Evaluación ecosistémica del golfo de Cádiz:

análisis integral y descripción de procesos

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D. Marcos Llope, científico titular en el Centro Oceanográfico de Cádiz del Instituto Español de Oceanografía

Hace constar que la presente memoria de tesis doctoral titulada: Evaluación ecosistémica del golfo de Cádiz: análisis integral y descripción de procesos, presentada por el licenciado en Biología Gustavo Freire de Carvalho-Souza, ha sido realizada bajo mi dirección. Considerando que reúne todos los requisitos legales, autorizo su presentación y defensa para optar al grado de Doctor en Ciencias del Mar por la Universidad de Cádiz.

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Fdo.: D. Dr. Marcos Llope
En Cádiz, Septiembre de 2019

Dedico este trabajo a los boquerones, copépodos
y demás seres marinos

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RESUMEN

Los modelos y análisis de ecosistemas son herramientas importantes que pueden ayudar a las partes interesadas a comprender sistemas complejos y evaluar cómo estos sistemas responden a los posibles cambios del ecosistema. En la presente tesis doctoral, ha sido investigado el estado del ecosistema del golfo de Cádiz (GoC) y la evolución temporal de sus recursos marinos utilizando un enfoque multidisciplinar, que ha combinado modelación y análisis de integración de datos. Los resultados resaltaron una serie de puntos relevantes para los ecosistemas costero y marino: el ecosistema del GoC en los últimos 20 años ha pasado por muchos cambios, desde la forma como le vemos, su explotación, así como las medidas de protección. En este sentido ese estudio aporta información inédita a través del desarrollo de un análisis integral del ecosistema del GoC, describiendo la evolución temporal del ecosistema de forma holística y conjunta, analizando los efectos naturales y antropogénicos en su principal zona de cría, el estuario del Río Guadalquivir, y, por último, caracterizando la distribución espacio-temporal de la comunidad zooplanctónica. Finalmente, el presente estudio ha identificado futuras líneas de investigación que podrán ayudar en el desarrollo ambiental y socioeconómico, y buscar maneras más eficaces para maximizar la equidad y la sostenibilidad de los recursos marinos.

Palabras-clave: Enfoque ecossistémico, Análisis integral del ecosistema, Boquerón, Zooplancton, estuario del Guadalquivir, golfo de Cádiz

ABSTRACT

Ecosystem models and ecosystem analysis are important tools that can help stakeholders understand complex systems and assess how these systems respond to possible ecosystem changes. In the present thesis, the state of the Gulf of Cádiz (GoC) ecosystem and the temporal evolution of its marine resources have been investigated using a multidisciplinary approach, which has combined modeling and data integration analysis. The results highlighted a series of relevant points for the coastal and marine ecosystems: the GoC ecosystem in the last 20 years has undergone many changes, from the way we see it, its exploitation, as well as protection measures. In this sense, this study provides unprecedented information through the development of a comprehensive analysis of the GoC ecosystem, describing the temporal evolution of the ecosystem in a holistic way, analyzing the natural and anthropogenic effects in its main nursery area, the estuary of the Guadalquivir River, and finally, characterizing the spatio-temporal distribution of the zooplankton community. Finally, the present study has identified future lines of research that can help in environmental and socioeconomic development and seek more effective ways to maximize equity and sustainability of marine resources.

Keywords: Ecosystem approach, Integrated ecosystem analysis, Boquerón, Zooplankton, Guadalquivir estuary, Gulf of Cádiz

RESUMO

Os modelos e análises de ecossistemas são ferramentas importantes que podem ajudar as partes interessadas a compreender sistemas complexos e avaliar como estes sistemas respondem as possíveis mudanças do ecossistema. Na presente tese doutoral, investigou-se o estado do ecossistema do golfo de Cádiz (GoC) e a evolução temporal dos recursos marinhos utilizando uma abordagem multidisciplinar, que combinou modelagem e análises de integração de dados. Os resultados ressaltaram uma seria de pontos relevantes para os ecossistemas costeiro e marinho: o ecossistema do GoC nos últimos 20 anos passou por muitas mudanças, desde a forma que o observamos, sua exploração, assim como as medidas de proteção. Neste sentido, o presente estudo aporta informação inédita através do desenvolvimento de uma análise integral do ecossistema do GoC, descrevendo a evolução temporal do ecossistema de forma holística e conjunta, analisando os efeitos naturais e antropogênicos em seu principal berçário, o estuário do Guadalquivir, e por último, caracterizando a distribuição espaço-temporal da comunidade zooplanctónica. Finalmente, o presente estudo identificou futuras linhas de investigação que podem ajudar no desenvolvimento ambiental e socioeconômico, e a buscar maneiras mais eficazes para maximizar a equidade e a sustentabilidade dos recursos marinhos.

Palavras-chave: Abordagem ecossistêmica, Análise integral do ecossistema, Anchova, Zooplâncton, estuário do Guadalquivir, golfo de Cádiz

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LISTA DE ABREVIACIONES

CSIC - Consejo Superior de Investigaciones Científicas
EBFM - Ecosystem Based Fisheries Management
EBSA – Ecologically or Biologically Significant Area
EEZ - Economic Exclusive Zone
EFH - Essential Fish Habitats
FAO - Food and Agriculture Organization
GoC - Golfo de Cádiz
ICES - International Council for the Exploration of the Sea
IEA - Integrated Ecosystem Analysis
IEO - Instituto Español de Oceanografía
IFAPA - Instituto Andaluz de Investigación y Formación Agraria, Pesquera, Alimentaria y de la Producción Ecológica
ITA - Integrated Trend Analysis
MPA - Marine Protected Area
MSP – Marine Spatial Planning
ONG - Organización No Gubernamental
UNCLOS - United Nations Convention on the Law of the Sea

ORGANIZACIÓN DE LA TESIS

La presente tesis doctoral esta compuesta de 7 capítulos. El **primer capítulo** presenta una descripción general de la importancia de un enfoque basado en los ecosistemas y nuestro caso de estudio: el socio-ecosistema del golfo de Cádiz. Los capítulos 2, 3 y 4 que componen esta tesis han sido estructurados como artículos científicos, y como tal conservan la ordenación de este tipo de publicaciones (Introducción, Material y Métodos, Resultados, Discusión, Conclusiones y Referencias) y se encuentran en lengua inglesa.

Por lo tanto, por mas que cada capítulo puede ser independiente, existen algunas repeticiones, principalmente dentro de la descripción de los métodos y área de estudio. Además, algunos aspectos generales han sido abordados brevemente en los capítulos y, por esta razón, la introducción general de la tesis cuenta con una descripción en detalle del ecosistema y las investigaciones desarrolladas en el GoC.

El **segundo capítulo, "Climate, international politics and fishery regulation drive a whole marine ecosystem"** abarca un análisis integral del ecosistema del GoC. En términos de monitoreo y cumplimiento de la regulación de la pesca, el GoC, es uno de los ecosistemas marinos europeos más jóvenes en cuanto a regulación y estudio y, por lo tanto, ha tenido una rápida historia de presiones e impactos sobre sus recursos marinos. En ese capítulo analizamos el desarrollo temporal del ecosistema del GoC durante las dos últimas décadas y encontramos evidencias de cambio consecuencia de decisiones políticas. Nuestros hallazgos revelan la efectividad de las medidas de regulación realizadas para revertir un ecosistema degradado y caracterizado por la alta presión de la pesca y el dominio de las especies oportunistas a una configuración más estable, caracterizada por una mayor biomasa de especies de pequeños pelágicos y depredadores superiores. Esta primera evaluación holística del ecosistema demuestra que, si tomamos las medidas adecuadas para gestionar las pesquerías basadas en un enfoque ecosistémico, es posible aliar las actividades humanas con el mantenimiento de un ecosistema equilibrado, evitando así el colapso de los recursos marinos. Ese trabajo esta formateado a la revista "Ecology and Evolution".

de Carvalho-Souza, G.F., Torres, M.A., Ramos, F., Acosta, J.J., Farias, C., Sobrino, I., Llope, M. Climate, international politics and fishery regulation drive a whole marine ecosystem.

El trabajo dentro del **tercer capítulo**, "**Natural and anthropogenic effects on the early life stages of European anchovy in one of its Essential Fish**

Habitats, the Guadalquivir estuary”, se centra en la serie temporal del programa de seguimiento ecológico del estuario del Guadalquivir, donde se describe el importante papel de dicho estuario como zona de cría para numerosas especies marinas (usando como modelo el boquerón, que es la más importante pesquería en la región), y puede considerarse un hábitat esencial para peces (EFH). A pesar de la larga serie de datos existente (18 años), una evaluación empírica de cómo los cambios en las condiciones ambientales afectan la abundancia de los estadios tempranos de este pequeño pelágico y sus principales presas (los misidáceos) no se había realizado hasta la fecha. En este estudio, cuantificamos los efectos que los factores naturales y antropogénicos tienen en los juveniles del boquerón y tres especies de misidáceos en este EFH. Al final, discutimos los resultados en relación con las implicaciones que tienen para mantener este servicio de regulación y sugerimos “puntos de referencia” para aquellos factores clave del sistema que es posible gestionar. Este capítulo ha sido el primer trabajo de la presente tesis, publicado en 2018 en “Marine Ecology Progress Series”.

de Carvalho-Souza, G.F., González-Ortegón, E., Baldó, F., Vilas, C., Drake, P., Llope, M. Natural and anthropogenic effects on the early life stages of European anchovy in one of its Essential Fish Habitats, the Guadalquivir estuary. Marine Ecology Progress Series, Advance View, 2018

El cuarto capítulo, **“Gulf of Cadiz zooplankton: zonation, community structure and temporal variation”**, se centra en describir por primera vez, la composición del zooplancton, su variabilidad espaciotemporal y su relación con los factores ambientales usando métodos estadísticos clásicos pero robustos. En este trabajo, se ha realizado un gran esfuerzo para recuperar y compilar la información de muestras que se encontraban almacenadas en diferentes laboratorios alrededor de Cádiz. Entre los principales resultados, encontramos que el GoC presenta una alta diversidad de especies y que las “explosiones” de cladóceros (especialmente en los periodos de aguas cálidas) son una característica importante en la configuración de la distribución espacial de las comunidades, en particular en el área en frente a la desembocadura del río Guadalquivir. Como se ha descrito anteriormente, esta área es conocida por ser un EFH y nuestros resultados respaldan su singularidad, también desde la perspectiva del zooplancton. Estos hallazgos, además, en particular la zonificación, se muestran relevantes para la implementación de las Directivas de la UE, como la Directiva Marco de la Estrategia Marina (MSFD), la Planificación del Espacio Marítimo (MSP) y para las áreas protegidas como la red Natura 2000. Creemos, por lo tanto, que este capítulo es capaz de contribuir con una importante “pieza de puzle” para la comprensión del ecosistema del GoC y los resultados serán oportunos para el desarrollo de la gestión basada en el ecosistema en la región. Ese trabajo se encuentra en revisión en la revista “Progress in Oceanography”.

de Carvalho-Souza, G.F., Licandro, P., Vilas, C., Baldó, F., González, C., Jiménez, M.P., Llope, M. Gulf of Cadiz zooplankton: zonation, community structure and temporal variation. Artículo sometido a la revista Progress in Oceanography en 15/12/2018

CAPÍTULO 1. INTRODUCCIÓN GENERAL

1. INTRODUCCIÓN GENERAL

Los océanos y mares son los ecosistemas más grandes de nuestro planeta. Ellos son importantes reguladores de la variabilidad en el clima (Bigg et al. 2003), mediante su papel en procesos bioquímicos (p. ej. absorber gases de efecto invernadero; Reid et al., 2009) y, en albergar una gran variedad de complejos habitats – que nos brindan múltiples bienes y servicios (Constanza et al., 1997). Por consiguiente, soportan la economía mundial, la nutrición, la salud y el bienestar, el suministro de agua y energía.

En el pasado, debido a su magnitud, se pensaba que el océano era un vasto compartimento indefinidamente resiliente, capaz de absorber las múltiples presiones de la actividad humana. Sin embargo, a medida que la humanidad creció y se concentró a lo largo de las costas (p. ej. hoy en día más del 40% de la población mundial vive a menos de 100 km de la costa; Martínez et al., 2007), el estado de los hábitats costeros y marinos se ha ido deteriorando y su fauna (sobre todo de especies comerciales) se están reduciendo a niveles alarmantes (Pauly y Zeller, 2016a).

Estas huellas ecológicas han llevado a los científicos a debatir en los últimos años, si estamos viviendo en una nueva época geológica, el Antropoceno (Waters, et al., 2016). Entre las principales amenazas que impactan y/o afectan a los ecosistemas marinos actualmente se encuentran el cambio climático, las especies invasoras, las actividades marítimas comerciales (p. ej. transporte, navegación, petróleo y el gas), la contaminación y, las pesquerías (Figura 1; Halpern et al. 2008; 2015).

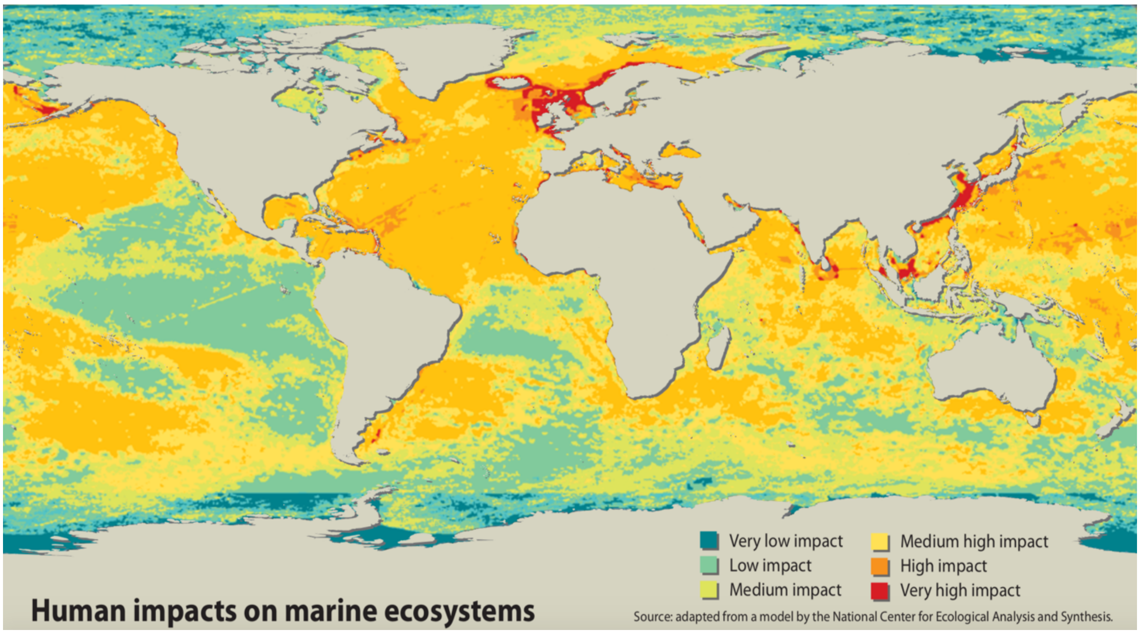

Fig. 1. Representación del impacto humano acumulado en los ecosistemas marinos (a partir de 2013; Halpern et al., 2015). Las puntuaciones de impacto se basan en 19 estresores antropogénicos (http://www.grida.no/publications/green-economy-blue-world/).

Los efectos de cualquiera de estos factores pueden ser tanto efectos directos, como el aumento de la mortalidad (por ej. esfuerzo pesquero), como efectos indirectos, a través de interacciones depredador-presa (Micheli 1999; Baum y Worm 2009). Además, esas relaciones causa-efecto de múltiples estresores son generalmente complejas, e incluyen una combinación de efectos aditivos y/o sinérgicos que pueden amplificar las respuestas ecológicas (Crain et al., 2008).

Por ejemplo, la pesca también contribuye al cambio climático: una reciente investigación estimó las tendencias globales de emisiones de CO_2 e intensidad de las emisiones de la combustión de combustible en la pesca marítima (Greer et al., 2019). Según este estudio, las emisiones totales de CO_2 del sector pesquero ascendieron de 47 millones emitidos en 1950 a los 207 millones de toneladas en 2016.

Otro impacto del sector pesquero en el clima estaría relacionado con las capturas de especies marinas de aguas profundas. Estas especies (p. ej. los peces mesopelágicos) son conocidas por realizar migraciones verticales para alimentarse en la superficie durante la noche, descendiendo de nuevo durante el día (Klevjer et al., 2016). Estas migraciones representan una vía directa para la transferencia de carbono de las aguas superficiales a las profundidades del océano, y, por lo tanto, indirectamente en la regulación climática (Davison et al., 2013; Trueman et al., 2014).

La pesca también deja su huella en los fondos marinos. Los aparejos de pesca perdidos o abandonados (p. ej. redes y líneas de pesca o anzuelos) pueden provocar daños como: la captura de especies objetivo y/o accesorias (impacto conocido como "ghost fishing"; Breen, 1990), incluyendo las que están amenazadas; el impacto físico sobre los hábitats bentónicos y; la introducción de materiales sintéticos en la cadena trófica (Macfadyen et al., 2009; NOAA, 2016; de Carvalho-Souza et al., 2018).

Por otro lado, el sector pesquero también puede tener un papel clave en la solución de algunas de estas amenazas. En la Bahía de Chesapeake, une reciente y exitosa experiencia consistió en la eliminación de material de pesca abandonado (nasas y alcatruces) por parte de los pescadores comerciales durante los periodos de cierre de las pesquerías, lo que resultó en ganancias de producción del 27% (21.3 millones de dólares) (Scheld et al., 2016). En la misma línea, la iniciativa "Fishing for Litter" en las rías de la costa gallega contaron con la participación de 152 arrastreros y otras embarcaciones artesanales (http://fishingforlitter.org/spain/) donde descargaron en el puerto toda la basura (p. ej. plásticos, redes y otros aparejos) recolectada en sus redes durante las operaciones regulares de pesca.

Otro buen ejemplo es el combate a la expansión del pez león, una especie invasora en el Atlántico occidental y el mar del Caribe. A través del incentivo a la pesca recreativa y al consumo del pez con la participación de investigadores, clubes de buceo, ONGs y otros sectores (p. ej. gastronomía), los programas regionales están teniendo éxito y resultando en una reducción significativa de la densidad local y la biomasa del invasor (Morris 2012; de León et al., 2013).

Por todo lo anterior, los impactos de cualquiera de estos factores, tales como la pesca, la contaminación o el clima, no deben tratarse de forma aislada en el estudio de los recursos marinos y el cambio global (Brander, 2007).

1.1. LA PESCA EN UN OCÉANO CAMBIANTE: DE LA SOBREEXPLOTACIÓN AL ENFOQUE BASADO EN LOS ECOSISTEMAS

Históricamente, las pesquerías se han caracterizado por la sobreexplotación salvo algunas excepciones (Fig. 2; Pauly and Zeller, 2016b). Esto ha provocado cambios profundos en la estructura y función de los ecosistemas marinos (Jackson et al., 2001; Worm et al. 2006). Algunos ejemplos del impacto directo e indirecto de las pesquerías ampliamente conocidos son el colapso del bacalao en el Atlántico noroccidental (Scheffer et al. 2005; Frank et al. 2005), el agotamiento de peces herbívoros debido a la pesca excesiva de tiburones en los arrecifes del Caribe y el descenso de la sardina en las costas del Pacífico (Chavez et al. 2003) y más recientemente de la Península Ibérica (ICES, 2019). O también en aguas ibéricas, el cierre de la pesquería de la anchoa del Cantábrico en los primeros años de 2000 (Irigoien et al., 2007; 2008).

Aunque los ejemplos del colapso de varios grupos tróficos son evidentes, el esfuerzo pesquero continúa aumentando mucho más allá de los niveles sostenibles (Pauly et al. 2002). Además, el crecimiento poblacional y la creciente popularidad del pescado en muchos países con economías desarrolladas o en rápido desarrollo (p. ej. miembros de la Unión Europea [EU], Estados Unidos, China y Japón) hace que la demanda sea cada vez mayor y los stocks dentro de sus caladeros históricos en sus zonas económicas exclusivas (EEZs) no sean capaces de satisfacerla (Pauly y Zeller, 2016b). Las EEZs son zonas delineadas por La Convención de las Naciones Unidas sobre el Derecho del Mar (UNCLOS, UN, 1982), y cada país es responsable por las actividades marítimas como la pesca sostenible dentro de sus aguas jurisdiccionales.

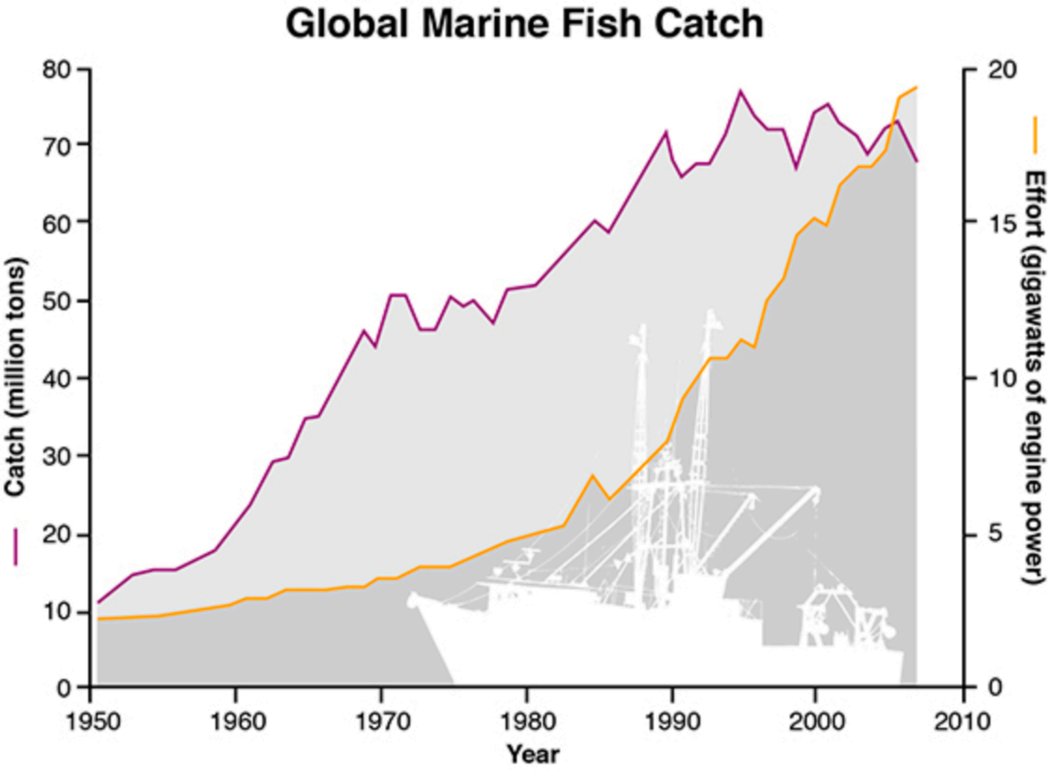

Fig. 2. Captura mundial de peces marinos desde 1950 hasta 2010 (Imagen del Proyecto Sea Around Us; http://www.seaaroundus.org). Más del 90% de las pesquerías evaluadas en el mundo han alcanzado o superado sus límites biológicos (FAO, 2014). La captura global de peces (línea púrpura) ha disminuido en los últimos años, a pesar de que las flotas están haciendo un mayor esfuerzo de captura (línea naranja).

De modo que, para satisfacer su mercado interno o mismo externo, muchos países tienen que recurrir a pesquerías más lejanas de sus costas, conocidas como "flotas de aguas distantes". En la EU, bajo la umbrela de su Política Pesquera Común (CFP), los países miembros han negociado acuerdos de pesca sostenible para sus flotas pesqueras, especialmente en aguas de países vecinos en desarrollo (Sustainable fisheries partnership agreements [SFPAs]; Le Manach et al. 2013). Sin embargo, a pesar de que estos acuerdos son beneficiosos para ambas partes (https://ec.europa.eu/fisheries/cfp/international/agreements_en), su entrada en vigor o incluso su suspensión, pueden desequilibrar y/o aumentar significativamente la presión de la pesca en los ecosistemas (capítulo 2).

Así, en un campo de juego "oceánico" cada vez más complejo y disputado, se hace necesario medidas rápidas pero eficaces. Esta necesidad ha motivado muchos científicos y demás actores implicados a impulsar una gestión más integrada y basada en los ecosistemas que reconoce los efectos interactivos y aditivos de los múltiples factores naturales y antropogénicos en los servicios ecosistémicos (McLeod y Leslie 2009; Link y Browman, 2014).

1. INTRODUCCIÓN GENERAL

En esto se basa, la gestión de la pesca basada en los ecosistemas (EBFM, sigla en inglés), un concepto que se introdujo como un enfoque holístico de la gestión de la pesca en la década de 1990. En particular, este concepto se convirtió en un “tema caliente de investigación”, después de la Conferencia de las Naciones Unidas sobre Medio Ambiente y Desarrollo (también conocida como Cumbre de la Tierra o “Rio92”) celebrada en Río de Janeiro en 1992.

El EBFM proporciona un marco para la toma de decisiones de los recursos marinos. Este enfoque interdisciplinar difiere del manejo convencional de los recursos en que se definen las estrategias y decisiones de gestión para el sistema y sus componentes en su conjunto (por ejemplo, puede reconocer sistemas socio-ecológicos acoplados), y no compartimentada o simplemente individualizada, tales como la gestión de una sola especie o cuestión (Leslie y McLeod, 2007; Levin et al., 2009; Long et al., 2015).

En este sentido, el uso de herramientas para el análisis integrado de la información ha avanzado en los últimos años con aplicaciones relacionadas tanto con la gestión de los recursos pesqueros como con la identificación de áreas prioritarias para la conservación (p. ej., véase en Bailey y Thompson, 2009; Levin et al., 2009; Möllmann et al., 2013; Halpern et al., 2015; Hao et al., 2015). Entre estas herramientas, las evaluaciones ecosistémicas integradas (IEA) son consideradas una de las más apropiadas por su naturaleza multisectorial (Levin et al., 2009; 2014), pero también por su característica adaptativa y innovadora, conceptuarla es un desafío (Dickey-Collas, 2014). Por otro lado, conceptuar las IEA son un desafio, una vez que pueden ser diseñadas para aplicaciones específicas de un sector marino en concreto (Link y Browman, 2014).

Diversos autores han dado diferentes definiciones de lo que es una evaluación integral de ecosistema (IEA), pero la idea central se mantiene. De acuerdo con Levin (2009) las IEAs son "una síntesis y análisis cuantitativo de información sobre procesos físicos, químicos, ecológicos y humanos relevantes en relación con objetivos específicos de manejo de ecosistemas". Dickey-Collas (2014) considera que el IEA es un "proceso que conduce a la provisión de un asesoramiento coherente y conjunto que aborda las necesidades de la sociedad para gestionar las presiones antropogénicas sobre el ecosistema marino". Las IEA abordan tres objetivos: (1) enfoque de posibles trayectorias del sistema natural y humano; (2) Desarrollo de cuestiones claves para la formulación de políticas y (3) mejorar la habilidad para identificar opciones políticas mas robustas (Levin et al., 2009; Long et al., 2015).

1. INTRODUCCIÓN GENERAL

Podemos considerar que las evaluaciones integradas son herramientas que proporcionan un marco de referencia para los ecosistemas, basado en la información y en el mejor conocimiento disponible destinado a facilitar el uso del espacio para la toma de decisiones y el desarrollo de políticas, o sea la EBFM.

La implementación de la EBFM es una prioridad actual tanto para la ciencia como para la política, siendo ampliamente destacada en la literatura (Möllmann et al., 2013), en la planificación institucional de la UE: Directiva Marco de la Estrategia Marina (MSFD, EC 2008), Política Marítima Integrada (IMP, EC 2011), Planificación Espacial Marítima (MSP, EC 2014a), Crecimiento Azul (EC 2014b), Política Pesquera Común (CFP, EC 2015), Directiva Marco del Agua (WFD, EC 2000), así como en políticas y obligaciones ambientales de nivel superior, como las resoluciones de Convenciones Marinas Regionales (RSCs), el Convenio sobre la Diversidad Biológica (CBD 2005) y la Organización de las Naciones Unidas para la Agricultura y la Alimentación (FAO, siglas en inglés).

Las evaluaciones integradas en los mares regionales son cada vez más necesarias, buscando conocer y entender los cambios y relaciones que ocurren en los ecosistemas a lo largo del tiempo, su biodiversidad, los servicios que proporcionan y los factores directos e indirectos que promueven los cambio, así como si las respuestas ofrecidas hasta el momento han sido las más adecuadas. Solo con esta base de conocimiento, los responsables de la formulación de políticas pueden tener las herramientas necesarias para tomar decisiones de gestión adecuadas con el fin de guiar una emergente “economía azul” más sostenible y adecuada, en el que todos los sectores costeros y marinos puedan contribuir al bienestar, la innovación y el crecimiento económico (Martin et al., 2015).

En este contexto y con el objetivo de desarrollar una evaluación ecosistémica, en esta tesis se presentan resultados de la aplicación de herramientas de modelado y análisis integral de ecosistemas en el golfo de Cádiz.

1.2. ÁREA DE ESTUDIO

1.2.1 GOLFO DE CÁDIZ Y ESTUARIO DEL GUADALQUIVIR

El golfo de Cádiz (GoC, de ahora en adelante) es el mar de la plataforma atlántica europea más austral, bordeado por la Península Ibérica (Portugal, España) y el continente africano (Marruecos). Su cuenca en forma de media luna (con unos 10.000 km^2) conecta el Océano Atlántico y el Mar Mediterráneo a través del Estrecho de Gibraltar. Este ecosistema alberga una alta biodiversidad y muchos sectores relacionados con el mar (turismo, transporte marítimo, industria naval, pesca) que abastecen a la economía local (Sobrino et al, 1994; Torres et al, 2013; Díaz del Río et al, 2014; Delacámara et al., 2015; Rueda et al., 2016; Llope, 2017) (Figura 3).

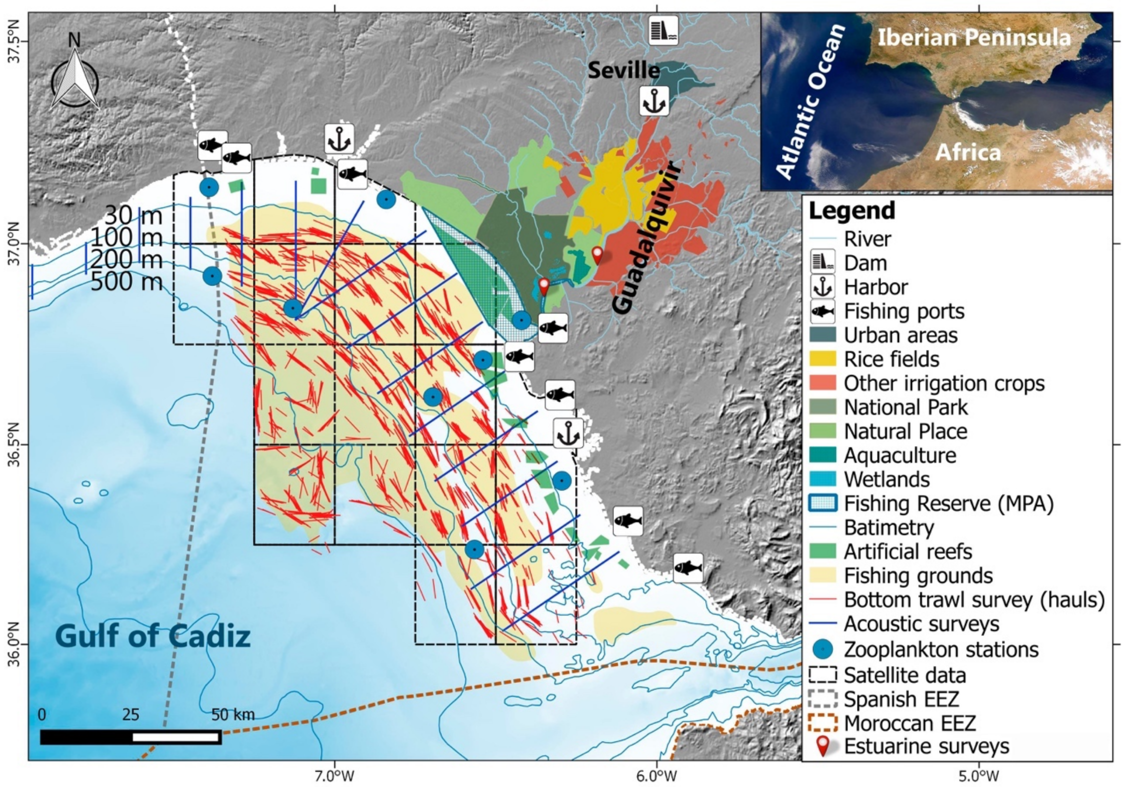

Fig. 3. Mapa del área estudiada en el golfo de Cádiz y estuario del Guadalquivir (SW España), donde se presenta las estaciones y zonas de muestreo, así como los principales usos terrestres y marinos.

Oceanográficamente, esta biodiversidad y las pesquerías asociadas están soportadas por una combinación única de factores, que incluyen: clima, eventos de afloramiento, mezcla de vientos, aguas mediterráneas y descargas de agua dulce de importantes ríos como el Guadalquivir, Tinto-Odiel y Guadiana (Relvas y Barton, 2002, García-Lafuente y Ruiz, 2007; Criado-Aldenueva et al., 2009; Sánchez-Leal et al., 2017).

La zona estuárica del río Guadalquivir, una de las principales cuencas de drenaje de Europa (650 km, 57.000 km^2), se considera un hábitat esencial para la puesta y/o el desarrollo juvenil de varias especies comerciales (por ejemplo, boquerón, sardina) (Baldó y Drake, 2002; González-Ortegón et al., 2015; Llope, 2017; de Carvalho-Souza et al., 2018, capítulo 3) y abarca un área marina protegida (MPA): la Reserva de Pesca de la desembocadura del río Guadalquivir (BOJA, 2004; Sobrino et al., 2005).

Por otro lado, esta conectividad también acentúa los riesgos asociados, ya que las actividades terrestres pueden afectar directa o indirectamente la dinámica ecológica marina (Halpern et al., 2008). A lo largo del bajo Guadalquivir, se cultivan grandes áreas para la producción de arroz, así como otros cultivos, que generan alrededor de 145 millones de euros anuales y una producción anual de más de 300 mil toneladas (Federación de Arroceros de Sevilla, 2016; http://www.federaciondearroceros.es). Además, la demanda y la gestión del agua en el estuario del Guadalquivir incluyen otros sectores, como el transporte marítimo y fluvial; por ejemplo, el puerto de Sevilla (4ª ciudad española) recibió 21.000 visitantes de crucero en 2016 (Junta de Andalucía, 2016a).

Por lo tanto, el flujo de agua dulce, regulado por la presa de Alcalá del Río (desde 1934), es un recurso crítico para los múltiples sectores y comunidades. Su regulación indudablemente aumenta los conflictos existentes por los recursos y el equilibrio de agua dulce del estuario, como el suministro de agua para la producción intensiva de arroz en comparación con la producción pesquera.

Los sectores dependientes del golfo en las provincias españolas que bordean el GoC (Cádiz y Huelva), generaron más de 100.000 empleos y aproximadamente € 19.437 millones, equivalente al 13% del producto interno bruto (PIB) regional en 2016 (Junta de Andalucía, 2016b; 2016c).

Las flotas pesqueras son muy diversificadas y se dirigen principalmente a las especies objetivo (por ejemplo, boquerón, sardina, merluza, pulpo, langostino, gamba, cigala) bajo una variedad de instrumentos regulatorios (Total de capturas permitidas - TAC y cuotas, planes de gestión para algunas especies clave, acuerdos bilaterales) regidos por el Reglamento del Consejo Europeo (bajo CFP). La actividad económica asociada con la producción pesquera se estima en al menos € 198 millones y, además, millones de turistas visitan, navegan y observan la vida marina a lo largo de la costa del GoC cada año (ver referencias anteriores). Sin embargo, esta alta productividad también está sujeta a crecientes presiones y usos competitivos, resultantes de los impactos negativos (como la pesca) en la red trófica y ecosistema del GoC (Torres et al., 2013; Llope, 2017).

A pesar de la clara importancia ecológica y socioeconómica de este ecosistema, ha venido sufriendo interferencias por numerosos estresores que probablemente tengan impactos aditivos o sinérgicos sobre las especies y el ecosistema (Ruiz et al., 2006; González-Ortegón et al. 2012; 2015; Torres et al., 2013; Llope, 2017). Además, en comparación con otros ecosistemas europeos (por ejemplo, el Mar Báltico, Mar del Norte), el GoC ha recibido poca atención en relación a su estructura y funcionamiento, los factores directos e indirectos de cambio, y la interacción entre el forzamiento climático y la influencia humana (Möllmann et al., 2009; Lindegren et al., 2012; Tomczak et al., 2013;

Blenckner et al., 2015). Por lo tanto, la identificación y comprensión de estos mecanismos y la escala de los cambios, y sus efectos potenciales sobre los componentes naturales y antropogénicos es crucial para implementar un enfoque basado en el ecosistema en cualquier ecosistema marino.

1.2.2 SERIES TEMPORALES

Las series temporales de datos proporcionan una información única del ecosistema adecuada para evaluar la dinámica espacio-temporal de las comunidades en respuesta al forzamiento ambiental (Beaugrand et al., 2003; Llope et al., 2012). Con estos datos en mano, es posible la aplicación de herramientas robustas (p. ej. modelos ecológicos y económicos, mistos y análisis integradas) capaces de predecir y comprender los efectos de los cambios ambientales y derivados de las actividades antropogénicas (p. ej. Fulton et al., 2011; Osterblom et al., 2013; Blenckner et al., 2015).

Desde el inicio de los años 90, el Centro Oceanográfico de Cádiz del Instituto Español de Oceanografía (IEO) viene desarrollando en asociación con instituciones académicas u otros organismos científicos (p. ej. Universidad de Cádiz, Universidad de Málaga, el Campus de Excelencia Internacional del Mar [CeiMar], Consejo Superior de Investigaciones Científicas [CSIC], Instituto Andaluz de Investigación y Formación Agraria, Pesquera, Alimentaria y de la Producción Ecológica [IFAPA], Centro Oceanográfico de Málaga) una serie de proyectos de investigación en el GoC con el objetivo de obtener datos sólidos e información necesaria para conocer ese ecosistema. Las series temporales usadas en la presente tesis doctoral se basan en estas investigaciones descritas en detalle a continuación.

En el año 1993 se realizó la primera de lo que ahora es una serie histórica de campañas de evaluación de recursos demersales de interés comercial que habitan los fondos arrastrables de la plataforma y el talud continental de la parte española del GoC (Arrastre demersal suratlántico Serie ARSA). Las campañas oceanográficas de ese proyecto se realizan anualmente, cubriendo los fondos blandos de la plataforma continental hasta el talud, entre 15 y 800 m de profundidad. Todos los lances se llevan a cabo durante las horas del día a una velocidad media de remolque de 3,0 nudos, utilizando una red de arrastre Baka 40/60 (con una cuerda de 43,6 m y 60,1 m). El muestreo aleatorio estratificado se aplica en 5 estratos de profundidad: a) 15-30 m; b) 31-100 m; c) 101-200 m, d) 201-500 m; e) 501-800 m (Silva et al. 2011). En el **capítulo 2** de la tesis se presenta los resultados de esta serie temporal en la primavera de los años 1993 hasta 2015 (un total de 876 lances, alrededor de 40 por año) a través de un análisis integral y se describen los métodos de clasificación y estimación de las especies. Más detalles de las características de los equipos y métodos de muestreo de la campaña se pueden encontrar en detalle en Silva et al. (2011), Torres et al. (2013) y en los informes técnicos de las campañas (IEO, 2018).

A partir del año 1997, un grupo de investigadores del IEO, CSIC y IFAPA iniciaron un proyecto de seguimiento ecológico a largo plazo del estuario del Guadalquivir con el objetivo de analizar el reclutamiento de especies de interés pesquero (peces y decápodos) y así establecer la importancia y función que desempeña dicho estuario como una zona de cría para muchas de las especies del GoC (p. ej. boquerón, anguila). La serie temporal usada en el **capítulo 3** de la tesis comprende el periodo de junio de 1997 hasta mayo de 2015.

La zona de estudio considerada en ese proyecto abarca los últimos 32 kilómetros del cauce principal del río Guadalquivir, medidos a partir de la desembocadura (Fig. 3), donde se encuentra la estación de Bonanza, ubicada cerca de la ciudad de Sanlúcar de Barrameda (provincia de Cádiz) hasta la zona conocida como Tarfía, situada en la provincia de Sevilla. Las capturas se realizaron desde un barco de pesca angulero tradicional usando un arte de pesca denominado arte de "persiana" que es usado tanto para la pesca de la angula (malla: 1 mm) como del camarón (malla: 1 cm). Dado que este es un método de pesca pasivo, los muestreos se realizan durante la luna nueva, para aprovechar la fuerza de las mareas vivas (cuando la velocidad de la corriente del agua es mayor) y, así obtienen una mayor efectividad en las capturas. Más detalles de los muestreos, clasificación y identificación de las especies son descritos(as) por Drake et al., 2007, González-Ortegón et al. (2012; 2015) y en el **capítulo 3**.

Desde el año 2001 se viene manteniendo una serie temporal centrada en un tercer componente del ecosistema: el medio pelágico. Tres de estos proyectos denominados GOLFO (2001-2004), FLUCTUACIONES (2005-2007) y STOCA (Series Temporales de Datos Oceanográficos en el Golfo de Cádiz; 2009-presente), han realizado muestreos sistemáticos de las comunidades planctónicas (ictio y zooplancton) en 5 radiales, distribuidas desde la desembocadura del río Guadiana hasta el estrecho de Gibraltar y con una periodicidad cuatrimestral (Fig. 1). En cada radial, dos estaciones (una más costera y otra más oceánica) fueron seleccionadas para analizar la comunidad zooplanctónica desde una perspectiva espaciotemporal. Para obtener las muestras, se utilizaron las técnicas clásicas para este grupo: arrastres oblicuos utilizando redes de tipo Bongo con un tamaño de malla de 200 µm (diámetro de la boca: 0,4 m) equipadas con dos medidores de flujo (General Oceanics 2030R). Los detalles del muestreo están descritos en el **capítulo 4**. En ese capítulo, se presenta los resultados de la compilación y análisis de esta primera descripción espacio-temporal de las comunidades zooplanctónicas del GoC, basada en la serie temporal más larga construida en ese ecosistema hasta la fecha.

1.3. OBJETIVOS

1.3.1 OBJETIVO GENERAL

La presente tesis doctoral tiene el objetivo de aportar información inédita sobre la estructura, funcionamiento y evolución histórica (de las últimas décadas) del ecosistema acoplado golfo de Cádiz-estuario del Guadalquivir a través del desarrollo de un análisis integral, modelado estadístico de procesos y descripción de componentes hasta ahora prácticamente desconocidos.

1.3.2 OBJETIVOS ESPECÍFICOS

- Desarrollar la primera evaluación integral del ecosistema del GoC inspirada en el análisis integral de tendencias (siglas en inglés, ITA) desarrollado en la ultima década por el Grupo de Trabajo ICES / HELCOM sobre Evaluación Integrada del Mar Báltico (WGIAB) (Möllmann et al., 2009; Diekmann y Möllmann, 2010; Levin y Möllmann, 2015), donde se incluyen también otras técnicas descriptivas tradicionales.

Esta evaluación del ecosistema busca estudiar las tendencias y el estado de los componentes ambientales y biológicos del sistema frente a los efectos naturales y derivados de actividades antropogénicas. La descripción de ese trabajo se encuentra en el capítulo 2.

- Modelado de los procesos del estuario del Guadalquivir.

El estuario del Guadalquivir como visto anteriormente tiene una influencia sobre los procesos en el GoC con una dependencia mutua para las pesquerías en cada contexto. Para esto se ha trabajado con la serie de datos con gran resolución a nivel individual descrita anteriormente, usando especies clave de la cadena trófica como los misidáceos, una especie de predador emblemática - el boquerón - y las variables ambientales que controlan directamente la abundancia y distribución de las especies estuáricas (Capítulo 3).

- Descripción de las comunidades zooplanctónicas, su variación espacial y temporal y la influencia de las variables climáticas y oceanográficas sobre las comunidades planctónicas;

A pesar de tener una base de datos sólida y continua para el GoC (como se puede ver en la sección 1.2.2), los estudios sobre comunidades de peces y hidrografía tenían prácticamente toda la atención hasta el momento, mientras que el zooplancton, aunque sea muestreado de forma rutinaria, no se ha explorado todavía como en otros ecosistemas europeos (Valdéz et al., 2007; Llope et al, 2011; Llope et al, 2012). Así que para contribuir al avance de esta información para el área de estudio se llevó a cabo la recuperación, procesado y análisis del zooplancton a partir de las muestras recogidas previamente por el IEO e instituciones colaboradoras para reconstruir la serie temporal e integrar esta información a la base de datos para evaluar el estado actual del ecosistema. Esta serie de datos de largo plazo ha permitido hacer la primera descripción espacial y temporal de la comunidad zooplanctónica del GoC (Capítulo 4).

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Capítulo 2. International politics must be considered together with climate and fisheries regulation as a driver of marine ecosystems

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2.1 ABSTRACT

Seafood is an essential source of protein globally and its demand continues to rise. Balancing food security and the health of marine ecosystems is a challenge. Ecosystem-based fisheries management (EBFM) has been adopted by the European Union (EU) Common Fisheries Policy (CFP) to meet this challenge by accounting for the multiple interacting natural and socio-economic drivers. The CFP includes both the implementation of regulatory measures to EU stocks and the establishment of bilateral fisheries agreements with developing countries, known as sustainable fisheries partnership agreements (SFPAs). While the effects of fisheries management regulations are well acknowledged, the consequences of the SFPAs on EU ecosystems have not commonly been considered. Here we investigate the development of the Gulf of Cadiz ecosystem over the last two decades and found evidence of the impact of both policy interventions. Our findings reveal the effectiveness of regulatory measures in reverting a progressively degrading ecosystem, characterised by high fishing pressure and dominance of opportunistic species, to a more stable configuration, characterised by higher biomass of small pelagics and top predators around 2005. Previously, knock-on effects of the EU-Morocco SFPA and climate marked the ecosystem changes at the end of the first decade, particularly, increased purse seine fishing effort, reduction of pelagic species and warm phases of climatic indices. This southern EU marine ecosystem has been one of the latest to introduce regulations and is very exposed to fishery agreements with neighbouring Morocco. Our study highlights the importance of taking into consideration, not only the effects of in situ fisheries regulations but also the indirect implications of political agreements in the framework of EBFM.

Keywords: Gulf of Cadiz, Integrated Ecosystem Assessment (IEA), ecosystem-based fisheries management (EBFM), Sustainable Fisheries Partnership Agreements (SFPA), regime shifts

2.2 INTRODUCTION

Marine ecosystems provide us with valuable services, contributing to nutrition, economic and socio-cultural well-being. Commercial fishing (alone) captures about 90 million tons of biomass per year, providing an essential source of protein to more than 3.1 billion people worldwide (FAO 2016). But fishing is also a top pressure on marine ecosystems. Fish stocks decline together with habitat loss, pollution and climate change are compromising these ecosystem services (Halpern et al. 2008; Hoegh-Guldberg and Bruno 2010; Lam et al. 2016; Pauly and Zeller 2016).

The United Nations Convention on the Law of the Sea (UNCLOS, UN 1982) delineated the area of national rights over marine resources, known as exclusive economic zones (EEZs). Accordingly, each country is responsible for sustainable fishing and sea-dependent-sectors potential impacts within their EEZs.

In the EU, a number of directives aim at harmonising efforts in order to achieve sustainable fisheries and healthy ecosystems. The most important are the Common Fisheries Policy (CFP, EC 2013) and the Marine Strategy Framework Directive (MSFD, EC 2008), respectively. These directives as well as higher-level environmental policies and obligations, such as the resolutions of Regional Sea Conventions, the Convention on Biological Diversity (CBD 2005) or the United Nations Food and Agriculture Organization (FAO) call for ecosystem-based fisheries management (EBFM) as the optimal framework to implement these policies. Quoting Patrick and Link (2015) EBFM recognizes "the combined physical, biological, economic, and social tradeoffs for managing the fisheries sector as an integrated system, specifically addresses competing objectives and cumulative impacts to optimize the yields of all fisheries in an ecosystem".

Components of EBFM are being adopted in compliance with the CFP, which foresees regionalization of decision structures, multi-annual plans, discard plans and establishment of stock recovery areas. But countries also hold responsibility beyond their EEZs since their flag vessels and fleets operate on other EEZs (Sumaila et al. 2015; McCauley et al. 2018).

Several EU countries have negotiated access agreements, through sustainable fisheries partnership agreements (SFPAs), for their fishing fleets, particularly in waters off neighbouring developing countries (Le Manach et al. 2013; Mallory 2013). The number of SFPAs notably increased after the implementation of the CFP in 1983 (Le Manach et al. 2013). These agreements affected around 266 EU vessels and generated about 31,500 jobs (including processing) for EU and third-country nationals. SFPAs production amounts to 45% of EU vessels total catches (Goulding 2016). The number of active SFPAs has oscillated largely over the last two decades because of difficulties to approve (e.g., Morocco and Micronesia) or renew (Mauritius and Senegal) or due to political instabilities (Guinea suspended in 2009) (EC 2009; Le Manach et al. 2013).

The entry into force (or suspension) of SFPAs results in displacement of entire fishing fleets, which can significantly release (or increase) fishing pressure within the home ecosystem. While the ecosystem effects of regulation measures taken under CFP guidelines are commonly acknowledged and investigated, those that are consequence of SFPAs are not often considered. Yet, EBFM should consider all human activities impacting the marine ecosystem, be these direct or indirect. For these reasons, integrated ecosystem assessments are recognised as useful tools in support of EBFM (Levin et al. 2009; 2014). Using the Gulf of Cadiz as an illustrative case study we here show evidence of the impact of both EU/national fisheries management regulations and bilateral political decisions on a particular ecosystem.

The Gulf of Cadiz (GoC) is the southernmost European Atlantic shelf sea, between the European (Portugal, Spain) and African (Morocco) continents (Fig. 1). It is a relatively young ecosystem in terms of policy implementation and regulations; for instance, the first total allowable catch for anchovy and the first marine protected area were set in 2004 (BOE 2004; BOJA 2004). Fishing fleets are highly diversified and target a number of species: anchovy, sardine, hake, rose shrimp, prawn or Norway lobster (Jiménez et al. 2004; Coll et al. 2014). At the same time, its proximity to Morocco's EEZ makes its fisheries dynamics dependent on the status of the SFPA with that country.

By using a comprehensive dataset consisting of a/biotic variables and human pressures we investigate how the different components of the GoC biota have changed over the last two decades (1993-2015) and relate them to major changes in the natural, anthropogenic and political settings. Understanding the interplay between these driving factors and the state and structure of marine ecosystems is crucial to implementing ecosystem-based management.

2.3 MATERIAL AND METHODS

2.3.1 Data collection

We compiled all available data featuring the GoC ecosystem (Spanish waters) over the period 1993-2015. Data on biotic, abiotic (including oceanographic and climatic variables) and human pressures were obtained from several sources (Fig. 4, Table S1 – Anexo A).

