon. The representatives of this (fishing) sector, along with the tourism sector, identify themselves as the most affected in their economic activities by the degradation of the lagoon. The stakeholders of the fishing sector observed a drop in sales of fish products from the Mar Menor, products which were previously marked as quality, but now under suspicion of toxicity. Some forecasts speak of a decrease in the number of fish catches in the immediate future. In the case of the tourism sector, those stakeholders observed a decrease in the number of tourists and a reduction in income in the service sector (Martínez and Esteve 2020).

Differing from other sectors, the interviewed experts point out that the main interest of the academic sector is to generate scientific-technical knowledge about the SESMM and make it available to all stakeholders, especially to the public administration, with whom it has been working through a scientific committee with the aim of advising them on relationship with the SESMM diagnosis and the proposal of possible solutions. However, since 2018, news reports in the media reflects abandonment of scientific committee by many of the academic sector members because the scientific committee is, in the opinion of these members, an agency instrumentalized by the regional Administration to divert attention from the true causes of the degradation of the lagoon and its solutions. All this implies a contradiction with the objective stated by the regional Administration itself of wanting to advance in effective solutions for the SESMM. On the other hand, citizen platforms and NGOs have disclosed the available information to society on the state of the SES. These stakeholders are exercising active social pressure to denounce and demonstrate the SES degradation, in order to ensure that the administration complies with current regulations and hastens to take management measures that are sustainable in the medium and long term.

Regarding the preferences of the stakeholders on possible measures to improve urban-tourist development in the Mar Menor, results from interviews with stakeholders show that there is a conflict between the stakeholders representing the construction sector and the tourism sector dedicated to services, and the stakeholders representing the rest of the sectors. The first ones prioritize improving bike lanes and spaces adapted for walking and sports, compared to the rest of stakeholders, who consider that the most urgent action should be do not make a greater offer of second homes. In this line of action, several studies (Romero et al. 2011; Pérez et al. 2016) point out the irreversible impacts associated with the development of new urban areas and a tourism model based on second homes, which justifies that given the diagnosis of the SESMM, this is a priority measure for most of the stakeholders. Also other studies in other socio-ecological systems of the Spanish Mediterranean, such as the Valencian coast (for example: Montgó Natural Park and the Mata and Torrevieja Lagoons Natural Park) have shown the negative environmental, social and economic consequences of this type of urban-tourist development model (Capdepon 2016; Martí and Nolasco 2011). Despite this discrepancy, it is important to point out that all the stakeholders agree that the second preference should be aimed at improving the management and protection of natural areas around the Mar Menor, coastal wetlands and free areas of buildings.

The Mar Menor lagoon and the surrounding wetlands were declared a protected natural space through various regional, national and international protection figures (see above). Despite all this, it has never been effectively managed as a natural space. The jurisdictions of the different Administrations (European, national, regional and local) related to the protection of the lagoon have not enforced the current regulations and have caused an inefficient outcome as shown by the degraded state of this SES. For this reason, it is necessary to have greater coordination and strong leadership of the public administration via the Autonomous Community of the Region of Murcia, providing that administration more powers related to the problem of the SESMM. Similar situations have been seen in other internationally recognized SES such as Doñana (Palomo, et al. 2011) and the Everglades (Childers et al. 2019), which, despite having the declarations of Biosphere Reserve, World Heritage and Importance Ramsar International, have been threatened by human pressure and climate change. As weak as they may be, it is necessary to insist on enforcing the instruments of planning and management of protected natural spaces which, according to current legislation, must prevail over urban planning. However, as pointed out in the examples presented, reality shows that in general these instruments are subject to urban plans that sometimes take precedence.

Regarding the prioritization of measures to limit the entry of nutrients into the Mar Menor lagoon, the results from the interviews with the stakeholders indicate that all them agree that the first measure should be to reduce the irrigated area. This consensus represents an important change of opinion since the irrigated area has been increasing since 1979. Data from Carreño, 2015 highlight that from 1988 to 2009, the irrigated area increased 141% and this expansion increased the water and nutrient flows reaching the Mar Menor lagoon and its surrounding wetlands (Martínez et al. 2005; Velasco et al. 2006; Carreño et al. 2008; Esteve et al. 2008; Martínez et al. 2014; Esteve et al. 2016). The increase in these flows has been confirmed by the rise in the piezometric levels of the Campo de Cartagena hydrogeological unit (Rodríguez 2009; Aragón et al. 2009), as well as by the increase in the water table, the periods of flooding and soil moisture in the Mar Menor wetlands (Álvarez et al. 2007).

However, results highlight significant differences regarding preferences for other management measures. The agricultural sector, the fishing sector and the tourism sector dedicated to hotels and restaurants, consider it to be a second priority measure to collect the brines and part of the flows of the waters of the "ramblas" and after their dislocation and denitrification pour their reject flow into the Mediterranean Sea. This measure is highly controversial because it does not act on the origin of the problem and against which the rest of the stakeholders disagree, placing it as the last option, and prioritizing measures such as require that each desalinator includes a brine treatment and the elimination of irregular uptake of groundwater.

We found that, in the design and implementation of a deliberative participation process towards consensus, it can be difficult to prioritize management measures which both improve urban tourism development and limit the entry of nutrients into the lagoon. However, it is necessary to highlight some consensus on the prioritization of management measures that represent a first important change of opinion, such as reducing the irrigated area. Although in this work the representatives of the agrarian sector agree with this measure, there is evidence in previous years in which stakeholders belonging to the agrarian sector deny the need to reduce irrigation.

Secondly, according to interviews with experts, the public administration has not complied with current regulations, has had a practical absence of effective measures, and has protected business sectors such as agriculture sector and construction sector with a short-term economy; instead of the natural heritage as a guarantee of a sustainable future in the medium and long term, which is part of their governing mandate. On the contrary, the opinion of the stakeholders interviewed who represented the public administration group indicates that they are not closer to specific economic sectors, and that they prioritize measures that are their responsibility, such as the management and protection of natural areas around the Mar Menor, do not make a greater offer of second homes or reduce the irrigated area. An explanatory hypothesis to this contrast is that experts have evaluated the effective practices of public administrations, which depend on the political level (where decisions are made), while the public administration stakeholders interviewed belong to the technical level and their positions do not always reflect those of the political level. In fact, discordant criteria have been identified between these two levels, technical and political, in different environmental policies in the Region of Murcia in the last two decades, such as those related to the protection of nature (Esteve et al. 2012).

Finally, the comparative analysis of the representatives of each stakeholder groups in this study, with the group of respondents in the survey to the local community in Guaita et al. (2020), on the preference for management measures for the restoration of the system points to discrepancies between them. This indicates that the positions between the stakeholders and the sector that they represent are not always coherent, except for the fishing sector. One possible explanatory hypothesis is that representative stakeholders are more technical than official spokespersons, so their positions tend to be more focused or close to those of other stakeholders. In this sense, in the design and implementation of a deliberative participation process, the participation of the identified stakeholders can be positive, given that they can act as intermediaries to generate consensus, despite having different positions to their sector. Therefore, the results of this stakeholder analysis can contribute to guiding future deliberative participation processes. In future works, the hypotheses that derive from these results will be investigated and participatory workshops will be carried out to establish consensual diagnoses and facilitate the incorporation of stakeholders in decision-making.

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Chapter 7.
Methodological proposal to evaluate sustainability in a complex social–ecological system through a system of indicators. Application to the case of the Mar Menor (Región de Murcia, Spain)

Agricultura intensiva en el Campo de Cartagena

Intensive agriculture in Campo de Cartagena

Fotografía: Pacto por el Mar Menor

7. Methodological proposal to evaluate sustainability in a complex socio-ecological system through a system of indicators. Application to the case of the Mar Menor (Region of Murcia, Spain)

Abstract

The development of indicator systems to assess the sustainability of complex socio-ecological systems is not yet sufficiently incorporated into institutional culture and practices. The situation of environmental degradation of the SESMM is increasingly recognized and highlighted by the eutrophic crisis of the Mar Menor lagoon. Given the lack of initiatives with indicators that adapt to the singularities of the system, this paper describes a methodology with an integral, systemic approach based on multidisciplinary dialogue to define a system of sustainability indicators that contributes to its diagnosis and integrated management. The final system of 61 indicators addresses the environmental, socioeconomic and institutional dimensions of sustainability. The results reveal the lack of information for the calculation of 39% of the indicators, with an imbalance among the different dimensions of the sustainability of the SESMM in relation to the availability of information. On the other hand, there are pending challenges for the indicators for which information is available, since in many cases the information is heterogeneous, dispersed, discontinuous and not always well described. Another emerging result is the absence of recommended reference values and the need for them for a system of indicators to be useful in terms of sustainability. This methodological approach, in addition to being useful for monitoring sustainability at the local scale and of specific socio-ecological systems, can contribute to the development of indicator systems that allow monitoring progress in socio-ecological systems and the degree to which the plans and measures implemented contribute to such advances.

Keywords: socio-ecological system of the Mar Menor; indicators; sustainability; integral approach, participatory process.

7.1. Introduction

The review of the scientific literature on the analysis and management of socio-ecological systems (SES) shows how the complexity of planning processes, as well as accelerated environmental changes, require a permanent and participatory evaluation in management (Xue et al. 2015; Megdal et al. 2017; Sterling et al. 2017). This evaluation requires the construction of indicators that reveal or indicate the degree of sustainability of the SES and the state of the quality of life of those who inhabit them. Since 1992, when the World Earth Summit was held, different tools and methodological approaches have emerged to assess sustainability at a global level and specifically in SES (Saldivar et al. 2002; Gallopín 2006; Böhringer & Jochem 2007; Singh et al. 2009, 2012, among others).

Among these approaches, sustainability indicators are a tool that quantify and simplify the complexity of the processes they represent, facilitating the elaboration of diagnoses and their follow-up over time, communication with the group of stakeholders and the use of the best available knowledge as basis for decision-making and public participation processes (Lotze-Campen 2008; Singh et al. 2012; Poveda and Lipsett, 2014). Antequera (2005) also points out that their usefulness depends a lot on the particular context, and they will only be useful if they fit into the SES conceptual model and can be related to each other.

However, the complex interrelationships with most natural systems and human activities create added difficulty for their integral analysis. In this sense, indicator systems are not always equally effective in relation to the stated objectives (Reed et al. 2006; Levrel et al. 2009; Kajikawa et al. 2011). Among its weaknesses Martínez et al. (2016) cites the following: 1) the absence of thresholds (Lancker and Nijkamp 2000; Moldan et al. 2012) that allow quantifying whether the changes suffered by the indicators are acceptable or not in terms of the sustainability of the specific system in question; 2) the standardization of indicators, which, although it facilitates the comparison between different systems, is less adapted to the requirements and singularities of specific territories; 3) its static nature, which prevents considering the synergies and contradictions among indicators, as well as assessing their possible future evolution under different management options and 4) a "top-down" approach, which reduces the involvement and co-responsibility of the different stakeholders in monitoring of objectives through such indicators. Authors such as Fraser et al. (2006) reiterate the importance of participatory processes for the identification of sustainability indicators, since they offer the opportunity to involve the community, something that the different conventional approaches have not achieved.

In the analysis and evaluation of the sustainability of a specific SES, several studies (Banos-González et al. 2015, 2016; Martínez et al. 2016; Tenza 2017) propose a methodological approach that includes in the first place a definition of specific objectives of sustainability and its indicators and subsequently a dynamic simulation model in which such indicators are integrated. This work contributes to obtaining the first component of this methodological approach in the analysis and integral evaluation of sustainability of the socio-ecological system of the Mar Menor (SESMM), located in the Southeast of the Iberian Peninsula. The accumulation of impacts caused by the different anthropic activities over the last decades has led the SESMM to a situation of environmental degradation that compromises the continuity of the ecosystem services it offers to society and human well-being (Comité de Asesoramiento Científico del Mar Menor 2017; Ruiz et al. 2019), so tools are required to help the recovery of this SES.

Given the importance of monitoring the sustainability of the SESMM with a holistic and systemic vision and considering how citizens can participate or influence effectively in the management of the SES to improve its governance (Stafford et al. 2010; Fischer et al. 2015; Van Bussel et al. 2020), the objective of this work is to present the methodology followed and its results to develop a system of sustainability indicators adapted to the requirements and singularities of the SESMM. For this, three specific objectives are proposed: 1) define the specific sustainability objectives; 2) select and define a set of relevant sustainability indicators and 3) validate the final indicator system by consulting a group of experts from different disciplines.

7.2. Methodology

7.2.1. Study area

The Mar Menor lagoon and the watershed sub-basin of the Mar Menor, known locally as Campo de Cartagena, are located on the Mediterranean coast of Southeast Spain (Fig. 7.1). It is an area with a high ecological value with a population of more than 300,000 inhabitants (357,266 in 2017) that during the months of June to September doubles (García-Ayllón 2018). The main economic activities, particularly urban-tourist development and intensive irrigated agricultural activity, act as the main driving forces, which develop around the lagoon and in the hydrographic sub-basin (León and Bellido 2016; Scientific Advisory Committee del Mar Menor 2017).

The coastal lagoon of the Mar Menor, originally hypersaline, is the largest in the Western Mediterranean (extension of 135 km^2, perimeter of 74 km, volume of water of 610 hm^3 and average depth of 4,5m). It is separated from the Mediterranean Sea by a sand barrier called "La Manga del Mar Menor" 22 kilometers long and with a maximum width of 900 m, which has been highly urbanized since the 1960s (Mar Menor Scientific Advisory Committee 2017). The lagoon is connected to the Mediterranean Sea through five channels called “golas”. The peripheral wetlands to the lagoon are the crypto-wetlands (Saladar de Punta de Lomas, Saladar de lo Poyo, Marina del Carmolí) and the wetlands with active salt flats and micro-tidal marshes (Humedal de las Salinas de Marchamalo, Humedal de las Salinas de San Pedro del Pinatar) and occupy a total area of around 1.000 hectares (Vidal-Abarca et al. 2003). It is important to highlight their environmental value due to the diversity of organisms that they host, both resident and migratory, as well as for the ecosystem service of retention and elimination of nutrients protecting the Mar Menor from eutrophication (Esteve et al. 2008).

The biological and ecological particularities of the lagoon and the peripheral wetlands give it an ecological value that is reflected in the existing protection figures in the area: San Pedro del Pinatar Regional Park, Protected Landscape of Open Spaces and Mar Menor Islands, declaration of the Mar Menor and associated wetlands as ZEPA (Special Protection Area for Birds) and SCI (Place of Community Importance), declaration of Mar Menor and its surroundings as Ramsar area (Wetland of International Importance of the Ramsar Convention) and ZEPIM zone (Especially Protected Area of Importance for the Mediterranean).

The SESMM is a paradigmatic example of environmental resilience (García-Ayllón 2018) that is threatened by a wide variety of anthropogenic effects (intensive irrigated agricultural activity, urban development around the lagoon, construction of ports, dredging, boardwalks, breakwaters, creation of artificial beaches, seasonal tourist overcrowding, among others). It is important to note that with the arrival of the Tajo-Segura transfer in 1979, there was a change in the agricultural practices developed in the hydrographic sub-basin, where traditional rainfed crops were replaced by intensive irrigated crops (Martínez-Fernández & Esteve-Selma 2005; Carreño 2015). This change led to a marked increase in the contribution to the lagoon of agricultural surplus waters with a high load of nutrients (nitrogen and phosphorus) and suspended particles (Martínez-Fernández & Esteve-Selma 2005; Velasco et al. 2006), in addition to a large number of organic pollutants commonly used in intensive agriculture, among which plant protection products stand out.

Since 2015, the eutrophic state of the lagoon, generated as a consequence of the massive entry of nutrients from, above all, intensive irrigated agriculture developed in the watershed (1,270 km^2 of extension, with more than 20 “ramblas” that flow into the lagoon) (Martínez- Fernández & Esteve-Selma 2005; Velasco et al. 2006), has triggered important environmental, social, economic and institutional impacts, which have forced the authorities to draw up action plans with a view to the recovery of the lagoon, that involve all stakeholders (Ministry for the Ecological Transition and the Demographic Challenge 2019).

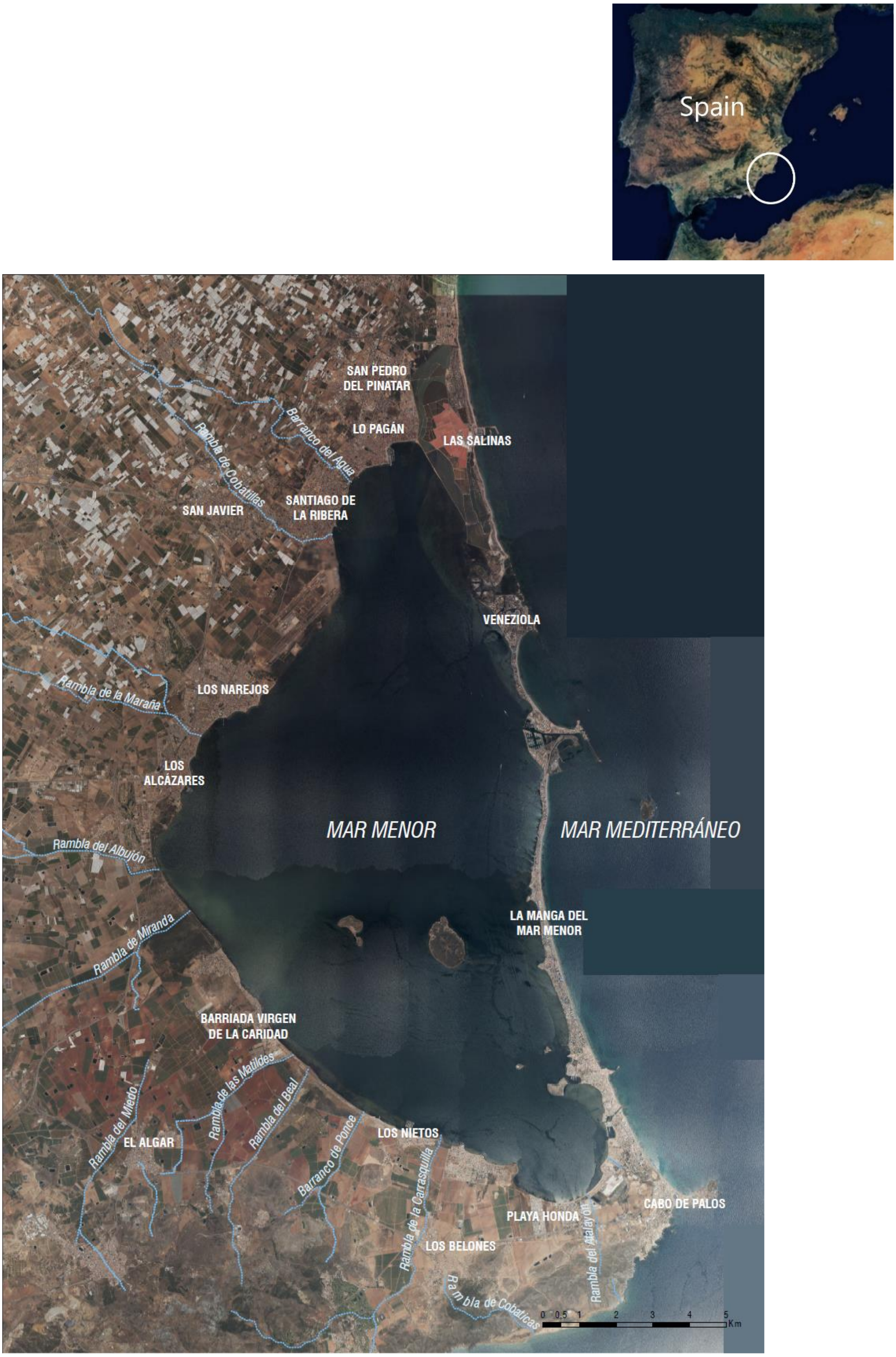

Figure 7.1. Location of the Mar Menor coastal lagoon and its surroundings. Source: Own elaboration from the National Geographic Institute.

7.2.2. Methodology

The methodological approach to achieve the three proposed objectives is as follows:

1) The sustainability objectives for the SESMM were defined in two stages. In the first stage, an integral diagnosis was made, which was synthesized in a qualitative model of the SESMM. For the elaboration of the model, the DPSIR (driving forces, pressure, state, impact, response) methodological framework was used (EEA 1999, taken from the OECD initiative, 1993). The DPSIR model was applied to describe the narrative of the conceptual model and build a qualitative model of the SESMM using the Vensim software (Ventana System 2011), with the most important socio-ecological variables of the system, as well as their main relationships, interactions and feedback.

To carry out the integral diagnosis of the SESMM, different sources and methods were used: 1) bibliographic review of scientific and technical publications in the study area (for example, Martínez-Fernández et al. 2009; Carreño 2015 ; Esteve Selma et al. 2016; Vidal et al. 2003; León and Bellido 2016; Mar Menor Scientific Advisory Committee 2017, among others) and 2) twenty structured interviews with expert scientist-technicians from different disciplines in the environmental, social, economic and institutional dimensions, which were carried out during the months of January to April 2017 (Appendix II).

In the second stage, a diagnostic survey was carried out to the local community to find out their perception of the main land use changes, their effects on the sustainability of the SESMM, and their preferences regarding different proposals for management measures. The survey was carried out in 2017 (Appendix I) and was repeated in 2019 after the intense rains of the DANA (depression isolated at high levels), to find out if this event had generated a change of opinion in the population. The results of the survey served to agree on the integral diagnosis and define the problems observed in the SES.

From the qualitative information obtained in these two stages of interdisciplinary and transdisciplinary work, which was carried out prior (chapters 4, 5 and 6 of this thesis) to this manuscript, the specific objectives were developed to achieve environmental, socioeconomic and institutional sustainability in the SSEMM.

2) The selection of sustainability indicators was made based on the specific objectives defined as just indicated in the previous point. For each specific objective, strategic questions were raised to answer the question of whether this specific objective has been achieved, or whether there is

progress towards it. For each of the strategic questions, the indicator or indicators that allowed them to answer it were identified. In this way, an initial catalog of indicators was formulated that allows evaluating and monitoring the degree of progress towards the specific established objectives. Linking the type of indicators to the specific objectives of the SES itself makes it possible to discriminate between a potentially broad catalog of indicators to monitor the recovery of an SES or ecosystem (Cairns et al. 1993), selecting a reduced number of indicators that are especially relevant to the SES.

3) For the discussion and subsequent validation of the final system of sustainability indicators, a consultation process was carried out with ten experts from different disciplines (environmental, social, economic and institutional) (Appendix V), during the month of December 2020. The experts who participated were contacted by email and telephone. Each expert selected in a practical way indicators that allow evaluating the specific associated objectives, corresponding to their field of knowledge, on the basis of the existing empirical evidence.

Next, a characterization of the indicators was carried out to determine the feasibility of their calculation. For this characterization, the existing information was analyzed based on five criteria: data availability (yes or no), available time series, data production periodicity, public accessibility to the data (yes or no) and data sources.

The information sources used come from different scientific publications (Belando et al. 2019; Esteve et al. 2016; Martínez et al. 2007, 2013, 2014; Carreño 2015, Robledano et al. 2010, Terrados and Ros 1991; Pérez Ruzafa et al. 1989, among others) and statistical and institutional sources, such as: the Murcia Regional Statistical Center (CREM) for statistical data on economic and population sectors, the Mar Menor Canal of the Ministry of Water, Agriculture, Livestock, Fishing and Environment (CARM) for data on the physical, chemical and biological properties of the Mar Menor lagoon, the Segura Hydrographic Confederation (CHS) for data on the watershed sub-basin, Spanish Institute of Oceanography (IEO) for data on the ecological status of the lagoon, as well as from the Institution for Sanitation and Wastewater Treatment of the Region of Murcia (ESAMUR), Tourism Institute of the Region of Murcia (ITRM), Regional Employment Service and Training (SREF), among others.

Once the indicators had been selected, a tentative proposal of reference values was made that, depending on the nature of the indicator, correspond in some cases to a threshold (limit value from the point of view of sustainability) and in other cases to a target value (value that is expected to be achieved as the final objective of the policy to be implemented) (Castro, 2004). These thresholds and target values were established for some indicators in which the available information allowed such determination. For this, reference values from four general sources were used: 1) values present in the existing regulations, 2) recommendations from different international organizations, 3) comparison with good practices in other territories and case studies where a value that can be considered as desirable (Benchmarking technique) (Martínez et al. 2016; Banos-González et al. 2015) and 4) historical values of the system in moments prior to the existence of impacts.

Finally, in order to facilitate communication actions based on the selected indicators, the evaluation of the information status of each indicator resulted in a characterization similar to that applied by different national and international organizations and reports (for example, the annual reports of the European Environment Agency or the Spanish Sustainable Development Network) to assess the degree of compliance with indicators. In this case, the semaphore code has been used depending on the status of the indicator information: green (Status of sufficient information), orange (Status of intermediate information), red (Status of insufficient information), gray (Status of information not available).

Figure 7.2 outlines the methodological phases followed.

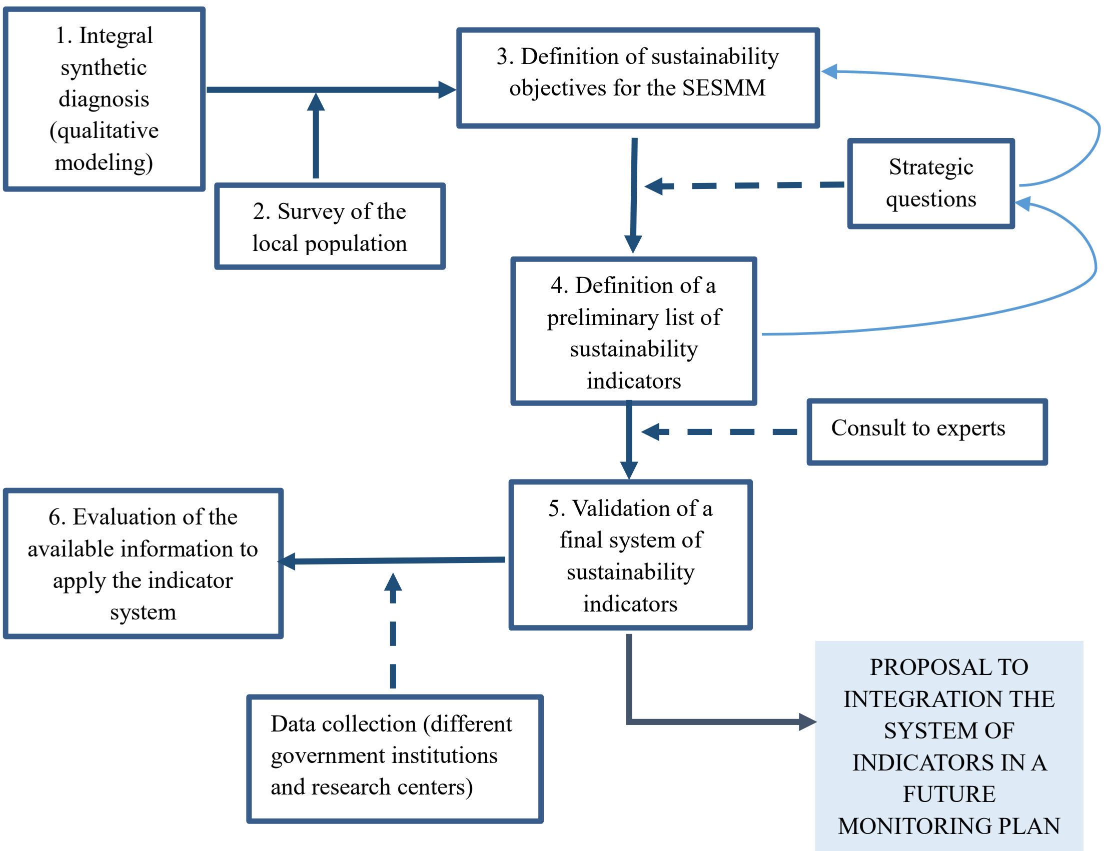

Figure 7.2. Stages for the selection of sustainability indicators for the SESMM.

