Universitat d'Alacant
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Evaluation of some management measures for trawling fishery in the western Mediterranean

Evaluación de algunas medidas de gestión de la pesquería de arrastre en el mediterráneo occidental

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MOHAMED SAMY KAMAL ELSAYED

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El doctor **JOSÉ LUIS SÁNCHES LIZASO** y el doctor **AITOR FORCADA ALMARCHA,** Profesores del Área de Zoología de la Universidad de Alicante

CERTIFICAN,

Que la memoria de la Tesis Doctoral "**Evaluación de algunas medidas de gestión de la pesquería de arrastre en el mediterráneo occidental**" presentada por **MOHAMED SAMY KAMAL ELSAYED** ha sido realizada bajo su dirección en el Departamento de Ciencias del Mar y Biología Aplicada de la Universidad de Alicante.

Y para que conste a los efectos oportunos, firman en Alicante a de de 2014.

V.º B.º Directores de la Tesis Doctoral

Dr. José Luis Sánchez Lizaso **Dr. Aitor Forcada Almarcha**

Presentation of the thesis

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LIST OF ABBREVIATIONS

AIC	Akaike Information Criterion
ANOVA	Analysis of Variance
CFP	Common Fisheries Policy
CL	Carapace length
CPUE	Catch per unit effort
EU	European union
EEZ	Exclusive economic zone
FAO	Food and Agriculture Organization of the United Nations
GFCM / CGPM	General Fisheries Commission for the Mediterranean / Comisión General de Pesca del Mediterráneo
GT	Gross tonnage
GRT	Gross relative tonnage
HP	Horse power
ICCAT	International Commission for the Conservation of Atlantic Tunas
ICES	The International Council for the Exploration of the Sea
ISSCAAP	International Standard Statistical Classification of Aquatic Animals and Plants
$\mathbf{L_X}$	is the length at which x% is retained
$\mathbf{L_{50}}$	is the length at which 50% is retained
$\mathbf{L_{cur}}$	The current critical length
$\mathbf{L_{opt}}$	The optimal length
MPAs	Marine Protected Areas
MLS	Minimum landing sizes
nMDS	non-metric multidimensional scaling
PERMANOVA	Permutational Multivariate Analysis of Variance
SIMPER	Similarity Percentage Analysis
SR	Selection range
SW	South-western
TACs	Total allowable catches (TACs) or fishing quotas
TL	Total vessel length

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LIST OF PAPERS

- Samy-Kamal, M., Forcada, A., Sánchez-Lizaso, J.L. 2014. Trawling fishery of the western Mediterranean Sea: Métiers identification, effort characteristics, landings and income profiles. ***Ocean & coastal management, 102: 269–284.***

- Samy-Kamal, M., Forcada, A., Sánchez-Lizaso, J.L. In press. Short-term effect of selectivity change in a trawling fishery in the western Mediterranean. ***Journal of applied ichthyology. In press.***

- Samy-Kamal, M., Forcada, A., Sánchez-Lizaso, J.L. Submitted. Effects of seasonal closures in a multi-specific fishery. ***Fisheries research. Submitted.***

- Samy-Kamal, M., Forcada, A., Sánchez-Lizaso, J.L. Daily variation in ex-vessel fish prices and their implication in management. In prep.

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Outline of the thesis

This thesis is structured in six chapters that follow a progressive advance through the objectives of the study. Each chapter is structured as an independent study which implies that repetitions might appear through the text. The thesis consists of a collection of publications and is structured as:

The first chapter includes the general introduction, which briefly outlines the background and current status of the Mediterranean fisheries, the exploited resources, peculiarities and problems of their management. Moreover, it gives a special consideration for trawling fishery in the study area, describing the fishery, fleets, and the current management measures. It also provides the objectives of the thesis.

The second chapter aims to analyse as well to describe the main characteristics of the fishing activity practiced in three representative trawling ports (Dénia, Xàbia and La Vila Joiosa) of the south-eastern Iberian Peninsula, one of the most important fishing grounds in the western Mediterranean Sea. This will serve as a keystone for more practical implications such as assessment of the applied management measures. For this: (a) the structure of the fleet, the evolution of fishing effort and landings were evaluated for each port; (b) the main métiers in the fishery were identified and examined according to their activity patterns, catch and income profiles; (c) distribution of fishing effort among métiers and the trends in effort were assessed based on the use of specific métiers in the study area; and finally, (d) relations between total landings (also by métier) and different fishing effort variables were analysed.

The third chapter aims to analyse the short-term effect of selectivity change and evaluate the consequences of inserting either a 40-mm square-mesh codend or a 50-mm diamond-mesh (instead of the traditionally 40-mm diamond-mesh codend) in a commercial Spanish trawling fishery of the south-western Mediterranean. Using commercial data of the fishing guild, the landings in terms of biomass, economic profits and catch composition were compared for each métier before and after applying the new mesh. The main métiers in the fishery were also identified and separated for the analysis, since it was necessary to correctly evaluate the effect of the management regulation.

The fourth chapter aims to to determine the effects of implementing a temporary/seasonal closure in biologic (total landings and landings of target species) and economic (ex-vessel price "first sale price" of target species at home and neighbor ports) terms at different seasons of the year. We used 10-years landings data of a commercial Spanish trawling fishery, derived from two representative fishing ports (Dénia and La Vila Joiosa) in the western Mediterranean.

The fifth chapter aims to analyse the daily variation of ex-vessel price to determine which day of the week is better to ban the fishery since it may be an alternative management measure to seasonal closure.

The sixth chapter address the general discussion and the final conclusions.

Esquema de la tesis

Esta tesis está estructurada en seis capítulos que siguen un avance progresivo a través de los objetivos del estudio. Cada capítulo está estructurado como un estudio independiente que implica que pueden aparecer repeticiones en diferentes partes del texto. La tesis consta de una colección de publicaciones y se estructura de acuerdo con el siguiente esquema:

El primer capítulo contiene la introducción general, que describe brevemente los antecedentes y el estado actual de las pesquerías del Mediterráneo, los recursos explotados, las particularidades y los problemas de su gestión, y las medidas de gestión viables. Por otra parte, se da una consideración especial sobre la pesca de arrastre en la zona de estudio, se describe la pesquería, las flotas y las medidas de gestión aplicadas actualmente. También contiene la justificación del problema, junto con los objetivos de la tesis.

El segundo capítulo tiene como objetivo analizar y describir las principales características de la actividad pesquera que se da en tres puertos representativos de la flota de arrastre del sureste de la Península Ibérica (Dénia, Xàbia y La Vila Joiosa), una de las zonas de pesca más importantes del Mediterráneo occidental. Este capítulo servirá como una base para el resto de estudios referidos a la evaluación de las medidas de gestión aplicadas. Para ello: (a) se evaluaron para cada puerto la estructura de la flota, la evolución del esfuerzo pesquero y los desembarques; (b) se identificaron y examinaron los principales métiers de la pesca y sus patrones de actividad, sus perfiles de captura y de ingresos; (c) se identificó la distribución del esfuerzo pesquero entre los métiers y se evaluó las tendencias en el esfuerzo para cada uno de los métiers; y, por último (d), se analizaron las relaciones entre los desembarques totales (también por métier) y distintas variables del esfuerzo pesquero.

El tercer capítulo tiene como objetivo, analizar el efecto a corto plazo del cambio de selectividad, evaluando las consecuencias de la introducción de un cambio en la red del copo, ya sea a 40 mm de malla cuadrada o a 50 mm de malla rómbica (en lugar de la tradicional de 40 mm de malla rómbica) en una pesquería de arrastre en el Mediterráneo occidental. Para ello, se compararon antes y después de aplicar la nueva malla, los datos pesqueros comerciales de la lonja, los desembarques en términos de biomasa, los beneficios económicos y la composición de las capturas. El análisis se realizó para cada uno de los principales métiers de la pesquería.

El cuarto capítulo tiene como objetivo, determinar los efectos de la aplicación de una veda temporal en términos biológicos (desembarques totales y desembarques de las especies objetivo) y económicos (precios de primera venta en lonja de las especies objetivo, en el puerto de origen y en el puerto vecino) en diferentes estaciones del año. Se utilizaron los datos de 10 años de desembarques de la pesca de arrastre de dos puertos pesqueros representativos en el Mediterráneo occidental (Dénia y La Vila Joiosa).

El quinto capítulo analiza la variación diaria del precio de primera venta en lonja, para determinar qué día de la semana sería preferible prohibir la pesca si se considera que, como una medida alternativa de gestión, se pudiese prohibir la pesca a un día más por semana en lugar de mantener la veda temporal.

En el sexto capítulo se aborda la discusión general de los resultados obtenidos, y se incluyen las conclusiones finales con las observaciones más relevantes resultantes del presente estudio.

Resumen

Desde hace muchos años las pesquerías mundiales están amenazadas por la sobrepesca y otros problemas, principalmente antropogénicos. El Mediterráneo no se encuentra apartado de esta situación, y se considera que gran porcentaje (50%) de los stocks evaluados se encuentran sobreexplotados, mientras que el 33% de los recursos evaluados totalmente explotada. Las Pesquerías del Mediterráneo son multi-específicas, incluyendo una amplia diversidad de recursos pesqueros; hasta 100 especies y categorías registradas en los desembarques en algunas áreas. Los recursos explotados de pesca en el Mediterráneo se pueden clasificar en tres categorías principales: pequeños pelágicos, grandes pelágicos y recursos demersales. Los pequeños pelágicos presentan la principal contribución (alrededor del 60%) a los desembarques totales del Mediterráneo. La mayoría de las pequeñas especies pelágicas están dispersas principalmente cerca de la costa, sobre la plataforma continental. La mayoría de estas especies son especies migratorias que migran en estaciones bien definidas, lo que explica la estacionalidad de sus pesquerías. Los recursos de grandes pelágicos se refieren principalmente a las grandes especies pelágicas migratorias. El atún rojo y el pez espada son los grandes pelágicos más importantes en el Mediterráneo. Los grandes pelágicos representan alrededor del 4-8% del total de los desembarques declarados, pero su valor económico es mucho mayor. Los recursos demersales están compuestos por aquellas especies que viven y se alimentan cerca del fondo marino. La pesca demersal se dirige a una gran cantidad de especies y muchas de ellas tienen alto valor de mercado, lo que refleja la importancia de esta pesquería. Las especies demersales representan alrededor del 30% de las capturas totales declaradas en el Mediterráneo.

Por otro lado, las flotas Mediterráneas se pueden clasificar en tres tipos: la flota artesanal "de pequeña escala", la flota industrial "a gran escala" y una flota intermedia que se suele denominar flota semi-industrial. La flota de pequeña escala tiende a usar los denominados artes menores y los barcos de menor eslora. El término también se refiere, a veces, al concepto de unos bajos niveles de tecnología y de capital invertido por pescador, aunque ese no es siempre el caso. El término "flota industrial" se refiere a las grandes flotas con inversiones realizadas por empresas o grupos financieros. En el Mediterráneo, se limita principalmente a la pesca del atún por los grandes cerqueros y palangreros. La flota "semi-industrial" es un grupo que se encuentra entre la flota artesanal y la industrial, pero más cerca de un perfil artesanal. Se refiere sobre todo a los arrastreros, cerqueros y algunos palangreros.

La evaluación y la gestión de las pesquerías mediterráneas conlleva importantes dificultades. La falta de información, las amplia distribución de las flotas dominadas por barcos de pequeña escala, la sobrecapacidad de las flotas, un gran número de puntos de desembarque, pesquerías multi-especificas, el nivel de cumplimiento de una normativa muy irregular y una cooperación en la gestión de la pesca limitada entre los países, son algunas de las dificultades para la gestión sostenible de la pesca en el Mediterráneo. Esto le da a las pesquerías del Mediterráneo una característica particular en su gestión frente a otras regiones. Esta situación, ha desempeñado un papel significativo en la promoción de la necesidad de nuevos enfoques para la gestión de la pesca y la reevaluación de las medidas de gestión actuales. En el Mediterráneo, la gestión global de todas las pesquerías se realiza en el marco de la Comisión General de Pesca del Mediterráneo (CGPM). Las pesquerías de los países de la Unión Europea (UE) se gestionan de acuerdo con la Política Pesquera Común (PPC). En la mayoría de los casos en el Mediterráneo, esta política se ha armonizado con la política de la CGPM. Los países no pertenecientes a la UE definen sus propias medidas de gestión pesquera, aunque la mayoría de ellos tratan de asegurarse de que son compatibles con las medidas de la CGPM. Las medidas del control del esfuerzo de pesca son las principales medidas utilizadas para la gestión de las pesquerías multi-específicas, como las pesquerías del Mediterráneo, en combinación con otras medidas técnicas, tal como, de tamaño o forma de la malla y las tallas mínimas de las especies desembarcadas o vedas espacio-temporales. Debido a la diversidad tanto de las características de la flota y la composición de las capturas, la CGPM ha puesto énfasis en el control directo de la capacidad pesquera y el esfuerzo, en lugar de limitación de capturas como una forma efectiva de reducir la mortalidad por pesca.

El Golfo de Alicante (SE España) sostiene una importante actividad pesquera, que comprende hasta el 10% de la flota del Mediterráneo español, que cada año desembarca hasta 20000 toneladas. La amplia extensión de la plataforma continental en esta zona, ha favorecido la pesca de arrastre con el desarrollo de una gran flota que opera en la plataforma continental fangosa y arenosa y en el talud entre 50 y 800 metros de profundidad. Por otra parte, los desembarques se venden, todos los días, a los intermediarios en cada puerto local en la lonja de pesca bajo la supervisión de las cofradías de pescadores, lo que facilita el control de los desembarques diarios por barco. La pesca de arrastre de la flota en la zona, es la segunda flota más importante en cuanto a los desembarques después la flota de cerco, y proporciona alrededor del 40% de los desembarques anuales. La flota de pesca de arrastre es la más grande en términos de número de barcos, con 109 arrastreros distribuidos en 12 puertos (desde Dénia hasta Torrevieja), y en términos de eslora del barco y potencia del motor. Los barcos se caracterizan por la escala semi-industrial de sus operaciones, y cada flota pesquera está registrada en un puerto base donde los barcos suelen volver todos los días o dentro de unos pocos días. Al igual que otras flotas de arrastre del Mediterráneo, sus actividades se llevan a cabo en zonas de pesca bien determinadas, que son seleccionadas por los pescadores dependiendo a las especies objetivo. Generalmente estos caladeros son utilizados por la flota pesquera del puerto más cercano.

Los objetivos de esta tesis son analizar los datos de desembarque y esfuerzo de pesca a largo plazo (2002-2011) (***capítulo* 2**), así como identificar los métiers de la pesca de arrastre en tres puertos en el Mediterráneo occidental. Por otra parte, analizar la mejora de la selectividad modificando la forma o el tamaño de la malla en el copo (***capítulo* 3**) y los efectos de las vedas temporales (***capítulo* 4**), como dos medidas de gestión aplicadas en la pesquería. Como último objetivo, evaluar la medida de gestión de la reducción de un día de pesca a la semana (cuando los precios son más bajos) como alternativa a las vedas temporales (***capítulo* 5**).

En las pesquerías de arrastre del Mediterráneo, donde algunas de las especies objetivo han estado sometidas a sobrepesca, el esfuerzo pesquero se puede dirigir hacia una u otra especie objetivo durante ciertos períodos, dependiendo del nivel de capturas obtenido en ese momento y a los precios de las especies objetivo en el mercado. Estas características aumentan la heterogeneidad de la pesquería y complican la evaluación, el seguimiento y la gestión de sus actividades. En tal marco de gestión de la actividad pesquera, las actividades de la flota en un área determinada, debe desagregarse en sub-segmentos que definan actividades específicas en el tiempo, el espacio y las oportunidades de captura que corresponde estrechamente con el concepto de "métier". Un métier se define como un grupo de operaciones pesqueras dirigidas a un grupo similar (un conjunto) de especies, con artes similares durante el mismo período del año y / o dentro de la misma zona, y que se caracterizan por un patrón de explotación similares. Por otro lado, debido a la diversidad de las características de la flota y composición de las capturas en las pesquerías del Mediterráneo, la Comisión General de Pesca del Mediterráneo ha puesto énfasis en el control directo de la capacidad y del esfuerzo pesquero, en lugar de establecer limitaciones de capturas.

El objetivo del ***capítulo* 2** fue analizar la evolución del esfuerzo pesquero, los desembarques y los métier (o tácticas de pesca) en tres puertos de pesca de arrastre del Mediterráneo occidental entre 2002 y 2011. Se aplicaron métodos no paramétricos que combinan el escalamiento no métrico multidimensional (nMDS) y de conglomerados jerárquicos (CLUSTER), para evaluar las diferencias en la biomasa de la composición de las capturas entre las muestras (barco / día). Una vez identificados los grupos, se utilizó el análisis del porcentaje de similitud (SIMPER) para reconocer las principales especies que caracterizan a cada grupo de muestras en peso y los ingresos, y de esta manera identificar los métier. Por otra parte, el Análisis de la Varianza (ANOVA) se utilizó para analizar las diferencias en la eslora total, arqueo bruto, la biomasa total y el ingreso total entre puertos y entre los métiers identificados en cada puerto. Finalmente, para explorar la relación entre los desembarques (total y también por cada métier) y distintas variables del esfuerzo pesquero (eslora del barco, arqueo bruto, y la potencia del motor), se utilizaron gráficos de dispersión y el coeficiente de correlación de Pearson.

El uso de técnicas multivariantes permitió la identificación de cuatro métiers o tácticas de pesca: el salmonete, la merluza europea, la cigala y la gamba roja. La composición media de captura dentro del mismo métier fue similar entre los puertos, aunque la importancia relativa de las especies difería ligeramente de un puerto a otro. La variación observada en el esfuerzo de pesca dedicado a cada métier, refleja las diferencias en la importancia y el uso de cada métier por puerto. Se detectaron variaciones temporales entre los diferentes métiers a escalas estacionales y anuales. Estas variaciones temporales mostraron que el métier del salmonete y de la merluza europea se alternaban. Se observaron correlaciones positivas significativas entre los desembarques y las diferentes variables del esfuerzo pesquero con una excepción, el de la relación con la potencia del motor en el métier de la cigala, que presentó una correlacion negativa. Se detectaron diferencias significativas en la eslora total del barco, arqueo bruto, CPUE total y el ingreso total, entre los cuatro métier en función de cada puerto, con pocas excepciones. Estos resultados se consideran claves y necesarios para implicaciones de gestión más prácticas, y ayudar así a los gestores pesqueros en el proceso de toma de decisiones.

El cambio de la selectividad como una medida de gestión se analizó en ***el capítulo* 3**. La pesca de arrastre del Mediterráneo tradicionalmente operaba usando en el copo mallas mínimas de 40 mm en forma rómbica, y éstas tienen una baja selectividad. Estas mallas suelen estirarse bajo la tensión durante la operación de pesca y tienen una tendencia a cerrarse cuando se llena el copo. Por tanto, tienden a retener un gran número de individuos de las especies objetivo por bajo de su tamaño mínimo de desembarque (MLS). En consecuencia, aumentan la mortalidad por pesca, impide la consecución de beneficios económicos en el futuro al tiempo que disminuyen el rendimiento por recluta. Por otra parte, estas mallas tienen efectos indirectos sobre otras capturas accesorias y las especies no comerciales, lo que contribuye desfavorablemente a la composición de las capturas aumentando las tasas de descartes, especialmente en la plataforma continental. Sin embargo, si en los copos se emplea una malla cuadrada del mismo tamaño nominal, ésta permanece abierta durante la operación de pesca y es más selectiva, es decir, tiene un L_{50} superior (L_x es la longitud en la que x% de los individuos que son retenido) y un rango de selección (SR) inferior en comparación con la malla rómbica tradicionalmente empleada. Por estas razones, el diseño de malla del copo se ha establecido como un factor importante que determina la selectividad de las redes de arrastre. Se ha recomendado, por parte de la CGPM, mejorar la selectividad de arrastre, ya que se considera que es una herramienta para reducir el impacto de arrastre en los ecosistemas y mejorar el patrón de explotación de las especies objetivo. La UE introdujo una mejora sobre la selectividad en el reglamento que regula las artes de arrastre que debía aplicarse, como muy tarde, a partir de junio de 2010. En este capítulo se evalúaron las consecuencias de la introducción, ya sea a 40 mm de malla cuadrada o a 50 mm de malla rómbica en los copos (en lugar de la malla rómbica tradicional de 40 mm) de los arrastreros españoles. Para ello se compararon los desembarques antes y después del cambio de malla en términos de biomasa, ingresos y composición de las capturas para cada uno de los cuatro métiers identificados en la pesqueria: merluza europea, salmonete, gamba roja y cigala. No se observaron diferencias significativas entre antes y después del cambio a la nueva malla, ni en la biomasa ni en los ingresos, tanto en el métier de la merluza europea y como en el de salmonete. Por el contrario, la biomasa total del métier de la gamba roja y la biomasa de *Nephrops norvegicus* del métier de la cigala, fueron significativamente más altos después del cambio de la malla. En cuanto a la composición de las capturas, sólo el métier de merluza europea mostró ligeros cambios -no significativos- después de aplicar la nueva malla. Teniendo en cuenta estos resultados, no hubo un efecto a corto plazo (pérdida sustancial en términos biológicos y económicos) como se esperaba según estudios previos. Probablemente, esto podría estar relacionado con un mayor rendimiento de la nueva malla, que puede compensar la menor retención de individuos de menor tamaño.

***El capítulo* 4**, tuvo como objetivo determinar los efectos de las vedas temporales en términos biológicos y económicos, utilizando datos de 10 años de desembarques de dos puertos de pesca de arrastre representativos del Mediterráneo occidental: Dénia y La Vila Joiosa. La adopción de las veda temporales es una de las medidas más simples utilizadas en la gestión de las pesquerías. La veda temporal en una pesquería significa un cierre total de la actividad pesquera durante un período determinado, que se traduce en una reducción del esfuerzo anual. Esta estrategia de gestión se basa principalmente en el control del esfuerzo que reduce la intensidad de pesca y protege stock objetivo de la mortalidad en una etapa específica de la historia de vida, es decir, cuando una especie se congrega en un área o en una estación específica para desovar. Desde una perspectiva económica, la veda temporal puede tener beneficios a corto plazo a los pescadores: (i) los beneficios derivados de la reducción de los costos operativos; (ii) la compensación económica derivada de la recuperación de las poblaciones ya que se deja de pescar ahora con el fin de aumentar la captura después; y (iii) el beneficio derivado de las subvenciones de compensación (en el caso de que la administración financie la veda). Sin embargo, el paro de la flota en períodos largos (por ejemplo, veda de uno o dos meses) provoca graves problemas logísticos y económicos, tales como: (i) el desempleo de los pescadores que tienen que buscar otro trabajo durante el período de cierre o consumir su subvención por desempleo; (ii) "efecto frontera" como resultado de los desequilibrios entre la actividad de las flotas pertenecientes a los puertos adyacentes a donde se produce el cierre; (iii) el desabastecimiento de algunas especies de alta demanda; (iv) los desequilibrios en los precios de mercado, debido a la irregularidad del suministro de pescado al mercado; y (v) los costos adicionales en la administración en forma de subsidios estatales.