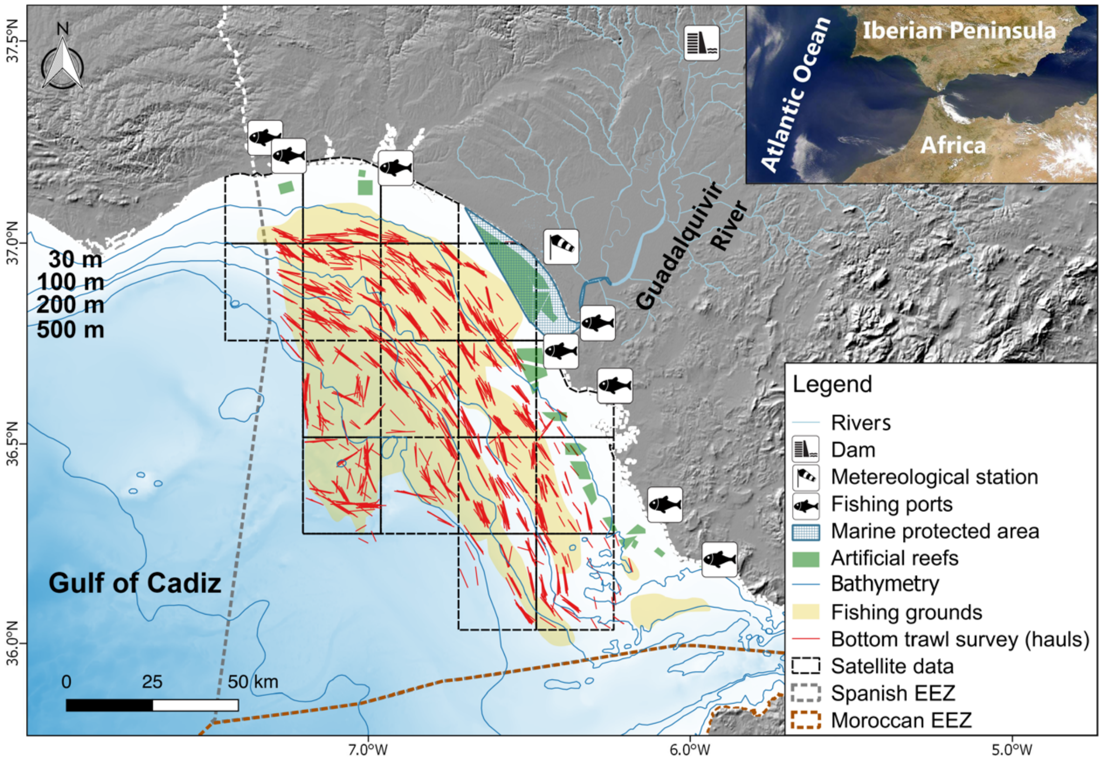

Fig 4. Map of the Gulf of Cadiz showing the location of the various data sources: satellite squares, bottom trawl hauls, fishing ports, Guadalquivir River dam as well as some other important features of the ecosystem, like the Guadalquivir mouth fishing reserve.

Biotic Data

Sampling and classification. Yield per species was obtained from a bottom trawl survey program (15 to 800 m depth) carried out in spring between 1993 and 2015 (IEO 2018; http://www.ices.dk/marine-data/data-portals/Pages/DATRAS.aspx). The time series comprised a total of 876 hauls (around 40 per year), carried out during daylight hours at a mean towing speed of 3.0 knots, using Baka 40/60 trawl gear with a 43.6 m footrope and a 60.1 m headline (details are given in Silva et al. 2011). In each haul, samples were sorted and individuals were counted and weighted. Individual species biomass was standardized to one square km (kg/km^2) and classified into thirty functional groups (Table S1 – Anexo A). The functional groups were chosen based on ecological similarities from a previous Ecopath model developed with the same database (Torres et al. 2013). A review and update of the species assigned to each group was performed and the complete species list is given in SI 2 (Anexo B). Among others, these groups included: polychaetes, crabs and lobsters, sharks, skates, two groups of cephalopods (benthic and benthopelagic) or benthic invertebrates, the latter also separated into two categories according to their feeding preferences: carnivores and filter-feeders/detritivores/suspensivores (F/D/S invertebrates). Eleven of those thirty functional groups correspond to commercial species (or genus) and were considered separately: anchovy, blue whiting, hake, horse mackerels, mackerels, mullets, sardine, mantis shrimp, Norway lobster and rose shrimp (Table S1– Anexo A).

Time series of comparable length were not available for nekton (e.g. acoustics surveys started in 2004). However, we included some pelagic species (anchovy and horse mackerels), which are known to have vertical diurnal migrations (feed on the bottom during the day) and are relatively well-sampled by bottom trawls (ICES 2014; Ramos 2015).

Abiotic Data

Satellite data. Daily sea surface temperature data (SST, °C) matching the biotic time series described above (1993-2015) were obtained from the satellite-based Advanced Very High Resolution Radiometer (Pathfinder v5; see SI 1) of the National Oceanic & Atmospheric Administration (http://www.ncdc.noaa.gov/oisst; Reynolds et al. 2007). Grid cells of 0.25° x 0.25° resolution (overlapping the area of biotic samplings, see Fig. 4) were generated with QGIS 2.18.2 – L. Palmas de Gran Canaria (http://qgis.org) – and averaged to annual values. The latter were validated with in-situ measurements.

Daily Chlorophyll (Chl, mg/m^3) and Particulate Organic and Inorganic Carbon (POC, PIC, mol/m^3) were obtained from the GlobColour project (European Space Agency, http://globcolour.info) (Maritorena et al. 2010). Annual averages were calculated similarly to SST data.

Other environmental data. Precipitation (total rainfall, l/m^2; 1993-2015) was acquired from "El Palacio" meteorological station (http://icts.ebd.csic.es/datos-meteorologicos). Sea surface height (SSH; 1996–2015) was obtained from a buoy moored off the coast of Cadiz (36.48°N, 6.96°W; maintained by the Spanish State Port Agency ("Puertos del Estado", http://www.puertos.es/).

Climate indices. The North Atlantic Oscillation (NAO; http://www.esrl.noaa.gov/psd/data/climateindices/list/) (Hurrell and Dickson 2004), the unsmoothed Atlantic Multidecadal Oscillation (AMO; http:/www.esrl.noaa.gov/psd/data/correlation/amon.us.long.data) (Enfield et al. 2001) and the annual Gulf stream index (GSNW; http://www.pml-gulfstream.org.uk/data.htm) (Taylor 1995; 1996) were included as climate indices.

Pressures

Fishery. Harvest rate of commercial functional groups/species (anchovy, blue whiting, hake, horse mackerels, mackerels, mullets, piscivores, sardine, mantis shrimp, Norway lobster and rose shrimp) was calculated as proportion of estimated total biomass over landings (tons) (FAO 2003). Landings from the fishing ports shown in Fig. 4 and fishing effort (fishing days/year) were obtained from official fishery statistics 1993-2015 (IEO Database; http://datos.ieo.es/geonetwork/srv/eng/catalog.search#/home).

River runoff. Freshwater discharges (hm^3) from the Alcalá del Río dam (Fig. 4) were provided by the Regional River Authority ("Confederación Hidrográfica del Guadalquivir"; http://www.chguadalquivir.es/saih/DatosHistoricos.aspx).

Marine litter. Anthropogenic debris items (size > 25 mm) were collected by the bottom trawl survey and classified following the master list of categories of the guidance document of the MSFD Common Implementation Strategy (Galgani et al. 2013). Densities of marine litter were standardized similarly to the benthos data (number of items/km^2).

Statistical methods

A total of 55 variables (Table S1– Anexo A) characterizing the biota (30 functional groups), natural drivers (9 abiotic variables) and human pressures (16 variables) was used in the analyses. To reduce complexity and help trend visualisation a panoply of multivariate and plotting techniques, traditionally utilized for integrated ecosystem analysis (Diekmann and Möllmann 2010), was used. Before-hand, missing values were replaced by the average of the neighbouring 2 years (or 4-year in the case of 2 consecutive missing years). Subsequently, data were log-transformed [ln (x + 1)] to both reduce skewness and normalize variances. These techniques included:

- *i) Principal Component Analyses (PCA).* This dimension-reduction technique is commonly used to extract the major modes of variability (principal components) in a data set on an ordination plot (Legendre and Legendre 1998). Yearly scores of the two principal components (PC1 and PC2) are usually plotted over time to visualize temporal trends and ecosystem shifts (Beaugrand et al. 2001, 2003). The trajectory of the system can be illustrated by placing the years in a scatter plot where the PC1 and PC2 define the x and y-axes (Link et al. 2002; Kenny et al 2009; Möllmann et al. 2009; Lindegren et al. 2012).

- *ii) Sequential t-test analyses of regime shifts (STARS).* The STARS algorithm (Rodionov 2004; 2006) is commonly applied on time-series of PCs scores to detect abrupt changes or regime shifts (see details in Möllmann et al. 2009). We ran STARS on the 1st and 2nd PCs of the previous analysis. In addition, STARS was used to identify statistically significant shifts in mean values in each time series separately (Table S2 – Anexo A). Cumulative Regime Shift Indices (RSI) (Rodionov 2004) were also estimated and are given in Table S2 (SI 1 – Anexo A). The RSI represents a cumulative sum of normalized deviations and used to detect the time of an abrupt change.

- *iii) Min/max autocorrelation factors analysis (MAFA).* MAFA is a multivariate statistical method, similar to PCA, that extracts common trends from multiple time series (Shapiro and Switzer 1989). One of the key differences between PCA and MAFA is that the latter maximizes the temporal autocorrelation structure rather than the variance. As with PCA, MAFA provides a series of orthogonal factors (MAFs) of decreasing autocorrelation that are continuous in time (see details in Woillez et al. 2009; Doray et al. 2018). The MAF analysis consists of 3 steps: (1) an initial selection of indicators based on the one-lag variogram of each indicator, scaled to the indicator variance and ranked. Since the number of variables cannot exceed the number of years, we selected the 17 most continuous variables following the pattern displayed by the variogram and the approach taking by Woillez et al. (2009); (2) MAFs are calculated on this reduced set of variables; (3) a continuity index is computed based on the loadings and one-lag variogram values of the first 2 MAFs. Subsequently, a selection of indicators is carried out based on this continuity index, aka MAF-based indicator selection procedure (Doray et al. 2018).

- *iv) Chronological Clustering (CC).* CC was used as another ordination technique, independent and complementary to PCA, STARS and MAFA. CC is based on a Euclidean distance matrix and was carried out to identify the years in which the largest shifts in the mean value of the time series occurred. This standardized method builds a hierarchy from the sequential years based on a time-variable matrix (Legendre and Legendre 1998).

- *vi) Traffic Light Plots (TLP).* A TLP was generated to visualize overall systematic patterns based on single time series (Link et al. 2002; Möllmann et al.

2009). The raw values of each variable are categorized into quintiles and each one of these is assigned a specific colour: red for the lowest (0–20%), green for the highest (80–100%) and a gradation of colours in between. The variables were then sorted by the 10-year standardized average and plotted against years. The use of the first PC loadings to sort variables on the y-axis was intentionally avoided in order to make the arising patterns independent of PCA. The code to produce the TLP was provided by Diekmann et al. (2012).

- *vii) Temporal anomalies*. Temporal anomalies were calculated for the main functional groups or drivers detected by PCA, MAFA and TLP.

All analyses were carried out in R version 3.5.0 (R Development Core Team 2018) with the R packages “vegan” (Version 2.5-5; Oksanen 2019), “factoextra” (Version 1.0.5; Kassambara and Mundt 2017), “ggplot2” (Version 3.2-0; Wicham and Chang 2019) and “gridExtra” (Version 2.3; Auguie, and Antonov 2017).

2.4 RESULTS

Principal Components Analysis (PCA)

The first two PCs of the PCA on the full dataset (a/biotic variables and pressures) described 60% of the total variance (Fig. 5A). The variable loadings (i.e. the length and orientation of vectors on the biplot) show the degree of correlation with the corresponding PC (Fig. 5A). The variables that correlated the most with the main mode of variability (PC1; 37%) are those arrows more or less parallel to the horizontal axis coloured in red/orange. Those showing positive correlations were anchovy, horse mackerel, sharks, skates, hake, and mullets. While demersal trawl effort, marine litter, carnivore benthic invertebrates, crabs & lobsters and polychaetes presented negative correlations with PC1. The variables that contributed the most to PC2 (23%) were: benthopelagic and benthic cephalopods, purse-seine effort and AMO all showing negative correlations. No clear-cut associations could be identified on the positive side (Fig. 5A).

In terms of time trajectories, the first PC was characterized by minor variations during the first decade, followed by an abrupt increase in the period 2005-2006 (Fig. 5B) and showed little variation thereafter. On the other hand, PC2 showed a steep decline at the end of the 1990s followed by moderate fluctuations (Fig. 5B). STARS analyses on PC1 and PC2 detected jumps in 1998-1999 and 2005-2006 (Fig. 5B) (RSI = 0.87 and 1.32, respectively).

The system trajectory over time (Fig. 5C) described a progressive drop within the left quadrant between 1993 and 1998, followed by a less marked downward trend towards the lower-left corner until 2004. This period (1993-2004) was mainly driven by changes in the second PC, which turned from positive to negative. The most remarkable change happened between 2005 and 2006 when the system jumped to the right side of the plot to describe a somewhat circular pattern for the remaining decade (2006-2015). This abrupt change was primarily driven by the first PC which turned positive in 2006, while PC2 showed little variation, oscillating around zero.

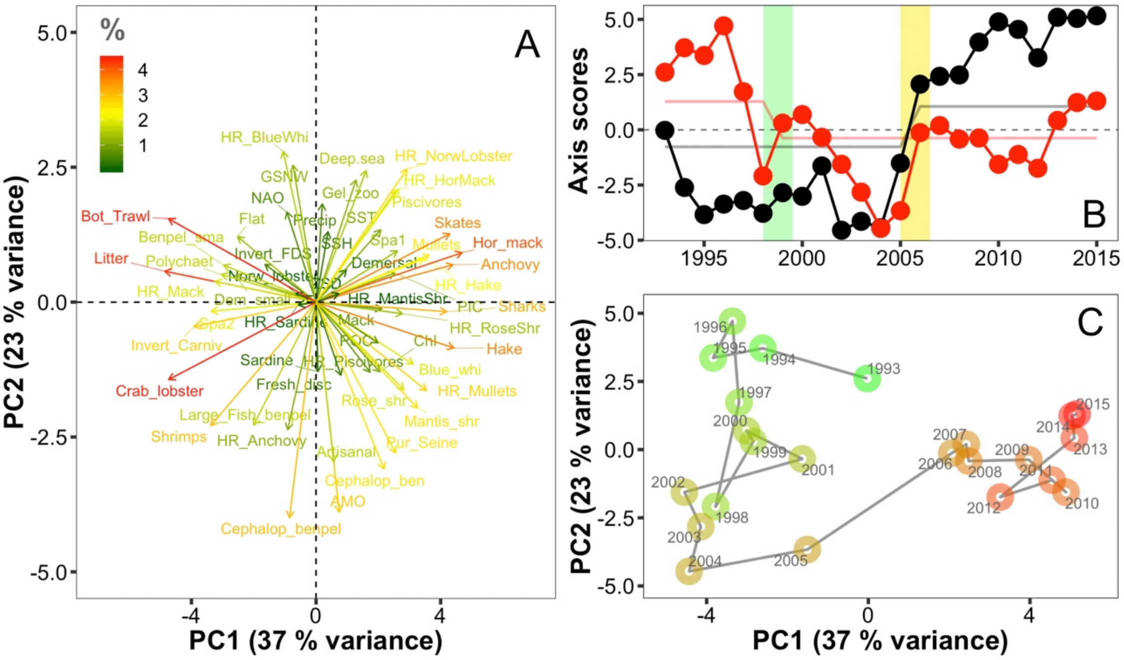

Fig 5. Principal Component Analysis (PCA). Panel A shows the degree of correlation of each given variable with the respective PC (variable acronyms are spelled out in Table S1). Variable contributions to the principal axes are colour-coded as shown in the legend (from green to red). Panel B shows the temporal trends of PC1 and PC2 scores (black and red lines, respectively). Transparent black and red straight lines show the results of STARS on the Principal Components. Vertical green and yellow shades mark the periods of shift. Panel C displays the trajectory of PCA biplot (PC1 and PC2). The colouring of the years (turning from green to red) simply indicates the temporal trajectory from 1993 to 2015.

Min/max Autocorrelation Factor Analysis (MAFA)

A normalized one-lag variogram was computed across the dataset and the 55 variables were ranked according to their variance (Fig. 6A). Based on this variogram, the 17 most continuous indicators to be included in the MAF computation were selected. The continuity index (Fig. 6B) showed that the most continuous, and hence most representative, indicators were: fishing pressure (artisanal, bottom trawl and purse-seine) and two functional groups (sharks and hake). Indeed, fishing pressure went down, from high to low values, over the studied period while sharks and hake showed the opposite trend.

MAF1 exhibited positive values at the beginning of the series (1993–2004) and negative ones from 2005 to 2015 (Fig. S1A – Anexo A), displaying an almost linear decrease. The temporal autocorrelation of MAF1, as shown by its variogram (Fig. S1B – Anexo A), has a period of around 20 years. Two indicators contributed the most to MAF1; bottom trawl effort and litter (positive loadings) (Fig S1C – Anexo A). The high contribution of these indicators (similarly to PCA) indicates the importance of these two variables in driving the ecosystem in the past (Fig. 6B) as well their reduced contribution in recent times.

MAF2 displayed negative values from 1993 to 1997 (Fig. S1D – Anexo A), became positive from 1998 until 2007, turned again to negative around 2008-10 and decreased constantly thereafter. MAF2 temporal autocorrelation has a period of 9-10 years (Fig. S1E – Anexo A). As before, two indicators contributed the most to MAF2; artisanal fisheries and sharks (positive loadings) (Fig S1F – Anexo A).

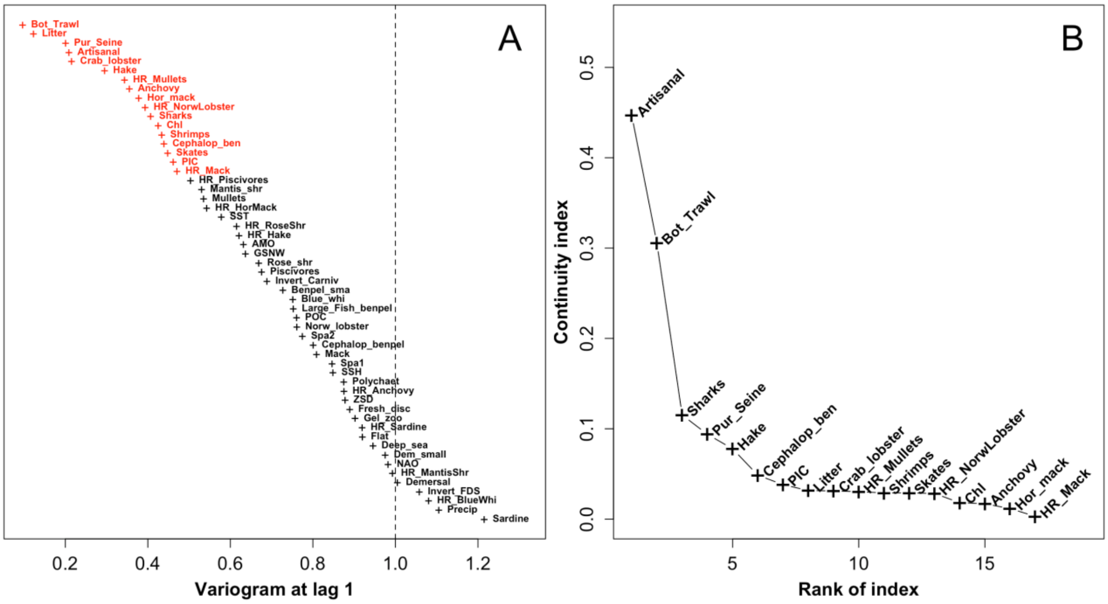

Fig 6. Min/max Autocorrelation Factor Analysis (MAFA). Panel A shows the normalized one-lag variogram. Indicators with a normalized one-lag variogram values <=1 are considered as sufficiently continuous (vertical line). The most continuous indicators here selected (<0.5) are coloured in red and were retained for the next step. Panel B presents the indicators ranked according to their continuity index on the first two MAFs.

Chronological Clustering (CC)

The CC broke the time series into two periods: 1993-2005 and 2006-2015, being 2005-2006 the major breakpoint (Fig. 7). Surprisingly, the changes detected in the late 1990s by the previous analyses did not show up as significant at this detection level (Cophenetic coefficient = 0.57).

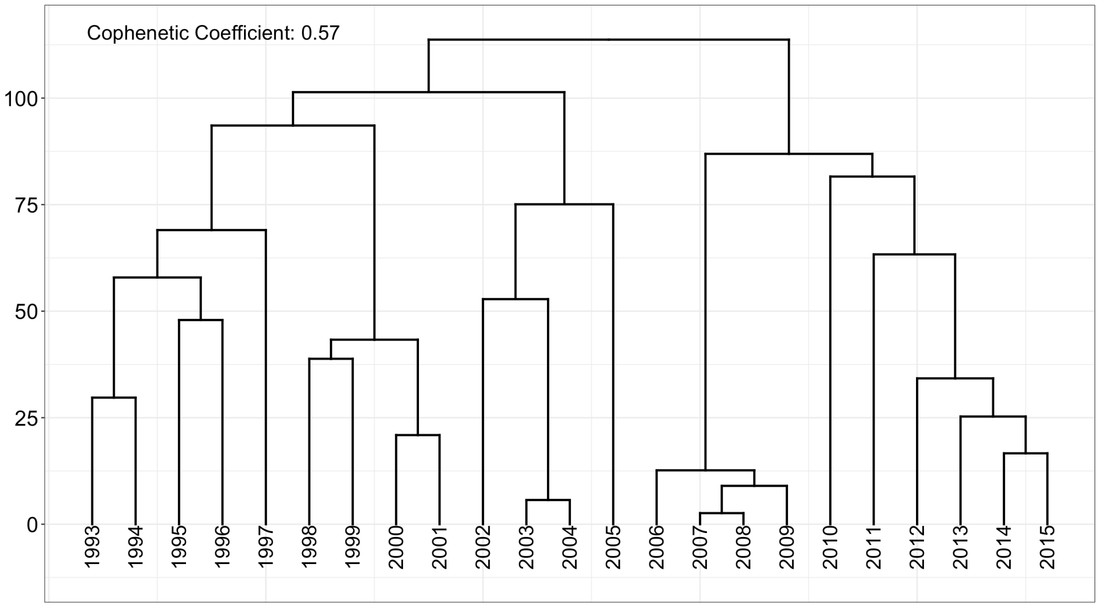

Fig 7. Chronological clustering analysis (CC). The dendrogram suggests two distinct periods characterized by breakpoints in 1993–2005 and 2006–2015.

Traffic Light Plots (TLP)

The temporal development of the GoC is shown in Fig. 8 in the form of a traffic light. Those variables that increased towards the end of the studied period are located in the upper half of the TLP. These were hake, anchovy, horse mackerels, skates, sharks and mullets. It can be appreciated how they turned from red (low values) to green (high values) after 2005. The lower half of the plot gathered those variables that showed the opposite pattern, turning from green to red after 2005. Here, we found demersal trawlers effort, marine litter, carnivore-benthic invertebrates, benthopelagic small fishes, polychaetes, F/D/S invertebrates, crabs & lobsters, Norway lobster and shrimps. All these groups decreased after 2005.

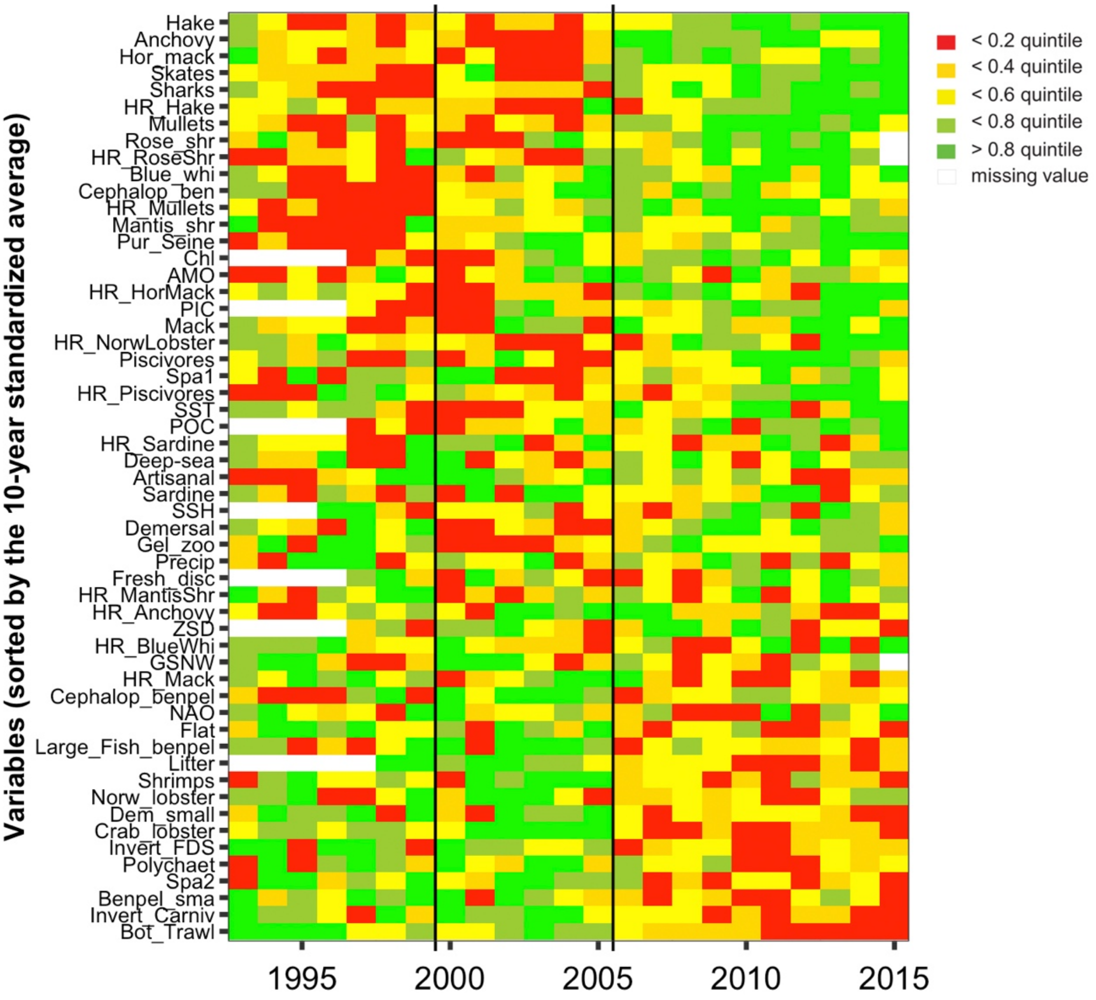

Fig 8. Traffic light plot (TLP). Time series were transformed to quintiles, colour coded and sorted in numerically according to the average of their first 10 years. Red represent low values while green represent high values of the corresponding variable (acronyms are spelled out in Table S1). Superimposed vertical black lines mark the shifts detected by STARS on PC1 and PC2.

Sequential regime shift analysis (STARS)

Sequential regime shift analysis (STARS) carried out on individual time series (Table S2) revealed that most of the significant changes occurred at the end of the 1990s and around the mid/late 2000s. The RSI identified 1994-2000 and 2002-2006 as potential periods of shifts.

Specifically, 5 out of 7 environmental variables (SST, precipitation, NAO, AMO, GSNW) and most of the harvest rates (10/16) displayed abrupt changes in the 1990s. The 2000s' change was observed in a few but important pressures, such as the demersal trawlers effort or the abundance of marine litter. The 28 biota components showed a more balanced distribution of changes, with 9 functional groups showing shifts in the 1990s (e.g. F/D/S benthic invertebrates, polychaetes, mantis shrimp, sharks) and 11 in the 2000s (e.g. hake, anchovy, skates, crabs & lobsters). A few groups (hake, rose shrimp) depicted drastic changes in both periods.

2.5 DISCUSSION

This article presents the first holistic assessment of the Gulf of Cadiz marine ecosystem over the last twenty years, with a focus on the impact of policy on its temporal development. Our results, arising from a number of visualisation and multivariate techniques, reveal two main periods of change: (1) a discontinuity, regime shift-like type of change, in 2005 and (2) an earlier but secondary, more progressive, change in the late 1990s. Interestingly, these changes coincided with the enforcement of two policy events: the implementation of the CFP regulation in 2004 and the halt of the SFPA with Morocco in 1999.

Effort regulation and spatial closure – the 2005 shift

The first change divided the time series in two halves: (1) before 2005 and (2) after 2006.

1993-2005 period

The initial state (1993-2005) was characterized by low biomasses of target and big species, such as hake, anchovy, sharks or skates. At the same time, less commercially important species, like crabs and lobsters, carnivorous invertebrates or polychaetes were found in high abundances. This ecosystem configuration is represented in Figure 9A.

The first GoC fishery management plan was not passed until 2004 (BOE 2004) so that this first period was characterised by a relatively loose regulation and consequently heavy fishing pressure (Fu et al. 2015; Kleisner et al. 2015; Coll et al. 2016; Bundy et al. 2017). This is reflected in our analyses by the high values of demersal trawl effort (number of days) but also by the high abundance of marine litter. Marine litter is to a great extent associated with the fishing activity since 37% of the items were nets, pots, cables and lines.

We hypothesize that the heavy fishing intensity of this period could have been responsible for the observed high biomasses of opportunistic benthic species. Bottom trawling is the most widespread source of physical disturbance to the seabed habitats (Hiddink et al. 2017). High trawling can have a twofold positive effect on these groups. On the one hand, trawling is known to cause resuspension of sediments which increases food availability for these functional groups (Groenewold and Fonds 2000; Hiddink et al. 2008). Detritus is an important source of food in the GoC and increases in this resource have been seen to have positive effects (via bottom-up) on most groups (Torres et al. 2013). Besides enhancing bottom-up processes heavy fishing can also act via top-down. Sharks, skates or hake are known to prey on these opportunistic groups (Torres et al. 2013). Hence, the high mortality imposed on these big predator species, reflected in their low biomasses during this period, could have released benthic groups from top-down control. Alternatively, their opportunistic feeding behaviour could have benefited from scavenging on organisms that are damaged by the trawl (Groenewold and Fonds 2000; Johnson et al. 2015).

2006-2015 period

In 2004 and following years, a number of fisheries management measures, in agreement with the CFP, were established by the Spanish Administration, entering into force at the end of 2004 (BOE 2004, see complete list in Table S3, SI 1 – Anexo A). Briefly, these regulations set an upper limit on fishing effort (200 days per year) and established autumn-winter closures (45-90 days) in order to favour the recovery of stocks. The bottom trawl and purse seine fleets were particularly affected by these measures.

Another management milestone happened in 2004 with the establishment of the fishing reserve of the Guadalquivir River mouth (BOJA 2004, IEO 2005), due to its role as an essential fish habitat (Llope 2017; de Carvalho-Souza et al. 2018). This Marine Protected Area (MPA) extends beyond the Guadalquivir mouth covering ~400 km2 of its area of influence (Fig. 4). The establishment of the Guadalquivir MPA resulted in bottom trawlers and purse seiners not being able to operate inside the MPA.

Our analyses detected the impact of these regulations already in 2005 (Fig. 5B-C) and more clearly in 2006 (Fig. 7 & 8). This second (and current) ecosystem state is characterised by a marked increase in the biomass of target species (e.g. anchovy) and those that occupy higher trophic levels, e.g. hake, horse mackerels, anchovy, sharks, skates and mullets (Fig. 9B). This food web reconfiguration is likely to be a direct a response to the decrease in fishing effort and the establishment of the Guadalquivir MPA described above.

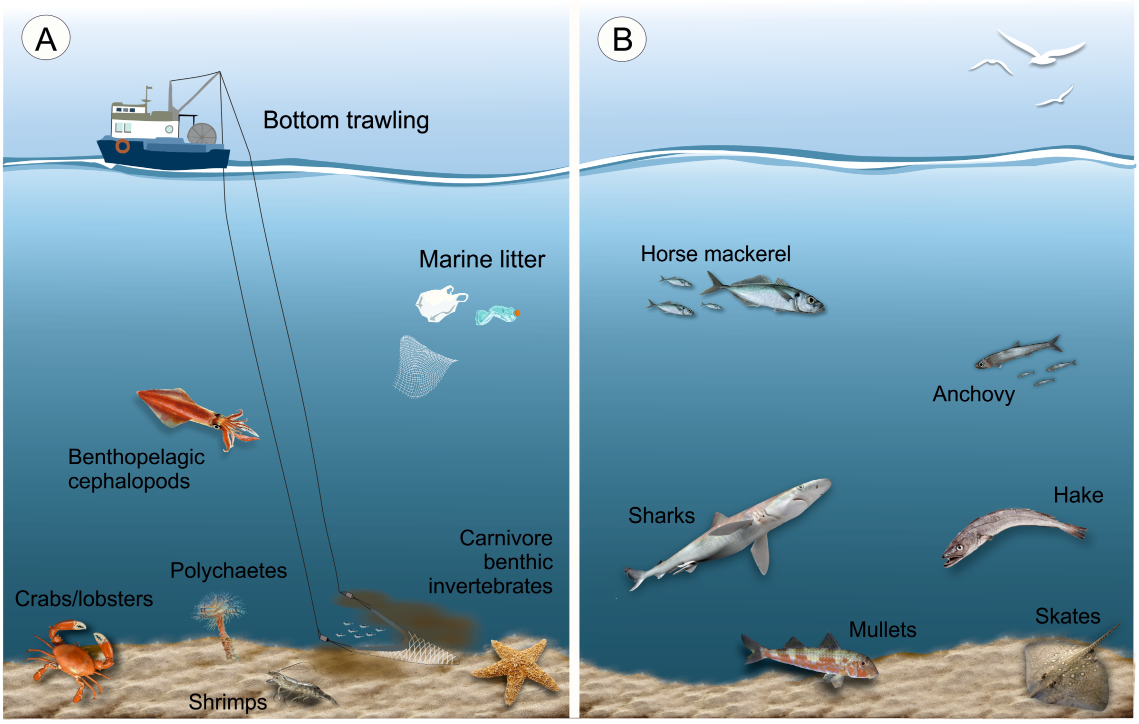

Fig 9. Diagrammatic representation of the two main configurations. Panel A shows the initial state (1993-2005), with high fishing pressure, poor quality habitat and opportunistic species dominance. Panel B presents a more stable ecosystem (2006-2015), with an increase of target species occupying the higher trophic levels.

International politics and Climate – the late 1990s

In 1997, the purse-seine (small pelagics) fleet voluntarily agreed to introduce a fishery closure every year from December to February (ICES 2014). This self-regulatory measure was suddenly interrupted in 1999. That year, the UE-Morocco SFPA, which had been in place since 1995, was not renewed (García-Isarch et al. 2012). As a consequence, the Spanish purse-seiners that would fish for anchovy in Moroccan waters had to come back, increasing the fishing pressure in the GoC.

The anchovy and horse mackerel very low values detected in the early 2000s (Fig. 8, and Fig. 10A, 10F) could be a consequence of this increase in fishing pressure. Unfortunately, we lack comparable information for other pelagic components (e.g. zooplankton) to be able to track cascading effects across trophic levels, as seen in other ecosystems (Lynam et al. 2017; Doray et al. 2018).

Local (SST, precipitation) and large-scale hydro-climatic forcing (NAO, AMO, GSNW) variability could have also played a role in the late 1990s. Most of the changes detected in these variables are concentrated around this period (see STARS analyses in Table S2) plus, these variables were found to correlate with PC2 (Fig. 5).

Environmental effects have been previously reported as important drivers in this ecosystem (Sobrino et al. 2002; Báez and Real 2011) and the warm phase of the AMO after 1995 is known to have led to simultaneous changes in plankton and fish in the North Atlantic (Edwards et al. 2013).

Disentangling the effects of fishing and environmental forcing is always a challenge. Both effects seem to have partly overlapped in this period, with climate gaining importance as key driver towards the early 2000s. This is when benthopelagic cephalopods increased (Fig. 10C) coinciding with a warm phase of the AMO and precipitation changes (Fig. 10K).

A recent global analysis revealed that cephalopod abundance has increased over the last decades in response to large-scale processes and declining fish populations (Doubleday et al. 2016), albeit casual mechanisms have not been identified. In the North Sea, climatic indices (AMO) and warming temperatures have also been associated with the increase of squids (van der Kooij et al. 2016).

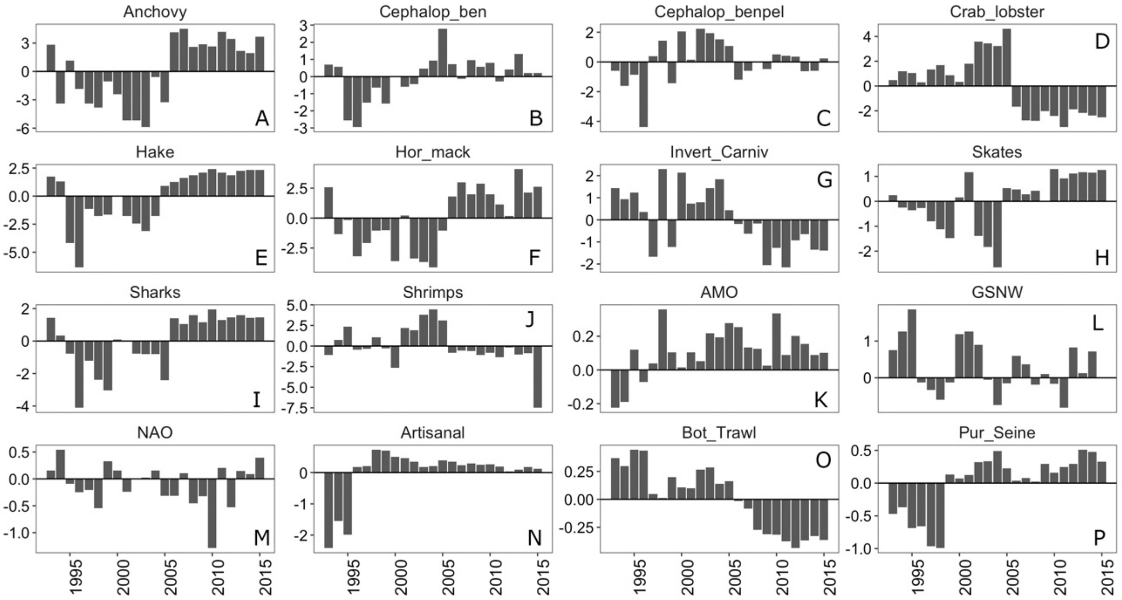

Fig 10. Anomaly plots of a/biotic factors, climatic indices and human pressures. Note that scales are logarithmic and adjusted to each variable's range of values. For acronyms, see Table S1.

Reconfiguration and stabilisation

Overfishing can entirely deplete fish stocks and permanently modify ecosystems, usually through trophic cascades. A classic is the collapse of cod in the Northwest Atlantic (Fogarty and Murawski 2008; Scheffer et al. 2005; Frank et al. 2005). In the Gulf of Mexico, commercial and recreational fishing caused the depletion of red snapper at the end of the 20th century, which led to the design of a broad rebuilding plan (SEDAR, 2018). The collapse of abalone stocks off the southern coast of California is another example of how poor fisheries management associated with pollution and climate (El Niño) can affect entire ecosystems through habitat (kelp forest) alterations (Rogers-Bennett et al. 2002; 2013).

Ecosystem reorganisations triggered by a combination of fishing and environmental changes (e.g. warming, eutrophication) have been relatively common in Europe, like the regime shifts reported in the Black Sea (Daskalov et al. 2007; Llope et al. 2011), the Baltic Sea (Möllmann et al. 2009; Blenckner et al. 2015) or the Kattegat (Lindegren et al. 2012). Contrary to the GoC, all these coastal seas are semi-enclosed ecosystems and are characterized by low biodiversity.

Apart from being an open and much more diverse sea (~860 taxa, SI 2), the Gulf of Cadiz main change (2005) presents some differences from the previous examples: The first period (Fig. 9A) was a progressively degrading non-static state and did not constitute a proper regime in the sense that it quickly improved after intervention. The second period (Fig. 9B) constitutes an improvement over the former and seems to be fairly stable (Fig. 4C). The changes before and after 2005 are, however, very remarkable. For instance, hake was a 196% (Fig. 10E) higher for the second regime (2006-2015) than the overall mean value (1993-2015), on a comparable scale anchovy increased by 217% (Fig. 10A) and so did horse mackerel (205%; Fig. 10F), skates (158%; Fig. 10H) and sharks (186%; Fig. 10I). Similarly, bottom trawl and artisanal fishing effort decreased by 72% and 101% respectively (Fig. 10O/10N) and shrimps dropped by 101% (Fig. 10J).

Policy and its implications for marine ecosystems

Considering the ecosystem-wide consequences that not only fisheries management and climate but also, and most surprisingly, international politics has had on the GoC, we recommend that the implications of SFPAs should be taken into consideration. In particular on those EU fishing grounds that would be primarily affected by these agreements. This applies to the current EU-Morocco SFPA (the latest expired in July 2018) which has just been endorsed by the European Parliament. But this is not the only case, Côte d'Ivoire is in a similar situation with its SFPA expired since 2018. Others are in a dormant state (e.g. Mozambique, Equatorial Guinea and Guinea-Bissau, Cabo Verde and Sao Tomé e Principe) (EC 2017) while 3 are active: Mauritius, Senegal and Gambia (https://ec.europa.eu/fisheries/cfp/international/agreements_en). The direct and indirect effects of fishing effort translocations need to be considered in ecosystem-based management.

Another regulation whose impact would need to be considered in the near future is the CFP "landing obligation" (EC 2013), which implies the landing of all catches of regulated commercial species. Heath et al. (2014) anticipated winners and looser for the North Sea. It is still quite unclear how this regulation will impact the Gulf of Cadiz (Gamaza et al. 2019). But the removal of previously discarded biomass from the ecosystem could in principle work in favour of the second configuration (2006-2015) described above, as it would be detrimental for the opportunistic trophic levels.

2.6 CONCLUSIONS

The Gulf of Cadiz is one of the youngest European marine ecosystems in terms of both monitoring and fisheries regulation enforcement. In the last 20 years it has shifted from a regime characterized by a progressive deterioration, due to weak fisheries regulation, climate sensitivity and knock-on effects of international politics, to a more stable regime where top-down control has recovered importance. These findings showcase how timely regulation prevented an incipient regime shift and highlights the need of considering international politics if we are to manage ecosystems holistically.

Acknowledgments

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Capítulo 3. Natural and anthropogenic effects on the early life stages of European anchovy in one of its Essential Fish Habitats, the Guadalquivir estuary

El papel del estuario del Guadalquivir como hábitat esencial para peces

de Carvalho-Souza, G.F., González-Ortegón, E., Baldó, F., Vilas, C., Drake, P., Llope, M. Natural and anthropogenic effects on the early life stages of European anchovy in one of its Essential Fish Habitats, the Guadalquivir estuary. Marine Ecology Progress Series, Advance View, 2018

3.1. ABSTRACT

Essential fish habitats (EFHs) are all aquatic habitats and substrates fundamental for spawning, breeding, feeding and/or growing to maturity. Estuaries are a good example of this because they play an important role as nursery grounds for several marine species. Despite their importance for completing the life cycle of some fish stocks, little is known about how early stages of these species respond to changes within estuarine environments. Understanding the response of fish juveniles to combinations of multiple drivers in these highly dynamic ecosystems is not straightforward. By analysing an 18 yr time series of European anchovy *Engraulis encrasicolus* and 3 mysid species in the Guadalquivir estuary (SW Spain), we quantified the effects of both natural and anthropogenic factors on the early stages of this small pelagic fish and its prey. Of the factors assessed, freshwater discharges and turbidity—both influenced by human activities—showed a remarkable effect on the abundance of anchovy. Natural environmental variables such as temperature, salinity, winds and prey abundance were also important. The relationship between anchovy and mysids suggests that the Guadalquivir food web is predominantly resource-driven and that indirect environmental effects can cascade up through a web of interactions. This study provides empirical information on the response of anchovy to environmental changes within its main essential habitat in the Gulf of Cadiz. Since the human-influenced variables can be managed to some extent, we discuss their implications for maintaining a healthy EFH, which in turn would contribute to developing an ecosystem approach to fisheries management in the region.

Key words: *Engraulis encrasicolus* · Anchovy juveniles · Nursery area · Trophic control · Environmental effects · Reference points · *Mesopodopsis slabberi* · *Neomysis integer* · *Rhopalophthalmus tartessicus*

3.2. INTRODUCTION

Estuaries are among the most productive and bio- logically important ecosystems on Earth (Alongi 1998, Barbier et al. 2011). They supply vast numbers of goods and services such as nursery habitats, nutrient storage and cycling, climate regulation and car- bon sequestration, as well as aesthetic and cultural benefits (Thrush et al. 2013). Estuarine ecosystems are particularly essential for fish owing to their ecological functions related to refugia for early life stages and high food availability (Beck et al. 2001, Elliott et al. 2007). These specific habitats, where fish can feed, grow, mature, breed and spawn to sustain their populations, are known as essential fish habitats (EFHs) as defined in the Magnuson-Stevens Act of 1996 (Rosenberg et al. 2000). The consideration of estuaries as EFHs is especially important if we are to develop an ecosystem approach to fisheries management (Schultz & Ludwig 2005, Link & Browman 2014, Long et al. 2015, Llope 2017).

The position of estuaries, interconnecting terrestrial and marine processes, and specific features, such as high salinity variations, high turbidity, muddy grounds and shallow depths, result in multiple combinations of conditions over space and time (Elliott et al. 2007, Cloern & Jassby 2012). On the other hand, estuaries are located at points that are highly prized by human activities and are therefore exposed to intense and increasing degradation, as coastal populations continue to expand (Kennish 2002).

In this context, the Guadalquivir estuary is not an exception (Fig. 1). Located in the northern half of the Gulf of Cadiz (GoC), Spain, with an area of influence that extends as far as the city of Seville, the estuary stands out as a key nursery area (Baldó & Drake 2002, Fernández-Delgado et al. 2007) embedded in a heavily degraded and continuously threatened set- ting (Vargas & Paneque 2015). The particularities of this socio-ecosystem require the consideration of multiple sectors and the corresponding conflicting interests. These include the shipping and tourism sectors, the agriculture, aquaculture, salt and mining industries, and the fisheries and conservation interests (Llope 2017). As a result of these pressures, the estuary has undergone various hydromorphological modifications over the last few decades that have resulted in alterations of its natural dynamics (del Moral 1991, Díez-Minguito et al. 2012). Today, the estuary covers an area of 1800 km^2 (Agencia Andaluza del Agua 2009) stretching over 90 km from its mouth to the Alcalá del Río dam (Fig. 11), which controls almost 80% of the freshwater river flow (CSIC 2010).

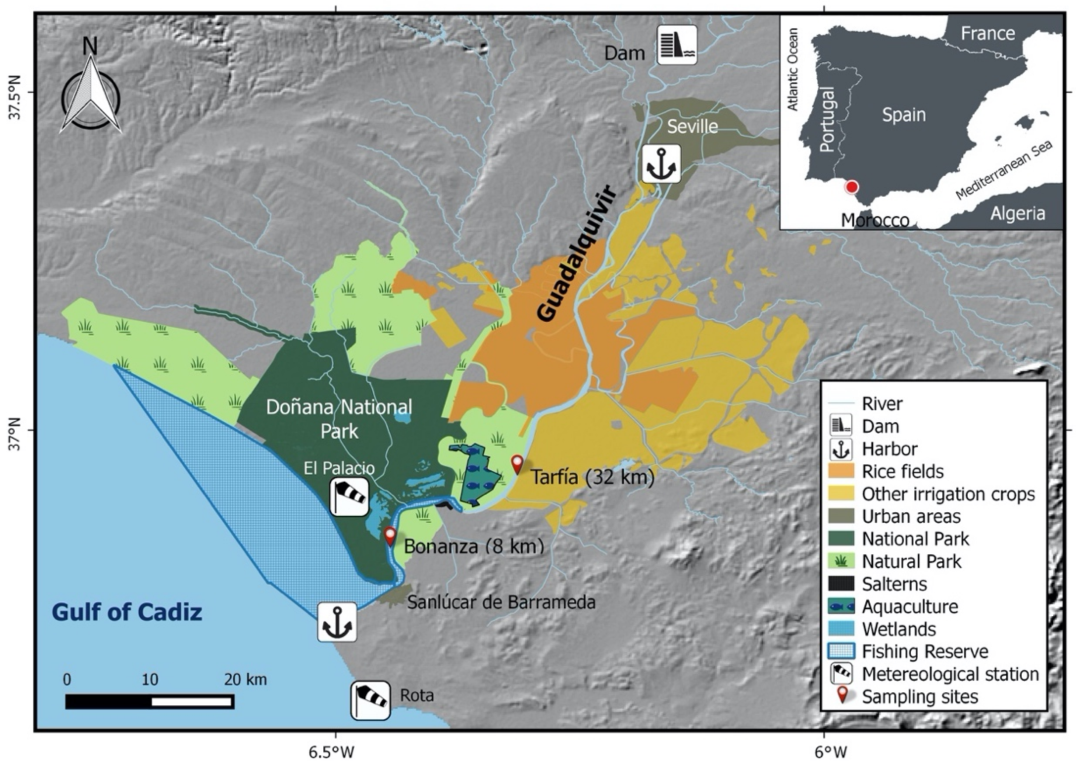

Fig. 11. Lower Guadalquivir area (SW Spain), showing the location of the 2 sampling sites — Bonanza (water masses I, II, sampled at ebb and flood tide, respectively) and Tarfía (water masses III, IV sampled at ebb and flood tide, respectively) —, Alcalá del Río dam and main land uses.

As a short-lived species, European anchovy *Engraulis encrasicolus*, Linnaeus, 1758 is strongly de- pendent on recruitment and is affected by year-to- year fluctuations in environmental processes. Temperature, winds and freshwater discharges have been identified as key factors influencing its recruitment in the GoC (Ruiz et al. 2006, 2009, Prieto et al. 2009). Within the estuary, the combination of both natural (weather) and anthropogenic (discharges) effects results in a broad range of combinations that makes the ecological response of the ecosystem to freshwater inputs equivocal (González-Ortegón et al. 2010, 2012, 2015, González-Ortegón & Drake 2012, González-Ortegón & Giménez 2014). Some of these drivers (salinity, turbidity) are known to be relevant, but other factors may or may not be as important.

Previous studies have shown that 3 mysid species make up to over 80% of total macrofauna biomass and are the major prey category of small fish (Baldó & Drake 2002). A synchrony between food availability (mysids) and the abundance of early life stages of several marine species, including anchovy, has also been reported (Baldó & Drake 2002, Drake et al. 2007), supporting the nursery role hypothesis. However, whether variations in mysid abundance have a statistical effect on anchovy has not been addressed.

Time series analyses have proven useful to reveal how populations respond to natural (climate) and anthropogenic (e.g. fishing) factors (Fernandes et al. 2010, Llope et al. 2011, Schmiing et al. 2013, Blenckner et al. 2015, Lynam et al. 2017). While the essential role of the Guadalquivir estuary as a nursery ground for the GoC anchovy stock has long been pointed out (IEO 2012), a comprehensive assessment of how the abundance of this species oscillates in response to varying environmental conditions and prey abundance is still missing.

To address this question, we developed nondeterministic statistical models (generalized additive models, GAMs) fitted to the empirical information provided by an 18 yr time series of monthly densities. GAMs are capable of modelling multiple effects and were used to estimate the combined effects that both natural (temperature, winds, precipitation) and anthropogenic (turbidity, freshwater discharges, salinity) factors have on the anchovy and mysid populations.

The goals of this study were to (1) assess how the population of this small pelagic species responds to environmental changes within its main essential habitat, (2) statistically test the effect of prey and (3) discuss the implications of these results in relation to maintaining a healthy EFH and hence contributing to a better managed stock according to ecosystem-based principles.

3.3. MATERIAL AND METHODS

3.3.1 STUDY AREA AND DATASET

The Guadalquivir estuary is a temperate well- mixed narrow estuary (Vannéy 1970) located on the Iberian margin of the GoC (Atlantic Ocean) (36° 47’ N, 04° 58’ W; 37° 25’ N, 07° 00’ W). Its tidal regime is semidiurnal, and the maximum tidal range at the river mouth is 3.86 m. The tidal influence reaches up to the Alcalá del Río dam (Fig. 11), which since 1938 controls the freshwater flow and salinity. This longitudinal gradient presents both short-term (tidal and dam-dependent) and long- term (seasonal and inter-annual) displacements along of the river course (Drake et al. 2002). Under normal or low river flow conditions (40 $m^3\ s^{-1}$) the estuary is regulated by the dam (tidally energetic estuary). Sporadically, when freshwater discharges are greater than 400 $m^3\ s^{-1}$, the estuary changes to a fluvial-dominated dynamic (Díez-Minguito et al. 2012) with consequences on turbidity and salinity (Díez-Minguito et al. 2013, 2014).