7.3. Results

Seven specific objectives for the SESMM were defined by means of the previously described methodology:

Objective nº1) Recover and preserve the good state of the water of the lagoon and aquifers.
Objective nº2) Recover and conserve the species and habitats of the lagoon and its wetlands and the natural connectivity of the basin.
Objective nº3) Recover the environmental functionality of the unbuilt surface of coastline.
Objective nº4) Implement an environmentally and socially sustainable agricultural model.
Objective nº5) Implement a sustainable and quality tourism model.
Objective nº6) Sustainable local development.
Objective nº7) Implement a model of polycentric, adaptive and participatory governance.

The final system of sustainability indicators includes a total of 61 indicators, of which 25 address issues of the environmental dimension, 26 of the socio-economic dimension and 10 of the institutional dimension of SSEMM sustainability.

Table 7.1 shows the specific objectives defined, along with the strategic questions and the set of validated indicators after consulting a multidisciplinary group of experts. A tentative proposal for threshold values and their sources is also included for some of the indicators for which information is available.

On the other hand, a characterization of each indicator has been carried out to know the status of the available information and the feasibility of its calculation. This characterization has been carried out according to five variables: 1) Availability of data, 2) Time series available, 3) Periodicity of data production, 4) Public accessibility to data and 5) Data sources.

Table 7.1. Proposal for a system of sustainability indicators for the SESMM. The specific objectives, the strategic questions, the indicators and their units, the status of the information available for their calculation and a proposal of thresholds and/or target values for some indicators are identified.

SESMM INDICATORS SYSTEM							
ENVIRONMENTAL SUSTAINABILITY							
Objective 1. Recover and preserve the good state of the water of the lagoon and aquifers							
Does the water in the lagoon maintain good ecological status?							
Code	*Description of the indicator and units*	*Availability*	*Time series*	*Data production periodicity*	*Public accessibility*	*Sources*	*Threshold and/or objective value proposal*
A1	**Chlorophyll-a.** Annual average concentration (µg/l) o (mg/m^3)	Yes	1980-2020	Monthly	Yes	CARM, IEO y (Rosique 2000; Perez Ruzafa et al. 2005, Velasco et al. 2006)	1,8 µg/l (R.D. 817/2015)
A2	**Phosphorus.** Annual average concentration (µmol/l)	Yes	1980-2020	Monthly	Yes	CARM, IEO y (Terrados y Ros 1991; Perez Ruzafa et al. 2009; Perez Ruzafa y Marcos Diego 2016; Baudron et al. 2015)	0,76 µmol /l (<200 m coastline) y 0,38 µmol /l (> 200 m coastline) (R.D. 817/2015)
A3	**Nitrates.** Annual average concentration (µmol/l)	Yes	1980-2020	Monthly	Yes	CARM, IEO y (Terrados y Ros 1991; Perez Ruzafa et al. 2009; Perez Ruzafa y Marcos Diego 2016; Baudron et al. 2015)	12,90 µmol /l (<200 m coastline) y 6,45 µmol /l (> 200 m coastline) (R.D. 817/2015)

A4	**Salinity** (ppt)	Yes	1980-2020	Monthly	Yes	CARM, IEO	42,7-47 ppm (Typical values of maximum salinity in the lagoon)
A5	**Dissolved oxygen.** Annual average concentration at different depth levels (mg/l)	Yes	1980-2020	Monthly	Yes	CARM	>6 mg/l (Swedish Environmental Protection Agency)
Do we maintain the good chemical status of the aquifers?							
Code	*Description of the indicator and units*	*Availability*	*Time series*	*Data production periodicity*	*Public accessibility*	*Sources*	*Threshold and/or objective value proposal*
A6	**Nitrates.** Annual average concentration in the Quaternary aquifer (mg/l)	Yes	Desde 1983-actualidad	Irregular. In most of the serie, annual and every six months, and recently, every three months.	Yes	IGME, CHS	≤50 mg/l (Directive 91/676/CE)
A7	**Pesticides.** Annual average concentration in the Quaternary aquifer (mg/l)	Yes	Desde 2005-actualidad	Every six months	Yes	CHS	0,1 µg/l: 0,1 µg/l (referred to each substance) y 0,5 µg/L (referred to the sum of all the pesticides detected and quantified in the monitoring procedure). (Surface water quality Decree, 2015)
Objective 2. Recover and conserve the species and habitats of the lagoon and its wetlands and the natural connectivity of the basin							
Do we keep the habitats of the lagoon and its wetlands in good condition?							
Code	*Description of the indicator and units*	*Availability*	*Time series*	*Data production periodicity*	*Public accessibility*	*Sources*	*Threshold and/or objective value proposal*

A8	**Proportion of seabed occupied by *Cymodea nodosa*** (%). (Density and coverage)	Yes	1950-2019	Sporadic data by decade. Annual data since 2014	Yes	CARM, IEO y (Terrados y Ros 1991; Perez Ruzafa et al. 1989, 2009; Perez Ruzafa y Marcos Diego 2016)	54% (Historical value of the system at the beginning of being part of the Directive 92/43/CE)
A9	**Proportion of seabed occupied by *Rupia cirrhosa*** (%). (Density and coverage)	Yes	1950-2019	Sporadic data by decade. Annual data since 2014	Yes	CARM, IEO y (Terrados y Ros 1991; Perez Ruzafa et al 1989, 2009; Perez Ruzafa y Marcos Diego 2016)	1,08% (Historical value of the system in 2014)
A10	**Proportion of seabed occupied by *Caulerpa prolifera*** (%).(Density and coverage)	Yes	1950-2019	Sporadic data by decade. Annual data since 2014	Yes	CARM, IEO y (Terrados y Ros 1991; Perez Ruzafa et al. 1989, 2009; Perez Ruzafa y Marcos Diego 2016)	87% (Historical value of the system in 2014)
A11	**Total wetlands area** (ha)	Yes	1984-2009	Sporadic data	Yes	Esteve y Calvo 2000; Carreño et al. 2008; Robledano et al. 2010	1.000 ha (Historical value of the system)
A12	**Percentage of total area occupied by habitats of community interest in wetlands: salt marsh and saline steppe** (%)	Yes	1984-2009	Sporadic data	Yes	Esteve y Calvo 2000; Carreño et al. 2008; Robledano et al. 2010	71% of surface of saline steppe and 20% of surface of salt marsh (Historical value of the system in 1984 according to Pardo et al. 2006)
Do we keep the most unique species of the lagoon and its wetlands in good condition?							
Code	*Description of the indicator and units*	*Availability*	*Time series*	*Data production periodicity*	*Public accessibility*	*Sources*	*Threshold and/or objective value proposal*

A13	**Population evolution of *Hippocampus guttulatus***	Yes	2012, 2018, 2020	Without periodicity	Yes	CARM, IEO, Asociación Hippocampus	191.120 specimens (Historical value of the system in 2012)
A14	**Population evolution of *Syngnathus Abaster***	No	No	No	No	No	
A15	**Population evolution of *Pholas dacyilus***	No	No	No	No	No	
A16	**Population evolution of *Anguila***	Yes	1988-actualidad	No	Limited	IEO, ANSE	
A17	***Pinna nobilis* distribution** (%)	Yes	2003, 2004, 2013, 2014, 2016, 2017, 2019	Without periodicity	Yes	IEO, Giménez Casalduero 2020	57,4% of the lagoon (Historical value of the system in 2014)
A18	**Population evolution of *Tarro blanco***	No	No	No	No	No	
A19	**Number of exotic species in the lagoon**	Yes	1979, 1989, 1991, 2004, 2009, 2012, 2013, 2015	Without periodicity	Limited	González Carrión 2015; Marambio et al. 2013; García Carrascosa 1979; Román et al. 2009; Arias et al. 2013; Gofas y Zenetos 2003; Pérez-Ruzafa 1989; Nicolaidou et al. 2012	
A20	**Evolution of steppe passerine birds** (Conservation index based on the Birds Directive)	Yes	1984-2008	Without periodicity	Limited	Robledano et al. 2010	2,8 in summer y 2 in winter (Robledano et al. 2010)

A21	**Kentish plover** (number of nesting pairs in the Mar Menor wetlands)	**Yes**	**1973-actualidad**	Annual	Yes	Censos invernales de aves acuaticas. ANSE, Departamento de Ecología e Hidrología.	270 pairs (Mar Menor waterfowl guide, 2007)
Do we maintain the environmental connectivity of the basin?							
Code	*Description of the indicator and units*	*Availability*	*Time series*	*Data production periodicity*	*Public accessibility*	*Sources*	*Threshold and/or objective value proposal*
A22	**Basin natural connectivity index (connectivity of occupied areas by natural vegetation and other natural systems)** (dimensionless)	No	No	No	No	No	
Objective 3. Recover the environmental functionality of the unbuilt surface of coastline							
Have we preserved the original banks of the lagoon?							
Code	*Description of the indicator and units*	*Availability*	*Time series*	*Data production periodicity*	*Public accessibility*	*Sources*	*Threshold and/or objective value proposal*
A23	**Proportion of the coastline of the Mar Menor physiologically similar to the original shoreline** (%)	No	No	No	No	No	
Have we recovered the lost wetland area?							
Code	*Description of the indicator and units*	*Availability*	*Time series*	*Data production periodicity*	*Public accessibility*	*Sources*	*Threshold and/or objective value proposal*

A24	**Proportion of total wetland area that has been recovered** (%)	No	No	No	No	No	
			Have we conserved the native natural vegetation in the undeveloped area?				
Code	*Description of the indicator and units*	*Availability*	*Time series*	*Data production periodicity*	*Public accessibility*	*Sources*	*Threshold and/or objective value proposal*
A25	**Proportion of unbuilt surface occupied by native species of the area** (%)	No	No	No	No	No	
			SOCIOECONOMIC SUSTAINABILITY				
			Objective 4. Implement an environmentally and socially sustainable agricultural model				
			Are we reducing the irrigated area to more sustainable levels?				
Code	*Description of the indicator and units*	*Availability*	*Time series*	*Data production periodicity*	*Public accessibility*	*Sources*	*Threshold and/or objective value proposal*
S1	**Total irrigated area (ha)**	Yes	1988-2017	Annual	Yes	Carreño 2015; SIGPAC; Catastro y UDAs del PHDS, CREM, CARM	43.071 ha (Official value recognized in the Segura Demarcation Plan 2015-2021)
			Do we reduce the input of nitrogen and phosphorus from the upland watershed?				
Code	*Description of the indicator and units*	*Availability*	*Time series*	*Data production periodicity*	*Public accessibility*	*Sources*	*Threshold and/or objective value proposal*
S2	**Average contribution of nitrogen in agricultural crops** (tn/ha/year)	Yes	2000-2005	Annual	Yes	CARM	170 kgN/ha/year (Directive 91/676/CE)

S3	**Average contribution of phosphorus in agricultural crops** (tn/ha/year)	Yes	2000-2005	Annual	Yes	CARM	
Do we manage the basin in such a way that it is able to manage its own nutrients?							
Code	*Description of the indicator and units*	*Availability*	*Time series*	*Data production periodicity*	*Public accessibility*	*Sources*	*Threshold and/or objective value proposal*
S4	**Area occupied by hedges of natural vegetation** (ha)	No	No	No	No	No	
S5	**Proportion of agricultural drainage and brines managed with green filters** (%)	No	No	No	No	No	
S6	**Linear kilometers of hydrological network with recovered natural vegetation** (km)	No	No	No	No	No	
Are we promoting organic agriculture?							
Code	*Description of the indicator and units*	*Availability*	*Time series*	*Data production periodicity*	*Public accessibility*	*Sources*	*Threshold and/or objective value proposal*
S7	**Proportion of irrigated land cultivated with organic farming systems** (%)	Yes	2012	Without periodicity	Yes	CREM	
Do we prioritize local agriculture?							

Code	*Description of the indicator and units*	*Availability*	*Time series*	*Data production periodicity*	*Public accessibility*	*Sources*	*Threshold and/or objective value proposal*
S8	**Proportion of total production destined to supply international, national and regional markets** (%)	No	No	No	No	No	
Do we have a quality job in the agricultural sector?							
Code	*Description of the indicator and units*	*Availability*	*Time series*	*Data production periodicity*	*Public accessibility*	*Sources*	*Threshold and/or objective value proposal*
S9	**Temporality and seasonality rate** (%)	Yes	2005-2020	Annual	Yes	SREF	
S10	**Average educational level of agricultural workers** (Basic studies, Secondary, Professional training, University)	No	No	No	No	No	
S11	**Complaints for irregularities in the contracts** (Number of complaints)	No	No	No	No	No	
Objective 5. Implement a sustainable and quality tourism model							
Do we adequately manage urban wastewater?							
Code	*Description of the indicator and units*	*Availability*	*Time series*	*Data production periodicity*	*Public accessibility*	*Sources*	*Threshold and/or objective value proposal*

S12	**Annual number and/or volume of untreated discharges to the lagoon (due to ruptures, torrential rains or other incidents)** (hm^3)	Yes	2015	Annual	Yes	ESAMUR	
S13	**Average annual concentration of nitrogen and phosphorus in treated wastewater destined for non-agricultural purposes** (mg/l)	Yes	2015	Annual	Yes	ESAMUR	
Have we overcome the tourist seasonality?							
Code	*Description of the indicator and units*	*Availability*	*Time series*	*Data production periodicity*	*Public accessibility*	*Sources*	*Threshold and/or objective value proposal*
S14	**Tourist seasonality** (%tourists/month)	Yes	2012-2017	Annual	Yes	ITRM	28% in summer 30% in fall 22% in winter 18 % in spring (Seasonality data for Canarias, INE, 2018)
Have we implemented quality torusim?							
Code	*Description of the indicator and units*	*Availability*	*Time series*	*Data production periodicity*	*Public accessibility*	*Sources*	*Threshold and/or objective value proposal*
S15	**Ratio of tourists to the resident population** (%)	No	No	No	No	No	

S16	**Tourists who repeat destination** (%)	No	No	No	No	No	
S17	**Visitors satisfaction level** (very satisfied, satisfied, unsatisfied, very dissatisfied)	No	No	No	No	No	
S18	**Proportion of companies offering activities in nature** (%)	No	No	No	No	No	
S19	**Average expenditure per day per tourist** (euros/person/day)	Yes	2015-2019	Annual	Yes	CREM	161 euros/person/day (Average daily expenditure per tourist in Spain for 2019)
Do we have a quality job in the tourist sector?							
Code	*Description of the indicator and units*	*Availability*	*Time series*	*Data production periodicity*	*Public accessibility*	*Sources*	*Threshold and/or objective value proposal*
S20	**Temporality and seasonality rate** (%)	Yes	2011-2019	Annual	Yes	CREM	
S21	**Average monthly salary** (euros/month)	No	No	No	No	No	
S22	**Average level of studies of the worker** (Basic studies, Secondary, Professional training, University)	No	No	No	No	No	
Objective 6. Sustainable local development							
Do we have diversified and balanced local economy?							

Code	*Description of the indicator and units*	*Availability*	*Time series*	*Data production periodicity*	*Public accessibility*	*Sources*	*Threshold and/or objective value proposal*
S23	**Relative contribution of the different economic sectors to the local economy of the municipalities that make up the SESMM** (%GVA)	Yes	2017	Without periodicity	Yes	García Ayllón 2018 CREM	
			Do we promote sustainable mobility?				
Code	*Description of the indicator and units*	*Availability*	*Time series*	*Data production periodicity*	*Public accessibility*	*Sources*	*Threshold and/or objective value proposal*
S24	**Pedestrian road space** (%)	Yes	2012	Without periodicity	Yes	Grupo de investigación Aries-UCAM 2014	75% (Rueda 2012)
S25	**Road space for bikes** (%)	Yes	2014	Without periodicity	Yes	EDUSI	20 km de La Manga del Mar Menor (Majano 2010)
S26	**Public transport users** (number of users)	Yes	2014	Without periodicity	Yes	CARM, EDUSI	606.350 in 2022 (EDUSI)
			INSTITUTIONAL SUSTAINABILITY				
			Objective 7. Implement a model of polycentric, adaptive and participatory governance				
			Is there coordination among administrations and adequate participation of the stakeholders?				
Code	*Description of the indicator and units*	*Availability*	*Time series*	*Data production periodicity*	*Public accessibility*	*Sources*	*Threshold and/or objective value proposal*

I1	**Is there just one representation of the public administration in the social participation councils?**	Yes	2015	Without periodicity	Yes	CARM	There should be a single representation (Greening et al. 2011; 2014 & 2016)
I2	**Do we have a scientific advisory institution that gathers the best scientific knowledge available around the SESMM and advises on the different subjects independently?**	Yes	2016	Without periodicity	Yes	CARM	Independently functioning scientific advisory committee (Greening et al. 2011; 2014 & 2016)
I3	**Do we have a participation institution that integrates all the stakeholders involved in the SESMM?**	Yes	2017	Without periodicity	Yes	CARM	Social participation committee made up of all the stakeholders involved with independent functioning (Greening et al. 2011; 2014 & 2016)
I4	**Proportion of legislative changes, programs, etc. who are consulted in the public participation institution in their initial phase** (%)	No	No	No	No	No	

I5	**Public access to information on the SESMM** (measures in application and their results, scientific reports, monitoring results, etc.)	No	No	No	No	No	
Are all the stakeholders (public administration, economic sectors, academia, social and citizen organizations) included in an equitable way in the SESMM management model and in the decision-making processes?							
Code	*Description of the indicator and units*	*Availability*	*Time series*	*Data production periodicity*	*Public accessibility*	*Sources*	*Threshold and/or objective value proposal*
I6	**Proportion of members of each type of stakeholder in the management and public participation institution related to SESMM** (%)	Yes	2015-2020	Without periodicity	Yes	CARM	Scientific committee: 100% scientific staff Social participation committee: 100% social and economic actors
Are the objectives and measures for the management of the SESMM reviewed cyclically?							
Code	*Description of the indicator and units*	*Availability*	*Time series*	*Data production periodicity*	*Public accessibility*	*Sources*	*Threshold and/or objective value proposal*
I7	**Average degree of implementation of the measures** (%)	Yes	1998-2020	Without periodicity	Yes	CARM	100% (Greening et al. 2011, 2014 & 2016)
I8	**Average degree of effectiveness of the implanted measures in reaching the planned objectives** (%)	No	No	No	No	No	

I9	**Is there a procedure for the review and continuous improvement of the objectives and measures of the SESMM?**	No	No	No	No	No	
I10	**Are there adequate control mechanisms over the execution of the measures: inspection, surveillance, evaluation of their execution and evaluation of their effectiveness?**	No	No	No	No	No	

The main results related to the characterization of indicators of the three dimensions of sustainability are presented in greater detail below.

7.3.1. Environmental sustainability

In the area of environmental sustainability, a total of 25 indicators have been selected, representing 41% of the total. Despite the existence of information available for 72% of the indicators, this information in many cases is heterogeneous, dispersed, discontinuous and is not always well described. Regarding the indicators related to the ecological status of the lagoon (A1-A5), information is available from 1980 to 2020. The data is updated monthly from the CARM regional institutional source and its accessibility is public. For its part, the IEO Murcia Oceanographic Center provides information through its own studies and analyzes and evaluates its own data, especially since the eutrophic crisis of the Mar Menor lagoon in 2016. Although this information can be consulted through the publication of their reports must be through a personal request to the institution for a greater level of detail. Other scientific publications (Rosique 2000; Pérez Ruzafa et al. 2005, Velasco et al. 2006; Baudron et al. 2015; Terrados and Ros 1991) provide analyzes and evaluations of these indicators using their own data, calculated from their research departments or either the information from the CARM regional institution and the IEO.

Regarding the indicators that respond to knowing the chemical status of the aquifers (A6 and A7), the information is available from 1983 (A6) and from 2005 (A7) to the present with an irregular data update frequency, although mostly semiannual.

The indicators related to the habitats of the lagoon (A8-A10) provide some type of information from 1950 to 2019, but the updating of this information throughout this time series is not periodic. Until 2014, specific data were found by decade and from that year on, an annual update was available. The sources of information are various: IEO, CARM and Terrados and Ros (1991), Pérez Ruzafa et al (1989 and 2009), Pérez Ruzafa and Marcos Diego (2016). Among these, the IEO's Oceanographic Center of Murcia provides a greater analysis of information and data updating, especially since the eutrophic crisis of the lagoon in 2016. Although the accessibility of the information is public, the institution should be contacted for a greater degree of detail in the analysis.

Regarding the indicators related to the status of wetland habitats (A11 and A12), only available data have been found for the period 1984-2009, through the following studies whose accessibility is public through their scientific publications: Esteve and Calvo 2000; Carreño et al. 2008; Robledano et al. 2010.

The most unique species of the lagoon and the wetlands are analyzed with nine indicators (A13-A21), of which information has been found for 6 (A13, A16, A17, A19, A20 and A21). Specifically, in the case of the "Population evolution of *Hippocampus guttulatus*" (A13) quantitative data have been found for the years 2012, 2018 and 2020, without there being a continuous periodicity of data update. Accessibility is public, although through different sources: IEO, CARM and the Hippocampus Association. It is important to note that there are partial results of the visual censuses carried out by the Hippocampus Association and the IEO from 2006 to 2011, but no quantitative data has been found available for each of the years included in that time series.

Regarding the “Distribution of *Pinna nobilis*” (A17) something similar happens, the quantitative data are specific for the years 2003, 2004, 2013, 2014, 2016, 2017 and 2019 and come from the sources of the Marine Angiosperm Ecology Group of the Oceanographic Center of Murcia of the IEO and Giménez Casalduero (2020).

Among the most unique species in the wetlands, it is worth highlighting the “*Kentish plover*” (A21), whose data availability dates from 1973 to the present with an annual data update period. The data are accessible through the following sources: winter waterfowl censuses, ANSE and the Department of Ecology and Hydrology of the University of Murcia.

It is important to point out the lack of information in relation to the three indicators (A23, A24 and A25) defined to know the status of the environmental functionality of the unbuilt stretches of coastline, given the importance of knowing the degree of progress in this area.

7.3.2. Socio-economic sustainability

A total of 26 indicators have been selected for the area of socioeconomic sustainability, of which 54% have information. In this case, the heterogeneity and dispersion of the information deserves a more detailed explanation, as indicated below.

For the indicator, "Total area dedicated to irrigation" (S1), there are different sources of information with different values for the period 1988-2017 that makes its evaluation difficult. The sources of official institutions such as the Geographic Information System of agricultural parcels (SIGPAC), Cadastre and Agricultural Demand Units (UDAs) of the Hydrological Plan of the Segura demarcation (PHDS) provide information that differs from the information provided by the prosecutor's office and by the scientific publication of Carreño (2015).

Regarding the indicators, "Average contribution of nitrogen in agricultural crops" and "Average contribution of phosphorus in agricultural crops" (Kg/ha/year) (S2 and S3), the available information is not well described since it refers to the contributions during the period 2000-2005, without being published as a long time series.

For indicators such as the “Proportion of irrigated land under organic farming systems” (S7), no long time series have been found. The CREM provides the latest updated information for 2012. Regarding the “Temporality and seasonality rate in employment in the agricultural sector” (S9), although the information provided by the SREF includes a long time series, the variable related to the type of contracts, the information is provided at an aggregated level, without specifying the economic sector to which it refers, which makes it difficult to calculate the temporary employment rate.

Regarding the indicators related to the tourism sector for which information is indicated ("Tourist seasonality" (S14), "Average expenditure per day per tourist" (S19), "Temporality and seasonality rate of employment in the tourism sector ”(S20)), it should be noted that this information is currently at the regional level, coming from CREM and ITRM sources with an annual update frequency, but on which it would be possible to obtain information at the municipal level working with the corresponding institutions, especially due to the relevance that the municipalities of the SESMM have to the region's tourism sector. The same happens with the indicator "Relative contribution of the different economic sectors to the local economy of the municipalities that make up the SESMM" (S23), which indicates the data provided by the publication of García Ayllón (2018) for 2017 specifically referred to the municipalities of the SESMM, given that the information provided by the CREM is available only at the regional level, with an annual update frequency.

The information for the sustainable mobility indicators is specific to studies carried out for La Manga del Mar Menor, which provide information for the indicator of "Pedestrian road space" (S24) for the year 2012, prepared by the Aries Research Group of the San Antonio de Murcia Catholic University (UCAM). For the year 2014, the Sustainable and Integrated Urban Development Strategy (EDUSI) details information for the indicators "Road space for bicycles" (S25) and "Users of public transport" (S26), which in turn draws on information from the CARM.

It is necessary to insist on the need to resolve the existing information gaps for some of the indicators, either because information has not been available, or because it is heterogeneous and dispersed information that has made it difficult to locate. This is the case for the indicators that answer the strategic question of *Do we manage the basin in such a way that it is capable of* *managing its own nutrients?* (S4, S5, S6). For others, it is because it is available at the regional level, such as the indicators that answer the questions of: *Do we prioritize local agriculture?* (S8), *Do we have a quality job in the agricultural sector?* (S10, S11), *Have we implemented quality tourism?* (S15-S18) and *Do we have a quality job in the tourism sector?* (S21, S22).