Como análisis preliminar, se estandarizaron las tasas de captura para separar la parte de la variabilidad de los datos que no es directamente atribuible a las variaciones en la abundancia. Para estandarizar la captura por unidad de esfuerzo (CPUE), se utilizaron modelos lineales generalizados (GLM). Los GLM se llevaron a cabo en la CPUE total (kg · barco^{-1} · día^{-1}), así como la CPUE de cada especie objetivo (*Mullus* spp., *M. merluccius*, *N. norvegicus* y *A. antennatus*) en su respectiva táctica de pesca (los métiers identificados en el capítulo 2). El Análisis de Varianza (ANOVA) se utilizó para detectar diferencias significativas en la CPUE así como en los precios de venta en el puerto de origen y en el puerto vecino, antes y después de la veda temporal en diferentes epocas del año (al principio y final de verano). Los resultados de los ANOVAs mostraron que la CPUE de *M. merluccius* y la CPUE total del métier de cigala fueron significativamente mayores tras la veda a principios de verano, pero no para todos los años. Por el contrario, se observaron significativamente menores la CPUE total del métier de gamba roja y la CPUE de *A. antennatus*, también a principios de verano. Se observaron CPUE similares en todos los métiers cuando la veda se llevó a cabo a finales del verano. En términos económicos, los precios de mercado de las especies objetivo disminuyeron, o no mostraron ningún cambio, tras la veda del puerto de origen y en el puerto vecino. La única excepción fue el aumento significativo del precio de *A. antennatus* en Dénia durante la veda en La Vila Joiosa. La veda podría tener algunos efectos positivos biológicos en algunas especies objetivo en función de su temporización. Sin embargo, esto lleva a una reducción inevitable en la mayoría de los precios de las especies objetivo. Una medida alternativa de gestión, basada en la reducción del esfuerzo en las pesquerías multi-específicas, podría ser prohibir la pesca un día a la semana, cuando los precios de mercado de las especies objetivo son menores, y que además se podría realizar independientemente de las subvenciones.

En las pesquerías multi-específicas, es necesaria la evaluación de medidas de gestión alternativas, porque la eficacia de las medidas de gestión actuales puede ser mejorable (véase el capítulo 3 y 4). Por ello, se analizó la variación diaria del precio de primera venta de la lonja en ***el capítulo 5***, para determinar qué día de la semana sería mejor para prohibir la pesca como una medida de gestión alternativa a la veda temporal. Se utilizaron los datos de 10 años de desembarques de dos puertos de pesca de arrastre representativos del Mediterráneo occidental: Dénia y La Vila Joiosa. El Análisis de la Varianza (ANOVA) se utilizó para detectar diferencias significativas entre los días de la semana en el precio de primera venta de las principales especies objetivo. Los precios medios más bajos para la mayoría de las especies objetivo se observaron los martes y los miércoles, y eran más altos los lunes y viernes, con pocas excepciones. La prohibición de un día por semana (martes o miércoles), cuando los precios de mercado de las especies objetivo son más bajos, puede reducir el doble de esfuerzo que una parada de la flota de un mes y, probablemente, se podría mantener sin necesidad de subvenciones.

En el Mediterráneo, aunque la pesca de arrastre se dirige a un número restringido de especies objetivo, los desembarques totales y su valor económico también se generan a partir de varias especies pertenecientes a las denominadas "especies accesorias" y por esta razón, la pesquería de arrastre del Mediterráneo ha sido clasificada como multi-específica. A pesar del gran número de especies, alrededor del 80% de los desembarques estuvieron representados por sólo 15 especies. Las especies dominantes en los desembarques de la pesca de arrastre del Mediterráneo occidental son: la merluza europea *Merluccius merluccius*, la bacaladilla *Micromesistius poutassou*, la gamba roja *Aristeus Antennatus*, los salmonetes *Mullus* spp., el pulpo *Octopus vulgaris*, y la cigala *Nephrops norvegicus*. La existencia de una gestión de las pesquerías multi-especifica, donde se explotan cuatro especies objetivo principales, asume que cualquier cambio en la intensidad de la pesca o de la selectividad se aplicará a todas las especies por igual. La realidad de la actividad de la flota de arrastre de fondo en el Mediterráneo es más complicada: Las cuatro especies objetivo no son capturadas simultáneamente. Como hemos visto (capítulo 2) cada métier opera en diferentes zonas de pesca y en temporadas diferentes durante el año. Es evidente que una reducción del esfuerzo pesquero global, así como la selectividad, no afectarán a todas las especies objetivo por igual, a menos que las características de las especies objetivo y la actividad de los barcos en cada uno de los métiers que se tengan en cuenta. Aunque los organismos de gestión pesquera tratan de garantizar la selectividad de forma más eficaz para mejorar el rendimiento, algunas de las pesquerías en el Mediterráneo todavía dependen mayoritariamente de los individuos pequeños de las especies objetivo, capturándolos antes de que puedan reproducirse, como la merluza. La mejora de la selectividad de los artes de pesca en el Mediterráneo es un reto, debido a su naturaleza multi-específica. El carácter multi-específico de las pesquerías mediterráneas también complica la adopción de otras medidas de gestión, tales como la veda temporal. La dificultad de ajustar la veda temporal para proteger a diversas especies objetivo, con diferentes ciclos de reproducción y distintos patrones estacionales de cambios de capturabilidad, dificulta la adopción de la veda temporal sobre bases biológicas.

La integración de los pescadores en los procesos de toma de decisiones de gestión, ayudaría a mejorar su cumplimiento y los resultados para el éxito global de la gestión. Sin embargo, este es un punto débil en el Mediterráneo. Sólo puede haber gestión eficaz de la pesca cuando exista un colaboración entre el sector, la administración y los científicos mucho mayor que la que se da actualmente en las pesquerías mediterráneas. El futuro de la pesca en el Mediterráneo requiere la formulación de nuevas estrategias de gestión, incorporando el enfoque basado en el ecosistema, porque la complejidad de la pesca hace que los enfoques de gestión clásicos no sean realistas. El enfoque ecosistémico de la pesca, requiere de nuevas herramientas para que el gestor pueda implementar medidas de gestión adecuadas y proteger así la integridad del medio ambiente. Ante la falta de información sobre la situación actual del medio ambiente o de determinados recursos pesqueros, así como la incertidumbre de gestión, existe un creciente énfasis en el uso de las restricciones espaciales mediante el uso de las áreas marinas protegidas (AMPs). Ambas herramientas se permiten conservar y restaurar la biodiversidad, promover la resiliencia de los ecosistemas, mantener la sostenibilidad de la pesca y contribuir al enfoque basado en los ecosistemas.

Chapter 1: General introduction

1.1. Introduction

For many years it is well known that the world's fisheries are threatened by overfishing and other mainly anthropogenic-induced problems (Pauly *et al.,* 2002; Mullon *et al.,* 2005; Clark, 2007). Over the last 20 years, the marine fishery resources of the world have been increasingly subjected to overexploitation, destructive fishing practices and environmental degradation. Several fish stocks are assessed as being either fully exploited (57%) or overexploited (30%) (FAO, 2012). This affects most of fisheries worldwide, with very critical consequences in terms of resource unsustainability, massive economic waste, increasing social cost and protein insecurity.

The high demand for limited resources normally leads to high prices of catches and, therefore, more incentives to invest in more fishing effort that in turn cause overfishing and, consequently, reduced biomass availability. The global fleet capacity increased by six-times between 1970 and 2005, while the global landings decreased by the same amount during the same period (the World Bank, 2009). In connection, there have been long-term declines in the spawning stock biomass of most commercial species. Most of these problems are related with fisheries of developed countries, especially those in North America, Europe and East Asia, where resource extraction levels exceed their maximum sustainable yield (Meaden and Aguilar-Manjarrez, 2013). In many cases, maximizing short-term profits is more important than sustaining long-term exploitation (Meaden and Aguilar-Manjarrez, 2013). Moreover, these fisheries frequently experience conflicts for use of the marine resource space, while in most cases fisheries management and political compromises are prioritizing short-term national socio-economic needs over longer-term sustainability (Agnew *et al.,* 2009). Most of these fisheries have mainly been managed on a single-species basis rather than as part of a holistic marine ecosystem. However, because fisheries production and consumption increasingly act as an international activity, therefore problems that may have arisen from developed world fisheries are now revealed at the global scale and are critically affecting fisheries in developing countries (Christensen *et al.,* 2007).

Although fisheries were often a lucrative sector the revenues generated by the sector are not allocated to the institutions needed to promote sustainability (fisheries research, management, monitoring or control). At the world scale, the effectiveness of fisheries management for each exclusive economic zone (EEZ) does not exceed the 80% effectiveness level in any case (Fig. 1.1) (Mora *et al.,* 2009). There is also an obvious relation between income levels and management effectiveness. For instance, it is relatively prosperous in areas such as Oceania, North America, Northern Europe and less efficient management in central America, much of equatorial Africa and southeast Asia.

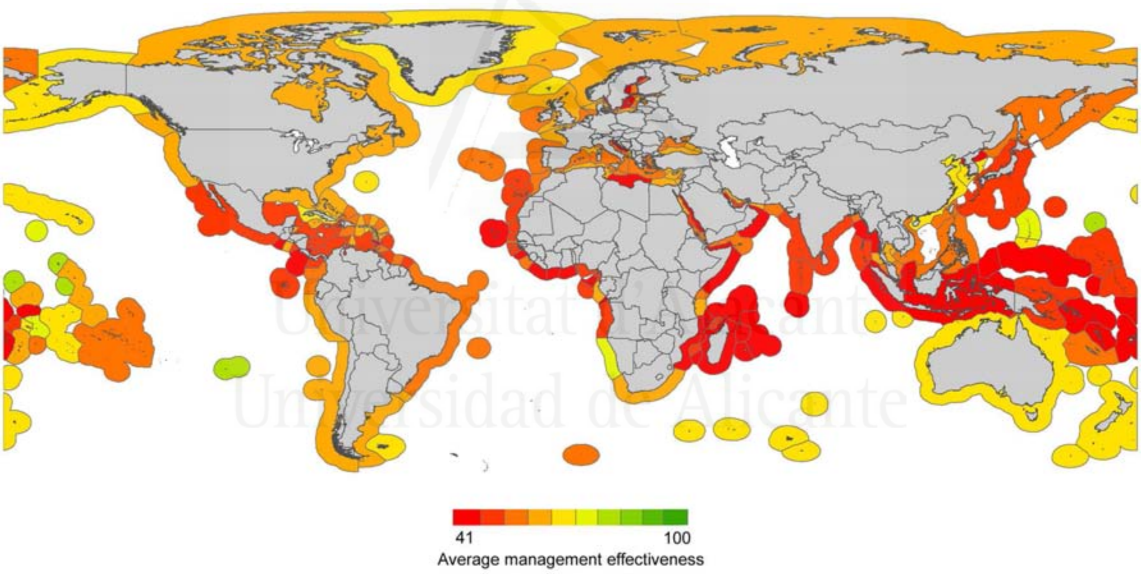


Figure 1.1. Overall management effectiveness of the world's EEZ. This map shows the average, for each surveyed area, of their scores on the scales of scientific robustness, policymaking transparency, implementation capability, fishing capacity, subsidies, and access to foreign fishing (Mora *et al.,* 2009).

This situation has played a significant role in promoting the need for new approaches to fisheries management. It is obvious that, because these problems are not being adequately resolved, many of the current management practices, measures and legal instruments controlling fisheries must be enhanced or re-evaluated and more management measures need to be applied.

1.2. Mediterranean Sea

The Mediterranean is a semi-enclosed marine area with generally narrow continental shelves. It covers an approximate area of 2.966 m illion km² (965000 sq mi), to which 461597 km ² correspond to the Black, Marmara and Azov seas. The area is connected with the Atlantic Ocean, the Black and Red Seas through narrow straits or channels that limit the exchange of water among the bodies of water they interconnect. The geomorphological structure of the Mediterranean is of great importance, it is divided into a western and an eastern basin by a sill at a depth of about 400m extending from Sicily to the North African coast (Fig. 1.2). With the exception of the Adriatic and Alboran Seas and the Gulfs of Lion and Gabes, in the rest of the areas the levels of biological production are considered low. The Mediterranean is globally considered as an oligotrophic sea (Estrada, 1996; Stergiou *et al.,* 1997a), with gradual decline in nutrient content as the water moves from west to east leads to an overall reduction in productivity. Despite this, there are local exceptions owing to incoming nutrients from rivers and from the Black Sea.

This sea has been linked to human activity for thousands of years. However, in the last decades, the increasing human pressure is threatening marine and coastal ecosystems. Problems such as pollution, eutrophication, degradation and fragmentation of habitats, and overfishing, are the main threats to marine resources in Mediterranean. Out of these factors mentioned, overfishing is considered the main factor causing the decline of marine living resources (Jackson *et al.,* 2001; Pauly *et al.,* 2002).

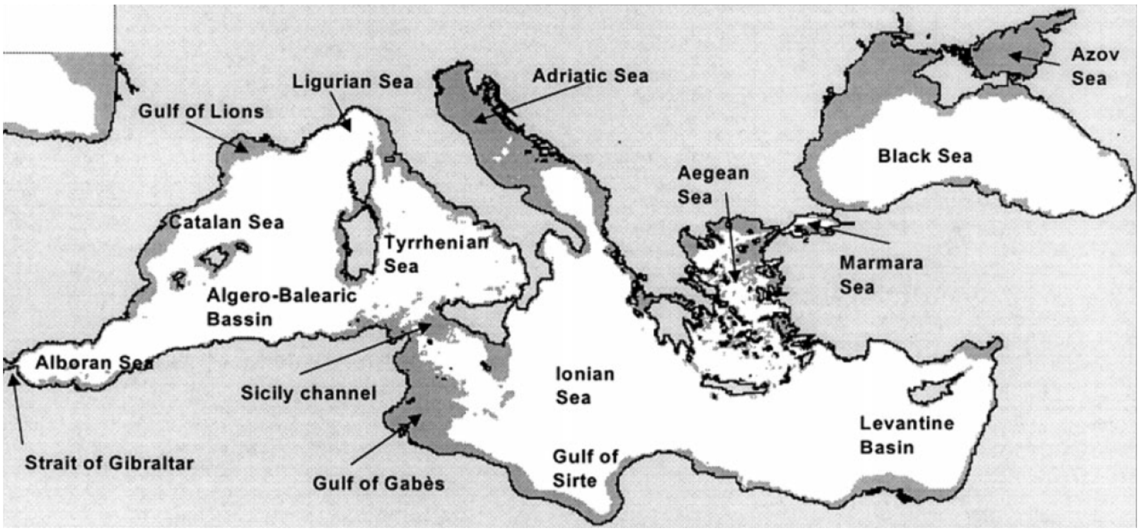


Figure 1.2. Map of the Mediterranean and Black Seas (Lleonart and Maynou, 2003).

1.3. Mediterranean fisheries

Mediterranean fisheries are multi-specific and offer a great variability of catches, according to their location and conditions, which reflect in landings with an average production around 1.5 million tonnes for the most recent years (FAO, 2011). Mediterranean fishing production represents an inconsiderable proportion of the world production, however, the average price of the products of Mediterranean fisheries, which are normally consumed fresh, are five to ten times higher than those in most other fisheries of the world. Besides, from the European point of view, Mediterranean is far from being negligible, since it is the third most important region for EU fisheries and represents almost 10% by weight and 35% by the value of the EU's fishery production (Eurostat, 2009).

The Mediterranean fisheries generally can be divided into coastal with artisanal gears, and deep fishing grounds, generally with trawlers and purse seiners. This can also be classified into pelagic and demersal, both with artisanal gears generally in coastal areas (e.g. trammel nets, long lines, and small towed gears) or purse seiners for pelagic resources and trawlers for deeper demersal resources (Farrugio *et al.,* 1993; Lleonart, 1990). The largest difference with other geographical areas is the absence of industrial fishing, except for tuna and tuna like species, with bigger vessels where the catches are processed (Demestre *et al.,* 1987; Martín, 1991). Mediterranean fisheries are dominated by small-scale vessels, distributed over a large number of fishing grounds in Mediterranean countries. Four main types of fisheries can be identified: (i) the industrial fishery for large pelagic fish, mainly tunas and swordfish, that is done by a number of highly sophisticated and powerful vessels using purse seines and longlines; (ii) a fishery for small pelagic fish, targeting mostly anchovy, sardine and sprat, carried out particularly by small to medium-sized purse seiners and pelagic trawlers; (iii) a multispecies demersal fishery, carried out by a plenty of small to medium-sized vessels that use a variety of gear types including trammel nets, gillnets, traps, pots, handlines, longlines and bottom trawls; and (iv) a fishery for deep-sea crustaceans (mostly deep-sea shrimps and Norway lobster) and fish (mostly hake), with a fleet of small to medium-sized bottom trawlers (FAO, 2011).

1.3.1. The fleet

The Mediterranean fleets can be categorized into three types: artisanal fleets "small scale fleets", industrial "large-scale" fleets and semi-industrial small trawling and seining fleets (Farrugio, 1996; Farrugio and Papaconstantinou, 1998; Lleonart *et al.,* 1998; Lleonart and Maynou, 2003). The term of small-scale fleet tends to present the use of a relatively small size gear and vessel. The term sometimes refers to the concept of low levels of technology and capital investment per fisher although that may not always be the case (Wilson and Delaney, 2005). In practice the definition varies between countries, from a one-man canoe in poor developing countries to more than 20m trawlers, seiners or long-liners in developed ones (e.g. in Northern Europe) (Garcia, 2009). Small scale or artisanal fisheries can be subsistence or commercial fisheries providing for local consumption or export (Garcia, 2009).

The term "industrial fleet" refers to large investments made by companies or financial groups. In the Mediterranean, it is mainly limited to the tuna fishery by large seiners and longliners. It is the only fishery where international fleets from non-Mediterranean countries, e.g. Japan and

Korea, who fish in the international waters, are engaged with the fleet of the Mediterranean border countries (Lleonart *et al.,* 1998; Lleonart and Maynou, 2003).

The "semi-industrial" fleet is a group that goes between the artisanal and the industrial fleet, but closer to an artisanal profile. It is mostly referred to trawlers, purse seiners and some longliners (Lleonart *et al.,* 1998; Lleonart and Maynou, 2003). Most of the trawlers could be classified as semi-industrial or industrial vessels, depending on the investment.

1.3.2. Exploited stocks

Mediterranean fisheries are multi-specific, including a very diverse fishery resources, with up to 100 species and categories recorded in landings in some areas. The exploited resources from Mediterranean fisheries can be classified into three main categories: small pelagic resources, large pelagic resources and demersal resources (Papaconstantinou and Farrugio, 2000; Lleonart and Maynou, 2003).

Small pelagic

Small pelagic resources present the main share (about 60%) in the total landings of the Mediterranean (Lleonart and Maynou, 2003). Most of the small pelagic species are dispersed mainly near the coast, over the continental shelf. Most of these species are migratory species that migrate in well-defined seasons, which explains the seasonality of their fisheries (Papaconstantinou and Farrugio, 2000). The purse seine and pelagic trawl are the gears used to catch small pelagics (Lleonart and Maynou, 2003). The most important small pelagic resources are: European anchovy *Engraulis encrasicolus*, European pilchard *Sardina pilchardus*, and sprat (European sprat) *Sprattus sprattus* and Black and Caspian Sea sprat *Clupeonella cultriventris*, those make up to 50–60% of total declared catch (Papaconstantinou and Farrugio, 2000; Lleonart and Maynou, 2003; FAO, 2011).

Large pelagic

Large pelagic resources refer mainly to the large migratory pelagic species. The Bluefin tuna and swordfish are the most important large pelagic species in the Mediterranean. They represent about 4-8% of the total declared landings but their economic value is away greater (Papaconstantinou and Farrugio, 2000; Lleonart and Maynou, 2003; FAO, 2011). The International Commission for the Conservation of Atlantic Tunas (ICCAT) is the organization responsible for the management of tuna and tuna-like species. It considers the Bluefin tuna for Eastern Atlantic and the Mediterranean as a si ngle stock that holds the main spawning areas (Lleonart and Maynou, 2003; FAO, 2011). The price of the Japanese market of Bluefin tunas *Thunnus thynnus* creates an intensive effort on this species. Swordfish *Xiphias gladius* comes in the second place as large pelagic species while Albacore *Thunnus alalunga* comes third (Lleonart and Maynou, 2003).

Demersal resources

Demersal resources consist of those species that live and feed close to the seabed. Fishing grounds of these resources are well-defined by fishermen. Depending on the target species, fishing is done with a specific gear type in a selected fishing ground. Demersal resources are mainly exploited by trawlers. Fishing grounds for trawlers are areas free from obstructions spread in rocky bottoms or mainly in the extended and homogeneous soft bottoms of continental shelves (Lleonart, 1990; Sánchez, 1991). The extension of the continental shelf implies that the exploited depth range from 50 to 800m, but mostly up to 400m (Papaconstantinou and Farrugio, 2000).

Demersal fishery targets a plenty of species and with many of high market value, which reflects the importance of this fishery (Bas, 2006). The demersal species represent about 30% of total reported catches in the Mediterranean and Black Sea (FAO, 2011). The most important of these are European hake *Merluccius merluccius*, red mullets *Mullus* spp., blue whiting *Micromesistius poutassou*, whiting *Merlangius merlangus*, anglerfishes *Lophius* spp., pandoras *Pagellus spp.*, bogue *Boops boops*, picarels *Spicara* spp., striped venus *Chamelea gallina*, octopus *Octopus* spp., cuttlefish *Sepia officinalis*, red shrimps *Aristeus antennatus*, Norway lobster *Nephrops norvegicus* and deep-water rose shrimp *Parapenaeus longirostris* (Papaconstantinou and Farrugio, 2000; Lleonart and Maynou, 2003; FAO, 2011). The multispecies nature of this catch complicates the design of management measures, as it requires a multispecies approach.

1.3.3. The state of the Mediterranean fisheries resources

According to fishery data by FAO, between 1950 and 1985 there was a worldwide increase in fish landings, however, in later years landings have remained constant despite technological advances, at about 90-100 million tonnes, due to depletion of traditional fishing grounds (mainly in the north Atlantic) (Pauly *et al.,* 2002). The Mediterranean was not apart of this process, indeed it is one of the most exploited marine areas with large traditional fishing practices. The situation of many fish stocks in the region is alarming. The quality of the catches has generally declined, both in terms of species composition and size of fish caught. Catch per unit effort (CPUE) has decreased dramatically when compared to decades ago, despite the fact that the power of fishing vessels has increased considerably over the same time period (UNEP/MAP, 2004). It has been argued that the Mediterranean fisheries have been reached to a kind of “an overfishing steady state” (Lleonart and Maynou, 2003).

The total catches in both the Mediterranean and Black Seas have been around 1.5 million tonnes in recent years (FAO, 2005; 2011). That's more than double the 700,000 tonnes landed in 1950, but is away less than the maximum 2 million tonnes reached between 1982 and 1988 (Fig. 1.3) (FAO, 2005; 2011). There is evidence that many important resources of the Mediterranean Sea are clearly overexploited (Aldebert *et al.,* 1993; Aldebert and Recasens, 1996; Lleonart *et al.,* 2003), or are subject to a non-optimal exploitation (Pertierra and Lleonart, 1996; Lleonart *et al.,* 2003). In general, the Mediterranean and Black Sea had 33% of assessed stocks fully exploited, while the great bulk (50%) overexploited (FAO, 2011; 2012). The situation varies between demersal and small pelagic fish. Almost all demersal fish and crustaceans stocks assessed were classified as overexploited. In contrast, about 70% of the small pelagic fish stocks were classified as fully exploited (FAO, 2011; 2012).