The dataset used in this work was compiled from several sources. Population densities and water environmental variables are the result of a long-term ecological research programme carried out between June 1997 and May 2015 in the Guadalquivir estuary (see Table S1 in the Supplement at www.int-res.com/articles/suppl/m12562_supp.pdf; or Anexo C. Supplementary Information). At each new moon, 2 samples were collected (each flood and ebb tide) at 2 sampling sites from a traditional river fishing boat at a standstill. Each sample consisted of a passive (tidal-powered) haul carried out during the first 2 h of each tide. Samples (both anchovy and mysids) were taken with 3 nets (10 m long, light mesh: 1 mm; net opening: 2.5 m wide and 3 m deep) working simultaneously. For more details see González-Ortegón et al. (2012, 2015). The 2 stations (Bonanza and Tarfía) are situated 8 and 32 km from the river mouth, respectively (Fig. 11). This scheme resulted in the sampling of 4 distinct water masses characterized by different salinities (I–IV, Fig. 12e), with a roughly monthly frequency, over a period of 18 yr. Water mass I had a mean salinity of 25.5 (sampled at Bonanza station at ebb tide), water mass II = 12.6 (Bonanza flood tide), water mass III = 6.6 (Tarfía ebb tide) and water mass IV = 3.4 (Tarfía flood tide). We considered water masses separately and did not average per station due to the considerable salinity differences observed between samples collected at ebb and flood at a given station (Fig. 12e).

Abundances of anchovy early stages (postlarvae and juveniles) and 3 mysid species, i.e. *Mesopodopsis slabberi* (Van Beneden, 1861), *Neomysis integer* (Leach, 1814) and *Rhopalophthalmus tartessicus* (Vilas-Fernandez, Drake & Sorbe, 2008), were estimated for the 4 water masses described above as ind. m^{-3} of filtered water. A digital flowmeter (Hydro-Bios®, 438 110) was used to calculate the volume of water. Most anchovy individuals were postlarvae (1 to 3 mo old). Their weight was quite homogeneous, ranging from 0.3 to 0.7 g along the estuary. Temperature (mercury thermometer ± 0.1°C), salinity (refractometer ATAGO® S/Mill) and turbidity (NTU) were measured in situ at the start of each haul.

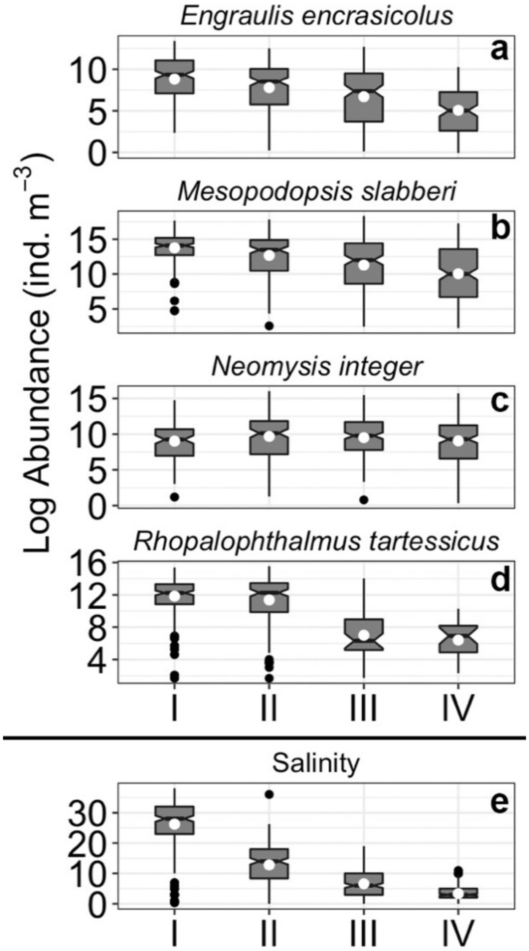

Fig. 12. Abundances of (a) anchovy and (b,c,d) the 3 mysid species, and (e) salinity in the 4 water masses (I, II, II, IV). Plots show the median, quartiles, minimum and maximum values, outliers (black dots) and means (white dots).

Wind data were obtained from the 'Rota' meteorological station (closest to the estuary) maintained by the Spanish 'Agencia Estatal de Metereología' (www. aemet.es). Two indices were estimated: (1) average velocity of easterlies and westerlies in a range of days before the sampling date and (2) the number of days (7, 15, 30) with levanters greater than 25 or 30 km h^{-1} previous to the sampling day. Levanters are strong easterly winds (Dorman et al. 1995). See Table S1 for details.

Freshwater discharges from the Alcalá del Río dam were provide by the Regional River Authority 'Confederación Hidrográfica del Guadalquivir' (www. chguadalquivir.es/saih/DatosHistoricos.aspx). Freshwater volumes were calculated by summing daily freshwater flow values (hm^3) recorded on a number of days (4, 7, 15, 30) prior to each sampling date (Table S1).

Precipitation in the area was acquired from 'El Palacio' meteorological station (http://icts.ebd.csic.es/datos-meteorologicos). Total rainfall (l m^{-2})

before the sampling date (4, 7, 15, 30 d) was estimated similarly to freshwater discharges (Table S1).

3.3.2 STATISTICAL MODELLING

The statistical analysis followed a 4-step approach as follows:

Step 1. Covariates were examined for collinearity using Pearson's correlation coefficient (r > 0.6–0.7) (Figs. S3–S6 in the Supplement) and a variance inflation factor (VIF) of 3 using the R function corvif (Zuur et al. 2007, 2009) (Table S2). Abundances, turbidity and freshwater discharges were log-transformed.

Step 2. A generalized additive model (GAM, Wood 2000, 2006) was estimated for each species at each water mass. GAMs are powerful modelling techniques that consist of fitting smooth additive functions in order to capture the relationship between the response variable and the explanatory factors. To avoid model over-fitting, the maximum number of knots (degrees of freedom) of the smoother (k) was set to 4.

Individual model selection was based on a step- wise approach removing covariates with a p > 0.05 and attempting to minimize the generalized cross validation criterion (Wood 2000) (Table S3). Expert judgement was used when appropriate. Non-significant covariates were lagged to assess any possible retarded effect.

Model residuals were checked for normality, independence and homoscedasticity (Figs. S7–S10). Regression assumptions were met except for independence in some cases. Nevertheless, the presence of autocorrelation did not affect the overall model structure (see complementary analyses in Figs. S1 & S2).

Step 3. Deviance was partitioned across the explanatory variables in order to explore their relative contribution (Table S4).

Step 4. Finally, for validation purposes, the models were used to hindcast the observations. Predictions recreated the time-series close enough and satisfactorily reproduced the observed seasonal cycles (Figs. S11 & S12).

All analyses were performed in R (Version 3.3.1) (R Core Team 2016), using the mgcv (version 1.8-17; Wood 2017) and corrplot (version 0.77; Wei & Simko 2016) packages.

3.4. RESULTS

SPECIES DISTRIBUTION ALONG THE SALINITY GRADIENT

The relative abundances of anchovy and the 3 species of mysids across the 4 water masses reflect the species' salinity preferences and overlap between predator and main prey along the estuary (Fig. 12). While anchovy and *Mesopodopsis slabberi*, both marine species, showed higher and more stable densities in the outer water masses (I and II) (Fig. 12a,b), *Neomysis integer*, a genuine estuarine species, showed slightly higher densities in the inner water masses (III and IV) (Fig. 12c). *Rhopalophthalmus tartessicus* showed the most confined distribution, restricted to the high salinities found in the outer stretches of the estuary (Fig. 2d), reflecting its stenohaline character.

ANCHOVY

The best models for anchovy included a total of 7 explanatory variables: temperature, salinity, turbidity, freshwater discharges, levanters, *M. slabberi* and *R. tartessicus* (Fig. 3) and described between 50.3 and 68.3% of total deviance (Tables S3 & S4).

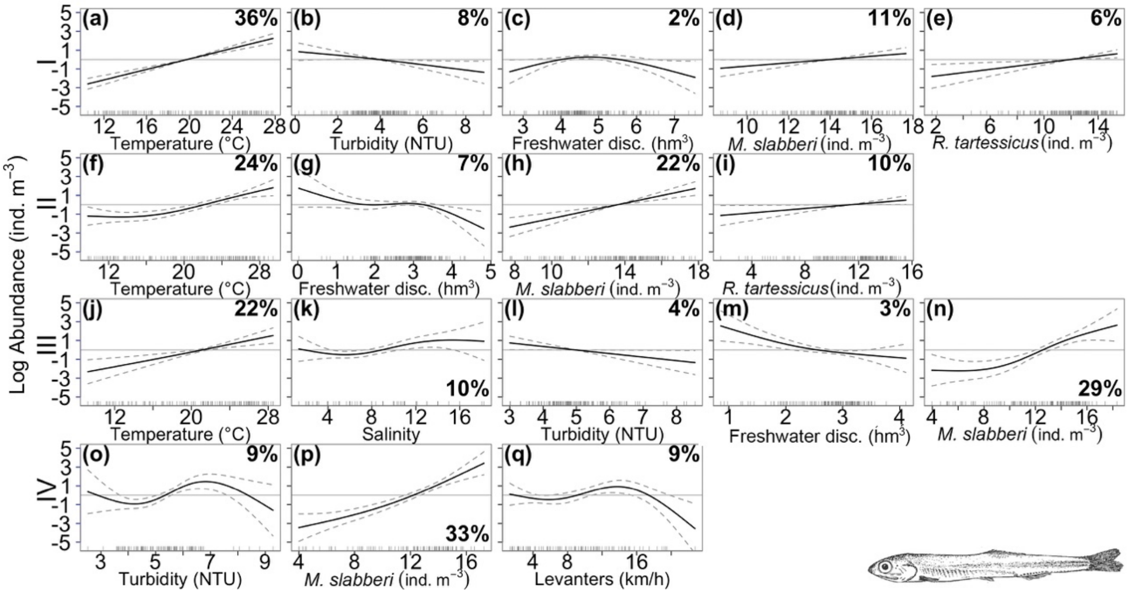

Fig. 13. Anchovy models for the 4 water masses (differentiated by salinity; see Fig. 2e): (a–e) I, (f–i) II, (j–n) III and (o–q) IV. Partial plots showing the effects (as fitted splines) of the various factors (x-axis) on the response variable (anchovy abundance). Dashed lines are 95% confidence intervals. Horizontal line at y = 0 is shown for reference. The percentage of deviance partition (by each covariate) is indicated. Estimated degrees of freedom and absolute deviance are presented in Tables S3 & S4 in the Supplement. Short vertical lines located on the x-axes of each plot indicate the values at which observations were made. ‘disc.’: discharge; hm^3: cubic hectometer.

In the outer water masses (I and II), temperature was the most important term with positive effects on abundance (Fig. 13a,f). In the inner water masses (III and IV), this variable entered the model only for water mass III (Fig. 3j). The model for water mass III was the only one that detected a relationship with salinity, showing a relatively flat effect, turning slightly positive for salinities >9 (Fig. 13k).

Both turbidity and freshwater discharges showed negative effects. Turbidity indicated a decrease in abundance for values ⩾100 NTU (~4.5 on a log scale) in water masses I and III (Fig. 13b,l). However, in water mass IV, a decrease in anchovy abundance tended to occur at higher concentrations of turbidity (7 on a log scale). The number of daily discharges with a significant impact on the abundance of anchovy can reflect both the buffer capacity of the different water masses and tolerance towards salinity. For example, in the outer water mass (I), the strongest signal was found for a cumulative effect of 30 d (Fig. 13c; Table S4), while in water masses II and III (under greater fluvial influence), this effect was noticeable with a cumulative sum of 7 d (Fig. 13m). In these water masses, anchovy are already at their salinity limit. Thus, any alteration, even if small, can lead to a large change in its density.

In the inner water mass (IV), the relationship with levanters was relatively flat for weak intensities, and negative for winds higher than ~16 km h^{-1} (Fig. 3q). Finally, the positive relationship with mysids (especially *M. slabberi*) across all water masses indicates a strong effect of this prey (Fig. 13d,e,h,i,n,p).

MESOPODOPSIS SLABBERI

The models for *M. slabberi* described between 52.8 and 71.4% of total deviance (Table S3), with 8 significant predictors (Fig. 14; Table S4).

Temperature was the most important positive factor in all water masses, except for water mass II, where it ranked second after turbidity (Fig. 14a,f,k,p). At this station, increases in temperature had a positive effect below 21°C, becoming slightly flat at higher temperatures. In the inner water masses, this factor presented a strong positive effect at both tides.

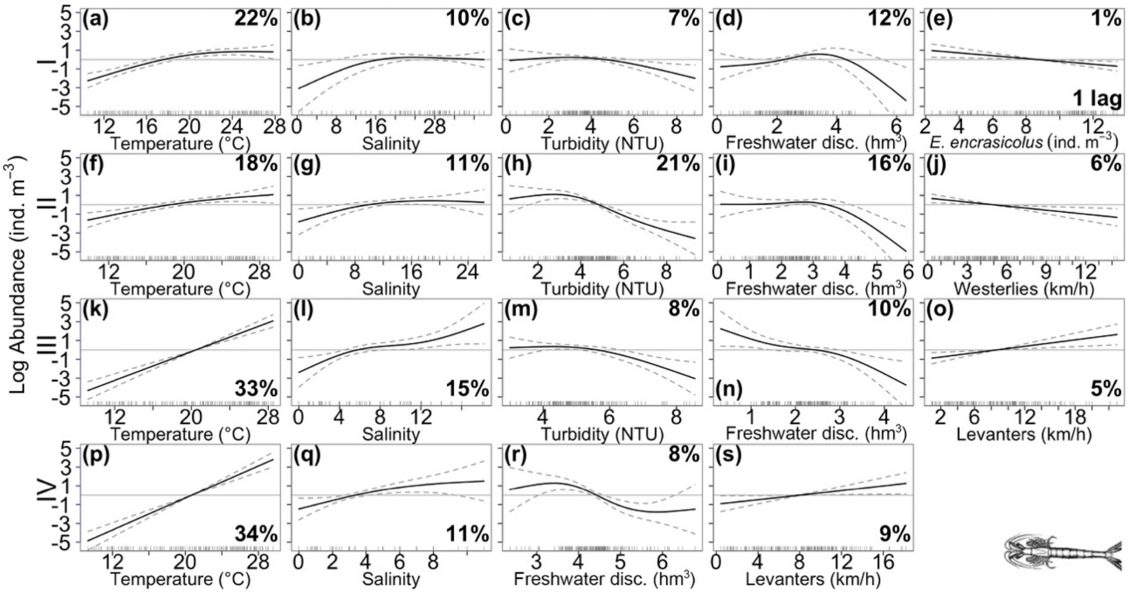

Fig. 14. As in Fig. 3, but for *Mesopodopsis slabberi* models (response variable is *M. slabberi* abundance) in water masses (a–e) I, (f–j) II, (k–o) III and (p–s) IV. Lags (when existing) are indicated.

Salinity followed a similar pattern with a positive effect for increasing salinities until favourable conditions are established at around 8–12, depending on the water mass, and little effect after these 'turning' points (Fig. 14b,g,l,q).
The anthropogenically induced variables, i.e. turbidity and freshwater discharges, showed nonlinear negative relationships in almost all water masses. These variables exhibited little or no effect below a certain point (100 NTU and 40 hm^3, respectively) turning negative beyond it (Fig. 14).
Interestingly, although it explained just 1% of variance, we found a negative effect of anchovy (lagged 1 mo) on *M. slabberi* abundance in the most saline water mass (I) (Fig. 14e).

M. slabberi decreased with increasing westerlies in water mass II (Fig. 14j), whereas for the upper estuary (III, IV), the abundance of this species increased linearly with strong levanters (Fig. 14o,s). Persistent levanters (30 d) are related to high turbidity in the outer estuary, whereas this is not necessarily the case in water masses III and IV.

NEOMYSIS INTEGER

N. integer models consisted of 5 covariates (Fig. 15a – j) and described between 10.8 and 22.9 % of total deviance (Table S3). At the outer station (most saline, water masses I and II), freshwater discharges had a positive effect on this estuarine mysid (Fig. 15b,d). Turbidity showed an overall positive effect mainly for intermediate values (Fig. 15a,c).

In the inner water masses (III, IV), positive relationships occurred with temperature (Fig. 15e,h). Salinity was not incorporated by water masses I and II models. The contrasting pattern in the inner water masses (Fig. 15f,i) suggests that *N. integer* prefers salinities up to approximately 10. Finally, increasing volumes of freshwater discharges and anchovy abundance resulted in decreased abundances.

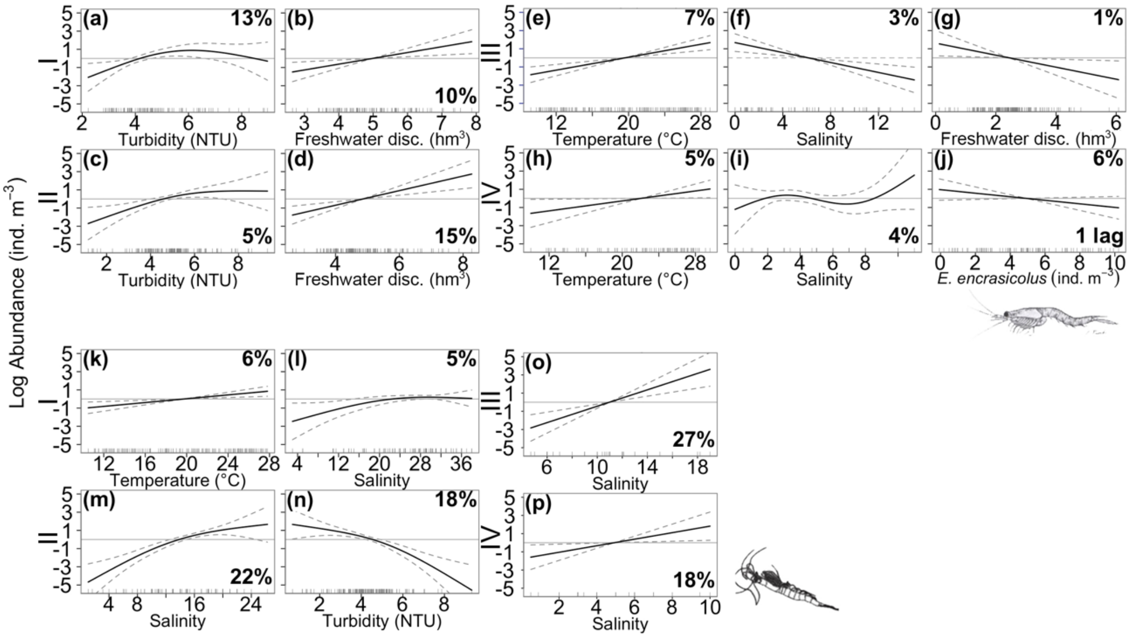

Fig. 15. As in Fig. 3, but for *Neomysis integer* in water masses (a,b) I, (c,d) II, (e–g) III and (h–j) IV and *Rhopalophthalmus tartessicus* in water masses (k,l) I, (m,n) II, (o) III and (p) IV (response variables are *N. integer* and *R. tartessicus* abundance). Lags (when existing are indicated).

RHOPALOPHTHALMUS TARTESSICUS

R. tartessicus models included a total of 3 explanatory variables (Fig. 15k – p), and the deviance explained ranged from 11 to 32.4% (Table S3). Salinity was the most important and often sole driver across water masses, except I, where it ranked second after temperature (Fig. 15l,m,o,p). Turbidity showed a strong negative relationship in water mass II (Fig. 15n).

3.5. DISCUSSION

Almost 2 decades of continuous monitoring witnessed the evolution of the estuary under a wide range of environmental conditions and allowed us to empirically populate the interaction food web shown in Fig. 16. This conceptualisation reflects the complexity of interactions in an EFH for a small pelagic species, anchovy, which is the most important fishery in the GoC. Climate (temperature, winds) and human-induced effects (turbidity, freshwater discharges and to some extent salinity) show direct effects on the abundance of anchovy juveniles but also act indirectly through their effects on mysids. Particularly important are *Mesopodopsis slabberi* and the endemic *Rhopalophthalmus tartessicus*, whose strong positive effects reveal the prevailing bottom-up regulation in this EFH.

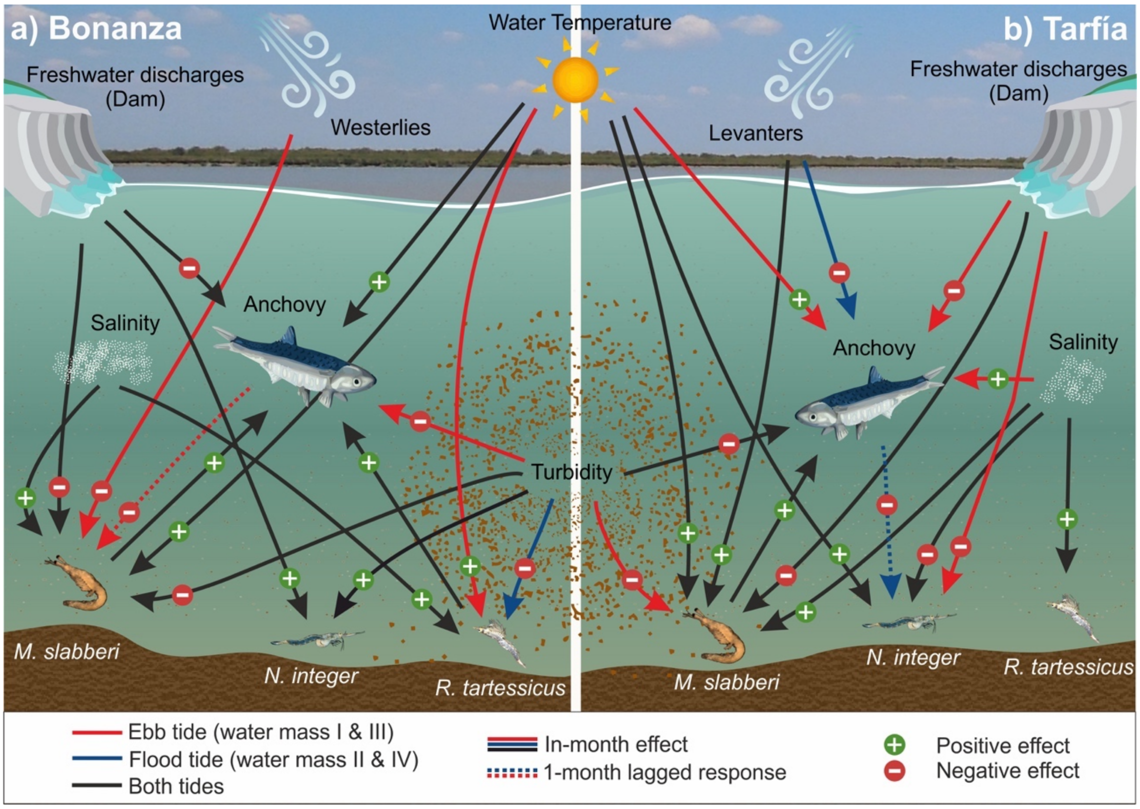

Fig. 16. Significant interactions modelled between anchovy, mysids and environmental drivers along the Guadalquivir estuary in (a) the outer (I and II) and (b) inner water masses (III and IV).

3.5.1. CLIMATE CHANGE AND WARMING

Globally, temperature is described as one of the main factors that control estuarine populations (Attrill & Power 2000, 2002, Pasquaud et al. 2012), as well as species richness (Vasconcelos et al. 2015) and trophic dynamics (Clasen et al. 2010). There is evidence that the Western Iberian Margin has warmed and a future increase of temperatures between 1.5 and 2.5°C is expected near the coast (Cordeiro Pires et al. 2016).

In our study, temperature stands out as the primary factor driving the abundance of anchovy and mysids. It most probably captures the well-defined seasonal pattern typical of temperate latitudes rather than an effect on survival through physiology or other processes. In any case, it seems that the temperature never becomes too hot, as there is no evidence of a negative effect at the highest temperatures.

Our results agree with studies carried out in other regions for this species. For example, in the Gironde estuary, water warming was related to increases in the abundance of anchovy juveniles (Pasquaud et al. 2012). In the Black Sea, using a bioenergetic model, Güraslan et al. (2014) demonstrated that warming could lead to an increase in the anchovy population. The forecasted warming of the Guadalquivir EFH could then, in principle, favour this marine species by enhancing its nursery function. However, note that this study does not consider temperature effects on anchovy spawning (intensity, phenology), which could have a major impact on the juvenile densities found within the estuary.

Other indirect consequences at community or ecosystem levels would also need be considered. Increases in temperature are known to affect mysids, through their physiology and life history traits (McKenney & Celestial 1995, Verslycke et al. 2004, Fockedey et al. 2005). There is some evidence that in the Guadalquivir estuary, the mean body size and fecundity of mysids could be reduced as a response to rising temperatures (C. Vilas pers. obs.). There- fore, the expected warming could also have indirect negative effects.

3.5.2. SALINITY

Salinity plays a unique role in structuring spatial patterns and in the functioning of estuaries (Telesh & Khlebovich 2010). As occurs in most estuaries (Kennish 2002), salinity is influenced by multiple drivers such as tides, climate or infrastructures like dams (Contreras & Polo 2012, Navarro et al. 2012, Díez-Minguito et al. 2012).

The Guadalquivir salinity gradient is pronounced. At its inner stretch, water masses oscillate from oligohaline to mesohaline (0.5–5 and 5–16, respectively, Vilas et al. 2009). However, during the dry season, salinity is usually kept on average between 6 and 22 along the whole estuary, which contributes to expand the effective nursery habitat for anchovy (Drake et al. 2007, Fernández-Delgado et al. 2007). Salinity only entered the anchovy models at the inner Guadalquivir, reflecting that it is only a limiting factor here.

The response of mysids to salinity reflects their specific salinity tolerances. *Neomysis integer* is a genuine estuarine mysid and therefore the most euryhaline species. It thrives in the oligohaline zone where salinity can be lower than 5 (Mees 1993, Vilas et al. 2009). At its distributional limit, it benefits from salinity increases as it tends to avoid mesohaline water masses. On the other hand, *M. slabberi* and *R. tartessicus*, as marine species, are mainly found in the outer zone and show negative relationships with low salinities (Mees 1993, Baldó et al. 2001, Vilas et al. 2009).

3.5.3. TURBIDITY

Human regulation of freshwater inputs severely alters natural regimes (Poff et al. 2007). In the Guadalquivir, high turbidity seems to be linked to the discharge regime and has been found to lead to declines in various trophic levels (González-Ortegón et al. 2010, 2015).

Mean water turbidity is generally below 75 NTU in summer, below 150 NTU in spring–autumn and only occasionally exceeds 300 NTU in winter (González-Ortegón et al. 2010). On 2 occasions (November 1999 to May 2000 and December 2007 to February 2009) there were strong and sudden increases in freshwater discharges, coupled with high and persistent turbidity events (HPTEs, sensu González-Ortegón et al. 2010), with maximum values of 631 and 713 NTU, respectively.

Our models were able to capture these HPTE extreme events, which negatively impacted anchovy and mysid densities. Other effects of HPTEs have been reported, such as inhibition of phytoplankton growth (Navarro et al. 2012) or upstream population displacements, with impacts on prey–predator relationships and food web structure (González-Ortegón et al. 2010, 2012, 2015). Under these conditions, the nursery function is gravely impaired (González-Ortegón et al. 2015). Additionally, fish may leave or avoid areas of high turbidity since this would decrease their perceptive abilities (Liljendahl-Nurminen et al. 2008, Lunt & Smee 2014).

3.5.4. INDIRECT (TROPHIC) EFFECTS

Estuarine production is regulated by abiotic (light, turbidity, nutrient and detritus supply) and biotic mechanisms (trophic interactions). Net production is the result of the interaction between top-down and bottom-up processes (Alpine & Cloern 1992, Cloern & Jassby 2012).

The abundance of anchovy was positively related to the abundance of mysids, especially *M. slabberi*, which is its main prey (Baldó & Drake 2002). *M. slabberi* accounted for a third (29 and 33%) of total anchovy variance in the inner water masses. The comparably high importance of trophic effects at these sites suggests that food availability would compensate for the physiological stress of a brackish environment, with salinities ranging from 0.5 to 16. These results support the hypothesis of high food availability (mysids) as one of the conditions (together with low predation) that grant the nursery function of the estuary (Baldó & Drake 2002, Drake et al. 2007, Fernández-Delgado et al. 2007).

Weak predation effects were also detected on *M. slabberi* and *N. integer*. Together, our results indicate that the Guadalquivir EFH is predominantly resource-driven and that mysids are key components in channelling production upwards.

3.5.5. REFERENCE POINTS

The setting of reference points has emerged in the last decade as a strategy to evaluate the status of aquatic ecosystems (Rice 2003, Samhouri et al. 2010, Foley et al. 2015) and comply with current legislation. Several EU policies use indicators for ecosystem assessments (Maes et al. 2016). The Marine Strategy Framework Directive (MSFD; European Commission 2008) and the Water Framework Directive (European Commission 2000) are relevant examples of this. Both directives seek to achieve good ecological status based on ‘reference values’ (European Commission 2017).

As additive models, GAMs can be helpful in identifying partial effects of drivers. This is clearly seen in the effect of freshwater discharges on anchovy or turbidity on *M. slabberi*. For the lower range of these 2 variables, there is little (or positive) effect. However, there exists a point (reference value) beyond which increasing values of the covariate result in decreasing abundances of the corresponding nekton species. Linear relationships can be interpreted in a similar fashion.

While identifying these points is not easy, especially in highly dynamic ecosystems, such as estuaries, ignoring them would be even more dangerous (Rice 2003). For that reason, we propose the use of these empirically estimated relationships to identify reference points of good (or bad) ecological status (sensu MSFD). The establishment of reference points for anthropogenically influenced factors is crucial because these are the ones that can be directly managed and there- fore can be used to inform management decisions.

Based on turbidity and discharge reference points (Table S5), we illustrate the development of the estuary status over the last 18 yr by means of a colour scale (Fig. 17). We can see that on average, turbidity conditions have not improved in recent years and have oscillated between yellow and red (indicating a poor status) since 2008. The 2004–2006 (outer water masses) and 2001–2002 (inner water masses) periods stand out for their good status (green). The 2 HPTEs of 1999–2000 and 2007–2009 are marked as orange/red, indicating very bad ecological status. Freshwater discharges followed a comparable trend to that of turbidity.

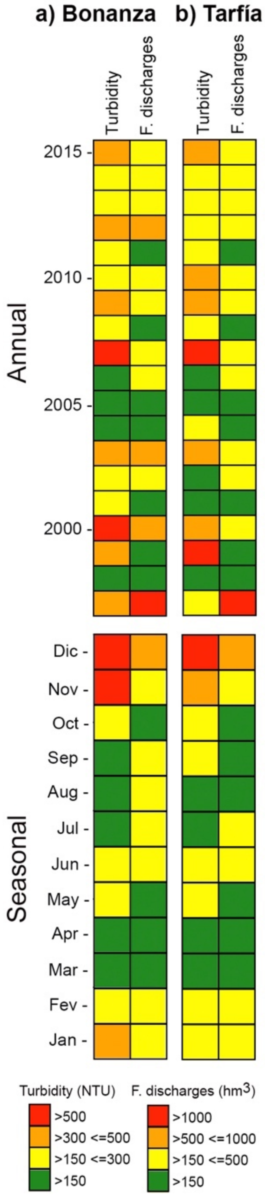

Fig. 17. Annual and seasonal classification of turbidity and freshwater (F.) discharges in (a) the outer (Bonanza station) and (b) inner (Tarfía station) water masses according to the reference points estimated by the models (see Figs. 3 & 4). The scale is composed of 4 categories: green if the effect is null or positive, yellow: slightly negative, orange: negative, red: extreme values (e.g. high and persistent turbidity events, HPTEs).

From a seasonal perspective, the most important months are those from May to November, when anchovy (and mysid) densities are at their highest. There seems to be a positive relationship between discharge and turbidity, with the winter months being more turbid and more impacted by discharges (yellow to red) than the spring–summer period (green–yellow, Fig. 17). Although this (mean) seasonal pattern does not seem to be too detrimental to the nursery function, there is room for improvement. The slightly negative (yellow) months could possibly improve (to green) if these considerations were taken into account when managing the dam.

3.5.6. MANAGEMENT IMPLICATIONS

Temperature and mysids are overall the most important predictors for anchovy and hence the most important indicators to maintaining the nursery serv- ice that this particular habitat provides. On the other hand, turbidity, salinity and freshwater discharges have comparably less influence.

Despite the seemingly secondary role of the anthropogenic variables on anchovy, it is worth noting that these drivers also act through the other nekton components. For instance, salinity has a positive effect on *M. slabberi*, which in turn has a positive effect on anchovy (Fig. 16a). Increases in salinity can cascade up through this mysid species to positively impact anchovy. Unlike natural effects, the anthropogenic variables are not totally independent. The increase in salinity illustrated before could probably be the result of a decrease in freshwater discharges and be tempo- rally associated with a decrease in turbidity. Again, discharges and turbidity have direct positive effects on anchovy and indirect effects via *M. slabberi*.

These anthropogenic variables have the particularity that they are to a certain extent influenced by the way humans perceive and manage the ecosystem. The most important infrastructure regarding the flow of freshwater into the estuary is the Alcalá del Río dam (Fig. 11), which contributes 80% of the total. As depicted in Fig. 6, discharges have direct effects on the Guadalquivir food web and indirectly affect salinity and turbidity, with knock-on effects on anchovy and mysids.

At present, river discharges essentially respond to the needs of the agriculture sector (rice irrigation) and do not take into account other side effects, such as those described above in relation to the nursery role of this EFH. This corresponds to the land use view (Llope 2017) and the historical inertia of the Guadalquivir socio-ecosystem (Vargas & Paneque 2015). An ecosystem approach to management of the anchovy fishery in the GoC should consider the trade-offs that the current management regime of the estuary has on its nursery function and hence on the recruitment of this species. The results presented in this study could be useful to inform management decisions, balance trade-offs, and by so doing, help the implementation of an ecosystem-based type of management.

3.6. CONCLUSIONS

Temperature, turbidity and freshwater discharges are key drivers in the Guadalquivir estuary. Turbidity and freshwater can be regarded as anthropogenic since these are, to a certain extent, manageable.

Bottom-up stands out as the prevailing type of trophic control and the mysids *M. slabberi* and *R. tartessicus* are identified as key in the upwards channelling of energy.

A number of issues, such as the effect of other prey items (zooplankton) on anchovy remain unknown and will need to be addressed in the future, as more information becomes available.

Using the Guadalquivir estuary as case study, our results show how indirect human activities (e.g. rice irrigation) can affect a fishery (e.g. anchovy, via recruitment) by impacting an EFH (nursery area).

Further studies will also need to quantify to which extent these sectoral activities (dam operation) propagate (via recruitment) all the way to the fishery.

Linking these apparently independent sectors— agriculture and fishing — will bring us a step for- ward in our understanding of this particular socio-ecosystem and its management.

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Capítulo 4. Gulf of Cadiz zooplankton: zonation, community structure and temporal variation

Zooplancton del golfo de Cádiz

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4.1 ABSTRACT

This study provides the first comprehensive description of the Gulf of Cadiz (SW Spain) marine zooplankton community. To do this we compiled information from a number of surveys and monitoring programs carried out in the area over the last 14 years. Using this time-series of quarterly (3 times per year) resolution, we describe their general composition, spatio-temporal variability and relationship with environmental factors. Zooplankton is dominated by copepods (mainly *Paracalanus, Oithona* and *Oncaea*), except in warm periods, when the cladoceran *Penilia avirostris* and some meroplanktonic forms (e.g. Cirripedia, Teleostei larvae) outnumber copepods, accounting for more than 75% of total density. Zooplankton diversity was found to be higher in deeper waters while the density of most taxa decreased towards the ocean. On top of this general coast-ocean pattern a north-south gradient could also be distinguished resulting in three distinct zones. In relation to environmental structuring, mesoscale processes, sea surface temperature, winds, river runoff and primary productivity were identified as main factors shaping this zonation. Overall, zooplankton abundance showed a decreasing trend during the study period (2001-2015), driven by a drop of summer densities.

KEY WORDS: diversity, density, composition, spatial and seasonal variability, copepods, cladocerans, Guadalquivir

4.2 INTRODUCTION

Zooplankton comprise a taxonomically diverse and abundant group of primary consumers that act as an essential link between primary producers and higher trophic levels (Richardson, 2008). Given their short life cycles, zooplankton respond promptly to ecosystem variability and, hence, changes in their abundance and composition quickly propagate across the food web (Banse, 1995; Beaugrand, 2005).

Zooplankton dynamics are affected by variations in bio-physical processes over a wide range of spatial and temporal scales (Bode *et al.*, 2013a). At small scales, zooplankton are directly affected by the local environmental (e.g. temperature, salinity, turbidity, river discharges) (Licandro and Ibanez, 2000; Islam *et al.*, 2006) and biological factors (e.g. food availability, trophic interactions) (Casini *et al.*, 2009; Llope *et al.*, 2012), as well as by mesoscale processes like gyres, coastal currents or upwelling events (Blanco-Bercial *et al.*, 2006; Labat *et al.*, 2009; Huggett, 2014).

At large spatio-temporal scales, zooplankton abundance and distribution respond to hydro-climatic forcing such as the North Atlantic Oscillation and the Atlantic Multidecadal Oscillation (Fromentin and Planque, 1996; Beaugrand and Reid, 2003; Batchelder *et al.*, 2012). For these reasons, they have been recognized as a sentinel taxa of climate variability and ecosystem functioning (Hays *et al.*, 2005; Molinero *et al.*, 2005).

The Gulf of Cadiz (GoC hereinafter) is a wide basin located between the SW Iberian Peninsula and NW North Africa, connecting the Atlantic Ocean and the Mediterranean Sea via the Strait of Gibraltar. The GoC system belongs to the North Atlantic subtropical gyre and consequently it is affected by its fluctuations (García-Lafuente and Ruiz, 2007). Its local hydrography exhibits the seasonal dynamics typical of temperate seas, with a strongly stratified upper layer in summer followed by winter mixing (García-Lafuente and Ruiz, 2007; Peliz *et al.*, 2007). Its meteorological and oceanographic dynamics include a variety of physical features such as continuous exchange of Atlantic and Mediterranean waters, cyclonic and anticyclonic gyres, coastal upwelling events, strong seasonal winds and a coastal counter-current (controlling the warm coastal water during the upwelling season) (García-Lafuente and Ruiz, 2007; Relvas *et al.*, 2007; Criado-Aldeanueva *et al.*, 2006; 2009; Garel *et al.*, 2016). Over the northern margin, freshwater discharges from the Guadiana, Tinto-Odiel, and Guadalquivir rivers inject large volumes of nutrient-rich waters and organic matter into the Gulf.

A number of studies have demonstrated that these specific oceanographic conditions influence coastal biological communities such as the spatial patterns of ichthyoplankton (Rubín *et al.*, 1997; Baldó *et al.*, 2006; Catalán *et al.*, 2006; Faria *et al.*, 2006; García-Isarch *et al.*, 2006; Mafalda and Rubín, 2006) or phytoplankton growth (García *et al.*, 2002; Huertas *et al.*, 2006; Reul *et al.*, 2006; Echevarría *et al.*, 2009; Anfuso *et al.*, 2010; 2013), especially on the inner shelf.

At the same time, the GoC supports important commercial fisheries, including demersal species (e.g. hake, rose shrimp, Norway lobster, cephalopods), medium-sized pelagic fish (horse mackerel, mackerel) and small pelagic fish (sardine, anchovy) (Jiménez *et al.*, 1998; Silva *et al.*, 2002; Coll *et al.*, 2015).

Despite the increasing number of studies carried out over the last decades in the area, the zooplankton component has received little attention. This is particularly true if we compare the GoC with other neighbouring regions like the southern Bay of Biscay (Queiroga *et al.*, 2005; Blanco-Bercial *et al.*, 2006; Stenseth *et al.*, 2006; Valdés *et al.*, 2007; Bode *et al.*, 2012, 2013b; Buttay *et al.*, 2016), where time-series were established in the 90s.

A few studies have indeed investigated the zooplankton community in the GoC. However, these works are either based on one single period (Rubín *et al.*, 1997; Villa *et al.*, 1997; Mafalda *et al.*, 2007; Ben-Hamadou *et al.*, 2010; Benavides *et al.*, 2010), or characterised by a limited spatial coverage, such as salt ponds, the mouth of the Guadalquivir River, shallow-water areas (Yúfera *et al.*, 1984; Villa *et al.*, 1997; Benavides *et al.*, 2010; Macías *et al.*, 2010; Taglialatela *et al.*, 2014), or devoted to one specific zooplankton groups: decapod larvae (González-Gordillo, 1999; González-Gordillo and Rodríguez, 2003; González-Gordillo *et al.*, 2003; Pochelon *et al.*, 2017).

There is a real need for a comprehensive overview of the GoC zooplankton community and their spatial and temporal variation since this information is lacking. In an effort to describe this little-known component of the GoC food web, we recovered, processed and analysed samples of zooplankton that were archived in different labs. This allowed us to build the longest time-series of zooplankton for this ecosystem to date (2001-2015).

The aim of this study is three-fold: (i) to describe the zooplankton community structure in terms of species richness, diversity and density (ii) to analyse the zonation and temporal variation of major zooplankton species/taxonomic and functional groups and (iii) to investigate the structuring effect of environmental gradients.

4.3 MATERIAL AND METHODS

4.3.1 Study area and dataset

This study was conducted on the northern shelf of the GoC (SW Iberian Peninsula) covering the area that stretches from Guadiana River to Cabo Trafalgar (Fig. 18). The continental shelf of the GoC extends out to approximately 15 km off West of Cabo Santa Maria in the north, to 50 km off Cabo Trafalgar in the south.

Three water masses dominate in the area: from the surface down to 100m depth, Surface Atlantic Water (SAW); an intermediate layer (100-250 m) of Eastern North Atlantic Central Water (ENACW); and a deeper layer (below 250 m), dominated by Mediterranean Outflow Water (MOW) (Bellanco and Sánchez-Leal, 2016).

Wind-driven seasonal upwellings occur around the areas off Guadiana and Tinto-Odiel rivers and off Cabo Trafalgar, providing colder, nutrient-rich waters which enhance phytoplankton growth (Echevarría *et al.*, 2009; Prieto *et al.*, 2009).

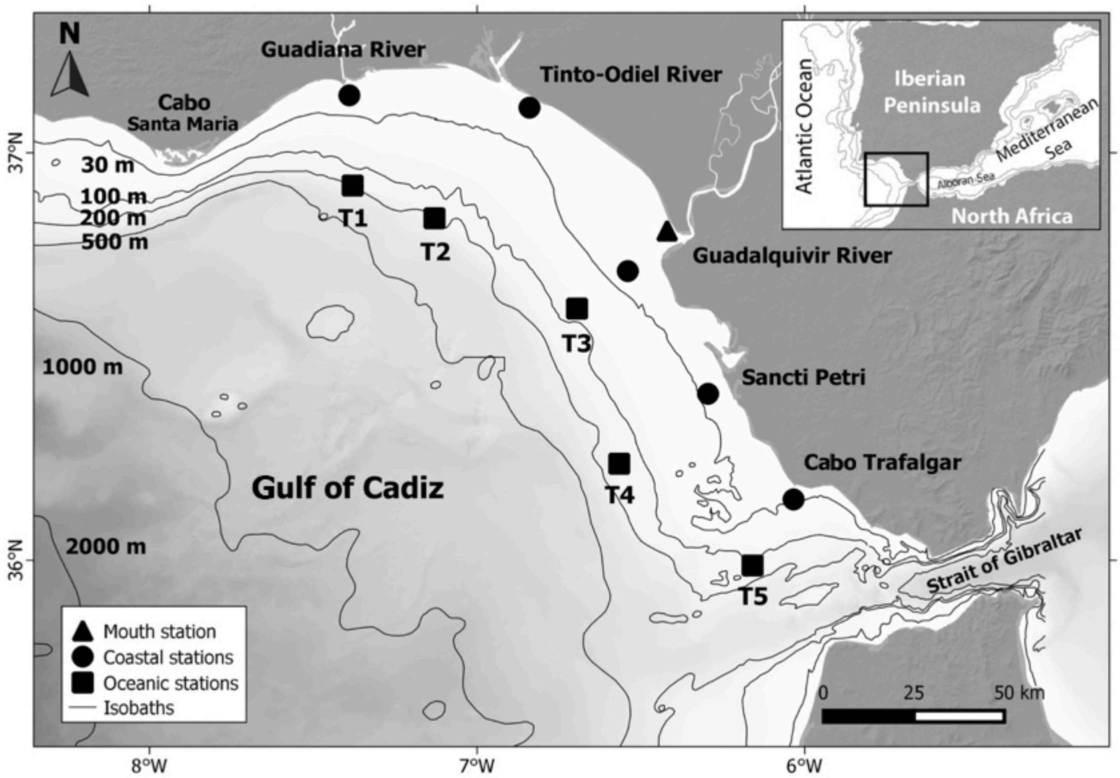

Fig 18. Sampling area in the Gulf of Cadiz, between the Guadiana River and Cape Trafalgar. Stations are represented by triangle (mouth), circles (coastal) and squares (oceanic) on the transects: Guadiana (T1); Tinto-Odiel (T2), Guadalquivir (T3); Sancti Petri (T4) and Trafalgar (T5).

4.3.2 Sampling

Zooplankton counts were obtained from samples collected during several surveys carried out by Instituto Español de Oceanografía (IEO) between 2001 and 2015: "GOLFO" (2001-2004), "FLUCTUACIONES" (2005-2007) and "STOCA" (2009-on-going). Table S1 – Anexo D, in Supplementary Information, gives a summary of the 169 samples used in this study. The samples were preserved in formalin and stored in the laboratory.

We analysed samples from 11 stations distributed along five transects, named: Guadiana (T1), Tinto-Odiel (T2), Guadalquivir (T3), Sancti Petri (T4) and Trafalgar (T5) (Fig. 1). To best resolve the seasonal variation and match the current monitoring program, samples were grouped quarterly: winter (Feb-Mar), summer (Jun-Aug) and autumn (Sep-Nov). Stations were classified as coastal or oceanic. By oceanic we refer to those that are furthest from the shore but we must note that all stations are on the continental shelf (Fig. 18). The Guadalquivir transect (T3) is the longest time-series we could build (14 years, except the period autumn 2007-winter 2009 that is missing) and consists of three stations (mouth, coastal and oceanic stations), one more than the other transects. This transect was used to describe the temporal variability and environmental effects related. The rest of transects were used to study the seasonal and spatial variation.

4.3.3 Zooplankton collection, identification and classification

Zooplankton samples were obtained by oblique tows using a 200-µm mesh size Bongo nets (mouth diameter: 0.4 m) fitted with two flowmeters (General Oceanics 2030R). Oblique bongo tows were done from near the bottom to the surface. The depth of the coastal stations ranged between 4 and 30 m, while the oceanic stations had max. depths of about 150-200 m. The tows occurred at a vessel speed of 2-2.5 knots. Plankton samples were fixed with 4% formalin in sea-water buffered with borax.

Back in the lab, the content was divided into aliquots of at least 200 organisms (>85% accuracy) using a Folsom plankton splitter. The organisms were counted and identified at the highest taxonomic resolution, using optical microscope and stereomicroscope equipment. However, some groups (e.g. larval forms) were only identified to major taxonomic groups. In general, dominant taxa such as copepods and cladocerans were well distinguished to genus or species. The taxonomy of zooplankton species *follows the* World Register of Marine Species (WORMS) database (http://www.marinespecies.org) and was determined using the main taxonomic references available (Nishida, 1985; Vives and Shmeleva, 2006a; 2006b; Castellani and Edwards, 2017).

The different taxa were classified as holoplanktonic (spend their entire lives as plankton) or meroplanktonic (are only temporary members of plankton), and their main diet preferences (carnivorous, herbivorous and omnivorous) was indicated, following Llope *et al*. (2012) and Benedetti *et al*. (2016) (see Table S2, Supplementary Information). Zooplankton densities were expressed as number of individuals per cubic meter (ind/m^3).

4.3.4 Environmental variables

Daily satellite-derived sea surface temperature data (SST, °C) were obtained from the Advanced Very High Resolution Radiometer (AVHRR Pathfinder v5, http://www.ncdc.noaa.gov/oisst, Reynolds *et al.*, 2007). Relationships between monthly satellite SST and in situ monthly mean SST data measured by a buoy moored off the coast of Cadiz (36.48°N, 6.96°W; maintained by the Spanish State Port Agency ("Puertos del Estado", http://www.puertos.es/), for the period 2001–2015, were highly significant (R2 = 0.95, n = 166, p-value <0.001).

Monthly 4-km satellite-derived chlorophyll-a (Chl, mg/m^3), particulate organic carbon (POC, mol/m^3) and particulate inorganic carbon (PIC, mol/m^3) were obtained from the GlobColour project (European Space Agency, http://globcolour.info) (Maritorena *et al.*, 2010) and used to assess primary production in the region. Note that the study area includes very shallow coastal zones plus areas under the influence of river plumes. In these particular areas ocean colour is likely to be a proxy for general ocean production (including benthic and fluorescent DOM) rather than pure chlorophyll a.

Precipitation (total rainfall, l/m^2) was obtained from "El Palacio" meteorological station (http://icts.ebd.csic.es/datos-meteorologicos). Wind speed (km/h) and direction was acquired from a meteorological station operated by the Spanish Meteorological Agency ("Agencia Estatal de Meteorología", http://www.aemet.es). Freshwater discharges (hm^3) from the "Alcalá del Río" dam were obtained from the Regional River Authority ("Confederación Hidrográfica del Guadalquivir"; http://www.chguadalquivir.es/saih/DatosHistoricos.aspx). The index to estimate the influence of river runoff (i.e. decreasing effect that the river might exert when moving away from its mouth) was calculated as follows (Gonzalez-Irusta *et al.*, 2014):

River index = Distance to closest river mouth (km)/Freshwater discharges (hm^3)

4.3.5 Data analysis

Dominant taxa were defined using k-dominance curve, where the cumulative density is plotted against a log species rank (Lambshead *et al.*, 1983), with the species ranked in decreasing order of contribution on the function (Table 1). The cutoff was defined as the point at which the increments were lower than 1.5%.

Using this criterion, 15 dominant taxa (corresponding to more than 83% of the density) were selected and their relative contributions were calculated for each station and season (Fig. 19). For each taxa, values of average density (AD, ind/m^3) and relative density (RD, %) were calculated (Table 1). The RD is estimated by dividing the density of one particular taxa by the total density.