7.3.3. Institutional sustainability

In the area of institutional sustainability, ten indicators have been selected, representing 16% of all indicators. Unlike the indicators selected for the environmental and socioeconomic areas, which are all quantitative, in this case half of the indicators are qualitative. Information is available in 50% of the cases, whose source is the CARM and whose access to the information is public. The information is sporadic for different years, without there being a periodicity of continuous updating, with the exception of the indicator “Average degree of execution of the measures” (I7). This indicator collects information from 1998 to 2020 on initiatives such as plans, programs and strategies that have been initiated and executed throughout that period. On the contrary, in indicators such as the “Proportion of members of each type of actor in the management and public participation institutions related to the SESMM” (I6), the time series 2015-2020 corresponds to the years in which the different management institutions were created (2015, 2016 and 2017) and the years in which some type of modification has been published in relation to its composition (2018, 2019 and 2020).

For the indicators "Is there just one representation of the public administration in the social participation councils?" (I1), "Do we have a scientific advisory institution with the best scientific knowledge available around the SESMM and advises on different matters independently?" (I2) and "Do we have a participation institution that integrates all the stakeholders involved in the SESMM?" (I3), the years in which the corresponding participation institutions were created are indicated.

It is important to note that no data has been found in relation to the indicators that provide information on whether the objectives and measures for the management of the SESMM are reviewed cyclically (I8, I9, I10). Neither has concrete information been found in relation to other indicators such as: “Proportion of legislative modifications, programs, etc. that are consulted in the public participation institutions in their initial phase” (I4) or the “Public access to information regarding the SESMM, such as measures in application and their results, scientific reports, monitoring results, etc.” (I5).

Table 7.2 shows the evaluation of the information status of each indicator.

Table 7.2. Evaluation of the information status of each indicator. Green color (Information status sufficient), orange color (Information status intermediate), red color (Information status insufficient), gray color (Information status not available).

Dimension	Indicator	Evaluation
Environmental	**A1. Chlorophyll-a.** Annual average concentration (µg/l) o (mg/m^3)	
	A2. Phosphorus. Annual average concentration (µmol/l)	
	A3. Nitrates. Annual average concentration (µmol/l)	
	A4. Salinity (ppt)	
	A5. Dissolved oxygen. Annual average concentration at different depth levels (mg/l)	
	A6. Nitrates. Annual average concentration in the Quaternary aquifer (mg/l)	
	A7. Pesticides. Annual average concentration in the Quaternary aquifer (mg/l)	
	A8. Proportion of seabed occupied by *Cymodea nodosa* (%). (Density and coverage)	
	A9. Proportion of seabed occupied by *Rupia cirrhosa* (%). (Density and coverage)	
	A10. Proportion of seabed occupied by *Caulerpa prolifera* (%).(Density and coverage)	
	A11. Total wetlands area (ha)	
	A12. Percentage of total area occupied by habitats of community interest in wetlands: salt marsh and saline steppe (%)	
	A13. Population evolution of *Hippocampus guttulatus*	
	A14. Population evolution of *Syngnathus Abaster*	
	A15. Population evolution of *Pholas dacyilus*	
	A16. Population evolution of *Anguila*	
	A17. *Pinna nobilis* distribution (%)	
	A18. Population evolution of *Tarro blanco*	
	A19. Number of exotic species in the lagoon	
	A20. Evolution of steppe passerine birds (Conservation index based on the Birds Directive)	
	A21. Kentish plover (number of nesting pairs in the Mar Menor wetlands)	
	A22. Basin natural connectivity index (connectivity of occupied areas by natural vegetation and other natural systems) (dimensionless)	
	A23. Proportion of the coastline of the Mar Menor physiologically similar to the original shoreline (%)	
	A24. Proportion of total wetland area that has been recovered (%)	
	A25. Proportion of unbuilt surface occupied by native species of the area (%)	
Socioeconomic	**S1. Total irrigated area (ha)**	
	S2. Average contribution of nitrogen in agricultural crops (tn/ha/year)	
	S3. Average contribution of phosphorus in agricultural crops (tn/ha/year)	
	S4. Area occupied by hedges of natural vegetation (ha)	
	S5. Proportion of agricultural drainage and brines managed with green filters (%)	
	S6. Linear kilometers of hydrological network with recovered natural vegetation (km)	
	S7. Proportion of irrigated land cultivated with organic farming systems (%)	
	S8. Proportion of total production destined to supply international, national and regional markets (%)	
	S9. Temporality and seasonality rate (%)	
	S10. Average educational level of agricultural workers (Basic studies, Secondary, Professional training, University)	
	S11. Complaints for irregularities in the contracts (Number of complaints)	
	S12. Annual number and/or volume of untreated discharges to the lagoon (due to ruptures, torrential rains or other incidents) (hm^3)	
	S13. Average annual concentration of nitrogen and phosphorus in treated wastewater destined for non-agricultural purposes (mg/l)	
	S14. Tourist seasonality (%tourists/month)	
	S15. Ratio of tourists to the resident population (%)	
	S16. Tourists who repeat destination (%)	

	S17. Visitors satisfaction level (very satisfied, satisfied, unsatisfied, very dissatisfied)	
	S18. Proportion of companies offering activities in nature (%)	
	S19. Average expenditure per day per tourist (euros/person/day)	
	S20. Temporality and seasonality rate (%)	
	S21. Average monthly salary (euros/month)	
	S22. Average level of studies of the worker (Basic studies, Secondary, Professional training, University)	
	S23. Relative contribution of the different economic sectors to the local economy of the municipalities that make up the SESMM (%GVA)	
	S24. Pedestrian road space (%)	
	S25. Road space for bikes (%)	
	S26. Public transport users (number of users)	
Institutional	**I1. Is there just one representation of the public administration in the social participation councils?**	
	I2. Do we have a scientific advisory institution that gathers the best scientific knowledge available around the SESMM and advises on the different subjects independently?	
	I3. Do we have a participation institution that integrates all the stakeholders involved in the SESMM?	
	I4. Proportion of legislative changes, programs, etc. who are consulted in the public participation institution in their initial phase (%)	
	I5. Public access to information on the SESMM (measures in application and their results, scientific reports, monitoring results, etc.)	
	I6. Proportion of members of each type of stakeholder in the management and public participation institution related to SESMM (%)	
	I7. Average degree of implementation of the measures (%)	
	I8. Average degree of effectiveness of the implanted measures in reaching the planned objectives (%)	
	I9. Is there a procedure for the review and continuous improvement of the objectives and measures of the SESMM?	
	I10. Are there adequate control mechanisms over the execution of the measures: inspection, surveillance, evaluation of their execution and evaluation of their effectiveness?	

7.4. Discussion and conclusions

7.4.1. Specific, integral, systemic and multidimensional nature of the indicator system and its explicit link with its objectives

One of the criticisms of the indicator catalogs for evaluating sustainability in SES or other territories is the large number of indicators that are frequently selected. Authors such as Rigby et al (2000) and Nardo et al (2005) point out the importance of selecting indicators that allow addressing the key aspects of the sustainability of the system to be analyzed and avoiding a large list that entails greater complexity and redundancy problems. Some examples can be cited, such as the case of the Fuerteventura Biosphere Reserve or the Network of Sustainable Local Development Networks at regional and provincial level in Spain, which have a large number of indicators whose application makes it more complicated and moves away from the priorities that are required for each system or territory.

On the contrary, in this work the selection of indicators that is proposed derives from the specific sustainability objectives defined for the SESMM, including exclusively 61 indicators that are considered really required for their monitoring. This also avoids including indicators that are not connected with the specific objectives that have been set for the SES (Cairns et al. 1993; Castro 2002).

As other studies point out (Martínez-Fernández et al. 2008, 2017; Banos-González et al. 2016), it is very important that the selected indicators are adapted to the uniqueness and specificity of each SES or territory, avoiding standardized indicator catalogs that they may not make sense or be confusing when applied to other territories and SESs. This approach is far from the one proposed in the SESMM Integrated Coastal Zone Management Strategy, in which a system of indicators is proposed that does not focus on the evaluation of the specific objectives required for the SESMM, but has a different purpose, as is the monitoring of the implementation of the proposed measures.

Another criticism that is often made of many indicator catalogs is that they are intended for application on national or regional scales (Medrano and Lardiés 2014). Since the United Nations Environment Program (UNEP) established the first set of indicators to assess sustainability in 1995, the governments of many countries and agencies have developed indicator systems at the national or regional level (for example, the proposed indicators in the: European Environment Agency, Sustainable Development Strategy of the European Union, Spanish Strategy for Sustainable Development, Agenda 2030 of the United Nations Organization), whose application is less useful at local scales due to environmental, social, economic, cultural and institutional particularities at such scales. However, despite the fact that in this work the 61 selected indicators are specific to the SESMM, there are some such as those related to the ecological status of the lagoon (A1-A5), employment in the agricultural and tourist sector (S9, S20), quality in the tourist sector (S19) or sustainable mobility (S24, S25, S26) that have already been defined in other studies and at other scales (Research Group ARIES 2014; Medrano and Lardiés 2014; Romero et al. 2017; Barragán and de Andrés 2020), which offers additional advantages as they are more consolidated indicators and allow comparison with other territories.

In addition, the system of sustainability indicators of the proposed SESMM aims to provide an integrative and systemic approach. Authors such as Antequera (2005) insist that before selecting and choosing indicators it is important to be clear about the cause-effect relationships in the SES and to develop conceptual models that contribute to their identification. As mentioned in the methodology section of this work, the specific objectives defined for the SESMM derive from an integral diagnosis previously carried out on this work (Chapter 4 of this thesis), the result of inter and transdisciplinary work, in which it was developed a socio-ecological conceptual model to evaluate the relationships and interactions among its main economic activities. This socio-ecological model has constituted a solid conceptual framework for the identification of the specific objectives and consequently of the indicators in its environmental, socio-economic and institutional aspects.

Although there are many research articles that point out the importance of generating and applying indicator systems, there are few that organize the indicators based on the relationships they maintain among themselves (Bermejo and Nebreda 1998; Medrano and Lardiés 2014; Zamora et al. 2017). It is important to insist on the importance of applying methodologies that identify the relationships among the different factors, as a basis for the definition of specific objectives, from which an integral and multidimensional system of indicators can be derived in the monitoring of local sustainability (Bermejo and Nebreda 1998). In this sense, it is important to highlight the role that indicators related to institutional sustainability play in ecological restoration projects (Eden & Tunstall 2006; Zamora et al. 2017), as will also be necessary in the SESMM. Despite the importance of developing indicators related to governance and the management model, there are many studies that develop systems of sustainability indicators incorporating the environmental and socioeconomic dimension, but ignoring or paying little attention to the institutional dimension (Chirino et al. 2008; Barragán and de Andrés 2020).

7.4.2. The importance of bottom-up processes for the selection of sustainability indicators

The development of indicators requires multidisciplinary collaboration, in dialogue among the different fields of knowledge (Lorenz et al. 1997; García 2006; Woolsey et al. 2007). The process of consultation with ten experts in the fields of environmental, socioeconomic and institutional sustainability that was carried out in this work contributed to refining the initially proposed system of indicators and to validating a final system of indicators, according to the state of knowledge in their respective fields in relation to the SESMM. However, in line with what other studies indicate (Fletcher et al. 2014; Zamora et al. 2017; Martínez-Fernández et al. 2016, 2021) it will be important to continue with a future participatory process and involve stakeholders in the design end of a system of indicators to favor their co-responsibility in its application.

7.4.3. Status and assessment of the available information

The availability of information and quality of data are great challenges for the calculation of many indicators proposed within the different areas of sustainability for the SESMM, as other studies have pointed out (Medrano and Lardiés 2014; Martínez et al. 2016; Sánchez et al. al. 2018). Among these indicators, the lack of information is relevant in half of the indicators in the area of institutional sustainability and in slightly less than half (46%) of the indicators related to the socioeconomic dimension. On the other hand, the lack of availability of information in the field of environmental sustainability is well below half (28%). In this sense, it can be affirmed that there is an imbalance among the different dimensions of the sustainability of the SESMM in relation to the availability of information.

Despite the existence of 61% of information available for the entire system of indicators, only 38% have a sufficient state of information to be able to evaluate them. On the contrary, 46% of the indicators have intermediate information for their evaluation and in 16% the state of the information is insufficient for their evaluation (Table 7.2), since they are indicators in which they have only been found specific data referring to one or more years, without periodicity of updating and there are no long time series. As an example, the following indicators can be pointed out: "Total area of wetlands" (A11) and "Percentage of total area occupied by habitats of community interest in wetlands: salt marsh and saline steppe" (A12), Population evolution of species in the lagoon and wetlands (A13, A16, A17, A19, A20), "Average contribution of nitrogen and phosphorus in agricultural crops" (S2 and S3), "Proportion of irrigated land with organic farming area" (S7), "Road space pedestrian ” (S24),“ Road space for bicycles” (S25),“ Public transport users ” (S26), among others. On the other hand, where there are longer time series, as in the case of indicators on the ecological status of the lagoon (A1-A5), the data are not standardized, they appear scattered in different sources, such as statistical repositories of different institutions or scientific publications of different authors and the accessibility to the data, depending on the sources, is not always public, having to resort to requesting them. Another of the difficulties detected is the inconsistency in the data provided by different sources around the same magnitude, as is the case of the "Total area dedicated to irrigation" (S1) or the "Proportion of seabed occupied by *Cymodea nodosa*”, “Proportion of seabed occupied by *Rupia cirrhosa*” and “Proportion of seabed occupied by *Caulerpa prolifera*” (A8, A9 and A10). It should also be noted that, despite the effort made to search for data at the municipal (local) level, some data are only available at the regional level, as is the case for indicators of the socio-economic sphere, specifically: “Tourist seasonality” (S14), “Expenditure average per day per tourist ”(S19),“ Temporality and seasonality rate ”of employment in the economic sectors of agriculture (S9) and tourism (S20), which makes their calculation difficult and that they are not useful to know the degree of progress towards the proposed objectives.

Regarding the 39% of indicators for which no available information has been found (Table 2), it is necessary to point out the need for a greater effort in the creation and maintenance of statistical series and other databases by the regional institutions. All this in order to be able to calculate all the proposed indicators, as well as those necessary to answer strategic questions as relevant as the following: *Do we maintain the environmental connectivity of the basin? Have we conserved the original banks of the lagoon? Have we recovered the lost wetland area? Have we conserved the native natural vegetation in the non-built area? Do we manage the watershed in such a way that it is capable of managing its own nutrients? Do we prioritize local agriculture? Do we have a quality job in the agricultural sector? Have we implemented quality tourism? Do we have a quality job in the tourist sector? Are all stakeholders included in an equitable manner in the SESMM management model and in the decision-making processes? Are the objectives and measures for the management of the SESMM reviewed cyclically?* Answering these questions will make it possible to know whether or not progress is being made in the specific objectives set out in the different dimensions of the SESMM's sustainability.

These results coincide with the conclusions of many other investigations (see, for example, Medrano and Lardiés 2014; Zamora et al. 2017) that underline the need to invest in improving information systems in order to calculate indicators that are objective, credible, reliable, sensitive, accessible and effective. On the other hand, the homogenization of sources and the creation of databases with long time series and georeferenced information with criteria of quality, transparency and accessibility are required.

7.4.4. Usefulness of the system of indicators to evaluate sustainability

In many papers on indicators, there is a certain recurrence in considering that indicators should be easy to measure, use and communicate (OECD 1997; Dale & Beyeler 2001; Palmer et al. 2005). However, this task is not always easy. The results of this work suggest that the evaluation of sustainability in the SESMM is evident as a complicated task, with practical and conceptual difficulties. On the one hand, biases in the availability of data may favor that in the end only what can be measured is valued and, on the other hand, the absence of clear thresholds for part of the indicators makes it less useful when using them to perform diagnoses and assess changes over time, as a basis for decision-making.

The availability and quality of data is essential to be able to contribute to assessment of the environmental status and socioeconomic situation of the SESMM, and identify trends and support decision-making processes. But, in addition, for the indicator system to be useful, it is necessary to have reference values of the desirable value in terms of sustainability, in order to quantify the distance of each indicator from its reference value. Many studies (Azar et al. 1996; Chirino et al. 2008; Medrano and Lardiés 2014; Lagunas et al. 2017; Zamora et al. 2017; Barragán and de Andrés 2020) have developed systems of environmental or sustainability indicators that lack threshold values, which makes them less useful. Authors such as Lancker and Nijkamp (2000);

Moldan et al. (2012); Proelss and Houghton (2012) point out that the establishment of threshold values and objectives plays a very important role in assessing the situation and evaluating the indicators in terms of sustainability, as well as in making decisions and prioritizing policies and management measures (Banos-González et al. 2016; Martínez et al. 2016). This work includes a tentative proposal of threshold values for those indicators in which the available information has allowed it (Table 1). In future works, such thresholds will be reviewed and completed, with a multidisciplinary group of experts, and later the indicator system will be discussed in future participatory workshops with the stakeholders.

After having a system of SESMM indicators contrasted with experts and with a participatory process, it would be ready for its application, which in turn requires three additional stages: calculation of the indicators by an interdisciplinary team, institutionalization of the indicator system and finally, the preparation and dissemination of evaluation and follow-up reports on the sustainability of the SESMM using the system of indicators. Specifically, it is proposed to include this system of indicators in the Integrated Coastal Zone Management Strategy of the SESMM, since as previously mentioned, this Strategy does not incorporate a system of indicators aimed at the specific objectives of the SESMM, since the indicators included they refer to the execution of the measures.

It is important to insist that, after the construction of the indicator system, it must be institutionalized and have political support. Building sustainability indicators that show the status and trends in its multiple dimensions is a great collaborative challenge due to its transversal nature to institutions and disciplines. Experience in other systems (Cepal 2009) indicates that collaboration and coordination among institutions is a central element for the sustainability of the indicators system itself and the achievement of its objectives in a shorter period of time. The collaboration of the different institutions involved in the management of the SESMM will be essential for its maintenance and progressive development. The creation of a Sustainability Observatory for the SESMM, as in other cases at the international and national level, could constitute the space from which to integrate environmental, socio-economic and institutional information, (which is currently dispersed), homogenize information sources, calculate the indicators and prepare periodic evaluation and follow-up reports. It will also be very important to pay attention to the dissemination of the System of Indicators so that society as a whole can know it and make use of it.

The development of a system of indicators for the recovery of the SESMM should be considered as a necessary investment by the administration, since it would eventually make it possible to have a tool capable of synthesizing the complex and profuse information on the SESMM, at the service of the different stakeholders (political, technical, economic sectors, social actors and citizens) for informed decision-making based on the best available knowledge.

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Chapter 8.

Governance in the Mar Menor social–ecological system: complexities and challenges in the management model

Encañizadas, modo de pesca tradicional del Mar Menor

Encañizadas, traditional fishing art of the Mar Menor

Fotografía: Javier Murcia Requena

8. Governance in the Mar Menor socio-ecological system: complexities and challenges in the management model *

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Abstract

The challenges of sustainability demand public policies that are promoted from a holistic, systemic and participatory perspective. Governance is one of the most important areas to guarantee the sustainability of socio-ecological systems (SES) in the long term. How societies choose to govern their natural resources has important consequences on the quality of life of the local community and the sustainability of the SES. In this sense, a better understanding of the governance processes in SESs is an essential step towards their sustainability. This paper analyzes the current governance conditions for the management of the Mar Menor socio-ecological system (SESMM), identifying the elements and structure of the governance system, as well as the positions of its stakeholders. The results indicate that the knowledge and methodological approach used for the elaboration of public policies and for the management of natural resources is not transparent, inclusive and responsible, therefore it is not adequate to address the current challenges of complexity, uncertainty and conflicts of interest associated with environmental problems. The lack of coordination and collaboration between the institutions, the deficient degree of co-management, the ineffectiveness of the management tools, the conflict of interest between stakeholders for the use and management of natural resources emerge as the main complexities and fundamental challenges. This weakness in the management system has generated inefficiency in the use of natural resources, a low incidence of management instruments, and as a result, no progress has been made in the environmental, social, economic and institutional sustainability of the SESMM. These results point to the importance of conceiving a polycentric, participatory and adaptive governance system that allows shared decisions to be made among all the actors involved for the benefit of the sustainability of the SESMM and social welfare, as other studies have already shown in other coastal SESs.

Keywords: Environmental governance; Co-management; Integrated policies; socio-ecological system; sustainability.

8.1. Introduction

Socio-ecological systems (SES) are complex systems that integrate approaches resulting from a co-evolutionary process in which ecological systems and social systems adapt each other (Anderies et al. 2004), and therefore an SES can´t be understood without taking into account the interactions between the two systems. The complexity of managing natural resources within an SES suggests the need for advanced governance systems. Governance systems are dynamic entities that include a great variety and diversity of institutions and stakeholders, interacting in different contexts (socioeconomic, environmental, political) and spatial scales. The way in which these components interact in an SES will determine the way in which decisions are made (Martín-López et al. 2009).

An important challenge in studying SES governance is to improve our understanding of the conditions under which cooperative solutions are sustained, how stakeholders can make decisions in the face of uncertainty, and how the topology of interactions among stakeholders and biophysical factors and processes affect governance (Jassen and Ostrom 2006).

Traditionally, governance has basically consisted of delegating all responsibility to government, with a vertical centralized approach; but the frequent lack of success has led to questioning its predominant role in these processes and its ability to achieve conservation and sustainability goals (Ostrom 2007) to which other considerations should be added, such as questioning its social legitimacy. Centralized and vertical management structures or approaches are not very appropriate for the management of SES, due to their inflexibility and lack of adjustability to the complexity of the socio-ecological processes (Ostrom 1990; Holling and Meffe 1996; Anderis el al. 2004). According to Ostrom (1990), there is no one better to sustainably manage a common use resource than the people involved. In this sense, there are many authors who point out that in order to achieve governance that is effective, and contribute to solve environmental management conflicts and transition towards the sustainability of SES, it is essential that SES management integrates the participation of all stakeholders. This integrated management should range from governmental and non-governmental organizations, to private sector, social and citizen organizations and the local community (Ostrom 1990; Özesmi and Özesmi 2003; Ford 2003; Bulkeley 2005; Prell et al. 2009; Bodin and Prell 2011).

Different approaches have been proposed to overcome the problems associated with centralized government management. Crona and Hubacek (2010) mention the co-management and adaptive co-management approaches, among others. Co-management is normally understood as a process by which public and private actors cooperate and share power, in order to solve problems associated with the management of natural resources (Carlsson and Berkes 2005). Euler and Heldt (2018) and Fritz and Binder (2020) point out that in co-management, decisions should be made within a deliberative process with the participation of all stakeholders (public managers and actors). The adaptive co-management system is an expansion of the co-management concept and consists of an iterative and participatory approach to environmental governance, where those responsible for managing the SES systematically adapt their practices while "learning by doing", through different tools, including experimentation or modeling (Armitage et al. 2009). This approach emphasizes the need for collaboration and learning among researchers, stakeholders, and resource managers.

On the other hand, Ostrom (1998) highlights the importance of polycentric governance in the management of SES. In polycentric governance, institutional systems are made up of institutions at different organizational scales (for example, local, regional, national, international), with several decision-making centers that act at these different scales, interacting vertically and horizontally to resolve issues or conflicts, rule-making and other governance tasks (Ostrom et al. 1961; Ostrom 2010; McGinnis 2011). The polycentric system ensures that each institutional unit at the local level has the autonomy and authority to use the local socio-ecological knowledge generated, including success and error learning processes, at the same time that it allows learning from the knowledge acquired also in other local communities (Folke et al. 1998).

Starting from the hypothesis that a greater participation of the stakeholders will allow better governance in the SES, the objective of this work is to analyze the dynamics of governance and community participation in the management of natural resources of the socio-ecological system of the Mar Menor (SESMM). The SESMM (SE, Spain) is a SES in which resources, users/stakeholders, governmental agencies at different scales, and policies/institutions interact with ecosystems associated with natural resources. In this paper, three issues were considered: 1) review/understand the current governance configuration in the SESMM; 2) analyze the solutions publicly proposed by the groups of stakeholders involved in the management of the SESMM, and; 3) define the challenges faced by environmental governance in the SESMM.

8.2. Methodology

Next, a brief description of the study area and the methodological approach and sources used for the scope of the three questions posed is detailed.

8.2.1. Study area

The Mar Menor lagoon, its surrounding wetlands and the watershed make up a coastal SES located in the Region of Murcia (SE, Spain) (Fig. 8.1). The SESMM population includes 357,266 inhabitants (2007) and is distributed among the municipalities of San Pedro del Pinatar, San Javier, Los Alcázares, Torre Pacheco, Cartagena, Fuente Álamo and La Unión. The town councils of these municipalities, the Ministry of Water, Agriculture, Livestock and Fisheries (belonging to the regional government) and the Segura Hydrographic Confederation (belonging to the state government) are the main government institutions.

The Mar Menor lagoon and its surrounding wetlands, with a total area of 15,000 ha (Vidal et al. 2003), stand out for their high ecological value, and therefore have several protected regions

(Protected Natural Areas, Site of Community Importance, Special Protection Area for Birds, Specially Protected Area of Mediterranean Importance and Wetland of International Importance of the Ramsar Convention). The fartet (*Aphanius iberus*), the nacra (*Pinna nobilis*), the seahorse (*Hippocampus guttulatus*), the seagrass meadows (*Cymodocea nodosa* and *Rupia cirrhosa*) and the aquatic birds such as *Mergus serrator* or *Tadorna tadorna* are some of the species protected nationally and internationally (Robledano 2003; Robledano et al. 2010; IEO 2016; Ruiz et al. 2020). The lagoon and its surroundings are also within the scope of some European Directives, such as Nitrates, Habitat (Natura 2000 Network), Water (Water Framework Directive) and Marine Strategies. The watershed has an area of 1,270 km^2 and is drained by more than twenty "ramblas" (temporary rivers) that flow into the lagoon. A sub-desert Mediterranean climate, with temperate and dry conditions (average temperature 17ºC) and low rainfall (not exceeding 300 mm per year) characterize the study area (Martínez et al. 2003).

The main uses and economic activities that currently (2020) take place in the SESMM are: 1) intensive irrigated agriculture, especially horticultural crops (lettuce, broccoli, melon and others), citrus (oranges and lemons) and greenhouse crops (pepper), developed in 80% of the watershed sub-basin (Comité de Asesoramiento Científico del Mar Menor 2017), and 2) urban-tourist development around the coastal lagoon. These activities, along with the population growth of the coastal areas, have operated as the main driving forces generating pressures and impacts on the SESMM for decades, which has led to environmental deterioration and the loss of natural and cultural values, as well as of traditional uses. Figures 8.2 and 8.3 describe the main events that have taken place and the main associated problem that was subsequently observed. This has generated a high social concern due to its collateral effects on economic activities and the employment they generate. In addition, it is especially relevant that the people of the Mar Menor watershed are closely connected with the lagoon, which they use as a regular meeting and enjoyment location.

Figure 8.1. Location of the study area. Aerial image of the Mar Menor coastal lagoon. Source: Own elaboration from the image obtained from the Cartagena City Council website.