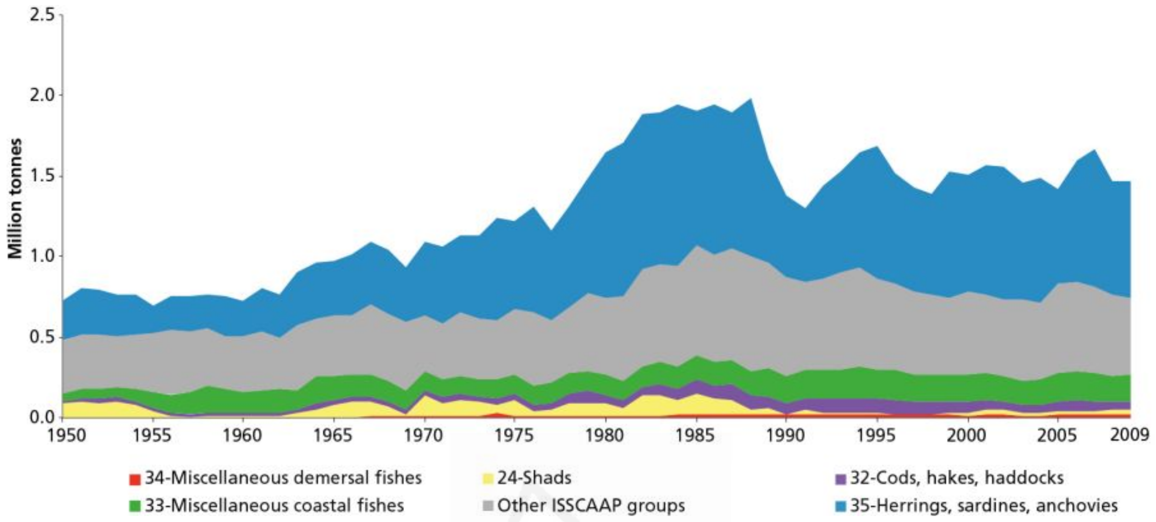


Figure 1.3. Total annual nominal catches from the Mediterranean and Black Seas from 1950 to 2009, grouped by major ISSCAAP groups (FAO, 2011).

1.3.4. Management peculiarities of Mediterranean fisheries (with focus on trawling fishery)

The analysis, assessment and management of Mediterranean fisheries have come across major difficulties and obstacles. The lack of information, widely distributed fleets dominated by small-scale vessels, the overcapacity of these fleets, a huge number of landing points, multispecies fisheries, and limited compliance and cooperation among countries in fisheries management are some of plenty serious difficulties for adequate fisheries management in the Mediterranean (FAO, 2011).

There are major difficulties in obtaining complementary and reliable data and information with reference to the global catches by species, groups and most characteristic species, as with regard to the evaluation of the exerted fishing effort. The catch data could be available in the

Mediterranean from fish markets and fishing guilds. However the quality of these data differs from country to another. Some countries or provinces can provide landing statistics by day and boat, while others by months and port (Lleonart *et al.*, 1998).

Furthermore, the peculiar "mentality" of the fishermen in the Mediterranean, especially small and medium scale fleets, makes the conduction of biological samplings, such as on board sampling of length and weight by an observer, much more difficult than on the Atlantic coast for instance. Moreover, most of fisheries resources are daily sold as fresh with high prices in Mediterranean markets. This makes, Mediterranean fishermen are very careful about the presentation, appearance and delivery of their catch, and refuse the handling of the fish by biologists (Lleonart *et al.*, 1998). Moreover, fishermen and those involved in resources exploitation lack the conviction and awareness of management regulations, and always try to avoid the control and to hide their actual catch as well as the real means to extract them (e.g. effort and characteristics of their gears).

Another difficulty comes from the interaction between foreign fleets from neighbour countries sharing the same fishing ground (e.g. Spain and France). Mediterranean countries have the juridical control of only the area within 12 miles from the coast. Still, a large surface of the Mediterranean is international water, which complicates the regulation of activities in international fishing grounds. The large number of countries involved in the management of the Mediterranean fisheries makes up another problem as so me of them are not subjected to European legislation and usually there is a lack of cooperation between them. The General Fisheries Commission for the Mediterranean (GFCM) is an international commission involving 24 countries and linked to FAO that can develop actions involving more than one country in the Mediterranean.

Furthermore, due to the multispecies nature of the Mediterranean fisheries and the large variety of landings, with up to 100 species and categories recorded in landings in some areas. The effort may be directed towards one or another target species during certain periods, depending on the level of catches obtained at that moment, the respective strength of recruitment and on the price of target species in the market, closely corresponding to the concept of “métier” (Biseau, 1998; Pelletier and Ferraris, 2000; EC, 2009). Where a “métier” is defined as: a group of fishing operations targeting a similar (assemblage of) species, using similar gear, during the same period of the year and/or within the same area and which are characterised by a similar exploitation pattern (EC, 2008). These characteristics increase the heterogeneity of the fishery and, under such circumstances, the evaluation of fishing effort; monitoring and management of fisheries are complicated.

Moreover, the socio-economic situation differs among countries of the Mediterraneanmaking the concept of globality more difficult. In turn, the high socio-economic pressure excreted on the fishery activity, prevents to a large extent setting up the necessary restrictive measures which are needed to improve the existing situation of the resources.

Owing to all the previous reasons, some management measures are not applicable solutions for the management of Mediterranean fisheries. This gives the Mediterranean fisheries a particular characteristic in their management than other regions. For instance, the system of TAC and quotas is not a viable option in the Mediterranean Sea, where the control and surveillance is difficult to carry out, because of the wide variety of species characterizing Mediterranean fisheries (Lleonart and Recasens, 1996).

1.4. The current management measures for the Mediterranean fisheries

In the Mediterranean, the overall management of all fisheries is done in the framework of the GFCM. The fisheries of the EU countries are managed according to the Common Fisheries Policy (CFP) of the EU. In most cases for the Mediterranean, this policy is harmonized with the GFCM policy. Non-EU countries define their own fisheries management measures, although most of them try to ensure they are compatible with GFCM regulations (FAO, 2011). This makes it difficult to introduce the concept of globality in the Mediterranean; this could be due to the different socio-economic situations in each country and their respective local administrations that have to put the GFCM recommendations into practice.

The CFP uses three types of fishing management tools, separately or in combination:

1. Fishing effort limitations - restrict the size of the fleet that sets to sea and the amount of time that it can spend fishing (e.g. fishing effort).
2. Catch limits - restrict the quantity of fish that can be taken from the sea before fishers need to stop fishing (e.g. TACs and quotas).
3. Technical measures - regulate how and where fishers can fish. They can, for example, be used to protect young fish (juveniles), encourage the use of more selective fishing gear or prevent serious damage to the marine environment (e.g. modification of codend mesh size or shape).

The management of the Mediterranean fisheries is mainly based on effort control. The system of TAC and quotas is not a viable option in the Mediterranean Sea because of the multi-species characteristics of Mediterranean fisheries and it is only applied to Bluefin tuna. Other technical measures are also implemented in combination with effort control, but not always enforced, and in all cases they are lower than in the Atlantic (Papaconstantinou and Farrugio, 2000; Alemany and Alvarez, 2003; Lleonart and Maynou, 2003).

Management measures in the Mediterranean are divided into two main categories: core measures are those designed to act directly on the intended goal, while subsidiary measures are those supplementing the core measures to strengthen their effectiveness.

1.4.1. Core measures

Limitation of fishing effort and fishing capacity

This is the oldest and most commonly used measure in the Mediterranean. Fish mortality is usually proportional to the fishing effort and therefore reducing fishing effort is a good measure to preserve the marine resources, not only for target species, but also for the by-catch and discarded species (Lleonart and Recasens, 1996). Fishing effort can be limited by different strategies. The objective is trying to reduce the pressure on fish stocks by limiting the overall size of the fleet as well as the amount of time that the fleet can spend fishing, this includes: limiting the number of vessels (fishing license), limiting fishing capacity (total and individual power), and limiting the fishing time (days in a week or hours in a day) (Lleonart and Recasens, 1996; Cacaud, 2005).

Regarding to fishing capacity limitation, this can result in insufficient regulation; for example, a vessel cannot increase its power but can improve the electronic tools for the detection of schools of fish or optimize its fishing gear etc., which results in the increase of possible catch (Lleonart and Recasens, 1996). However, in many cases the maximum engine power permitted is not achieved (Farrugio *et al.,* 1993; Sánchez-Lizaso, 2002). In recent decades the trawler fleet was clearly oversized, particularly with reference to engine power. Undoubtedly, the engine power over 1000 hp cannot be justified in the Mediterranean coastal fisheries, which happens in many trawling fleets of the western Mediterranean.

1.4.2. The main subsidiary measures

Fishing gears restrictions

Regulation of fishing gears and methods is a common measure of fisheries legislation in Mediterranean. This measure is designed to prevent fishers from using particularly destructive gears or methods (Lleonart and Recasens, 1996; Cacaud, 2005). Specifications of authorized gears (e.g. mesh size, length) and conditions of their use (e.g. area of use, time of use, depth) are often regulated (Lleonart and Recasens, 1996; Cacaud, 2005). Modification into more selective or less aggressive fishing practices can yield good results. The modification of mesh sizes, either by increase the size or modify the shape, is an important measure for trawl regulation, since the smallest mesh sizes for trawls in the world were found in the Mediterranean (Lleonart and Recasens, 1996).

Closed season and temporary suspension

An important way of limiting effort is linked to use temporary or seasonal closure with periods set up according to the different species characteristics. This management strategy is mainly based on effort control, to reduce fishing intensity. Seasonal closures may be used to protect target stocks from mortality at a specific stage of the life history, such as when a species aggregates in an area or in a specific season to spawn (Horwood *et al.,* 1998; Dinmore *et al.,* 2003). It also can help reproductive success and support recruitment (Arendse *et al.,* 2007), hence, assisting in the sustainability of fishery resources. However, in some cases the reasons for adopting this measure are based on economic factors than biological ones (Lleonart and Recasens, 1996). From the economic perspective, a closure should mean financial compensation arising from the recovery of stocks, fishing is less now, to catch more after. It may have short-term benefits to the fisherman: the first benefit arises from the reduction of operating costs, another financial compensation arising from the recovery of stocks and, the third benefit derived from compensation income (in case the administration funds the closure) (Lleonart and Franquesa, 1999).

Prohibited fishing areas and marine reserves

Closed fishing grounds are used in many countries to protect areas closest to the coast from trawling with the objective of conserving seabeds and nurseries by designating prohibited fishing areas, e.g. closing certain areas to fishing or to prohibit the use of a specific gear(s) or method(s) in a specified area or areas or at certain depths (Lleonart and Recasens, 1996; Cacaud, 2005). Surveillance is not always easy and illegal fishing in these shallow waters yield high profits. Some artificial reefs may be also used to ensure the protection against trawling.

Marine Protected Areas (MPAs) are a particular kind of areas closed to fishing that have been suggested as complementary management tools for the conservation of the marine living resources and biodiversity. In multi-specific fisheries, like Mediterranean trawling fisheries, where the existence of multi-target species prevents managers from applying single-species stock assessment techniques, MPAs could be one of the most effective tools (Badalamenti *et al.*, 2000).

Minimum landing sizes

Minimum landing sizes for fish species and other aquatic organisms are often set to prevent the capture of juvenile fish or non-fish species and allow sufficient time for fish and the other species to mature and thus reproduce (Cacaud, 2005).

1.5. Trawling fishery in Alicante Gulf and the current management

The Alicante Gulf (SE Spain) supports an important fishing activity, comprising up to 10% of the Spanish Mediterranean fleet, which annually land up to 20000 tonnes (García-Rodríguez *et al.,* 2006). The wide expanse of the continental shelf in this area has favoured the trawling fishery, the development of a large fleet, which operate in muddy and sandy continental shelf and slope between 50 and 800 meters depth. Furthermore, landings are daily sold to intermediaries at each local port in the fish market "lonja" under the supervision of the fishing guild, which facilitates the monitoring of daily landings by vessels. Trawling fleet in the area is representative of Spanish Mediterranean trawling fleets. Currently, it is the second most important fleet in terms of the landings, after the purse-seine fleet, providing around 40% of the annual landings in this area (García-Rodríguez *et al.,* 2006). The trawling fleet is the largest in terms of vessels number, with 109 trawlers distributed in 12 ports (from Dénia to Torrevieja), and in terms of vessel length and engine power (BOE, 2013). They are characterised by the semi-industrial scale of their operations, each fishing fleet is based in one port where they usually return every day or within a few days. Like other Mediterranean trawling fleets, their activities are carried out in well delimited, by fishermen, fishing grounds that are selected according to the target species, and that are generally controlled by the fishing fleet from the closest port (Demestre *et al.,* 2000).

The Spanish Mediterranean trawling fisheries are controlled at national and regional levels, both subjected to the European legislation: coastal waters are regulated by the regional government and external waters, which encompass the trawl fisheries, are controlled by the national government. The main regulations comprise a limitation of 12 fishing hours per day from Monday to Friday, a maximum horse power of 500 HP, a minimum landing size of most commercial species, the implementation of seasonal closure (usually one month per year), and finally improving selectivity by setting a minimum 50-mm diamond-mesh or 40-mm square-mesh in trawlers codend instead of the traditionally used 40- mm diamond-mesh. However, the enforcement of fishery regulation in the Mediterranean fishery, including our case of study, is not always achieved, and some of the restrictions are not fulfilled, like the maximum hp permitted (Farrugio *et al.,* 1993; Sánchez Lizaso, 2002). Others are not based on scientific bases, such as the time scheduling of the seasonal closure, while it is agreed upon by fishermen in each port or community.

1.6. Justification and objectives of the study

Trawling fisheries traditionally represent an important share of the fisheries sector in the Mediterranean and their considerable role in the region has long been recognized. They are characterized by a great diversity of valuable resources. This is why there is a genuine and widespread interest in securing their sustainable development in the whole region. However, they have a high environmental impact as well as a high contribution to the unsustainable development of marine ecosystems and resources.

In the context of fisheries management in the Mediterranean, the demersal resources remain the most attention-worthy stocks, since all demersal stocks assessed were considered as overexploited and due to their highly economic importance. The trawling fisheries stand out with greater importance due to their higher contribution of demersal catches compared to artisanal fisheries and due their unselective and multispecies characteristics that hinder the use of single-species stock management techniques. Therefore, most of the regulations concerning the management of demersal fisheries have been developed for trawling (Lleonart and Maynou, 2003).

Moreover, there is a lack of information of the actual and real benefits of some management measures applied in trawling fisheries in the Mediterranean. Some of these regulations were adopted by the European Union and the GFCM based on experimental studies without verifying the consequences and the predictions of these studies after their implementation (e.g. mesh size or shape modification). Other measures were adopted with little theoretical justification (e.g. temporal closures in case of trawling). The effectiveness of temporal closure as a management strategy depends on the biology of the target species and the dynamics of the fishery. For the case of trawling fisheries, especially in multi-species fisheries such as Mediterranean Sea, the biological justification is not clear.

In the light of all above, and given these reasons, the management measures and regulations should be re-evaluated within the current fishery activities in biological and economical terms, to assess their effectiveness of being able to bring about an improvement in the state of the exploited resources.

Moreover, due to the diversity of both the characteristics of fleet and the catch composition in Mediterranean trawling fisheries, the GFCM has stressed on direct control of fishing capacity and effort instead on the catch. Understanding how the fishing effort of trawls is distributed among the various métiers and the specific details of each one is valuable for the management of multi-specific fisheries. This help to understand how fishers adapt their behaviour under changeable management strategies and to evaluate these regulations correctly taking into account the characteristics of each métier.

It has been well documented, that catch and effort data from commercial fisheries provide one of the most readily available cost-effective sources of information to assess the condition of exploited stocks (Gavaris, 1980; Kimura, 1981; Fox and Starr, 1996). In response to the need of fisheries statistics, long-time series of landings and effort data of 10 years (2002 to 2011) were collected from the fishing guilds of three trawling ports Dénia, Xàbia and La Vila Joiosa in the SW Mediterranean Sea. Based on these registration data, this thesis seeks to understand and evaluate the effectiveness of some management measures employed in the area of study.

Therefore, the specific objectives of this study were:

1. Provide an overview of the trawling fishery by describing fishing effort and their patterns of use, the structure of the fleet, the long-term evolution of fishing effort, landings, income and catch composition of the three ports in the period of the study (2002-2011).
2. Grouping by multivariate techniques, the daily landings of vessels during the period of study (2002-2011) by defining specific catch composition and assign these types to fishing tactics or métiers.
3. Analyse the temporal (annual and monthly) distribution of fishing effort between métiers and the long-term trends in effort based on the use of specific métiers in the study area.
4. Determine the effects of implementing a seasonal closure at different seasons of the year on total landings and landings of the main target species, in biologic and economic terms.
5. Analyse the short-term effect of selectivity change and evaluate the consequences of inserting either a 40-mm square-mesh codend or a 50-mm diamond-mesh (instead of the traditionally 40-mm diamond-mesh codend) in the trawling fishery of the fleet under study.
6. Analyse the daily evolution of average price since the reduction of one day per week will be a possible alternative to seasonal closures.

Chapter 2: Trawling fishery of the western Mediterranean

Abstract

Due to the diversity of fleet characteristics and catch composition in Mediterranean fisheries, the General Fisheries Commission for the Mediterranean has placed emphasis on the direct control of fishing capacity and effort rather than catch limitation. This paper aims to analyse the evolution of fishing effort, landings and métiers in three trawling ports of the western Mediterranean between 2002 a nd 2011. F our métiers were identified, using multivariate techniques, in the fishery: Red mullet, European hake, Norway lobster and Red shrimp. The mean catch composition within the same métier was similar between ports, although the relative importance of species differed slightly from one port to another. Variation in fishing effort exerted was observed between métiers reflecting differences in the importance and usage of each métier by port. Temporal variations were found among different métiers at seasonal and annual scales. These temporal variations showed that métiers Red mullet and European hake were alternated. Positive significant correlations were observed between landings and different fishing effort variables with an exception of the relation between landings and engine power in the Norway lobster métier with negative significant correlations. Significant differences in total vessel length, gross tonnage, total CPUE and total income were detected among the four métiers depending on each port with few exceptions. These findings are considered a keystone for more practical implications and to assist fisheries' managers in the decision-making process. As demonstrated in the current paper, the management of multi-specific fisheries should start off considering the characteristics of each métier separately. In the sound of métier-based management, the patterns observed in the effort temporal distribution between métiers can indicate the most suitable time to reduce effort on specific target species.

Keywords: Effort distribution, métiers, multi-species trawl fishery, western Mediterranean.

2.1. Introduction

For many reasons multi-species and multi-gear fisheries (e.g. Mediterranean fisheries) present an immensely more difficult challenge for fisheries management than single-species fisheries (Ulrich *et al.,* 2012). Mediterranean trawl fisheries are multi-specific, with up to 100 species and categories recorded in landings in some areas (Massutí *et al.,* 1996; Caddy, 2009). In Mediterranean trawl fisheries, where some of the target species suffer from overfishing (FAO, 2011; Colloca *et al.,* 2013), the effort may be directed towards one or another target species during certain periods, depending on the level of catches obtained at that moment, the respective strength of recruitment and on the price of target species in the market (Oliver, 1993). These characteristics increase the heterogeneity of the fishery and complicate assessment, monitoring and management of the sector (Biseau, 1998). In such management framework, the fishing activity of a given fleet segment in a given area needs to be disaggregated into sub-segments that define specific activities in time, space and catch opportunities closely corresponding to the concept of "métier" (Biseau, 1998; Pelletier and Ferraris, 2000; EC, 2009). Where a "métier" is defined as: a group of fishing operations targeting a similar (assemblage of) species, using similar gear, during the same period of the year and/or within the same area and which are characterised by a similar exploitation pattern (EC, 2008). Usually, the identification of a métier is based on the analysis of the species' composition of large catch datasets, which are available from logbooks or landings data (e.g. Holley and Marchal, 2004; Ulrich and Andersen, 2004; Forcada *et al.,* 2010). This approach consists of conducting multivariate analyses on species' composition in catch data by day or fishing operation, referred to as landings profiles, then associate similar profiles into métiers. This grouping can be performed by direct visual inspection (Biseau and Gondeaux, 1988; Laurec *et al.,* 1991) or statistically through cluster analysis.

Measures to regulate fishing effort are the main measures used for the management of multi-specific fisheries, such as Mediterranean fisheries, in combination with other technical measures, i.e. minimum mesh and landing size or spatio-temporal closures. Due to the diversity of both the characteristics of fleet and the catch composition, the General Fisheries Commission for the Mediterranean (GFCM) has placed emphasis on the direct control of fishing capacity and effort rather than catch limitation as an effective way to reduce fishing mortality (Alemany and Álvarez, 2003). In this context, effort information is needed to interpret changes in the fishery. Understanding how the fishing effort of trawls is distributed among the different métiers and the specific details of each one is valuable for the management of multi-specific fisheries. This can help to improve assessment of alternative management measures and select appropriate and valid management strategies (Salas and Gaertner, 2004).

The Alicante Gulf (SE Spain) supports an important fishing activity, comprising up to 10% of the Spanish Mediterranean fleet, which annually land up to 20000 tonnes (García-Rodríguez *et al.,* 2006). The wide expanse of the continental shelf in this area has favoured the trawling fishery, the development of a large fleet, which operate in muddy and sandy continental shelf and slope between 50 and 800 meters depth. Furthermore, landings are daily sold to intermediaries at each local port in the fish market “lonja” under the supervision of the fishing guild, which facilitates the monitoring of daily landings by vessels. Trawling fleet in the area is the second most important fleet in terms of the landings, after the purse-seine fleet, providing around 40% of the annual landings in this area (García-Rodríguez *et al.,* 2006). The trawling fleet is the largest in terms of number of vessels, with 109 trawlers distributed in 12 ports (from Dénia to Torrevieja), and in terms of vessel length and engine power (BOE, 2013). Vessels are characterised by the semi-industrial scale of their operations, and each fishing fleet is based in one port where vessels usually return every day or within a few days. Like other Mediterranean trawling fleets, their activities are carried out in well determined fishing grounds that are selected by fishermen according to the target assemblages of species. Generally these fishing grounds are controlled by the fishing fleet of the nearest port (Demestre *et al.,* 2000).

Taking into account the difficulty of obtaining data from Mediterranean fisheries and in response to the need of fisheries statistics, long-time series of landings and effort are very valuable in providing information on changes in the fishery. Therefore, landing and effort data of 10 years (2002 to 2011) in three representative western Mediterranean trawling ports (Dénia, Xàbia and La Vila Joiosa) were collected to provide information on landings, effort and métiers in the fishery that can benefit management decisions. For this: (a) the structure of the fleet, the evolution of fishing effort and landings were evaluated for each port; (b) the main métiers in the fishery were identified and examined according to their activity patterns, catch and income profiles; (c) distribution of fishing effort among métiers and the trends in effort were assessed based on the use of specific métiers in the study area; and finally, (d) relations between total landings (also by métier) and different fishing effort variables were analysed. This will serve as a keystone for more practical implications such as assessment of the applied management measures.