Table 1. List of most abundant zooplankton taxa (>0.1%) in decreasing order of density (equivalent to 98.5% of total density). Relative density (RD %) and average density plus standard deviation (AD±SD, ind/m^3) are presented. The full list is available in Table SI, Supplementary Information 1

Taxa	RD (%)	AD±SD
Penilia avirostris	23.5	528.14±1515.51
Paracalanus spp.	11.4	199.41±269.55
Oithona spp.	7.8	141.66±283.43
Oncaea spp.	7.4	142.68±262.08
Larvacea	7	130.34±156.92
Clausocalanus spp.	4.3	114.17±150.11
Pleopis polyphemoides	3.8	231.77±522.69
Acartia (Acartiura) clausi	2.85	71.32±94.78
Mollusca larvae	2.62	49.06±95.13
Cirripedia larvae	2.44	71.16±180.44
Teleostei larvae	2.41	76.04±161.53
Pseudevadne tergestina	2.25	87.43±346.33
Euterpina acutifrons	2.19	62.55±131.72
Chaetognatha	1.59	44.03±68.52
Doliolida	1.56	76.09±144.05
Centropages ponticus	1.42	103.24±174.63
Decapoda larvae	1.33	37.85±68.16
Siphonophora	1.31	41.47±94.14
Copepod nauplius	0.96	29.72±39.79
Podon intermedius	0.90	50.44±68.62
Other larval forms	0.87	30.39±93.47
Sagitta sp.	0.84	150.07±196.29
Oikopleura (Vexillaria) dioica	0.62	31.58±66.3
Polychaete larvae	0.61	495.25±283.73
Rhopalophthalmus tartessicus	0.58	155.6±318.08
Temora stylifera	0.56	23.38±28.61
Evadne spinifera	0.55	27.59±36.21
Evadne nordmanni	0.55	55.15±78.67
Corycaeus spp.	0.47	28.88±76.22
Centropages chierchiae	0.46	24.63±31.83
Radiolaria	0.36	42.48±79.54

Paracartia grani	0.35	56.53±73.53
Temora longicornis	0.35	86±241.19
Harpacticoida	0.35	104.44±265.65
Ditrichocorycaeus spp.	0.31	14.87±28.24
Foraminifera	0.30	53.67±82.45
Calocalanus spp.	0.28	12.15±13.42
Hydromedusae	0.21	18.55±23.84
Goniopsyllus clausi	0.20	39.5±134.57
Ctenocalanus vanus	0.17	9.6±13.22
Calanus helgolandicus	0.16	17.52±20.87
Echinodermata larvae	0.11	32.17±34.35

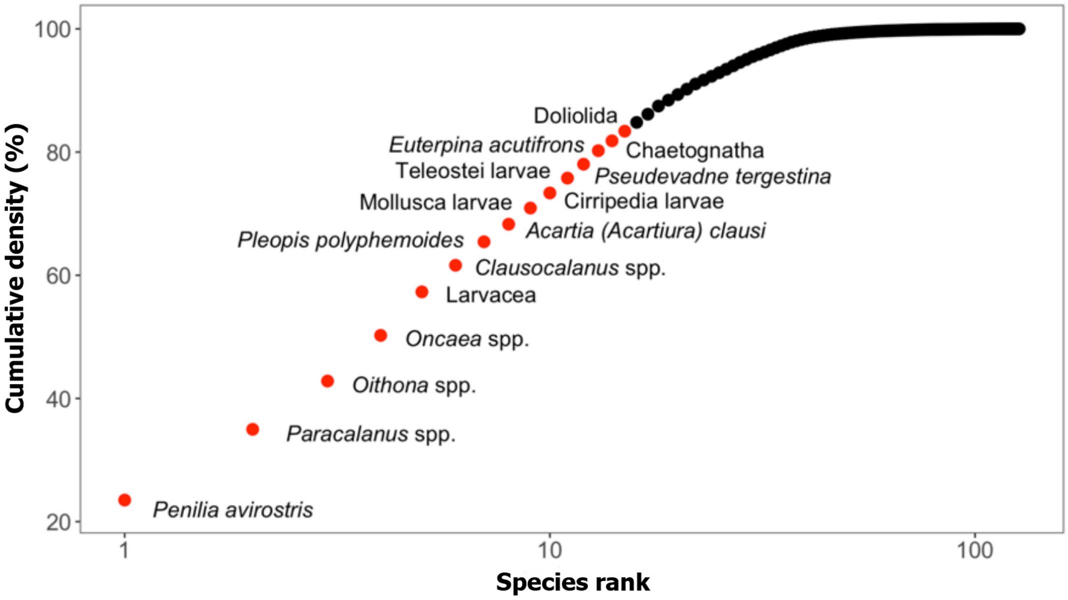

Fig 19. Density-species curve (k-dominance plot). Red points indicate the 15 most abundant species/taxa (in density, ind./m^3), whose names are indicated.

Normality and homogeneity of the data were tested using Shapiro-Wilk's and Levene's tests. Before analysis, only those species that represented at least 0.1% of density were used (Table 1). All zooplankton densities were log10(x+1) transformed to reduce skewness and to homogenize variances. Differences and patterns in the zooplankton community between stations were detected using weighted average hierarchical cluster analysis (Bray–Curtis similarity index) and visualized using nonmetric multidimensional scaling (nMDS, 'metaMDS' function in R from the Vegan package) (Oksanen *et al.*, 2018). Relationships between zooplankton community structure and environmental variables (SST, CHL, PIC, POC, River index, rainfall) were tested with the 'envfit' function (Vegan package). This function estimates the correlation and direction of climatic and environmental forcing within the nMDS state space.

To verify spatial and temporal variability, we used a non-parametric permutational multivariate analysis of variance (PERMANOVA, ʻadonis' function; Vegan package) using 999 permutations on the Bray–Curtis dissimilarity index. We applied four factors to the function: station, transect, season and year. Species that showed up only once in the entire dataset were excluded from the PERMANOVA. Following the design used for the PERMANOVA, we assessed the spatial and temporal changes (and their interaction) in zooplankton density using analysis of variance (univariate ANOVA). When the univariate ANOVA test detected significant p levels, specific pair-wise differences were identified using the Bonferroni post hoc test (Zar, 1984).

To characterize the zooplankton community in terms of taxa composition associated with groups defined by: station, transect and season, the "Indicator Value Index" (IndVal) (Dufrêne and Legendre, 1997) was used. This index was obtained with the formulas below:

$A_{ij} = Nsp_{ij}/Nsp_{i}$

$B_{ji} = Nobservations_{ij}/Nobservations_{i}$

$IndVal_{ij} = A_{ij} \times B_{ij} \times 100$

where A_{ij} is the specificity of species *i* to group *j*. Nsp_{ij} is the mean density of species *i* in group *j*, and Nsp_{i} is the sum of the mean density of species *i* among all groups. B_{ij} is the fidelity of species *i* to group *j*. $Nobservations_{ji}$ is the number of observations in group *j* where species *i* occurs, and $Nobservations_{i}$ is the total number of observations in group *j*.

The IndVal combines the relative frequency of occurrence of each taxa with its relative density in a defined group. It ranges from 0 to 1, being higher when all individuals of a given species are found in a single sample or group of samples. The statistical significance of the IndVal values was examined using the Monte Carlo randomization test (999 permutations) (Dufrêne and Legendre, 1997).

All statistical analyses and graphs were conducted using the R statistical software (R Core Team, 2018) with R packages: ʻggplot2ʻ (Wickham, 2009), ʻlabdsv' (Roberts, 2016), ʻpolar histogram' (Ladroue, 2012) and ʻvegan' (Oksanen *et al.*, 2018).

4.4. RESULTS

4.4.1 Environmental conditions

Environmental satellite-based variables showed spatio-temporal variation associated with the regional oceanographic regime and seasonal cycle. As expected, SST values were consistent with the typical pattern of temperate regions (Fig. 20A-C), characterized by summer warming (~21.3 °C) and winter cooling (~16.7 °C). The widest SST amplitude was found at the mouth of Guadalquivir River (maximum of 26.6 °C and minimum of 20.6 °C). Sea surface colour revealed persistent high production on the northwest coast, under the influence of the rivers (Fig. 20D-F).

PIC concentration exhibited a seasonal pattern with peak concentrations in winter (up to 0.006 mg/m^3) and values virtually below the detection limit in summer (Fig. 20G-I). Similarly, POC concentrations (Fig. 20J-L) were highest at coastal stations under the influence of river mouths (especially in winter). Both PIC and POC matched the cycle of ocean colour. Note that these maps were built using the same seasons that we used for grouping the zooplankton samples. This means that, for instance, winter (February-March) incorporates the spring bloom in the case of ocean colour.

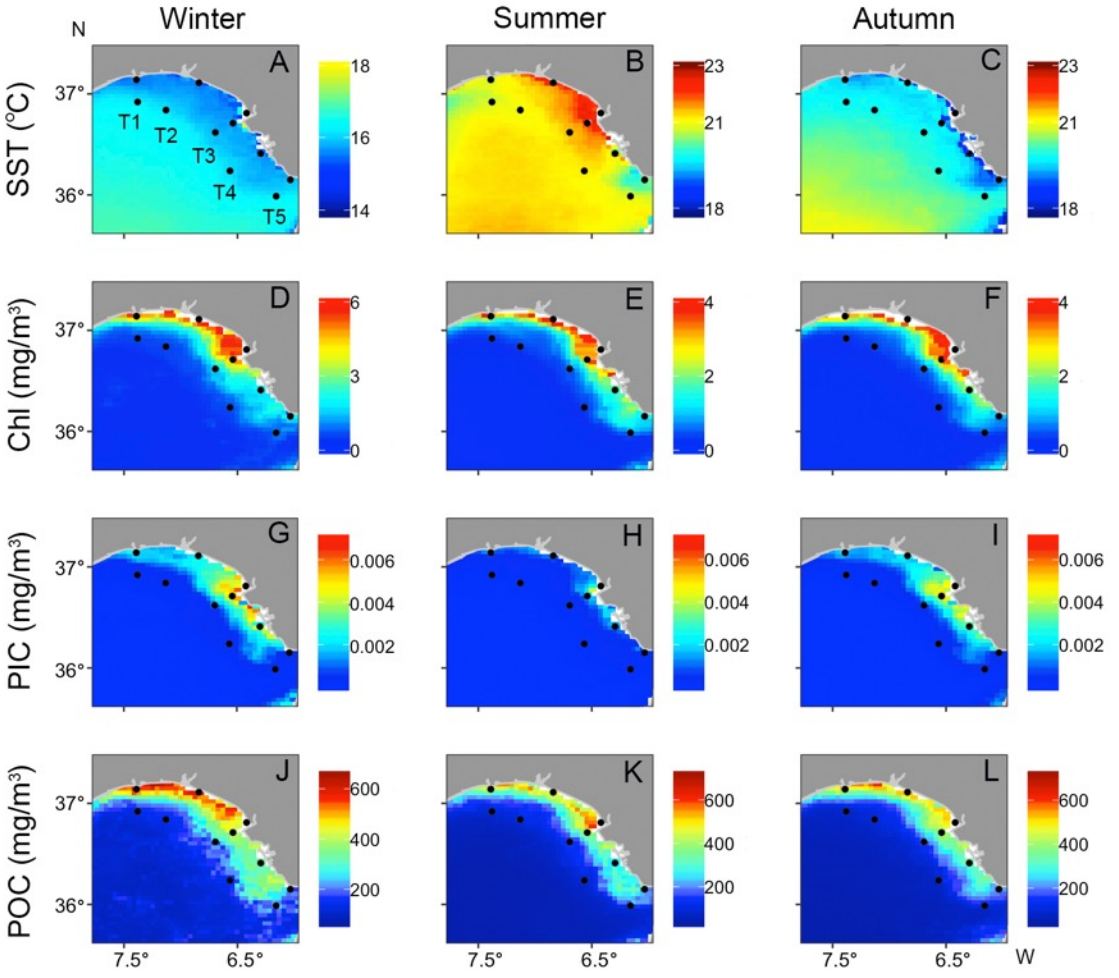

Fig 20. Seasonal pattern of sea surface temperature (SST, °C, panels A-C), chlorophyll a (Chl a, mg/m^3, panels D-F), particulate inorganic carbon (PIC, mol/m^3, panels G-I), and particulate organic carbon (POC, mol/m^3, panels J-L). Note that the scales can vary to better account for spatial variation according to the season. Stations are shown as black dots. Guadiana (T1); Tinto-Odiel (T2), Guadalquivir (T3); Sancti Petri (T4) and Trafalgar (T5) transects are indicated in panel

A. Seasons correspond to those used to group zooplankton samples: winter (Feb-Mar), summer (Jun-Aug), autumn (Sep-Nov).

4.4.2 Zooplankton community composition

A total of 128 zooplankton taxa belonging to 15 taxonomic groups were identified out of a set of 169 samples collected at eleven sites across the GoC. A complete list of taxa is provided as supplementary material (Table S2). The top 15 dominant taxa from the cumulative density of all stations were: *Penilia avirostris*, *Paracalanus* spp., *Oithona* spp., *Oncaea* spp., Larvacea, *Clausocalanus* spp., *Pleopis polyphemoides*, *Acartia (Acartiura) clausi*, Mollusca larvae, Cirripedia larvae, Teleostei larvae, *Pseudevadne tergestina*, *Euterpina acutifrons,* Chaetognatha and Doliolida (Fig. 19).

At the taxonomic level, copepoda were numerically the most abundant (~930 ind/m^3), most recurrent (RD 53.2%) and species-rich group (56.2% of the total, n=72) (Fig. 21 and Fig. 22A). Cladocerans (RD 26%; 9 taxa) were the second most abundant group but the third most diverse, and larvaceans were the third most abundant group (RD 6.3%; 3 taxa) (Fig. 21 and Fig. 22A). Other crustaceans (RD 3.8%; 28 taxa) were the second most diverse (Fig. 21). The other taxonomic groups (e.g. cnidarians, echinoderms, radiolarians, polychaete larvae and other larval forms) were less frequent, contributing to less than 1% of total zooplankton (Fig. 21).

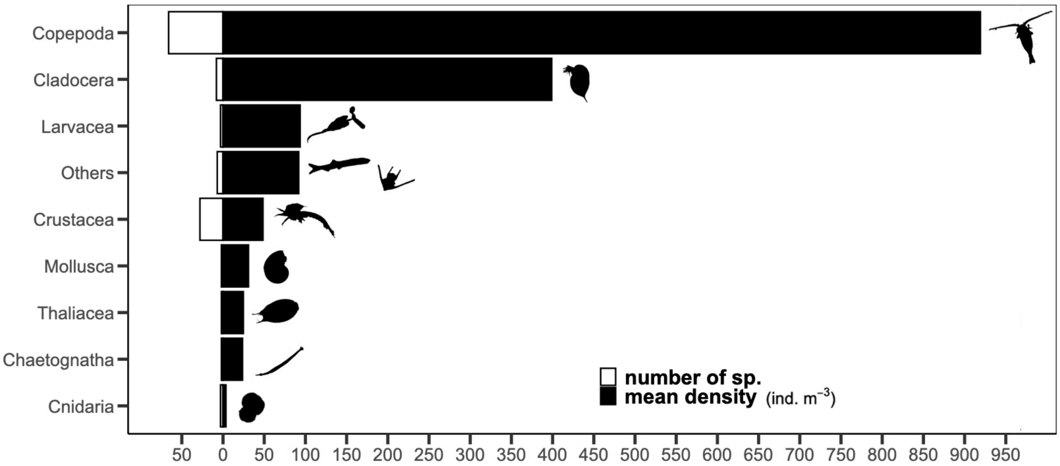

Fig 21. Number of taxa (left column) and mean density (right column, ind/m^3) of the major zooplanktonic groups.

Holoplankton was the most important lifestyle group across all transects, as well as per station and season. The thirteen meroplanktonic taxa (13 taxa) which included larvae of Crustacea (mainly decapods and euphausiids), Mollusca, Cnidaria, Polychaeta and Teleostei (e.g. Clupeidae, Engraulidae, Sparidae) represented 8.8% of the zooplankton community and were mainly concentrated in the coastal station of the Guadalquivir River (T3) followed by Tinto-Odiel (T2) and Guadiana (T1), particularly during winter (Figure 22A). In terms of trophic level, omnivores were composed primarily of copepod species, the majority of herbivores were cladocerans while the carnivorous group was dominated by chaetognaths and some copepods (Fig. 22A).

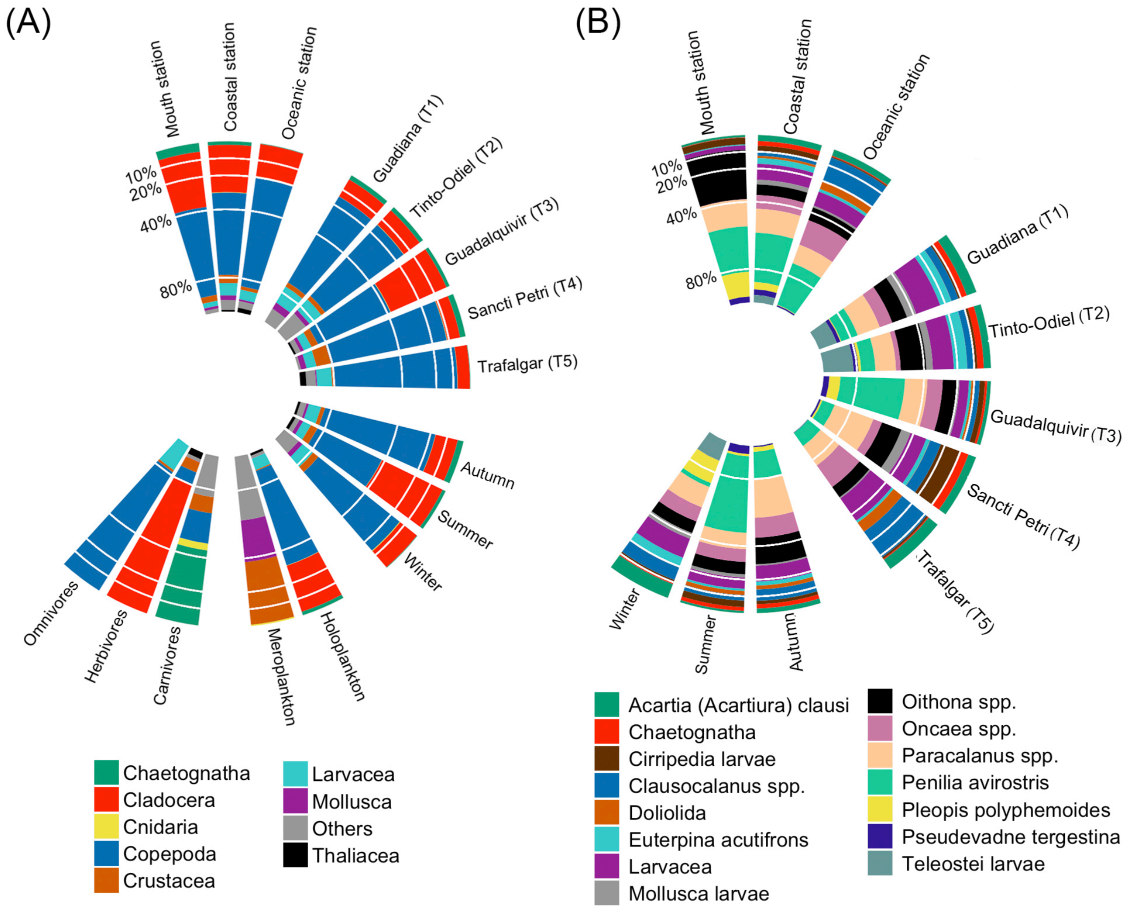

Fig 22. Zooplankton community and functional groups. A) Relative density of taxa by station (mouth, coastal and oceanic), transect (T1-T5), season (winter, summer, autumn), and functional groups (by lifestyle and diet); B) Relative density of the 15 most abundant taxa by station, transect and season.

4.4.3 Spatial variation

Spatially, variation followed two main gradients: coast-ocean and north-south:

With regard to the coastal-oceanic gradient, the copepod *Oithona* spp. dominated at the mouth of Guadalquivir River (T3), followed by *P. avirostris, Paracalanus* spp. and *P. polyphemoides* (Fig. 5B). The other coastal stations were characterised by comparatively lower densities of *Oithona* spp. and higher of larvaceans, *Oncaea* spp., *A. (Acartiura) clausi, E. acutifrons* and chaetognaths.

The oceanic stations included species of *Clausocalanus* and Doliolida that were not very represented on the coast.

At the northern limit of the study area (T1), Larvacea and *Paracalanus* spp., were the first and second most abundant taxa. Teleostei larvae and *Oithona* spp. dominated in transect 2 (Fig. 22B). The Guadalquivir transect (T3) differed from T2 in the clear predominance of cladocerans. *Paracalanus* species showed high densities in transect 4. At the south end, in the Trafalgar transect (T5), *Clausocalanus* spp. was the most abundant taxa followed by Larvacea, *Oncaea* spp., and *Paracalanus* spp. Unlike others transects, T5 also stands out by the absence of *P. polyphemoides* (Fig. 22B).

From a spatially-explicit perspective, cladocerans (especially, *P. avirostris*) showed its highest densities along the Guadalquivir transect (T3), at all 3 stations (Fig. 23A, G, L). Copepods were well represented across the shelf with a fairly even distributional pattern (Fig. 23B, C, D), with the exception of *Clausocalanus* spp. that presented its highest densities in the oceanic zone and in the south and was not detected at the mouth of the Guadalquivir River (Fig. 23F). The meroplanktonic taxa, Mollusca, Cirripedia and Teleostei larvae (*Sardina pilchardus, Boops boops, Diplodus* spp. and Gobiidae) reached their highest densities close to the river mouths (Fig. 23I, J, K). Doliolida were found in high numbers in the Guadalquivir (T3) and Trafalgar (T5) transects and missing from the coastal/mouth stations of the northern transects T2 and T3 (Fig. 23O).

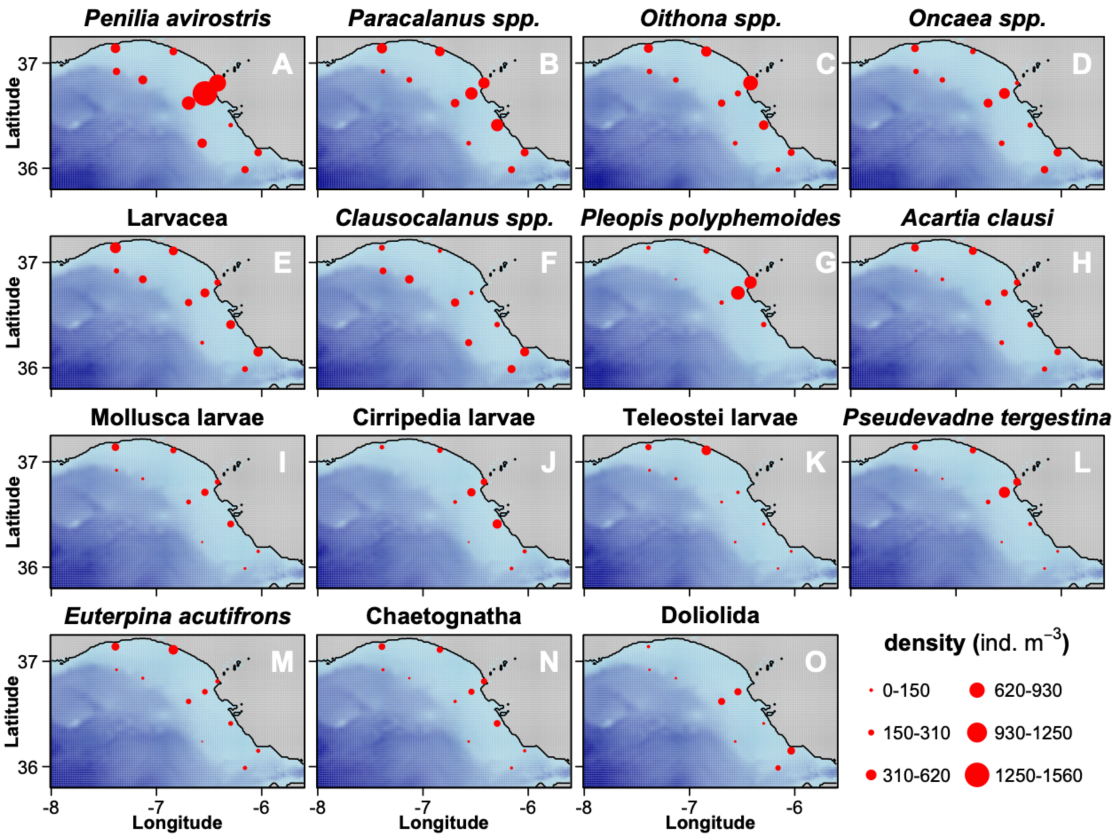

Fig. 23. Spatial distribution of the 15 most abundant zooplankton species/taxa in the Gulf of Cadiz. Dot sizes are proportional to (square root) densities. Six reference values are shown in the legend.

The dendrogram analysis carried out on stations (Fig. 24) identified three branches: (1) a first cluster consisting of all the oceanic stations, except that of the Guadalquivir transect (T3), plus the coastal station of the southernmost transect (T5), (2) the mouth station of the Guadalquivir River (T3), and (3) all coastal stations (except the one on T5) plus the oceanic station of the Guadalquivir transect.

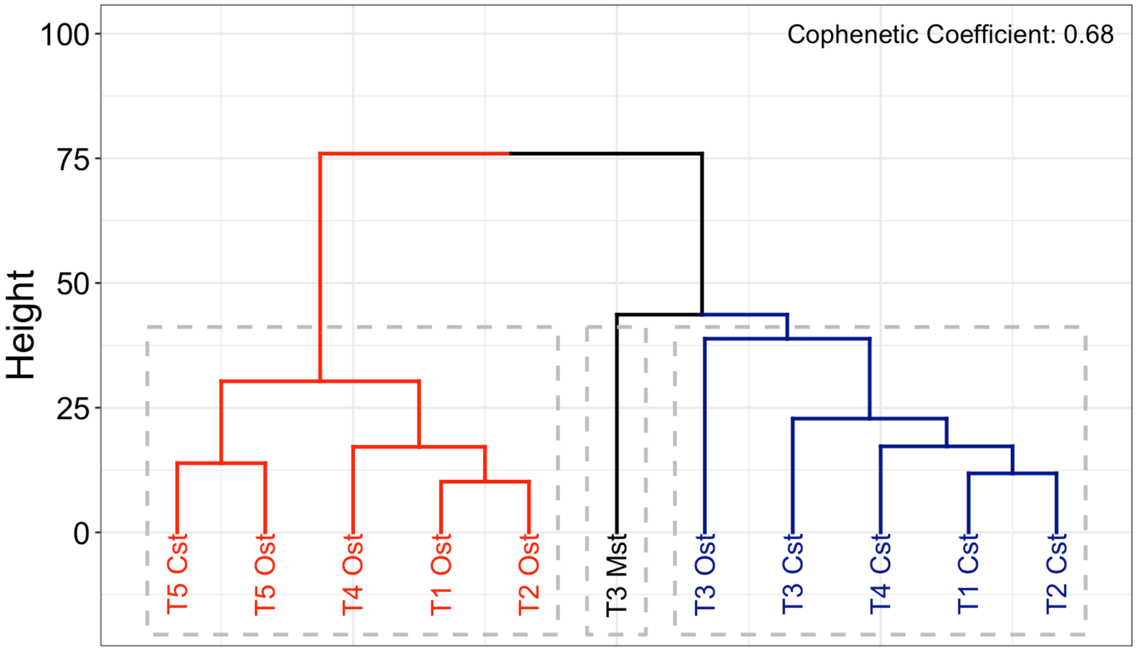

Fig 24. Results of the spatial cluster analysis of the zooplankton community structure. Legend: Mouth station (Mst); Coastal station (Cst); Oceanic station (Ost). Tansects: Guadiana (T1); Tinto-Odiel (T2), Guadalquivir (T3); Sancti Petri (T4) and Trafalgar (T5).

4.4.4 Seasonal and long-term variation

In general, the seasonal cycle of zooplankton matches the expected pattern at these latitudes, with comparatively higher densities in summer and lower densities for the autumn-winter season (Fig. 25A). At the Guadalquivir transect, this seasonal pattern has become less distinct in recent years, with similar averaged densities across seasons (Fig. 25B).

In terms of specific taxa *P. polyphemoides*, Teleostei larvae and *P. avirostris* showed the largest seasonal variation; *P. polyphemoides* and Teleostei larvae were most abundant in winter, while *P. avirostris* dominated in the summer (Fig. 25B).

The long-term variation was resolved using the 14-year series at the Guadalquivir transect (T3, coastal and oceanic stations). Total density displayed three major peaks in the summer of 2002, 2004 and 2007 (Fig. 26A). From 2010 there was a general decline, with the autumn of 2013 marking the minimum of the whole period, followed by autumn 2011.

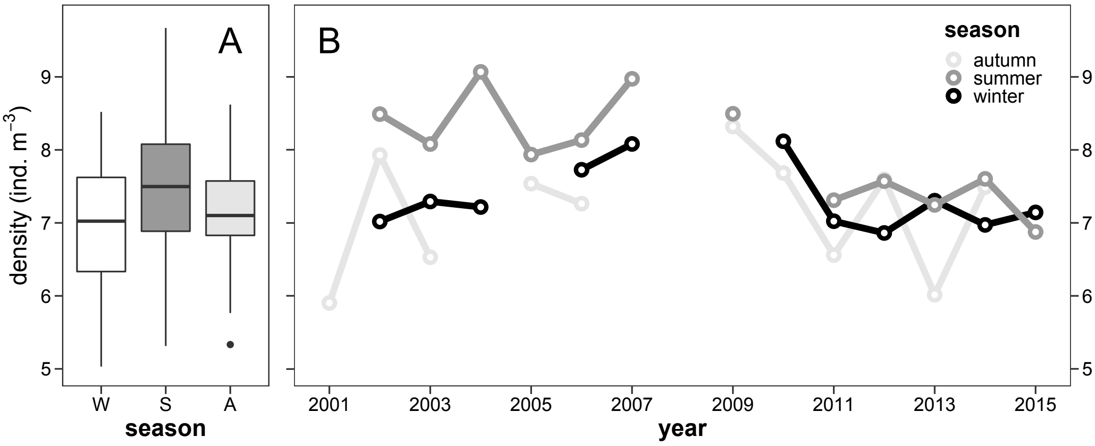

Fig 25. Seasonality. A) Boxplot showing the seasonal variation of zooplankton densities (ind/m^3). B) Interannual changes in mean densities per season (autumn, summer, winter) of total zooplankton at the Guadalquivir transect (mean of coastal and oceanic stations). Note the logarithmic scale.

At a finer taxonomic resolution, copepods were most plentiful in autumn 2009, winter 2010 and summer 2003, and least abundant in autumn 2013 (Fig. 26B). Cladocerans were always most abundant during the summer, especially in years 2002, 2004 and 2007, mainly due to *P. avirostris* outbreaks (Fig. 9C). The density of larvaceans, crustaceans and molluscs varied out of synchrony, peaking in different years (Fig. 26D-F).

Holoplankton followed the general trend, being higher in summer (e.g. 2002, 2004, 2007 and 2009), whereas the numbers for meroplankton peaked in the summers of 2007 2009 and 2014 (Fig. 26G-H). Carnivores showed marked variability at interannual scales, with peaks in density in 2004, 2007, 2009 and 2012 (Fig. 9I). Herbivores and omnivores depicted a decreasing trend at the end of the time-series (Fig. 26J-L, respectively).

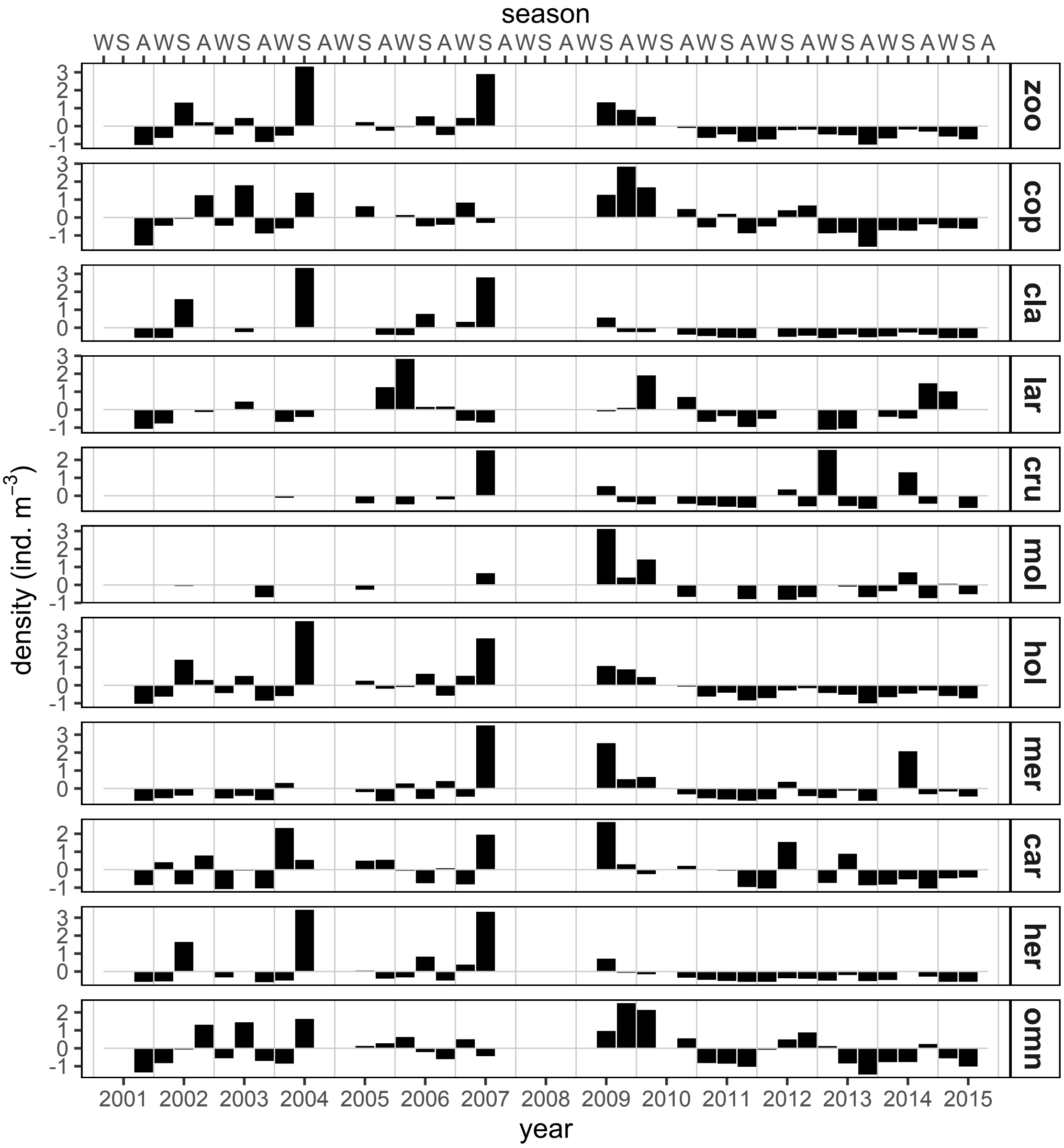

Fig 26. Time-series anomalies from 2001 to 2015 of *total density (ind/m^3) for the major zooplankton groups.* Note that values were log-transformed and standardised. Legend: W - winter; S - summer; A - autumn; ZOO - All zooplankton; COP - Copepoda; CLA - Cladocera; LAR - Larvacea; CRU - Crustacea; MOL - Mollusca; HOLO - holoplankton; MERO - meroplankton; CAR – carnivores; HER - herbivores; and OMNI - omnivores.

4.4.5 Zooplankton and environment

The nMDS analysis indicated that the zooplankton community structure was significantly correlated with SST, CHL, POC, River index and westerlies (Fig. 27). Easterlies, PIC and rainfall, however, did not significantly explain the groupings (Table 2). Community compositions were significantly different by station ($p < 0.001$), season ($p < 0.001$) and years ($p < 0.001$). There was also two significant interactions between the factors, stations:year and season:year ($p = 0.02$ and $p = 0.009$, respectively; Table 3). The same pattern emerged for total density: significant differences between stations (ANOVA, $F = 6.22$, $p = 0.002$) and seasons (ANOVA, $F = 7.42$, $p = 0.0006$) but not for the interaction between the last two factors (ANOVA, $F = 1.72$, $p = 0.14$).

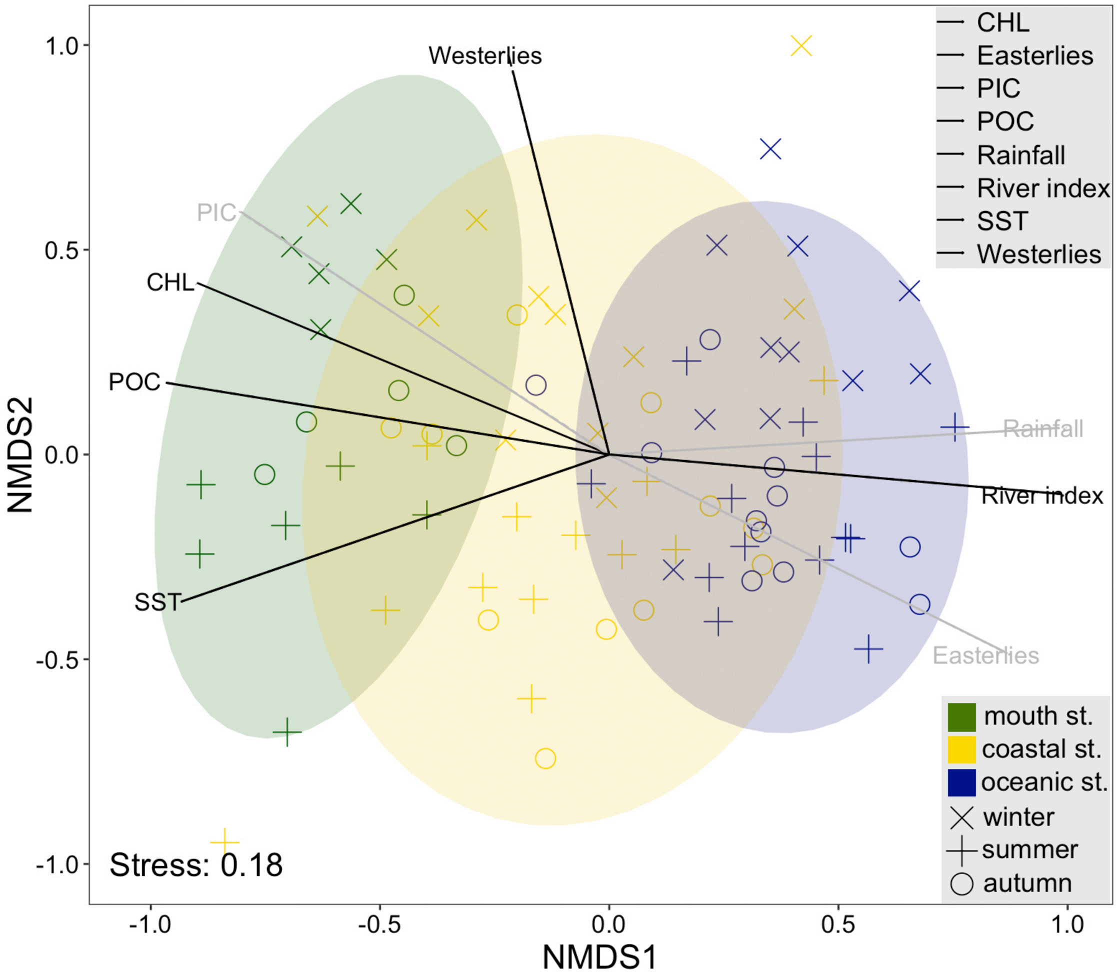

Fig 27. nMDS ordination analysis. Each data point is represented by a combination of a colour (depending on site: mouth, coastal, oceanic) and a symbol (depending on season: winter, summer, autumn) in the nMDS1 and nMDS2 space, see legend. Circles indicate confidence intervals. Black arrows show significant environmental variables: Sea surface temperature (SST), Chlorophyll-a (CHL), Particulate organic carbon (POC), River index and westerlies.

Table 2. PERMANOVA output for abundance using the factors: station, transect, season and year. Table shows degrees of freedom (df), sum of squares (SS), mean squares (MS), R^2 and P-values (Bold font indicates statistical significance).

	df	SS	MS	R^2	P-values
Station	2	2.9502	1.4751	0.1905	**0.0001**
Season	2	1.5025	0.7512	0.0970	**0.0001**
Year	1	0.6279	0.6278	0.0405	**0.0002**
Station:Season	4	0.5566	0.1391	0.0359	0.2987
Station:Year	2	0.4272	0.2136	0.0276	**0.0257**
Season:Year	2	0.4943	0.2471	0.0319	**0.0095**
Residuals	71	8.9232	0.1258	0.5763	

Table 3. nMDS output and environmental variables fitting. nMDS1 and nMDS2 give vector directions. R^2 is the squared correlation coefficient. Significance levels (P-values indicates in bold) are based on random permutations (999).

	nMDS1	nMDS2	R^2	P-values
SST	-0.9332	0.3592	0.0834	**0.018**
CHL	-0.9062	0.4226	0.3610	**0.001**
PIC	-0.8056	0.5923	0.0180	0.495
POC	-0.9839	0.1784	0.2894	**0.001**
River index	0.9952	-0.0973	0.1620	**0.002**
Westerlies	-0.2197	0.9755	0.0820	**0.028**
Easterlies	0.8727	0.4882	0.0365	0.205
Rainfall	0.9978	-0.0655	0.0128	0.605

4.4.6 Species Indicator (IndVal)

According to the IndVal index, five taxa were significantly associated with the Guadalquivir transect (T3): *Oikopleura (Vexillaria) dioica*, *P. polyphemoides*, *Paracartia grani*, Foraminifera and *Sagitta* sp. (Table S3). Only Doliolida were identified as indicators of the Trafalgar transect (T5). Five taxa (all copepods): *Clausocalanus* spp., *Calocalanus* spp., *Ditrichocorycaeus* spp., *Ctenocalanus vanus* and *Ditrichocorycaeus* spp. were considered indicators of the continental shelf (T1, T2, T4 and T5), except in the transect under the influence of the Guadalquivir River (Table S3).

Clear changes in species distribution were detected across seasons. The cladoceran *Pseudovadne tergestina* was associated to summer, while the *P. polyphemoides* was observed only in winter. Six taxa were also preferentially found in the summer-autumn period: the cladocerans *P. avirostris* and *Evadne spinifera*, chaetognaths (*Sagitta* sp. and rest of chaetognaths) and two copepods (*Centropages chierchiae*, *Temora stylifera*). There are only two taxa associated with the winter-summer period, Copepoda nauplius and *Evadne nordmanni*. No species were identified as indicator for stations. A list of taxa associated with each of groups is provided as supplementary material (Table S3).

4.5. DISCUSSION

By describing the GoC zooplankton community structure and its spatio-temporal variation this study makes a step forward in understanding this component of the marine food web and bridges the existing gap between the hydrographical processes (Ruiz and García-Lafuente, 2006; Sánchez-Leal *et al.*, 2017) and upper trophic levels (Torres *et al.*, 2013; Llope, 2017; Delgado *et al.*, 2018), traditionally better studied in the region.

Our results are consistent with previous studies carried out in the area (Rubín *et al.*, 1997; Villa *et al.*, 1997; Mafalda *et al.*, 2007; Ben-Hamadou *et al.*, 2010, Benavides *et al.*, 2010; Taglialatela *et al.*, 2014) and depict a diverse community dominated by a relatively small number of taxa. The copepods of the genus *Paracalanus*, *Oithona*, *Oncaea and Clausocalanus* and the cladocerans *P. avirostris* and *P. polyphemoides* make the bulk of the zooplankton community. Meroplanktonic forms and chaetognaths are also important.

Mafalda *et al.* (2007) studied the GoC zooplankton with a comparable spatial coverage during the summers of 1994 and 1995. The authors reported high abundances of cladocerans, copepods, cirripeds, chaetognaths and Doliolida, which are coincident with our results.

Concerning the variation of diversity and density over space, we found the classical gradient consisting of high diversity and low density at the oceanic stations changing to fewer species but higher densities as we move closer to the coast. The same pattern has been recently described for chlorophyll and phytoplankton in the area (González-García *et al.*, 2018). The outbreaks in warm periods of the cladocerans *P. avirostris* and *P. polyphemoides*, and to a lesser extent the *Paracalanus* and *Oithona* copepod *species,* contribute to shape this spatial gradient.

As expected, holoplankton dominated the assemblages all over the area while meroplankton were important close to river mouths. These areas are known to be nursery grounds for species of commercial interest (Baldó *et al.*, 2006; Catalán *et al.*, 2006; Mafalda and Rubín, 2006), particularly the Guadalquivir estuary and adjacent waters, which is considered an essential habitat for anchovy due to this role on the population dynamics of this fish species (de Carvalho-Souza *et al.*, 2018). The high densities of cladocerans and meroplankton observed in the Guadalquivir transect (T3 in Fig. 23), together with the previously described high densities of mysids species, support this nursery role by contributing to the food supply to early life stages of higher trophic levels.

Anchovy and sardine are the main forage fish in the area. While adult sardine tend to occur off Portugal (west of transect 1), the more zooplankton-dependent anchovy is very abundant in the area between transects T1 (Guadiana) and T4 (Sancti Petri), with highest biomasses usually found around T3 (Guadalquivir) (ICES 2018a, 2018b). Anchovy eggs and recruits are also plentiful in this area, which overlaps with the highest densities of zooplankton and cladocerans outbreaks described in this paper (Fig. 23). Although the spatial distribution of pelagic fish shows interannual variations, there also seem to be a preference by mid-size pelagic fish (horse mackerels, *Trachurus* spp.) for zones near the estuaries (Canseco, 2016).

Pelagic fish operate the energy pathways that link zooplankton and the upper components of the ecosystem, since copepods, cladocerans and euphausiids are known to be their main food items (Torres *et al.*, 2013). Future studies addressing dietary changes (e.g., ontogenetic or feeding behaviour) and the resemblance between diet and environmental composition and season (availability or outbreaks) will help us better understand the role of zooplankton in the GoC trophodynamics.

Looking at anomalies over time (Fig. 26) we detected a general decrease in density. This trend has to be taken with caution since to build the time series we pooled together samples from independent surveys carried out in different periods of time, using different ships. All these circumstances might affect this finding. However, the sampling methodology was consistent across surveys and the negative anomalies that appear after 2010 followed a short period of positive anomalies in 2009. Since 2009 there is a consistent on-going monitoring programme. The fact that the shift from positive to negative anomalies is captured by the current survey supports this conclusion.

This decreasing trend seem to be primarily driven by a drop in summer densities, which used to be clearly above winter/autumn values before 2008. This pattern has become less distinct in recent years and summer values are now indistinguishable from those of autumn and winter (Fig. 25B). The causes behind this change are unclear and future studies should focus on disentangling the role of bottom-up environmental changes, such us warming or the amount and frequency of river discharges, from top-down control from small pelagics.

Clustering and ordination (Fig. 24, 27) defined three different zones: (i) the area under the direct influence of the Guadalquivir river (mouth station), (ii) stations shallower than 100 m and (iii) stations deeper than 100 m plus the coastal station off Cabo Trafalgar. This zonation reflects the role of hydrography and productivity as underlying structuring factors, in particular upwellings (Sala *et al.*, 2018), winds (Vargas *et al.*, 2003), and freshwater discharges (Navarro *et al.*, 2006; Caballero *et al.*, 2014).

The area around the Guadalquivir River mouth is known for its high productivity throughout the year due to the interaction between the tidal forcing and the river flow. These waters are characterised by warmer temperatures, higher levels of organic matter, nutrients and chlorophyll (Navarro and Ruiz, 2006; Caballero *et al.*, 2014) that result in high densities of zooplankton, boosted by frequent outbreaks of cladocerans (Fig. 26). These features provide favourable conditions for growth of early stages of many marine species and make this area an essential fish habitat (de Carvalho-Souza *et al.*, 2018). Our results further support the singularity of this area from a zooplankton perspective.

The second zone is characterized by shallow waters and the influence of the Guadiana, Tinto-Odiel and Guadalquivir Rivers, except the Guadalquivir mouth station described above, which stands alone. The influence of the Guadalquivir in the GoC is greater than that of the Guadiana and Tinto-Odiel. This explains the inclusion of the Guadalquivir transect intermediate station and the two coastal Guadiana and Tinto-Odiel stations in the same group. Mixing conditions on the continental shelf would be another common feature of this area.

The third zone was composed of the southernmost coastal station and all the oceanic stations but the one on the Guadalquivir transect (Fig. 18). The latter is the only oceanic station shallower than 100 m and that can explain its classification in the coastal zone. On the other hand, the Trafalgar coastal station is affected by a local upwelling (Sala *et al.*, 2018) which can explain its belonging to this group. The two northern oceanic stations (on transects T1 and T2) are located in an area characterised by warm-cold-warm waters in a NW-SE direction called the 'Huelva Front'. The formation of this front is facilitated by westerly winds (Vargas *et al.*, 2003) and results in an increase of surface chlorophyll (mainly in summer). A similar process occurs off Cabo Trafalgar due to the wind-driven local upwelling and tide–topography interactions (Vargas-Yañez *et al.*, 2002; Navarro and Ruiz, 2006; Sala *et al.*, 2018).

The reconstruction of Guadalquivir time series transect (14 years, 3 seasons, 3 stations) allowed us to investigate the structuring role of the environment. The nMDS analysis selected surface temperature, chlorophyll (or ocean production), particulate organic carbon, river discharges and westerlies as primary drivers and discarded particulate inorganic carbon, rainfall and easterlies (Fig. 26C). The x axis captured the spatial gradient, from the mouth of the river to open waters on the continental shelf, with the intermediate station spanning a wider range. The vertical axis captured the seasonal variability with winter samplings being more distinguishable than those carried out in summer and autumn. The great variability in this particular area of the Gulf, under the influence of the Guadalquivir River, which at times can extend all the way to the outer stations, is revealed by the overlap between stations.

Ocean colour (chlorophyll and other production sources) and POC are proxies for food (Legendre and Michaud, 1999) and were also found to be structuring factors in this transect. The Guadalquivir River conveys large amounts of organic matter to the ocean and this fertilising effect has been studied by means of satellite suspended solids (Caballero *et al.*, 2014) and in situ measurements of fluorescent dissolved organic matter (González-Ortegón *et al.*, 2018). These particular conditions of the Guadalquivir transect make the area the most productive of the GoC (Navarro and Ruiz, 2006). Easterlies and westerlies are known to influence the upper circulation in the GoC (García-Lafuente and Ruiz, 2007). However, the selection of westerlies by the nMDS could be simply reflecting their prevalence in winter time.

Temperature stands out as the one of the main structuring factors of the assemblages. Warm water periods are dominated by the cladocerans *P. avirostris*, and *P. tergestina*, as well as cirripeds, chaetognaths and Doliolida. The prevalence of these taxa is probably associated with their life history traits. The outbreaks of *P. avirostris* are likely to be favoured by the parthenogenetic behaviour of this species, short developmental times and high growth rates (Atienza *et al.*, 2008; Li *et al.*, 2014). In this regard, the scenarios for the Western Iberian Margin that anticipate a surface water temperature increase between 1.5 and 2.5°C near the coast (Cordeiro Pires *et al.*, 2015), might favour these outbreaks.

But warming can bring about indirect effects, such as the strengthening of the stratification with implications on the depth of the mixed layer (Richards, 2008). Top-down effects should also be considered. Small pelagics are mainly planktivorous. Anchovy, for instance, feeds on copepods, cladocerans and meroplanktonic forms (Torres *et al.*, 2013) and is known to use the Guadalquivir area as nursery ground. Anchovy and horse mackerel (de Carvalho-Souza *et al.*, in prep.) populations have been in a good state in the last years and this could partly explain the decline observed in cladocerans since 2011. As in better understood ecosystems, like the Baltic Sea (Casini *et al.*, 2009; Möllmann *et al.*, 2009) or the North Sea (Nicolas *et al.*, 2014; Lynam *et al.*, 2017), future studies addressing to which extent the seasonal and long term changes reported here respond to hydrographical (bottom-up) or trophic (top-down) forcing are necessary.

This study provides a baseline and set the scene of the zooplankton component in the Gulf of Cadiz. This information will be valuable for environmental policy implementation –zooplankton is a key indicator in the Marine Strategy Framework Directive (MSFD)– or the identification of pelagic marine protected areas (Natura 2000) that will eventually inform the Maritime Spatial Planning (MSP) Directive. A better understanding of zooplankton dynamics will also facilitate the development of ecosystem-based management.

4.6. CONCLUSIONS

The zooplankton community composition in the Gulf of Cadiz is dominated by copepods and secondarily by cladocerans. The latter group (especially *P. avirostris*) stands out by its population outbreaks under warm conditions, particularly in the area of influence of the Guadalquivir River, which is considered an Essential Fish Habitat. Moreover, the zonation singled out the station located at the mouth of this river, which supports the singularity of this area, also from the zooplankton perspective. The effect of river-related factors, such as organic matter input and freshwater inflow are important structuring factors along the Guadalquivir transect, whose influence extends further away into the continental shelf compared to other rivers in the area.