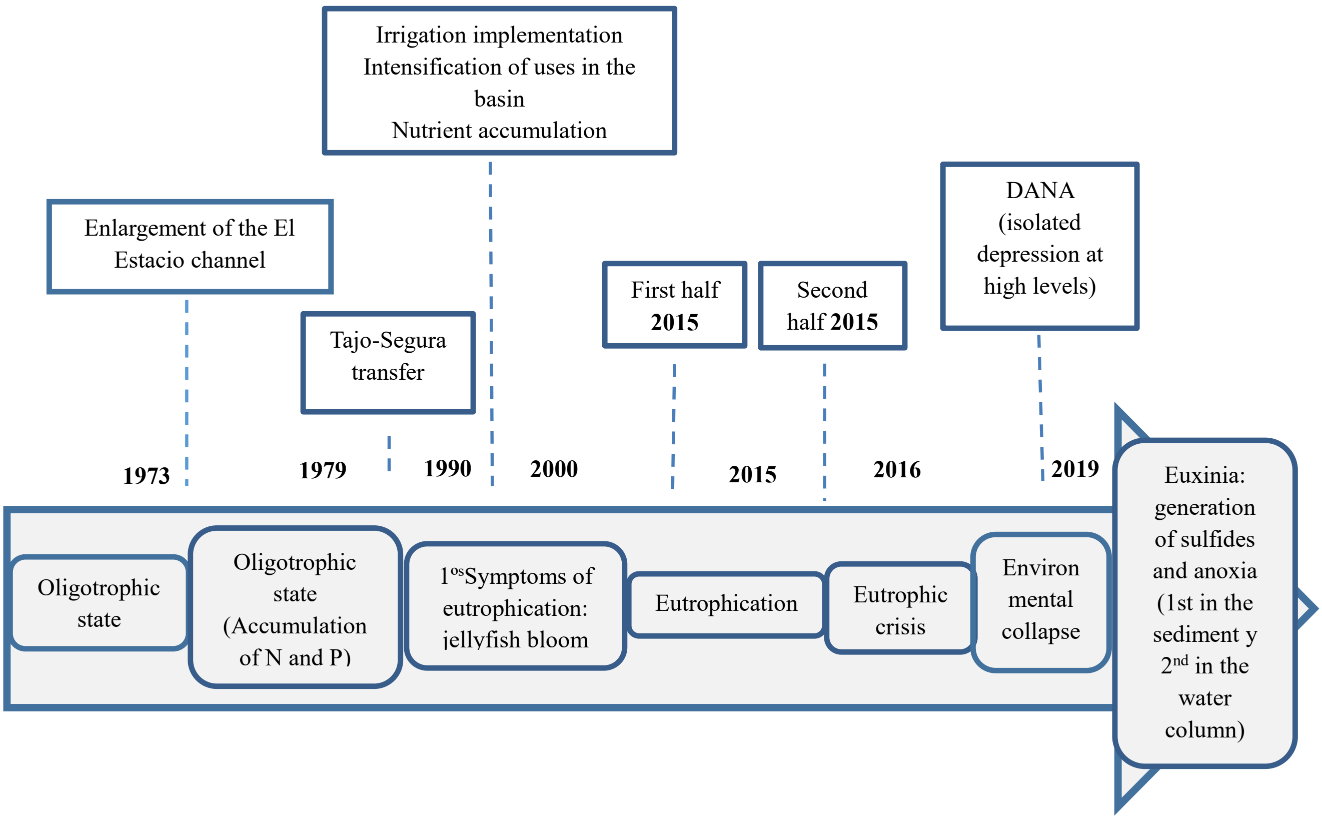

Figure 8.2. Sequence of the main changes and events that have taken place in the SESMM from the 1970s to 2019.

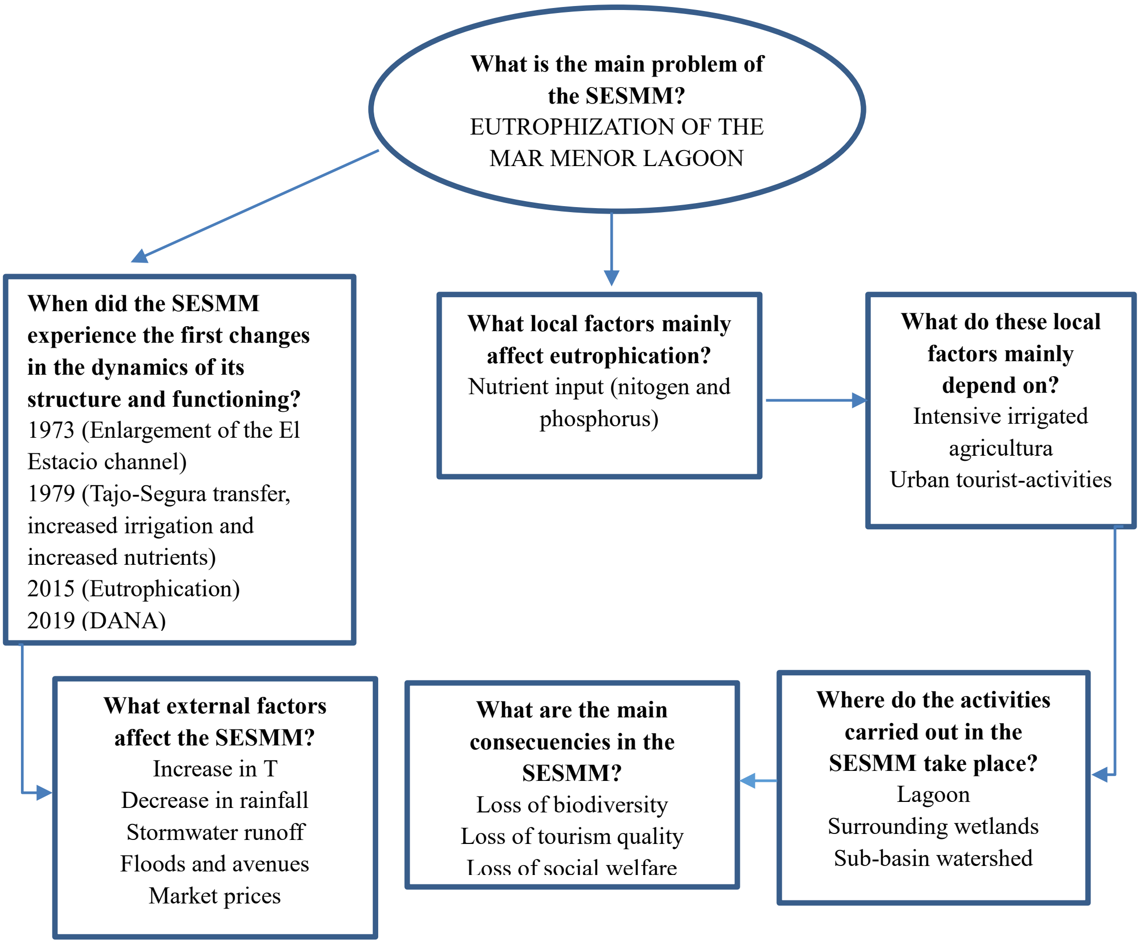

Figure 8.3. Summary diagram of the main issues that define the SESMM, starting with the main problem observed.

8.2.2. Methodology

Regarding the first issue that we address: 1) understanding the current governance configuration in the SESMM. The elements and structure of the governance system were analyzed in relation to its regulatory framework, institutional framework, planning and management tools and the participation of stakeholders or the degree of existing co-management. For this, an extensive bibliographic and documentary search of technical reports, plans and strategies was carried out (for example, Comité de Asesoramiento Científico del Mar Menor 2017; Integrated Territorial Investment of the Mar Menor; Integrated Management Strategy of Coastal Zones of the Socio-Ecological System of the Mar Menor and its surroundings; Comprehensive Management Plans for Protected Spaces of the Mar Menor and the Mediterranean coastline of Región de Murcia, among others) and in institutional sources such as, for example, the Autonomous Community of Region of Murcia (CARM), Boletín Oficial del Estado (BOE) and Boletín Oficial de la Región de Murcia (BORM). Twenty structured interviews of five questions were also conducted with scientific-technical experts from different disciplines in the environmental, social, economic and institutional dimensions during the months of January to April 2017 (Appendix II). The interviews were conducted in person and by email and provided information on the main processes that affect the environmental degradation situation of the SESMM, their solutions, the key stakeholders involved in the management of the SESMM and the main challenges that the experts perceived in relation to the governance of the SESMM.

For the second issue that we address: 2) analyze the solutions publicly proposed by the groups of stakeholders involved in the management of the SESMM. The groups of stakeholders identified according to the previously mentioned interview with the experts were used, and we reviewed scientific articles (for example, Martínez et al. 2009; Carreño 2015; Esteve et al. 2016) and technical reports (such as Vidal et al. 2003; León and Bellido 2016; Mar Menor Scientific Advisory Committee 2017, among others) that were related to the study area, in order to verify and complete the identification of stakeholders. Subsequently, the proposed solutions that the groups of stakeholders have made public for the management of the SESMM were analyzed. A primary conceptual tool that we used for this was DPSIR: Driving Force-Pressure (primary and final) -State-Impact-Response. The primary pressure (1ª) is defined as the one that derives directly from the driving force and the final pressure is the one that most directly affects the change of state. Thus, our analysis of solutions was made based on several criteria: a) according to where the measure was directed within the DPSIR scheme of the SESMM; b) according to the specific sustainability objectives of the SESMM to which they are directed and c) according to the specificity and approach of the measure (sectorial, integral or circumscribed to a specific vector). It is important to note that the sustainability objectives for the SESMM (Table 8.1) were defined from the inter and trans-disciplinary diagnosis carried out for the SESMM, as a result of various sources of information: the previously mentioned interview with the experts; bibliographic review of scientific and technical publications in the study area; and a diagnostic survey carried out among the local community to find out their perception of the main land use changes, their effects on the sustainability of the SESMM and their preferences on a proposed measure management in 2017 (Guaita et al. 2020).

Finally, for the third issue, and in order to identify the main complexities and challenges of environmental governance in the SESMM, we analyzed the strengths and weaknesses of the current governance system based on the integrated assessment of the two previous questions. To complete this evaluation and have a better understanding of the interests and preferences of each group of stakeholders, fourteen structured interviews were conducted (Appendix III) between the months of January and February 2019. These interviews provided information on their perception of the situation current status of the SESMM and its preferences regarding a set of solutions to improve the environmental degradation situation of the SESMM. In this set of measures, the opinion of the stakeholders was compared with the opinion of the local population surveyed in Guaita et al. (2020). To carry out the interview, the representatives of each group of stakeholders associated with the SESMM were designated by their corresponding entities and contacted by email, telephone and in person.

Table 8.1. Specific sustainability objectives defined for the SESMM from an inter and trans-disciplinary research.

Objective nº1) Recover and preserve the good state of the water of the lagoon and aquifers
Objective nº2) Recover and conserve the species and habitats of the lagoon and its wetlands and the natural connectivity of the basin
Objective nº3) Recover the environmental functionality of the unbuilt surface of coastline
Objective nº4) Implement an environmentally and socially sustainable agricultural model
Objective nº5) Implement a sustainable and quality tourism model
Objective nº6) Sustainable local development
Objective nº7) Implement a model of polycentric, adaptive and participatory governance

8.3. Results and discussion

8.3.1. Configuration of current governance in SESMM

The SESMM has a broad international, European, state and regional regulatory framework that supports the regulatory model of human activities in the SESMM from the 1980's to the present. Although the most relevant regulations formulated in Appendix VI, it is worth highlighting the approval in 1987 of Law 3/1987 on Harmonization and Protection of Uses of the Mar Menor, the declaration in 2001 of the Mar Menor sub-basin as a Vulnerable Zone in application of the Nitrates Directive (91/676 / CEE), the declaration of the lagoon as a Sensitive Area in application of the Urban Wastewater Directive (91/271 ECC), Law 1/2018, on urgent measures to guarantee environmental sustainability in the surroundings of the Mar Menor and Law 3/2020, recovery and protection of the Mar Menor, among many others.

Despite a broad regulatory framework and different planning instruments, the situation of environmental degradation described in the latest studies in relation to the SESMM (Martínez et al. 2017; Comité de asesoramiento científico del Mar Menor 2017; Martínez and Esteve et al.

2019; Guaita et al. 2020; Ruiz et al. 2020) reveals that a good part of this regulatory framework has been non-complianced and that planning instruments are not being effective. Furthermore, there is no management institution aimed at managing the SESMM to move towards a new management model adapted to its uniqueness. In this sense, the institutions with competencies in the management of the SESMM are distributed in three levels: state, regional and local (Fig. 8.4).

Within the competences of the state administration, it is worth highlighting the role that the Segura Hydrographic Confederation plays within the General Water Directorate, with competences in hydrological planning, resource management and exploitation, protection of the public hydraulic domain, rights concessions of private use of water, control of water quality, project and execution of new hydraulic infrastructures, safety programs for dams and data banks. On the other hand, the General Directorate of the Coast and the Sea has powers in the protection of the coastal and marine environment, as well as in guaranteeing its public and free use.

Most of the competences in the management of the SESMM are held by the regional administration, which are divided between two departments: 1) The Department of Agriculture, Water, Livestock, Fisheries and Environment, on which depends four directorates with responsibilities in: hydraulic works, sanitation and purification, water resources, modernization and improvement of irrigation and hydraulic infrastructures, rural roads and those of control, prevention and monitoring of areas vulnerable to contamination by nitrates of agricultural origin. It also has powers and functions of study, planning, execution and development of projects and actions in the Mar Menor related to the protection and environmental regeneration of its ecosystem. It also assumes the competences and functions regarding planning and management of protected natural areas of the Natura 2000 Network, natural habitats and wild fauna and flora, as well as the promotion of the natural environment and the fight against climate change and 2) the Department of Development and Infrastructures, with powers in matters of transport, logistics, coasts, ports, nautical activities, as well as the promotion and coordination of airport infrastructures.

In terms of local administration, the municipalities that are part of the SESMM have the competences related to urban planning, urban environment, drinking water supply and wastewater treatment, road infrastructure, evaluation and information on situations of social need and care for people at risk of social exclusion, police, transport and mobility, protection of public health.

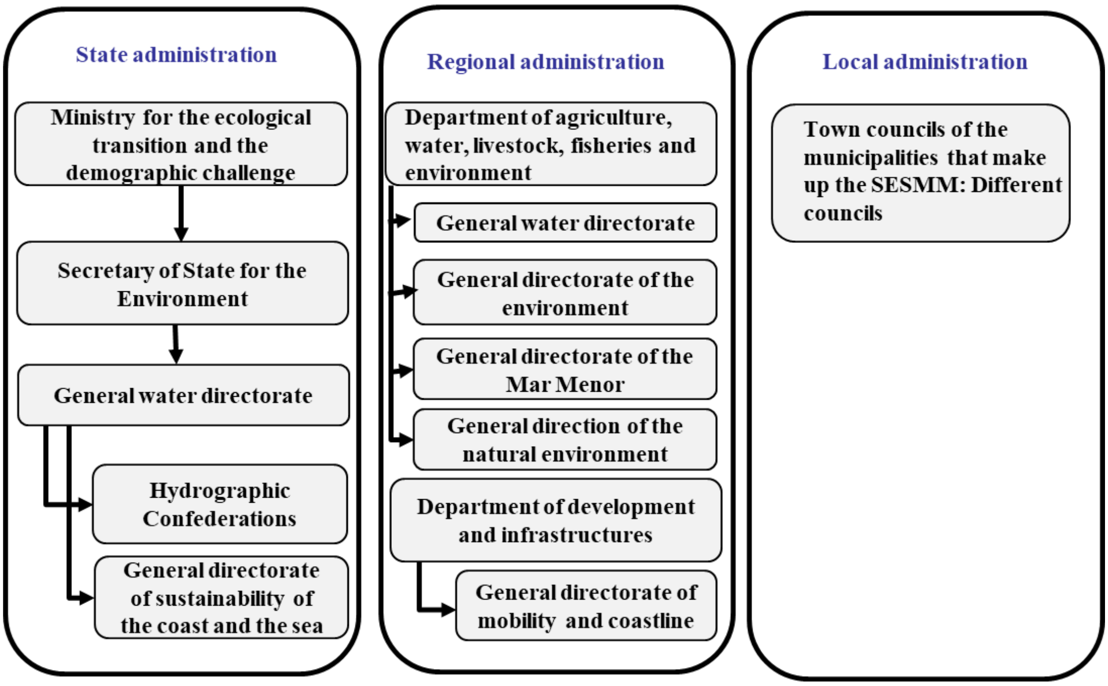

Figure 8.4. Scheme of the institutional framework for the management of the SESMM.

The distribution of competences between the different administrations at different organizational levels shows the complexity of the objectives and functions of each one of them. In recent years, different media[1] and stakeholders, such as the NGO "Ecologistas en Acción" or the Citizens' Platform "Pacto por el Mar Menor", among others, revealed the lack of coordination, cooperation and collaboration between these administrations, in addition to the lack of responsibility for not enforcing the current regulatory framework in each of its powers. This is the only way to explain many of the actions that have been carried out in the SESMM and have resulted in its degradation. For example, the state administration has not controlled the use of water in the Mar Menor sub-basin, which explains why the irrigated area has grown disproportionately to 20,000 ha more than legally allowed (Comité de Asesoramiento Científico 2017), as well as allowing new desalination plants[2] and open wells without the corresponding concession. There is also no control over the discharge of brines from private desalination plants with high concentrations of nitrates. On the part of the regional administration, land uses have not been controlled, measures against erosion have not been implemented, nor have limits been established on the distance from the Mar Menor at which it can be cultivated. All this has led to disastrous floods, among which those that occurred in 2015 in Mar de Cristal and Los Nietos should be highlighted, which has led to a complaint before the Magistrate Courts of Cartagena by the Public Prosecutor's Office for the Environment

[1] https://www.laopiniondemurcia.es/comunidad/2019/10/18/comunidad-reconoce-dejadez-administraciones/1060864.html; https://www.laverdad.es/lospiesenlatierra/noticias/punaladas-menor-20191020223149-nt.html
[2] https://www.ondacero.es/emisoras/murcia/murcia/noticias/siguen-localizando-desalobradoras-ilegales-campo-cartagena-que-ano_202011105faa697b2416a60001a56dd9.html

and Urban Planning. Nor have any controls been established on the use of nitrates and other agricultural fertilizers in the Mar Menor sub-basin until a few years ago, despite the fact that a good part of it was declared a Vulnerable Zone to Nitrate Pollution, with a delay of more than ten years with respect to the deadlines established in Directive 91/676/EEC. At the same time, the Management Plans for the natural spaces with which the lagoon is endowed have not been developed for years, until in 2019 the corresponding Comprehensive Management Plan (PGI) was approved. Regarding the proliferation of jellyfish, the only solution provided by the regional government was to proceed to attempt their elimination, despite the ineffectiveness of this measure and the warnings made by the scientific community that this proliferation was due to the large amount of nutrients that the waters of the lagoon contained (Comité de Asesoramiento Científico 2017; Martínez and Esteve 2020). On the other hand, the Town Halls around the lagoon (Cartagena, Los Alcázares, San Javier and San Pedro del Pinatar) have carried out harmful practices for the lagoon, such as the creation of artificial beaches (for example, in Los Alcázares), with the associated dredging, despite being repeatedly denounced by the scientific community and environmental associations.

These are just some examples that show the carelessness and lack of responsibility of these administrations at multiple organizational levels. According to sources from environmental associations (personal communication), they attribute this behavior to a lack of environmental awareness and culture, and to protecting economic sectors such as agriculture and construction. This involves setting priorities on political (electoral) interests and short-term economic growth. Faced with this situation, the Environmental and Urban Planning Office of the Superior Court of Justice has an open investigation that, in all probability, will soon be sent to the competent Courts in the form of a complaint to clarify responsibilities[3].

Regarding the participation of stakeholders or the degree of co-management, in 2016 and 2017 the regional government created two working groups for the participation of different groups of stakeholders. First of all, in 2016 the regional government created the Mar Menor Scientific Advisory Committee. This advisory group was set up with the objective of scientifically advising the regional government in all the actions carried out in order to improve the ecological status of the Mar Menor and the promotion of applied research in relation to the environmental problems of the lagoon. According to the Order of July 29, 2016, of the Ministry of Water, Agriculture and the Environment, the Mar Menor Scientific Advisory Committee was made up of a president and a member of each of the research groups with experience in lines of research on the environmental problems of the Mar Menor, belonging to the universities of the Region of Murcia, the CSIC

[3] https://www.efeverde.com/noticias/juez-individualizar-dano-49-empresas-agricolas-vertidos-mar-menor/

(Spanish National Research Council), the IMIDA and the Spanish Institute of Oceanography, elected by each group, as well as by an official from each of the management centers of the Department of Water, Agriculture and Environment.

The reality regarding the functioning of this (2016) Mar Menor Scientific Advisory Committee is that during the years 2018 and 2019 eight members left[4] this working group, claiming the lack of transparency and access to the information generated, as well as the lack of autonomy to independently advise the administration and report directly and transparently to society. The current composition includes workers and technicians of the public administration, but also political positions attend their meetings, so it is not an eminently scientific group, which causes its functions to be distorted. According to the order of January 5, 2018 of the Ministry of Tourism, Culture and Environment, which modifies the initial composition of the same, it does not specify the scientists' current membership.

On the other hand, the Mar Menor Social Participation Committee was created by the regional government in 2017 with the aim of integrating groups that have economic, social and neighborhood interests around the Mar Menor. In accordance with the objectives established for this consultative group, it was created to promote dialogue, social participation and the search for consensus solutions to carry out all the management, conservation and recovery measures of the natural, landscape and cultural values of the Mar Menor (BORM, nº 52, 4-3-2017). What was intended is the establishment of sustainable development models in the different economic and social sectors that guarantee the conservation of a heritage, ensuring the future of future generations. According to the Order of February 28, 2017 of the Ministry of Water, Agriculture and Environment, the functions of the Mar Menor Social Participation Committee are to become aware of the ecological status of the Mar Menor and its evolution, as well as the assessment of the different actions necessary for its progressive improvement, contributing, integrating and expressing social, economic and neighborhood interests, to facilitate that a global perspective is taken into account in the formulation of solutions (BORM Nº. 52, 4-3-2017).

The reality in relation to the composition and operation of this working group is that the public administration represents 45% of its members (BORM Nº. 52, 4-3-2017), which is incompatible with its character as a participatory social group. In 2018 six organizations (Platform "Pacto por el Mar Menor"; the Federation of Associations of Neighbors of Cartagena and Comarca (FAVCAC); the NGO Ecologists in Action; the Fishermen's Association of San Pedro del Pinatar; the NGO Association of Southeast Naturalists (ANSE), and the Mar de Cristal Neighbors

[4] https://www.laverdad.es/lospiesenlatierra/noticias/cuatro-expertos-abandonan-20191020213140-nt.html

association) left[5] the social participation committee, explaining that the objectives for which this advisory group was created are not being met, and there is a lack of real participation and access to relevant information.

The intervention of academic and scientific institutions is necessary to incorporate scientific and technical knowledge, as a basis to inform decision-making (Voinov et al. 2016; Norstrom et al. 2020). On the other hand, the participation of social and economic actors, as well as social and environmental organizations and the local community is essential for advanced governance, such as that required by SESs (Hauck et al. 2019), especially in cases as complex as the SESMM. Despite the fact that in Spain the participatory culture in public issues is scarce (Barragán and de Andrés 2020), it is necessary for public institutions to organize permanent processes and spaces for public participation. Such works should be transparent with respect to the objectives pursued, with management instruments that are receptive to the citizen proposals received, and informative about the progress of these processes.

Regarding the tools for territorial planning and natural resource management, Table 8.2 lists the most outstanding instruments for territorial planning and management actions related to the governance of the SESMM that have been proposed in the last two decades. The analysis of these instruments indicates that from 1998 to the present, many initiatives such as plans, programs and strategies have been initiated, but their frequency greatly increased since 2016, coinciding with the first eutrophication crisis of the Mar Menor lagoon (Martínez et al. 2017). Specifically, in 2016, 30% of these initiatives were started. However, although many of the instruments have been initiated with the objective of improving the environmental degradation situation of the SESMM and specifically of the lagoon, only half have been approved and executed (as of this publication date). And of those that have been approved, only 43% had a process of active public participation. Also, only 36% of the instruments that have been initiated and/or approved present an integrated management approach.

Table 8.2. Main planning initiatives and management actions of special relevance related to the governance of the SESMM during the last two decades.

Instrument	Year of initiation	Year of approval	Active public participation*
Plan for the Management of Natural Resources of the Protected Landscape, Open Spaces and Islands of the Mar Menor. Council of Water, Agriculture and Environment	1998	Restarted repeatedly. Not approved and finally discarded	No

[5] https://www.laverdad.es/murcia/seis-organizaciones-abandonan-20180326112422-nt.html

		(subsumed in the PGI del Mar Menor)	
Integrated management program for the Mar Menor coastline and its area of influence (Camp Mar Menor). Council of Water, Agriculture and Environment	2003	Not approved	Sí
Action Program corresponding to the Vulnerable Zone to contamination by nitrates of agricultural origin, the one corresponding to the Quaternary and Pliocene aquifers in the area defined by the Eastern Irrigable Zone of the Tajo-Segura Transfer and the Mar Menor Coastal Sector. Council of Water, Agriculture and Environment	2003	2003	No
First approach for the conclusion of an action program in the Mar Menor area. Mar Menor Commission. General Directorate of Coasts and the Segura Hydrographic Confederation. Ministry of the Environment	2007	Not approved	Sí
Action Program on the Vulnerable Zone corresponding to the Quaternary Aquifers and Pliocene in the area defined by Zona Regable Oriental del Tajo-Segura Diversion and the Mar Menor Littoral Sector. Council of Water, Agriculture and Environment	2009	2009	No
Integrated Territorial Investment (ITI) of the Mar Menor. Council of Water, Agriculture and Environment	2013	2016	Sí
Sustainable and Integrated Urban Development Strategy (EDUSI) "La Manga Abierto 365". Ministry of Development and Infrastructures	2014	2019	Sí
Regeneration / Environmental Restoration of the Mar Menor through the temporary installation of nets against jellyfish. Counseling in environment	Actuación anual	Approved (annually)	No
Integral Management Plan for the Protected Areas of the Mar Menor and the Mediterranean coastline of Region of Murcia. Council of Water, Agriculture, Livestock, Fisheries and the Environment	2015	2019	No
Green filter in the surroundings of the mouth of the Rambla del Albujón to the Mar Menor. Council of Water, Agriculture, Livestock, Fisheries and the Environment	2016	Not approved	No

Preparation of the Strategic Plan for La Manga del Mar Menor. Phase I- North Zone. Ministry of Development and Infrastructures	2016	Not approved	Sí
Integrated Management Strategy of Coastal Zones of the Socio-Ecological System of the Mar Menor and its surroundings. Ministry of Development and Infrastructures	2016	2019	Sí
Analysis of solutions for the objective of zero discharge to the Mar Menor from Campo de Cartagena. Council of Water, Agriculture, Livestock, Fisheries and Environment and General Directorate of Water of the Ministry for Ecological Transition	2016	Not approved (although the Environmental Impact Statement was approved in 2019)	No
Plan for the protection of the Litoral Edge of the Mar Menor. Directorate General of the Coast and the Sea. Ministry for the Ecological Transition and the Demographic Challenge	2020	Not approved	No
Integrated green program of actions for the recovery of the Mar Menor. Ministry for the Ecological Transition and the Demographic Challenge	2020	Not approved	No
*The public exposure to wich some instruments have been subjected is not considered.			