2.2. Material and methods

2.2.1. Study area

This study was conducted in three trawling ports, Dénia, Xàbia and La Vila Joiosa, located in the south-western Mediterranean Sea off the coasts of Spain (Fig. 2.1). Along the gulf of Alicante, there are 12 f ishing ports from Dénia to Torrevieja that have traditionally been locations of an important fishing activity. According to the number of trawlers, these three ports are important as they account for about 46% of the total trawlers operating on the Alicante coast (about 7.5% of the total Spanish trawlers in the Mediterranean coast) (BOE, 2013). The Mediterranean trawl fishery in Spain is an input-controlled fishery where effort is controlled by limiting the time at sea: fishing is permitted for 12 hours/day from Monday to Friday, stopping the fishing activity completely on weekends (Maynou *et al.,* 2006). The fishing activity is ceased normally a month by year as a seasonal closures, alternating the North ports (e.g. Dénia and Xàbia) with the south ports (e.g. La Vila Joiosa) to avoid the closure of the whole gulf at once. However, closure is not applied in the same months every year, but mostly applied in May, June, July and September (Samy-Kamal *et al.,* submitted). Other technical measures are applied such as prohibiting activity on bot toms shallower than 50m, and limiting of vessel nominal engine power to maximum of 500 HP. In addition, to improve the selectivity of gears, all trawlers have changed to either a 40-mm square-mesh codend or a 50-mm diamond-mesh (instead of the traditional 40-mm diamond-mesh codend) (EC, 2006; Samy-Kamal *et al.,* in press).

2.2.2. Data collection

Data records of daily auctions were obtained from the fishing guild of each port for years 2002 to 2011. For each fishing day, data on species landing weight (kg) and first sale value (€) were available by vessel. Data were arranged in a t wo-way matrix of daily landings per vessel as samples (rows) and species landed as variables (columns). Vessels with sporadic landings events within the ports were excluded from the analysis, considering only those vessels registered in the studied ports (home port) to avoid possible biases in the data. Most of the included set of vessels have had activity throughout the period considered.

Technical characteristics of vessels within analysis were obtained from the Census of Fleet of the General Secretariat of Maritime Fisheries of Spain (BOE, 2013). Vessel features considered in the analysis were: total vessel length (TL), relative gross tonnage (GRT) and tonnage (GT). In many ports of the western Mediterranean the registered vessel power is known to depart from real values as vessel power is regulated (Goñi *et al.,* 1999; Sánchez Lizaso, 2002). However, it has been also included to give a general idea of the capacity of the fleet. Both databases, landings and vessels characteristics, were crossed to conduct the analysis.

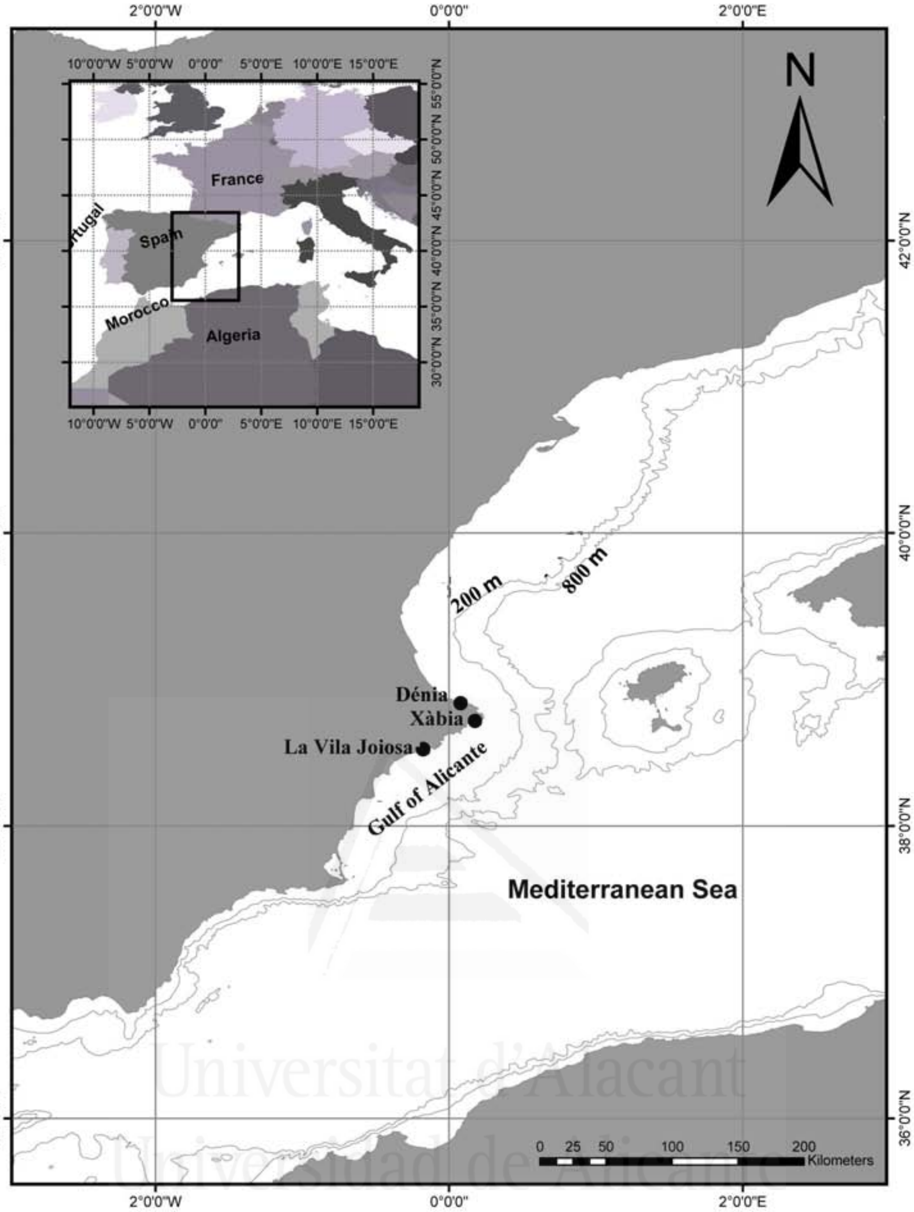


Figure 2.1. Map of the study area (SW Mediterranean) showing the location of the three trawling ports La Vila Joiosa, Xàbia and Dénia (Spain).

2.2.3. Data analysis

2.2.3.1. Description of fleet and temporal changes

In this paper, the fishing effort was defined by six variables: number of vessels, fishing days, TL, GT, GRT, and engine power (HP). Landings (catch) were defined by biomass (landings weight) and income (first sell value), total and by species (Fig. 2.2). An exploratory analysis of fleet data was performed to describe the structure of the fleet (by TL, GT, GRT and HP) at each port. To analyse temporal evolution of the fishing effort (for the total fleet and by port) at a year scale, number of vessels, fishing days (within this paper, the term fishing days refers to fishing days per vessel), TL and total GT were used. Additionally, for the total fleet mean HP and mean GT were analysed also to explore effort trends over years. To analyse the possible seasonality (within year) in each port of total fishing effort, as well of effort for each métier (later), the mean number of fishing days for each month were calculated, considering all months including those in management based temporal closures occurred. Moreover, the temporal evolution (for the total fleet and by port) of total landings and Catch per Unit Effort (CPUE), in terms of biomass and income, were evaluated for the10 years studied (2002-2011).

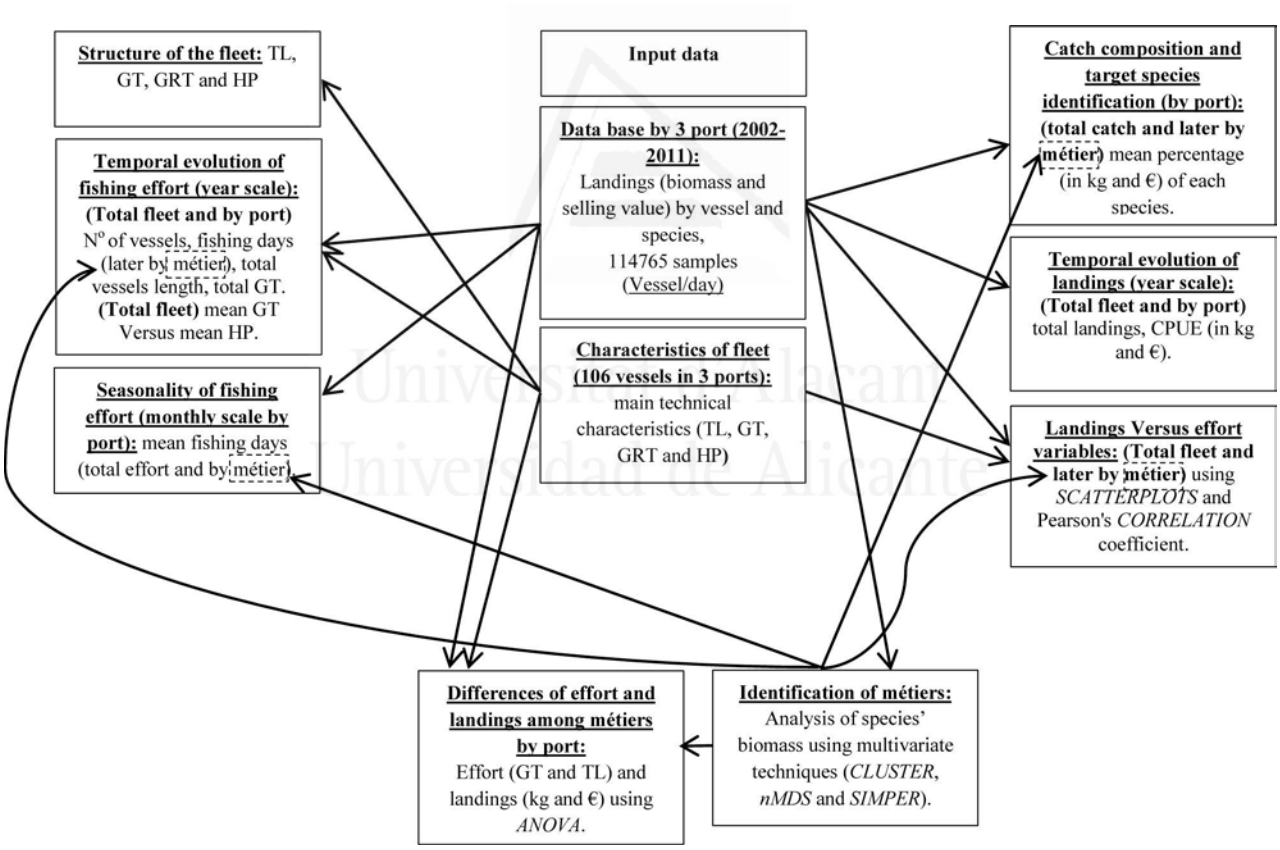


Figure 2.2. Flow chart shows the data used and presents the general scheme of the analysis. Total length (TL), relative gross tonnage (GRT), gross tonnage (GT) and engine power (HP).

2.2.3.2. Identification, description and temporal distribution of métiers

The target species of each métier in the fishery were first determined by their relative importance in each port, given as the percentage of biomass and income for each species in the total catch. As the three fleets are using the same fishing gear (trawling) and sharing the same fishing ground (gulf of Alicante) the definition of métiers was named (informally) after the main target species to simplify the interpretation. Multivariate techniques (cluster, nMDS and SIMPER, later described in detail) were used to determine catch profiles and to link it back to the vessels by assigning each of the samples (vessel·day^{-1}) with their characteristics to one of the métiers. Non-parametric approaches were applied combining non-metric multi-dimensional scaling (nMDS) and hierarchical cluster (Clarke, 1993; Clarke and Warwick, 2001), to assess differences in the biomass of the catch composition among samples (vessel·day^{-1}). Through an iterative process, groups of samples were identified in the cluster with similarity levels between 20% and 45%. The resulting clusters were overlaid on the nMDS ordination. Once groups were identified, the Similarity Percentage Analysis (SIMPER) routine, included in PRIMER v6 software (Clarke and Gorley, 2006), was used to recognise the main species characterising each group of samples by weight and income, and thereby identify the métier. The whole amount of data (114765 daily samples), even annual data, did not fit (at once) into the PRIMER software (it has been already tested), even if it did, the result of cluster and nMDS would be impossible to interpret. Hence, due to the large amount of data, and for more precise identification, this process was made in a monthly base. Therefore, this process was repeated 330 times (11 months · 10 years · 3 ports).

Analysis of Variance (ANOVA) was used to test for significant differences in total length, gross tonnage, total biomass and total income between the identified métiers within each port, and between ports within each métier (Underwood, 1997). When the ANOVA F-test was significant, post hoc analyses were conducted using Student-Newman-Keuls (SNK) multiple comparisons (Underwood, 1981). Before (ANOVA) analysis, Bartlett's test was used to test for homogeneity of variance (Sokal and Rohlf, 1969). When significant heterogeneity was found, the data were transformed by √(x + 1) or ln(x + 1). When transformations did not remove heterogeneity, analyses were performed on the untransformed data, with the F-test α-value set at 0.01, since ANOVA is more restricted to departures from this assumption, especially when the design is balanced and contains a large number of samples/treatments (Underwood, 1997). ANOVA was conducted by R statistical computing software (R Development Core Team, 2010) and the R’s package GAD (Sandrini-Neto and Camargo, 2011). The experimental design consisted of two factors: *Métier* (4 levels, fixed) and *Port* (3 levels, fixed and orthogonal), while an even number of samples were randomly selected to maintain our balanced data within each level of the factors considered in the experimental design. Therefore, with n = 988 replicates for each level, there were a total of 11856 observations.

Finally, the mean percentage and CPUE for each species was used to identify the main species (catch composition) characterising each métier by port in terms of both biomass and market value.

2.2.3.3. Relationship between "effort" and "landings" overall, and broken down by métier

To explore the relationship between landings (total and also for each métier) and different fishing effort variables (TL, GT, and HP), scatterplots and Pearson's product moment correlation coefficient were used. The significance of each correlation coefficient was tested by mean of Student’s t-Tests.

2.3. Results

2.3.1. Description of fleet and temporal changes

Over the 10 years studied a total of 106 different fishing vessels were listed in the official fleet register of Dénia, Xàbia and La Vila Joiosa (34, 13 and 59 vessels respectively). The bulk of the fleet is composed of vessels up to 23-25 m length, 40-80 GT, 40-60 GRT and 200-400 registered HP (Fig. 2.3). On average, vessels based in Xàbia were bigger (length, GT and HP) than those in La Vila Joiosa and Dénia. Mean GRT of La Vila Joiosa fleet however, was slightly higher.

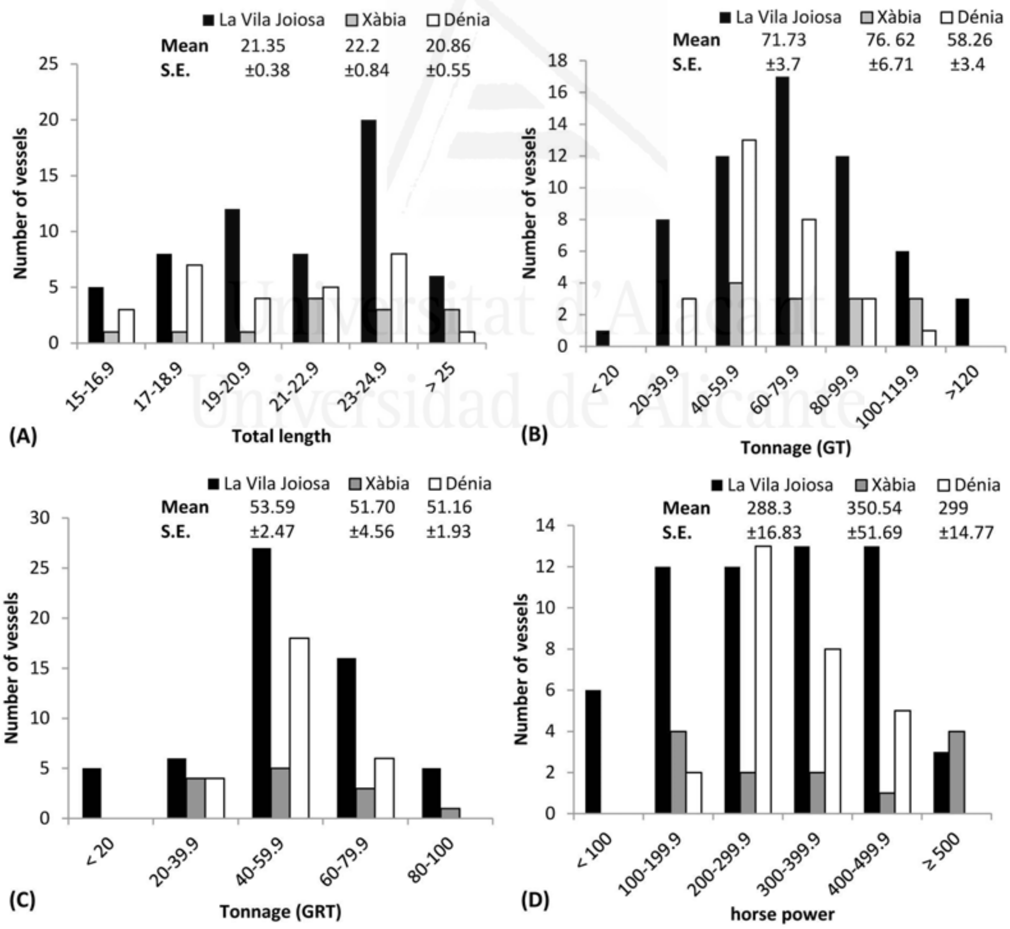


Figure 2.3. Structure of the trawling fleets of La Vila Joiosa, Xàbia and Dénia by (A) vessel length, (B) gross tonnage (C) relative gross tonnage and (D) horse power. Mean characteristics and standard error are shown under the legend.

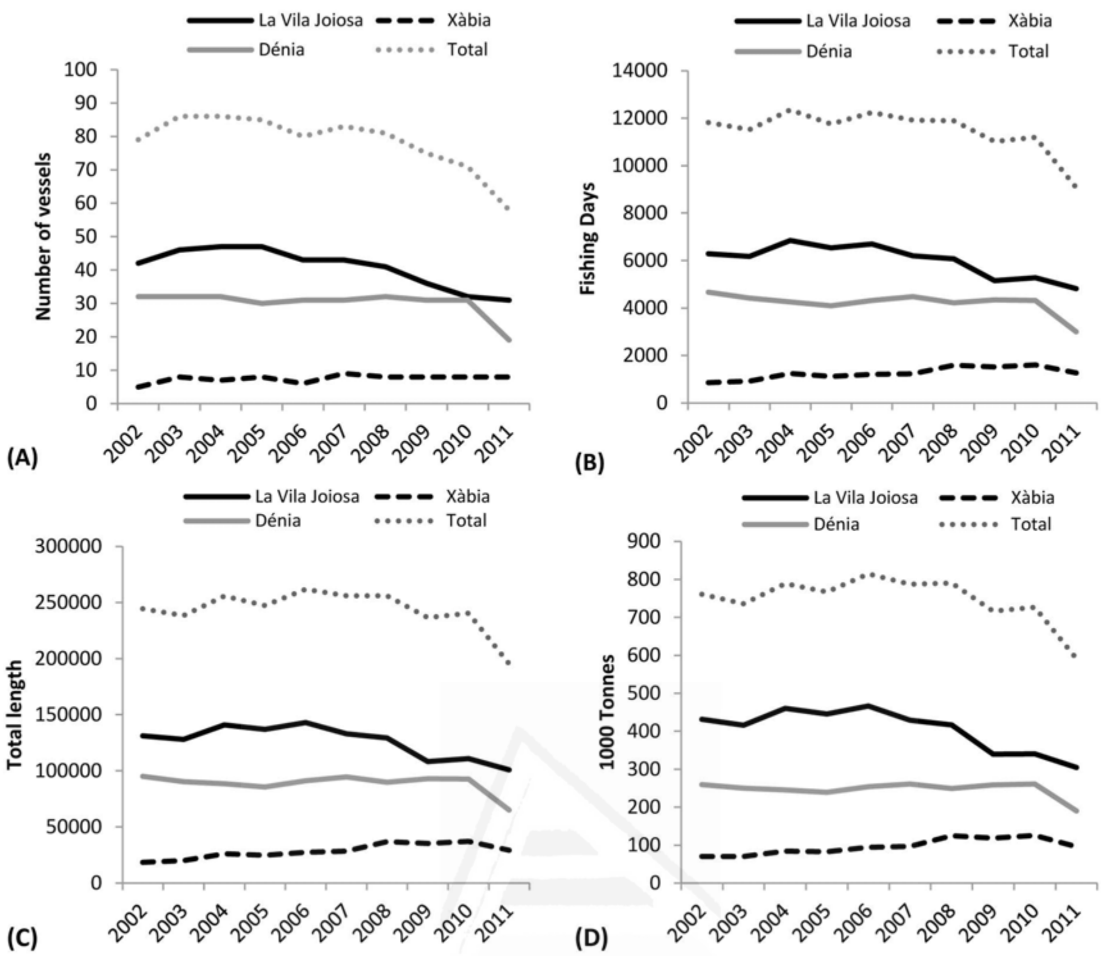


Figure 2.4. Temporal evolution of the fishing effort of the trawling fleets in La Vila Joiosa, Xàbia and Dénia over the period of study expressed as: (A) number of vessels, (B) total fishing days (fishing days per vessel), (C) total length of vessels and (D) total gross tonnage.

The number of active vessels declined over the study period, from 86 vessels in 2002 to 58 vessels in 2011 (Fig. 2.4A). The decline is mainly attributable to the fleet of La Vila Joiosa that showed a gradual decline over time, while vessels in Dénia made up substantial decline in 2011. The number of fishing days over the 10 years showed a slight decrease in both La Vila Joiosa and Dénia. Fishing days in Xàbia were consistent with the number of vessels (Fig. 2.4B). The number of fishing days mirror the trends observed in vessel numbers, including the 2011 decline. The evolution of another two measures of effort capacity, the TL and the total GT, indicate the same gradual decreases (Fig. 2.4C and D). Horsepower and total GT means vary throughout the period (Fig. 2.5), with an overall decrease. Fleet activity is regular throughout most of the year, with a slight peak in August (Fig. 2.6). However, during May, June, July and September, less fishing days were observed coinciding with timing of temporal closure.

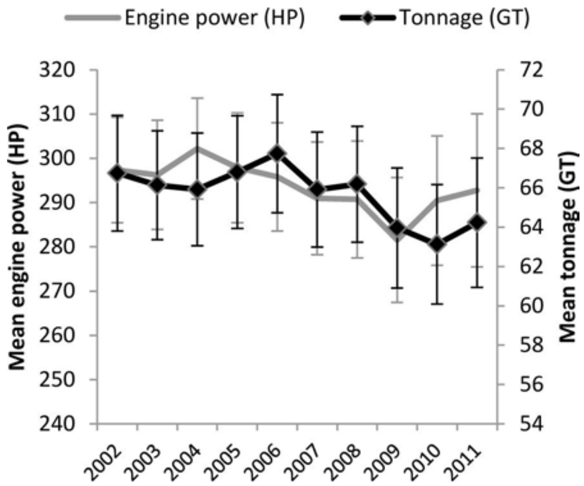


Figure 2.5. For the total fleet annual change in both (GT) and (HP) means over 10 years of study (2002-2011). Error bars show the standard error.