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Capítulo 5. Discusión general

5. DISCUSIÓN GENERAL

5.1 EVALUANDO EL ECOSISTEMA A PARTIR DE UN ENFOQUE BASADO EN EL ECOSISTEMA A LA GESTIÓN PESQUERA: LECCIONES DEL ESTUARIO DEL GUADALQUIVIR Y GOLFO DE CÁDIZ

El objetivo de desarrollar una evaluación cuantitativa para apoyar el desarrollo del EBFM pretende obtener una comprensión del ecosistema de forma holística mediante el análisis y síntesis de información, considerando la dinámica de las especies (sean objetivo o no para las pesquerías) y la complejidad del sistema socio-ecológico en el tiempo (McLeod y Leslie 2009; Levin et al., 2009; Link y Browman, 2014; Long et al., 2015). En esta tesis, investigué los efectos de variables ambientales, climáticas y de múltiples actividades antropogénicas en el socio-ecosistema del estuario del Guadalquivir - golfo de Cádiz mediante la aplicación de un enfoque de modelado y análisis de integración de datos. La aplicación de ese enfoque basado en ecosistemas implicó en la recopilación, el análisis y la integración de una gran cantidad de información para construir modelos y conocer la dinámica espacio-temporal de ese sistema acoplado.

Este estudio representa, hasta donde sabemos, el primer intento de evaluar las series temporales del estuario del Guadalquivir y golfo de Cádiz y describir la evolución temporal del ecosistema de forma holística y conjunta. En particular, describimos por primera vez los cambios del golfo de Cádiz en las dos ultimas décadas, la distribución espacio-temporal de la comunidad zooplanctónica y como las especies del estuario del Guadalquivir respondían al forzamiento ambiental en ese hábitat esencial para peces (EFH). Además, el desarrollo de ese trabajo me permitió aprender y verificar las principales características del sistema acoplado y como los distintos factores (p. ej. sociales, ambientales, antropogénicos) influenciaron el ecosistema en las dos ultimas décadas, así como sus limitaciones y perspectivas futuras.

5.1.1 ESTUARIO DEL GUADALQUIVIR

El estuario del Guadalquivir es un ecosistema altamente impactado debido a las intensas presiones humanas que ha sufrido especialmente a partir del siglo XVIII. Esos impactos resultaron en cambios drásticos como la eliminación de marismas, transformación de su red hidrográfica, sobreexplotación de stocks (p. ej. anguila), control del agua dulce descargada y, introducción de grandes cantidades de materia orgánica y nutrientes en el sistema; resultando en uno de los estuarios con la mayor cantidad de solidos en suspensión del mundo (Ruiz et al., 2015). En la actualidad, todos estos aspectos generan una seria de conflictos de intereses. Llope (2017) hizo una conceptualización actual de los sectores y principales actividades desarrolladas en el estuario (Fig. 28). Estos incluyen la agricultura, la acuicultura, la navegación, las industrias de sal y minería, la pesca, el turismo, así como las partes interesadas en la conservación.

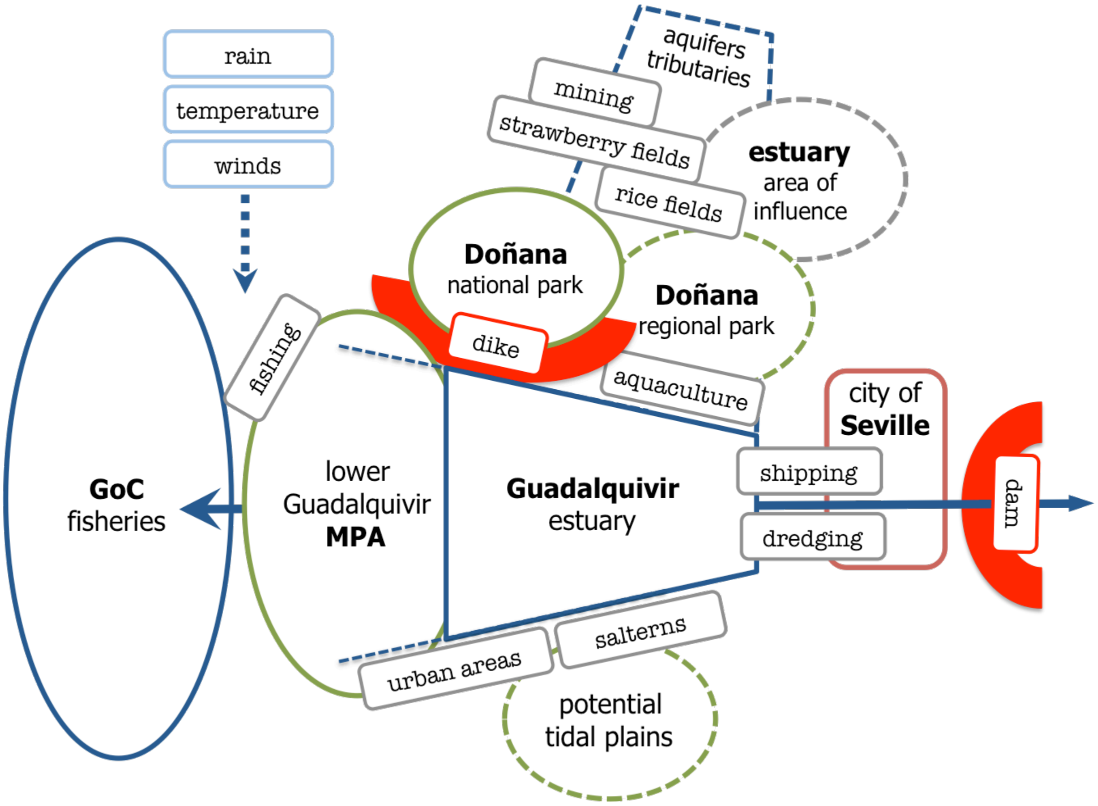

Fig. 28. Diagrama de conceptualización del estuario del Guadalquivir (Llope, 2017). La flecha azul representa el gradiente de salinidad, desde su desembocadura (donde se localiza la MPA) hasta la presa de Alcalá del Río. Las principales infraestructuras (dique y presa) se muestran en rojo. En la parte superior están los sectores cuyas actividades tienen consecuencias a través de afluentes como minería, acuíferos (fresas) o directamente relacionadas con el flujo de agua dulce (arroz). En la parte inferior están las actividades que ocupan potenciales llanuras mareales (acuicultura, producción de sal, áreas urbanas). Las demás actividades con los posibles riesgos (dragado, navegación) se muestran cerca de Sevilla. Factores ambientales que no son gestionables (lluvia, temperatura y vientos) se muestran entre el mar y el estuario.

Además, el estuario se encuentra regido por una serie de marcos legislativos nacionales e internacionales como el de Aguas, Estrategias Marinas e Hábitats (EC, 1992; 2000; 2008). Estas directivas requieren la identificación y el uso de indicadores que buscan la definición de métricas claves de monitoreo a largo plazo y evaluación del estado del ecosistema, y así lograr sus objetivos para un buen estado medioambiental (GES) de sus aguas (EC, 2000; 2008).

Como pudimos verificar en el **capitulo 3** de la tesis, dos variables se muestran claves para las larvas y juveniles del boquerón y sus presas, así como para muchos de los sectores (p. ej. agrícola): la turbidez y la salinidad. Vale recordar que estas variables están directamente asociadas a la frecuencia y intensidad (volumen) de las descargas de agua dulce, controladas por la presa de Alcalá del Rio.

Para ilustrar la evolución temporal de estas variables y los demás factores que influyen el ecosistema, expandimos el uso de algunas de las herramientas del **capitulo 2** (PCA y TLP) para los principales grupos funcionales del estuario (Anexo A). Los dos primeros ejes del PCA explicaron el 46.5% de la variación entre muestras (Fig. x). La turbidez, las descargas y los peces estuarinos tuvieron el mayor peso en la formación del eje 1, lo que explica el 27.3% de la variación total. Los misidáceos y la salinidad tuvieron el mayor peso en la formación del eje 2, lo que explica el 21.3% de la variación total. En general, la ordenación de las variables evidenció el efecto de las descargas del río a lo largo del eje 1, que muestran una menor salinidad. El aumento de la turbidez muestra una relación negativa con la temperatura, los peces marinos migrantes y los misidáceos.

Como podemos observar en la figura 29, las variables que disminuyen hacia el final del período evaluado (1997-2015) fueron la salinidad y los grupos directamente relacionados y/o influenciados por estas condiciones y/o niveles como peces estuarinos y especies marinas migrantes (la mitad superior del TLP). Por otro lado, en la mitad inferior se concentró aquellas variables que aumentaron sus promedios a lo largo del tiempo como los decápodos estuarinos, la turbidez y descargas de agua dulce. En el TLP (Fig. 30) también podemos observar los eventos de turbidez extrema a lo largo de todo el estuario que ocurrieron al final de la década de 1990 y entre los anos de 2007-2009 (González-Ortegón et al., 2015). Eses eventos desencadenaron una combinación de alta turbidez y salinidad que tienen efectos perjudiciales para la producción de arroz (Llope, 2017). Por otro lado, la alta turbidez y la baja salinidad tienen un efecto negativo en la zona cría (**capitulo 3**); que son factores que están directamente relacionados con la presencia de presas y el flujo de agua dulce descargado. Asociado a esto, están los cambios en la geomorfología que han incrementado las velocidades y favorecen la continua resuspensión de los sedimentos (Díez-Minguito et al. 2014; Caballero et al. 2014). Como resultado, el estuario presenta una baja o casi ninguna estratificación, aguas con tiempos de residencia generalmente altos que contribuyen a los problemas de calidad del agua (Ruiz et al., 2015).

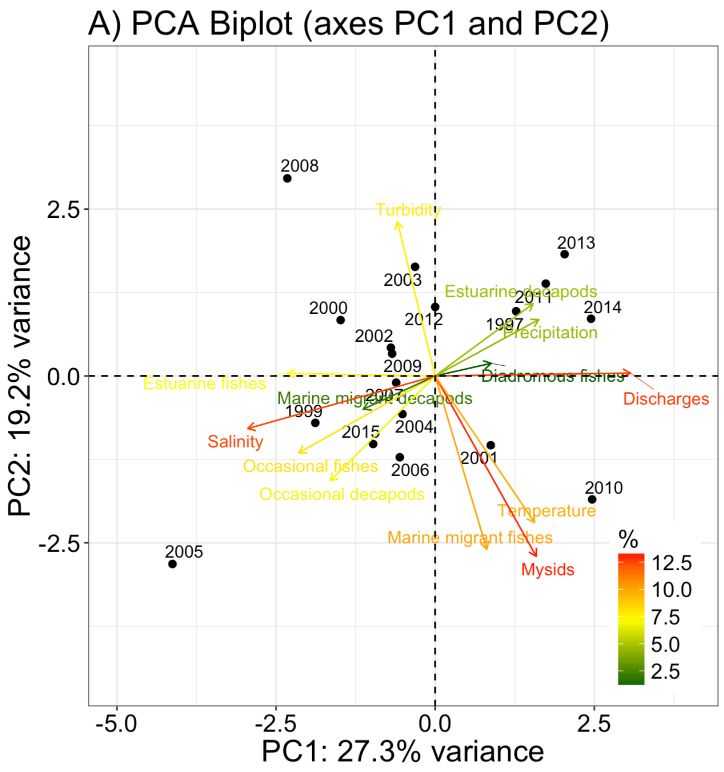

Fig. 29. La Análisis de componentes principales (PCA) muestra el grado de correlación de cada variable dada con el respectivo eje (PC1 y PC2). Las contribuciones de cada variable a los ejes principales son ilustradas por colores como se muestra en la leyenda (de verde a rojo).

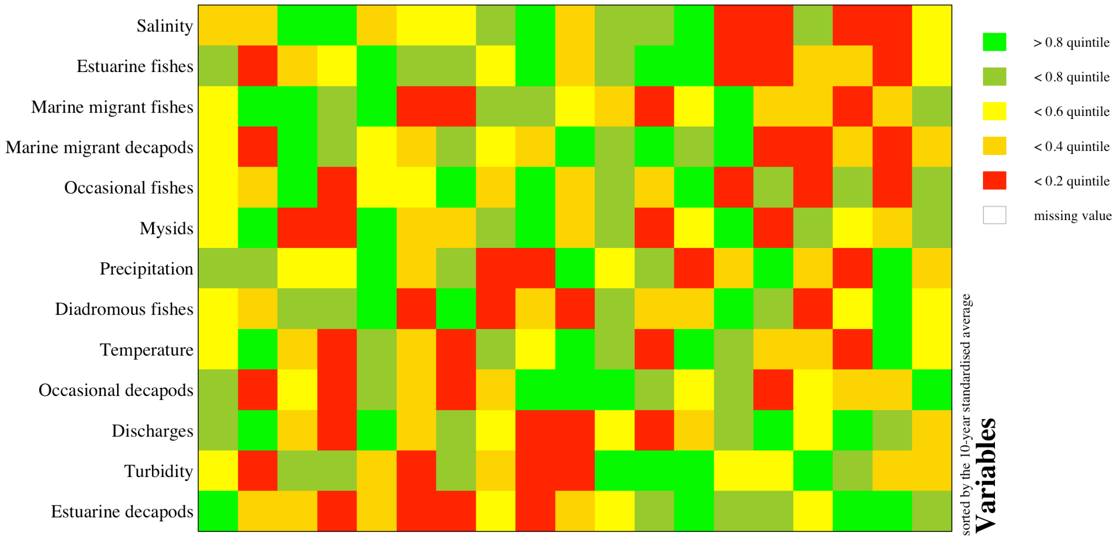

Fig. 30. Grafico de semáforo que representa el desarrollo del ecosistema del estuario. Las series temporales se transformaron en quintiles, son presentadas por colores y se ordenaron numéricamente de acuerdo con el promedio de sus primeros 10 años. El rojo representa valores bajos, mientras que el verde representa valores altos para cada una de las variables correspondientes.

Por lo tanto, mejorar el estado ambiental del estuario del Guadalquivir es un gran reto, pero más factible una vez que existe conocimiento científico derivado de series temporales (ver referencias del **capitulo 3**), así como los monitoreos en tiempo real (Ruiz et al., 2015). Sobre este conocimiento las partes interesadas deberán buscar un balance entre las demandas sociales, económicas y ambientales convergiendo en una solución sostenible para el funcionamiento saludable del ecosistema y el mantenimiento de sus servicios. Un paso más para esto ha sido dado en el **capitulo 3,** con la identificación y definición de posibles "puntos de referencia" para estos indicadores con influencia antropogénica y que, por lo tanto, pueden variar acorde a las decisiones de gestión.

5.1.2 GOLFO DE CÁDIZ

El GoC es un ecosistema modificado que ha sido influenciado por las actividades humanas a lo largo de los siglos, una vez que se asientan humanos en sus costas. Por otro lado, las medidas de regulación y políticas basadas en el conocimiento científico, así como el interés de las partes interesadas pueden traer importantes y prácticos resultados para la mejora y gestión del ecosistema. El **capitulo 2** de la tesis ha demostrado que el GoC es un buen ejemplo de cómo eso es posible. Las medidas adoptadas continuaron salvaguardando el GoC como un "hotspot" de biodiversidad del Atlántico norte - con más de 1000 taxones reportados (Anexo B, D, E) – y así integrando el corredor de biodiversidad de la cuenca mediterránea (Fig. 31).

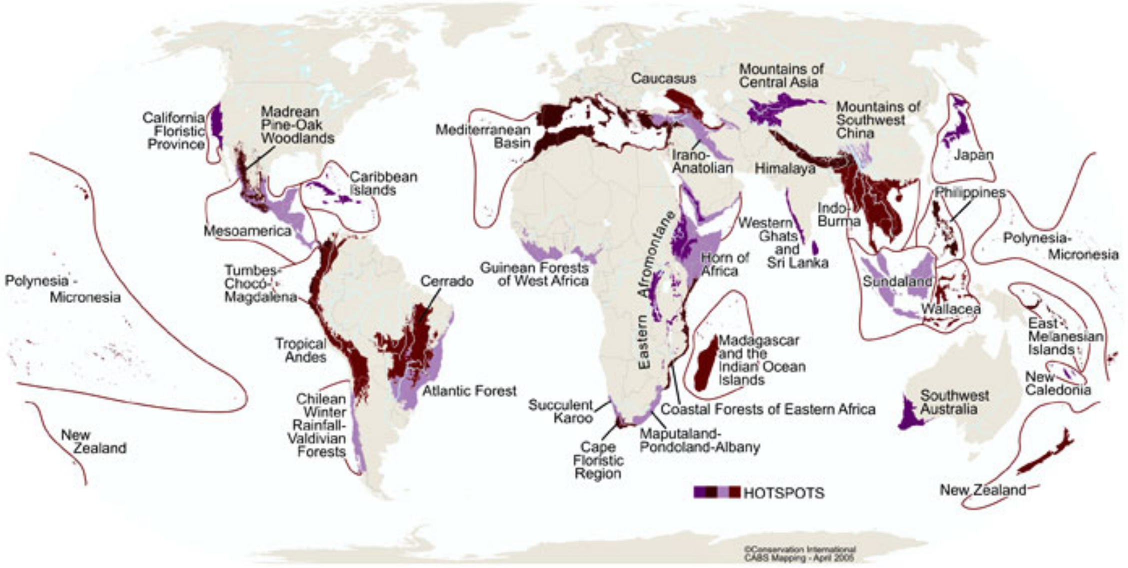

Fig. 31. Mapa de hotspots de biodiversidad en el mundo (Conservation International).

Sin embargo, a pesar de su importancia, pocos estudios han considerado previamente el funcionamiento y la estructura de este ecosistema. El primer y uno de los más recientes intentos de describir este ecosistema se llevó a cabo utilizando un modelo Ecopath (Torres et al., 2013). Este estudio construyó un modelo actual de cadena trófica, destacando la importancia de varios componentes, entre ellos el zooplancton y la necesidad de avanzar en los estudios de este grupo particular. El **capitulo 4** de la presente tesis ha contribuido para el avance del conocimiento de ese importante componente pelágico y base de la cadena trófica.

En ese estudio se identificó también tres importantes zonas para las comunidades zooplanctónicas (**capitulo 4**). Podemos observar que estas zonas convergen con los hallazgos de otros importantes trabajos desarrollados en la parte española de la plataforma continental del GoC (Fig. 32). Del punto de vista oceanográfico, tres de esas zonas se muestran claves para el GoC: (1) la zona costera de la plataforma norte, donde se encuentran también las desembocaduras de los ríos Guadiana y Tinto-Odiel, (2) la región central en frente a la desembocadura del río Guadalquivir, y (3) una zona sur, situada entre Trafalgar y el estrecho de Gibraltar.

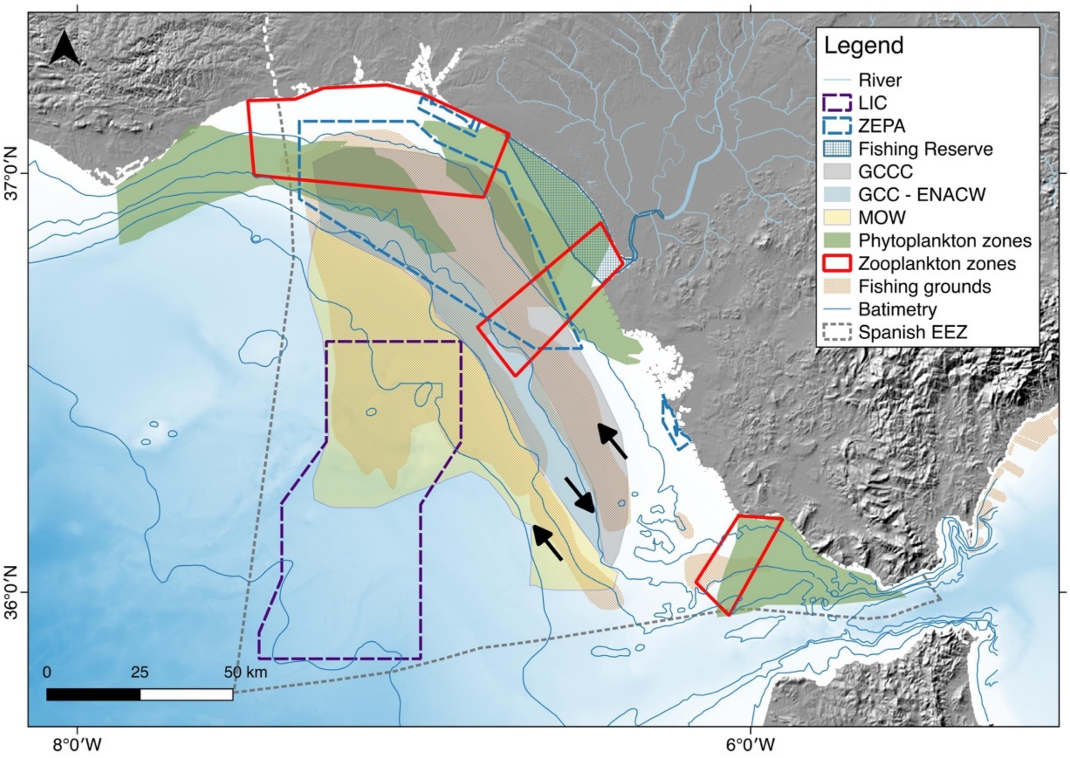

Fig. 32. Mapa ilustrando importantes y convergentes zonas del GoC, desde el punto de vista oceanográfico. Las líneas discontinuas señalan las zonas de especial protección para las aves (azul) y lugares de importancia comunitaria (morado) (Red Natura 2000; https://www.miteco.gob.es). En azul próximo a la costa esta la Reserva de Pesca de la

desembocadura del río Guadalquivir (BOJA, 2004). GCCC representa la contracorriente costera del golfo de Cádiz (gris); GCC, la corriente del golfo de Cádiz, ENACW, las aguas centrales del Atlántico norte oriental (azul claro) y la MOW (siglas en inglés; amarillo), representa la masa de agua mediterránea (ver detalles en Bellanco y Sánchez-Leal, 2016). Las flechas negras indican la dirección relativa del flujo de las corrientes a partir de las observaciones de Bellanco y Sanchez-Leal, 2016. Las zonas fitoplanctónicas en el área del presente estudio fueron evidenciadas por Navarro y Ruiz (2006) como zonas con altas concentraciones de clorofila (verde). Las zonas zooplanctónicas son las encontradas en el capitulo de la presente tesis (rojo; **capitulo 4**). En naranja se encuentran los caladeros más importantes de la plataforma continental.

En la parte española del GoC, Navarro y Ruiz (2006) revelan tres zonas importantes para la distribución del fitoplancton y relacionan con la presencia de varios procesos que favorecen la entrada de nutrientes, como eventos de afloramiento, descargas de ríos, vientos y otras condiciones climáticas y oceanográficas (profundidad, precipitación, etc). Además, un reciente estudio (Sala et al., 2018) a partir de datos satelitales identificó la región del Cabo de Trafalgar (zona 3) como crucial para sostener la producción primaria en la región.

Las zonas 1 y 2 también fueron evidenciadas como importantes hábitats reproductivos (puesta y crecimiento) para huevos y larvas de varias especies de peces de importancia comercial como el boquerón, la sardina y la acedía (García-Isarch et al., 2006; Baldó et al., 2006). Recientemente Canseco (2016) estudiando los padrones espaciales de peces pelágicos (caballas, jureles) ha demostrado que todas estas tres zonas son áreas preferenciales para esas especies.

Es importante resaltar que esas áreas convergentes son posiblemente adecuadas para la implementación de áreas ecológica o biológicamente significantes (sigla en inglés, EBSA; CBD, 2005). Una vez que el diseño, la elección y el establecimiento de nuevas áreas prioritarias para la conservación como las EBSAs deben realizarse a través de un proceso participativo que tenga en cuenta la importancia de las áreas previamente identificadas para las comunidades y sectores que dependen de estas regiones.

Además, que el establecimiento de espacios marinos o otras medidas de gestión de áreas prioritarias de conservación puede limitar o cambiar las actividades económicas, particularmente los sectores extractivos (Micheli et al., 2013). En ambientes con alta concentración de usos múltiples, como el GoC, tales consideraciones no pueden ser ignoradas. Por ejemplo, en las tres zonas identificadas anteriormente como posibles y futuras áreas prioritarias para la conservación en el GoC, se encuentran zonas de pesca. Por lo tanto, se requiere una colaboración entre las partes interesadas dispuestas al aprendizaje conjunto, intercambio de informaciones, concesiones y cumplimiento de sus obligaciones. Las diferentes estructuras de gobernanza pueden ser exitosas si las partes interesadas las consideran legítimas y justas, crean consenso a partir de posibles conflictos de interese, usan el mejor conocimiento científico disponible en un enfoque de gestión adaptativa y consideran las necesidades económicas de las partes interesadas (García et al., 2013).

La gestión conjunta del ecosistema, incluyendo la declaración de áreas prioritarias para la conservación, es una forma de gobernanza que puede conducir, a la gestión sostenible y los objetivos en el ámbito regional, nacional e internacional (p. ej. MSP, MSFD, CBD), la protección de los hábitats y especies y la sostenibilidad de las actividades económicas (Lleonart et al., 2014). Sabemos que es un desafío hacerlos, pero también tenemos que enfatizar la urgencia y la necesidad de considerar la conservación de los ecosistemas y la gestión de los recursos de una manera holística y más integrada, si deseamos revertir las tendencias actuales de efectos deletéreos en la salud de los océanos y la manutención de los servicios ecosistémicos.

5.1.3 LIMITACIONES Y PERSPECTIVAS FUTURAS

La falta de datos para ciertos grupos y/o períodos fue una de las limitaciones de este trabajo. Para el estuario del Guadalquivir, la futura inclusión de series temporales de la comunidad zooplanctónica pueden ayudar a comprender las relaciones y la estructura de la red trófica. Relacionar los datos sociales y económicos de las actividades desarrolladas a lo largo del estuario (por ejemplo, navegación, agricultura) también podría contribuir a evaluar los impactos relacionados con cada sector. Además, el acoplamiento entre las series temporales del estuario y las pesquerías en el GoC podrá ser utilizado para crear análisis de escenarios y trazar políticas mas especificas para la gestión adoptando consideraciones sociales, económicas y ambientales (Fig. 33).

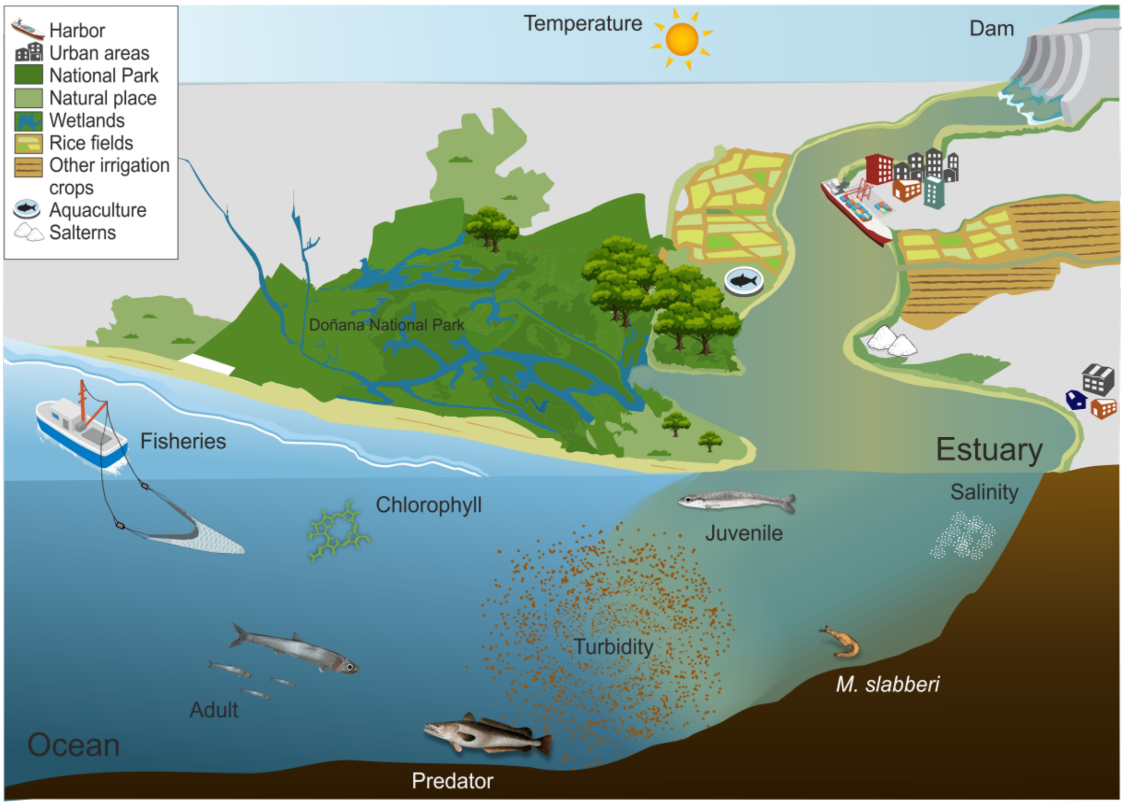

Fig. 33. Conceptualización de las áreas mas importantes, principales actividades y sectores, variables ambientales y procesos que deben evaluarse para avanzar en la EBFM del GoC.

Para el GoC, las series temporales utilizadas en este estudio cubrieron los principales factores y todos los niveles tróficos del ecosistema, a excepción de algunos años en la primera década (1990) para algunos grupos como fitoplancton, zooplancton, datos acústicos (algunos pequeños pelágicos), mamíferos marinos y aves marinas. La falta de datos sobre grupos tróficos inferiores, por ejemplo, podría causar limitaciones en la detección de otros cambios debido a una respuesta rápida de estas comunidades en relación con los procesos climáticos y oceanográficos.

Para los futuros estudios seria interesante ampliar la recopilación de información histórica, acoplamiento con otros modelos (p. ej., Ecopath y Ecosim) y extensión del conjunto de datos más allá del período y zona (parte española del GoC) evaluados actualmente, así como la inclusión de sectores adicionales (como transporte marítimo, turismo, recreación, actividades terrestres) en un entorno más amplio. Este enfoque multi-sectorial también puede proporcionar información adicional sobre el estado de los ecosistemas marinos, así como los servicios sociales y culturales que proporcionan. Esta información podrá ayudar a los gobiernos y a las organizaciones regionales de gestión del medio marino a buscar de manera más eficaz objetivos compartidos para maximizar la equidad, la seguridad alimentaria y la sostenibilidad marina en el futuro cercano hacia la EBFM.

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Capítulo 6. Conclusiones

6. CONCLUSIONES

Las principales conclusiones derivadas de este estudio son:

1) El ecosistema del golfo de Cádiz ha pasado los últimos 20 años de un régimen caracterizado por un deterioro gradual -debido a la débil regulación pesquera, a los efectos colaterales de acuerdos políticos internacionales en materia de pesca y factores climáticos- a un régimen más estable -resultado de las medidas de regulación donde el controle trófico ha recuperado su importancia.

2) Depredadores como tiburones, rayas y merluzas, así como importantes eslabones de la cadena trófica (algunas especies de pequeños y medios pelágicos) han incrementado sus biomasas en la ultima década.

3) El estuario del Guadalquivir es un hábitat esencial del socioecosistema debido a su papel como zona de cría de especies marinas (ej. boquerón) y la concentración de actividades humanas de importancia económica (ej. pesca, agricultura).

4) La temperatura, la turbidez y las descargas de agua dulce son factores clave en el estuario del Guadalquivir que determinan su carácter de hábitat esencial. Las estrategias de gestión de este área deberán tener en cuenta los límites de tolerancia de las especies que lo habitan para garantizar la función de zona de cría.

5) El control trófico de recurso “*bottom-up*” destaca como el dominante en el estuario de Guadalquivir, siendo los misidáceos, *Mesopodopsis slabberi* y *Rhopalophthalmus tartessicus* claves en la canalización de la energía hacia niveles tróficos superiores.

6) La comunidad zooplanctónica de la plataforma del golfo de Cádiz está dominada por copépodos y secundariamente por cladóceros. Ese último grupo (especialmente la especie *Penilia avirostris*) destaca por sus “explosiones” de población, particularmente durante periodos cálidos en el área de influencia del Guadalquivir.

7) La distribución, densidad media y dinámica poblacional de los cladóceros apoyan la singularidad del área bajo la influencia del Guadalquivir en la zonación pelágica del golfo de Cádiz.

8) En comparación con otros ríos del área, los factores ambientales relacionados con el Guadalquivir, como el aporte de materia orgánica o el flujo de agua dulce, se extienden más allá de su desembocadura y ejercen un papel estructurante de la comunidad de zooplancton sobre la plataforma continental.

Capítulo 7. Curriculum vitae

1. CURRICULUM VITAE

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Timeline

2009	Graduate in Biology, UCSal, Brazil
2010 2011	Environmental Consultancy Services
2012	Specialization in Coastal and Marine Ecology, UNIME, Brazil
2013	MSc in Marine Geology, UFBA, Brazil
2014	PhD Project, IEO, Spain
2015	PhD Student, UCA, Spain
2016	Interuniversity Exchange Doctorate, UAlg, Portugal

Scientific Production

Conference Papers: ▮▮▮▮▮ 36

Scientific Papers: ▮▮ 9

Technical Reports: ▮▮▮▮ 25

Other works: ▮▮▮ 13

Languages

Portuguese: Native language

Spanish:

English:

Interests

Technical Skills

For more details, this scan code

Experience

1. CURRICULUM VITAE

Gustavo Freire de Carvalho-Souza es biólogo marino y buceador avanzado. Nació en Salvador de Bahía, Brasil. Con un grado en Ciencias Biológicas por la UCSal, especialización en Ecología de Ecosistemas Costeros y Marinos (UNIME) y máster en Geología Marina (UFBA), actualmente realiza el doctorado en el Centro Oceanográfico de Cádiz del Instituto Español de Oceanografía (IEO) y Universidad de Cádiz (UCA) dentro del Campus de Excelencia Internacional del Mar (Cei.Mar). Los temas principales de interés en la investigación son: ecología marina, conservación de los ecosistemas acuáticos, impactos antropogénicos, popularización de las ciencias. Sus investigaciones actuales se centran en el uso de modelos ecológicos para comprender el estado y estructura de los sistemas naturales frente a los cambios globales.

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ANEXO A

Supplementary Information 1 for

Climate, international politics and fishery regulation drive a whole marine ecosystem

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Supplementary Tables

Table S1. Abbreviations, full name and units of the variables used in the analyses.

Acronym	Variable name	Unit
Biotic variables		
Anchovy	Anchovy	kg/km^2
Benpel_sma	Benthopelagic small fishes	kg/km^2
Blue_whi	Blue whiting	kg/km^2
Cephalop_ben	Benthic cephalopods	kg/km^2
Cephalop_benpel	Benthopelagic cephalopods	kg/km^2
Crab_lobster	Crabs and lobsters	kg/km^2
Deep-sea	Deep-sea fishes	kg/km^2
Demersal	Demersal fishes	kg/km^2
Dem_small	Demersal small fishes	kg/km^2
Flat	Flatfishes	kg/km^2
Gel_zoo	Gelatinous zooplankton	kg/km^2
Hake	Hake	kg/km^2
Hor_mack	Horse mackerels	kg/km^2
Invert_Carniv	Carnivores-benthic invertebrates	kg/km^2
Invert_FDS	F/D/S benthic invertebrates$^+$	kg/km^2
Large_Fish_benpel	Large benthopelagic fishes	kg/km^2
Mack	Mackerels	kg/km^2
Mantis_shr	Mantis shrimp	kg/km^2
Mullets	Mullets	kg/km^2
Norw_lobster	Norway lobster	kg/km^2
Piscivores	Piscivores	kg/km^2
Polychaet	Polychaetas	kg/km^2
Rose_shr	Rose shrimp	kg/km^2
Sardine	Sardine	kg/km^2
Sharks	Sharks	kg/km^2
Shrimps	Shrimps	kg/km^2
Skates	Skates	kg/km^2
Spa1	Sparids 1	kg/km^2
Spa2	Sparids 2	kg/km^2
Chl	Chlorophyll	mg/m^3
Abiotic variables		
SST	Sea Surface Temperature	˚C
SSH	Sea Surface Height	meters
POC	Particulate Organic Carbon	mol/m^3
PIC	Particulate Inorganic Carbon	mol/m^3
ZSD	Water transparency	meters

Precip	Precipitation	l m^{-2}
NAO	North Atlantic Oscillation	index
AMO	Atlantic Multidecadal Oscillation	index
GSNW	Gulf stream	index
Pressures		
Fresh_disc	Freshwater discharges	hm^{3}
Litter	Marine litter	number/km^{2}
HR_Anchovy	Harvest rate for Anchovy	index
HR_BlueWhi	Harvest rate for Blue whiting	index
HR_Hake	Harvest rate for Hake	index
HR_HorMack	Harvest rate for Horse mackerels	index
HR_Mack	Harvest rate for Mackerels	index
HR_Mullets	Harvest rate for Mullets	index
HR_Piscivores	Harvest rate for Piscivores	index
HR_Sard	Harvest rate for Sardine	index
HR_MantisShr	Harvest rate for Mantis shrimp	index
HR_NorLobster	Harvest rate for Norway lobster	index
HR_RoseShr	Harvest rate for Rose shrimp	index
Bot_Trawl	Otter bottom trawl fishery	fishing days/year
Artisanal	Artisanal fishery	fishing days/year
Pur_Seine	Pelagic purse-seine fishery	fishing days/year

[+] F/D/S = filters/detritivores/suspensivores feeders

Table S2. Timing of shifts detected using STARS on time series of functional groups, abiotic variables and pressures. RSI: Cumulative sum of normalized deviations.

Variables	**Shift 1990s**	**Shift 2000s**	**RSI**
Biotic			
Anchovy		2006	-0.76
Benpel_lar	1996		-0.31
Benpel_sma		2003	0.13
Blue_whi		2000	-0.17
Carben_inv		2004	0.28
Cephalop_benpel	1997		-0.31
Chl		2003	-0.34
Crab_lobster		2006	0.61
Deep_fish			
Demersal			
Dem_small			
Invert_FDS	1994		0.78
Flat	1997		0.24
Gel_zoo	1997		0.12
Hake	1995	2005	1.02 / -0.93
Hor_mack		2006	-0.63
Mac		2002	-0.09
Mantis_shr	1999		-0.58
Mullets			
Shrimps			
Norw_lobster			
Piscivores			
Polychaet	1998		0.19
Rose_shr	1995	2003	0.07 / -0.33
Sardine			
Sharks	1995		0.60
Skates		2005	-0.23
Spa1			
Spa2			
Abiotic			
SST	1995		0.11
SSH			
PIC			
Precip	1995		-0.23
NAO	1995		0.48
AMO	1998		-0.64

GSNW	1996		0.60
Pressures			
Litter		2005	0.93
Fresh_disc	1999		0.03
HR_Anchovy	1995		-0.15
HR_BlueWhi	1997		0.08
HR_Hake		2005	-0.12
HR_Mack	1998		0.13
HR_Piscivores	1996		-1.75
HR_Sard			
HR_MantisShr			
HR_NorLobster	1997		0.25
HR_RoseShr	1995		-1.02
Bot_Trawl	1996	2006	0.42 / 0.69
Artisanal	1996		-2.73
Pur_Seine	1999		-1.16

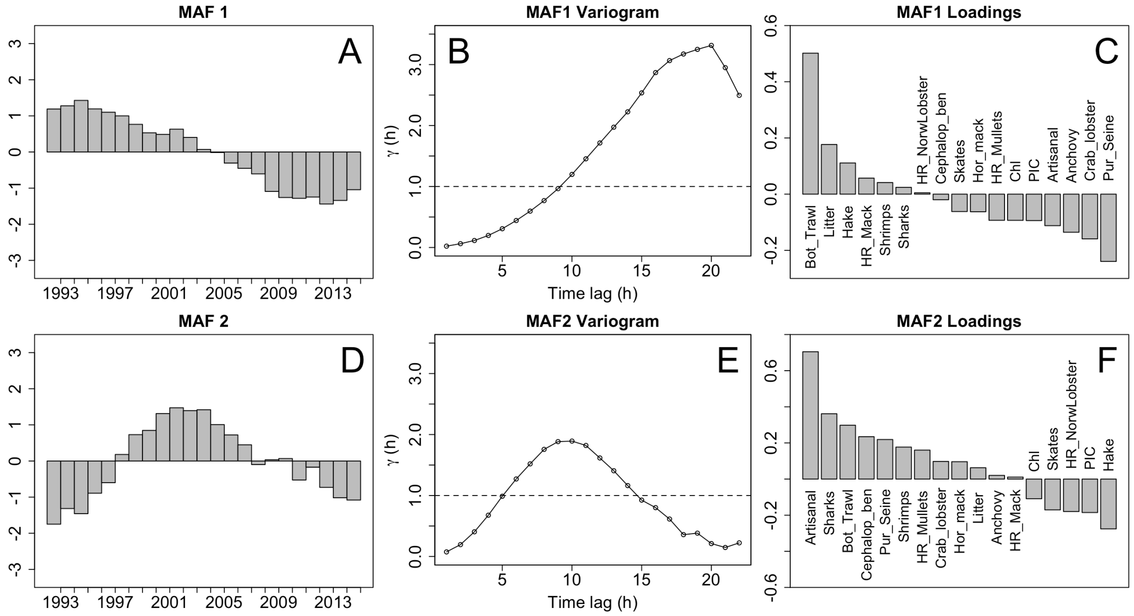
Table S3. Fishery management plans of the purse-seine and bottom trawl fisheries for the Gulf de Cádiz established in the Official Spanish Gazette (https://www.boe.es/diario_boe/).

Regulation/Plan	Total number of fishing days/year	Closed fishing season		Reference (Official Spanish Gazette)
		Period	Number of days	
Purse-seine fleet				
APA/3506/2004	200	17 Nov – 31 Dic	45	BOE-A-2004-18545
APA/3568/2005	200	17 Nov – 31 Dic	45	BOE-A-2005-18919
APA/3239/2006	200	1 Nov – 30 Dic	60	BOE-A-2006-18348
APA/3288/2007	200	15 Nov – 12 Feb	90	BOE-A-2007-19656
ARM/249/2009	200	1 Dic – 14 Feb	90	BOE-A-2009-2546
Bottom trawl fleet				
APA/3423/2004	200	25 Oct - 8 Dic	45	BOE-A-2004-18203
APA/2858/2005	200	15 Sep - 29 Oct	45	BOE-A-2005-15357
APA/2883/2006	200	20 Sep - 18 Nov	60	BOE-A-2006-16479
APA/2801/2007	200	24 Sep - 22 Nov	60	BOE-A-2007-17109
ARM/58/2010*	200	25 Sep - 23 Nov 2009 16 Jan - 22 Jan 2010 1 Feb - 14 Feb 2010	90	BOE-A-2010-1070 (modified the ARM/2515/2009)
ARM/2296/2011	200	24 Sep - 7 Nov	50	BOE-A-2011-14084 (modified the ARM/2457/2010)
AAA/627/2013	200	24 Sep - 7 Nov	50	BOE-A-2013-4084

*The closed fishing season is established in three periods

Supplementary Figures

Figure S1. Summary of the first 2 MAFs: A) MAF1 Time series; B) MAF1 Variogram; C) Indicators loadings on MAF1; D) MAF2 Time series; E) MAF2 Variogram; F) Indicators loadings on MAF2.



ANEXO B

Table S1. Lista de especies del golfo de Cádiz

Functional Groups	Species	Author/Year	Data Source/Reference	Added	Reference Trophic Category
anchovy	*Engraulis encrasicolus*	(Linnaeus, 1758)	ARSA surveys/Acoustic surveys	ML	Torres et al., 2013
benthic cephalopods	*Alloteuthis africana*	Adam, 1950	ARSA surveys	ML	Torres et al., 2013
benthic cephalopods	*Alloteuthis media*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013
benthic cephalopods	*Alloteuthis subulata*	(Lamarck, 1798)	ARSA surveys	ML	Torres et al., 2013
benthic cephalopods	*Bathypolypus arcticus*	(Prosch, 1849)	ARSA surveys	GCS	IUCN, 2017
benthic cephalopods	*Bathypolypus ergasticus*	(P. Fischer & H. Fischer, 1892)	ARSA surveys	GCS	IUCN, 2017
benthic cephalopods	*Bathypolypus sponsalis*	(P. Fischer & H. Fischer, 1892)	ARSA surveys	GCS	IUCN, 2017
benthic cephalopods	*Callistoctopus macropus*	(Risso, 1826)	ARSA surveys	GCS	Torres et al., 2013
benthic cephalopods	*Eledone cirrhosa*	(Lamarck, 1798)	ARSA surveys	ML	Torres et al., 2013
benthic cephalopods	*Eledone moschata*	(Lamarck, 1798)	ARSA surveys	ML	Torres et al., 2013
benthic cephalopods	*Macrotritopus defilippi*	Vérany, 1851	ARSA surveys	GCS	Torres et al., 2013
benthic cephalopods	*Neorossia caroli*	(Joubin, 1902)	ARSA surveys	ML	Torres et al., 2013
benthic cephalopods	*Neorossia spp.*		ARSA surveys	GCS	Torres et al., 2013
benthic cephalopods	*Octopus salutii*	Vérany, 1836	ARSA surveys	ML	Torres et al., 2013
benthic cephalopods	*Octopus vulgaris*	Cuvier, 1797	ARSA surveys	ML	Torres et al., 2013
benthic cephalopods	*Pteroctopus tetracirrhus*	(Delle Chiaje, 1830)	ARSA surveys	GCS	IUCN, 2017

benthic cephalopods	*Rossia macrosoma*	(Chiaie, 1830)	ARSA surveys	ML	Torres et al., 2013
benthic cephalopods	*Sepia elegans*	Blainville, 1827	ARSA surveys	ML	Torres et al., 2013
benthic cephalopods	*Sepia officinalis*	Linnaeus, 1758	ARSA surveys	ML	Torres et al., 2013
benthic cephalopods	*Sepia orbignyana*	Férussac in d'Orbigny, 1826	ARSA surveys	ML	Torres et al., 2013
benthopelagic cephalopods	*Abralia veranyi*	(Rüppell, 1844)	ARSA surveys	ML	Torres et al., 2013
benthopelagic cephalopods	*Heteroteuthis dispar*	(Rüppell, 1844)	ARSA surveys	GCS	IUCN, 2017
benthopelagic cephalopods	*Illex coindetii*	(Verany, 1839)	ARSA surveys	ML	Torres et al., 2013
benthopelagic cephalopods	*Leachia atlantica*	(Degner, 1925)	ARSA surveys	GCS	IUCN, 2017
benthopelagic cephalopods	*Loligo forbesii*	Steenstrup, 1856	ARSA surveys	ML	Torres et al., 2013
benthopelagic cephalopods	*Loligo vulgaris*	Lamarck, 1798	ARSA surveys	ML	Torres et al., 2013
benthopelagic cephalopods	*Pyroteuthis margaritifera*	Pyroteuthis margaritifera	ARSA surveys	GCS	IUCN, 2017
benthopelagic cephalopods	*Rondeletiola minor*	(Naef, 1912)	ARSA surveys	ML	Torres et al., 2013
benthopelagic cephalopods	*Scaeurgus unicirrhus*	(Delle Chiaje [in Férussac & d'Orbigny], 1841)	ARSA surveys	ML	Torres et al., 2013
benthopelagic cephalopods	*Semirosia sp.*		ARSA surveys	GCS	IUCN, 2017
benthopelagic cephalopods	*Sepietta neglecta*	Naef, 1916	ARSA surveys	ML	Torres et al., 2013
benthopelagic cephalopods	*Sepietta obscura*	Naef, 1916	ARSA surveys	ML	Torres et al., 2013
benthopelagic cephalopods	*Sepietta oweniana*	(d'Orbigny, 1839-41 in Férussac & d'Orbigny 1834-1848)	ARSA surveys	ML	Torres et al., 2013
benthopelagic cephalopods	*Sepietta sp.*		ARSA surveys	ML	Torres et al., 2013
benthopelagic cephalopods	*Sepiola affinis*	Naef, 1912	ARSA surveys	MT	Torres et al., 2013
benthopelagic cephalopods	*Sepiola atlantica*	d' Orbigny, 1839-1842 in Férussac & d'Orbigny 1834-1848	ARSA surveys	ML	Torres et al., 2013
benthopelagic cephalopods	*Sepiola aurantiaca*	Jatta, 1896	ARSA surveys	MT	Torres et al., 2013
benthopelagic cephalopods	*Sepiola intermedia*	Naef, 1912	ARSA surveys	GCS	IUCN, 2017

benthopelagic cephalopods	*Sepiola ligulata*	Naef, 1912	ARSA surveys	MT	Torres et al., 2013
benthopelagic cephalopods	*Sepiola robusta*	Naef, 1912	ARSA surveys	MT	Torres et al., 2013
benthopelagic cephalopods	*Sepiola rondeletii*	Leach, 1817	ARSA surveys	MT	Torres et al., 2013
benthopelagic cephalopods	*Sepiola sp.*		ARSA surveys	ML	Torres et al., 2013
benthopelagic cephalopods	*Todarodes sagittatus*	(Lamarck, 1798)	ARSA surveys	ML	Torres et al., 2013
benthopelagic cephalopods	*Todaropsis eblanae*	(Ball, 1841)	ARSA surveys	ML	Torres et al., 2013
benthopelagic bigfishes	*Aphanopus carbo*	Lowe, 1839			
benthopelagic bigfishes	*Bathophilus vaillanti*	(Zugmayer, 1911)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic bigfishes	*Belone belone*	(Linnaeus, 1761)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic bigfishes	*Belone svetovidovi*	Collette & Parin, 1970	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic bigfishes	*Benthodesmus simonyi*	(Clarke, 1879)	ARSA surveys	ML	Torres et al., 2013
benthopelagic bigfishes	*Beryx decadactylus*	Cuvier, 1829	ARSA surveys	ML	Torres et al., 2013
benthopelagic bigfishes	*Beryx splendens*	Lowe, 1834	ARSA surveys	ML	Torres et al., 2013
benthopelagic bigfishes	*Brama brama*	(Bonnaterre, 1788)	ARSA surveys	ML	Torres et al., 2013
benthopelagic bigfishes	*Campogramma glaycos*	(Lacepède, 1801)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic bigfishes	*Coccorella atlantica*	(Parr, 1928)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic bigfishes	*Hoplostethus mediterraneus*	Cuvier, 1829	ARSA surveys	ML	Torres et al., 2013
benthopelagic bigfishes	*Lepidopus caudatus*	(Euphrasen, 1788)	ARSA surveys	ML	Torres et al., 2013
benthopelagic bigfishes	*Schedophilus ovalis*	(Cuvier, 1833)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic bigfishes	*Scomberesox saurus*	(Walbaum, 1792)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic bigfishes	*Sphyraena sphyraena*	(Linnaeus, 1758)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic bigfishes	*Synaphobranchus kaupi*	Johnson, 1862	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Alosa fallax*	(Lacepède, 1803)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017

benthopelagic smallfishes	*Anthias anthias*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013
benthopelagic smallfishes	*Argylopelecus aculeatus*	Valenciennes, 1850	ARSA surveys	ML	Torres et al., 2013
benthopelagic smallfishes	*Argylopelecus gigas*	Norman, 1930	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Argyropelecus hemigymnus*	Cocco, 1829	ARSA surveys	ML	Torres et al., 2013
benthopelagic smallfishes	*Argylopelecus olfersi*	(Cuvier, 1829)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Avocettina infans*	(Günther, 1878)	ARSA surveys	ML	Torres et al., 2013
benthopelagic smallfishes	*Bonapartia pedaliota*	Goode & Bean, 1896	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Brachydeuterus auritus*	(Valenciennes, 1832)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Capros aper*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013
benthopelagic smallfishes	*Caranx rhonchus*	Geoffroy Saint-Hilaire, 1817	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Cepola macrophthalma*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013
benthopelagic smallfishes	*Cerastocopelus maderensis*	(Lowe, 1839)	ARSA surveys	ML	Torres et al., 2013
benthopelagic smallfishes	*Chauliodus sloani*	Bloch & Schneider, 1801	ARSA surveys	ML	Torres et al., 2013
benthopelagic smallfishes	*Chlorophthalmus agassizi*	Bonaparte, 1840	ARSA surveys	ML	Torres et al., 2013
benthopelagic smallfishes	*Cubiceps gracilis*	(Lowe, 1843)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Cyclothone sp.*		ARSA surveys	ML	Torres et al., 2013
benthopelagic smallfishes	*Cyttopsis roseus*	(Lowe, 1843)	ARSA surveys	ML	Torres et al., 2013
benthopelagic smallfishes	*Ctenolabrus rupestris*	(Linnaeus, 1758)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Diaphus adenomus*	Gilbert, 1905	ARSA surveys	ML	Torres et al., 2013
benthopelagic smallfishes	*Diaphus dumerilii*	(Bleeker, 1856)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Diaphus holti*	Tåning, 1918	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Diaphus rafinesquii*	(Cocco, 1838)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Diaphus sp.*		ARSA surveys	ML	Torres et al., 2013
benthopelagic smallfishes	*Dicentrarchus labrax*	(Linnaeus, 1758)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017