8.3.2. Analysis of the proposed solutions for the management of the SESMM by the groups of stakeholders involved.

In the SESMM the following groups of stakeholders were identified: (1) public administration, (2) agricultural sector, (3) tourist sector, (4) fishing sector, (5) construction and real estate development sector, (6) academic sector and (7) citizen platforms, neighborhood associations and NGOs. All of them, with the exception of the tourism sector and the construction and real estate development sector, have publicly expressed proposals for different solutions to improve the environmental degradation situation of the SESMM. The analysis of these measures proposed by each stakeholder group reveals some elements of their interests, presented below.

8.3.2.1. Proposed solutions by public administrations

In 2019, the regional and state administration, through the Segura Hydrographic Confederation (SHC), proposed 21 measures to address the environmental degradation of the SESMM and specifically of the lagoon, which are included in the project "Analysis of solutions for the objective of zero discharge to the Mar Menor from Campo de Cartagena" (MITECO 2019) (Table 8.3). The analysis of these measures reveals that around 30% (28,6%) of the measures act on impact variables and although more than half are directed at variables defined as (DPSIR) pressures (52,4%) and driving forces (14,3 %), they are not prevention measures at the origin since they are aimed at final pressures (Fig. 8.5). The measures to change the production model are scarce and weak, limiting themselves to control and monitoring. On the contrary, the main measures that act on these pressures are focused on the capture of water, promotion of the Mojón and Arco Sur infrastructures, desalination, generation of water for irrigation, denitrification and discharge to the Mediterranean. The scientific community and non-governmental organizations consider these measures to be the "end of the pipeline", so they have little guarantee of solving the problems of nutrient entry into the Mar Menor lagoon. For example, non-governmental organizations such as Ecologistas en Acción evaluated some of the main measures, including the capture of water from the Quaternary aquifer and the Albujón Rambla, pumping to the El Mojón desalination plant, at the northern end of the riverbank of the Mar Menor, desalobration of such flows for reuse in irrigation, denitrification of brines and their discharge into the Mediterranean. They conclude that these are ineffective measures, because high operating and maintenance costs make it likely that the sector that would have to pay for such management (the irrigators who are beneficiaries of the desalinated water) would not willing to assume the cost. Moreover, any accident or breakdown would make such infrastructures non-functional, and thus the nutrients contained in the captured flows would initiate processes of eutrophication (if they reach the Mediterranean Sea), or aggravate the existing problems (if they reach the Mar Menor) (Ecologistas en Acción 2019). In addition, these and other measures have been highly questioned by other stakeholders, especially the academic sector (Martínez et al. 2017; Ruiz et al. 2019, 2020; Martínez and Esteve 2020): under normal operating conditions it would mean the discharge of 2.125 tons of nitrates per year to the Mediterranean, affecting the marine Site of Community Importance and degrading its habitats, including the *Posidonia oceanica* meadow, included in the Habitat Directive (Ecologists in Action 2019).

It is also important to note that 80% of these 21 measures are directed at specific vectors and only 10% of the measures have an integral approach (Fig. 8.6).

On the other hand, almost half of the measures (42,8%) are not aimed at any of the sustainability objectives defined for the SESMM. With respect to the other half, 38% of the measures are related to the objective nº 4 of "Implement an environmentally and socially sustainable agricultural model" and 14,3% of the measures are aimed at the objective nº1 "Recover and preserve the good state of the water of the lagoon and aquifers".

It can be concluded that part of these solutions seem more directed towards the availability of water for irrigation than towards avoiding the entry of nutrients into the lagoon. In the opinion of some stakeholders such as the NGO Ecologistas en Acción, the Citizen Platform "Pacto por el Mar Menor", the academic sector (Ecologistas en Acción 2019; Comité de Asesoramiento Científico 2017; Martínez and Esteve 2020; Ruiz et al. 2020), are measures with a high economic cost, which cannot solve most of the problem of diffuse agricultural pollution and which could create new problems, while presenting uncertainties regarding their environmental viability and of maintenance.

Table 8.3. Analyzed measures, publicly proposed by the regional and state administration sector (Segura Hydrographic Confederation) to improve the situation of environmental degradation in the SESMM. DPSIR: Driving Force-Pressure (primary and final)-State-Impact-Response. The primary pressure (1^a) is defined as the one that derives directly from the driving force and the final pressure is the one that most directly affects the change of state.

Meaures proposed by the regional and state (Segura Hydrographic Confederation) administration sector. 2019.	**DPSIR**	**Approach**	**Objective nº**
Improved fertilization	$P1^a$	Specific vector	4
Adaptation of the production model	D	Integral	4
Review and adaptation of waste storage facilities	P (final)	Specific vector	Unidentified
Establishment of the regime for the exploitation of the underground water	P (final)	Specific vector	Unidentified
Direct extraction for aquifer drainage and discharge	P (final)	Specific vector	Unidentified
Extraction of groundwater for exploitation by wells, treatment and utilization	P (final)	Specific vector	Unidentified
Measures to minimize irrigation returns	P (final)	Specific vector	4
Control of erosive processes and sediment transport at the plot level	$P1^a$	Specific vector	4
Control of erosive processes and sediment transport at the basin level	$P1^a$	Specific vector	4
Hydrological-forestry restoration of mining basins	I	Specific vector	Unidentified
Improvement of sanitation systems	P (final)	Specific vector	1
Adaptation and improvement of purification systems and facilities	P (final)	Specific vector	1
Agricultural waste management	I	Specific vector	4
Management of livestock manure (georeferenced information systems)	I	Specific vector	Unidentified

Management and dimensioning of livestock activity at the regional scale	D	Sectorial	Unidentified
Conditioning and improvement of controlled landfills and elimination of uncontrolled ones	I	Specific vector	Unidentified
Adaptation and expansion of agricultural drainage systems	I	Specific vector	Unidentified
Closure or adaptation of wells involved in cross contamination between aquifers	P (final)	Specific vector	4
Improvement in the environmental integration of uses	D	Integral	4 y 5
Improvement of the physicochemical conditions of the lagoon	S	Specific vector	1
Environmental recovery of coastal areas	I	Sectorial	3

In 2020 the state administration, specifically the Ministry for Ecological Transition and Demographic Challenge (MITECO) started the "Integrated Green Program" for the recovery of the lagoon, which has not yet been approved[6]. This program emphasizes the importance of promoting prevention measures at the origin and on nature-based solutions, at the same time it proposes the implementation of a common governance, management and monitoring model for all the stakeholders involved in the SES (Table 8.4). This proposal is far from the 21 measures proposed a year before by the Segura Hydrographic Confederation, (which is also part of the state administration), along with the regional administration, for which apparently discrepancies are observed between institutions of the same organizational level (state) as well as between the different levels of government (state and regional).

Half of the measures included in the "Integrated Green Program" focus on pressure and driving force variables (Fig. 8.5) and have an integral approach (Fig. 8.6). They address various specific sustainability objectives in the SESMM such as: "Implement an environmentally and socially sustainable agricultural model"; "Implement an adaptive and participatory governance model"; "Recover the environmental functionality of the unbuilt stretches of coastline" and "Recover and preserve the good state of the lagoon water and aquifers".

Table 8.4. Analyzed measures, publicly proposed by the state administration sector (MITECO) to improve the situation of environmental degradation in the SESMM. DPSIR: Driving Force-Pressure (primary and final)-State-Impact-Response. The primary pressure (1[a]) is defined as the one that derives directly from the driving force and the final pressure is the one that most directly affects the change of state.

[6] https://www.iagua.es/noticias/ministerio-transicion-ecologica-y-reto-demografico/publicada-actualizacion-informe

Measures proposed by the state (MITECO) administration sector. 2020.	DPSIR	Approach	Objective nº
Inspection activities to demand environmental responsibility from people and legal institutions who have influenced the pollution and degradation of the Mar Menor	R	Integral	7
Actions to reduce and avoid discharges to the lagoon	P1[a]	Specific vector	4 y 1
Protection of the coastline	D/P1[a]	Sectorial	3 y 4
Studies for the recovery of the natural space	I	Integral	2 y 3

8.3.2.2. Proposed solutions by the agricultural sector

In 2017 the agricultural sector (UPA, ASAJA; COAG, PROEXPORT, FECOAM, CRCC, SCRATS, CR Arco Sur), the fishing sector (Cofradía de Pescadores de San Pedro del Pinatar) and the Federation of Associations of Neighbors, Users and Consumers from Cartagena and the Comarca proposed a total of ten urgent measures to reduce the environmental degradation of the Mar Menor (MITECO 2017) (Table 8.5). Although all measures are directed to act on different pressures of the SESMM, as with the most measures proposed by the regional government, they do not contemplate the principle of prevention and action on the origin of the problem (Fig. 8.5), since they mainly focus on in increasing water resources. This group of measures are directed to specific vectors, with a lack of integral approach (Fig. 8.6). None of the measures is directed to the sustainability objectives defined for the SESMM.

The measures focused on actions at the "end of the pipeline" with large infrastructures for the collection of polluting water flows once distributed throughout the sub-basin. Different experts and studies (Ecologistas en Acción 2017; Ruiz et al. 2019, Martínez and Esteve 2020) point out that these measures can be effective for localized discharges (such as urban discharges) but not for diffuse pollution, such as agrarian, which requires action throughout the sub-basin, originally and preferably on a plot scale. In relation to the desalination of groundwater, the experts point out that the prevention of contamination at the origin of the problem requires prioritizing the denitrification of the captured water prior to its desalination, as opposed to the option of denitrifying the brines. The experts also point out that some of the actions may generate negative environmental impacts and in some there are serious doubts regarding their legal viability.

It is important to note that in 2020 the “Ingenio Foundation” was created, made up of 10,000 farmers, cooperatives, fruit and vegetable companies, irrigation communities and agrarian societies for the transformation of Campo de Cartagena, from where a proposal for the recovery and protection of the Mar Menor has been made, called "Environmental Protection Ring".

However, according to the citizen platform "Pact for the Mar Menor"[7] this project includes a set of unilateral proposals from a single economic sector.

Table 8.5. Analyzed measures, publicly proposed by the agricultural sector to improve the situation of environmental degradation in the SESMM. DPSIR: Driving Force-Pressure (primary and final)-State-Impact-Response. The primary pressure (1ª) is defined as the one that derives directly from the driving force and the final pressure is the one that most directly affects the change of state.

Measures proposed by the agricultural sector. 2017.	**DPSIR**	**Approach**	**Objective nº**
Commissioning of private wells and desalination plants, as well as drought wells under the current Drought Decree	P (final)	Specific vector	Unidentified
Repair and adaptation of existing brine pipelines and construction of those that are necessary	P (final)	Specific vector	Unidentified
Authorization for the start-up of all private drilling without brine generation during the period of drought	P (final)	Specific vector	Unidentified
To undertake new impulsion pipes to replace the current ones and their greater capacity, to conduct the waters of the quaternary aquifer collected by the State drainage network and its future extension to El Mojón.	P (final)	Specific vector	Unidentified
Carry out an installation for the denitrification of these drainage waters	P (final)	Specific vector	Unidentified
Undertake an expansion of the current El Mojón desalination plant, including its drainage and catchment network, which makes it possible to reuse these aquifer drainage waters for irrigation, avoiding their discharge to the Mar Menor	P (final)	Specific vector	Unidentified
Build an outfall to the sea for the evacuation of rejection waters once denitrified to the Mediterranean Sea	P (final)	Specific vector	Unidentified
Construction of well batteries and expansion of the drainage network	P (final)	Specific vector	Unidentified
Authorization for the start-up of the pipeline from Rambla del Albujón to the desalination plant of the Arco Sur irrigation community	P (final)	Specific vector	Unidentified
Authorization to be able to treat the flows from the drainage network that could reach the Mar Menor Sur Treatment Plant, for its denitrification and subsequent discharge of the rejection into the Mediterranean Sea	P (final)	Specific vector	Unidentified

8.3.2.3. Proposed solutions by citizen platforms, neighborhood associations and NGOs, and the fishing sector

[7] https://pactoporelmarmenor.blogspot.com/search?q=fundaci%C3%B3n+ingenio

In 2015 the citizen platform "Pacto por el Mar Menor" and in 2016 the NGO Ecologistas en Acción, made their own manifestos with a set of measures to address the environmental degradation of the SESMM. Later in 2019, these groups of stakeholders, along with other NGOs (ANSE, WWF, SEO/BirdLife), the Federation of Associations of Neighbors, Users and Consumers of Cartagena and the Comarca and the Fishermen's Association of San Pedro del Pinatar, signed a document jointly combining all their solution proposals and prioritizing eleven measures for the ecological restoration of the Mar Menor[8] (Table 8.6). Around half of these measures (54,5%) are directed to the pressures of the SESMM, 27,3% to the responses, 9,1% to the impact and the other 9,1% to the driving forces (Fig. 8.5). On the other hand, 64% of these measures have an integral approach, 27% are on specific vectors and 9% have a sectoral approach (Fig. 8.6). The objectives to which these measures are directed are to "Implement an environmentally and socially sustainable agricultural model" (54,5%); "Implement an adaptive and participatory governance model" (27,3%); "Recover and preserve the good state of the water in the lagoon and aquifers" (9,1%); and to "Recover the environmental functionality of the unbuilt surface of coastline" (9,1%).

These measures are fundamentally focused on prevention and reduction in the origin of the problem at the scale of the plot, which according with what other studies indicate (Comité de Asesoramiento Científico 2017; Ruiz et al. 2020; Martínez and Esteve 2020) is the most effective and least expensive way to reduce the entry of polluting flows into the lagoon.

It is important to note that citizen mobilizations also took place through demonstrations initiated by different social stakeholder groups to demand solutions to serve the Mar Menor. It is worth highlighting those called for by agricultural and non-agricultural organizations in March 2017[9], those called for by environmental organizations in May 2017[10] and those called for in October 2019 by a large number of entities[11].

Table 8.6. Analyzed measures, publicly proposed by the stakeholders of the citizen platform "Pacto por el Mar Menor", neighborhood associations and NGOs and the fishing sector to improve the situation of environmental degradation in the SESMM. DPSIR: Driving Force-Pressure (primary and final)-State-Impact-Response. The primary pressure (1[a]) is defined as the one that derives directly from the driving force and the final pressure is the one that most directly affects the change of state.

[8] https://www.laopiniondemurcia.es/comunidad/2019/10/17/ocho-medidas-salvar-mar-menor-31473945.html
[9] https://cadenaser.com/emisora/2017/04/05/radio_murcia/1491387342_943273.html
[10] https://www.laopiniondemurcia.es/comunidad/2017/02/22/calle-salvar-proteger-mar-menor-31931244.html
[11] https://elpais.com/sociedad/2019/10/30/actualidad/1572457756_941576.html

Measures proposed by citizen platforms, neighborhood associations and NGOs, and the fishing sector. 2019.	**DPSIR**	**Approach**	**Objective nº**
Containment and reorganization of the irrigated area	P1ª	Specific vector	4
Reduce agricultural pollution at source	P1ª	Integral	4
Application of nature-based measures throughout the basin to reduce agricultural pollution flows	P1ª	Integral	4
Recovery of natural wetland surfaces around the lagoon that act as green filters and intercept all flows	P1ª	Integral	4
Effective monitoring commission so that the laws and the decided measures are applied	R	Integral	7
Illegal well closures	P1ª	Specific vector	4
Reconversion of the agrarian model	FM	Integral	4
Stop urbanism	FM/P1ª	Sectorial	3
Sanitation and purification of urban wastewater	I	Specific vector	1
Management of funds for the measures adopted in the protection of the Mar Menor	R	Integral	7
Ensure the destination of the investment of public funds in public spaces around the Mar Menor	R	Integral	7

8.3.2.4. Proposed solutions by the academic sector

The academic sector in 2017 proposed six measures (Comité de Asesoramiento Científico 2017), mostly (66,7%) with an integral approach (Fig. 8.6), while 16,7% involved a specific vector, and the other 16,7% had a sectoral approach. A total of 83,3% of these measures are directed to the pressures of the SESMM, and 16,7% to the impacts (Fig. 8.5). The majority of the measures (83,3%) were directed to the objective of "Implement an environmentally and socially sustainable agricultural model".

Table 8.7. Analyzed measures, publicly proposed by the academic sector to improve the situation of environmental degradation in the SESMM. DPSIR: Driving Force-Pressure (primary and final)-State-Impact-Response. The primary pressure (1ª) is defined as the one that derives directly from the driving force and the final pressure is the one that most directly affects the change of state.

Measures proposed by the academic sector. 2017.	DPSIR	Approach	Objective nº
Containment and reorganization of the irrigated area	P1ª	Specific vector	4
Reduce agricultural pollution at source	P1ª	Integral	4
Application of nature-based measures throughout the basin	P1ª	Integral	4
Recovery of natural wetland surfaces around the lagoon	P1ª	Integral	4
Search for water alternatives for the adaptation of agricultural production to hydrological circumstances	P1ª	Integral	4
Implementation of measures to mitigate mining waste pollution	I	Sectorial	Unidentified

8.3.2.5. General analysis of the proposed solutions by all stakeholders

The results indicate that the measures of: 1) Reduce the lack of control of irrigation in the Mar Menor basin, 2) Reduce agricultural pollution at source, 3) Apply the wide existing battery of nature-based solutions to reduce the flows of agricultural pollution in the whole of the basin and 4) In the vicinity of the lagoon, create a band of new wetland surfaces that act as green filters and intercept all flows, have been proposed by the academic sector, NGOs, citizen platform "Pacto por el Mar Menor", Federation of Associations of Neighbors, Users and Consumers of Cartagena and the Region and the Fishermen's Association of San Pedro del Pinatar. This set of measures acts on primary pressures, has an integral approach and is aimed at the objective nº4 of "Implement an environmentally and socially sustainable agricultural model".

These results indicate that the proposed measures of the agricultural sector and the regional administration, which continue to avoid tackling the root of the problems and the need to reduce the pollution caused by intensive irrigation activity in the Mar Menor basin, are in disagreement with to the rest of the stakeholders, which reveals conflicting interests. It is also important to point out the different orientation and priorities that emerge from the measures that are proposed by different administrative areas of the same organizational level (state), in this case between the Segura Hydrographic Confederation and the Ministry for Ecological Transition and the Demographic Challenge, as well as between different organizational levels: state and regional.

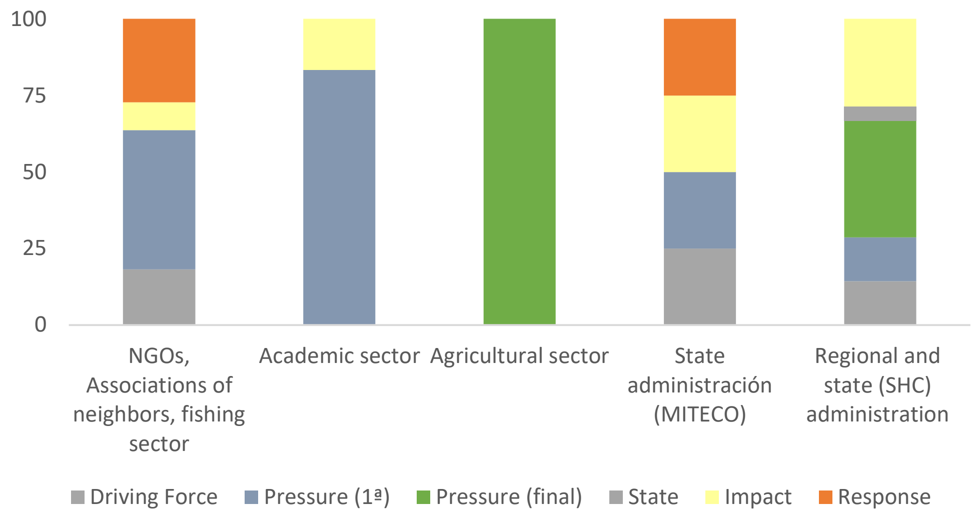

Figure 8.5. Percentage of proposed measures by the stakeholders, classified according to whether they are directed at a Driving Force-Pressure (primary and final)-State-Impact-Response of the SESMM

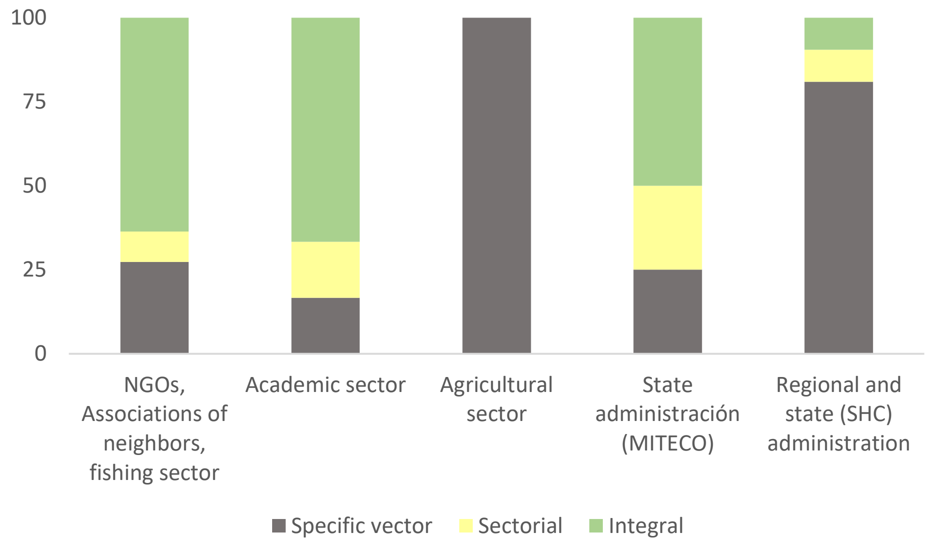

Figure 8.6. Percentage of proposed measures by stakeholders classified according to specificity and management approach.

8.3.3. Challenges faced by environmental governance in the SESMM

These results show some of the complexities and challenges faced by the environmental governance of the SESMM, and which are also typical of the integrated management of other SESs in coastal areas (Maya 2019; Barragán and de Andrés 2020):

1) Lack of coordination and collaboration between institutions. The large number of institutions with vested interests in the SESMM as a whole at different scales, constitutes a challenge that

requires a notable effort of coordination among them, an effort that has not been made. The principles of polycentric governance are not met (Thiel 2016), where management units at the local organizational level are embedded or nested with other management units at higher organizational levels, whose main objective is to ensure rights and duties of smaller-scale institutions and ensure the transmission of information and knowledge (both experiential or local and scientific or technical) between organizational levels and between institutions of the same level. In polycentric systems with bottom-up approaches, local management has independence to create and strengthen the rules and regulations appropriate to the local SES (Folke et al. 1998; Ostrom 2010; McGinnis 2011).

2) Deficient degree of co-management among stakeholders. Despite the existence of two working groups for stakeholder participation, they were not established until after the eutrophic crisis of the Mar Menor lagoon in 2016. Moreover, many of their members have abandoned their participation in these working groups after a year or two years being constituted because they consider that these groups are instrumentalized by the regional government and do not meet the objectives for which they were created (see footnotes 4 and 5). In short, the SESMM does not meet the basic principles for effective socio-environmental governance, such as access to information and active public participation, including all stakeholders in decision-making (Euler and Heldt 2018; Fritz and Binder 2020).

3) Ineffective management tools. Public management instruments so far have proven not to be efficient in protecting and conserving the SESMM for a variety of reasons. First, half of them have not been approved or executed. Second, there is a lack of participation of all the stakeholders involved in its elaboration. And finally, in many cases they are only sectoral instruments. Of those that have been approved, it is worth highlighting as positive elements two examples of integrated planning or management, such as the Integrated Management Strategy of Coastal Zones of the Socio-Ecological System of the Mar Menor and its surroundings and the Integral Management Plan of Protected Areas of the Mar Menor and the Mediterranean coastline of the Region of Murcia, approved in 2019. However, it should not be forgotten that the management instruments, once approved, require that they be periodically evaluated and adaptive, in order to verify whether the measures adopted are the most appropriate to achieve the proposed objectives or, on the contrary, it is necessary to modify such measures.

4) Deep differences of views between different stakeholders regarding the management measures for the restoration of the SESMM. The analysis of the measures publicly proposed by the different groups of social, economic and governmental actors reveals opposing views mainly between two aggregated groups; a) the agricultural sector and regional government and b) the academic sector,

fishing sector, neighborhood associations, citizen platform, NGOs and state government. The results also reveal certain contradictory actions within the same group of actors. In one example, the vision of different areas of the state administration (Ministry for the Ecological Transition and the Demographic Challenge and the Segura Hydrographic Confederation) reveals significant differences within that administration. And the measures that the Segura Hydrographic Confederation promoted along with the regional government in 2019, do not correspond to the priorities raised by MITECO a year later. Another example of contradictions involves the initial support of agricultural organizations' 2017 measures by the fishing sector and the Federation of Associations of Neighbors, Users and Consumers of Cartagena and the Comarca; however, since then, they have distanced themselves from the proposals of the agricultural sector. In 2019 they joined and shared a set of measures along with the NGOs sector and the citizen platform "Pacto por el mar menor".

To try to better understand these processes, the results of the interviews with the stakeholders about their preferences regarding a set of measures to limit the entry of nutrients to the lagoon were analyzed (Chapter 6). In these interviews, all the stakeholders gave priority to reducing the irrigated area, something that is contradictory to what the agricultural organizations sector has publicly stated. In these personalized interviews, the agricultural sector and the fishing sector considered a second priority measure to be collecting the brines and part of the flow of the waters of the "ramblas", and after their desalobration and denitrification, to discharge their rejection flow to the Mediterranean Sea, something that clearly the agrarian sector has also defended publicly. Faced with this measure, which is highly controversial and does not act on the origin of the problem, the rest of the stakeholders disagreed. Those stakeholders placed it as the last option, preferring measures such as forcing each desalination plant to include a treatment of brines and eliminating irregular collection of groundwater. All this is in accordance with what the organizations of these stakeholders have publicly stated. In this sense, the only contradiction observed between the results of the personalized interviews with the stakeholders and what they have publicly expressed appears in the agricultural sector regarding the measure of reducing the irrigated area. The rest of the stakeholders express the same positions both publicly and through personalized interviews.