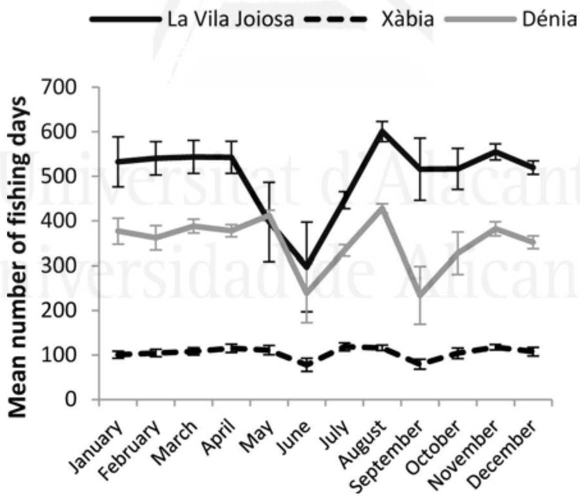


Figure 2.6. Monthly trend of mean fishing days (fishing day per vessel) of the trawling fleets of La Vila Joiosa, Xàbia and Dénia over 10 years of study (2002-2011). Error bars show the standard error.

Over the 10 years, the total landings ranged around 2400 tonnes annually, except in 2006 and 2007 when landings increased appreciably up to 3000 tonnes (Fig. 2.7A). This increase is mainly attributable to the ports of La Vila Joiosa and Dénia. Landings in Xàbia increased slowly over the 10 years in a steady way. Disparity in landings occurs between the three ports, the majority (62%) originates from La Vila Joiosa, while Dénia and Xàbia contribute far lower values (27% and 11% respectively). Income at the three ports sustained the same trend (Fig. 2.7B). The trends of CPUE were quite similar to the previous trend, in addition to a sudden increase in 2011 in both biological and economic terms (Fig. 2.7C and D). Nevertheless, CPUE along the studied period was apparently higher in La Vila Joiosa, followed by Xàbia and Dénia.

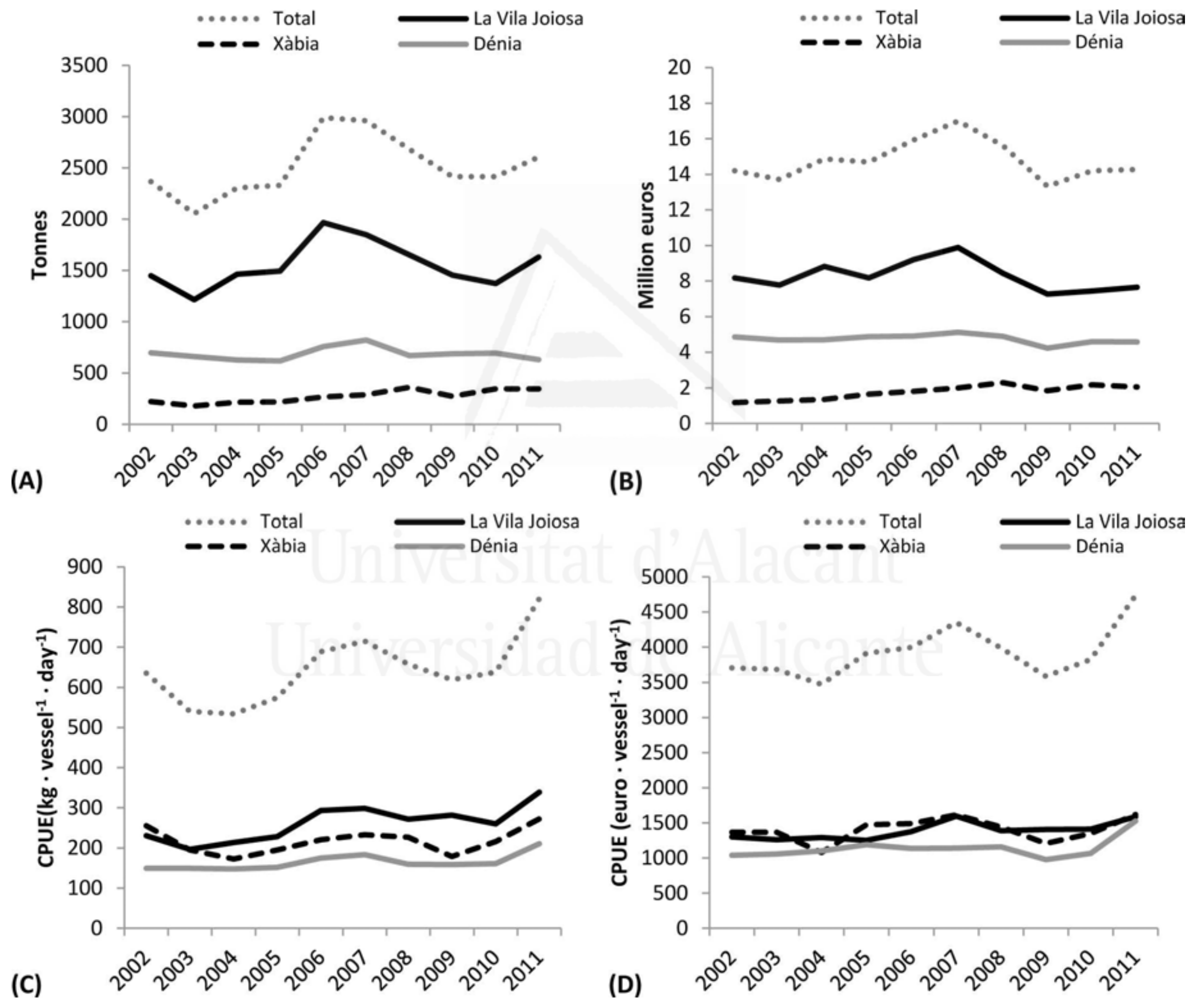


Figure 2.7. Temporal evolution of (A) total annual landings (ton), (B) total annual income (euros), (C) annual CPUE (kg·vessel^{-1}·day^{-1}) and (D) annual income €PUE (euros·vessel^{-1}·day^{-1}) for the trawling fleets of La Vila Joiosa, Xàbia and Dénia over 10 years of study (2002-2011).

2.3.2. Identification, description and temporal distribution of métiers

In total, about 115 commercial species and categories of species were recorded during the period studied. Despite the large number of species, around 80% of landing was represented by just 15. According to biomass, the most important species were: European hake (*Merluccius merluccius* (Linnaeus, 1758)) (up to 18% in La Vila Joiosa), blue whiting (*Micromesistius poutassou* (Risso, 1827)) (up to 18% in Xàbia), octopuses (*Octopus vulgaris* Cuvier, 1797) (up to 14% in Dénia), “morralla” (a Spanish commercial category that refers to a mix of low-valued small fishes of mainly Sparidae and Labridae) (up to 7.5% in La Vila Joiosa) and the Red shrimp (*Aristeus antennatus* (Risso, 1816)) (up to 6.6% in Dénia) (Fig. 2.8). In economic terms, the most profitable species were: the Red shrimp (*A. antennatus*) (up to 44% in Dénia), European hake (*M.merluccius*) (up to 21% in La Vila Joiosa), the Norway lobster (*Nephrops norvegicus* (Linnaeus, 1758)) (up to 15% in Xàbia) and the Red mullet (*Mullus* spp.) (up to 5% in Xàbia) (Fig. 2.8). According to these results, the four species *M. merluccius*, *Mullus* spp., *A. antennatus* and *N. norvegicus* were the most targeted by fishermen and accounted for around 57% of the total income of the fishery.

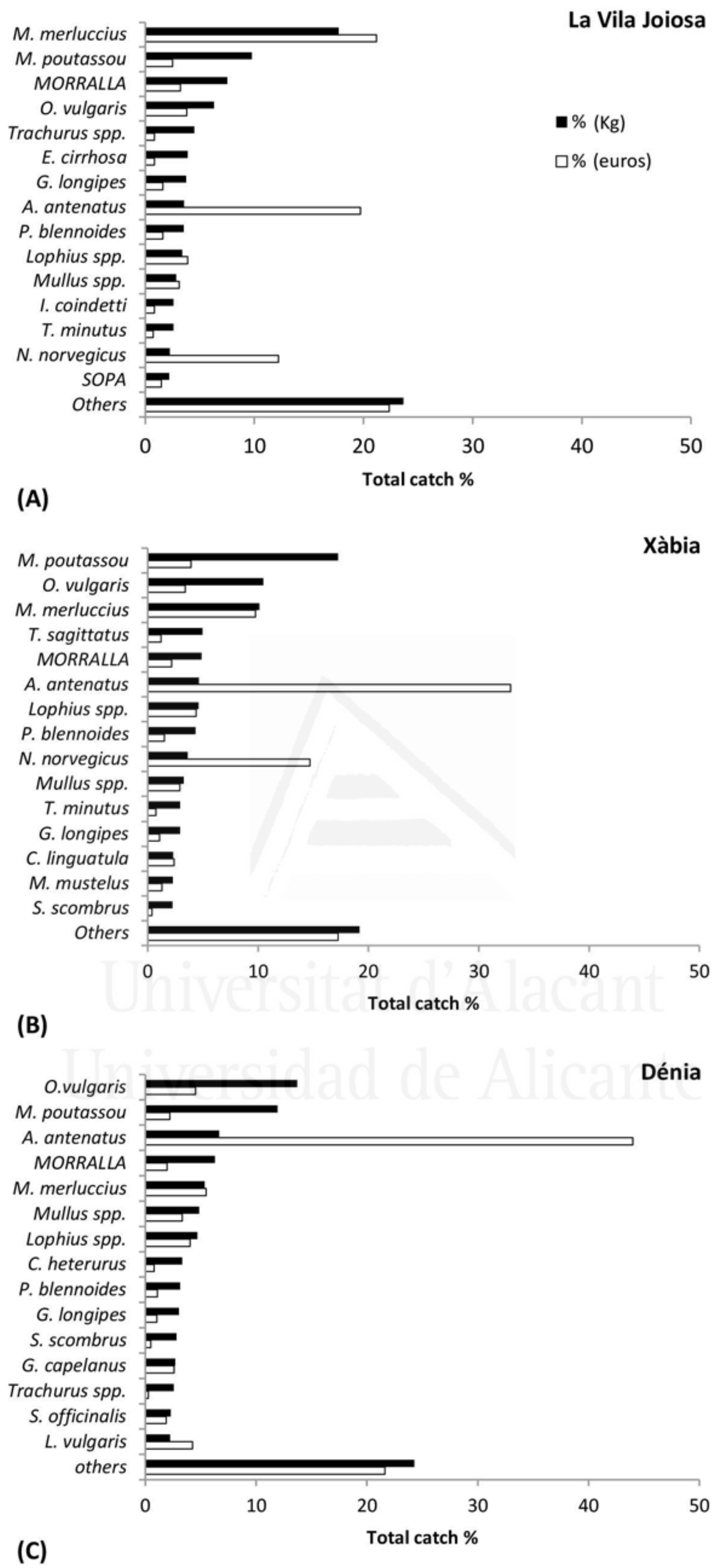
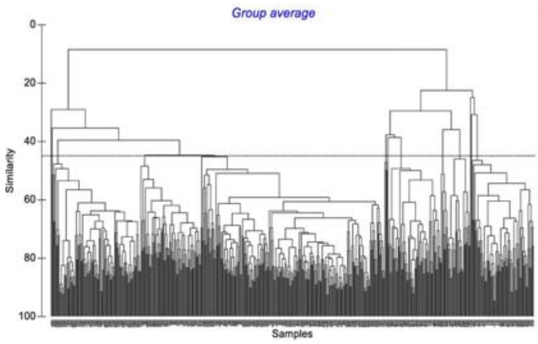


Figure 2.8. Mean catch composition for the ports (A) La Vila Joiosa, (B) Xàbia and (C) Dénia, showing the mean proportion (in biomass and income) of the 15 most important species in the total catch.



Metiér Red mullet		**Metiér European hake**	
Average similarity	61.46	**Average similarity**	53.62
Species	**Contrib%**	**Species**	**Contrib%**
Octopus vulgaris	39.22	*Merluccius merluccius*	27.35
Trachurus spp.	11.47	*Octopus vulgaris*	20.14
MORRALLA	9.72	*Illex coindetti*	10.98
Mullus spp.	8.8	MORRALLA	9.59
Trisopterus minutus	7.5	*Lophius* spp.	7.99
Pagellus erythrinus	6.74	*Geryon longipes*	7.25
		Trisopterus minutus	6.2
Metiér Norway lobster		**Metiér Red shrimp**	
Average similarity	43.50	**Average similarity**	57.94
Species	**Contrib%**	**Species**	**Contrib%**
Micromesistius poutassou	28.97	*Aristeus antenatus*	32.16
Eledone cirrhosa	20.07	*Eledone cirrhosa*	25.7
Phycis blennoides	19.44	*Geryon longipes*	20.92
Nephrops norvegicus	15.43	*Pleisonika* spp.	7.11

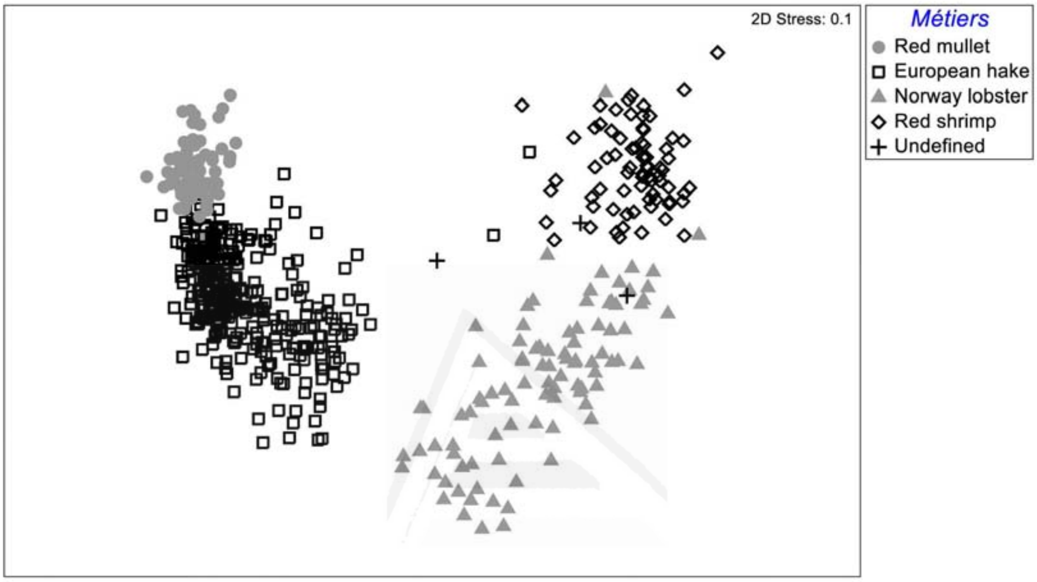


Figure 2.9. Dendrogram and two dimensional nMDS ordination of samples (vessel·day^{-1}) used to identify métiers. In this example (month), grouping samples were identified at similarity level of 45%, then the resulting clusters were overlaid on the nonmetric multi- dimensional scaling ordination. At this similarity level, the four métiers were identified: Red mullet (solid circles), European hake (empty squares), Norway lobster (triangles), Red shrimp (empty diamonds), and undefined samples (asterisks). Species percentage contribution (that contributed more than 5%) of dissimilarity between métiers is also provided according to a SIMPER analysis, using a similarity level of 90%. *Morralla* is a Spanish category that refers to a mix of low-valued small fishes (mainly Sparidae and Labridae).

The four principal métiers, Red mullet, European hake, Norway lobster and Red shrimp, were identified in cluster procedures at a similarity level between 20% and 45%, depending on the data in each month. As an example, results of just a month are presented in (Fig. 2.9) where cluster analyses revealed 5 groups (4 métiers and one group corresponding to the undefined group of samples) of samples at a similarity level of 45%. The nMDS results provided a 2-dimensional graphical configuration which corroborated clustering results. Further, the SIMPER showed the species that most contributed in the separation of each group, helping to identify the métier of each group of samples. However, the four métiers did not occur each month. Dominance of métiers in relation to fishing days over the period is given in Table 2.1, from which European hake is dominant (47941), followed by Red shrimp (33441), Red mullet (16689), and lastly Norway lobster (7046). In addition, 9648 intermediate samples (about 8%) for which métier could not be identified, possibly arising when a vessel has used more than one métier on the same day. Hence, these samples were categorised as undefined and, consequently, were excluded to increase the accuracy of the analyses.

Table 2.1. Number of fishing days (samples vessel·day^{-1}) by port and métier.

Métiers	La Vila Joiosa	Xàbia	Dénia	Total
Red mullet	5853	988	9848	16689
European hake	36531	3591	7819	47941
Norway lobster	3806	1590	1650	7046
Red shrimp	11653	5228	16560	33441
Undefined	2229	1181	6238	9648
Total	60072	12578	42115	114765

For each métier, normally there was a decline of activity in months of temporal closure (Fig. 2.10). The mean number of fishing days per month indicates that both Norway lobster and Red shrimp métiers, had a relatively parallel activity. This was apparent with some peaks in April, May, July and August in both Xàbia and Dénia, while in La Vila Joiosa, this pattern was not clear. On the contrary, both métiers Red mullet and European hake were counteractive (Fig. 2.10A, C and E). Annually, this opposing pattern was evident between Norway lobster and Red shrimp métiers, and Red mullet and European hake métiers, in the three ports (Fig. 2.10B, D and F).

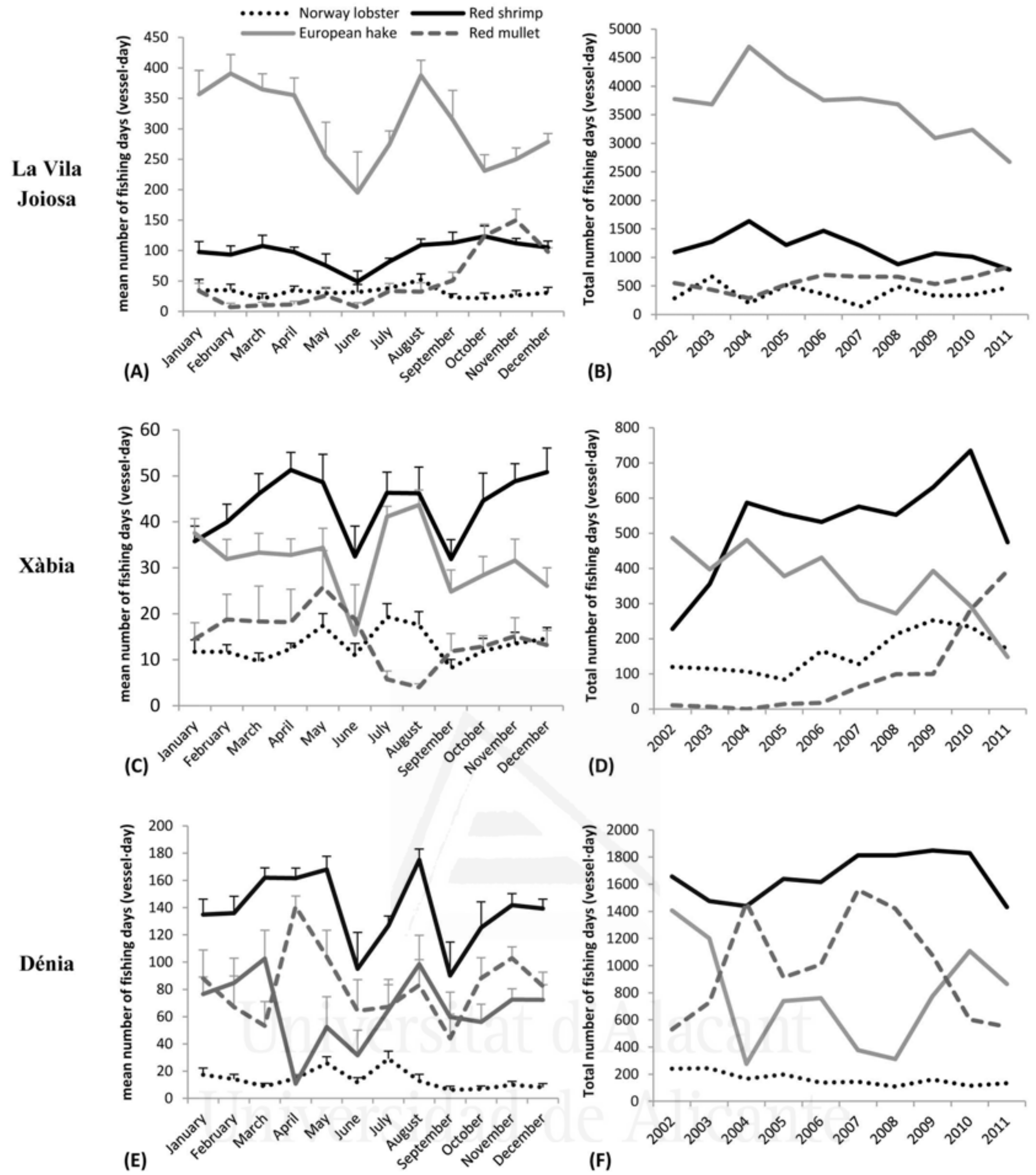


Figure 2.10. Mean number of fishing days of each métier by month (left), and total number of fishing days of each métier by year (right), for the trawling fleets of (A, B) La Vila Joiosa, (C, D) Xàbia and (E, F) Dénia over 10 years of study (2002-2011). Error bars show the standard error.

Concerning capacity of vessels directed to each métier, significant variation in TL and GT were observed (Table 2.2), that reflect differences in the fishing effort exerted in each métier by port. In La Vila Joiosa and Dénia (Fig. 2.11A, B, E and F), vessels focused on Red shrimp have higher capacity (TL and GT) than the rest of métiers; whereas TL of both European hake and Norway lobster in Dénia were statistically equal. In Xàbia (Fig. 2.11C), vessels directed to Red mullet were bigger, while in both European hake and Red shrimp, such differences were not detected. Nevertheless, the highest GT was observed for métier Norway lobster, as both Red mullet and European hake métiers were similar (Fig. 2.11D). Comparisons among ports within the same métier show that for Red shrimp and Norway lobster métiers, higher capacity vessels (TL and GT) were observed in La Vila Joiosa. On the contrary, for Red mullet and European hake métiers, longer vessels with higher tonnage were observed in Xàbia.