benthopelagic smallfishes	*Dicentrarchus punctatus*	(Bloch, 1792)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Dysomma brevirostre*	(Facciolà, 1887)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Echiodon dentatus*	(Cuvier, 1829)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Epigonus denticulatus*	Dieuzeide, 1950	ARSA surveys	ML	Torres et al., 2013
benthopelagic smallfishes	*Epigonus telescopus*	(Risso, 1810)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Gadiculus argenteus*	Guichenot, 1850	ARSA surveys	ML	Torres et al., 2013
benthopelagic smallfishes	*Gonostoma denudatum*	Rafinesque, 1810	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Gonostoma elongatum*	Günther, 1878	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Gonostoma sp.*		ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Gonostomatidae*		ARSA surveys	GCS	Fishbase, 2017
benthopelagic smallfishes	*Grammicolepis brachiusculus*	Poey, 1873	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Howella sherborni*	(Norman, 1930)	ARSA surveys	ML	Torres et al., 2013
benthopelagic smallfishes	*Ichthyococcus ovatus*	(Cocco, 1838)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Lampanyctus crocodilus*	(Risso, 1810)	ARSA surveys	ML	Torres et al., 2013
benthopelagic smallfishes	*Lappanella fasciata*	(Cocco, 1833)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Liza aurata*	(Risso, 1810)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Liza ramada*	(Risso, 1827)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Lobianchia dofleini*	(Zugmayer, 1911)	ARSA surveys	ML	Torres et al., 2013
benthopelagic smallfishes	*Lobianchia gemellarii*	(Cocco, 1838)	ARSA surveys	ML	Torres et al., 2013
benthopelagic smallfishes	*Lobianchia sp.*		ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Macroramphosus scolopax*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013
benthopelagic smallfishes	*Magnisudis atlantica*	(Krøyer, 1868)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Maurolicus muelleri*	(Gmelin, 1789)	ARSA surveys	ML	Torres et al., 2013
benthopelagic smallfishes	*Margrethia obtusirostra*	Jespersen & Tåning, 1919	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017

benthopelagic smallfishes	*Mugil cephalus*	Linnaeus, 1758	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Myctophum punctatum*	Rafinesque, 1810	ARSA surveys	ML	Torres et al., 2013
benthopelagic smallfishes	*Myctophidae*		ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Nemichthys scolopaceus*	Richardson, 1848	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Notacanthus bonapartei*	Risso, 1840	ARSA surveys	ML	Torres et al., 2013
benthopelagic smallfishes	*Notoscopelus elongatus*	(Costa, 1844)	ARSA surveys	ML	Torres et al., 2013
benthopelagic smallfishes	*Notoscopelus kroyeri*	(Malm, 1861)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Notoscopelus spp.*		ARSA surveys	ML	Torres et al., 2013
benthopelagic smallfishes	*Oblada melanura*	(Linnaeus, 1758)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Opisthoproctus soleatus*	Vaillant, 1888	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Photostomias guernei*	Collett, 1889	ARSA surveys	ML	Torres et al., 2013
benthopelagic smallfishes	*Physiculus dalwigki*	Kaup, 1858	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Polymetme corythaeola*	(Alcock, 1898)	ARSA surveys	ML	Torres et al., 2013
benthopelagic smallfishes	*Psenes pellucidus*	Lütken, 1880	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Ruvettus pretiosus*	Cocco, 1833	ARSA surveys	ML	Torres et al., 2013
benthopelagic smallfishes	*Stromateus fiatola*	Linnaeus, 1758	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Stomias boa boa*	(Risso, 1810)	ARSA surveys	ML	Torres et al., 2013
benthopelagic smallfishes	*Symphodus roissali*	(Risso, 1810)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Symphodus sp.*		ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Taractichthys longipinnis*	(Lowe, 1843)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Trisopterus luscus*	(Linnaeus, 1758)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
benthopelagic smallfishes	*Xenolepidichthys dalgleishi*	Gilchrist, 1922	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
blue whiting	*Micromesistius poutassou*	(Risso, 1827)	ARSA surveys	ML	Torres et al., 2013

demersal fishes	*Argentina sphyraena*	Linnaeus, 1758	ARSA surveys	ML	Torres et al., 2013
demersal fishes	*Balistes capriscus*	Gmelin, 1789	ARSA surveys	GCS	Torres et al., 2013
demersal fishes	*Callanthias ruber*	(Rafinesque, 1810)	ARSA surveys	GCS	Torres et al., 2013
demersal fishes	*Centrolophus niger*	(Gmelin, 1789)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
demersal fishes	*Chaunax pictus*	Lowe, 1846	ARSA surveys	GCS	Torres et al., 2013
demersal fishes	*Chelidonichthys cuculus*	(Linnaeus, 1758)	ARSA surveys	MT	Torres et al., 2013
demersal fishes	*Chelidonichthys lastoviza*	(Bonnaterre, 1788)	ARSA surveys	ML	Torres et al., 2013
demersal fishes	*Chelidonichthys lucerna*	(Linnaeus, 1758)	ARSA surveys	MT	Torres et al., 2013
demersal fishes	*Chelidonichthys obscurus*	(Walbaum, 1792)	ARSA surveys	MT	Torres et al., 2013
demersal fishes	*Dalophis imberbis*	(Delaroche, 1809)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
demersal fishes	*Echelus myrus*	(Linnaeus, 1758)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
demersal fishes	*Epinephelus caninus*	(Valenciennes, 1843)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
demersal fishes	*Eutrigla gurnardus*	(Linnaeus, 1758)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
demersal fishes	*Facciolella oxyrhyncha*	(Bellotti, 1883)	ARSA surveys	ML	Torres et al., 2013
demersal fishes	*Glossanodon leioglossus*	(Valenciennes, 1848)	ARSA surveys	ML	Torres et al., 2013
demersal fishes	*Gnathophis mystax*	(Delaroche, 1809)	ARSA surveys	ML	Torres et al., 2013
demersal fishes	*Gymnammodytes cicerelus*	(Rafinesque, 1810)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
demersal fishes	*Halobatrachus didactylus*	(Bloch & Schneider, 1801)	ARSA surveys	ML	Torres et al., 2013
demersal fishes	*Helicolenus dactylopterus*	(Delaroche, 1809)	ARSA surveys	ML	Torres et al., 2013
demersal fishes	*Hippocampus guttulatus*	Cuvier, 1829	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
demersal fishes	*Hippocampus hippocampus*	(Linnaeus, 1758)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
demersal fishes	*Labrus mixtus*	Linnaeus, 1758	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
demersal fishes	*Lepidotrigla cavillone*	(Lacepède, 1801)	ARSA surveys	ML	Torres et al., 2013
demersal fishes	*Lepidotrigla dieuzeidei*	Blanc & Hureau, 1973	ARSA surveys	ML	Torres et al., 2013

demersal fishes	*Muraena helena*	Linnaeus, 1758	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
demersal fishes	*Parapristipoma octolineatum*	(Valenciennes, 1833)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
demersal fishes	*Peristedion cataphractum*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013
demersal fishes	*Polyprion americanus*	(Bloch & Schneider, 1801)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
demersal fishes	*Scorpaena elongata*	Cadenat, 1943	ARSA surveys	MT	Torres et al., 2013
demersal fishes	*Scorpaena notata*	Rafinesque, 1810	ARSA surveys	ML	Torres et al., 2013
demersal fishes	*Scorpaena porcus*	Linnaeus, 1758	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
demersal fishes	*Scorpaena scrofa*	Linnaeus, 1758	ARSA surveys	ML	Torres et al., 2013
demersal fishes	*Serranus cabrilla*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013
demersal fishes	*Serranus hepatus*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013
demersal fishes	*Setarches guentheri*	Johnson, 1862	ARSA surveys	ML	Torres et al., 2013
demersal fishes	*Sphoeroides pachygaster*	(Müller & Troschel, 1848)	ARSA surveys	MT	Torres et al., 2013
demersal fishes	*Sphoeroides spengleri*	(Bloch, 1785)	ARSA surveys	GCS	Torres et al., 2013
demersal fishes	*Symbolophorus veranyi*	(Moreau, 1888)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
demersal fishes	*Trachyscorpia cristulata echinata*	(Köhler, 1896)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
demersal fishes	*Trigla lyra*	Linnaeus, 1758	ARSA surveys	ML	Torres et al., 2013
demersal fishes	*Uranoscopus scaber*	Linnaeus, 1758	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
demersal fishes					
demersal fishes	*Aphia minuta*	(Risso, 1810)	ARSA surveys	ML	Torres et al., 2013
demersal fishes	*Benthosema glaciale*	(Reinhardt, 1837)	ARSA surveys	GCS	Torres et al., 2013
demersal fishes	*Blennius ocellaris*	Linnaeus, 1758	ARSA surveys	ML	Torres et al., 2013
demersal fishes	*Callionymus lyra*	Linnaeus, 1758	ARSA surveys	ML	Torres et al., 2013
demersal fishes	*Callionymus maculatus*	Rafinesque, 1810	ARSA surveys	ML	Torres et al., 2013
demersal fishes	*Callionymus reticulatus*	Valenciennes, 1837	ARSA surveys	ML	Torres et al., 2013
demersal fishes	*Callionymus risso*	Lesueur, 1814	ARSA surveys	ML	Torres et al., 2013

demersal fishes	*Carapus acus*	(Brünnich, 1768)	ARSA surveys	GCS	Torres et al., 2013
demersal fishes	*Crystallogobius linearis*	(Düben, 1845)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
demersal fishes	*Crystallogobius sp.*		ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
demersal fishes	*Deltentosteus quadrimaculatus*	(Valenciennes, 1837)	ARSA surveys	ML	Fishbase, 2017; IUCN, 2017
demersal fishes	*Deltentosteus sp.*		ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
demersal fishes	*Diplecogaster bimaculata*	(Bonnaterre, 1788)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
demersal fishes	*Gobiidae*		ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
demersal fishes	*Gobius niger*	Linnaeus, 1758	ARSA surveys	ML	Torres et al., 2013
demersal fishes	*Guttigadus latifrons*	(Holt & Byrne, 1908)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
demersal fishes	*Hygophum benoiti*	(Cocco, 1838)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
demersal fishes	*Hygophum sp.*		ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
demersal fishes	*Lesueurigobius friesii*	(Malm, 1874)	ARSA surveys	ML	Torres et al., 2013
demersal fishes	*Lesueurigobius sanzi*	(de Buen, 1918)	ARSA surveys	ML	Torres et al., 2013
demersal fishes	*Minyichthys sentus*	Dawson, 1982	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
demersal fishes	*Parablennius gattorugine*	(Linnaeus, 1758)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
demersal fishes	*Parablennius sanguinolentus*	(Pallas, 1814)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
demersal fishes	*Pomatoschistus minutus*	(Pallas, 1770)	ARSA surveys	GCS	Torres et al., 2013
demersal fishes	*Pomatoschistus sp.*		ARSA surveys	ML	Torres et al., 2013
demersal fishes	*Synchiropus phaeton*	(Günther, 1861)	ARSA surveys	ML	Torres et al., 2013
demersal fishes	*Zenion hololepis*	(Goode & Bean, 1896)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
Deep-sea fishes	*Callorhinchus callorynchus*	(Linnaeus, 1758)	ARSA surveys	GCS	Torres et al., 2013
Deep-sea fishes	*Coelorinchus caelorhincus*	(Risso, 1810)	ARSA surveys	GCS	Torres et al., 2013
Deep-sea fishes	*Chimaera monstrosa*	Linnaeus, 1758	ARSA surveys	ML	Torres et al., 2013
Deep-sea fishes	*Gadella maraldi*	(Risso, 1810)	ARSA surveys	ML	Torres et al., 2013

Deep-sea fishes	*Gaidropsarus biscayensis*	(Collett, 1890)	ARSA surveys	ML	Torres et al., 2013
Deep-sea fishes	*Gaidropsarus mediterraneus*	(Linnaeus, 1758)	ARSA surveys	GCS	Torres et al., 2013
Deep-sea fishes	*Hymenocephalus gracilis*	(Gilbert & Hubbs, 1920)	ARSA surveys	ML	Torres et al., 2013
Deep-sea fishes	*Hymenocephalus italicus*	Giglioli, 1884	ARSA surveys	ML	Torres et al., 2013
Deep-sea fishes	*Malacocephalus laevis*	(Lowe, 1843)	ARSA surveys	ML	Torres et al., 2013
Deep-sea fishes	*Molva dipterygia*	(Pennant, 1784)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
Deep-sea fishes	*Molva macrophthalma*	(Rafinesque, 1810)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
Deep-sea fishes	*Molva molva*	(Linnaeus, 1758)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
Deep-sea fishes	*Mora moro*	(Risso, 1810)	ARSA surveys	ML	Torres et al., 2013
Deep-sea fishes	*Nezumia aequalis*	(Günther, 1878)	ARSA surveys	ML	Torres et al., 2013
Deep-sea fishes	*Nezumia sclerorhynchus*	(Valenciennes, 1838)	ARSA surveys	GCS	Torres et al., 2013
Deep-sea fishes	*Phycis blennoides*	(Brünnich, 1768)	ARSA surveys	ML	Torres et al., 2013
Deep-sea fishes	*Phycis phycis*	(Linnaeus, 1766)	ARSA surveys	GCS	Torres et al., 2013
Deep-sea fishes	*Trachyrincus scabrus*	(Rafinesque, 1810)	ARSA surveys	GCS	Torres et al., 2013
flatfishes	*Arnoglossus imperialis*	(Rafinesque, 1810)	ARSA surveys	ML	Torres et al., 2013
flatfishes	*Arnoglossus laterna*	(Walbaum, 1792)	ARSA surveys	ML	Torres et al., 2013
flatfishes	*Arnoglossus rueppelii*	(Cocco, 1844)	ARSA surveys	ML	Torres et al., 2013
flatfishes	*Arnoglossus thori*	Kyle, 1913	ARSA surveys	ML	Torres et al., 2013
flatfishes	*Bathysolea profundicola*	(Vaillant, 1888)	ARSA surveys	ML	Torres et al., 2013
flatfishes	*Bothus podas*	(Delaroche, 1809)	ARSA surveys	GCS	Torres et al., 2013
flatfishes	*Buglossidium luteum*	(Risso, 1810)	ARSA surveys	ML	Torres et al., 2013
flatfishes	*Citharus linguatula*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013
flatfishes	*Dagetichthys lusitanicus*	(de Brito Capello, 1868)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
flatfishes	*Dicologoglossa cuneata*	(Moreau, 1881)	ARSA surveys	ML	Torres et al., 2013

flatfishes	*Dicologoglossa hexophtalma*	(Bennett, 1831)	ARSA surveys	ML	Torres et al., 2013
flatfishes	*Lepidorhombus boscii*	(Risso, 1810)	ARSA surveys	ML	Torres et al., 2013
flatfishes	*Lepidorhombus whiffiagonis*	(Walbaum, 1792)	ARSA surveys	ML	Torres et al., 2013
flatfishes	*Microchirus azevia*	(de Brito Capello, 1867)	ARSA surveys	ML	Torres et al., 2013
flatfishes	*Microchirus boscanion*	(Chabanaud, 1926)	ARSA surveys	ML	Torres et al., 2013
flatfishes	*Microchirus ocellatus*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013
flatfishes	*Microchirus sp.*		ARSA surveys	GCS	Torres et al., 2013
flatfishes	*Microchirus variegatus*	Microchirus variegatus (Donovan, 1808)	ARSA surveys	ML	Torres et al., 2013
flatfishes	*Monochirus hispidus*	Rafinesque, 1814	ARSA surveys	GCS	Torres et al., 2013
flatfishes	*Monolene microstoma*	Cadenat, 1937	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
flatfishes	*Solea senegalensis*	Kaup, 1858	ARSA surveys	ML	Torres et al., 2013
flatfishes	*Solea solea*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013
flatfishes	*Scophthalmus rhombus*	(Linnaeus, 1758)	ARSA surveys	MT	Torres et al., 2013
flatfishes	*Scophthalmus maximus*	(Linnaeus, 1758)	ARSA surveys	GCS	Torres et al., 2013
flatfishes	*Symphurus nigrescens*	Rafinesque, 1810	ARSA surveys	ML	Torres et al., 2013
flatfishes	*Synapturichthys kleinii*	(Risso, 1827)	ARSA surveys	GCS	Torres et al., 2013
hake	*Merluccius merluccius*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013
horse mackerels	*Trachurus trachurus*	(Linnaeus, 1758)	ARSA surveys/Acoustic surveys	ML	Torres et al., 2013
horse mackerels	*Trachurus mediterraneus*	(Steindachner, 1868)	ARSA surveys/Acoustic surveys	ML	Torres et al., 2013
horse mackerels	*Trachurus picturatus*	(Bowdich, 1825)	ARSA surveys/Acoustic surveys	ML	Torres et al., 2013

mackerels	*Scomber colias*	Gmelin, 1789	ARSA surveys/Acoustic surveys	ML	Torres et al., 2013
mackerels	*Scomber scombrus*	Linnaeus, 1758	ARSA surveys/Acoustic surveys	ML	Torres et al., 2013
mola/sunfishes	*Ranzania laevis*	(Pennant, 1776)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
mola/sunfishes	*Mola mola*	(Linnaeus, 1758)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
mullets	*Mullus barbatus*	Linnaeus, 1758	ARSA surveys	ML	Torres et al., 2013
mullets	*Mullus surmuletus*	Linnaeus, 1758	ARSA surveys	ML	Torres et al., 2013
piscivores	*Conger conger*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013
piscivores	*Lophius budegassa*	Spinola, 1807	ARSA surveys	MT	Torres et al., 2013
piscivores	*Lophius piscatorius*	Linnaeus, 1758	ARSA surveys	MT	Torres et al., 2013
piscivores	*Lophius sp.*		ARSA surveys	ML	Torres et al., 2013
piscivores	*Ophichthus rufus*	(Rafinesque, 1810	ARSA surveys	ML	Torres et al., 2013
piscivores	*Ophisurus serpens*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013
piscivores	*Pomatomus saltatrix*	(Linnaeus, 1766)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
piscivores	*Zenopsis conchifer*	(Lowe, 1852)	ARSA surveys	ML	Torres et al., 2013
piscivores	*Zeus faber*	Linnaeus, 1758	ARSA surveys	ML	Torres et al., 2013
sardine	*Sardina pilchardus*	(Walbaum, 1792)	ARSA surveys/Acoustic surveys	ML	Torres et al., 2013
sharks	*Centrophorus granulosus*	(Bloch & Schneider, 1801)	ARSA surveys	ML	Torres et al., 2013
sharks	*Centrophorus squamosus*	(Bonnaterre, 1788)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
sharks	*Centrophorus uyato*	(Rafinesque, 1810)	ARSA surveys	MT	Torres et al., 2013

sharks	*Dalatias licha*	(Bonnaterre, 1788)	ARSA surveys	ML	Torres et al., 2013
sharks	*Deania calcea*	(Lowe, 1839)	ARSA surveys	ML	Torres et al., 2013
sharks	*Deania profundorum*	(Smith & Radcliffe, 1912)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
sharks	*Etmopterus princeps*	Collett, 1904	ARSA surveys	MT	Torres et al., 2013
sharks	*Etmopterus pusillus*	(Lowe, 1839)	ARSA surveys	MT	Torres et al., 2013
sharks	*Etmopterus spinax*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013
sharks	*Galeorhinus galeus*	(Linnaeus, 1758)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
sharks	*Galeus atlanticus*	(Vaillant, 1888)	ARSA surveys	ML	Torres et al., 2013
sharks	*Galeus melastomus*	Rafinesque, 1810	ARSA surveys	ML	Torres et al., 2013
sharks	*Heptranchias perlo*	(Bonnaterre, 1788)	ARSA surveys	ML	Torres et al., 2013
sharks	*Hexanchus griseus*	(Bonnaterre, 1788)	ARSA surveys	ML	Torres et al., 2013
sharks	*Mustelus mustelus*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013
sharks	*Oxynotus centrina*	(Linnaeus, 1758)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
sharks	*Scyliorhinus canicula*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013
sharks	*Scymnodon ringens*	Barbosa du Bocage & de Brito Capello, 1864	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
sharks	*Somniosus rostratus*	(Risso, 1827)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
sharks	*Squalus acanthias*	Linnaeus, 1758	ARSA surveys	MT	Torres et al., 2013
sharks	*Squalus blainvillei*	(Risso, 1827)	ARSA surveys	ML	Torres et al., 2013
sharks	*Squalus megalops*	(Macleay, 1881)	ARSA surveys	MT	Torres et al., 2013
skates	*Aetomylaeus bovinus*	(Geoffroy Saint-Hilaire, 1817)	ARSA surveys	GCS	Torres et al., 2013
skates	*Bathyraja brachyurops*	(Fowler, 1910)	ARSA surveys	GCS	Torres et al., 2013
skates	*Dasyatis pastinaca*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013
skates	*Dipturus batis*	(Linnaeus, 1758)	ARSA surveys	GCS	Torres et al., 2013

skates	*Dipturus oxyrinchus*	(Linnaeus, 1758)	ARSA surveys	GCS	Torres et al., 2013
skates	*Gymnura altavela*	(Linnaeus, 1758)	ARSA surveys	GCS	Torres et al., 2013; Fishbase, 2017
skates	*Leucoraja circularis*	(Couch, 1838)	ARSA surveys	GCS	Torres et al., 2013
skates	*Leucoraja fullonica*	(Linnaeus, 1758)	ARSA surveys	GCS	Torres et al., 2013
skates	*Leucoraja naevus*	(Müller & Henle, 1841)	ARSA surveys	GCS	Torres et al., 2013
skates	*Myliobatis aquila*	(Linnaeus, 1758)	ARSA surveys	GCS	Torres et al., 2013
skates	*Neoraja iberica*	Stehmann, Séret, Costa & Baro, 2008	ARSA surveys	ML	Torres et al., 2013
skates	*Pteroplatytrygon violacea*	(Bonaparte, 1832)	ARSA surveys	GCS	Torres et al., 2013
skates	*Raja asterias*	Delaroche, 1809	ARSA surveys	ML	Torres et al., 2013
skates	*Raja clavata*	Linnaeus, 1758	ARSA surveys	ML	Torres et al., 2013
skates	*Raja microocellata*	Montagu, 1818	ARSA surveys	ML	Torres et al., 2013
skates	*Raja miraletus*	Linnaeus, 1758	ARSA surveys	ML	Torres et al., 2013
skates	*Raja montagui*	Fowler, 1910	ARSA surveys	ML	Torres et al., 2013
skates	*Raja radiata*	(Donovan, 1808)	ARSA surveys	ML	Torres et al., 2013
skates	*Raja sp.*		ARSA surveys	MT	Torres et al., 2013
skates	*Raja undulata*	Lacepède, 1802	ARSA surveys	ML	Torres et al., 2013
skates	*Rostroraja alba*	(Lacepède, 1803)	ARSA surveys	GCS	Torres et al., 2013
skates	*Torpedo marmorata*	Risso, 1810	ARSA surveys	ML	Torres et al., 2013
skates	*Torpedo nobiliana*	(Bonaparte, 1835)	ARSA surveys	MT	Torres et al., 2013
skates	*Torpedo torpedo*	(Linnaeus, 1758)	ARSA surveys	MT	Torres et al., 2013
sparids 1	*Boops boops*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013
sparids 1	*Diplodus annularis*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013
sparids 1	*Diplodus bellottii*	(Steindachner, 1882)	ARSA surveys	ML	Torres et al., 2013

sparids 1	*Diplodus cervinus*	(Lowe, 1838)	ARSA surveys	GCS	Torres et al., 2013
sparids 1	*Diplodus puntazzo*	(Walbaum, 1792)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
sparids 1	*Diplodus vulgaris*	(Geoffroy Saint-Hilaire, 1817)	ARSA surveys	ML	Torres et al., 2013
sparids 1	*Pagellus acarne*	(Risso, 1827)	ARSA surveys	ML	Torres et al., 2013
sparids 1	*Pagellus bellottii*	Steindachner, 1882	ARSA surveys	ML	Torres et al., 2013
sparids 1	*Pagellus bogaraveo*	(Brünnich, 1768)	ARSA surveys	ML	Torres et al., 2013
sparids 1	*Pagellus erythrinus*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013
sparids 1	*Spicara flexuosa*	(Linnaeus, 1758)	ARSA surveys	MT	Torres et al., 2013
sparids 1	*Spicara maena*	(Linnaeus, 1758)	ARSA surveys	MT	Torres et al., 2013
sparids 1	*Spicara smaris*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013
sparids 1	*Spondyliosoma cantharus*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013
sparids 1	*Trachinus draco*	Linnaeus, 1758	ARSA surveys	ML	Torres et al., 2013
sparids 2	*Argyrosomus regius*	(Asso, 1801)	ARSA surveys	ML	Torres et al., 2013
sparids 2	*Dentex canariensis*	Steindachner, 1881	ARSA surveys	ML	Torres et al., 2013
sparids 2	*Dentex dentex*	(Linnaeus, 1758)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
sparids 2	*Dentex gibbosus*	(Rafinesque, 1810)	ARSA surveys	ML	Torres et al., 2013
sparids 2	*Dentex macrophtalmus*	(Bloch, 1791)	ARSA surveys	ML	Torres et al., 2013
sparids 2	*Dentex maroccanus*	Valenciennes, 1830	ARSA surveys	ML	Torres et al., 2013
sparids 2	*Diplodus sargus sargus*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013
sparids 2	*Lithognathus mormyrus*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013
sparids 2	*Pagrus auriga*	Valenciennes, 1843	ARSA surveys	ML	Torres et al., 2013
sparids 2	*Pagrus caeruleostictus*	(Valenciennes, 1830)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
sparids 2	*Pagrus pagrus*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013
sparids 2	*Plectorhinchus mediterraneus*	(Guichenot, 1850)	ARSA surveys	ML	Torres et al., 2013

sparids 2	*Pomadasys incisus*	(Bowdich, 1825)	ARSA surveys	ML	Torres et al., 2013
sparids 2	*Sarpa salpa*	(Linnaeus, 1758)	ARSA surveys	GCS	Fishbase, 2017; IUCN, 2017
sparids 2	*Sparus aurata*	Linnaeus, 1758	ARSA surveys	ML	Torres et al., 2013
sparids 2	*Umbrina canariensis*	Valenciennes, 1843	ARSA surveys	ML	Torres et al., 2013
sparids 2	*Umbrina cirrosa*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013
sparids 2	*Umbrina ronchus*	Valenciennes, 1843	ARSA surveys	ML	Torres et al., 2013
bivalves	*Abra longicallus*	(Scacchi, 1835)	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Abra nitida*	(O. F. Müller, 1776)	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Acanthocardia aculeata*	(Linnaeus, 1758)	ARSA surveys	MT	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Acanthocardia echinata*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Acanthocardia paucicostata*	(G. B. Sowerby II, 1834)	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Acanthocardia sp.*		ARSA surveys	MT	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Acanthocardia spinosa*	(Lightfoot, 1786)	ARSA surveys	MT	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Acanthocardia tuberculata*	(Linnaeus, 1758)	ARSA surveys	MT	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Aequipecten commutatus*	(Monterosato, 1875)	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Aequipecten opercularis*	(Linnaeus, 1758)	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Anadara corbuloides*	(Monterosato, 1878)	ARSA surveys	ML	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Anadara gibbosa*	(Reeve, 1844)	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Anadara inaequivalvis*	(Bruguière, 1789)	ARSA surveys	ML	Torres et al., 2013; WoRMS, 2017; IUCN, 2017

bivalves	*Anadara polii*	(Reeve, 1844)	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Anomia ephippium*	Linnaeus, 1758	ARSA surveys	ML	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Astarte fusca*	(Poli, 1791)	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Atrina fragilis*	(Pennant, 1777)	ARSA surveys	ML	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Atrina pectinata*	(Linnaeus, 1767)	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Bivalvia*		ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Brachiopods*		ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Callista chione*	(Linnaeus, 1758)	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Cardium sp.*		ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Cerastoderma sp.*		ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Chamelea gallina*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Chlamys sp.*		ARSA surveys	ML	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Clausinella fasciata*	(da Costa, 1778)	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Crassostrea sp.*		ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Cuspidaria cuspidata*	(Olivi, 1792)	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Donax venustus*	Poli, 1795	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Dosinia sp.*		ARSA surveys	ML	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Ensis ensis*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Flexopecten flexuosus*	(Poli, 1795)	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017

bivalves	*Flexopecten glaber*	(Linnaeus, 1758)	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Flexopecten sp.*		ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Glossus humanus*	(Linnaeus, 1758)	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Glycymeris glycymeris*	(Linnaeus, 1758)	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Glycymeris spp.*		ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Gouldia minima*	(Montagu, 1803)	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Hiatella arctica*	(Linnaeus, 1767)	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Jolya martorelli*	(Hidalgo, 1878)	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Laevicardium crassum*	(Gmelin, 1791)	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Laevicardium sp.*		ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Lutraria angustior*	Philippi, 1844	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Macoma sp.*		ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Mactra stultorum*	(Linnaeus, 1758)	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Magallana gigas*	(Thunberg, 1793)	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Mimachlamys varia*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Modiolus modiolus*	(Linnaeus, 1758)	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Mya arenaria*	Linnaeus, 1758	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Mytilidae*		ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Neopycnodonte cochlear*	(Poli, 1795)	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017

bivalves	*Nucula nucleus*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Nucula sulcata*	Bronn, 1831	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Ostrea edulis*	Linnaeus, 1758	ARSA surveys	MT	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Ostrea sp.*		ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Pecten maximus*	(Linnaeus, 1758)	ARSA surveys	MT	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Pharus legumen*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Philine aperta*	(Linnaeus, 1767)	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Pinna nobilis*	Linnaeus, 1758	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Pinna sp.*		ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Pitar rudis*	(Poli, 1795)	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Polititapes rhomboides*	(Pennant, 1777)	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Pseudamussium clavatum*	(Poli, 1795)	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Pteria hirundo*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Ruditapes decussatus*	(Linnaeus, 1758)	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Solecurtus sp.*		ARSA surveys	ML	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Solecurtus strigilatus*	(Linnaeus, 1758)	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Spisula sp.*		ARSA surveys	ML	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Spisula subtruncata*	(da Costa, 1778)	ARSA surveys	ML	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Polititapes rhomboides*	(Pennant, 1777)	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017

bivalves	*Tellina sp.*		ARSA surveys	ML	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Thracia convexa*	(W. Wood, 1815)	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Venerupis corrugata*	(Gmelin, 1791)	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Venus casina*	Linnaeus, 1758	ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Venus nux*	Gmelin, 1791	ARSA surveys	ML	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Venus sp.*		ARSA surveys	GCS	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
bivalves	*Venus verrucosa*	Linnaeus, 1758	ARSA surveys	MT	Torres et al., 2013; WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Aegidae*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Anapagurus bicorniger*	A. Milne-Edwards & Bouvier, 1892	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Anapagurus laevis*	(Bell, 1846)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Anapagurus longispina*	A. Milne-Edwards & Bouvier, 1900	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Atelecyclus rotundatus*	(Olivi, 1792)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Atelecyclus undecimdentatus*	(Herbst, 1783)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Bathynectes longipes*	(Risso, 1816)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Bathynectes maravigna*	(Prestandrea, 1839)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Bathynectes superba*	(Prestandrea, 1839)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Calappa granulata*	(Linnaeus, 1758)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Cancer pagurus*	Linnaeus, 1758	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Cestopagurus timidus*	(Roux, 1830)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Dardanus arrosor*	(Herbst, 1796)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Derilambrus angulifroms*	(Latreille, 1825)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Diogenes pugilator*	(Roux, 1829)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017

crabs and lobsters	*Distolambrus maltzami*	(Miers, 1881)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Dorhynchus thomsoni*	C. W. Thomson, 1873	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Dromia personata*	(Linnaeus, 1758)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Ebalia sp.*		ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Ergasticus clouei*	A. Milne-Edwards, 1882	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Eriphia verrucosa*	(Forskål, 1775)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Ethusa mascarone*	(Herbst, 1785)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Euchirograpsus liguricus*	H. Milne Edwards, 1853	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Eupaguridae spp.*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Eurynome aspera*	(Pennant, 1777)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Galathea dispersa*	Bate, 1859	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Galathea intermedia*	Lilljeborg, 1851	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Galathea sp.*		ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Galathea strigosa*	(Linnaeus, 1761)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Goneplax rhomboides*	(Linnaeus, 1758)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Homarus gammarus*	(Linnaeus, 1758)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Homola barbata*	(Fabricius, 1793)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Inachus communissimus*	Rizza, 1839	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Inachus dorsettensis*	(Pennant, 1777)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Inachus leptochirus*	Leach, 1817	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Inachus sp.*		ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Inachus thoracicus*	Roux, 1830	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Latreillia elegans*	Roux, 1830	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Liocarcinus depurator*	(Linnaeus, 1758)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017

crabs and lobsters	*Liocarcinus holsatus*	(Fabricius, 1798)	ARSA surveys	MT	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Liocarcinus maculatus*	(Risso, 1827)	ARSA surveys	MT	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Liocarcinus navigator*	(Herbst, 1794)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Liocarcinus pusillus*	(Leach, 1816)	ARSA surveys	MT	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Liocarcinus sp.*		ARSA surveys	MT	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Liocarcinus vernalis*	(Risso, 1827)	ARSA surveys	MT	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Macropipus tuberculatus*	(Roux, 1830)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Macropodia linaresi*	Forest & Zariquiey-Álvarez, 1964	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Macropodia longipes*	(A. Milne-Edwards & Bouvier, 1899)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Macropodia longirostris*	(Fabricius, 1775)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Macropodia rostrata*	(Linnaeus, 1761)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Macropodia sp.*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Macropodia tenuirostris*	(Leach, 1814)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Maja squinado*	(Herbst, 1788)	ARSA surveys	MT	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Medorippe lanata*	(Linnaeus, 1767)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Monodaeus couchii*	(Couch, 1851)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Munida intermedia*	A. Milne Edwards & Bouvier, 1899	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Munida iris*	A. Milne Edwards, 1880	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Munida rugosa*	(Fabricius, 1775)	ARSA surveys	MT	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Munida rutllanti*	Zariquiey Álvarez, 1952	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Munida sp.*		ARSA surveys	MT	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Munida tenuimana*	Sars, 1872	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Necora puber*	(Linnaeus, 1767)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Neomaja goltziana*	(d'Oliveira, 1889)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017

crabs and lobsters	*Nepinnotheres pinnotheres*	(Linnaeus, 1758)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Paguridae*		ARSA surveys	MT	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Paguristes eremita*	(Linnaeus, 1767)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Paguristes sp.*		ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Pagurus alatus*	Fabricius, 1775	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Pagurus bernhardus*	(Linnaeus, 1758)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Pagurus excavatus*	(Herbst, 1791)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Pagurus prideaux*	Leach, 1815	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Palinurus elephas*	(Fabricius, 1787)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Palinurus mauritanicus*	Gruvel, 1911	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Parapagurus pilosimanus*	Smith, 1879	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Paromola cuvieri*	(Risso, 1816)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Parthenopoides massena*	(Roux, 1830)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Pestarella tyrrhena*	(Petagna, 1792)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Phronima spp.*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Pilumnus hirtellus*	hirtellus (Linnaeus, 1761)	ARSA surveys	MT	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Pilumnus sp.*		ARSA surveys	MT	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Pilumnus spinifer*	H. Milne Edwards, 1834	ARSA surveys	MT	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Pilumnus villosissimus*	(Rafinesque, 1814)	ARSA surveys	MT	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Pinnotheres pisum*	(Linnaeus, 1767)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Pisa armata*	(Latreille, 1803)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Pisa nodipes*	Leach, 1815	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Pisa sp.*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Pisidia longicornis*	(Linnaeus, 1767)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017

crabs and lobsters	*Polybiidae*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Polybius henslowii*	Leach, 1820	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Polycheles typhlops*	Heller, 1862	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Portunidae*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Pseudosquilla sp.*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Rissoides desmaresti*	(Risso, 1816)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Rissoides pallidus*	(Giesbrecht, 1910)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Rissoides sp.*		ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Scyllaridae*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Scyllarus arctus*	(Linnaeus, 1758)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Sicyonia carinata*	(Brünnich, 1768)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Spinolambrus macrochelos*	(Herbst, 1790)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Strigopagurus strigimanus*	(White, 1847)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Upogebia pusilla*	(Petagna, 1792)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Upogebia tipica*	(Nardo, 1869)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Xantho hydrophilus*	(Herbst, 1790)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Xantho sp.*	(Herbst, 1790)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
crabs and lobsters	*Xhanto pillipes*	A. Milne-Edwards, 1867	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
mantis shrimp	*Squilla mantis*	(Linnaeus, 1758)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
Norway lobster	*Nephrops norvegicus*	(Linnaeus, 1758)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
rose shrimp	*Parapenaeus longirostris*	(Lucas, 1846)	ARSA surveys	ML	Torres et al., 2013

shrimps	*Acanthephyra pelagica*	(Risso, 1816)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
shrimps	*Acanthephyra purpurea*	A. Milne-Edwards, 1881	ARSA surveys	MT	WoRMS, 2017; IUCN, 2017
shrimps	*Acanthephyra spp.*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
shrimps	*Aegaeon cataphractus*	(Olivi, 1792)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
shrimps	*Aegaeon lacazei*	(Gourret, 1887)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
shrimps	*Alpheus glaber*	(Olivi, 1792)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
shrimps	*Alpheus macrocheles*	(Hailstone, 1835)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
shrimps	*Alpheus sp.*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
shrimps	*Aristaeomorpha foliacea*	(Risso, 1827)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
shrimps	*Aristeus antennatus*	(Risso, 1816)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
shrimps	*Calocaris macandreae*	Bell, 1853	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
shrimps	*Chlorotocus crassicornis*	(Costa, 1871)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
shrimps	*Deosergestes corniculum*	(Krøyer, 1855)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
shrimps	*Euphasia sp.*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
shrimps	*Eusergestes arcticus*	(Krøyer, 1855)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
shrimps	*Gennadas elegans*	(S. I. Smith, 1882)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
shrimps	*Hadropenaeus affinis*	(Bouvier, 1906)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
shrimps	*Heterocarpus ensifer*	A. Milne-Edwards, 1881	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
shrimps	*Hymenopenaeus debilis*	S. I. Smith, 1882	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
shrimps	*Jaxea nocturna*	Nardo, 1847	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
shrimps	*Ligur ensiferus*	(Risso, 1816)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
shrimps	*Lophogaster spinosus*	Ortmann, 1906	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
shrimps	*Lophogaster typicus*	M. Sars, 1857	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
shrimps	*Meganyctiphanes norvegica*	(M. Sars, 1857)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017

shrimps	*Melicertus kerathurus*	(Forskål, 1775)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
shrimps	*Nematocarcinus ensifer*	(Smith, 1882)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
shrimps	*Notostomus sp.*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
shrimps	*Oplophoridae*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
shrimps	*Oplophorus spinosus*	(Brulle, 1839)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
shrimps	*Palaemon serratus*	(Pennant, 1777)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
shrimps	*Pandalidae*		ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
shrimps	*Pasiphaea multidentata*	Esmark, 1866	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
shrimps	*Pasiphaea sivado*	(Risso, 1816)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
shrimps	*Penaeidae*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
shrimps	*Penaeopsis serrata*	Bate, 1881	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
shrimps	*Periclimenes sp.*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
shrimps	*Philocheras echinulatus*	(M. Sars, 1862)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
shrimps	*Philocheras fasciatus*	(Risso, 1816)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
shrimps	*Plesionika acanthonotus*	(Smith, 1882)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
shrimps	*Plesionika antigai*	Zariguiey Alvarez, 1955	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
shrimps	*Plesionika edwardsii*	(Brandt, 1851)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
shrimps	*Plesionika gigliolii*	(Senna, 1903)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
shrimps	*Plesionika heterocarpus*	(Costa, 1871)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
shrimps	*Plesionika martia*	(A. Milne-Edwards, 1883)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
shrimps	*Plesionika narval*	(Fabricius, 1787)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
shrimps	*Plesionika sp.*		ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
shrimps	*Pontophilus norvegicus*	(M. Sars, 1861)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
shrimps	*Pontophilus spinosus*	(Leach, 1815)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017

shrimps	*Processa canaliculata*	Leach, 1815	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
shrimps	*Processa edulis*	(Risso, 1816)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
shrimps	*Processa intermedia*	Holthuis, 1951	ARSA surveys	MT	WoRMS, 2017; IUCN, 2017
shrimps	*Processa macrophthalma*	Nouvel & Holthuis, 1957	ARSA surveys	MT	WoRMS, 2017; IUCN, 2017
shrimps	*Processa mediterranea*	Leach, 1815	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
shrimps	*Processa nouveli nouveli*	Al-Adhub & Williamson, 1975	ARSA surveys	MT	WoRMS, 2017; IUCN, 2017
shrimps	*Processa sp.*		ARSA surveys	MT	WoRMS, 2017; IUCN, 2017
shrimps	*Sergestes arachnipodus*	(Cocco, 1832)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
shrimps	*Sergestes atlanticus*	H. Milne Edwards, 1830	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
shrimps	*Sergestes sp.*		ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
shrimps	*Sergestes sp3*		ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
shrimps	*Solenocera membranacea*	(Risso, 1816)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
shrimps	*Stylopandalus richardi*	(Coutière, 1905)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
shrimps	*Systellaspis debilis*	(A.Milne-Edwards, 1881)	ARSA surveys	ML	WoRMS, 2017; IUCN, 2017
shrimps	*Systellaspis spp.*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
gelatinous zooplankton	*Aurelia aurita*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013; IUCN, 2017
gelatinous zooplankton	*Hydroid cnidarian*		ARSA surveys	ML	Torres et al., 2013
gelatinous zooplankton	*Jellyfish*		ARSA surveys	ML	Torres et al., 2013
gelatinous zooplankton	*Pelagia noctiluca*	(Forskål, 1775)	ARSA surveys	ML	Torres et al., 2013; IUCN, 2017
gelatinous zooplankton	*Rhizostoma pulmo*	(Macri, 1778)	ARSA surveys	ML	Torres et al., 2013; IUCN, 2017
gelatinous zooplankton	*Salpa maxima*	Forskal, 1775	ARSA surveys	MT	Torres et al., 2013; IUCN, 2017
gelatinous zooplankton	*Salpidae*		ARSA surveys	ML	Torres et al., 2013; IUCN, 2017
gelatinous zooplankton	*Siphonophorae*		ARSA surveys	ML	Torres et al., 2013; IUCN, 2017

carnivores-benthic invertebrates	*Actinia sp.*		ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Aglaja tricolorata*	Renier, 1807	ARSA surveys	MT	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Ampulla priamus*	(Gmelin, 1791)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Anseropoda placenta*	(Pennant, 1777)	ARSA surveys	MT	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Aplysia depilans*	Gmelin, 1791	ARSA surveys	MT	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Aplysia spp.*		ARSA surveys	MT	Torres et al., 2013
carnivores-benthic invertebrates	*Aporrhais pespelecani*	(Linnaeus, 1758)	ARSA surveys	MT	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Aporrhais serresianus*	(Michaud, 1828)	ARSA surveys	MT	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Arbacia lixula*	(Linnaeus, 1758)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Armina maculata*	Rafinesque, 1814	ARSA surveys	ML	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Armina tigrina*	Rafinesque, 1814	ARSA surveys	ML	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Asterina gibbosa*	(Pennant, 1777)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Asteroidea*		ARSA surveys	MT	Torres et al., 2013
carnivores-benthic invertebrates	*Astropecten aranciacus*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Astropecten irregularis*	(Pennant, 1777)	ARSA surveys	ML	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Astropecten spinulosus*	(Philippi, 1837)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Astropecten spp.*		ARSA surveys	ML	Torres et al., 2013
carnivores-benthic invertebrates	*Astrospartus mediterraneus*	(Risso, 1826)	ARSA surveys	MT	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Bivetiella cancellata*	(Linnaeus, 1767)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Bolinus brandaris*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Bolma rugosa*	(Linnaeus, 1767)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Buccinum humphreysianum*	Bennett, 1824	ARSA surveys	MT	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Buccinum sp.*		ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Calliostoma granulatum*	(Born, 1778)	ARSA surveys	ML	Torres et al., 2013; IUCN, 2017

carnivores-benthic invertebrates	*Calyptraea chinensis*	(Linnaeus, 1758)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Capulus ungaricus*	(Linnaeus, 1758)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Centrostephanus longispinus*	(Philippi, 1845)	ARSA surveys	ML	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Chaetopleura angulata*	(Spengler, 1797)	ARSA surveys	ML	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Chaetaster longipes*	(Retzius, 1805)	ARSA surveys	MT	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Charonia lampas*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Chiton olivaceus*	Spengler, 1797	ARSA surveys	MT	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Cidaris cidaris*	(Linnaeus, 1758)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Colus gracilis*	(da Costa, 1778)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Coscinasterias tenuispina*	(Lamarck, 1816)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Cymbium olla*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Cymbuliidae*		ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Diodora graeca*	(Linnaeus, 1758)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Discodorididae*		ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Doris pseudoargus*	Rapp, 1827	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Doris verrucosa*	Linnaeus, 1758	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Echinaster sepositus*	(Retzius, 1783)	ARSA surveys	MT	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Echinus melo*	Lamarck, 1816	ARSA surveys	ML	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Epitonium clathrus*	(Linnaeus, 1758)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Euspira catena*	(da Costa, 1778)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Euspira fusca*	(Blainville, 1825)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Euspira sp.*		ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Flabellum (Flabellum) chunii*	Marenzeller, 1904	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Fusinus rostratus*	(Olivi, 1792)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017

carnivores-benthic invertebrates	*Fusiturris similis*	(Bivona Ant. in Bivona and., 1838)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Fusiturris undatiruga*	(Bivona Ant. in Bivona And., 1838)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Galeodea echinophora*	(Linnaeus, 1758)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Galeodea rugosa*	(Linnaeus, 1771)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Gasteropteron meckeli*	Kosse, 1813	ARSA surveys	MT	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Genocidaris maculata*		ARSA surveys	MT	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Gracilechinus acutus*	(Lamarck, 1816)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Haliotis tuberculata lamellosa*	Lamarck, 1822	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Hexaplex trunculus*	(Linnaeus, 1758)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Hymenodiscus coronata*	(Sars, 1871)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Luidia ciliaris*	(Philippi, 1837)	ARSA surveys	MT	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Luidia sarsii*	Düben & Koren in Düben, 1844	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Luria lurida*	(Linnaeus, 1758)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Marionia blainvillea*	(Risso, 1818)	ARSA surveys	ML	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Marthasterias glacialis*	(Linnaeus, 1758)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Mitra sp.*		ARSA surveys	MT	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Monoplex corrugatus*	(Lamarck, 1816)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Monoplex parthenopeus*	(Salis Marschlins, 1793)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Nassarius elatus*	(Gould, 1845)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Nassarius idyllius*	(Melvill & Standen, 1901)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Nassarius sp.*		ARSA surveys	MT	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Naticarius hebraeus*	(Martyn, 1786)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Naticidae*		ARSA surveys	MT	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Neverita josephinia*	Risso, 1826	ARSA surveys	MT	Torres et al., 2013; IUCN, 2017

carnivores-benthic invertebrates	*Nudibranchia spp.*		ARSA surveys	ML	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Nymphaster arenatus*	(Perrier, 1881)	ARSA surveys	MT	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Ocenebra erinaceus*	(Linnaeus, 1758)	ARSA surveys	MT	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Odontaster mediterraneus*	(von Marenzeller, 1893)	ARSA surveys	MT	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Ophidiaster ophidianus*	(Lamarck, 1816)	ARSA surveys	MT	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Ophioderma longicauda*	(Bruzelius, 1805)	ARSA surveys	MT	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Ophiopsila aranea*	Forbes, 1843	ARSA surveys	MT	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Ophiothrix fragilis*	(Abildgaard in O.F. Müller, 1789)	ARSA surveys	ML	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Ophiothrix sp.*		ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Ophiura ophiura*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Ophiura sp.*		ARSA surveys	ML	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Ophiuroidea*		ARSA surveys	MT	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Opisthobranchia spp.*		ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Ova canalifera*	(Lamarck, 1816)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Paracentrotus lividus*	(Lamarck, 1816)	ARSA surveys	ML	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Peltaster placenta*	(Müller & Troschel, 1842)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Phormosoma placenta*	Thomson, 1872	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Pleurobranchaea meckeli*	(Blainville, 1825)	ARSA surveys	ML	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Psammechinus microtuberculatus*	(Blainville, 1825)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Psammechinus miliaris*	(P.L.S. Müller, 1771)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Pseudarchaster gracilis*	(Sladen, 1889)	ARSA surveys	MT	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Pseudarchaster parelii*	(Düben & Koren, 1846)	ARSA surveys	MT	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Ranella olearium*	(Linnaeus, 1758)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Scaphander lignarius*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013; IUCN, 2017

carnivores-benthic invertebrates	*Sclerasterias guernei*	Perrier, 1891	ARSA surveys	MT	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Semicassis granulata*	(Born, 1778)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Semicassis saburon*	(Bruguière, 1792)	ARSA surveys	MT	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Spatangus purpureus*	O.F. Müller, 1776	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Sphaerechinus granularis*	(Lamarck, 1816)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Stichastrella rosea*	(Müller, 1776)	ARSA surveys	MT	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Tethyaster subinermis*	(Philippi, 1837)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Tethys fimbria*	Linnaeus, 1767	ARSA surveys	ML	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Tonna galea*	(Linnaeus, 1758)	ARSA surveys	MT	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Tritia incrassata*	(Strøm, 1768)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Tritia reticulata*	(Linnaeus, 1758)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Tritonia hombergii*	Cuvier, 1803	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Tritonia sp.*		ARSA surveys	ML	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Turridae*		ARSA surveys	MT	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Turritella communis*	Risso, 1826	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Turritella spp.*		ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
carnivores-benthic invertebrates	*Xenophora crispa*	(König, 1825)	ARSA surveys	ML	Torres et al., 2013; IUCN, 2017
F/D/S benthic invertebrates	*Acanthogorgia hirsuta*	Gray, 1857	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
F/D/S benthic invertebrates	*Actinauge richardi*	(Marion, 1882)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
F/D/S benthic invertebrates	*Adamsia palliata*	(Müller, 1776)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
F/D/S benthic invertebrates	*Adeonella calveti*	(Canu & Bassler, 1930)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
F/D/S benthic invertebrates	*Aglaophenia pluma*	(Linnaeus, 1758)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
F/D/S benthic invertebrates	*Aglaophenia tubulifera*	(Hincks, 1861)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
F/D/S benthic invertebrates	*Alcyonium palmatum*	Pallas, 1766	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017

F/D/S benthic invertebrates	*Antedon mediterranea*	(Lamarck, 1816)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
F/D/S benthic invertebrates	*Ascidia conchilega*	Müller, 1776	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
F/D/S benthic invertebrates	*Ascidia mentula*	Müller, 1776	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
F/D/S benthic invertebrates	*Ascidia sp.*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
F/D/S benthic invertebrates	*Ascidiacea*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
F/D/S benthic invertebrates	*Ascidiella aspersa*	(Müller, 1776)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
F/D/S benthic invertebrates	*Asconema setubalense*	Kent, 1870	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
F/D/S benthic invertebrates	*Aulactinia verrucosa*	(Pennant, 1777)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
F/D/S benthic invertebrates	*Axinella sp.*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017
F/D/S benthic invertebrates	*Balanophyllia europaea*	(Risso, 1826)	ARSA surveys	GCS	Torres et al., 2013; IUCN, 2017
F/D/S benthic invertebrates	*Balanus sp.*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Botryllus schlosseri*	(Pallas, 1766)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Brissopsis atlantica mediterranea*	Mortensen, 1913	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Brissopsis lyrifera*	(Forbes, 1841)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Brissus unicolor*	(Leske, 1778)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Bryozoa*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Calliactis parasitica*	(Couch, 1842)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Callogorgia verticillata*	(Pallas, 1766)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Caryophyllia (Caryophyllia) smithii*	Stokes & Broderip, 1828	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Caryophyllia sp.*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Cellaria salicornoides*	Lamouroux, 1816	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017