Despite the complexities and challenges faced by the environmental governance of the SESMM, it is important to point out other examples of SES, such as the case of Tampa Bay (Florida, USA), which with a diagnosis similar to the SESMM, has changed its situation towards a sustainable development model (Greening et al. 2016; Sherwood et al. 2017) thanks to a management model based on the principles of environmental governance (Ostrom 1990; Prell et al. 2009; Bodin and Prell 2011; Euler and Heldt 2018 and Fritz and Binder 2020). Tampa Bay in 1970 had a eutrophication problem similar to the Mar Menor, as a consequence of the massive influx of nutrients from urban, agricultural and industrial activities. Like the Mar Menor, in the 1950-1990 period, Tampa Bay lost 50% of its seagrass (Greening et al. 2016), a lower percentage than the Mar Menor, which in 2016 lost 85% of its initial meadow (IEO 2016), but still considerable. As a consequence, the population demanded responses from the local and federal governments, as has also happened in the case of the Mar Menor and has been pointed out in this work. In 1980, the input of nutrients was reduced due to one of the first actions that were carried out, such as the improvement of the wastewater treatment plants. It should be remembered that in the SSEMM this was also one of the earliest actions that were implemented, what reduced the input of nutrients of urban origin to the Mar Menor lagoon (Mar Menor Scientific Advisory Committee 2017).

Since then, more than 500 actions have been carried out in Tampa Bay aimed at reducing the use of fertilizers and water by the agricultural sector; the increase in stormwater infrastructure; to reduce industrial discharges; to reduce the use of fertilizers in gardens by citizens and to restore habitat in the estuary and in the watershed (Greening et al. 2011, 2014 & 2016). All this has led in 2016 to reduce the input of nutrients by half, to have a water transparency similar to 1950 and to recover 16,857 ha of seagrass (Sherwood et al. 2017)

Unlike the management in the SESMM, the key to the effectiveness of these measures and in particular of the ecological restoration project of Tampa Bay was thanks to five fundamental elements, which still do not appear in the current governance model of the SESMM : 1) agreement and collaboration between all levels of government (local, state, federal), 2) identification of the problem through a diagnosis by the local community where the recovery of seagrass beds was identified as an indicator of a healthy bay , 3) an agreement between the public and private sectors to adopt a long-term goal of restoring seagrass beds as they were in 1950, 4) involving the academic sector in developing the scientific basis for restoring water quality and 5) identify a scientifically based neutral coordinator. To this end, an independent institution was created and it made up of all interested stakeholders, where each had the same vote, with a technical advisory committee made up of scientists who evaluated the results and provided recommendations for science-based actions. This institution was in charge of involving the local community in the restoration program. All these elements led to the recovery of the seagrass at levels similar to 1950, and to reconcile the different economic activities in the area, contributing one in every five jobs in the basin (13% of the local economy) (TBRPC 2014).

Although the power relationships between the stakeholders involved have not been studied in this work, some of the hypotheses that may explain the reasons why these elements of governance have not yet happened in the SESMM, but that would require a future research are:

1) The stakeholders involved in the SESMM have more important power relationships, so that power differences, especially between economic sectors, are more extreme in the SESMM than in the case of Tampa Bay.
2) There is low correspondence between the political weight of the economic sectors and the economic contribution of these sectors in the SESMM.

8.4. Conclusions

The results of this analysis of the governance model allow us to conclude that the SESMM does not have transparent, inclusive and effective governance when it comes to advance towards the sustainability of this SES. The fragmentation of responsibilities in government institutions related to the management of the SESMM, the absence of specific mechanisms for the participation of all stakeholders in the decision-making processes, the difficulty in approving effective instruments for territorial planning and resource management natural resources, the absence of integral approaches in the application of action measures to address the problems, conflicts of interest due to the use of natural resources between stakeholders and non-compliance with the current regulatory framework have led the SESMM to a situation of environmental degradation with serious social and economic consequences that put its sustainability at risk in the medium and long term.

Centralized governance, from the top-down, without the participation of all stakeholders in decision-making in the SESMM, has not been and is not effective in terms of sustainability. The response to the SESMM problem cannot be identified with an unidirectional solution due to the technical, environmental and social complexity, which is why collaboration processes and partial consensus building are required, processes that, given the divergence of views and social conflicts and existing policies, will necessarily be long and complex. This situation requires establishing channels of dialogue that allow for the creation of cooperation ties between the different stakeholders involved. For this, it would be of interest: 1) To create an institution with leadership that can promote coordination and cooperation between state, regional and local administrations and in turn with social and economic actors, through dialogue to reconcile opposing interests, channel conflict and set shared goals. 2) Develop new approaches in the development of management instruments for the SESMM with conceptual and methodological frameworks that are comprehensive, participatory and adaptive. 3) A robust legal and juridical framework that supports through public policies all the instruments and decisions on the management of the SESMM and where the government institutions in charge of formulating public policies effectively guarantee compliance with the regulations by stakeholders and implement management.

All these elements of a polycentric, participatory and adaptive governance system, would allow shared decisions that can ultimately contribute to advancing the sustainability of the SESMM and social well-being, as has been demonstrated in other SESs such as the case of Tampa Bay.

The challenge of reversing the environmental degradation of the SESMM and recovering the ecosystem services that it provides to human populations requires that all these significant changes be introduced in the governance model, a purpose to which this work aims to contribute.

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CONCLUSIONES Y FUTURAS LÍNEAS DE INVESTIGACIÓN

Capítulo 9.

Conclusiones y futuras líneas de investigación

Atardecer en Salinas de San Pedro del Pinatar

Sunset in Salt Marshes of San Pedro del Pinatar

Fotografía: Javier Murcia Requena

9. Conclusiones y futuras líneas de investigación

9.1. Conclusiones

A continuación se detallan las principales conclusiones respecto a cada una de las preguntas de investigación planteadas en la tesis doctoral y una conclusión general.

¿Cuáles son los métodos y enfoques más frecuentemente utilizados para evaluar el cambio global, específicamente los cambios de uso del suelo y sus implicaciones para la sostenibilidad en los SSE?

Los resultados de la revisión de la literatura científica realizada para el periodo 1995-2019, muestran que casi la mitad de los estudios analizan escenarios relativos al cambio global en cuencas hidrográficas. Estos estudios aplican mayoritariamente un análisis sectorial de tipo hidrológico a través sobre todo de modelos dinámicos distribuidos espacialmente. En la otra mitad de artículos que analizan escenarios de cambios de usos de suelo a otras escalas espaciales distintas a la cuenca hidrográfica, el enfoque de análisis es 100% sectorial aplicando modelos dinámicos distribuidos espacialmente en cerca de la mitad de los casos y modelos estadísticos en algo más de un tercio de los casos. Solo el 4% del total de los artículos revisados aplican enfoques participativos en el desarrollo de escenarios.

Sobre la base de esta revisión se han identificado cuatro retos pendientes de cara a futuros análisis de escenarios sobre los SSE. Estos retos son los siguientes: 1) trabajar en la compleja interfaz de los sistemas ecológicos y sociales, que es donde se desarrollan las políticas relativas a los usos del suelo. Esto implica la integración de las ciencias sociales y biofísicas (perspectiva interdisciplinar), así como la incorporación de los actores (perspectiva transdisciplinar), dado que es clave para enfrentar los desafíos ambientales, 2) integrar múltiples procesos y fuerzas impulsoras operando a diferentes escalas espacio-temporales, incorporando entre otras las interacciones entre cambios de usos del suelo y cambio climático, 3) desarrollar modelos que apliquen enfoques integrados e incorporen factores biofísicos y socioeconómicos y 4) promover enfoques participativos en el desarrollo de escenarios, integrando ambos tipos de conocimiento, académico y no académico. El avance en estos retos podría mejorar el uso y la utilidad de las herramientas prospectivas en los procesos de toma de decisiones orientados a la sostenibilidad.

¿Cuáles son los principales factores ambientales, sociales y económicos implicados en la dinámica del SSEMM?

El modelo socio-ecológico cualitativo del SSEMM, elaborado con la literatura científica disponible y contando con la opinión de 20 expertos de diferentes disciplinas en las dimensiones ambiental, social, económica e institucional, ha permitido un diagnóstico sintético, pero integral, de la problemática del Mar Menor, en la que destaca la interrelación de 76 factores identificados como principales fuerzas motrices (6), presiones (23), estado (26) e impactos (21).

Entre las diferentes fuerzas motrices identificadas en el SSEMM, al menos tres de ellas; el crecimiento poblacional, el desarrollo urbano-turístico y la agricultura de regadío intensivo, presentan claras interacciones, generando múltiples presiones que han alterado el estado inicial del conjunto del SSEMM. Entre las múltiples presiones definidas, cabe destacar seis presiones que afectan más directamente al estado del SSEMM: la expansion urbana y el desarrollo de infraestructuras, la creación de playas artificiales, la roturación y transformación del suelo, el aumento de la superficie de regadío, la generación y arrastre de sedimentos y el aumento de los flujos hídricos con alta carga de nutrientes.

Estas presiones han desencadenado cambios en el estado de la subcuenca hidrográfica vertiente, los humedales periféricos y la laguna del Mar Menor, estado que se ha caracterizado a través de un total de 26 factores, entre los que cabe mencionar: los cambios de uso del suelo en la subuenca, los cambios en el area y la composición de los habitat naturales de los humedales periféricos y el aumento de los nutrientes en la laguna.

La contaminación del acuífero Cuaternario por nitratos, el aumento del riesgo de inundaciones, la fragmentación del territorio, la pérdida de usos tradicionales, la pérdida de hábitats y especies singulares y el estado eutrófico de la laguna emergen como los principales impactos primarios, que a su vez, han desencadenado otros impactos sociales y económicos, como la pérdida de calidad y empleo de sectores económicos como el turismo, especialmente en la hostelería y la pesca, al menos en algunos periodos temporales, que suponen una pérdida del valor económico del conjunto del SSEMM, así como del bienestar social.

¿Cuál es la percepción que tiene la comunidad local en relación a la situación actual de degradación ambiental del SSEMM?

La comunidad local percibe una crisis ecológica que acarrea impactos sociales importantes para la población del entorno del Mar Menor en cuanto a pérdida de calidad de vida y disminución progresiva de oportunidades socioeconómicas ligadas a la menor funcionalidad del propio sistema. Cabe señalar el amplio consenso entre los encuestados acerca de que la actividad agrícola es la principal causa de la entrada de nutrientes a la laguna, y la prioridad que los encuestados otorgan a las medidas para reducir el aporte de nutrientes.

Este consenso, muy diferente a los resultados obtenidos en estudios realizados en periodos temporales anteriores a la crisis eutrófica desencadenada en 2016, representa un cambio de percepción muy reciente en relación al papel de la agricultura en el Mar Menor. La correcta identificación por parte de la comunidad local del principal origen de la contaminación podría deberse a la labor continuada de divulgación realizada desde el ámbito científico y de distintas organizaciones ambientales y, sobre todo, al gran impacto que la crisis eutrófica de 2016 generó en la población en su conjunto.

Sin embargo, el amplio consenso en el diagnóstico de las causas del problema actual no se ha traducido a un consenso en torno a las soluciones u opciones de manejo. Las respuestas de la comunidad local variaron mucho entre los diferentes grupos de encuestados. Se han identificado diferencias importantes entre a) las percepciones de los encuestados sobre las mejores soluciones, y b) las preferencias mayoritarias de la población, por un lado y las medidas de gestión por las que ha apostado la administración pública hasta este momento. Esto apunta a un posible conflicto que debe considerarse en cualquier proceso de toma de decisiones.

¿Quiénes son los actores que interactúan con los ecosistemas y recursos naturales del SSEMM y cuáles son sus principales percepciones?

Se han identificado siete grupos de actores principales asociados al SSEMM, los cuales están implicados, interesados o afectados por la situación de degradación ambiental. Estos se clasifican en las siguientes categorías: 1) administración pública, 2) sector agrícola, 3) sector turístico, 4) sector pesquero, 5) sector de la construcción y promoción inmobiliaria, 6) organismos de investigación y 7) plataformas ciudadanas, asociaciones de vecinos y ONGs.

Los resultados evidencian un amplio consenso en que el problema central y movilizador que perciben todos, al igual que la comunidad local, es la degradación de la calidad ambiental del SSEMM y particularmente de la laguna del Mar Menor, por la actual situación de eutrofización. También están de acuerdo en que se necesitan actuaciones o medidas de gestión para limitar la entrada de nutrientes a la laguna del Mar Menor y para mejorar el desarrollo urbano-turístico del entono del Mar Menor.

Sin embargo, este consenso no se traslada a las preferencias de los grupos de actores por las soluciones o medidas de gestión. Merece la pena destacar como el sector agrícola, el sector pesquero y el sector del turismo dedicado a hostelería y alojamiento turístico, consideran como segunda medida prioritaria para limitar la entrada de nutrientes a la laguna, la medida de *Recoger las salmueras y parte de los caudales de las aguas de las ramblas y tras su desalobración y desnitrificación verter su caudal de rechazo al Mar Mediterráneo*. Esta medida es muy controvertida porque aunque ha sido propuesta por el gobierno regional y por el organismo de cuenca (Confederación Hidrográfica del Segura), no actúa sobre el origen del problema y frente a la que el resto de los grupos de actores, como: administración pública, sector turístico dedicado a los servicios, sector de la construcción y promoción inmobiliaria, organismos de investigación y plataformas ciudadanas, asociaciones de vecinos y ONGs, no están de acuerdo, situándola como última opción. Estos actores consideran más preferentes medidas como *Obligar a que cada desalobradora incluya un tratamiento de salmueras* y la *Eliminación de la captación irregular de aguas subterráneas*.

En cuanto a las medidas para mejorar el desarrollo urbano turístico, se observan discrepancias entre los actores del sector de la construcción y el sector del turismo dedicado a los servicios, que consideran prioritaria la medida de *Mejorar el carril bici y de los espacios adaptados para el paseo y deportes*, frente al resto de actores (administración pública, sector agrícola, sector del turismo dedicado a la hostelería y alojamiento turístico, sector pesquero, organismos de investigación y plataformas ciudadanas, asociaciones de vecinos y ONGs) que priorizan la medida de *No realizar una mayor oferta de segundas residencias*.

A pesar de estas discrepancias entre los grupos de actores por el orden preferente de las soluciones o medidas de gestión, es importante señalar el consenso de todos los actores entrevistados en relación a priorizar dos medidas: *Mejorar la gestión y protección de los espacios naturales del entorno del Mar Menor, humedales litorales y las zonas libres de edificaciones* para mejorar el desarrollo urbano-turístico y *Reducir la superficie de regadío* para limitar la entrada de nutrientes a la laguna. Aunque en este trabajo los actores entrevistados del sector agrario están de acuerdo con esta última medida, existen evidencias en años anteriores y en la actualidad acerca de que los actores pertenecientes al sector agrario niegan la necesidad de reducir el regadío.

Por otro lado, del análisis comparativo de los actores entrevistados con el grupo de encuestados perteneciente a su ámbito profesional en relación con la preferencia por las medidas de gestión, se concluye la existencia de discrepancias entre las preferencias expresadas por los actores entrevistados y el conjunto del sector poblacional al que tales actores pertenecen. En este sentido, los actores entrevistados pertenecientes a la administración pública, sector del turismo dedicado a los hoteles y hostelería y sector agrícola son los que más se diferenciaron en sus preferencias de medidas de gestión para mejorar el desarrollo urbano-turístico respecto a los grupos de encuestados correspondientes a tales ámbitos. En el caso de las medidas para limitar la entrada de nutrientes, el nivel de discrepancia entre las preferencias de los actores entrevistados y el grupo de encuestados fue todavía mayor que en el caso anterior. Los actores entrevistados del sector agrícola y sector del turismo dedicado a la hostelería y alojamiento turístico sólo coincidieron con las de los grupos de encuestados de tales ámbitos en dos medidas: *Recoger las salmueras y parte de los caudales de las aguas de las ramblas y tras su desalobración verter su caudal de rechazo al Mar Mediterráneo* y *Establecer y vigilar la aplicación de valores máximos de aportación de fertilizantes*. De igual forma la opinión de los actores del sector de la administración, sector académico, sector de la construcción y sector del turismo de servicios solo coincidieron con los encuestados cuya profesión o principal actividad económica pertenecía a los sectores respectivos en la medida de *Establecer y vigilar la aplicación de valores máximos de aportación de fertilizantes*. También en el sector de la administración y en el sector del turismo de servicios, los actores respectivos coincidieron con los grupos de encuestados correspondientes en la *Eliminación de la captación irregular de aguas subterráneas* y en *Recuperar y potenciar la superficie perdida de humedal natural en la periferia de la laguna*, respectivamente.

Por otra parte, la distancia en las preferencias sobre las medidas, tanto para mejorar el desarrollo urbano-turístico como para limitar la entrada de nutrientes a la laguna, entre los grupos de encuestados es mayor que la observada entre los actores entrevistados, donde se distinguen varios clústeres en base a la similitud en las respuestas que los actores dieron para ordenar sus preferencias. En las preferencias de medidas para mejorar el desarrollo urbano-turístico se forman tres clústeres, los actores representantes de: 1) sector de la construcción y el sector del turismo dedicado a los servicios, 2) sector pesquero, sector de la administración pública, sector de las ONGs y plataforma ciudadana, y dos de los tres actores representantes del sector académico y 3) sector del turismo dedicado a la hostelería y alojamiento turístico, sector agrícola y un actor del sector académico. Para limitar la entrada de nutrientes se forman dos clústeres: 1) sector agrícola, sector pesquero y el sector del turismo dedicado a hostelería y alojamiento turístico y 2) el resto de actores.

A partir de estos resultados emergen dos conclusiones de interés de cara al diseño y puesta en marcha de un proceso de participación deliberativa. En primer lugar, cabe prever dificultades, al menos en su fase inicial, para alcanzar posibles consensos en torno a la priorización de las medidas. En segundo lugar, la implicación de los actores identificados y entrevistados en el marco de este trabajo en tales procesos participativos puede ser positiva, dado que presentan entre sí una distancia entre sus respectivas posiciones menor a la detectada entre sus sectores, de acuerdo con los resultados obtenidos con la encuesta a la población. Por tanto, la implicación de tales actores en procesos participativos puede facilitar la generación de consensos que, posteriormente, pudieran extenderse a sus sectores respectivos.

¿Cómo evaluar los avances y retrocesos en relación con los objetivos de sostenibilidad del SSEMM?

Se ha realizado una propuesta metodológica para seleccionar indicadores de sostenibilidad específicamente adaptados a los requerimientos y singularidad del SSEMM, con un enfoque integral e interdisciplinar, que atiende a las distintas dimensiones de la sostenibilidad ambiental, socioeconómica e institucional. El sistema final de indicadores de sostenibilidad integra un total de 61 indicadores, de los que 25 atienden cuestiones de la dimensión ambiental, 26 de la dimensión socioeconómica y 10 de la dimensión institucional de la sostenibilidad del SSEMM.

Posteriormente se ha caracterizado cada indicador en términos de la información disponible para su cálculo, lo que ha mostrado carencias de información en la cuarta parte de los indicadores ambientales, en cerca de la mitad de los indicadores socioeconómicos y en la mitad de los indicadores de sostenibilidad institucional. Se puede afirmar que existe un desequilibrio entre las diferentes dimensiones de la sostenibilidad del SSEMM en relación a la disponibilidad de información. Se requiere por tanto avanzar en la generación de la información básica necesaria para el cálculo de tales indicadores.

No obstante existen necesidades de mejora en el caso de los indicadores para los que se dispone de cierta información, por tratarse en muchos casos de información heterogénea, dispersa, discontinua y no siempre bien descrita.

Finalmente, otro de los resultados emergentes es la ausencia de valores de referencia recomendados y la necesidad de los mismos para que un sistema de indicadores sea útil en términos de sostenibilidad. Por ello, se incorpora una propuesta tentativa de valores umbral y valores objetivo para algunos de los indicadores con información disponible, con el fin de que los mismos sean más útiles para la evaluación de la sostenibilidad y su seguimiento en el tiempo.

Los resultados de este trabajo apuntan a que la evaluación de la sostenibilidad en el SSEMM se evidencia como una tarea complicada, con dificultades prácticas y conceptuales. Por un lado, los sesgos en la disponibilidad de datos pueden favorecer que al final sólo se valore lo que se puede medir y, por otro lado, la ausencia de umbrales claros para parte de los indicadores le resta utilidad a la hora de utilizarlos para realizar diagnósticos y valorar los cambios en el tiempo, como base para la toma de decisiones.

Se concluye que la elaboración de un sistema de indicadores para la recuperación del SSEMM debería ser considerada como una inversión necesaria por parte de la administración, ya que eventualmente permitiría disponer de una herramienta capaz de sintetizar la compleja y profusa información en torno al SSEMM, al servicio de los distintos actores (ámbito político, técnico, sectores económicos, actores sociales y ciudadanía) para una toma de decisiones informada sobre la base del mejor conocimiento disponible.

¿Cúal es el modelo de gobernanza para la gestión del SSEMM y cúales son las respuestas abordadas?

El SSEMM no cuenta con un modelo de gobernanza transparente, inclusivo y eficaz a la hora de avanzar hacia la sostenibilidad. La fragmentación de responsabilidades en las instituciones gubernamentales relacionadas con la gestión, la falta de coordinación y colaboración entre las instituciones, la ausencia de mecanismos específicos para la participación de todos los actores en los procesos de toma de decisiones, la dificultad en la aprobación de instrumentos eficaces de planificación territorial y gestión de recursos naturales, la ausencia de enfoques integrales en la aplicación de medidas de actuación para abordar los problemas, los conflictos de intereses por el uso de los recursos naturales entre actores y entre sectores socioeconómicos y el incumplimiento del marco normativo vigente, emergen como las principales complejidades y retos fundamentales.

En cuanto a las respuestas abordadas, se concluye que los instrumentos de gestión pública hasta el momento han demostrado no ser eficientes para proteger y conservar el SSEMM. Primero, porque la mitad de ellos no se han aprobado ni ejecutado. Segundo, por la falta de participación de todos los actores implicados en su elaboración y, tercero, porque en muchos casos son instrumentos sectoriales. De los que se han aprobado, merece la pena destacar como elementos positivos dos figuras de planificación o gestión integrada, como es la Estrategia de Gestión integrada de Zonas Costeras del Sistema Socio-Ecológico del Mar Menor y su entorno y el Plan de Gestión Integral de Espacios Protegidos del Mar Menor y de la franja litoral mediterránea de la Región de Murcia, las cuales han sido aprobadas en 2019.

Los grupos de actores implicados en la gestión del SSEMM que han propuesto públicamente medidas para mejorar la situación de degradación ambiental del SSEMM son: 1) administración pública (gobierno estatal y gobierno regional), 2) sector agrícola, 3) sector pesquero, 4) organismos de investigación y 5) plataformas ciudadanas, asociaciones de vecinos y ONGs.

El análisis de las medidas propuestas públicamente por los grupos de actores sociales, económicos y gubernamentales revela visiones contrapuestas principalmente entre dos grupos; por un lado, el sector académico, sector pesquero, asociaciones de vecinos, plataforma ciudadana, ONGs y gobierno estatal, que proponen un conjunto de medidas que actúa sobre presiones primarias, tienen un enfoque más integral y se dirigen principalmente al objetivo de "Implantar un modelo agrario ambientalmente y socialmente sostenible". Y, por otro lado, el sector agrícola y gobierno regional, que proponen medidas que siguen evitando afrontar la raíz de los problemas y la necesidad de reducir la contaminación causada por la actividad del regadío intensivo en la subcuenca del Mar Menor. Este grupo de medidas están dirigidas a vectores específicos y sin enfoque integral.

Los resultados también revelan ciertas acciones contradictorias dentro de un mismo grupo de actores: la visión de distintos ámbitos de la administración estatal (Ministerio para la Transición Ecológica y el Reto Demográfico y Confederación Hidrográfica del Segura) revela diferencias significativas. En este sentido, las medidas que la Confederación Hidrográfica del Segura promovió junto al gobierno regional en el año 2019, no se corresponden con las prioridades planteadas desde el Ministerio para la Transición Ecológica y el Reto Demográfico un año después.

Por otra parte, el análisis comparativo de los resultados de las entrevistas personalizadas a los actores y lo que públicamente éstos han manifestado, revela contradicciones en el sector agrario en torno a la medida de *Reducir la superficie de regadío*. En dichas entrevistas, como ya se ha mencionado, todos los actores daban prioridad a *Reducir la superficie de regadío*, algo que es contradictorio con lo que públicamente ha manifestado el sector de las organizaciones agrarias. El resto de sectores manifiestan las mismas posiciones tanto públicamente como a través de las entrevistas personalizadas. Estos factores deberían ser tenidos en cuenta en el diseño de futuros procesos participativos, con el fin de facilitar al máximo tales procesos y la oportunidad de avanzar de forma progresiva hacia ciertos consensos.

Los fallos de gobernanza han sido fundamentales en el proceso que ha llevado al SSEMM a una situación de degradación ambiental profunda, con serias consecuencias sociales, y económicas, que ponen en riesgo su sostenibilidad en el medio y largo plazo. Es necesario un sistema de gobernanza policéntrico, participativo y adaptativo, que permita tomar decisiones compartidas entre todos los actores implicados en beneficio de la sostenibilidad del SSEMM y del bienestar social.

9.2. Conclusions

The main conclusions regarding each of the research questions posed in the doctoral thesis and a general conclusion are detailed below.

What methods and approaches are most used to assess global change, specifically land use changes and their implications for sustainability in Socio-Ecological Systems (SES)?

The results of the review of the scientific literature carried out for the period 1995-2019 show that almost half of the studies analyze scenarios related to global change in hydrographic basins. These studies mostly apply a hydrological sectoral analysis through spatially distributed dynamic models. In the other half of the articles that analyze scenarios of land use changes at spatial scales other than the river basin, the analysis approach is 100% sectoral, applying spatially distributed dynamic models in about half of the cases and statistical models in slightly more than a third of the cases. Only 4% of the total articles reviewed apply participatory approaches in the development of scenarios.

Based on this review, four pending challenges have been identified for future analysis of scenarios on SES. These challenges are as follows: 1) working at the complete interface of ecological and social systems, which is where policies related to land use are developed. This implies the integration of the social and bio-physical sciences (interdisciplinary perspective), as well as the incorporation of the actors (transdisciplinary perspective), since it is key to face environmental challenges, 2) integrating multiple processes and driving forces operating at different spatial-temporal scales, incorporating, among others, interactions between land use changes and climate change, 3) developing models that apply integrated approaches and incorporate biophysical and socioeconomic factors and 4) promoting participatory approaches in the development of scenarios, integrating both types of knowledge, academic and non-academic. Advancing these challenges could improve the use and usefulness of prospective tools in decision-making processes towards sustainability.