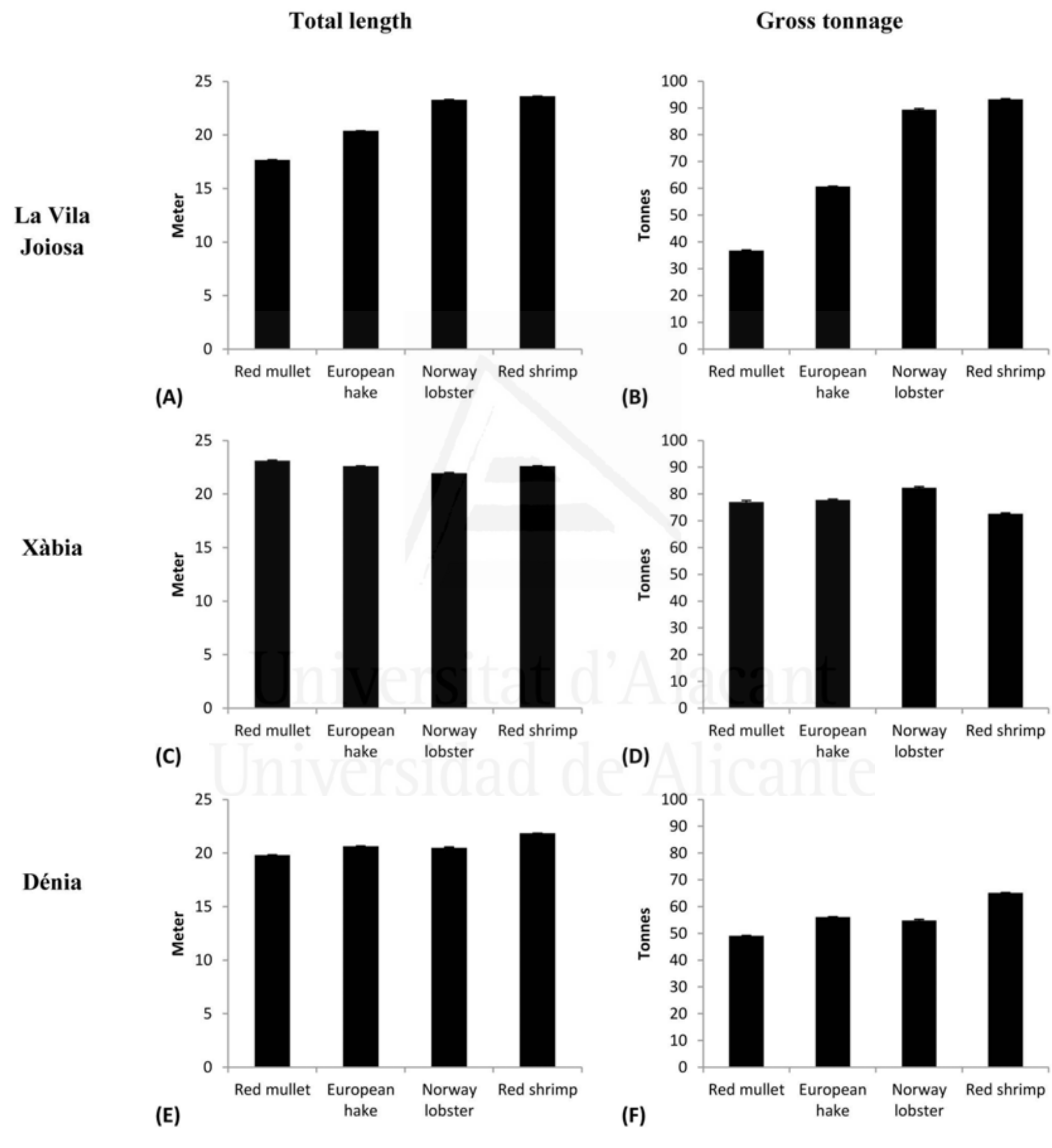


Figure 2.11. Mean characteristics and standard error calculated for (left A, C, E) mean TL and (right B, D, F) mean GT, of each métier for the ports (A, B) La Vila Joiosa, (C, D) Xàbia and (E, F) Dénia over 10 years of study (2002-2011).

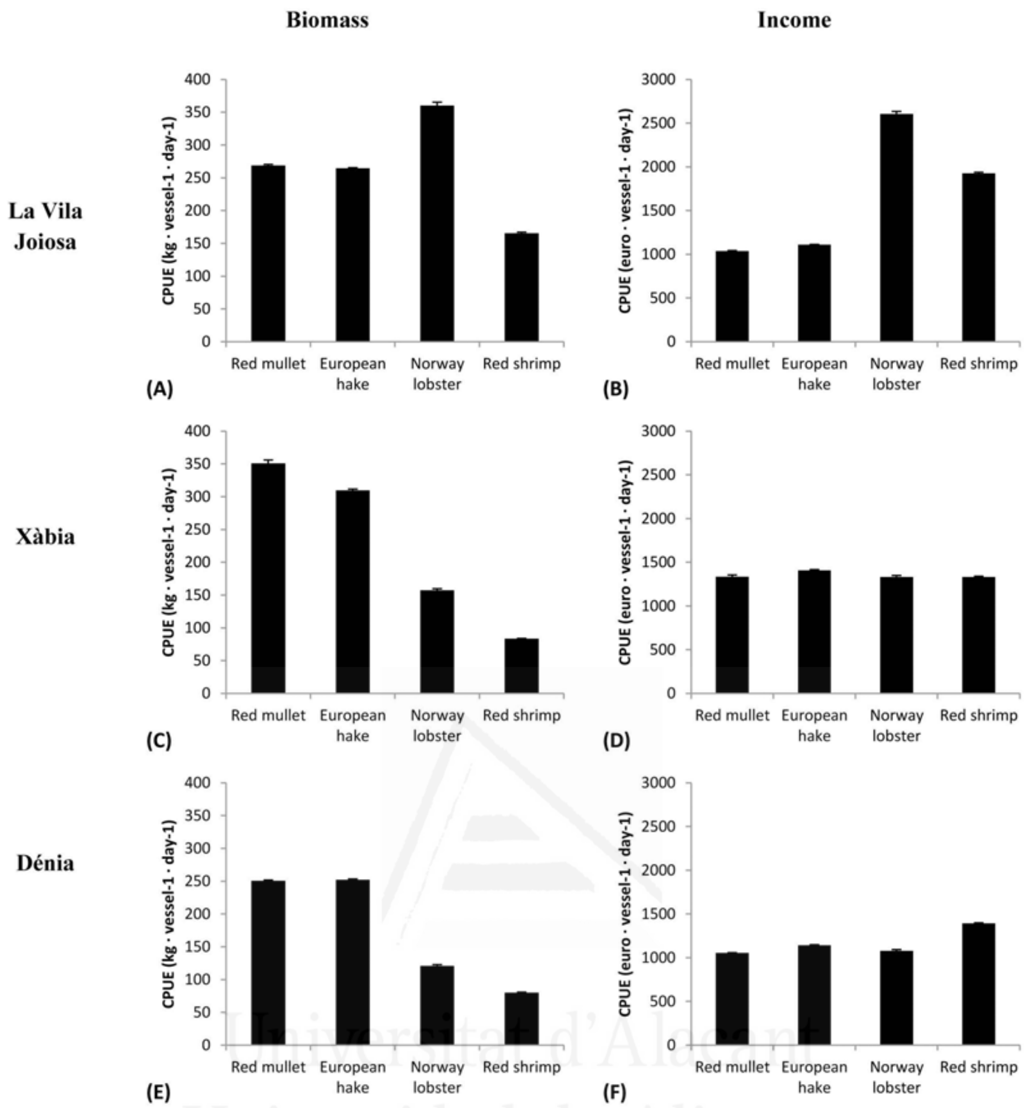


Figure 2.12. Mean CPUE and standard error of the total catch, calculated as (left A, C, E) biomass and (right B, D, F) income, of each métier for the ports (A, B) La Vila Joiosa, (C, D) Xàbia and (E, F) Dénia over 10 years of study (2002-2011).

In respect to differences in CPUE among the identified métiers, analysis showed differences in the importance and the usage of each métier by port in both biomass and income (Table 2.2). In La Vila Joiosa, the métier targeting Norway lobster showed the highest biomass and income; while no differences in biomass were detected between métiers targeting European hake and Red mullet (Fig. 2.12A and B). In Xàbia, the highest biomass was detected for métier Red mullet, followed by European hake although the latter generated higher values (Fig. 2.12C and D). Economically, the remaining 3 métiers were statistically similar. In Dénia, Red mullet and European hake métiers afforded the highest biomass; however, no statistical differences were detected between both métiers (Fig. 2.12E and F). Nevertheless, the highest income was detected for métier Red shrimp, while the rest of the métiers were statistically equal.

Table 2.2. Analysis of variance (ANOVA) results with 2 factors (M: *Métier*; P: *Port*) for mean characteristics by total length and Gross Tonnage and for the total catch by biomass and income. D.f.: degrees of freedom; MS: mean square. Dash (–) indicates that there is no transformation. (a) indicates that there is no homogeneity of variance, the level of significance being $^{**}p < 0.001$.

Sources of variation	D.f.	Total length		Gross tonnage		Total biomass		Total income	
		MS	F value	MS	F value	MS	F value	MS	F value
M	3	3152.5	645.89**	329048	980.12**	20275874	1002.16**	204270560	259.52**
P	2	3661.0	750.07**	447582	1333.20**	7907447	390.84**	263248630	334.45**
M×P	6	2613.4	535.43**	204833	610.13**	4661073	230.38**	194607826	247.24**
Residual	11844	4.9		336		20232		787111	
Transform.		–a		–a		–a		–a	

With regard to differences among ports within the same métier (Fig. 2.12), for both Red shrimp and Norway lobster métiers, the dominant ports by biomass were La Vila Joiosa, Xàbia and Dénia respectively. However, no differences in biomass were observed between Dénia and Xàbia for Red shrimp métier. In contrast, for both Red mullet and European hake métiers, the highest biomass was observed for Xàbia, La Vila Joiosa and Dénia respectively. Economically, for the Norway lobster métier, highest incomes were achieved in La Vila Joiosa, Xàbia and Dénia respectively. For the métier Red shrimp, higher income was observed at La Vila Joiosa, Dénia and Xàbia respectively, although differences between La Vila Joiosa and Dénia were not significant. For both métiers Red mullet and European hake, higher income was observed in Xàbia, Dénia and then La Vila Joiosa, despite that La Vila Joiosa and Dénia were not statistically different.

The mean catch composition, as well the mean CPUE of the most important species, is presented in Fig. 2.13 for each métier by port, in terms of biomass and income. The main species within each métier were similar among the three ports, although with slight differences in their relative importance. We found that only for the métier Red shrimp, the largest catches by weight and income were recorded for its target species (*A. antennatus*) in the three ports. On the contrary, in métier Red mullet, European hake and Norway lobster, the highest catches by weight were not always registered for their respective target species. In some of these métiers, *M. poutassou* and *O. vulgaris* were the most landed species replacing their respective target species. However, as their target species are very valuable in the market, they provided the main income for all métiers along the three ports (Fig. 2.13).

2.3.3. Relationship between "effort" and "landings" overall, and broken down by métier

The explorative data analysis conducted by scatterplot matrix (Fig. 2.14) shows a significant correlation between landings and all the effort variables considered: TL, GT and HP. The landings grew with the increase of all fishing effort variables, but the highest relationship was observed between landings and GT.

Scatterplots of the landings versus the vessel variables disaggregated by métier are shown in (Fig. 2.15). Significant correlations were observed in all métiers. Positive correlations were observed in all cases, except for the landings versus HP of métier Norway lobster as it showed a negative correlation (Fig. 2.15C). Generally, landings in all métiers increased with the increase of all fishing effort variables. The highest relationship was observed between landings and TL in European hake métier, while the lowest, of positive correlation, was observed between landings and HP in Red shrimp métier. For both European hake and Red mullet métiers, landings showed higher correlation with TL, while Norway lobster and Red shrimp métiers landings showed higher correlation with GT.

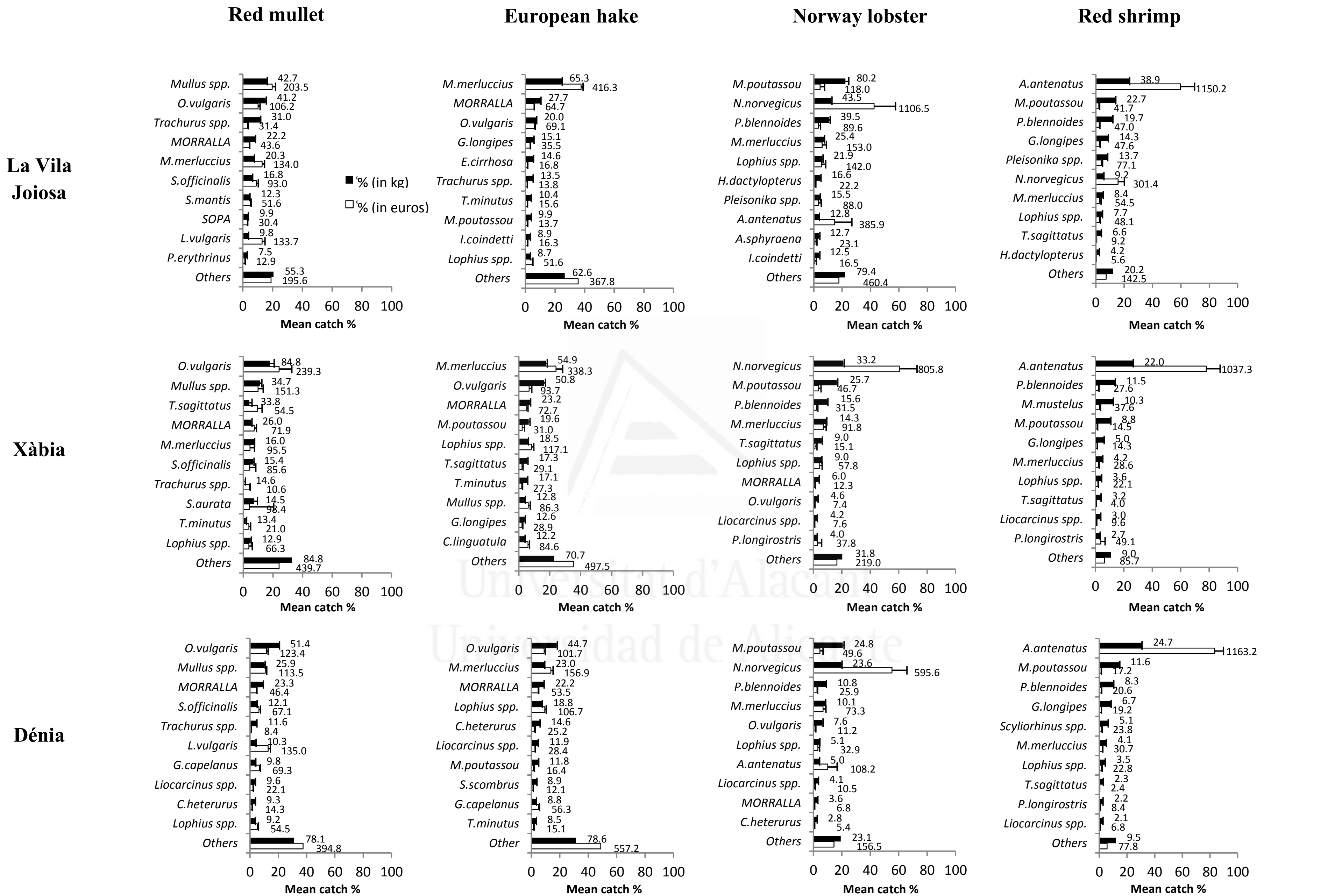


Figure 2.13. Mean catch composition for the identified métiers by port, showing the mean proportion (in biomass and income) of the 10 most important species. Error bars show the standard error. Data labels show mean CPUE in biomass ($kg \cdot vessel^{-1} \cdot day^{-1}$) and income ($euros \cdot vessel^{-1} \cdot day^{-1}$). *Morralla* is a Spanish category that refers to a mix of low-valued small fishes (mainly Sparidae and Labridae); *Sopa* is a Spanish category that refers to a mix of high-valued medium-sized fishes (mainly Scorpaenidae and Serranidae).

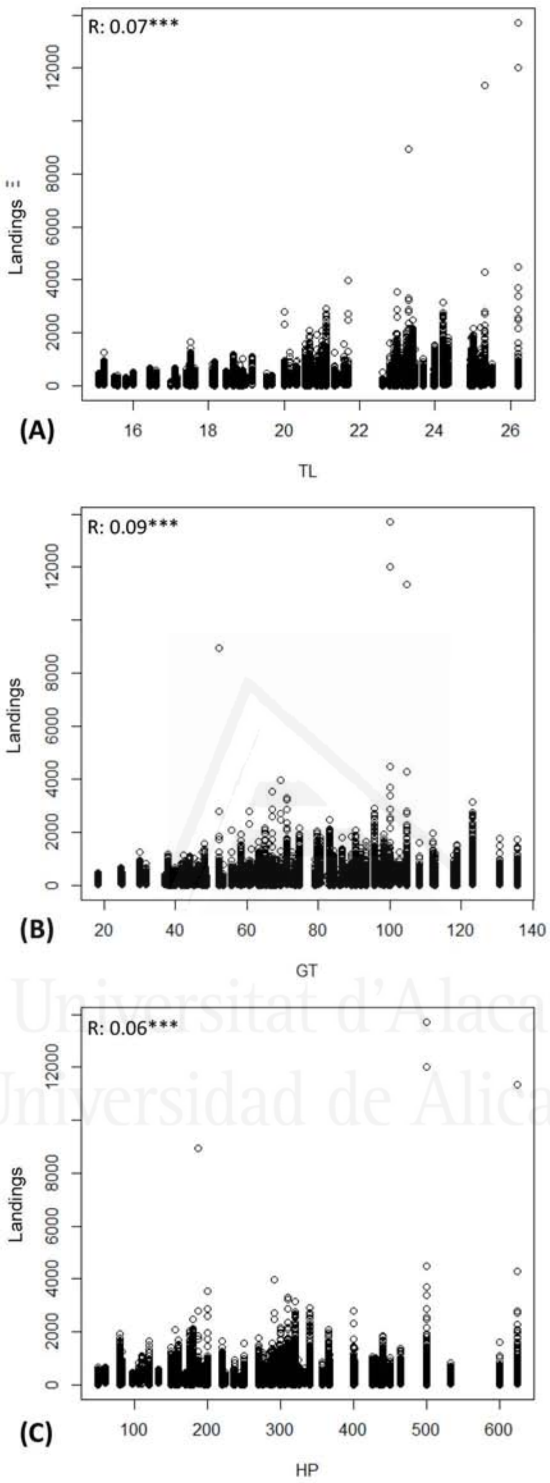


Figure 2.14. Scatterplots and Pearson's product moment correlation coefficient (r) between landings (kg·vessel^{-1}·day^{-1}) and different fishing effort variables: (A) vessel length, (B) gross tonnage, and (C) engine power. Level of significance was ***p < 0.001.

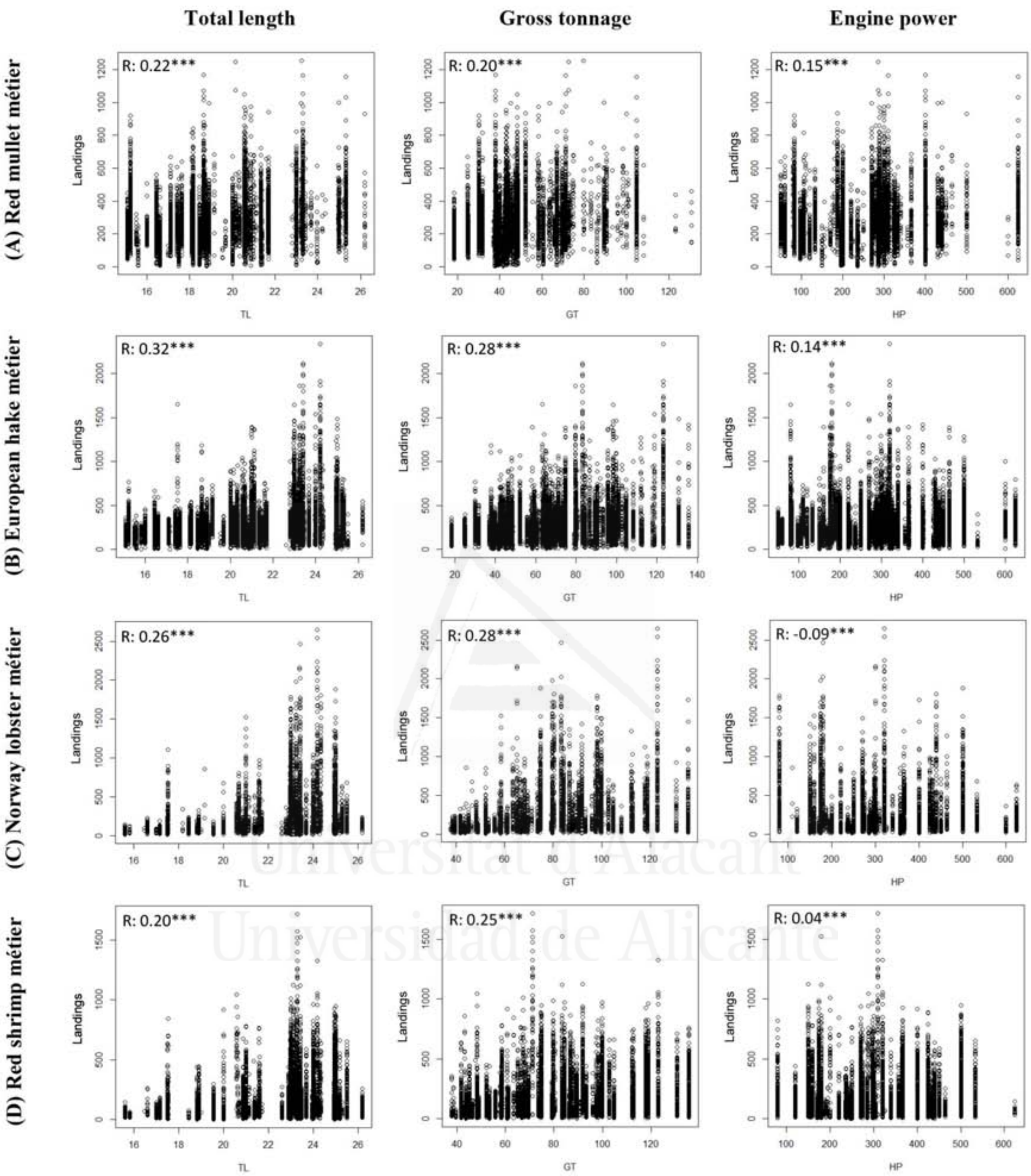


Figure 2.15. Pair scatterplots by métier Scatterplots and Pearson's product moment correlation coefficient (r) between the landings (kg·vessel^{-1}·day^{-1}) and different fishing effort variables: total length (TL), gross tonnage (GT) and engine power (HP). Level of significance was ***$p < 0.001$.

2.4. Discussion

Our results show the diversity of the fishing practices in a typical trawling fleet in the western Mediterranean. The analysis of long-time series of landings and effort data revealed: the annual decline in the fishing effort, expressed in total number of vessels, fishing days, TL and GT in the two most important ports, La Vila Joiosa and Dénia. The monthly activity was regular throughout the year, except for August and months of temporal closure in the three ports. Positive correlations were observed between landings and effort capacity in general and by métier with the exception of the landings versus HP of métier Norway lobster.

Many authors have pointed out the difficulty in obtaining data in the Mediterranean (Lleonart *et al.,* 1998). The data used in this study are very valuable, due to the difficulty in obtaining such long-time series of unbroken period (2002-2011) in Mediterranean fisheries. In addition, it provides very detailed information of the fishing activity, on biological, economic terms and the exerted fishing effort. Such type of data has been used in many other works in Mediterranean fisheries (e.g. Maynou *et al.,* 2011). However, these data are not controlled under scientific supervision and it may have some biases due to misidentification of some non-target species.