F/D/S benthic invertebrates	*Cellaria sp.*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Cellepora pumicosa*	(Pallas, 1766)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Cerianthus membranaceus*	(Gmelin, 1796)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Cerianthus sp.*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Ciona edwardsi*	Roule, 1884	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Cliona celata*	Grant, 1826	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Dentalium sp.*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Dendrodoa grossularia*	(Van Beneden, 1846)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Dendrophyllia cornigera*	(Lamarck, 1816)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Diazona violacea*	Savigny, 1816	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Didemnum spp.*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Diphasia alata*	(Hincks, 1855)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Diphasia nigra*	(Pallas, 1766)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Diphasia margareta*	(Hassall, 1841)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Diphasia rosacea*	(Linnaeus, 1758)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Diphasia sp.*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Dysidea sp.*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Epizoanthus incrustatus*	(Düben & Koren, 1847)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Epizoanthus sp.*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017

F/D/S benthic invertebrates	*Eunicella filiformis*	(Studer, 1879)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Eunicella verrucosa*	(Pallas, 1766)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Funiculina quadrangularis*	(Pallas, 1766)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Geodia megastrella*	Carter, 1876	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Geodia sp.*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Gorgonia sp.*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Gryphus vitreus*	(Born, 1778)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Halecium halecinum*	(Linnaeus, 1758)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Haliclona (Soestella) mucosa*	(Griessinger, 1971)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Halocynthia papillosa*	(Linnaeus, 1767)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Holothuria forskali*	Delle Chiaje, 1823	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Holothuria sp.*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Holothuria tubulosa*	Gmelin, 1790	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Holothuroidea*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Hormatia alba*	(Andrès, 1880)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Hydrozoa*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Kophobelemnon stelliferum*	(Müller, 1776)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Isidella elongata*	(Esper, 1788)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Leiopathes glaberrima*	(Esper, 1788)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017

F/D/S benthic invertebrates	*Lepas anatifera*	Linnaeus, 1758	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Lepas sp.*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Leptometra celtica*	(M'Andrew & Barrett, 1857)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Leptopentacta elongata*	(Düben & Koren, 1846)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Leptopentacta tergestina*	(M. Sars, 1857)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Lytocarpia myriophyllum*	(Linnaeus, 1758)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Madrepora oculata*	Linnaeus, 1758	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Microcosmus vulgaris*	Heller, 1877	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Molgula appendiculata*	Heller, 1877	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Molpadia musculus*	Risso, 1826	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Molpadia sp.*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Nemertesia antennina*	(Linnaeus, 1758)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Nemertesia ramosa*	(Lamarck, 1816)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Nemertesia sp.*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Parastichopus regalis*	(Cuvier, 1817)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Parastichopus tremulus*	(Gunnerus, 1767)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Pennatula phosphorea*	Linnaeus, 1758	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Pennatula rubra*	(Ellis, 1761)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Pennatula sp.*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017

F/D/S benthic invertebrates	*Pentapora fascialis*	(Pallas, 1766)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Petrosia vansoesti*	Boury-Esnault, Pansini & Uriz, 1994	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Phakellia robusta*	Bowerbank, 1866	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Phakellia sp.*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Phallusia mammillata*	(Cuvier, 1815)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Phascolosoma (Phascolosoma) granulatum*	Leuckart, 1828	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Phyllophorus (Phyllophorus) urna*	Grube, 1840	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Poecillastra sp.*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Polyplumaria sp.*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Porifera*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Pteroeides spinosum*	(Ellis, 1764)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Pyura dura*	(Heller, 1877)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Reteporella beaniana*	(King, 1846)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Sagartiogeton undatus*	(Müller, 1778)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Scalpellum scalpellum*	(Linnaeus, 1767)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Scleractinia sp1*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Scleractinia sp2*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Securiflustra securifrons*	(Pallas, 1766)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Sertularella gayi*	(Lamouroux, 1821)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017

F/D/S benthic invertebrates	*Sertularella tenella*	(Alder, 1857)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Sipunculidae*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Sipunculus (Sipunculus) nudus*	Linnaeus, 1766	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Sipunculus sp.*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Spinimuricea atlantica*	(Johnson, 1862)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Suberites domuncula*	(Olivi, 1792)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Swiftia pallida*	Madsen, 1970	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Synaptidae*		ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Synoicum blochmanni*	(Heiden, 1894)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Tethya citrina*	Sarà & Melone, 1965	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Thecocaulus diaphanus*	Vannucci, 1946	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Thenea muricata*	(Bowerbank, 1858)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Veretillum cynomorium*	(Pallas, 1766)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
F/D/S benthic invertebrates	*Virgularia mirabilis*	(Müller, 1776)	ARSA surveys	GCS	WoRMS, 2017; IUCN, 2017; Sealifebase 2017
polychaetes	*Aphrodita aculeata*	Linnaeus, 1758	ARSA surveys	ML	Torres et al., 2013
polychaetes	*Aphrodita spp.*		ARSA surveys	ML	Torres et al., 2013
polychaetes	*Aphroditidae*		ARSA surveys	GCS	Torres et al., 2013
polychaetes	*Capitellidae sp1*		ARSA surveys	GCS	Torres et al., 2013
polychaetes	*Chloeia venusta*	Quatrefages, 1866	ARSA surveys	GCS	Torres et al., 2013

polychaetes	*Eunice sp.*		ARSA surveys	ML	Torres et al., 2013
polychaetes	*Eunicidae*		ARSA surveys	GCS	Torres et al., 2013
polychaetes	*Eupanthalis sp.*		ARSA surveys	GCS	Torres et al., 2013
polychaetes	*Filogranidae*		ARSA surveys	GCS	Torres et al., 2013
polychaetes	*Glycera unicornis*	Lamarck, 1818	ARSA surveys	GCS	Torres et al., 2013
polychaetes	*Glycera sp.*		ARSA surveys	ML	Torres et al., 2013
polychaetes	*Harmothoe spinifera*	(Ehlers, 1864)	ARSA surveys	GCS	Torres et al., 2013
polychaetes	*Harmothoe spp.*		ARSA surveys	GCS	Torres et al., 2013
polychaetes	*Hermodice sp.*		ARSA surveys	ML	Torres et al., 2013
polychaetes	*Hesionidae*		ARSA surveys	ML	Torres et al., 2013
polychaetes	*Hyalinoecia tubicola*	(O.F. Müller, 1776)	ARSA surveys	ML	Torres et al., 2013
polychaetes	*Laetmonice filicornis*	Kinberg, 1856	ARSA surveys	GCS	Torres et al., 2013
polychaetes	*Leodice torquata*	(Quatrefages, 1866)	ARSA surveys	GCS	Torres et al., 2013
polychaetes	*Nereis sp.*		ARSA surveys	GCS	Torres et al., 2013
polychaetes	*Orbinia sp.*		ARSA surveys	GCS	Torres et al., 2013
polychaetes	*Phyllodoce sp.*		ARSA surveys	GCS	Torres et al., 2013
polychaetes	*Polychaetes indet.*		ARSA surveys	ML	Torres et al., 2013
polychaetes	*Pontobdella muricata*	(Linnaeus, 1758)	ARSA surveys	ML	Torres et al., 2013
polychaetes	*Sabella sp.*		ARSA surveys	ML	Torres et al., 2013
polychaetes	*Sabellidae*		ARSA surveys	ML	Torres et al., 2013
polychaetes	*Salmacina incrustans*	Claparède, 1870	ARSA surveys	GCS	Torres et al., 2013
polychaetes	*Serpulidae*		ARSA surveys	ML	Torres et al., 2013
polychaetes	*Sigalionidae*		ARSA surveys	GCS	Torres et al., 2013
polychaetes	*Spiochaetopterus sp.*		ARSA surveys	GCS	Torres et al., 2013

polychaetes	*Sternaspis scutata*	(Ranzani, 1817)	ARSA surveys	ML	Torres et al., 2013
polychaetes	Tubicola indet.		ARSA surveys	ML	Torres et al., 2013

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ANEXO C

The following supplement accompanies the article

Natural and anthropogenic effects on the early life stages of European anchovy in one of its essential fish habitats, the Guadalquivir estuary

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Supplement

Additional information on datasets and variables as well model outputs and diagnostics.

Supplementary Methods

Regression assumptions: Independence

Some models (eg. water mass I) showed autocorrelation in the residuals. To assess the importance of violating this regression assumption we created five alternative models or sub-models (Figure S1). Each of the models accounted for this problem in a different way: (i) alternative model 1 included 'month' as a temporal factor, (ii) sub-model 2 included the response variable (anchovy abundance) as an explanatory term lagged by one month, (iii) in sub-model 3 the trigonometric functions $\sin(2\pi t/12)$ and $\cos(2\pi t/12)$ were added as covariates, where t is the monthly index (Stenseth et al. 2006), (iv) model 4 used 'month' again, but this time entered with cubic spline basis, and finally (v) model 5 formulation incorporated an autoregressive term in a mixed model framework (GAMM) (Wood 2006, Hefley et al. 2017). All sub-models showed non-correlated residuals (Figure S2) and therefore corrected for the lack of independence. Some of the sub-models (models 1 and 3, for example) did not retained some of the covariates (freshwater discharges and *M. slabberi*) while models 2, 4 and 5 kept practically the same structure. All things considered we can conclude that autocorrelation, when present, does not affect the main results.

Model validation

Overall, model predictions matched well the observed anchovy densities although some extreme values were not efficiently captured (Fig. S11a). However, it is worth noticing that the models captured well the detrimental effects that the events of high and persistent turbidity (*sensu* González-Ortegón et al. 2010) and high freshwater inputs had on the abundance of the early stages of this fish. Predictions for *M. slabberi* also reproduced the observed dynamics fairly well (Fig. S12a). The seasonal cycle was well resolved, particularly for the summer months when their abundances are at their highest (Figs. S11b & S12b).

Figure S1. Sub-models 1-5 partial plots showing the partial effect of each predictor on the response variable. The R-squared (R^2), generalized cross validation (GCV), deviance explained (Dev. Expl.) and the number of observations (*n*) for the model are presented to the right of the plots.

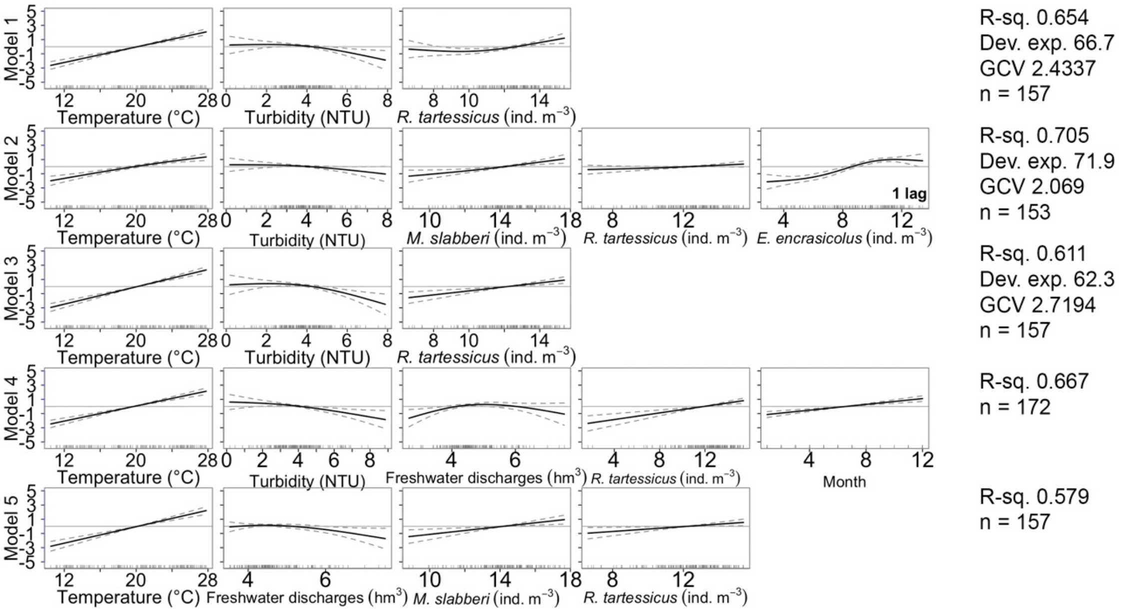
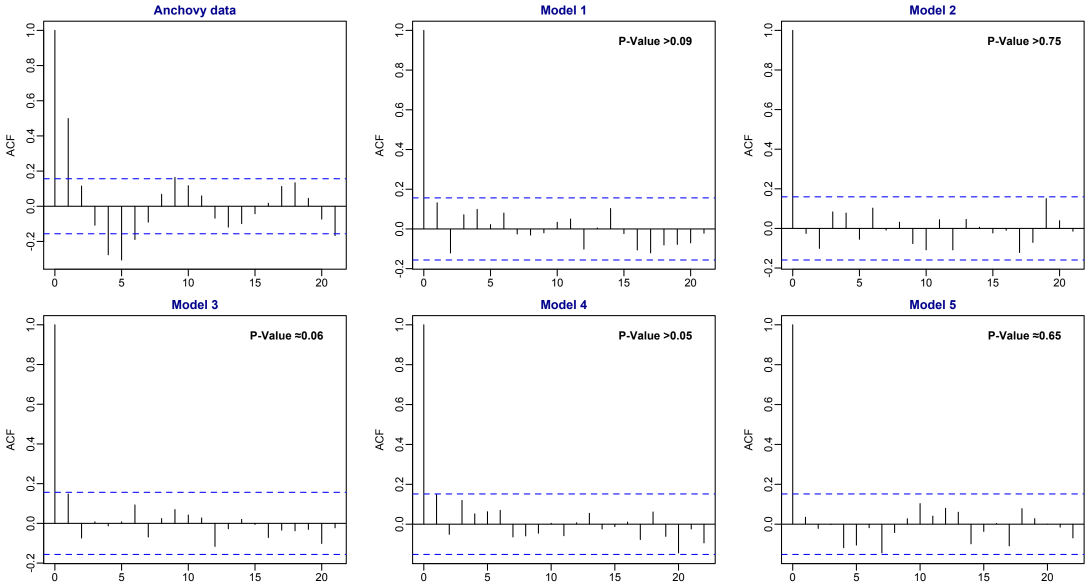


Figure S2. Residual autocorrelation plots corresponding to the five alternative model formulations (Fig. S1a). The first plot shows the structure of the response variable (anchovy density).



Supplementary References

Hefley, TJ, Broms, KM, Brost, BM, Buderman, FE, Kay, SL, Scharf, HR, Tipton, JR, Williams, PJ Hooten, MB (2017) The basis function approach for modeling autocorrelation in ecological data. Ecology 98:632–646

Stenseth NC, Llope M, Anadón R, Ciannelli L, Chan K-S, Hjermann DØ, Bagøien E, Ottersen, G (2006) Seasonal plankton dynamics along a cross-shelf gradient. Proc R Soc Lond B 273:2831–2838

Supplementary Tables

Table S1. List of predictors used in the models: acronyms, definition and source. Long-term Program = Guadalquivir Monitoring program; AEMET = Agencia Española de Metereologia (http://www.aemet.es/es/eltiempo/observacion/ultimosdatos); CHG = Confederación Hidrográfica del Guadalquivir; EBD/CSIC = Estación Biológica de Doñana; NOAA = National Oceanic & Atmospheric Administration.

Monthly Mean North Atlantic Oscillation (NAO) index were obtained from the Climate Prediction Center (NOAA) (http://www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/nao.shtml).

Acronym	**Definition**	**Data source**
Temp	Temperature (˚C)	Long-term Program
Sal	Salinity	Long-term Program
Tur	Turbidity (NTU)	Long-term Program
Vol4, Vol7, Vol15, Vol30	Freshwater discharges (hm^3) at 4, 7, 15 and 30 days prior to sampling day	CHG
P4, P7, P15, P30	Precipitation at 4, 7, 15 and 30 days prior to sampling day	EBD/CSIC
Un4, Un7, Un15, Un30	Average velocity (km) of levanters (4, 7, 15 and 30 prior to sampling day)	AEMET
Up4, Up7, Up15, Up30	Average velocity (km) of westerlies (4, 7, 15 and 30 prior to sampling day)	AEMET
D7PW25, D15PW25, D30PW25, D7PW30, D15PW30, D30PW30	Days per month (7, 15 and 30 prior to sampling day) with winds >25 and 30 km	AEMET
NAO	North Atlantic Oscillation Index	NOAA
AncA	Anchovy abundance (ind. m^{-3})	Long-term Program
Mesop	Mesopodopsys slabberi abundance (ind. m^{-3})	Long-term Program
Neom	*Neomysis integer* abundance (ind. m^{-3})	Long-term Program
Rhop	*Rhopalophthalmus tartessicus* abundance (ind. m^{-3})	Long-term Program

Table S2. Variance-inflation factor (VIF) of the significant covariates in each selected model. Acronyms for the predictors are indicated in Table S1 and for the models are described as follows: I – Water mass I models (Bonanza station at ebb tide); II – water mass II models (Bonanza station at flood tide); III – water mass III models (Tarfía station at ebb tide); IV – water mass IV models (Tarfía station at flood tide).

	Engraulis encrasicolus				***Mesopodopsis slabberi***				***Neomysis integer***				***Rhopalophthalmus tartessicus***			
Predictor	**I**	**II**	**III**	**IV**	**I**	**II**	**III**	**IV**	**I**	**II**	**III**	**IV**	**I**	**II**	**III**	**IV**
Temp	1.36	1.25	1.61	-	1.37	1.75	1.51	1.52	-	-	1.14	1.13	1.12	-	-	-
Sal	-	-	1.66	-	1.86	1.77	1.54	1.27	-	-	1.30	1.12	1.08	1.04	1.41	1.41
Tur	1.04	-	1.23	1.03	1.03	1.10	1.89	-	1.01	1.00	-	-	-	1.01	-	-
Vol4	-	-	-	-	1.75	1.56	1.94	-	-	-	1.17	-	-	-	-	-
Vol7	-	1.06	1.36	-	-	-	-	-	-	-	-	-	-	-	-	-
Vol30	1.03	-	-	-	-	-	-	1.22	1.06	1.01	-	-	-	-	-	-
Un4	-	-	-	1.04	-	-	-	-	-	-	-	-	-	-	-	-
Un7	-	-	-	-	-	-	1.14	-	-	-	-	-	-	-	-	-
Un15	-	-	-	-	-	-	-	1.39	-	-	-	-	-	-	-	-
Up30	-	-	-	-	-	1.34	-	-	-	-	-	-	-	-	-	-
AncA	1.45	1.34	1.23	1.65	-	-	-	-	-	-	-	-	-	-	-	-
AncA1	-	-	-	-	1.19	-	-	-	-	-	-	1.04	-	-	-	-
Mesop	1.21	1.31	1.07	1.64	1.06	1.14	1.08	1.10	-	-	-	-	-	-	-	-
Neom	-	-	-	-	-	-	-	-	1.04	1.00	1.06	1.06	-	-	-	-
Rhop	1.13	1.33	-	-	-	-	-	-	-	-	-	-	1.04	1.05	1.04	1.04

Table S3. Model summary statistics per species and water mass (I-IV). The generalized cross validation (GCV), R-squared (R^2), deviance explained (Dev. Expl.) and number of observations (*n*) are indicated. Model number correspondences (I-IV) are given in Table S2.

Variable Response	**GAMs**	**GCV**	**R2(adj.)**	**Dev. Expl. (%)**	**n**
Engraulis encrasicolus	I	2.8704	0.61	63	172
	II	2.5361	0.61	62.9	162
	III	3.7709	0.7	68.3	140
	IV	4.3227	0.46	50.3	103
Mesopodopsis slabberi	I	2.4691	0.49	52.8	171
	II	2.8172	0.70	71.4	190
	III	4.6138	0.68	70.5	165
	IV	6.1983	0.6	62.1	173
Neomysis integer	I	5.5684	0.2	22.9	100
	II	7.0734	0.18	20.2	140
	III	7.1005	0.09	10.8	177
	IV	6.8478	0.11	14.7	111
Rhopalophthalmus tartessicus	I	5.0627	0.095	11	172
	II	5.9878	0.307	32.4	158
	III	7.2323	0.253	27.1	43
	IV	4.4111	0.14	18.1	27

Table S4. Model results for each predictor. Estimated degrees of freedom (edf), significance value (*p-value*), absolute and partial deviance (relative to total deviance) partitioned per predictor (%) are provided. Model number correspondences (I-IV) are given in Table S2.

RV	GAM	factors	edf	F	P-value	% Absolute Deviance	% Partition Deviance
Engraulis encrasicolus	I	Temperature	1	77.71	<0.001	36	57
		Turbidity	1.209	4.70	0.03	8	13
		Fresh. discharges	2.238	3.57	0.01	2	3
		M. slabberi	1	4.19	0.04	11	17
		R. tartessicus	1	7.99	0.005	6	10
	II	Temperature	2.286	13.33	<0.001	24	38
		Fresh. discharges	2.725	2.94	0.02	7	12
		M. slabberi	1	22.47	<0.001	22	34
		R. tartessicus	1	4.59	0.03	10	16
	III	Temperature	1.120	11.14	<0.001	22	32
		Salinity	2.605	3.18	0.04	10	15
		Turbidity	1	4.38	0.03	4	6
		Fresh. discharges	1.737	5.10	0.005	3	5
		M. slabberi	2.519	9.93	<0.001	29	43
	IV	Turbidity	2.901	5.88	0.01	9	17
		M. slabberi	1.731	25.38	<0.001	33	65
		Levanters	2.801	2.96	0.02	9	18
Mesopodopsis slabberi	I	Temperature	2.18	20.42	<0.001	22	43
		Salinity	2.53	3.64	0.03	10	19
		Turbidity	2.04	4.30	0.01	7	13
		Fresh. discharges	2.48	3.82	0.04	12	23
		E. encrasicolus	1	6.15	0.01	1	2
	II	Temperature	1.66	9.42	<0.001	18	26
		Salinity	1.94	2.39	0.01	11	15
		Turbidity	2.69	14.97	<0.001	21	30
		Fresh. discharges	2.64	4.39	0.003	16	22
		Westerlies	1	8.48	0.004	6	7
	III	Temperature	1	84.61	<0.001	33	46
		Salinity	2.53	5.08	0.002	15	22
		Turbidity	2.03	5.88	0.002	8	11
		Fresh. discharges	2.50	4.74	0.004	10	14
		Levanters	1	8.93	0.003	5	7
	IV	Temperature	1	96.43	<0.001	34	54
		Salinity	1.56	4.69	0.009	11	18
		Fresh. discharges	2.73	6.20	<0.001	8	13
		Levanters	1	4.90	0.02	9	15

Neomysis integer	I	Turbidity	2.06	3.83	0.01	13	57
		Fresh. discharges	1	7.86	0.006	10	43
	II	Turbidity	1.85	5.03	0.05	5	24
		Fresh. discharges	1	12.98	0.004	15	76
	III	Temperature	1	18.69	<0.001	7	62
		Salinity	1	12.00	<0.001	3	28
		Fresh. discharges	1	5.41	0.02	1	9
	IV	Temperature	1.36	6.94	0.008	5	35
		Salinity	1.41	3.14	0.03	4	26
		E. encrasicolus	1	10.86	0.001	6	39
Rhopalophthalmus tartessicus	I	Temperature	1	9.48	0.002	6	53
		Salinity	2.26	2.97	0.04	5	47
	II	Salinity	2.31	14.83	<0.001	22	55
		Turbidity	1.95	10.84	<0.001	18	45
	III	Salinity	1	15.21	<0.001	27	100
	IV	Salinity	1	5.52	0.02	18	100

Table S5. Reference points were calculated based on the effects that turbidity and freshwater discharges had on the abundance of anchovy and *M. slabberi* (Fig. 3b,c,g,l,m,o and Fig. 4c,d,h,i,m,n,r, respectively). The coloured scaled and correspondence between raw vs. logged values is given as follows (approximate values):

	turbidity	log(turbidity)	freshwater	log(freshwater)
	NTU	NTU	hm^3	hm^3
red	>500	>6.2	>1000	>6.9
orange	>300 & <=500	>5.7 & <=6.2	>500 & <=1000	>6.2 & <=6.9
yellow	>150 & <=300	>5.0 & <=5.7	>150 & <=500	6.2> & <=5.0
green	>0 & <=150	>0 & <=5.0	>0 & <=150	>0 & <=5.0

Supplementary Figures

Figure S3. Correlation Matrix of covariates at water mass I. The colour scale indicates Pearson correlation values.

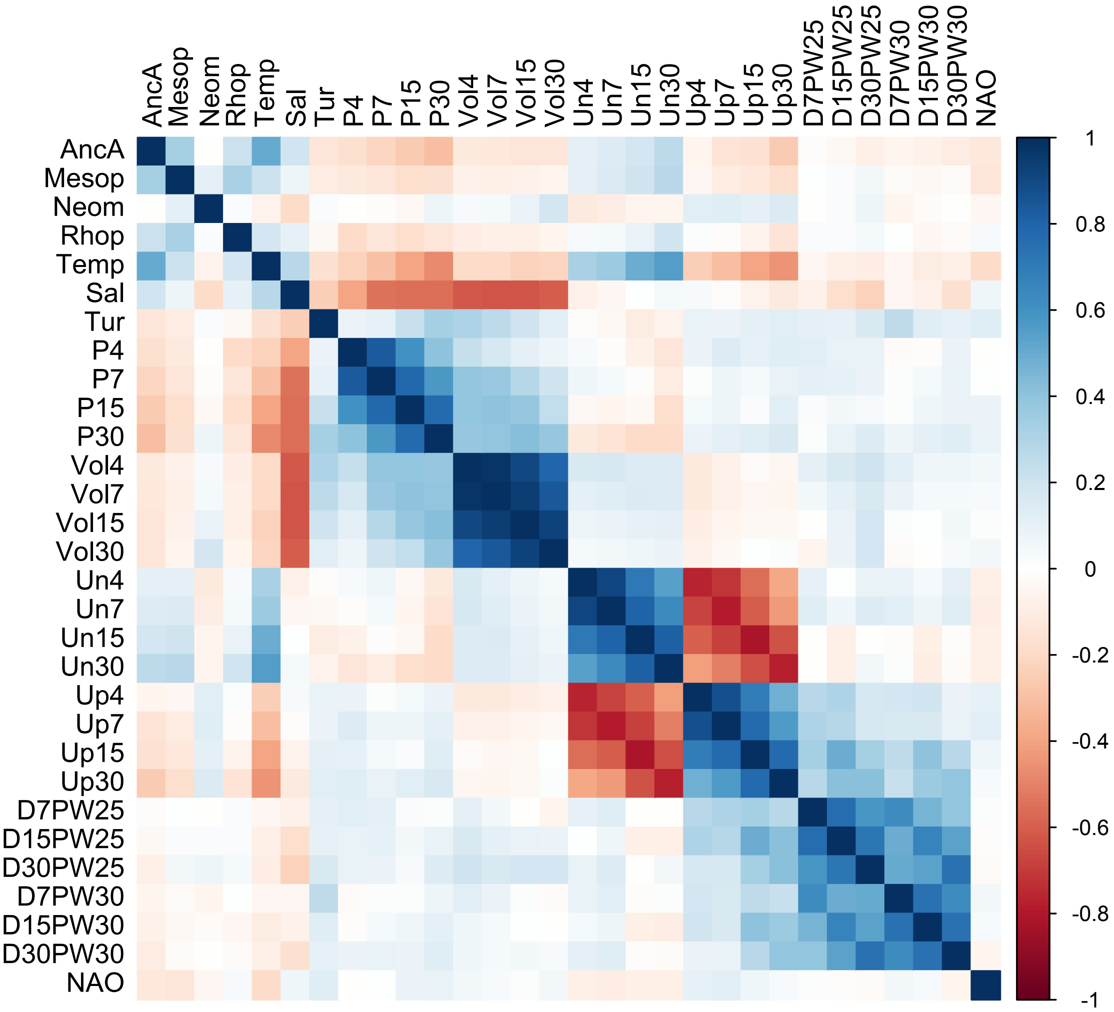


Figure S4. Correlation Matrix of covariates at water mass II. The colour scale indicates Pearson correlation values.

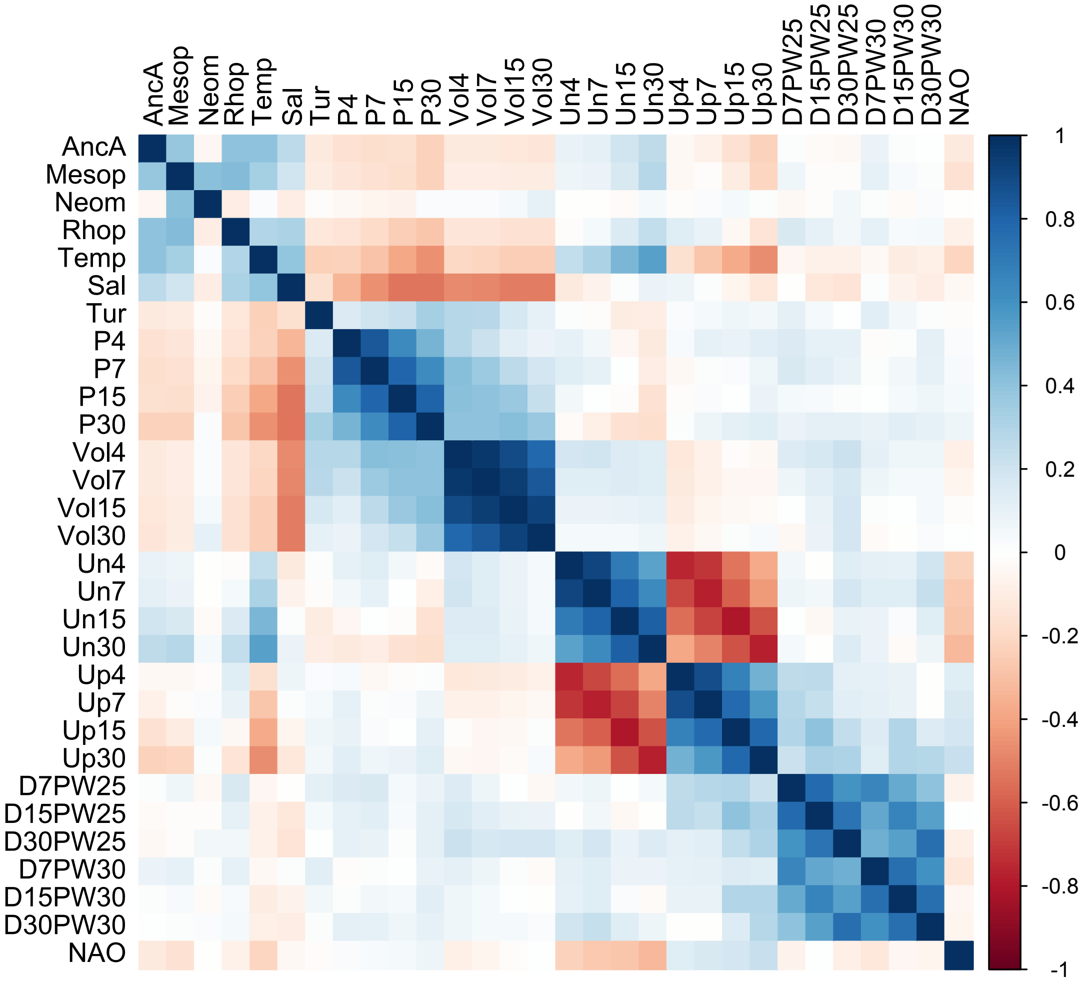


Figure S5 - Correlation Matrix of covariates at water mass III. The color scale indicates Pearson correlation values.

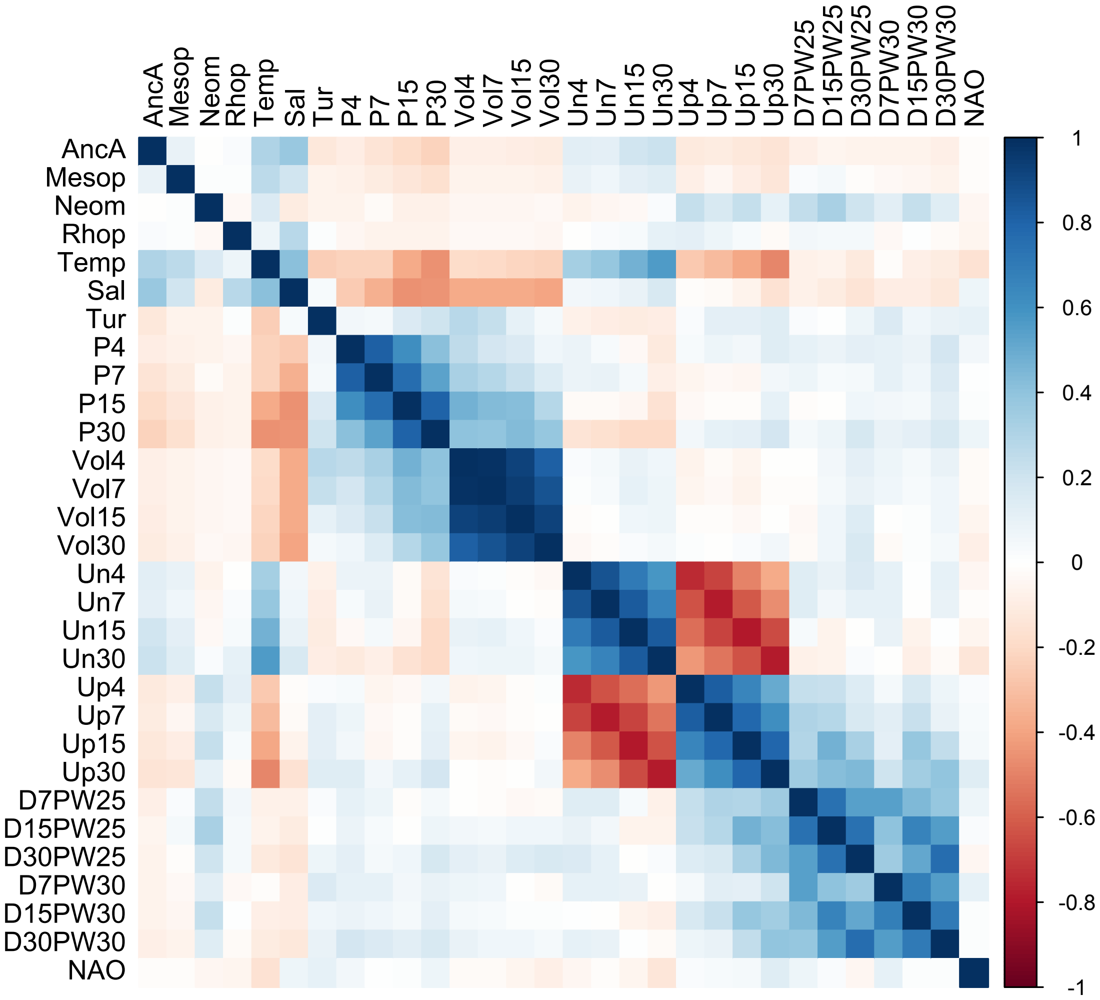


Figure S6 - Correlation Matrix of covariates at water mass IV. The colour scale indicates Pearson correlation values.

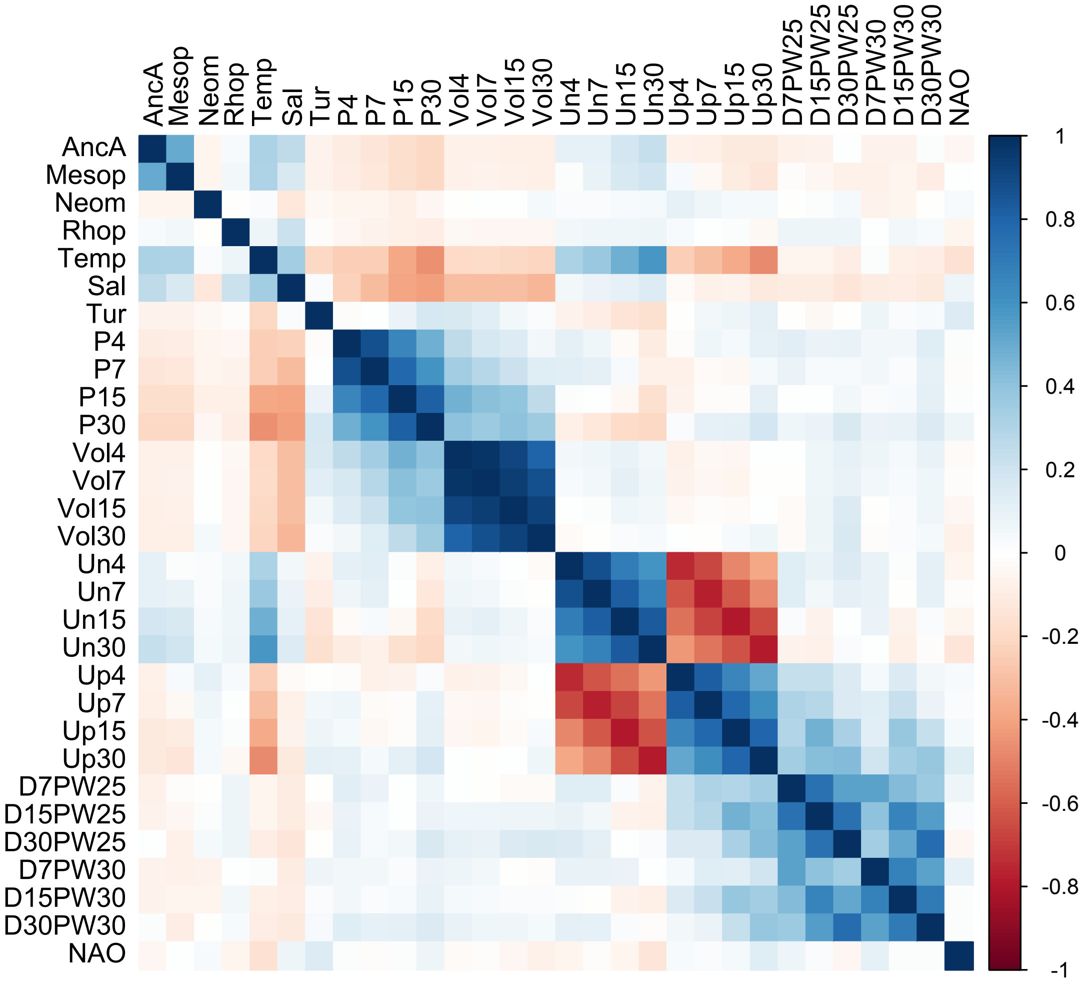


Figure S7. Residuals. The graphs are structured as follows: rows correspond to each of the anchovy individual models. First column shows the autocorrelation within the residuals (correlations are not significant if they lie within the dashed blue lines). Second column assesses homoscedasticity. Third and fourth columns evaluate normality.

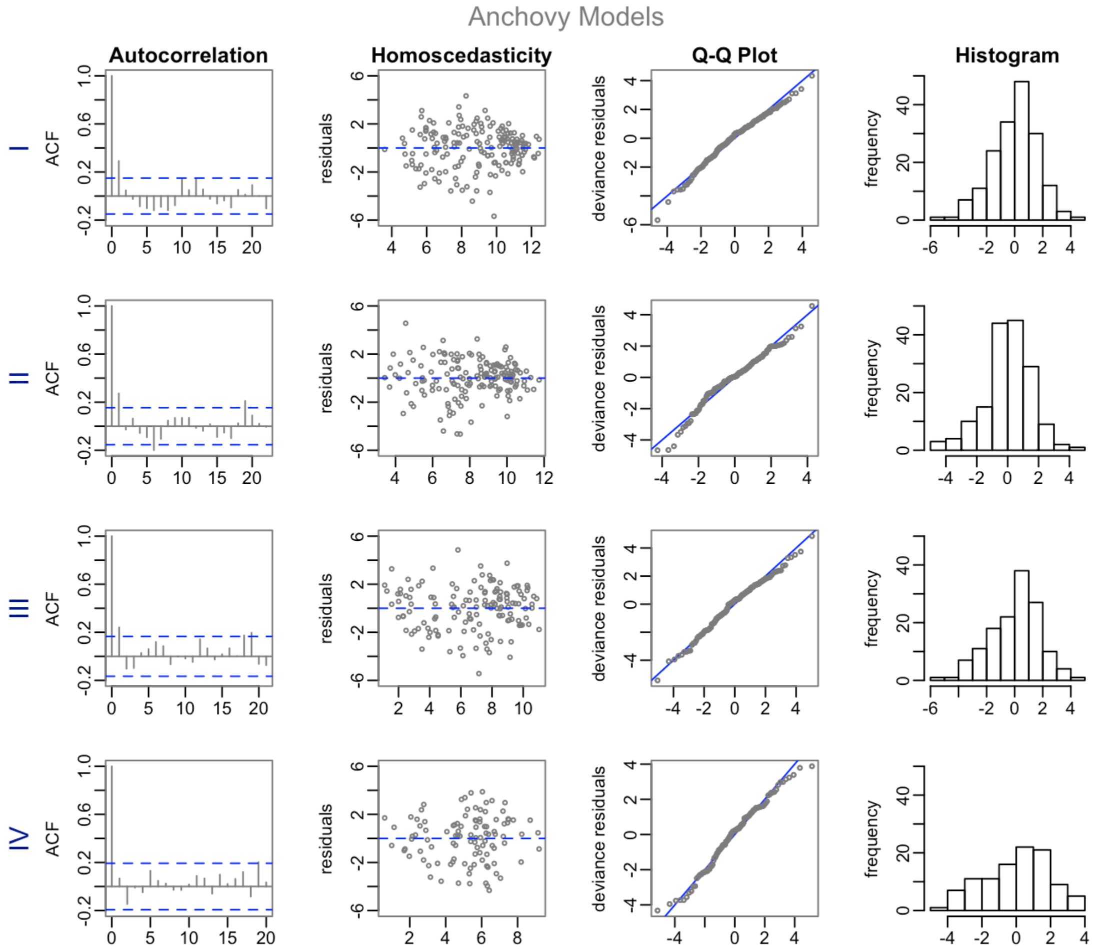


Figure S8. Residuals. The graphs are structured as follows: rows correspond to each of the *M. slabberi* individual models. First column shows the autocorrelation within the residuals (correlations are not significant if they lie within the dashed blue lines). Second column assesses homoscedasticity. Third and fourth columns evaluate normality.

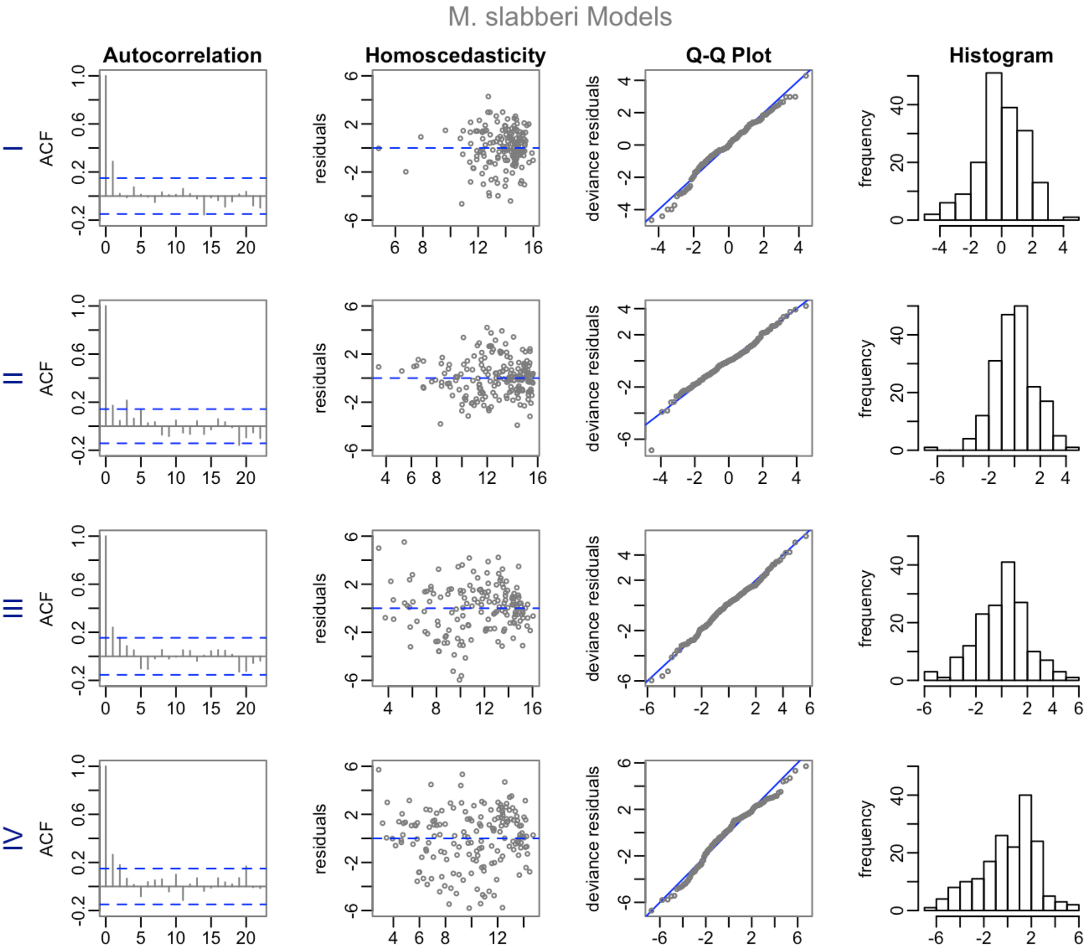


Figure S9. Residuals. The graphs are structured as follows: rows correspond to each of the *N. integer* individual models. First column shows the autocorrelation within the residuals (correlations are not significant if they lie within the dashed blue lines). Second column assesses homoscedasticity. Third and fourth columns evaluate normality.

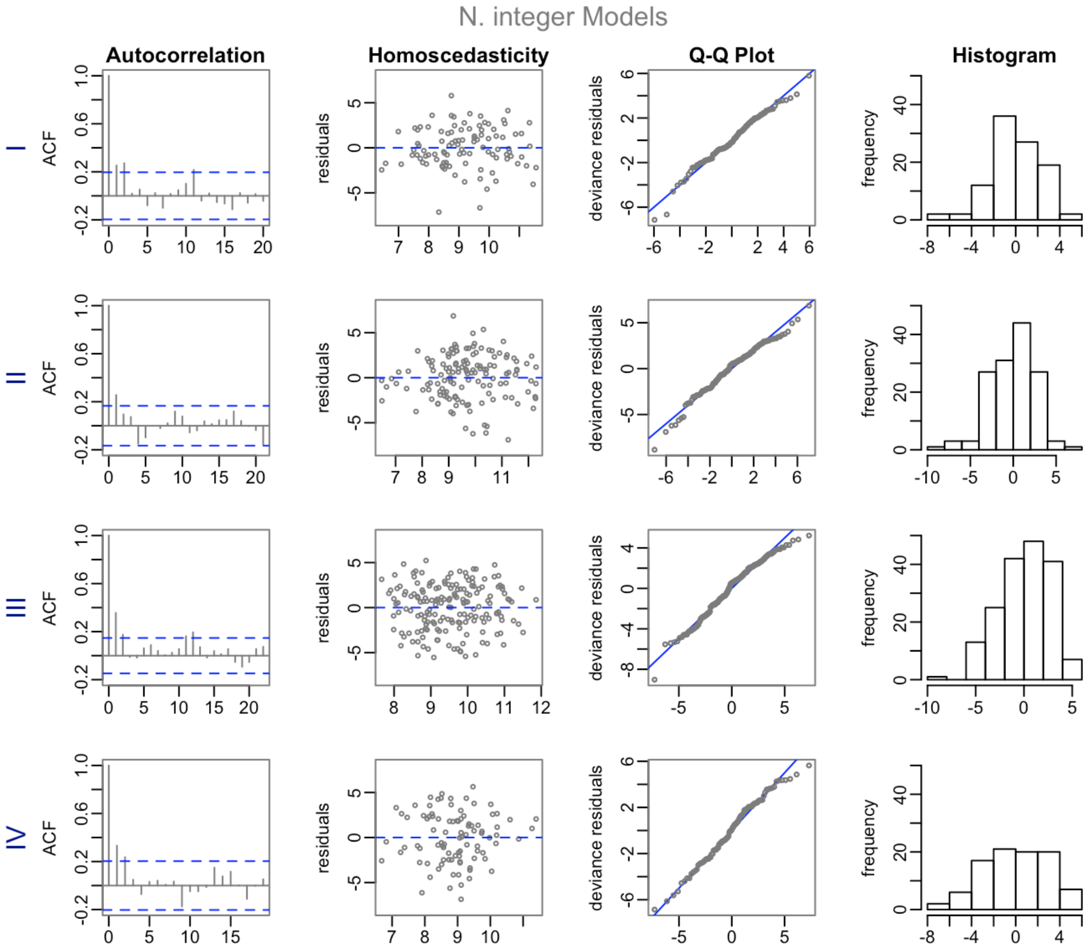


Figure S10. Residuals. The graphs are structured as follows: rows correspond to each of the *R. tartessicus* individual models. First column shows the autocorrelation within the residuals (correlations are not significant if they lie within the dashed blue lines). Second column assesses homoscedasticity. Third and fourth columns evaluate normality.

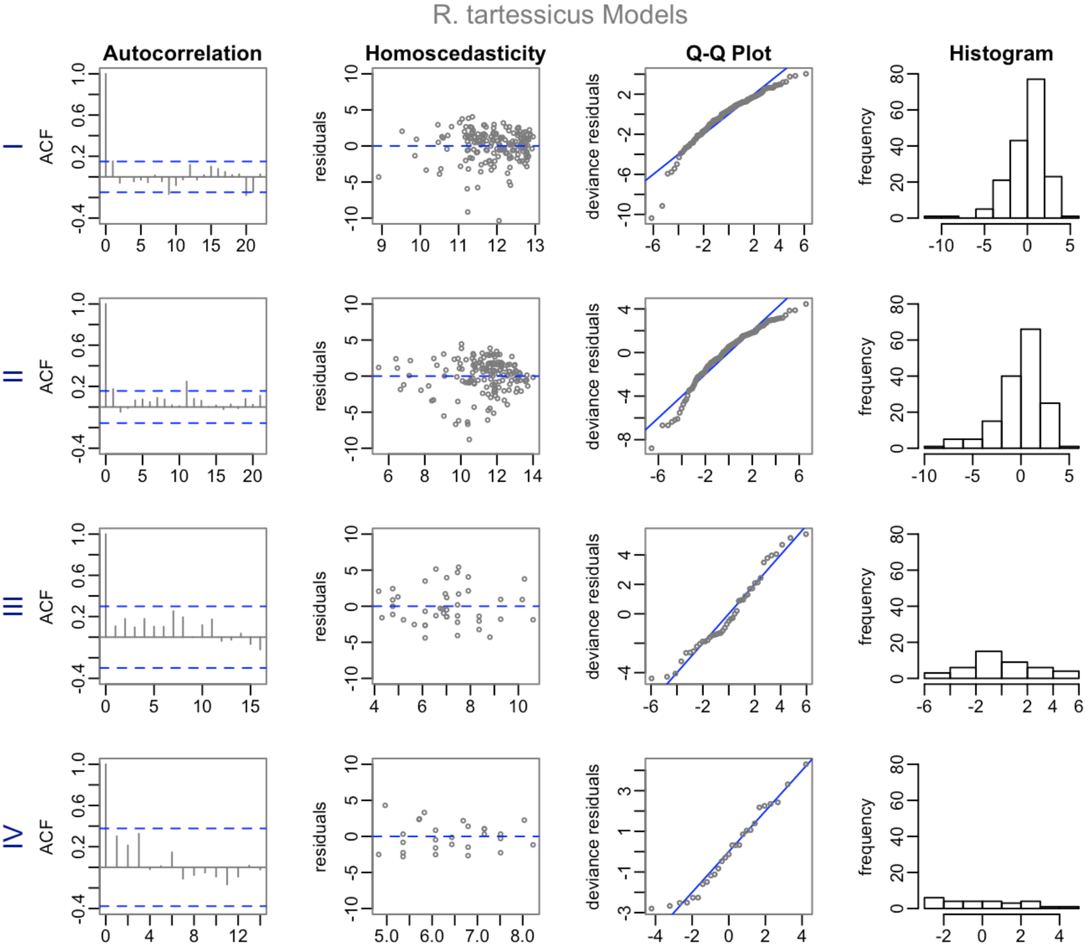


Figure S11. Time series of anchovy abundance: (a) month-to-month and (b) seasonal cycle for the four water masses. Black and red lines represent observations and predictions, respectively. Blue stripes shows the occurrence of high freshwater discharges [>20 and >400 hm^3 (7 and 30 days, respectively) depending on water mass] and grey shading those of high turbidity (>100 and >550 NTU, respectively). Pearson's correlations are presented in the upper left corner. Correlations with a $p < 0.05$ are indicated *, $p < 0.01$**, $p < 0.001$***.