What are the main environmental, social and economic factors involved in the dynamics of the Socio-Ecological System of the Mar Menor (SESMM) basin?

The qualitative socio-ecological model of the SESMM, prepared with the available scientific literature and with the opinion of 20 experts from different disciplines in the environmental, social, economic and institutional dimensions, has allowed a synthetic, but integrative, diagnosis of the problem of the Mar Menor. The DPSIR (driving forces, pressure, state, impact, response) methodological framework showed the importance of interrelation of 76 factors identified as main *driving forces* (6), *pressures* (23), *state* (26) and *impacts* (21).

Among the different *driving forces* identified in the SESMM, at least three of them; population growth, urban-tourism development and intensive irrigated agriculture show clear interactions, generating multiple *pressures* that have altered the initial state of the SESMM as a whole. Among the multiple pressures defined, it is worth highlighting six pressures that most directly affect the state of the SESMM: urban expansion and infrastructure development, the creation of artificial beaches, the plowing and transformation of the soil, the increase in irrigated area, the generation and entrainment of sediments and the increase of water flows with high nutrient load.

These *pressures* have triggered changes in the *state* of the upland watershed, the peripheral wetlands and the Mar Menor lagoon, a *state* that has been characterized by a total of 26 factors, among which it is worth mentioning: land use changes in the upland watershed, changes in the area and composition of the natural habitats of the peripheral wetlands and the increase in nutrients in the lagoon.

The contamination of the Quaternary aquifer by nitrates, the increased risk of flooding, the fragmentation of the territory, the loss of traditional uses, the loss of habitats and unique species and the eutrophic state of the lagoon emerge as the main primary *impacts*, which in turn on the other hand, they have triggered other social and economic impacts, such as the loss of quality and employment in economic sectors such as tourism, especially in the hotel industry and fishing, at least in some time periods, which imply a loss of the economic value of the entire SESMM, as well as social welfare.

What is the perception of the local community in relation to the current situation of environmental degradation of the SESMM?

The local community perceives an ecological crisis that has significant social impacts for the population around the Mar Menor in terms of loss of quality of life and a progressive decrease in socioeconomic opportunities linked to the lower functionality of the system itself. It is worth noting the broad consensus among survey respondents that agricultural activity is the main cause of the entry of nutrients into the lagoon, and the priority that respondents give to measures to reduce the contribution of nutrients.

This consensus, very different from the results obtained in studies carried out in time periods prior to the eutrophic crisis unleashed in 2016, represents a very recent change in perception regarding the role of agriculture in the Mar Menor. The correct identification by the local community of the main source of pollution could be due to the continuous dissemination of results from the scientific environmental organizations and, above all, to the great impact that the eutrophic crisis of 2016 generated on the population as a whole.

However, the broad consensus in diagnosing the causes of the current problem has not been translated into a consensus regarding solutions or management options. Responses from the local community varied widely among different groups of respondents. Important differences have been identified between a) the perceptions of the respondents about the best solutions, and b) the majority preferences of the population, on the one hand, and the management measures for which the public administration has opted to date. This points to a potential conflict that should be considered in any decision-making process.

Who are the stakeholders that interact with the ecosystems and natural resources of the SESMM and what are their main perceptions?

Seven main stakeholder groups associated with the SESMM have been identified, which are involved, interested in or affected by the situation of environmental degradation. These are classified into the following categories: 1) public administration, 2) agricultural sector, 3) tourist sector, 4) fishing sector, 5) construction and real estate development sector, 6) research organizations and 7) citizen platforms, associations of neighbors and NGOs.

The interviews of these groups show a broad consensus that the central and mobilizing problem perceived by all, like the local community, is the degradation of the environmental quality of the SESMM and particularly of the Mar Menor lagoon, due to the current situation of eutrophication. They also agree that actions or management measures are needed to limit the entry of nutrients to the Mar Menor lagoon and to improve the urban-tourist development of the Mar Menor environment.

However, this consensus does not translate to stakeholder group preferences for solutions or management measures. It is worth noting how the agricultural sector, the fishing sector and the tourism sector (dedicated to hotels and restaurants), all consider the limitation of the entry of nutrients to the lagoon as a secondary measure, after the measure of *Collect the brines and part of the flows from the waters of the "ramblas" and after its desalobration and denitrification, pour its rejection flow into the Mediterranean Sea*. This measure is highly controversial because, although it has been proposed by the regional government and by the Segura Hydrographic Confederation, it does not act on the origin of the problem. That measure is also against the views of rest of the groups of stakeholders. Public administration, the tourism sector dedicated to services, the construction and real estate development sector, research organizations and citizen platforms, neighborhood associations and NGOs, do not agree, placing it as the last option. These stakeholders consider more preferred measures such as *Require that each desalinator includes a treatment of brines* and the *Elimination of irregular uptake of groundwater*.

Regarding the measures to improve urban-tourist development, there are discrepancies among the stakeholders representing the construction sector and the tourism sector dedicated to services, who consider the measure of *Improving the bike lane and the spaces adapted for walking and sports* to be a priority, compared to the rest of the stakeholders (public administration, agricultural sector, tourism sector dedicated to the hotels and restaurants, fishing sector, research organizations and citizen platforms, neighborhood associations and NGOs) who prioritize the measure of *Do not make a greater offer of second homes*.

Despite these discrepancies among the groups of stakeholders in the preferential order of the solutions or management measures, it is important to point out the consensus of all the stakeholders interviewed in relation to prioritizing two measures: *Improve the management and protection of natural areas around the Mar Menor, coastal wetlands and free areas of buildings* to improve urban-tourist development and *Reduce the irrigated area* to limit the entry of nutrients into the lagoon. Although in this work the stakeholders interviewed from the agricultural sector agree with this last measure, there is evidence in previous years and at present that the actors belonging to the agricultural sector deny the need to reduce irrigation.

On the other hand, from the comparative analysis of the stakeholders interviewed with the group of respondents belonging to their professional field in relation to the preference for management measures, it is concluded that there are discrepancies among the preferences expressed by the stakeholders interviewed and the group of population to which such actors belong. In this sense, the interviewed stakeholders belonging to the public administration, the tourism sector dedicated to hotels and restaurants, and the agricultural sector are the ones who differed the most in their preferences for management measures to improve urban-tourist development with respect to the groups of respondents corresponding to these areas. In the case of measures to limit the entry of nutrients to the lagoon, the level of discrepancy among the preferences of the interviewed stakeholders and the group of respondents was even greater than in the previous case. The stakeholders interviewed from the agricultural sector and the tourism sector dedicated to hotels and restaurants only coincided with those of the groups of respondents from these areas in two measures: *Collect the brines and part of the flows from the waters of the "ramblas" and after its desalobration and denitrification, pour its rejection flow into the Mediterranean Sea* and

Establish and monitor the application of maximum values of fertilizer contribution. Similarly, the opinion of the stakeholders representing the administration sector, the academic sector, the construction sector and the tourism sector dedicated to the services only coincided with those surveyed whose profession or main economic activity belonged to the respective sectors to the measure of *Establish and monitor the application of maximum values of fertilizer contribution*. Also in the administration sector and in the tourism sector dedicated to the services, the respective stakeholders coincided with the corresponding groups of respondents in the measures of Elimination *of the irregular uptake of groundwater* and in *Recover and enhance the lost surface of natural wetland in the periphery of the lagoon*, respectively.

Regarding the distance in the preferences on the measures, both to improve urban-tourist development and to limit the entry of nutrients to the lagoon, among the groups of respondents is greater than that observed among the interviewed stakeholders, where there are various clusters based on the similarity in the responses that the stakeholders gave to order their preferences. In the preferences for measures to improve urban-tourism development, three clusters are formed, the stakeholders representing: 1) the construction sector and the tourism sector dedicated to services, 2) the fishing sector, the public administration sector, the NGOs and citizen platform, and two of the three actors representing the academic sector and 3) the tourism sector dedicated to hotels and restaurants, the agricultural sector and an actor from the academic sector. To limit the input of nutrients, two clusters are formed: 1) the agricultural sector, the fishing sector and the tourism sector dedicated to hotels and restaurants, and 2) the rest of the stakeholders.

From these results, two interesting conclusions emerge regarding the design and implementation of a deliberative participation process. In the first place, it is possible to foresee difficulties, at least in its initial phase, in reaching possible consensus on the prioritization of measures. Second, the involvement of the stakeholders identified and interviewed in the framework of this work in such participatory processes can be positive, since they present a distance between their respective positions that is less than that detected between their sectors, according to the results obtained with the population survey. Therefore, the involvement of these actors in participatory processes can facilitate the generation of consensus that, later, could be extended to their respective sectors.

How to assess progress and setbacks in relation to the SESMM sustainability objectives?

Here, a methodological proposal has been made to select sustainability indicators specifically adapted to the requirements and uniqueness of the SESMM, with an integral and interdisciplinary approach, which addresses the different dimensions of environmental, socioeconomic and institutional sustainability. The final system of sustainability indicators includes a total of 61 indicators, of which 25 address issues of the environmental dimension, 26 of the socio-economic dimension and 10 of the institutional dimension of SESMM sustainability.

Subsequently, each indicator has been described in terms of the information available for its calculation, which has shown information gaps in a quarter of the environmental indicators, in about half of socioeconomic indicators and in half of the institutional sustainability indicators. There is an imbalance among the different dimensions of SESMM sustainability in relation to the availability of information. Therefore, it is necessary to advance the generation of the necessary information for the calculation of such indicators.

Moreover, there are needs for improvement in the case of indicators for which certain information is available, since in many cases this information is heterogeneous, disperse, discontinuous and not always well described.

Finally, another of the emerging results is the absence of recommended reference values, needed for a system of indicators to be useful in terms of sustainability. For this reason, a tentative proposal of threshold values and target values is incorporated for some of the indicators with available information, in order to make them more useful for the evaluation of sustainability and its follow-up over time.

The results of this work suggest that the evaluation of sustainability in the SESMM is evident as a complicated task, with practical and conceptual difficulties. On the one hand, biases in the availability of data may favor that in the end only what can be measured is valued and, on the other hand, the absence of clear thresholds for part of the indicators makes it less useful when using them to perform diagnoses and assess changes over time, as a basis for decision making.

It is concluded that the development of a system of indicators for the recovery of the SESMM should be considered as a necessary investment by the administration, since it would eventually allow to have a tool capable of synthesizing the complex and profuse information around the SESMM, by service of the different stakeholders (political, technical, economic sectors, social actors and citizens) for an informed decision-making based on the best available knowledge.

What is the governance model for the management of the SESMM and what are the responses addressed?

The SESMM does not have a transparent, inclusive and effective governance model when it comes to moving towards sustainability. These are the main governance complexities and fundamental challenges that emerge from this work: fragmentation of responsibilities in government institutions related to management; lack of coordination and collaboration between the institutions; absence of specific mechanisms for the participation of all stakeholders in the decision-making processes; difficulty in the approval of instruments effective territorial planning and management of natural resources; absence of integral approaches in the application of action measures to address the problems; conflicts of interest for the use of natural resources among stakeholders and among socio-economic sectors; and non-compliance with the regulatory framework.

Regarding the responses addressed, it is concluded that the public management instruments so far have proven not to be efficient to protect and preserve the SESMM. Several factors are involved. First, half of the management instruments have not been approved or executed. Second, there is a lack of participation of all the stakeholders involved in its elaboration and, third, in many cases they are sectoral instruments. Of those that have been approved, it is worth highlighting as positive elements two efforts of integrated planning or management, such as the Integrated Management Strategy of Coastal Zones of the Socio-Ecological System of the Mar Menor and its surroundings and the Integral Management Plan of Protected Areas of the Mar Menor and the Mediterranean coastline of the Murcia Region, which have been approved in 2019.

The groups of stakeholders involved in the management of the SESMM that have publicly proposed measures to improve the environmental degradation situation of the SESMM are: 1) public administration (state government and regional government), 2) agricultural sector, 3) fishing sector, 4) research organizations and 5) citizen platforms, neighborhood associations and NGOs.

The analysis of the measures publicly proposed by the groups of stakeholders reveals opposing views mainly between two groups. One broad group includes the academic sector, the fishing sector, neighborhood associations, citizen platform, NGOs and the state government, which propose a set of measures that acts on primary pressures. They collectively have a more integral approach and are mainly aimed at the objective of "Implementing an environmentally and socially sustainable agrarian model". The second group, on the other hand, is the agricultural sector and regional government, which propose measures that continue to avoid tackling the root of the problems and the need to reduce pollution caused by intensive irrigation activity in the Mar Menor sub-basin. This group of measures are directed at specific vectors and without an integral approach.

The results also reveal certain contradictory actions within the same group of stakeholders: the visions among different areas of the state administration (Ministry for the Ecological Transition and the Demographic Challenge and the Segura Hydrographic Confederation) reveal significant differences (within one group). In this sense, the measures that the Segura Hydrographic Confederation promoted together with the regional government in 2019, do not correspond to the priorities raised by the Ministry for the Ecological Transition and the Demographic Challenge a year later.

On the other hand, the comparative analysis of the results of the personalized interviews with the stakeholders and what they have publicly stated, reveals contradictions in the agricultural sector regarding the measure of *Reducing the irrigated area*. In these interviews, as already mentioned, all the stakeholders gave priority to *Reducing the irrigated area*, something that is contradictory to what the agricultural organizations sector has publicly stated. The rest of the sectors express the same positions both publicly and through personalized interviews. These factors should be taken into account in the design of future participatory processes, in order to facilitate such processes as much as possible and the opportunity to progressively advance towards certain consensuses.

Governance failures have been fundamental in the process that has led the SESMM to a situation of deep environmental degradation, with serious social and economic consequences, which jeopardize its sustainability in the medium and long term. A polycentric, participatory and adaptive governance system is necessary, which allows shared decisions to be made among all the stakeholders involved for the benefit of the sustainability of the SESMM and social well-being.

9.3. Futuras líneas de investigación

Los resultados de esta tesis permiten plantear nuevas líneas de investigación futuras, las cuales se exponen a continuación:

1. Una línea de trabajo futuro, que da continuidad al trabajo presentado, es la realización de talleres participativos con los actores para debatir comúnmente algunos de los resultados obtenidos en esta tesis: 1) el modelo cualitativo desarrollado para el SSEMM, 2) las necesidades e intereses de los actores, 3) sus preferencias sobre las medidas de gestión para la restauración del sistema y 4) los consensos, disensos y conflictos que emergen. Este trabajo futuro con los actores ha de incorporar, además, una perspectiva que analice y tenga en cuenta las relaciones de poder

existentes entre los distintos actores y cómo se pueden gestionar de forma adecuada tales relaciones dentro de un proceso participativo.

2. Por otro lado, el sistema de indicadores planteado, como ya se ha indicado, requiere de un trabajo iterativo en varias fases que no ha culminado. En una segunda fase se propone mejorar el sistema de indicadores a través de talleres participativos con un grupo multidisciplinar de expertos y posteriormente con los actores, con el fin de recoger sus aportaciones. Un sistema de indicadores respaldado por un proceso participativo, sería de gran interés para incentivar la implicación y corresponsabilidad de los distintos actores en el seguimiento de los objetivos a través de dichos indicadores.

3. También se propone como nueva línea de investigación el desarrollo de un modelo dinámico cuantitativo integral del SSEMM para 1) comprender en detalle las interacciones en los distintos componentes del sistema, así como las sinergias y efectos contrapuestos entre los diferentes indicadores de sostenibilidad y 2) explorar diferentes escenarios de gestión con el fin de evaluar la contribución relativa de diferentes medidas y combinaciones de medidas a los objetivos específicos de sostenibilidad, como herramienta para mejorar los procesos de toma de decisiones en el SSEMM. Para ello, a partir del modelo cualitativo ya elaborado, la siguiente etapa de trabajo continuará con la formulación y verificación de un modelo cuantitativo del SSEMM. El modelo será aplicado para explorar un conjunto de escenarios cuya definición, continuando con una óptica de trabajo transdisciplinar, se llevará a cabo a través de talleres participativos con los diferentes actores.

9.4. Future lines of research

The results of this thesis clearly lead to new lines of future research, which are set out below:

1. A future line of continuity work is the holding of participatory workshops with the stakeholders to commonly discuss some of the results obtained in this thesis: 1) the qualitative model developed for the SESMM, 2) the needs and interests of the stakeholders, 3) their preferences regarding the management measures for the restoration of the system and 4) the consensus, dissent and conflicts that emerge. This future work with the stakeholders must also incorporate a perspective that analyzes and takes into account the existing power relations among the different stakeholders and how such relations can be adequately managed within a participatory process.

2. On the other hand, the proposed system of indicators, as already indicated, requires an iterative work in several phases that has not been completed. In a second phase, it is proposed to improve

the system of indicators through participatory workshops with a multidisciplinary group of experts, and later with the stakeholders, in order to collect and integrate their contributions. A system of indicators supported by a participatory process would be of great interest to encourage the involvement and co-responsibility of the different stakeholders in the monitoring of the objectives through the indicators.

3. The development of an integral quantitative dynamic model of the SESMM is also proposed as a new line of research to 1) understand in detail the interactions in the different components of the system, as well as the synergies and opposing effects among the different sustainability indicators and 2) explore different management scenarios in order to evaluate the relative contribution of different measures and combinations of measures to the specific sustainability objectives, as a tool to improve decision-making processes in the SESMM. To do this, based on the qualitative model already developed, the next work will continue with the formulation and verification of a quantitative model of the SESMM. The model will be applied to explore a set of scenarios whose definition, continuing with a transdisciplinary work perspective, will be carried out through participatory workshops with the different stakeholders.

APPENDICES

Appendix I.
Survey

Dear,

From the University of Alcalá in collaboration with the University of Florida (USA), we are carrying out a study to know the current situation and changes in the Mar Menor basin in relation to changes in land use and its effects. The objective is to quantify and identify the current state of the main land use changes such as the urban tourism sector (Block I) and agricultural sector (Block II), as well as its impacts on the Mar Menor basin and how these have changed over time. It is also intended to have a diagnosis of the current state of the water resource (Block III) and environmental values and ecosystem services (Block IV), because of its importance to the surrounding community. Your participation, anonymous, is very important for this research, as well as for your community and the improvement of the situation in the Mar Menor and its surroundings.

Thank you in advance for your collaboration.

Regards,

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Block I. Urban tourist development

Q1. Do you think that the current urban tourist development of the Mar Menor area is adequate?

□ Yes

□ No. Should be developed more.

□ No. It is too crowded.

Q2. How do you assess the current tourist quality of the Mar Menor area?

□ Very good.

□ Good.

□ Acceptable.

□ Regular.

□ Bad.

Q3. What aspects have you taken into account to make your assessment? Order them from 1 to 3 in order of importance, without repeating the assessments, with 1 being the most important and 3 being least important. Put 0 if you have NOT taken it into account.

□ Ecological aspects (Landscape, water quality of the Mar Menor lagoon and nature).

□ Economic aspects (Affordable travel, lodging and hotel services costs).

□ Social aspects (Cultural offer, leisure, available health services, tranquility).

□ Others. Which one?

Q4. Indicate how you would place the tourism quality of the Mar Menor basin compared with the tourism quality in Spain according to the following aspects, taking into account: 1 = on the average, 2 = above the average, 3 = below the average, 4 = I do not have elements of comparison. Do not give the same value to different aspects.

Q4_1. Ecological aspects (Landscape, water quality of the Mar Menor lagoon and nature).

□ Average.

□ Above.

□ Below.

□ I do not have elements of comparison.

Q4_2. Economic aspects (Affordable travel, accommodation and hotel services costs).

□ Average.

□ Above.

□ Below.

□ I do not have elements of comparison.

Q4_3. Social aspects (cultural offer, leisure, health services available).

□ Average.

□ Above.

□ Below.

□ I do not have elements of comparison.

Q5. Do you think there is a need for improvements in the urban tourist development of the Mar Menor area?

□ Yes (In this case, answer question 6).

□ No

Q6. What aspects and measures need an urgent improvement in the urban tourist development of the Mar Menor area? Order them from 1 to 10 in order of importance without repeating the assessments, with 1 being the most important and 10 the least important. Put 0 for that activity that you DO NOT want done.

Q6_1. Urban moratorium.

Q6_2 Improve the management and protection of the natural areas around the Mar Menor, coastal wetlands and free areas of buildings.

Q6_3 Greater construction of hotels.

Q6_4 Greater offer of second homes.

Q6_5 Remodeling built buildings for an improvement of tourist image.

Q6_6 Improvement of the bike lane and spaces adapted for walking and sports.

Q6_7 Improvement of the public transport network.

Q6_8 Improvement of the infrastructure for road traffic.

Q6_9 Improvement of accessibility to urbanizations and beaches.

Q6_10 Improvement of parking.

Q6_11 Other. Which one?

Block II. Agricultural activity

Q7. How do you assess the existing agricultural activity in the Mar Menor basin in terms of its economic importance? Check ONE option.

□ Irrigated agriculture is essential for economic development in the Mar Menor area.

□ Irrigated agriculture is a relatively important sector, although it does not generate the greatest economic wealth of the Mar Menor area.

□ Irrigated agriculture does not contribute significantly to the general wealth of the Mar Menor area.

Q8. How do you assess the existing agricultural activity in the Mar Menor basin in terms of its social importance? Check ONE option.

□ Irrigated agriculture is very important because of the quantity and quality of the employment it generates. Irrigation is a guarantee of present and future for the surrounding population.

□ Irrigated agriculture generates many jobs, but employment is not quality or a guarantee for the future.

□ Irrigated agriculture is in the hands of large companies that create scarce and precarious employment.

Q9. What is your assessment of the environmental impacts caused by the agricultural activity of the Campo de Cartagena on the Mar Menor lagoon? Check ONE option.

□ Agriculture does not generate environmental impacts.

□ Agriculture needs fertilizers and phytosanitary products, but its environmental effect is not considerable.

□ Agriculture is causing pollution of the Mar Menor lagoon and measures are needed to reduce the impact of agriculture and the use of pesticides and fertilizers.

□ The intensive agriculture of the Campo de Cartagena is the main responsible for the current eutrophic state of the Mar Menor lagoon. The sector must assume its share of co-responsibility, and the polluter-pays principle.

Q10. What effects does irrigated agriculture have on the Mar Menor lagoon and the value of its surroundings? Check ONE or SEVERAL options.

□ Pesticide and fertilizer pollution.

□ Negative impact due to the degradation of the landscape.

□ Negative effects on recreational and leisure uses of the Mar Menor lagoon.

□ Negative effects on other economic sectors such as tourism (Tourism quality).

□ Positive effect because people like to see the irrigated crops of Campo de Cartagena.

□ There is no effect.

□ Others. Which one?

Q11. Do you think that the entry of nutrients into the Mar Menor lagoon should be limited?

□ Yes. (In this case, answer question 12).

□ No.

Q12. What measures would you use to limit the entry of nutrients into the Mar Menor lagoon? Order them from 1 to 9 in order of importance without repeating the assessments, with 1 being the most important measure and 9 the least important. Enter 0 for that activity that you DO NOT want done.

Q12_1. Reduce the irrigated area.

Q12_2. Elimination of irregular uptake of groundwater.

Q12_3. Require that each desalinator includes a brine treatment.

Q12_4 Establish and monitor the application of maximum values of fertilizer contribution.

Q12_5 Collect the brines and pour them into the Mediterranean Sea.

Q12_6. Collect the brines and part of the flows of the waters of the ramblas and after its dislocation, pour its reject flows into the Mediterranean Sea.

Q12_7 Build a green filter to treat the flow of the Albujón watercourse (“rambla”)

Q12_8 Apply natural measures of water and nutrient retention at plot scale and in the basin as a whole (example: green hedges, small ponds, etc.).

Q12_9 Recover and enhance the lost surface of natural wetland in the periphery of the lagoon.

Q12_10 Other. Which one?

Block III. Water resources

Q13. Indicate what is the economic activity in the Mar Menor and its basin that requires more water. Order from 1 to 3, with 1 being the one that requires more water and 3 requiring less water.

□ Agriculture.

□ Urban tourist consumption.

□ Industry.

Q14. Do you think that the water quality of the lagoon is good?

□ Yes, the water quality is good.

□ Yes, water quality is good despite specific episodes of pollution.

□ No, the water quality in the lagoon is no longer good.

Q15. What do you think is the main cause of water pollution in the Mar Menor lagoon? Order from 1 to 3 in order of importance, with 1 being the most important and 3 the least important.

Q15_1. Discharges spills.

Q15_2 Discharges of agriculture.

Q15_3. Discharges of urban-tourist wastewater.

Q15_4. None of the discharges is relevant.

Q16. Who do you think is the main responsible with regard to water pollution by nutrients in the Mar Menor lagoon? Check ONE option.

□ Many of the farmers with little responsible use of fertilizers.

□ The autonomous public administration (Ministry of water, agriculture and environment) and state (Segura Hydrographic Confederation), for its insufficient control and monitoring of agricultural activity in general, and the uses of water.

□ Agricultural technical advisors for their insufficient involvement or training in low-impact agricultural techniques (for example, in organic farming techniques, etc.).

□ Others. Which one?

Q17. What would be the main problems caused by the loss of water quality in the lagoon? Order them from 1 to 5 in order of importance without repeating the assessments, with 1 being the most important and 5 the least important. Put 0 with the option you do not agree with.

□ The loss of quality of bathing water (cloudy water, etc.).

□ The loss of species and habitat most characteristic of the Mar Menor.

□ Impacts on tourism quality and the image of the Mar Menor, with the arrival of fewer visitors.

□ Changes and reduction of the fishing catch of usual species of the Mar Menor.

□ Problem of legal breach at regional, state and European level.

□ No additional problems generated by the loss of water quality.

Q18. Do you think that climate change can improve or worsen the state of the lagoon?

□ Yes, climate change can make it worse.

□ Yes, climate change can improve it.

□ I do not think it affects.

Q19. What measures would be applied to improve the water quality status in the Mar Menor lagoon? Check ONE option.

□ Eliminate or reduce the entry of nutrients from the basin.

□ Expand communication channels with the Mediterranean.

□ Apply direct intervention measures within the lagoon (supply of oxygen, promote filtering species in the lagoon, etc.).

□ I would not apply any measure.

□ Others. Which one?

BLOCK IV. Environmental values and ecosystem services of the Mar Menor lagoon

Q20. Do you think that the Mar Menor lagoon has relevant environmental values and ecosystem services?

□ Yes. (In this case, answer question 21).

□ No.