For multispecies fisheries, such as t hose of the current study, albeit a l arge number of commercial species, only a small number of species accounts for a large proportion of the catch and its economic value. Cluster analysis, based on disaggregated landings by catch composition, has permitted the identification of four métiers: Red mullet, European hake, Norway lobster and Red shrimp (Table 2.3). Generally, the mean catch composition within the same métier was very similar between ports, although relative importance of species differed slightly from one port to another. The different fishing tactics or métiers and their characteristic species are quite known in the western Mediterranean trawling fishery (e.g. Moranta *et al.,* 2000; García-Rodríguez, 2003; Massutí and Reñones, 2005). There is considerable agreement among authors about which are the main métiers underpinning trawling fishery. Moranta *et al.* (2000) have found three groups between 300 and 600 meter in fishing ground off Balearic Islands. These three groups were dominated by *N. norvegicus* and *A. antennatus*, correspondingly to the same métiers in our results. García-Rodríguez (2003) has identified three métiers in the gulf of Alicante dominated by: *M. merluccius*, *M. poutassou* and *A. antennatus*. This result does not contradict with the present study, as mentioned in our results that *M. poutassou* was one of the most landed species in the Norway lobster métier (more than *N. norvegicus* itself), in this sense both results are in accordance. The blue whiting *M. poutassou* is not a target species although it appears in large schools that are caught in areas of common trawling. The blue whiting does not have high market value, plus that it is a very delicate species to get it arrive in good condition for sale, especially for trawlers. We also have been able to differentiate two métiers targeting fish on the continental shelf the shallower Red mullet métier and the deeper European hake métier, that were aggregated in the work of García-Rodríguez *et al.* (2003). Moreover, Massutí and Reñones (2005) have observed the existence of six main groups in fishing ground off Balearic Islands, associated to smaller depth intervals. This work also agreed with the current analysis in three métiers.

Table 2.3. A complete typology of the métier identified based on the different analysis made in the paper. **Morralla* is a Spanish category that refers to a mix of low-valued small fishes (mainly Sparidae and Labridae).

Métiers	Main gear	Target species	Main accessory species	Peak Months	Mean vessels characteristics (± standard error)			Fishing grounds	Main port
					TL	GT	HP		
Red mullet	Demersal trawl	*Mullus* spp.	O. *vulgaris* *Trachurus* spp. M. *merluccius* S. *officinalis*	Apr., May Oct. and Nov.	19.2 ± 0.019	46.4 ± 0.12	254.2 ± 0.84	The continental shelf (> 100 m)	Denía
European hake	Demersal trawl	*Merluccius merluccius*	Morralla* O. *vulgaris* *Lophius* spp.	Mar. and Aug.	20.6 ± 0.1	61.2 ± 0.12	292.2 ± 0.55	The shelf edge and the beginning of the continental slope (100-199 m)	Villajoyosa
Norway lobster	Demersal trawl	*Nephrops norvegicus*	M. *poutassou* P. *blennoides* M. *merluccius*	Jul. and Aug.	22.3 ± 0.02	79.7 ± 0.27	308.2 ± 1.48	Deeper areas of the slope (200-399 m)	Javea
Red shrimp	Demersal trawl	*Aristeus antennatus*	M. *poutassou* P. *blennoides* G. *longipes*	Mar., Apr., Jul., Oct., Nov. and Dec.	22.5 ± 0.01	76.1 ± 0.12	298.2 ± 0.55	Deeper areas of the slope (400-800 m)	Denía, Javea

The common fisheries policy European Union has traditionally included both aid for construction and modernisation, as well as aids for permanent withdrawals (Hatcher, 2000) which may have produced a lower number of vessel, but more effective limiting the adjustment of fleet capacity. However, we have observed a reduction in fishing effort (e.g. number of fishing days) but also reductions in vessel mean horsepower and GT, indicating that more powerful vessels have been withdrawn from the fishery. This removal is probably linked to the higher fuel prices during last years that make fishing for this fleet segment less profitable. Moreover, positive correlation was found between landings and effort as it make sense that a bigger vessel with higher GT and more powerful engine catches more than a smaller one, but probably these higher catches, at this moment, do not compensate the higher expenses.

Variation in the exerted fishing effort was revealed among métiers that reflect differences in the importance and the usage of each métier by port. The distribution of vessels among different métiers is linked with the availability of fishing grounds. The wide expanse of the continental shelf in the south of the gulf of Alicante, in front of La Vila Joiosa (Fig. 2.1), has favoured the development (more powerful vessels) of the fleet that target in a greater proportion continental shelf métiers (Red mullet and European hake) in comparison with Dénia and Xàbia with a smaller continental shelf (Fig. 2.1). Moreover, the larger distance to the slope resources (Norway lobster and Red shrimp métiers) from La Vila Joiosa port rationalises the observed higher capacity, in terms of TL and GT of these vessels. However, in the north of the gulf of Alicante, near Xàbia and Dénia, such differences were not evident due to the stretch continental shelf.

Exploring the pattern of métier succession throughout the year in a large sample (10 years) of fishing vessels provided more insights into the fishing activity and the seasonality of the target species. Temporal variations were also found in the practice of different métiers at seasonal and annual scales. Observed peaks in August and October are mainly associated with the reopening of the fishery after the temporal closure. This may result from fishers taking advantage of the increased catches after the closure. Furthermore, switching between both Red mullet and European hake métiers was clear on both monthly and annually scales. From a biological point of view, the European hake *M. merluccius* represents a spawning period extending almost throughout the year that is interpreted as an adaptive strategy to maximize the survival of early stages (Martin *et al.,* 1999; Domínguez-Petit, 2008). This is reflected in the usage of this métier throughout the year. In contrast, Red mullet *Mullus* spp. recruits mostly during a well-defined and regular season. The reproduction of both *Mullus barbatus* and *Mullus surmuletus* in the western Mediterranean occurs mainly between spring and summer, almost exclusively from May to July (Relini *et al.,* 1999; Voliani, 1999; Sieli *et al.,* 2011). In this sense, some trawlers along the three ports shift from targeting European hake métier to the Red mullet métier, specifically in the last three months of the year, as mullet recruits in late autumn. Changes in métier preferences are also driven by economic forces. Market values determine the decision of fishermen, while fish prices are largely governed by local patterns of demand and supply. This is another possible explanation for the seasonality between métiers. Guillen and Maynou (2014) found out that seasonality in Red shrimp prices (where prices increase at the end of the year) is due to the higher demand for the Christmas and New Year's period (December registers a 40% price increase). This is the main reason that induces fishers to devote more effort to Red shrimp métier in this period.

Total catches (biomass and income) demonstrated variability between and within métiers. Such variability within the same métier may be attributable to the difference in abundance of the target assemblage in each port. However, variability between métiers, are because the abundance of deep-sea Mediterranean fishes decreases with depth with a tendency to stabilise at depths greater than 500 m (Moranta *et al.,* 2007). This is evident in both Xàbia and Dénia where the biomass of deep-sea métiers is less than continental shelf métiers. It is noteworthy that the pattern of differences in biomass was quite similar among métiers in the three ports except for métier Norway lobster in La Vila Joiosa which was fairly high. Comparing the catch composition of this métier in the three ports indicates that these differences in biomass are due to the higher abundance of *M. poutassou* in La Vila Joiosa.

The concepts of fleet(s) and métier(s) are important providing a convenient and valuable balance between decreasing the complexity of the fishery into few manageable categories, while preserving sufficient information on its characteristics and dynamics (Ulrich *et al.,* 2012). The fleet describes the vessels while the métier(s) describes the fishing activities in which the fleet engages. Such information were essential for a variety of fisheries researches analysing discards (e.g. Tzanatos *et al.,* 2007) and different management strategies (e.g. Maynou et al., 2006; Samy-Kamal *et al.,* submitted; in press). However, actually there are few cases where these interactions have been taken into account in EU fisheries management plans. For instance, the case of the North Sea flatfish (sole and plaice) management plan (EC, 2007), is based on a long previous studies of mixed-fishery interactions in the Dutch beam trawl fishery (e.g. Kraak *et al.,* 2008). Noteworthy that, this fishery is relatively simple with only two species and relatively few and homogeneous fleets involved (Ulrich *et al.,* 2012), which means that the pre-required categorization of fishing activity described above was easier than Mediterranean case.

2.5. Conclusions and recommendations

Our analysis represents a contribution to identify métiers and the distribution of fishing effort between them in one of the most important fisheries of the western Mediterranean. These findings may be considered as a k eystone for more practical implications. In the absence of TACs or quotas in the Mediterranean, the GFCM strategy relies mainly on technical measures and effort-control programmes. Consequently, the development of management at the métier level (métier-based measures) may aid in maintaining or rebuilding of specific stocks, through protection spatially or temporally of vulnerable life cycle stages.

Management regulations are constantly subject to adaptation and modification towards the improved sustainability and health of fisheries. However, in many cases, it may lead to unexpected consequences, as it is difficult to anticipate the reaction of fleets and fishers. The improved detailed information of métiers and distribution of fishing effort acquired here could be useful in two ways: firstly in understanding how fishers adapt their behaviour under changeable management strategies (e.g. temporal closures), and secondly an improved ability to evaluate regulations taking into account the characteristics of each métier.

The inconsistency of single-stock management approaches in a multi-specific fisheries context has repeatedly been highlighted as a key issue in the European Common Fishery Policy, and it has long been suggested that this issue would be better addressed through fleet and métier-based measures (Ulrich *et al.,* 2012). The management of multi-specific fisheries should start off considering the characteristics of each métier separately, and not to manage them as a same fishery. In this paper we quantify the effort allocated to different trawling métiers in different ports, which is the first step to improve the fishery management. Since fishing effort regulations are the main management measures in the Mediterranean fisheries, the patterns observed in the distribution of effort can indicate when is the most suitable time to reduce the overall effort (e.g. to set a seasonal closure). For example, closing the fishing ground during months of lower activity would have fewer effects on fishing sector and may be easily accepted, but it will produce a lower reduction in fishing mortality than if the closure was established in months with higher activity. On the other hand, closure can be set in months of the most intense fishing effort directed on certain métier when there is a need to protect a specific target species or an accessory species of this métier. Moreover, effort variables: TL, GT and HP are not very important in predicting overall landings, unless broken down by métier. Taking into account that landings of each métier were differently correlated to each effort variable, a management implication would be that controlling fleet capacity could be effective when done by métier. This might indicate that management for Red mullet and European hake would benefit mostly by controlling vessels TL while lobster and red shrimp by GT capacity. However, such measure is quite difficult in the Mediterranean.

Furthermore, as observed in this paper, many economic forces (e.g. market prices or fuel prices) are the main forces that affect fishers' critical decision (e.g. shift from a métier to another or exit the fishery). More attention should be given to socio-economic management measures as it could be more effective way to achieve management goals. Managers should also strengthen means to ensure effective regulation of vessel capacity, as it is significantly related to catch.

It is important to note that trawl fisheries in the Mediterranean target the same species but the relative importance of each métier may be different in different areas and it has to be quantified for a better management within a national or regional (GFCM) scale.

Chapter 3: Short-term effect of selectivity change

Abstract

The change of mesh size or shape as a management measure to improve selectivity proposed by the EU should be assessed using a real fishery's data, despite being tested experimentally by previous studies. This work was conducted to evaluate the consequences of inserting either a 40-mm square-mesh or a 50-mm diamond-mesh codends (instead of the traditional 40-mm diamond-mesh) in commercial Spanish trawlers. Under commercial condition, the landings in terms of biomass, income and catch composition were compared. Four métiers were identified in the fishery: European hake, Red mullet, Red shrimp and Norway lobster. No significant differences were observed in biomass or income owing to the new mesh in both European hake and Red mullet métiers. In contrast, the total biomass of Red shrimp métier and the biomass of *Nephrops norvegicus* of the Norway lobster métier were significantly higher after the selectivity change. Regarding the catch composition, only the métier European hake showed slight -no significant- changes after applying the new mesh. Considering these results, there was no short-term effect (substantial biological and economic loss) as expected by previous studies. Probably, this could be related with a higher performance of the new gear that may compensate the lower retention of small sizes.

Keywords: diamond-mesh, European hake, Norway lobster, métiers, multi-species trawl fishery, Red mullet, Red shrimp, square-mesh, fishing management.

3.1. Introduction

Mediterranean demersal trawl fisheries are multi-species, with a large number and variety of commercially important species that are subject to a high fishing pressure on the target adult individuals, as well on the younger and immature ones (Caddy, 1993). These fisheries traditionally operate using minimum 40-mm diamond-shaped meshes in the codend that are poor selective (Caddy, 1993). These meshes usually stretch under tension during the haul and have a tendency to close when the codend fills (Guijarro and Massutí, 2006). They tend to retain a large number of individuals from the target species under their minimum landing size (MLS) (Stergiou *et al.,* 1997b; Stewart, 2002). Therefore, they increase the fishing mortality, preventing any economic profit and decreasing the yield per recruit. Moreover, these meshes have indirect effects on other bycatch and non-commercial species, which contributes to the unfavourable catch composition and relatively high discard rates, especially on the continental shelf (Sánchez *et al.,* 2004). However, comparing these mesh codends with square-mesh codends of the same nominal mesh size, the square-mesh codends remain open during the tow and are more size-selective, i.e. have a higher L_{50} (L_x is the length at which x% is retained) and a lower SR (selection range = L_{75} to L_{25}) (ICES, 2007; Frandsen *et al.,* 2010).

For these reasons, the codend mesh design has been established as an important factor determining the selectivity of a trawl. It has been recommended by the General Fisheries Commission for the Mediterranean (GFCM) to improve trawl selectivity, since it is considered to be a tool to reduce the trawling impact on the ecosystems and to improve the exploitation pattern of target species (GFCM, 2001). It also has been specified as a conservation requirement in the ICES regions. These recommendations have been adopted by the EU to establish the immediate implementation of at least a 50-mm diamond-mesh size or 40-mm square-mesh for the whole codends of trawlers for the members of EU. The regulation provided for transitional arrangements and gave EU operators the chance using smaller mesh sizes up to 31 May, 2010 to change their gear appropriately.

Several studies have been conducted to assess the selectivity of these two types of mesh in the codends, both in the Atlantic (e.g. Campos *et al.,* 2003) and the eastern Mediterranean (e.g. Stergiou *et al.,* 1997b; Metin *et al.,* 2005; Aydin *et al.,* 2011; Özbilgin *et al.,* 2012). In the western Mediterranean, the information on the performance of square-shaped mesh in the codend is limited to the trawl fishery on the shelf off the Ebro River delta, the Gulf of Lions (Bahamón *et al.,* 2006; Sardà *et al.,* 2006), on the slope off the Balearic Islands (Guijarro and Massutí, 2006; Ordines *et al.,* 2006) and in the Central Adriatic Sea (e.g. Sala and Lucchetti, 2011). Guijarro and Massutí (2006) have analysed, for crustaceans off Balearics catch composition, commercial yields, retention efficiency, discards, and size selectivity parameters, using the 40-mm ‘‘traditional’’ diamond-mesh codend, and an ‘‘experimental’’ square-mesh codend of similar mesh size. Ordines *et al.* (2006) compared catch composition, yields, size selectivity of both target and by-catch species, and discards between the two mesh types. In Catalan sea, Bahamón *et al.* (2006), assessed the size selectivity of European hake (*Merluccius merluccius*), Norway lobster (*Nephrops norvegicus*), poor cod (*Trisopterus minutus*) and greater forkbeard (*Phycis blennoides*) and the potential economic losses by the introduction of a 40-mm square-mesh codend. Most of these works are experimental studies that use research vessels conducting sea trials. Results of these works indicated that size selectivity parameters were lower for the diamond-mesh than for the square-mesh codend. The mean selection length (L_{50}) has clearly increased for most species by using 40-mm square-mesh, escaping more individuals under their minimum landing size (MLS) (Bahamón *et al.,* 2006; Guijarro and Massutí, 2006; Ordines *et al.,* 2006). Increments in L_{50} were important for target species such as *M. surmuletus* (5 cm with diamond-mesh to 12 cm square-mesh) which is larger than the MLS (11 cm) (Ordines *et al.,* 2006). For European hake *M. merluccius*, L_{50} of 16.0, 15.4 and 15.2 cm were estimated for the 40-mm square-mesh, while it was 10.1, 11.6 and 10.6 cm for the 40-mm diamond-mesh (Bahamón *et al.,* 2006; Guijarro and Massutí, 2006; Ordines *et al.,* 2006, respectively). Although this indicates an improvement of selectivity, these values are still below the MLS for *M. merluccius* (20 cm). For *N. norvegicus*, the L_{50} with the square-mesh (22 and 24 mm CL), was higher than its MLS (20 mm CL) (Bahamon *et al.,* 2006; Guijarro and Massutí, 2006, respectively). However *A. antennatus*, is a species without a minimum legal landing size, the estimated L_{50} with square-mesh was (22.6 mm), which is at the size at first maturity, estimated at 16-29 mm CL (Guijarro and Massutí, 2006).

On the other hand, the previous works were usually focused on target species (e.g. Sala *et al.,* 2007). According to Ordines *et al.* (2006), in the Mediterranean, only two works extended their analysis to the effects on catch composition: Stergiou *et al.* (1997b) in the eastern Mediterranean, and Guijarro and Massutí (2006) for a slope bottom trawl fishery in the western Mediterranean. However, to understand and verify the predictions of previous studies, it is essential to assess adequately the true biological and economic benefits or loss of mesh regulation based on data of the real commercial trawl fisheries.

Generally, technical measures such as mesh size increase or modification are, by nature, long-term management measures (i.e. long-term gains are assumed when they are implemented) (Lleonart *et al.,* 1996; Suuronen, 2005). However, substantial biological and economic losses are normally associated with their adoption (Lleonart *et al.,* 1996; Suuronen, 2005; Suuronen and Sardà, 2007). If these short-term effects (losses) do not occur, the assumed long-term benefits may not be realised (Suuronen, 2005). It is also very important to address comprehensively the socioeconomic impacts of the new mesh because short-term loss in economic profits will cause fishers to not accept changes.

Turning again to the Mediterranean trawl fisheries, where some of the target species suffer from overfishing (Caddy, 1993), the effort may be directed towards one or another target species during certain periods, depending on the level of catches obtained at that moment, the respective strength of recruitment and on the price of target species in the market. These characteristics increase the heterogeneity of the fishery and complicate assessment, monitoring and management of the sector (EC, 2009). In such management framework, the fishing activity of a given fleet segment in a given area needs to be disaggregated into sub-segments that define specific activities in time, space and catch opportunities corresponding closely to the concept of "métier" (EC, 2009). Usually, the identification of métier is based on analysis of the species composition of large datasets of catch data, which are available from logbooks or landings data (e.g. Ulrich and Andersen, 2004). In this sense, it is essential to separate data into main métiers in order to increase the accuracy of the analysis and to correctly evaluate the effect of the management regulation.

This study was undertaken to analyse the short-term effect and evaluate the consequences of inserting either a 40-mm square-mesh codend or a 50-mm diamond-mesh (instead of the traditional 40-mm diamond-mesh codend) in a commercial Spanish trawling fishery of the south-western Mediterranean. Using commercial data of the fishing guild, the landings in terms of biomass, economic profits and catch composition were compared for each métier before and after applying the new mesh. The main métiers in the fishery were also identified and separated for the analysis, since it was necessary to correctly evaluate the effect of the management regulation.

3.2. Material and methods

3.2.1. Study area and fleet description

This study was conducted in the trawl fishery of Villajoyosa, located in the south-western Mediterranean Sea off the coasts of Spain (Fig. 3.1). According to the landing data, approximately 33 trawlers were estimated to be active during the period of the study (Samy-Kamal *et al.*, 2014). Vessels' length range between 15 and 28 m and average 21.68 ± 0.58 m (se, standard error), while it has a mean tonnage of 50.4 ± 3.65 GRT. According to the number of vessels used for the trawl fleet, the port is considered one of the most important ports, representing about 31% of the total trawlers operate in Alicante coast (12 ports) (BOE, 2013).

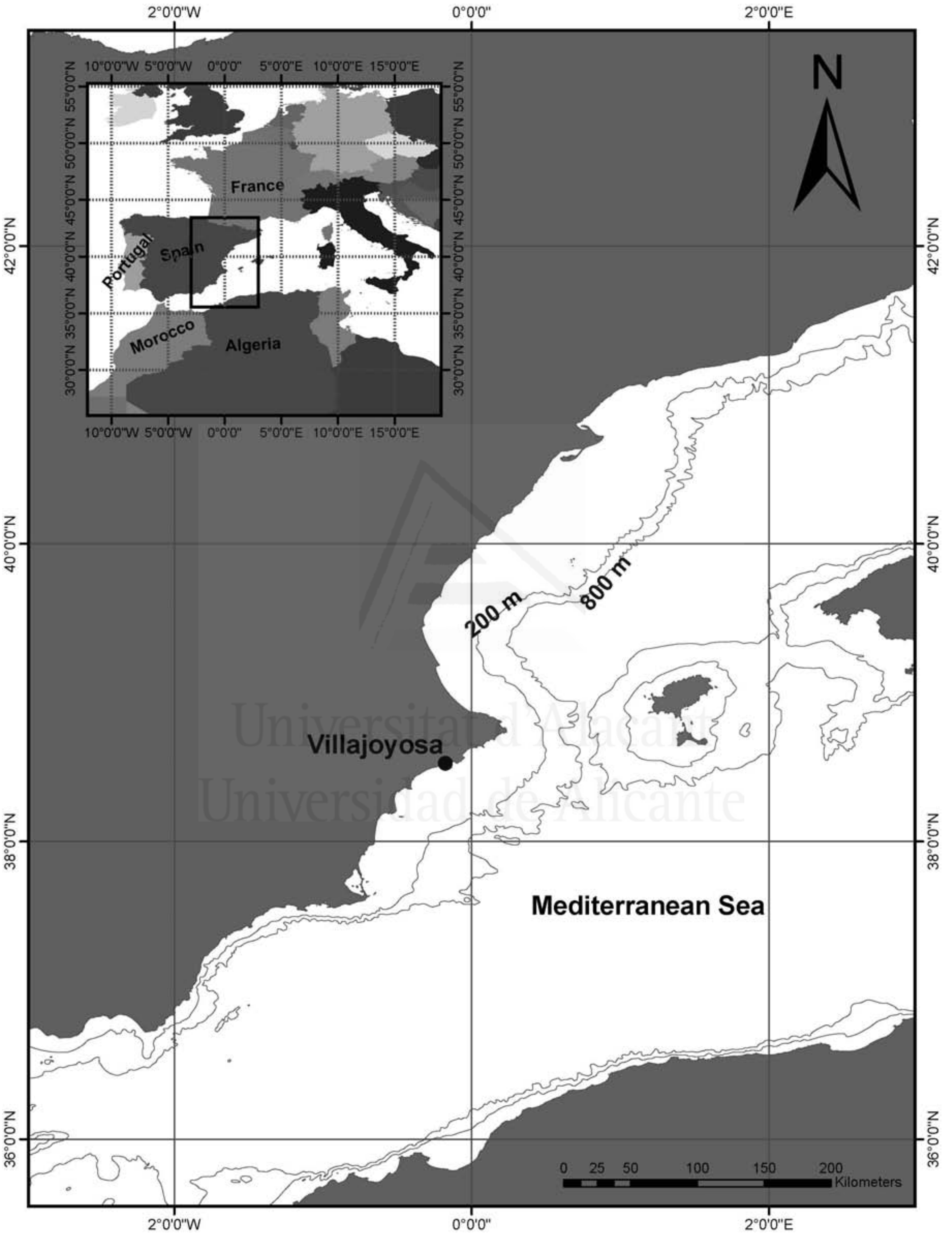


Figure 3.1. Map of the study area (SW Mediterranean) showing the location of Villajoyosa port (Spain).