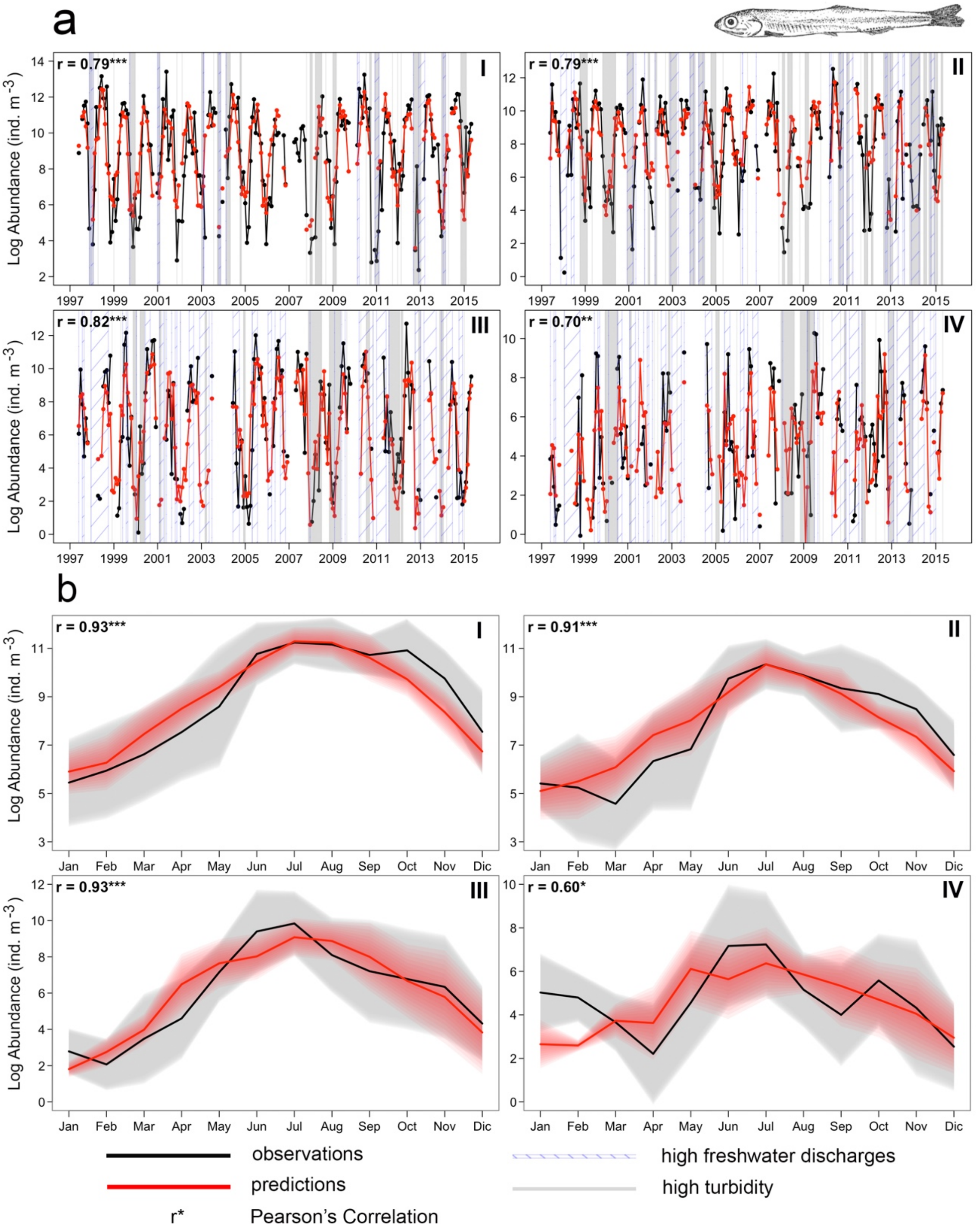
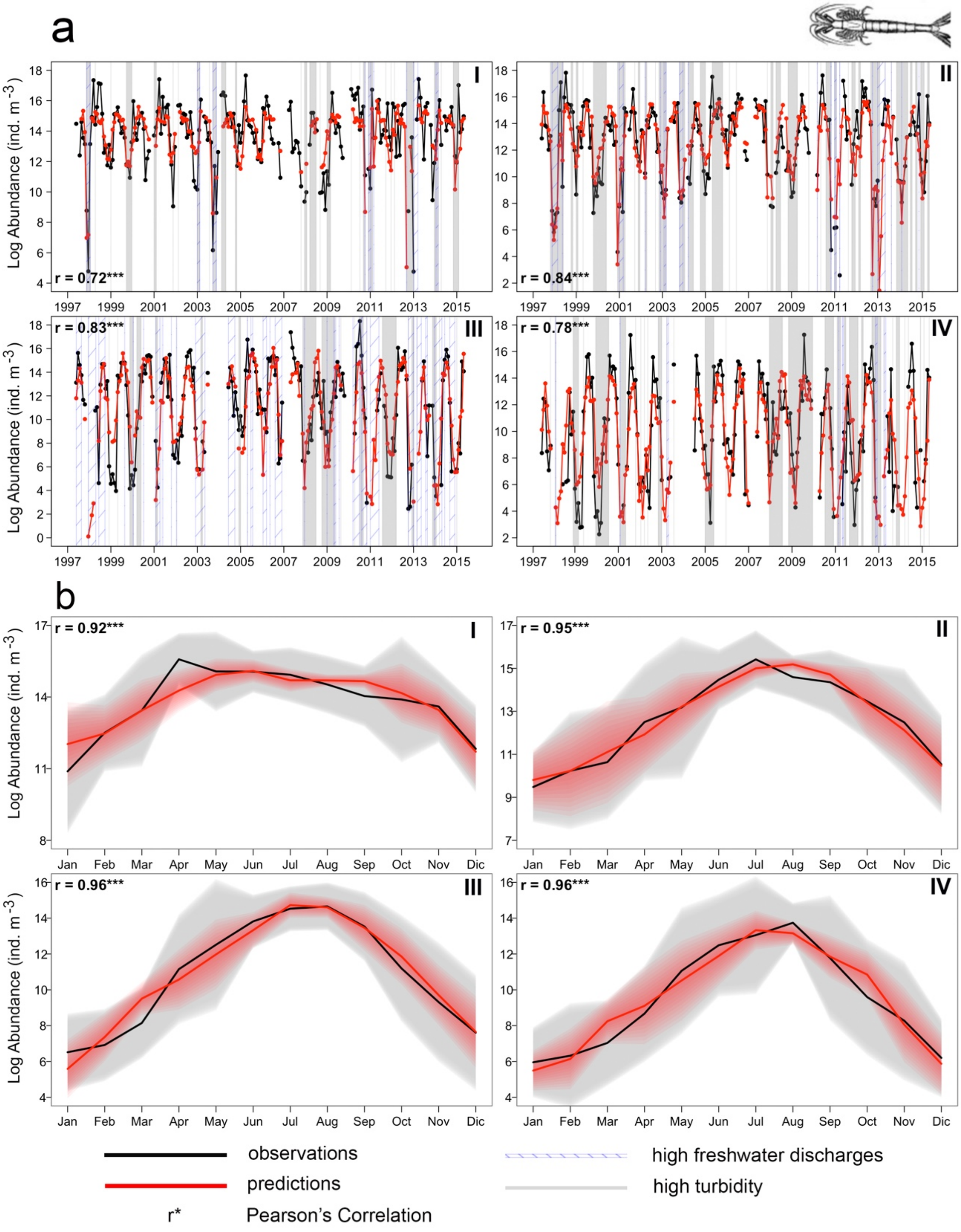


Figure S12. Time series of *M. slabberi* abundance: (a) month-to-month and (b) seasonal cycle for the four water masses. Black and red lines represent observations and predictions, respectively. Blue stripes shows the occurrence of high freshwater discharges [>1.5 and >2.5 hm^3 (4 days, respectively) depending on water mass] and grey shading those of high turbidity (>100 and >250 NTU, respectively). Pearson's correlations are presented in the upper left corner.



ANEXO D

Supplementary Information for

Gulf of Cadiz zooplankton: zonation, community structure and temporal variation

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Table S1. Number of samples per station (see also map in Fig. 1). Sampling dates (dd/mm/yyyy) and projects (GOLFO, FLUCTUACIONES or STOCA) are indicated.

			date	
Transect	**n**	**St.**	**dd/mm/yyyy**	**Survey**
T1 | Guadiana	1	1.1	22/03/2002	GOLFO
	2	1.1	10/08/2002	GOLFO
	3	1.1	09/11/2002	GOLFO
	4	1.1	10/03/2003	GOLFO
	5	1.1	09/08/2003	GOLFO
	6	1.1	07/11/2003	GOLFO
	7	1.1	18/03/2004	GOLFO
	8	1.1	11/08/2004	GOLFO
	9	1.1	29/07/2005	FLUCTUACIONES
	10	1.1	16/11/2005	FLUCTUACIONES
	11	1.1	16/03/2006	FLUCTUACIONES
	12	1.1	03/08/2006	FLUCTUACIONES
	13	1.1	09/11/2006	FLUCTUACIONES
	14	1.1	08/03/2007	FLUCTUACIONES
	1	1.2	29/07/2005	FLUCTUACIONES
	2	1.2	16/11/2005	FLUCTUACIONES
	3	1.2	16/03/2006	FLUCTUACIONES
	4	1.2	03/08/2006	FLUCTUACIONES
	5	1.2	09/11/2006	FLUCTUACIONES
	6	1.2	08/03/2007	FLUCTUACIONES
T2 | Tinto-Odiel	1	2.1	22/03/2002	GOLFO
	2	2.1	10/08/2002	GOLFO
	3	2.1	09/11/2002	GOLFO
	4	2.1	10/03/2003	GOLFO
	5	2.1	09/08/2003	GOLFO
	6	2.1	07/11/2003	GOLFO
	7	2.1	18/03/2004	GOLFO
	8	2.1	11/08/2004	GOLFO
	9	2.1	29/07/2005	FLUCTUACIONES
	10	2.1	15/11/2005	FLUCTUACIONES
	11	2.1	16/03/2006	FLUCTUACIONES
	12	2.1	03/08/2006	FLUCTUACIONES
	13	2.1	09/11/2006	FLUCTUACIONES
	14	2.1	08/03/2007	FLUCTUACIONES
	1	2.2	09/11/2002	GOLFO
	2	2.2	29/07/2005	FLUCTUACIONES
	3	2.2	16/11/2005	FLUCTUACIONES
	4	2.2	16/03/2006	FLUCTUACIONES
	5	2.2	03/08/2006	FLUCTUACIONES
	6	2.2	09/11/2006	FLUCTUACIONES
	7	2.2	08/03/2007	FLUCTUACIONES

T3 | Guadalquivir	1	3.1	03/12/2001	GOLFO
	2	3.1	22/03/2002	GOLFO
	3	3.1	10/08/2002	GOLFO
	4	3.1	09/11/2002	GOLFO
	5	3.1	10/03/2003	GOLFO
	6	3.1	09/08/2003	GOLFO
	7	3.1	07/11/2003	GOLFO
	8	3.1	18/03/2004	GOLFO
	9	3.1	11/08/2004	GOLFO
	10	3.1	27/07/2005	FLUCTUACIONES
	11	3.1	15/11/2005	FLUCTUACIONES
	12	3.1	15/03/2006	FLUCTUACIONES
	13	3.1	02/08/2006	FLUCTUACIONES
	14	3.1	08/11/2006	FLUCTUACIONES
	15	3.1	07/03/2007	FLUCTUACIONES
	16	3.1	18/07/2007	FLUCTUACIONES
	1	3.2	03/12/2001	GOLFO
	2	3.2	22/03/2002	GOLFO
	3	3.2	10/08/2002	GOLFO
	4	3.2	09/11/2002	GOLFO
	5	3.2	10/03/2003	GOLFO
	6	3.2	09/08/2003	GOLFO
	7	3.2	07/11/2003	GOLFO
	8	3.2	18/03/2004	GOLFO
	9	3.2	11/08/2004	GOLFO
	10	3.2	27/07/2005	FLUCTUACIONES
	11	3.2	15/11/2005	FLUCTUACIONES
	12	3.2	15/03/2006	FLUCTUACIONES
	13	3.2	02/08/2006	FLUCTUACIONES
	14	3.2	08/11/2006	FLUCTUACIONES
	15	3.2	07/03/2007	FLUCTUACIONES
	16	3.2	18/07/2007	FLUCTUACIONES
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	23	3.2	21/11/2011	STOCA
	24	3.2	29/03/2012	STOCA
	25	3.2	05/08/2012	STOCA
	26	3.2	29/10/2012	STOCA
	27	3.2	13/03/2013	STOCA
	28	3.2	11/06/2013	STOCA
	29	3.2	28/09/2013	STOCA
	30	3.2	28/03/2014	STOCA
	31	3.2	25/06/2014	STOCA
	32	3.2	01/10/2014	STOCA

	33	3.2	28/03/2015	STOCA
	34	3.2	19/06/2015	STOCA
	1	3.3	03/12/2001	GOLFO
	2	3.3	22/03/2002	GOLFO
	3	3.3	10/08/2002	GOLFO
	4	3.3	09/11/2002	GOLFO
	5	3.3	10/03/2003	GOLFO
	6	3.3	09/08/2003	GOLFO
	7	3.3	07/11/2003	GOLFO
	8	3.3	18/03/2004	GOLFO
	9	3.3	11/08/2004	GOLFO
	10	3.3	27/07/2005	FLUCTUACIONES
	11	3.3	15/11/2005	FLUCTUACIONES
	12	3.3	15/03/2006	FLUCTUACIONES
	13	3.3	02/08/2006	FLUCTUACIONES
	14	3.3	08/11/2006	FLUCTUACIONES
	15	3.3	07/03/2007	FLUCTUACIONES
	16	3.3	18/07/2007	FLUCTUACIONES
	17	3.3	07/07/2009	STOCA
	18	3.3	10/11/2009	STOCA
	19	3.3	04/03/2010	STOCA
	20	3.3	26/07/2010	STOCA
	21	3.3	06/11/2010	STOCA
	22	3.3	09/03/2011	STOCA
	23	3.3	03/08/2011	STOCA
	24	3.3	21/11/2011	STOCA
	25	3.3	29/03/2012	STOCA
	26	3.3	05/08/2012	STOCA
	27	3.3	29/10/2012	STOCA
	28	3.3	13/03/2013	STOCA
	29	3.3	11/06/2013	STOCA
	30	3.3	28/09/2013	STOCA
	31	3.3	28/03/2014	STOCA
	32	3.3	25/06/2014	STOCA
	33	3.3	01/10/2014	STOCA
	34	3.3	28/03/2015	STOCA
	35	3.3	19/06/2015	STOCA
T4 | Sancti Petri	1	4.1	27/07/2005	FLUCTUACIONES
	2	4.1	15/11/2005	FLUCTUACIONES
	3	4.1	15/03/2006	FLUCTUACIONES
	4	4.1	02/08/2006	FLUCTUACIONES
	5	4.1	08/11/2006	FLUCTUACIONES
	6	4.1	06/03/2007	FLUCTUACIONES
	1	4.2	27/07/2005	FLUCTUACIONES
	2	4.2	15/11/2005	FLUCTUACIONES
	3	4.2	15/03/2006	FLUCTUACIONES
	4	4.2	02/08/2006	FLUCTUACIONES

	5	4.2	08/11/2006	FLUCTUACIONES
T5 | Trafalgar	1	5.1	26/07/2005	FLUCTUACIONES
	2	5.1	14/11/2005	FLUCTUACIONES
	3	5.1	14/03/2006	FLUCTUACIONES
	4	5.1	01/08/2006	FLUCTUACIONES
	5	5.1	07/11/2006	FLUCTUACIONES
	6	5.1	06/06/2007	FLUCTUACIONES
	7	5.1	29/03/2012	STOCA
	8	5.1	05/08/2012	STOCA
	9	5.1	29/10/2012	STOCA
	10	5.1	13/03/2013	STOCA
	11	5.1	11/06/2013	STOCA
	12	5.1	28/09/2013	STOCA
	13	5.1	28/03/2014	STOCA
	14	5.1	25/06/2014	STOCA
	15	5.1	01/10/2014	STOCA
	16	5.1	28/03/2015	STOCA
	17	5.1	19/06/2015	STOCA
	1	5.2	26/07/2005	FLUCTUACIONES
	2	5.2	14/11/2005	FLUCTUACIONES
	3	5.2	01/08/2006	FLUCTUACIONES
	4	5.2	07/11/2006	FLUCTUACIONES
	5	5.2	06/03/2007	FLUCTUACIONES
	6	5.2	29/03/2012	STOCA
	7	5.2	05/08/2012	STOCA
	8	5.2	29/10/2012	STOCA
	9	5.2	13/03/2013	STOCA
	10	5.2	11/06/2013	STOCA
	11	5.2	28/09/2013	STOCA
	12	5.2	28/03/2014	STOCA
	13	5.2	25/06/2014	STOCA
	14	5.2	01/10/2014	STOCA
	15	5.2	28/03/2015	STOCA

Table S2. Taxonomy, lifestyle (Holoplankton - H; Meroplankton - M), diet preferences (Carnivores - Car; Herbivores - Her; Omnivores - Omn), distribution per site (Mouth station; Coastal stations - Cst; Oceanic stations - Ost; All sites - All), transects (Guadiana - T1; Tinto-Odiel - T2; Guadalquivir - T3; Sancti Petri - T4; Trafalgar - T5; All transects - All) and season (Autumn - A; Summer - S; Winter - Win; A) for all taxa found between 2001 and 2015 in the Gulf of Cadiz.

Taxonomic Group	Family	Taxa	Author,Year	Lifestyle	Diet preferences	Station	Tran	Season
Chaetognatha		Chaetognatha		H	Car	All	All	All
	Sagittidae	Sagitta sp.		H	Car	All	T3	All
Cladocera		Cladocera		H	Her	Cst	T2,T4	S
	Podonidae	*Evadne nordmanni*	Lovén, 1836	H	Her	All	T1,T2, T3,T5	All
	Podonidae	*Evadne* sp.		H	Her	Ost	T3	S
	Podonidae	*Evadne spinifera*	P.E.Müller, 1867	H	Her	Cst, Ost	All	All
	Sididae	*Penilia avirostris*	Dana, 1849	H	Her	All	All	All
	Podonidae	*Pleopis polyphemoides*	(Leuckart, 1859)	H	Her	All	T1,T2, T3,T4	All
	Podonidae	*Podon intermedius*	Lilljeborg, 1853	H	Her	Cst, Ost	All	All
	Podonidae	*Podon leuckartii*	(Sars G.O., 1862)	H	Her	Cst, Ost	T3	W, S
	Podonidae	*Pseudevadne tergestina*	(Claus, 1877)	H	Her	All	All	All
Cnidaria		Cnidaria		M		Cst, Ost	T3	All
		Hydromedusae		H	Car	Cst, Ost	All	All
	Campanulariidae	*Obelia* sp.		H	Car	Cst	T1	A
Copepoda	Acartiidae	*Acartia (Acanthacartia) bifilosa*	(Giesbrecht, 1881)	H	Omn	Cst	T3	W
	Acartiidae	*Acartia (Acanthacartia) tonsa*	Dana, 1849	H	Omn	Cst	T1,T3	W
	Acartiidae	*Acartia (Acartia) danae*	Giesbrecht, 1889	H	Omn	Cst, Ost	All	S, A
	Acartiidae	*Acartia (Acartiura) clausi*	Giesbrecht, 1889	H	Omn	All	All	All
	Acartiidae	*Acartia (Acartiura) margalefi*	Alcaraz, 1976	H	Omn	Mst	T3	A, W
	Acartiidae	*Acartia* sp.		H	Omn	All	T3,T5	All
	Aetideidae	*Aetideus armatus*	(Boeck, 1872)	H	Omn	Cst	T5	A
	Corycaeidae	*Agetus flaccus*	(Giesbrecht, 1891)	H	Car	Ost	T1,T2, T5	A
	Corycaeidae	*Agetus* sp.		H	Car	Cst, Ost	T2,T3, T5	A, W
	Augaptilidae	*Augaptilus* sp.		H	Car	Ost	T3	W
	Megacalanidae	*Bradycalanus typicus*	Scott A., 1909	H	Car	Ost	T3	W
		Calanidae		H		Mst, Ost	T1,T3	A, W
	Pseudodiaptomidae	*Calanipeda aquaedulcis*	Krichagin, 1873	H	Omn	Cst	T1	A

	Calanoida		H		Cst, Ost	T1,T2, T3,T5	All
Calanidae	*Calanoides natalis*	(Brady, 1914)	H	Omn	Ost	T3,T5	All
Calanidae	*Calanus helgolandicus*	(Claus, 1863)	H	Her	Cst, Ost	T1,T3, T4,T5	All
Calanidae	*Calanus* sp.		H	Her	All	T3	W, S
Paracalanidae	*Calocalanus* spp.		H	Her	Cst, Ost	All	All
Candaciidae	*Candacia armata*	Boeck, 1872	H	Car	All	T3,T5	A, W
Candaciidae	*Candacia simplex*	(Giesbrecht, 1889)	H	Car	Ost	T5	A
Centropagidae	*Centropages brachiatus*	(Dana, 1849)	H	Omn	Ost	T3	A
Centropagidae	*Centropages chierchiae*	Giesbrecht, 1889	H	Omn	Cst, Ost	All	All
Centropagidae	*Centropages hamatus*	(Lilljeborg, 1853)	H	Omn	Cst	T3	W
Centropagidae	*Centropages kroyeri*	Giesbrecht, 1893	H	Omn	Mst, Cst	T3,T4	All
Centropagidae	*Centropages ponticus*	Karavaev, 1895	H	Omn	All	T1,T2, T3,T4	All
Centropagidae	*Centropages* sp.		H	Omn	Mst, Cst	T3,T4	A, W
Centropagidae	*Centropages typicus*	Krøyer, 1849	H	Omn	Cst, Ost	T3	W, S
Clausocalanidae	*Clausocalanus* spp.		H	Omn	Cst, Ost	All	All
Peltidiidae	*Clytemnestra gracilis*	(Claus, 1891)	H	Omn	Ost	T3	S
	Copepoda		H		Cst	T2	S
	Copepoda nauplius		H		Cst, Ost	All	All
	Copepodites		H		All	All	All
Corycaeidae	*Corycaeus* spp.		H	Car	All	T1,T2, T3,T5	All
Clausocalanidae	*Ctenocalanus vanus*	Giesbrecht, 1888	H	Her	Cst, Ost	All	All
Cyclopidae	Cyclopinae		H		Cst	T1	W
	Cyclopoida		H		Cst	T1,T3	A
Diaixidae	*Diaixis pygmaea*	(Scott T., 1894)	H	Omn	Cst, Ost	T3,T4, T5	All
Corycaeidae	*Ditrichocorycaeus* spp.		H	Car	Cst, Ost	All	All
Euchaetidae	*Euchaeta* sp.		H	Car	Ost	T3	A
Euchaetidae	*Euchaeta spinosa*	Giesbrecht, 1893	H	Car	Cst	T1	W
Euterpinidae	*Euterpina acutifrons*	(Dana, 1847)	H	Her	All	All	All
Corycaeidae	*Farranula* sp.		H	Car	All	T1,T2, T3,T5	All
Clytemnestridae	*Goniopsyllus clausi*	Huys & Conroy-Dalton, 2000	H	Omn	Cst, Ost	T2,T3, T4,T5	All
	Halyciclopinae		H		Cst	T1	W
	Harpacticoida		H	Omn	Cst, Ost	T1,T2, T3,T5	All
Heterorhabdidae	*Heterorhabdus* sp.		H	Car	Ost	T3	A
Centropagidae	*Isias clavipes*	Boeck, 1865	H	Her	Cst	T1	A
Pontellidae	*Labidocera wollastoni*	(Lubbock, 1857)	H	Car	All	T1,T3, T5	All
Lucicutiidae	*Lucicutia* sp.		H	Omn	Ost	T3	A
Paracalanidae	*Mecynocera clausi*	Thompson I.C., 1888	H	Her	Cst, Ost	All	All

	Clausocalanidae	*Microcalanus pygmaeus*	(Sars G.O., 1900)	H	Omn	Ost	T1,T3, T5	All
	Ectinosomatidae	*Microsetella rosea*	(Dana, 1847)	H	Omn	Ost	T3	S, A
	Monstrillidae	*Monstrilla* sp.		H		Cst	T5	A
	Calanidae	*Nannocalanus minor*	(Claus, 1863)	H	Car	Cst, Ost	T2,T4, T5	A
	Calanidae	*Neocalanus gracilis*	(Dana, 1852)	H	Car	Ost	T5	A
	Oithonidae	*Oithona* spp.		H	Omn	All	All	All
	Oncaeidae	*Oncaea* spp.		H	Omn	All	All	All
	Corycaeidae	*Onychocorycaeus* sp.		H	Car	Cst, Ost	All	S, A
	Paracalanidae	*Paracalanus* spp.		H	Omn	All	All	All
	Acartiidae	*Paracartia grani*	Sars G.O., 1904	H	Omn	All	T1,T2, T3,T4	All
	Euchaetidae	*Paraeuchaeta* sp.		H	Car	Ost	T3	W
	Metridinidae	*Pleuromamma gracilis*	Claus, 1863	H	Omn	Ost	T1,T5	S, A
	Pontellidae	*Pontella mediterranea*	(Claus, 1863)	H	Car	Mst, Cst	T3	S
	Pseudocyclopidae	*Pseudocyclops obtusatus*	Brady & Robertson D., 1873	H	Her	Cst	T5	A
	Scolecitrichidae	*Scaphocalanus curtus*	(Farran, 1926)	H	Omn	Cst	T5	W
	Scolecitrichidae	*Scolecithrix danae*	(Lubbock, 1856)	H	Her	Ost	T4	S
	Eucalanidae	*Subeucalanus* sp.		H	Her	Ost	T3	W
	Temoridae	*Temora longicornis*	(Müller O.F., 1785)	H	Omn	Cst, Ost	T3,T5	All
	Temoridae	*Temora stylifera*	(Dana, 1849)	H	Omn	All	All	All
	Oncaeidae	*Triconia* sp.		H	Omn	Ost	T2,T4, T5	A, W
	Corycaeidae	*Urocorycaeus* sp.		H	Car	Ost	T3	A
	Sapphirinidae	*Vettoria granulosa*	(Giesbrecht, 1891)	H	Omn	Ost	T5	A
Crustacea	Mysidae	*Acanthomysis longicornis*	(Milne Edwards, 1837)	H	Omn	Cst	T1,T4	A, W
		Amphipoda		H	Her	Cst, Ost	T1,T2, T3,T5	A, W
	Mysidae	*Anchialina agilis*	(G.O. Sars, 1877)	H	Omn	Cst, Ost	T3,T4, T5	All
		Cirripedia larvae		M	Her	All	All	All
		Crustacea larvae		M		Cst, Ost	T3	S, A
		Cypris larva		M		Cst, Ost	All	All
		Decapoda larvae		M	Car	All	T1,T3	All
	Mysidae	*Erythrops elegans*	(G.O. Sars, 1863)	H	Omn	Ost	T3	S
		Euphausiacea larvae		M		Cst, Ost	T2,T3, T5	All
	Mysidae	*Gastrosaccus sanctus*	(Van Beneden, 1861)	H	Omn	Cst	T1,T4, T5	A, W
	Mysidae	Gastrosaccus sp.		H	Omn	Cst	T1,T4	A, W
	Mysidae	*Haplostylus lobatus*	(Nouvel, 1951)	H	Omn	Cst	T1,T4	A, W
	Mysidae	*Haplostylus normani*	(G.O. Sars, 1877)	H	Omn	Cst, Ost	T3,T4	All
		Isopoda		H		Cst, Ost	All	All

	Mysidae	Leptomysini	Czerniavsky, 1882	H	Omn	Cst	T5	A
	Mysidae	*Leptomysis gracilis*	(G.O. Sars, 1864)	H	Omn	Ost	T3	S
	Mysidae	*Leptomysis lingvura*	(G.O. Sars, 1866)	H	Omn	Cst, Ost	T3	S, A
	Mysidae	*Leptomysis* sp.		H	Omn	Ost	T3	W, S
		Megalopa		M		Cst, Ost	T3,T5	All
	Mysidae	*Mesopodopsis slabberi*	(Van Beneden 1861)	H	Omn	Cst	T1,T3, T4	A, W
	Mysidae	Mysida		H	Omn	Cst, Ost	T1,T3, T4	All
		Ostracoda		H	Car	Cst, Ost	All	All
	Mysidae	*Paraleptomysis banyulensis*	(Bacescu, 1966)	H	Omn	Cst, Ost	T1,T3, T4	All
	Mysidae	*Paramysis (Longidentia) helleri*	(G.O. Sars, 1877)	H	Omn	Cst	T1,T4	A, W
	Mysidae	*Rhopalophthalmus tartessicus*	(Vilas-Fernandez, Drake & Sorbe 2008)	H	Omn	Cst, Ost	T1,T3, T4	A, W
	Mysidae	*Siriella clausii*	G.O. Sars, 1877	H	Omn	Cst, Ost	T3	S, A
	Mysidae	*Siriella jaltensis*	Czerniavsky, 1868	H	Omn	Cst	T4	W
		Stomatopoda larvae		M	Car	Ost	T3	S
Echinodermata		Echinoderm larvae		M	Her	Cst	T3	S
Foraminifera		Foraminifera		H		Cst, Ost	T3	All
Larvacea		*Fritillaria* sp.		H	Omn	Cst, Ost	T3	All
		Larvacea		H	Omn	Mst	T3	A
		Oikopleura (Vexillaria) dioica	Fol, 1872	H	Omn	All	T3	All
Mollusca		Mollusca larvae		M		Cst, Ost	All	All
		Pteropoda		H	Her	Ost	T3	A
Other larval forms		Other larval forms		M		All	All	All
Polychaeta		Polychaeta larvae		M	Her	All	All	All
Radiozoa		Radiolaria		H		Cst, Ost	T2,T3, T5	All
Siphonophora		Siphonophora		H	Car	All	All	All
Teleostei larvae		Teleostei larvae		M		Cst, Ost	All	All
Thaliacea		Doliolida		H	Her	Cst, Ost	All	All
Thaliacea (Salpida)		Salpidae		H	Her	Ost	T1,T3	W

Table S3. IndVal Output for species indicator per transect and season.

Group	Taxa	IndVal	P-value
per transect(s)			
T3 - Guadalquivir	*Oikopleura (Vexillaria) dioica*	0.743	0.003
	Pleopis polyphemoides	0.663	0.029
	Paracartia grani	0.562	0.016
	Foraminifera	0.488	0.016
	Sagitta sp.	0.488	0.042
T5 - Trafalgar	Doliolids	0.759	0.003
T1 - Guadiana - T2 - Tinto and Odiel - T4 - Sancti Petri - T5 - Trafalgar	*Clausocalanus* spp.	0.875	0.001
	Calocalanus spp.	0.786	0.005
	Ditrichocorycaeus spp.	0.707	0.006
	Ctenocalanus vanus	0.659	0.005
	Ditrichocorycaeus spp.	0.659	0.012
per season			
Summer	*Pseudevadne tergestina*	0.786	0.001
Winter	*Pleopis polyphemoides*	0.636	0.028
Summer - Autumn	*Penilia avirostris*	0.917	0.001
	Chaetognatha	0.735	0.001
	Temora stylifera	0.692	0.002
	Centropages chierchiae	0.558	0.023
	Evadne spinifera	0.552	0.012
	Sagitta sp.	0.490	0.029
Summer - Winter	Copepoda nauplius	0.613	0.039
	Evadne nordmanni	0.455	0.037

ANEXO E

Table S1. Lista de especies del estuario del Guadalquivir y golfo de Cádiz

Functional Groups	Species	Author/Year	IUCN	Data Source/Reference	Added	Reference Trophic Category
Diadromous fishes	Alosa fallax	(Lacepède, 1803)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Diadromous fishes	Anguilla anguilla	(Linnaeus, 1758)	CR	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Diadromous fishes	Petromyzon marinus	Linnaeus, 1758	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Estuarine fishes	Atherina boyeri	Risso, 1810	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Estuarine fishes	Cyprinus carpio	Linnaeus, 1758	VU	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Estuarine fishes	Fundulus heteroclitus	(Linnaeus, 1766)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Estuarine fishes	Gobius niger	Linnaeus, 1758	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Estuarine fishes	Gobius paganellus	Linnaeus, 1758	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Estuarine fishes	Pomatoschistus microps	(Krøyer, 1838)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Estuarine fishes	Pomatoschistus minutus	(Pallas, 1770)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Estuarine fishes	Pomatoschistus spp.			Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
	Syngnathus abaster	Risso, 1827	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Ammodytes tobianus	Linnaeus, 1758	DD	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Aphanius baeticus	Doadrio, Carmona & Fernández-Delgado, 2002	EN	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Belone belone	(Linnaeus, 1760)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Callionymus reticulatus	Valenciennes, 1837	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Caranx rhonchus	Geoffroy Saint-Hilaire, 1817	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012

Occasional fishes	Carassius auratus	(Linnaeus, 1758)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Chelidonichthys lucerna	(Linnaeus, 1758)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Cobitis paludica	(de Buen, 1930)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Conger conger	(Linnaeus, 1758)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Dagetichthys lusitanicus	(de Brito Capello, 1868)	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Dalophis imberbis	(Delaroche, 1809)	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Dicologlossa cuneata	(Moreau, 1881)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Dicologlossa hexophthalma	(Bennett, 1831)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Diplecogaster bimaculata	(Bonnaterre, 1788)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Diplodus puntazzo	(Walbaum, 1792)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Echelus myrus	(Linnaeus, 1758)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Echiichthys vipera	(Cuvier, 1829)	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Gambusia holbrooki	Girard, 1859	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Hippocampus hippocampus	(Linnaeus, 1758)	DD	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Hippocampus ramulosus	Cuvier, 1829	DD	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Lepomis gibbosus	(Linnaeus, 1758)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Lichia amia	(Linnaeus, 1758)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Lipophrys pholis	(Linnaeus, 1758)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Lipophrys trigloides	(Valenciennes, 1836)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Luciobarbus sclateri	(Günther, 1868)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Monochirus hispidus	Rafinesque, 1814	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Mullus surmuletus	Linnaeus, 1758	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Nerophis ophidion	(Linnaeus, 1758)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Parablennius gattorugine	(Linnaeus, 1758)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Pseudochondrostoma willkommii	(Steindachner, 1866)	VU	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Salaria pavo	(Risso, 1810)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012

Occasional fishes	Sardinella aurita	Valenciennes, 1847	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Sarpa salpa	(Linnaeus, 1758)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Serranus hepatus	(Linnaeus, 1758)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Scomber japonicus	Houttuyn, 1782	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Scophthalmus rhombus	(Linnaeus, 1758)	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Sphyraena sphyraena	(Linnaeus, 1758)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Symphodus bailloni	(Valenciennes, 1839)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Symphodus cinereus	(Bonnaterre, 1788)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Symphodus roissali	(Risso, 1810)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Syngnathus acus	Linnaeus, 1758	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Syngnathus typhle	Linnaeus, 1758	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Ophisurus serpens	(Linnaeus, 1758)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Torpedo torpedo	(Linnaeus, 1758)	DD	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Trachinus draco	Linnaeus, 1758	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional fishes	Trachurus trachurus	(Linnaeus, 1758)	VU	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Marine migrant fishes	Aphia minuta	(Risso, 1810)	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Marine migrant fishes	Argyrosomus regius	(Asso, 1801)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Marine migrant fishes	Chelon aurata	(Risso, 1810)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Marine migrant fishes	Chelon labrosus	(Risso, 1827)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Marine migrant fishes	Chelon ramada	(Risso, 1827)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Marine migrant fishes	Chelon saliens	(Risso, 1810)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Marine migrant fishes	Dicentrarchus labrax	(Linnaeus, 1758)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Marine migrant fishes	Dicentrarchus punctatus	(Bloch, 1792)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Marine migrant fishes	Diplodus annularis	(Linnaeus, 1758)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Marine migrant fishes	Diplodus bellottii	(Steindachner, 1882)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Marine migrant fishes	Diplodus sargus sargus	(Linnaeus, 1758)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012

Marine migrant fishes	Diplodus vulgaris	(Geoffroy Saint-Hilaire, 1817)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Marine migrant fishes	Dicologoglossa cuneata	(Moreau, 1881)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Marine migrant fishes	Engraulis encrasicolus	(Linnaeus, 1758)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Marine migrant fishes	Halobatrachus didactylus	(Bloch & Schneider, 1801)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Marine migrant fishes	Hyporhamphus picarti	(Valenciennes, 1847)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Marine migrant fishes	Mugil cephalus	Linnaeus, 1758	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Marine migrant fishes	Pomadasys incisus	(Bowdich, 1825)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Marine migrant fishes	Pomatomus saltatrix	(Linnaeus, 1766)	VU	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Marine migrant fishes	Sardina pilchardus	(Walbaum, 1792)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Marine migrant fishes	Solea senegalensis	Kaup, 1858	DD	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Marine migrant fishes	Solea solea	(Linnaeus, 1758)	DD	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Marine migrant fishes	Sparus aurata	Linnaeus, 1758	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Marine migrant fishes	Stromateus fiatola	Linnaeus, 1758	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Marine migrant fishes	Trachinotus ovatus	(Linnaeus, 1758)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Marine migrant fishes	Umbrina canariensis	Valenciennes, 1843	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Marine migrant fishes	Umbrina cirrosa	(Linnaeus, 1758)	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Estuarine decapods	Palaemon longirostris	H. Milne-Edwards, 1837	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Estuarine decapods	Palaemon macrodactylus	M. J. Rathbun, 1902	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Estuarine decapods	Palaemonetes varians	(Leach, 1814)	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional decapods	Acantharctus posteli	(Forest, 1963)	DD	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional decapods	Athanas nitescens	(Leach, 1813)	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional decapods	Atyaephyra desmarestii	(Millet, 1831)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional decapods	Axius stirhynchus	Leach, 1815	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional decapods	Brachynotus atlanticus	Forest, 1957	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012

Occasional decapods	Carcinus maenas	(Linnaeus, 1758)	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional decapods	Eriocheir sinensis	H. Milne Edwards, 1853	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional decapods	Goneplax rhomboides	(Linnaeus, 1758)	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional decapods	Hippolyte inermis	Leach, 1816	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional decapods	Jaxea nocturna	Nardo, 1847	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional decapods	Liocarcinus navigator	(Herbst, 1794)	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional decapods	Liocarcinus vernalis	(Risso, 1816)	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional decapods	Lysmata sp.			Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional decapods	Macropodia rostrata	(Linnaeus, 1761)	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional decapods	Nepinnotheres pinnotheres	(Linnaeus, 1758)	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional decapods	Ogyrides rarispina	Holthuis, 1951	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional decapods	Pachygrapsus marmoratus	(Fabricius, 1787)	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional decapods	Palaemon adspersus	Rathke, 1837	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional decapods	Palaemon elegans	Rathke, 1837	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional decapods	Pisidia sp.			Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional decapods	Porcellana platycheles	(Pennant, 1777)	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional decapods	Procambarus clarkii	(Girard, 1852)	LC	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional decapods	Processa sp.			Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional decapods	Rhithropanopeus harrisii	(Gould, 1841)	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional decapods	Sicyonia carinata	(Brünnich, 1768)	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional decapods	Uca tangeri	(Eydoux, 1835)	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional decapods	Upogebia deltaura	(Leach, 1815)	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional decapods	Upogebia pusilla	(Petagna, 1792)	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Occasional decapods	Upogebia tipica	(Nardo, 1869)	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Marine migrant decapods	Crangon crangon	(Linnaeus, 1758)	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012

Marine migrant decapods	Melicertus kerathurus	(Forskål, 1775)	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Marine migrant decapods	Palaemon serratus	(Pennant, 1777)	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Marine migrant decapods	Penaeus kerathurus	(Forskål, 1775)	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Mysids	Mesopodopsis slabberi	(Van Beneden 1861)	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Mysids	Neomysis integer	(Leach 1814)	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
Mysids	Rhopalophthalmus tartessicus	(Vilas-Fernandez, Drake & Sorbe 2008)	NE	Guadalquivir LTER	EGO	González-Ortegón and Drake, 2012
turtles	*Caretta caretta*	(Linnaeus, 1758)	EN	Regional Reports	GCS	Bellido et al. 2008; CMAOT Regional Report (2008-2015); DELPHIS Report (2003-2015); END Report (2010-2014); IMA Report (1993-2015)
turtles	*Chelonia mydas*	(Linnaeus, 1758)	EN	Regional Reports	GCS	CMAOT Regional Report (2008-2015); DELPHIS Report (2003-2015); END Report (2010-2014); IMA Report (1993-2015)
turtles	*Dermochelys coriacea*	(Vandelli, 1761)	CR	Regional Reports	GCS	Bellido et al. 2008; CMAOT Regional Report (2008-2015); DELPHIS Report (2003-2015); END Report (2010-2014); IMA Report (1993-2015)
turtles	*Lepidochelys kempii*	(Garman, 1880)		Regional Reports	GCS	CMAOT Regional Report (2008-2015); DELPHIS Report (2003-2015); END Report (2010-2014); IMA Report (1993-2015)
whales	*Balaenoptera physalus*	(Linnaeus, 1758)		Regional Reports	GCS	CMAOT Regional Report (2008-2015); DELPHIS Report (2003-2015); END Report (2010-2014); IMA Report (1993-2015)

whales	*Balaenoptera brydei*	Anderson, 1879	Regional Reports	GCS	CMAOT Regional Report (2008-2015); DELPHIS Report (2003-2015); END Report (2010-2014); IMA Report (1993-2015)
whales	*Balaenoptera acutorostrata*	Lacépède, 1804	Regional Reports	GCS	CMAOT Regional Report (2008-2015); DELPHIS Report (2003-2015); END Report (2010-2014); IMA Report (1993-2015)
whales	*Balaenoptera sp.*		Regional Reports	GCS	CMAOT Regional Report (2008-2015); DELPHIS Report (2003-2015); END Report (2010-2014); IMA Report (1993-2015)
whales	*Megaptera novaeangliae*	(Borowski, 1781)	Regional Reports	GCS	CMAOT Regional Report (2008-2015); DELPHIS Report (2003-2015); END Report (2010-2014); IMA Report (1993-2015)
Sperm whale	*Physeter macrocephalus*	Linnaeus, 1758	Regional Reports	GCS	CMAOT Regional Report (2008-2015); DELPHIS Report (2003-2015); END Report (2010-2014); IMA Report (1993-2015)
dolphins	*Delphinus delphis*	Linnaeus, 1758	Regional Reports	GCS	CMAOT Regional Report (2008-2015); DELPHIS Report (2003-2015); END Report (2010-2014); IMA Report (1993-2015)
dolphins	*Delphinus/Stenella*		Regional Reports	GCS	CMAOT Regional Report (2008-2015); DELPHIS Report (2003-2015); END Report (2010-2014); IMA Report (1993-2015)
dolphins	*Dolphin Indet.*		Regional Reports	GCS	CMAOT Regional Report (2008-2015); DELPHIS Report (2003-2015); END Report (2010-2014); IMA Report (1993-2015)

dolphins	*Globicephala melas*	(Traill, 1809)	Regional Reports	GCS	CMAOT Regional Report (2008-2015); DELPHIS Report (2003-2015); END Report (2010-2014); IMA Report (1993-2015)
dolphins	*Grampus griseus*	(Cuvier, 1812)	Regional Reports	GCS	CMAOT Regional Report (2008-2015); DELPHIS Report (2003-2015); END Report (2010-2014); IMA Report (1993-2015)
dolphins	*Kogia breviceps*	(Blainville, 1838)	Regional Reports	GCS	CMAOT Regional Report (2008-2015); DELPHIS Report (2003-2015); END Report (2010-2014); IMA Report (1993-2015)
dolphins	*Kogia sima*	(Owen, 1866)	Regional Reports	GCS	CMAOT Regional Report (2008-2015); DELPHIS Report (2003-2015); END Report (2010-2014); IMA Report (1993-2015)
dolphins	*Mesoplodon densirostris*	(Blainville, 1817)	Regional Reports	GCS	CMAOT Regional Report (2008-2015); DELPHIS Report (2003-2015); END Report (2010-2014); IMA Report (1993-2015)
dolphins	*Mesoplodon europaeus*	(Gervais, 1855)	Regional Reports	GCS	CMAOT Regional Report (2008-2015); DELPHIS Report (2003-2015); END Report (2010-2014); IMA Report (1993-2015)
dolphins	*Mesoplodon bidens*	(Sowerby, 1804)	Regional Reports	GCS	CMAOT Regional Report (2008-2015); DELPHIS Report (2003-2015); END Report (2010-2014); IMA Report (1993-2015)
dolphins	*Phocoena phocoena*	(Linnaeus, 1758)	Regional Reports	GCS	CMAOT Regional Report (2008-2015); DELPHIS Report (2003-2015); END Report (2010-2014); IMA Report (1993-2015)
dolphins	*Pseudorca crassidens*	(Owen, 1846)	Regional Reports	GCS	CMAOT Regional Report (2008-2015); DELPHIS Report (2003-2015); END Report (2010-2014); IMA Report (1993-2015)

dolphins	*Stenella coeruleoalba*	(Meyen, 1833)		Regional Reports	GCS	CMAOT Regional Report (2008-2015); DELPHIS Report (2003-2015); END Report (2010-2014); IMA Report (1993-2015)
dolphins	*Tursiops truncatus*	(Montagu, 1821)		Regional Reports	GCS	CMAOT Regional Report (2008-2015); DELPHIS Report (2003-2015); END Report (2010-2014); IMA Report (1993-2015)
dolphins	*Ziphius cavirostris*	Cuvier, 1823		Regional Reports	GCS	CMAOT Regional Report (2008-2015); DELPHIS Report (2003-2015); END Report (2010-2014); IMA Report (1993-2015)
dolphins	*Ziphiidae*			Regional Reports	GCS	CMAOT Regional Report (2008-2015); DELPHIS Report (2003-2015); END Report (2010-2014); IMA Report (1993-2015)
Killer whale	*Orcinus orca*			Regional Reports	GCS	CMAOT Regional Report (2008-2015); DELPHIS Report (2003-2015); END Report (2010-2014); IMA Report (1993-2015)
seabirds	*Alca torda*	Linnaeus, 1758	VU	SEO/BirdLife/INDEMARES	GCS	SEO/BirdLife, 2014
seabirds	*Calonectris diomedea*	(Scopoli, 1769)	LC	SEO/BirdLife/INDEMARES	GCS	SEO/BirdLife, 2014
seabirds	*Catharacta skua*	(Brünnich, 1764)	LC	SEO/BirdLife/INDEMARES	GCS	SEO/BirdLife, 2014
seabirds	*Fratercula arctica*	(Linnaeus, 1758)	VU	SEO/BirdLife/INDEMARES	GCS	SEO/BirdLife, 2014
seabirds	*Hydrobates pelagicus*	(Linnaeus, 1758)	LC	SEO/BirdLife/INDEMARES	GCS	SEO/BirdLife, 2014
seabirds	*Hydrobates / Oceanites*			SEO/BirdLife/INDEMARES	GCS	SEO/BirdLife, 2014
seabirds	*Larus argentatus*	Pontoppidan, 1763	LC	SEO/BirdLife/INDEMARES	GCS	SEO/BirdLife, 2014
seabirds	*Larus audouinii*	Payraudeau, 1826	LC	SEO/BirdLife/INDEMARES	GCS	SEO/BirdLife, 2014
seabirds	*Larus canus*	Linnaeus, 1758	LC	SEO/BirdLife/INDEMARES	GCS	SEO/BirdLife, 2014
seabirds	*Larus fuscus*	Linnaeus, 1758	LC	SEO/BirdLife/INDEMARES	GCS	SEO/BirdLife, 2014
seabirds	*Larus melanocephalus*	Temminck, 1820	LC	SEO/BirdLife/INDEMARES	GCS	SEO/BirdLife, 2014

seabirds	*Larus michahellis*	J. F. Naumann, 1840	LC	SEO/BirdLife/INDEMARES	GCS	SEO/BirdLife, 2014
seabirds	*Larus michahellis / fuscus*			SEO/BirdLife/INDEMARES	GCS	SEO/BirdLife, 2014
seabirds	*Larus ridibundus*			SEO/BirdLife/INDEMARES	GCS	SEO/BirdLife, 2014
seabirds	*Larus sp.*			SEO/BirdLife/INDEMARES	GCS	SEO/BirdLife, 2014
seabirds	*Melanitta nigra*	(Linnaeus, 1758)	LC	SEO/BirdLife/INDEMARES	GCS	SEO/BirdLife, 2014
seabirds	*Morus bassanus*	(Linnaeus, 1758)	LC	SEO/BirdLife/INDEMARES	GCS	SEO/BirdLife, 2014
seabirds	*Hydrobates leucorhous*	(Vieillot, 1818)	VU	SEO/BirdLife/INDEMARES	GCS	SEO/BirdLife, 2014
seabirds	*Oceanites oceanicus*	(Kuhl, 1820)	LC	SEO/BirdLife/INDEMARES	GCS	SEO/BirdLife, 2014
seabirds	*Phalaropus fulicarius*	(Linnaeus, 1758)	LC	SEO/BirdLife/INDEMARES	GCS	SEO/BirdLife, 2014
seabirds	*Ardenna gravis*	(O'Reilly, 1818)	LC	SEO/BirdLife/INDEMARES	GCS	SEO/BirdLife, 2014
seabirds	*Ardenna grisea*	(Gmelin, 1789)	NT	SEO/BirdLife/INDEMARES	GCS	SEO/BirdLife, 2014
seabirds	*Puffinus mauretanicus*	Lowe, 1921	CR	SEO/BirdLife/INDEMARES	GCS	SEO/BirdLife, 2014
seabirds	*Puffinus yelkouan*	(Acerbi, 1827)	VU	SEO/BirdLife/INDEMARES	GCS	SEO/BirdLife, 2014
seabirds	*Rissa tridactyla*	(Linnaeus, 1758)	LC	SEO/BirdLife/INDEMARES	GCS	SEO/BirdLife, 2014
seabirds	*Stercorarius parasiticus*	(Linnaeus, 1758)	LC	SEO/BirdLife/INDEMARES	GCS	SEO/BirdLife, 2014
seabirds	*Stercorarius longicaudus*	Vieillot, 1819	LC	SEO/BirdLife/INDEMARES	GCS	SEO/BirdLife, 2014
seabirds	*Stercorarius pomarinus*	(Temminck, 1815)	LC	SEO/BirdLife/INDEMARES	GCS	SEO/BirdLife, 2014
seabirds	*Sterna bengalensis*			SEO/BirdLife/INDEMARES	GCS	SEO/BirdLife, 2014
seabirds	*Sterna hirundo*	Linnaeus, 1758	LC	SEO/BirdLife/INDEMARES	GCS	SEO/BirdLife, 2014
seabirds	*Sterna paradisaea*	Pontoppidan, 1763	LC	SEO/BirdLife/INDEMARES	GCS	SEO/BirdLife, 2014
seabirds	*Thalasseus sandvicensis*	(Latham, 1787)	LC	SEO/BirdLife/INDEMARES	GCS	SEO/BirdLife, 2014
seabirds	*Xema sabini*	(Sabine, 1819)	LC	SEO/BirdLife/INDEMARES	GCS	SEO/BirdLife, 2014

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