Q21. What are the most relevant environmental values and ecosystem services of the Mar Menor lagoon? Order them from 1 to 4, without repeating the assessments, with 1 being the most important and 4 the least important. Enter 0 with the option that you do not agree with.

Q21_1. Fishing Production.

Q21_2 Biodiversity conservation of the lagoon and the surrounding wetlands.

Q21_3 Sports / recreational activities healthy, tourist and leisure.

Q21_4 Cultural identity and quality of life.

Q21_5 Others. Which one?

Q22. Do you think that the environmental values and ecosystem services of the Mar Menor lagoon are threatened?

□ Yes. (In this case, answer question 23).

□ No.

Q23. Which of these environmental values and ecosystem services are most threatened? Order them from 1 to 4, without repeating the assessments, with 1 being the most threatened service and 4 the least threatened service. Enter 0 with the option that you do not agree with.

Q23_1. Fishing Production.

Q23_2 Biodiversity conservation of the lagoon and the surrounding wetlands.

Q23_3. Sports/recreational activities healthy, tourist and leisure.

Q23_4 Cultural identity and quality of life.

Q23_5 None of the values and services are threatened.

Q23_6. Others. Which one?

Block V. Respondent information

• How old are you?   years

• Gender: □ Male □ Female

• What is your level of education?

□ Basic studies.

□ Secondary.

□ Professional training (FP, Modules).

□ University.

□ Postgraduate (Master, Doctorate).

• Place of habitual residence.

• If you live in the basin or surroundings of the Mar Menor, how long have you lived in the Mar Menor environment?   Years

• What is your current occupation and main economic activity?

□ Fishing.

□ Agriculture. If you are a farmer, do you have an irrigation system? □ Yes □ No

□ Livestock

□ Tourism: (Hotels and restaurants).

□ Tourism: (Services).

□ Industry.

□ Construction.

□ University student or other similar levels.

□ Professor or researcher.

□ Administration

□ Others. Which one?

• What relationship does it have with the Mar Menor and the surrounding wetlands?

□ Resident.

□ Regular visitor.

□ Sporadic Visitor.

□ No visitor.

• Do you participate in any association?

□ Association of sports activities.

□ Neighborhood association.

□ Social or cultural association.

□ Association related to the Environment.

□ I do not participate in any association.

Appendix II.

Interview with experts

Universidad de Alcalá UF UNIVERSITY of FLORIDA IFAS
Fort Lauderdale
Research & Education Center

Dear,

From the University of Alcalá in collaboration with the University of Florida (USA), we are carrying out a study to know the current situation and changes in the Mar Menor basin in relation to land use changes and its effects. The objective is to quantify and identify the current state of the main land use changes such as the urban tourism and agricultural sectors, as well as their impacts on the Mar Menor basin and how these have changed over time. It is also intended to have a diagnosis of the current state of the water resource and of the environmental values and ecosystem services, due to their importance for the surrounding community. Given his experience, his participation, completely anonymous, is very important for this research, as well as for his community and the improvement of the situation in the Mar Menor and its surroundings.

Thank you in advance for your collaboration.

Regards,

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Current situation and changes in the Mar Menor basin

1. What are the main processes (ecological, social, economic) that affect the current socio-ecological crisis in the Mar Menor?

2. As an expert, what solutions could be provided?

3. Who are the main stakeholders in the basin and what are their roles?

4. What is the central and mobilizing problem perceived by the different stakeholders in the Mar Menor basin?

5. Regarding the solutions mentioned in question 2, which stakeholders (individuals or groups) could contribute to implement those solutions or would they be potential allies to implement those solutions?

Respondent information

- Identify your scientific-technical area of experience or knowledge in relation to the Mar Menor theme.

- What is your relationship with the Mar Menor?

Appendix III.

Interview with stakeholders

Dear,

The Mar Menor socio-ecological system (SESMM) is facing a serious environmental degradation, which is generating significant economic and social costs. Faced with this situation, it is necessary to search for management measures with an integrated approach from the different groups of stakeholders involved with the common objective of improving their environmental and socioeconomic situation. From the University of Alcalá in collaboration with the University of Florida (USA), we carried out an interview between the months of February to May 2017 to find out the social perception of the Mar Menor area on the pressures, impacts and possible measures to adopt to improve the current situation of the SESMM and a list of preferred measures was obtained to 1) improve the urban-tourist development of the Mar Menor and 2) limit the entry of nutrients into the Mar Menor lagoon. Given your position as a stakeholder and experience, we want to know your opinion regarding the order of preference of these selected management measures and your perception of the SESMM diagnosis. Your participation, anonymous, is very important for this research, as well as for your community and the improvement of the situation in the Mar Menor and its surroundings.

Thank you in advance for your collaboration.

Regards,

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1. What is the central and mobilizing problem that, as a stakeholder, you perceive in the socio-ecological system of the Mar Menor (hydrographic basin, lagoon and surrounding wetlands)?

2. The following management measures to improve urban-tourist development in the Mar Menor were rated according to their level of importance on a scale of 0 to 100. Update these ratings according to your knowledge.

1º) Improve the public transport network	74%
2 º) Do not make a greater offer of second homes	100%
3 º) Improve the bike lane and the spaces adapted for walking and sports	30%
4 º) Do not carry out a greater construction of hotels	1%
5 º) Improve the management and protection of natural areas around the Mar Menor, coastal wetlands and free areas of buildings	16%
6º) Remodeling built buildings for an improvement of tourist image	55%
7º) Improvement of parking areas	52%
8º) Improvement of the infrastructure for road traffic	14%
9º) Improvement of accessibility to urbanizations and beaches	19%
10º) Urban moratorium	16%

Others. Which ones?

3. The following management measures to limit the entry of nutrients into the Mar Menor lagoon were rated according to their level of importance on a scale of 0 to 100. Update these ratings to the best of your knowledge.

1º) Establish and monitor the application of maximum values of fertilizer contribution	47%
2º) Elimination of irregular uptake of groundwater	60%
3º) Require that each desalinator includes a brine treatment	64%
4º) Apply natural measures of water and nutrient retention at plot scale and in the watershed	52%
5º) Reduce the irrigated area	100%
6º) Do not collect the brines and pour them directly into the Mediterranean Sea	13%
7º) Recover and enhance the lost surface of natural wetland in the periphery of the lagoon	53%
8º) Build a green filter to treat the flow of the Albujón watercourse	22%
9º) Collect the brines and part of the flows of the waters of the "ramblas" and after their dislocation and denitrification pour their reject flow into the Mediterranean Sea	1%

Others. Which ones?

Are you totally sure of the ratings you provided for each measure? Review the qualifications, and if necessary, update the ones you consider.

Appendix IV.

Stakeholders characterization and their relationship with the social-ecological system

Table 6.4. Identification and characterization of stakeholders. Source: own elaboration from interviews with experts.

Stakeholder groups	Who are they?	What do they do?	What do they perceive?	What do they propose?
Public administration (National, Regional and Local)	Government agencies responsible for the management of the territory, the uses and activities that take place there and the conservation of the environment	National administration (Confederación Hidrográfica del Segura): it has not carried out a minimum control over the use of water in the watershed, it has not intervened in the development of new agricultural infrastructures, it has not controlled the dumping of brines with high nitrate content into awtercourses, especially that of Albujón. -Regional administration (Ministry of Water, Agriculture and Environment): it has not carried out any control over land uses, it has not implemented measures against erosion, it has not established the distance limits to the lagoon to which it can be cultivated, It has not carried out any control on the use of fertilizers and fertilizers until the current regulations have been released to the public, the Management Plans that the SESMM is endowed with have not been developed.	-Regional administration: Socio-environmental impact in the SESMM. -Local administration: does not take seriously the current deterioration of the lagoon. Try to get the best economic return to the lagoon not always taking environmental care as a priority.	It is forced to take urgent action, although without quite knowing in which direction. The regional Administration created a social participation committee and a scientific committee for advice on making decisions on the management of the SESMM.

		-Local Administration (Town Halls): has carried out harmful practices on the lagoon such as; the poor regeneration of beaches and the dredging operations that it carries with it, have protected business sectors such as agriculture and construction sectors with a short-term economy against the protection of natural heritage as a guarantee of a sustainable future in the medium and long term.		
Agricultural sector	Influential primary sector in the society and economy of the SESMM, as well as in the political groups. There are two different groups, the farmer who manages his land and the multinational or large company that rents it.	Intensive irrigated agricultural activities that have had and continue to have a significant environmental impact on the lagoon, wetlands and watershed. Management and regulatory measures have not been applied to reduce the impact. They do not assume that resources and physical space are limited.	It is in the process of accepting its responsibility for the environmental degradation of the SESMM, especially the lagoon, but the sector lacks the organizational tradition to adopt coordinated and effective responses. The sector believes that they are in the crosshairs and there is negative publicity for their activity among society. But they do not believe that they are the only ones responsible for the deterioration of the	The sector considers that the solutions should be adopted by the administration and should not affect the reconversion of its activities. They are reluctant to change current cultivation practices. The farmer who manages his land is available to take measures for recovery, while the multinational or large company that rents it, exploits the resources without respect for the ecosystem.

			Mar Menor lagoon and watershed.	
Tourism sector	Influential sector in the society and economy of the SESMM. There are two groups, the one dedicated to hotels and restaurants, and the one dedicated to services.	They maximize profit. It has had and continues to have a relevant environmental impact on the lagoon and its surroundings due to its connection and/or promotion of unsustainable uses with its own business activity. They do not assume that resources and physical space are limited.	Decrease in the number of tourists. Reduction of income in the service sector. The sector does not acknowledge his share of blame and points to the agricultural sector as the only responsible for the degradation of the lagoon. It is one of the sectors that may experience the greatest loss in value if the current situation continues. The tourism sector dedicated to hotels and restaurants perceives the impact differently than service tourism.	It is still committed to short-term and future-proof solutions that are incompatible with improving the lagoon's environmental and tourist quality. They want the lagoon to have a suitable aspect for the development of its short-term activity and the regeneration of sandy beaches. There is no impact on diversification, new production niches based on sustainability or the circular economy.
Fishing sector	Economically marginal sector that constitutes a good indicator of environmental health and a key component of the identity of the lagoon, with an important potential for reconversion towards new forms of tourism.	It is a local, artisanal and traditional fishing, which operates with very particular and unique fishing gear from the lagoon itself.	Deterioration of the water quality of the lagoon. Changes in fishing catches of common species in the Mar Menor. Drop in product sales from the Mar Menor. Along with the tourism sector, it is one of the sectors most affected by the degradation of the lagoon.	They are in favor of adopting comprehensive measures for the recovery of the lagoon.
Construction and real estate sector	Influential economic sector in the SESMM society, as well as	The sector is waiting to recover after the bursting of the housing	The sector is aware of the situation of environmental degradation of the	New urban constructions and infrastructures when the real estate market

	one of the main drivers of change.	bubble to maximize profit.	SESMM in recent years, although due to the inactivity of the sector in this same period, it points out that the agricultural and tourist sectors are the main responsible for this situation.	recovers. Meanwhile the remodeling of buildings and infrastructure already built.
Academic sector	Universities and research centers that focus their scientific activity on the SESMM by carrying out different basic and applied research studies.	It constitutes a powerful source of knowledge about the SESMM, with diagnostic capacity, an integrated aporach of the situation and the proposal of reasonable and reasoned solutions. They are the ones that have alerted the administration to the degradation situation of the SESMM.	They show the urgent need for action on the main driving forces. The numerous human pressures are generating serious impacts on the SESMM, which puts its uniqueness and sustainability at risk in the medium and long term.	Search for urgent measures and actions with an integrated approach from the stakeholders involved with the objective of improving the socio-economic and environmental state of the SESMM.
Citizen platforms, NGOs	Neighborhood, sports, cultural and environmental protection associations.	They exert active social pressure on the complaint and evidence of the situation of the SESMM so that the administrations rush to take measures to solve the problems.	Loss of ecosystem services and quality of life. Failure to comply with current regulations, lack of coordination and effective measures, and social concern about the impact/deterioration situation in the lagoon and its watershed.	Protection of the lagoon, surrounding wetlands and its watershed. They demand action by the public administration.

Table 6.5. Relationship of stakeholder with the SES. Source: own elaboration from interviews with experts.

Stakeholder groups	Relationship with SES and its degradation	Main interest of the stakeholders	Main relationships between stakeholders

Agricultural sector	Intensive irrigated agricultural activities	High economic productivity in crops	Public administration: influence and votes for regional and local governments
Tourism sector	Demand for infrastructures and leisure activities	Maximize profit with uses and activities with the claim of associated infrastructures without considering that natural resources are limited. The sector demands a clean Mar Menor	Agricultural sector: sector responsible for environmental degradation in the SES. Administration: votes for the regional and local governments.
Construction and real estate sector	Urbanization and infrastructure development	New urban development and infrastructure	Local administration: maximize the benefit in relation to urban development. Agriculture and tourism sectors: sectors responsible for environmental degradation.
Fishing sector	Overfishing	Traditional fishing of local species with high economic value in the market	Agricultural, construction and tourism sectors: responsible for the eutrophication of the lagoon.
Academic sector	Exchange of scientific-technical knowledge	Generation of technical studies and scientific research in relation to regarding ecological and socio-economic aspects of the SES	Public administration: collaboration through analysis and evaluations with scientific and technical reports. All sectors: contribution through the generation of useful information
Public administration (National, Regional and Local)	Establishment of management policies: apply the regulations and sustainable management measures. Coordination between the three levels of administration	Define management strategies that integrate the interests of different stakeholders	Relationship with all sectors, especially with the economic sectors of agriculture, construction and tourism. Underlying economic interest.

NGOs, Citizen platform	Social pressure on the management of the SES to the administration and the economic sectors	Achieve sustainable development in the SSE. Apply the current legislation and regulations.	Public administration: social pressure to apply current regulations and report their non-compliance. Report illegalities or environmental damage. Agricultural sector, tourism sector and construction sector: inform civil society and institutional organizations about their uses and activities in the SES. Academic sector: disseminate scientific-technical studies in relation to the SES.

Appendix V.
Consulting experts on a system of sustainability indicators

Dear,

The situation of environmental degradation of the socio-ecological system of the Mar Menor (SESMM) is increasingly recognized and highlighted due to the deterioration of the Mar Menor coastal lagoon. Given the importance of monitoring sustainability in the SESMM through indicators and considering how citizens can participate or influence effectively in its management to improve governance, a proposal for a system of indicators has been developed that we want to improve based on consultation with different experts. The objective of this document is to describe the methodology followed to prepare the initial proposal of sustainability indicators for the SESMM. Given your experience, we would like to have your opinion and participation, absolutely anonymous, to achieve this objective.

Thanks in advance for your collaboration,

Regards,

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VALIDATION OF A SYSTEM OF SUSTAINABILITY INDICATORS FOR THE SOCIAL-ECOLOGICAL SYSTEM OF THE MAR MENOR (SESMM)

Environmental sustainability

Objective 1) Recover and preserve the good state of the water of the lagoon and aquifers

Does the water in the lagoon maintain good ecological status?

I1.1. Chlorophyll-a. Annual average concentration (µg/l) o (mg/m^3)

I1.2. Dissolved oxygen. Annual average concentration at different depth levels (mg/l)

Do we maintain the good chemical status of the aquifers?

I1.3. Nitrates. Annual average concentration in the Quaternary aquifer (mg/l)

I1.4. Pesticides. Annual average concentration in the Quaternary aquifer (mg/l)

Objective 2) Recover and conserve the species and habitats of the lagoon and its wetlands and the natural connectivity of the basin

Do we keep the habitats of the lagoon and its wetlands in good condition?

I2.1. Proportion of seabed occupied by *Cymodea nodosa* (%).

I2.2. Proportion of seabed occupied by *Zostera noltii* (%)

I2.3. Proportion of seabed occupied by *Ruppia cirrhosa* (%).

I2.4. Total wetlands area (ha)

I2.5. Total área dedicated to the production of salt (ha)

Do we keep the most unique species of the lagoon and its wetlands in good condition?

I2.6. Population evolution of *Hippocampus guttulatus*

I2.7. *Pinna nobilis* distribution (%)

I2.8. Population evolution of *Tarro blanco*

I2.9. Number of exotic species in the lagoon

Do we maintain the environmental connectivity of the basin?

I2.10. Basin natural connectivity index (connectivity of occupied areas by natural vegetation and other natural systems)

Objective 3) Recover the environmental functionality of the unbuilt surface of coastline

Have we preserved the original banks of the lagoon?

I3.1. Proportion of the coastline of the Mar Menor physiologically similar to the original shoreline (%)

Have we recovered the lost wetland area?

I3.2. Proportion of total wetland area that has been recovered (%)

Have we conserved the native natural vegetation in the undeveloped area?

I3.3. Proportion of unbuilt surface occupied by native species of the area (%)

Socioeconomic sustainability

Objective 4) Implement an environmentally and socially sustainable agricultural model

Are we reducing the irrigated area to more sustainable levels?

I4.1. Total irrigated area (ha)

Do we reduce the input of nitrogen and phosphorus from the upland watershed?

I4.2. Average contribution of nitrogen in agricultural crops (tn/ha/year)

14.3. Average contribution of phosphorus in agricultural crops (tn/ha/year)

Do we manage the basin in such a way that it is able to manage its own nutrients?

14.4. Nature-based solutions at the parcel scale

14.5. Nature-based solutions at the scale of basin

Are we promoting organic agriculture?

14.6. Proportion of irrigated land cultivated with organic farming systems (%)

14.7. Production of traditional varieties versus technified varieties (%)

Do we prioritize local agriculture?

14.8. Total production destined to supply international, national and regional markets (%)

Do we have a quality job in the agricultural sector?

14.9. Temporality and seasonality rate (%)

14.10. Average monthly salary (euros/month)

14.11. Average educational level of agricultural workers

Objective 5) Implement a sustainable and quality tourism model

Do we adequately manage urban wastewater?

I5.1. Annual number and/or volume of untreated discharges to the lagoon

I5.2. Average annual concentration of nitrogen and phosphorus in treated wastewater destined for non-agricultural purposes (mg/l)

Have we overcome the tourist seasonality?

I5.3. Tourist activity seasonality index

I5.4. Number of tourists by origin (tourist/country)

Have we implemented quality tourism?

I5.5. Ratio of tourists to the resident population (%)

I5.6. Tourist seasonality (%tourists/month)

I5.7. Tourists who repeat destination (%)

I5.8. Visitors satisfaction level

I5.9. Proportion of companies offering activities in nature (%)

Do we have a quality job in the tourist sector?

I5.10. Temporality and seasonality rate (%)

I5.11. Average monthly salary (euros/month)

I5.12. Average educational level of workers

Objective 6). Sustainable local development

Do we have diversified and balanced local economy?

I6.1. Relative contribution of the different economic sectors to the local economy of the municipalities that make up the SESMM (%GVA)

Institutional sustainability

Objetivo 7) Implement a model of polycentric, adaptive and participatory governance

Are all the stakeholders (public administration, economic sectors, academia, social and citizen organizations) included in an equitable way in the SESMM management model and in the decision-making processes?

I7.1. Proportion of members of each type of stakeholder in the management and public participation institution related to SESMM (%)

I7.2. Proportion of legislative changes, programs, etc. who are consulted in the public participation institution in their initial phase (%)

I7.3. Public access to information on the SESMM (measures in application and their results, scientific reports, monitoring results, etc.)

Are the objectives and measures for the management of the SESMM reviewed cyclically?

I7.4. Average degree of implementation of the measures (%)

I7.5. Average degree of effectiveness of the implanted measures in reaching the planned objectives (%)

I7.6. ¿ Is there a procedure for the review and continuous improvement of the objectives and measures of the SESMM?

Is there coordination among administrations and adequate participation of the stakeholders?

I7.7. Is there just one representation of the public administration in the social participation councils?

I7.8. Do we have a scientific advisory institution that gathers the best scientific knowledge available around the SESMM and advises on the different subjects independently?

Appendix VI.

Regulatory framework

Most relevant international, European, state and regional legislation in the SESMM

International

Convenio sobre los Humedales de Importancia Internacional (Convenio Ramsar, 1971).

Convenio para la protección del Medio Marino y de la Región Costera del Mediterráneo (Convenio de Barcelona). Protocolo relativo a la GIZC del Mediterráneo, 2011.

European

Recomendación del Parlamento Europeo y del Consejo, de 30 de mayo de 2002, sobre la aplicación de la Gestión Integrada de las Zonas costeras de Europa.

Directiva 91/271/CEE del Consejo, de 21 de mayo, sobre el Tratamiento de las Aguas Residuales Urbanas.

Directiva 91/676/CEE del Consejo, de 12 de diciembre de 1991, relativa a la protección de las aguas contra la contaminación producida por nitratos utilizados en agricultura.

Directiva 92/43/CEE del Consejo, de 21 de mayo de 1992, relativa a la conservación de los hábitats naturales y de la fauna y flora silvestre.

Directiva 2000/60/CEE del Parlamento Europeo y del Consejo, de 23 de octubre de 2000, por la que se establece un marco comunitario de actuación en el ámbito de la política de aguas

Directiva 2008/1/CE del Parlamento y del Consejo, de 15 de enero relativa a la prevención y al control integrado de la contaminación.

Directiva 2008/56/CE, de 17 de junio de 2008, sobre la estrategia marina.

Directiva 2009/147/CE, de 30 de noviembre de 2009, relativa a la conservación de las aves silvestres.

Directiva 2014/89/UE del Parlamento Europeo y del Consejo, de 23 de julio de 2014, por la que se establece un marco para la ordenación del espacio marítimo.

State

Artículo 45 de la Constitución Española

Ley 22/1988, de 28 de julio, de Costas.

Real Decreto 261/1996, de 16 de febrero sobre protección de aguas contra la contaminación por nitratos procedentes de fuentes agrarias.

Real Decreto Legislativo 1/2001, de 20 de julio, por el que se aprueba el texto refundido de la Ley de Aguas.

Ley 3/2001, de 26 de marzo, de Pesca Marítima del Estado.

Ley 16/2002, de 1 de julio, de prevención y control integrados de la contaminación.

Real Decreto 435/2004, de 12 de marzo, por el que se regula el Inventario nacional de zonas húmedas.

Ley 27/2006, de 18 de julio, por la que se regulan los derechos de acceso a la información, de participación pública y de acceso a la justicia en materia de medio ambiente.

Ley 4/2007, de 16 de marzo, de Patrimonio Cultural de la Comunidad Autónoma de Murcia

Ley 42/2007, de 13 de diciembre, del Patrimonio Natural y de la Biodiversidad.

Real Decreto 903/2010, de 9 de julio, de evaluación y gestión de riesgos de inundación.

Ley 41/2010, de 29 de diciembre, de protección del medio marino.

Ley 11/2012, de 19 de diciembre de medidas urgentes en materia de medio ambiente.

Ley 2/2013, de 29 de mayo, de protección y uso sostenible del litoral.

Real Decreto 876/2014, de 10 octubre, por el que se aprueba el Reglamento General de Costas.

Regional

Ley Orgánica 4/1982, de 9 de junio, de Estatuto de Autonomía para la Región de Murcia.

Ley 3/1987 de 23 de abril, de protección y Armonización de usos del Mar menor.

Ley 4/1992, de 30 de julio, de ordenación y protección del territorio de la Región de Murcia.

Ley 7/1995, de 21 de abril, de la fauna silvestre, caza y pesca fluvial.

Ley 3/1996 de 16 de mayo, de Puertos de la Comunidad Autónoma de la Región de Murcia.

Ley 11/1997, de 12 de diciembre, de Turismo de la Región de Murcia.

Ley 3/2000, de 12 de julio, de Saneamiento y Depuración de aguas residuales de la Región de Murcia e implantación del canon de saneamiento.

Orden 20 de diciembre de 2001, por la que se designan las zonas vulnerables a la contaminación por nitratos procedentes de fuentes agrarias en la Comunidad Autónoma de la Región de Murcia.

Orden de 3 de diciembre de 2003, de la Consejería de Agricultura, Agua y Medio Ambiente por la que se aprueba el código de buenas prácticas agrarias de la Región de Murcia.

Ley 2/2007, de 12 de marzo, de Pesca Marítima y Acuicultura de la Región de Murcia.

Ley 4/2007, de 16 de marzo, de Patrimonio Cultural de la Comunidad Autónoma de Murcia.

Decreto Nº 133/2008, de 30 de mayo, sobre Proyectos y Ejecución de Obras en Materia de Ordenación del Litoral.

Orden de 3 de marzo de 2009, de la Consejería de Agricultura y Agua por la que se establece el programa de actuación sobre la zona vulnerable correspondiente a los Acuíferos de Cuaternario y Plioceno en el área definida por la zona regable oriental del Trasvase Tajo-Segura y el Sector litoral del Mar Menor.

Ley 11/2009, de 11 de marzo, de Transporte Marítimo de Pasajeros de la Región de Murcia.

Ley 4/2009, de 14 de mayo, de Protección Ambiental Integrada.

Orden de 27 de junio de 2011, de la Consejería de Agricultura y Agua, por la que se modifica la Orden de la Consejería de Agricultura de 3 de marzo de 2009, por la que se establece el programa de actuación sobre la zona vulnerable correspondiente a los acuíferos cuaternario y plioceno en el área definida por zona regable oriental del trasvase Tajo-Segura y el sector litoral del Mar Menor (BORM Viernes, 5 de agosto de 2011, núm. 179).

Orden de 14 de junio 2012, de la Consejería de Agricultura y Agua por el que se establece un horario especial de calamento de las artes de pesca de la zona delimitada para el baño en el Mar Menor.

Orden de fecha 10 de noviembre de 2012, de la Consejería de Presidencia sobre la planificación integrada de los espacios Naturales de la Región de Murcia.

Resolución de 28 de julio por la que se dispone la publicación del acuerdo de Consejo de Gobierno sobre designación de los lugares de importancia comunitaria de la Región de Murcia.

Ley 13/2015, de ordenación territorial y urbanística de la Región de Murcia.

Real Decreto Legislativo 7/2015, de 30 de octubre, por el que se aprueba el texto refundido de la Ley de Suelo y Rehabilitación Urbana.

Decreto n.º 55/2015, de 17 de abril, de Declaración de Zonas Especiales de Conservación y -Aprobación del Plan de Gestión Integral de los espacios protegidos Red Natura 2000 del Noroeste de la Región de Murcia

Decreto-ley nº 1/2017 de sostenibilidad del mar menor.

Ley 1/2018, de 7 de febrero, de medidas urgentes para garantizar la sostenibilidad ambiental en el entorno del Mar Menor.

Decreto n.º 259/2019, de 10 de octubre, de declaración de Zonas Especiales de Conservación (ZEC), y de aprobación del Plan de gestión integral de los espacios protegidos del Mar Menor y la franja litoral mediterránea de la Región de Murcia

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