Fishing activity is carried out five days a week and fishers sell their catch to intermediaries in the market located in Villajoyosa port, where landings data are also registered. Normally, as a Mediterranean fishery, this fleet is engaged in various métiers: Red mullet *Mullus* spp.; fishing at depth between 50-99 m, European hake (*Merluccius merluccius* (Linnaeus, 1758)); between 100-199 m, Norway lobster (*Nephrops norvegicus* (Linnaeus, 1758)); between 200-399 m and Red shrimp (*Aristeus antennatus* (Risso, 1816)); between 400-800 m (Ordines *et al.,* 2006, Guijarro and Massutí, 2006; Samy-Kamal *et al.,* 2014).

3.2.2. Data collection

Data were obtained from the fishing guild from 2008 to 2011. For each fishing day, the data were collected by vessel including landings by species (in kg) and economic value (in €) from selling. Due to the fear of skippers that the catches will be lower after the mesh change, all the fleet adapted their nets to the new legislation just in the deadline of the regulation. Accordingly, to analyse the short-term effect of the new regulation, the comparison was made between two years before (2008 and 2009) and two years after (2010 and 2011) the mesh change. The analysis was focused on the data of two months of the summer season (both July and August) to avoid the difference in catch due to seasonal variation. Accordingly, about 3386 registries (vessel·day^{-1}) were considered for the study.

3.2.3. Data analysis

Multivariate techniques were used to identify the métiers used by the fishery and to assign each of the samples (vessel·day^{-1}) to one of the métiers. Therefore, non-parametric approaches were selected by combining non-metric multidimensional scaling (nMDS) and hierarchical cluster (Clarke and Warwick, 2001), to assess differences in the biomass of the catch composition among samples (vessel·day^{-1}). Finally, the Similarity Percentage Analysis (SIMPER) routine included in PRIMER v6 software (Clarke and Gorley, 2006), was used to identify the main species characterising each métier by weight and income.

As the number of vessels and samples identified in each métier differed, the experimental design used to assess the effect of the mesh change was also slightly different among métiers. Hence, for each métier, only vessels that were fishing continuously for a minimum number of fishing days by month were considered. Additionally, for each métier, vessel, year and month, an even number of samples were randomly selected to maintain our balanced data within each level of the factors considered in the experimental design. For métiers European hake, Red mullet and Red shrimp, the experimental design consisted of the four factors: *Mesh* (2 levels, fixed), *Vessel* (6, 5 and 5 levels respectively, fixed and orthogonal), *Year* (2 levels, random and nested in *Mesh*) and *Month* (2 levels, random and nested in *Year*). Thus, for métiers European hake, Red mullet and Red shrimp with n = 10, 4 and 8 replicates respectively; there were a total of 480, 160 and 320 observations. For métier Norway lobster, due to the lack of data to include the factor *Vessel*, the experimental design consisted of three factors: *Mesh* (2 levels, fixed), *Year* (2 levels, random and nested in *Mesh*) and *Month* (2 levels, random and nested in *Year*). Therefore, with n = 14, there were a total of 112 observations.

We considered the factor *Mesh* as fixed, because the main aim of this study was to investigate if mesh size produce any significant effect on the response (biomass/income) variables. Despite we did not aim to investigate the effect of the factor *Vessel*, it was also considered as fixed, because it accounted for the different catchability of vessels. In the Mediterranean small and medium-scale fisheries, the experience and skills of the fisherman, as w ell as the technical characteristics of the vessel, determine and influence the result of fishing operations. This fact justifies that it is more appropriate to include the factor *Vessel* in statistical models (Maunder and Punt, 2004). The factor *Vessel* also includes other effects that are not directly related to the technical characteristics of the vessels, but that may influence catch rates (Maynou *et al.*, 2003). Because comparing (before and after the new *Mesh*) catch rates of different vessels with different catchability would lead to misleading results. Considering the factor *Vessel* as fixed and orthogonal, entails that the catch rates of the same vessel were compared between the temporal levels (*Year* and *Month*) of the experimental design. This ensures the separation of any effect due to changes in vessel catchability from the effect of *Mesh* size. On the other hand, the temporal factors (*Year* and *Month*) were categorized as random because they only accounted for temporal variation as replicates over time to avoid pseudo-replication. The incorporation of a suitable temporal replication in the experimental design, as applied here, is very important to distinguish the differences and effects caused by the management measure (selectivity), of those caused by other sources of variability (the inter-annual and monthly variations).

The Analysis of Variance (ANOVA) was used to test for significant differences in total biomass, total income, as well as in biomass of target species (Underwood, 1997). When the ANOVA F-test was significant, post hoc analyses were conducted using Student-Newman-Keuls (SNK) multiple comparisons (Underwood, 1981). Before analysis, Bartlett's test was used to test for homogeneity of variance (Sokal and Rohlf, 1969). When significant heterogeneity was found, the data were transformed by $\sqrt{(x + 1)}$ or $\ln(x + 1)$. When transformations did not remove heterogeneity, analyses were performed on the untransformed data, with the F-test α-value set at 0.01, since ANOVA is more restricted to departures from this assumption, especially when the design is balanced and when it contains a large number of samples or treatments (Underwood, 1997). ANOVA was conducted by R statistical computing software (R Development Core Team, 2010) and the R's package GAD (Sandrini-Neto and Camargo, 2011).

For each métier, to determine whether mesh change caused significant differences in the structure of the catch assemblages, non-parametric approaches were performed by combining non-metric multidimensional scaling (nMDS), analysis of hierarchical clusters (Clarke and Warwick, 2001; Clarke and Gorley, 2006) and Permutational Multivariate Analysis of Variance (PERMANOVA, Anderson, 2001; 2005). PERMANOVA was conducted following the prior experimental designs, wherein each term in the analysis was tested using 9999 random permutations of the appropriate units (Anderson, 2005). Finally, Similarity Percentage Analysis (SIMPER) was applied to identify the species that mostly contributed to the differences between meshes. For the overall multivariate testing technique, similarities among samples were calculated using the Bray-Curtis similarity index (Bray and Curtis, 1957) on the biomass data by species.

3.3. Results

3.3.1. Métiers identification

In total, about 95 commercial species were recorded during the period studied. Despite the large number of species, around 65% of the catch was represented by 10 species. According to biomass, the most important species was the European hake (*Merluccius merluccius*), which represented about 20% of the total catch. It was followed by "morralla" (a Spanish commercial category that refers to a mix of low-valued small fishes of mainly Sparidae and Labridae). Other species were also important, the blue whiting (*Micromesistius poutassou* (Risso, 1827)) and octopuses (*Octopus vulgaris* Cuvier, 1797) plus (*Eledone cirrhosa* (Leach, 1817)). In economic terms, *M. merluccius* came as well in the first place as the most profitable species, representing about 24% of the total income. This was followed by the Red shrimp (*Aristeus antennatus*) (15%), the Norway lobster (*Nephrops norvegicus*) (11.5%) and the Red mullet (*Mullus* spp.) (6%). According to these results, the four species *M. merluccius*, *Mullus* spp., *A. antennatus* and *N. norvegicus* were the most targeted by fishermen and accounted for around 57% of the total income of the fishery.

The four principal métiers were identified in cluster procedures at a similarity level of 33%. The nMDS showed clearly the four métiers used by the fishery: European hake, Red mullet, Red shrimp and Norway lobster (Fig. 3.2). The final number of samples (vessel·day^{-1}) for each métier was: European hake, 1599 samples; Red mullet, 855 samples; Red shrimp, 680 samples; and Norway lobster, 172 samples. In addition, there were about 80 i ntermediate samples (approximately 2% of the data) for which métier could not be identified. These days correspond to polyvalent fishing days, possibly arising when a vessel has used more than one métier on the same day. Hence, these samples were categorised as u ndefined and, consequently, were excluded to increase the accuracy of the analyses.

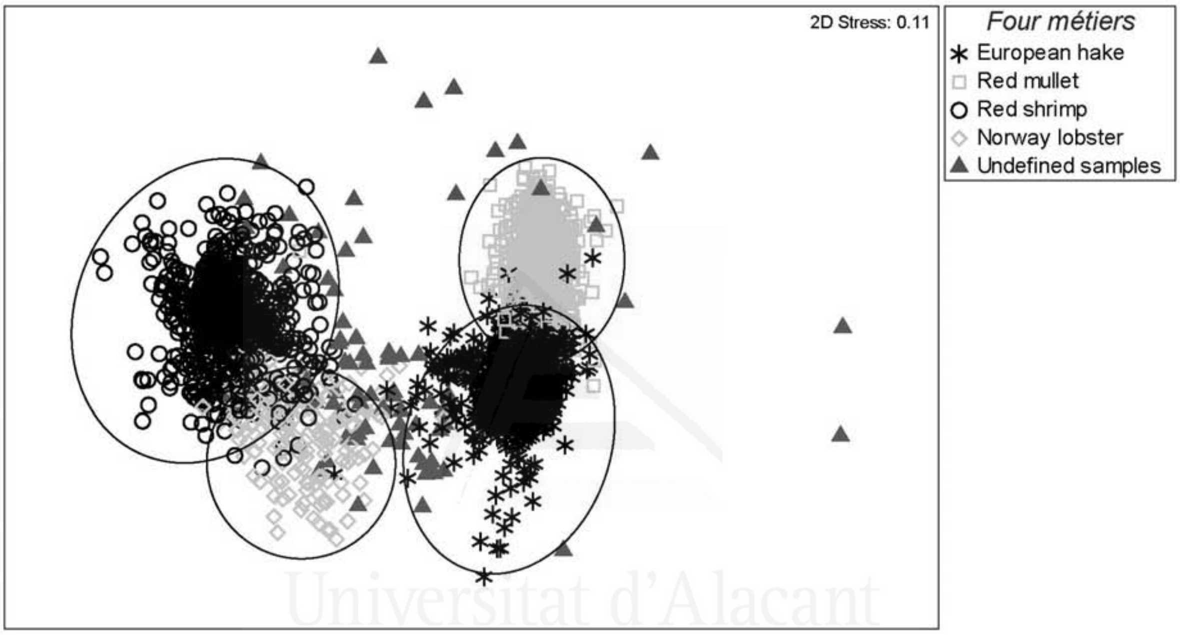


Figure 3.2. Two dimensional nMDS ordination of biomasses of the species captured at each vessel·day^{-1}. Cluster results were superimposed, grouping with similarity level of 33%. At this similarity level, the four métiers were identified: European hake (asterisks), Red mullet (empty squares), Red shrimp (empty circles) and Norway lobster (empty diamonds), while undefined samples (triangles).

Analysing the catch separately for each métier, we found that only for the métier European hake (Fig. 3.3A), the largest catches by weight and income were recorded for its target species (*M. merluccius*). On the contrary, in métiers Red mullet (Fig. 3.3B), Red shrimp (Fig. 3.3C) and Norway lobster (Fig. 3.3D), the highest catches by weight were not registered for their respective target species. However, as their target species are very valuable in the market, they provided the main income for all three métiers. This finding was also evidenced by the elevated similarity percentages (Fig. 3.3).

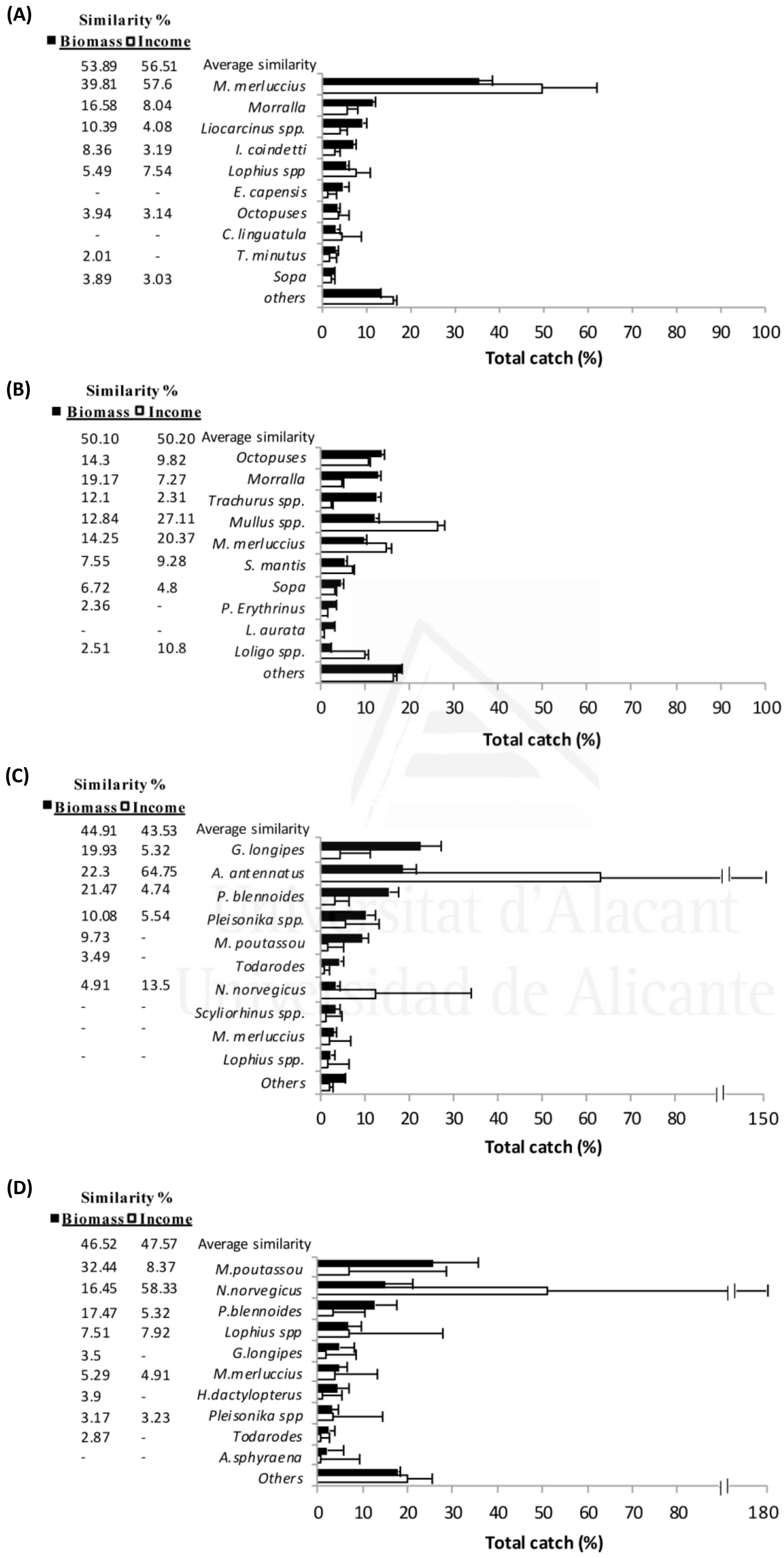


Figure 3.3. Mean catch composition for métiers European hake (A), Red mullet (B), Red shrimp (C) and Norway lobster (D), showing the mean percentage in biomass (black) and income (white) of the 10 most important species. Error bars show the standard error. Percentage contribution to the within-métier similarity of these species is also provided according to a SIMPER analysis, using a similarity level of 90%. *Morralla* is a Spanish category that refers to a mix of low-valued small fishes (mainly Sparidae and Labridae); *Sopa* is a Spanish category that refers to a mix of high-valued medium-sized fishes (mainly Scorpaenidae and Serranidae).

3.3.2. Effects of the mesh change in total catch and in target species

For the catch of métier European hake, changes in total biomass and biomass of *M. merluccius* (Fig. 3.4A) were not related with the mesh change. However, some interannual fluctuations were observed (Fig. 3.4A), although these differences among years were not significant (Table 3.1). In contrast, total income and income of *M. merluccius* (Fig. 3.4B) showed a progressive slight increase after new mesh was applied. Such economic enhancement was not significant in the factor *Mesh*, but for total catch, significant differences were found between years. Additionally, catches of *M. merluccius*, in biomass and income, were significantly different among vessels and between months. Total biomass also showed significant temporal variability at month scale.

Regarding métier Red mullet, no pattern was found in relation with the *Mesh* change, neither in total catch nor catch of *Mullus* spp. in both biomass (Fig. 3.4C) and income (Fig. 3.4D). Nevertheless, for all these variables, significant inter-annual variations depending on the *Vessel* were observed (Table 3.1). Furthermore, significant temporal variations at month scale for biomass and income of *Mullus* spp. were also found.

Concerning Red shrimp métier, significant higher total biomass was detected after inserting the new mesh (Fig. 3.4E, Table 3.1). However, this pattern was not observed in the biomass of *A. antennatus*. Economically, both the total mean income and the income of *A. antennatus* did not show any effect due to the new mesh (Fig. 3.4F, Table 3.1). Moreover, total catch, in biomass and income, was statistically different among vessels. With regard to the temporal variability, the biomass of *A. antennatus* showed significant differences between years depending on the *Vessel*. On the other hand, the income of total catch exhibited significant temporal variability at month scale.

Finally, in métier Norway lobster, total catch and catch of *N. norvegicus* increased after the mesh change, in both biomass (Fig. 3.4G) and income (Fig. 3.4H). However, this pattern was significant only for the biomass of *N. norvegicus* (Table 3.2). There is no temporal variation was observed in this métier.

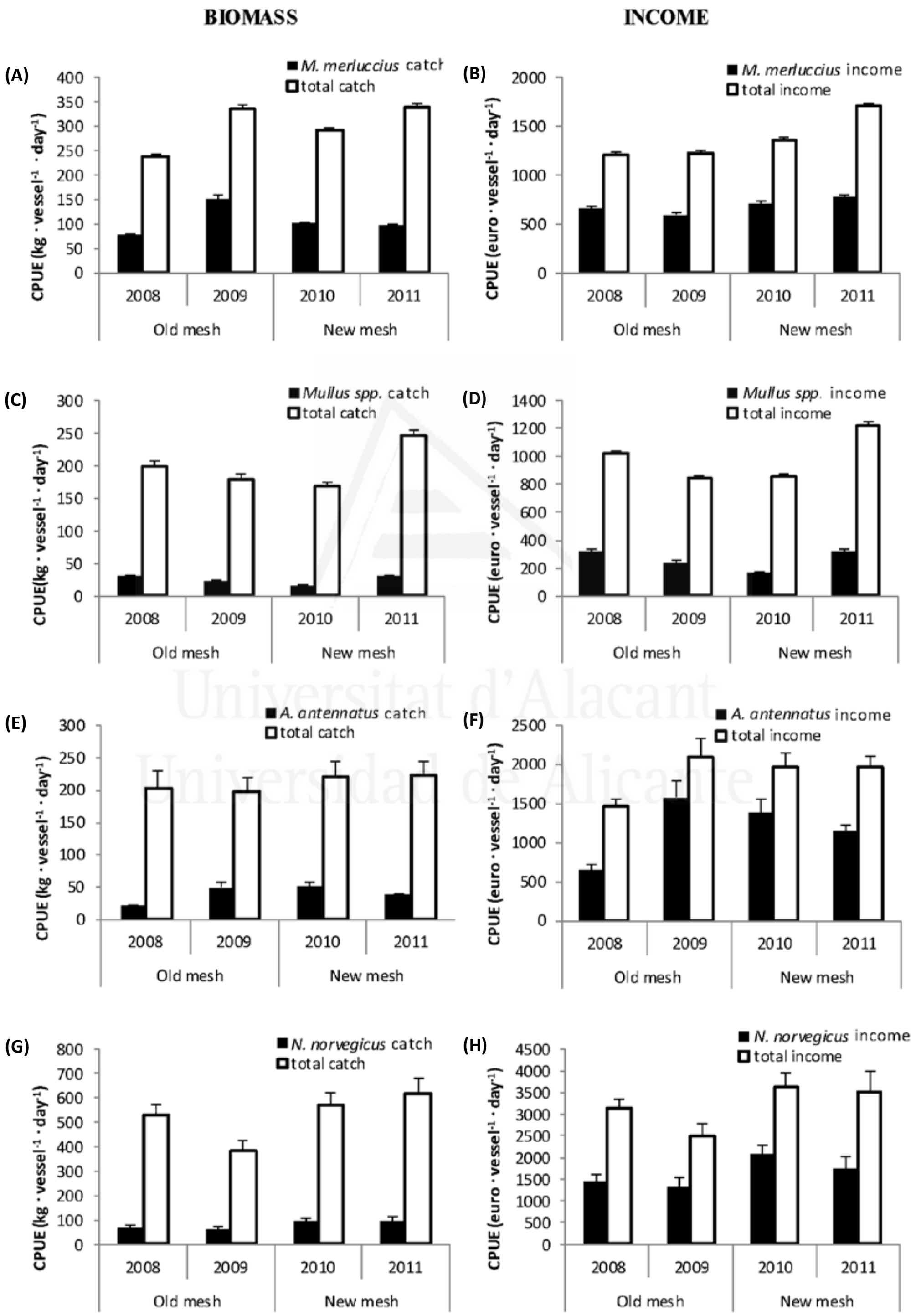


Figure 3.4. Mean CPUE and "se" of the total catch (white) and target species (black), calculated as biomass (left) and income (right), of the four métiers ((A, B) European hake, (C, D) Red mullet, (E, F) Red shrimp and (G, H) Norway lobster) during two years before and after applying the new mesh.

Table 3.1. Results of analysis of variance (ANOVA) with 4 factors (M: *Mesh*; Ve: *Vessel*; Yr: *Year*; Mo: *Month*) for the total catch and the catch of the target species, by biomass and income, of métiers European hake, Red mullet and Red shrimp. D.f.: degrees of freedom; MS: mean square. Levels of significance were *p <0.05, **p <0.01 and ***p <0.001. Dash (–) indicates that there is no transformation. (a) indicates that there is no homogeneity of variance, the levels of significance being *p <0.01; **p <0.001.

Métier European hake

Sources of variation	D.f.	Total Catch				*Merluccius merluccius*				
		Biomass		Income		Biomass		Income		
		MS	F Value	MS	F Value	MS	F Value	MS	F Value	F versus
M	1	96 890	0.272	5.955	3.557	29 078	0.186	461.09	4.215	Yr(M)
Ve	5	28 840	2.848	0.439	3.051	25 965	6.800*	526.33	12.887***	Ve×Yr(M)
M×Ve	5	9 875	0.975	0.079	0.553	290	0.076	43.15	1.056	Ve×Yr(M)
Yr(M)	2	356 253	12.929	1.673	52.275**	155 606	6.469	109.38	2.310	Mo(Yr(M))
Ve×Yr(M)	10	10 126	2.078	0.144	2.064	3 818	1.493	40.84	0.982	Ve×Mo(Yr (M))
Mo(Yr(M))	4	27 554	4.969**	0.032	0.570	24 052	5.635**	47.35	2.565*	Residual
Ve×Mo(Yr (M))	20	4 872	0.878	0.069	1.244	2 557	0.599	41.58	2.252**	Residual
Residual	432	5 544		0.056		4 268		18.45		
Transform.		–a		Ln(x + 1)		–a		√(x + 1)		

Métier Red mullet

Sources of variation	D.f.	Total Catch				*Mullus* spp.				
		Biomass		Income		Biomass		Income		
		MS	F Value	MS	F Value	MS	F Value	MS	F Value	F versus
M	1	25 251	0.193	874 714	0.273	3.575	0.062	75.73	0.098	Yr(M)
Ve	4	164 687	10.955**	3519 351	7.850**	39.370	1.569	506.47	1.743	Ve×Yr(M)
M×Ve	4	15 170	1.009	254 176	0.567	13.187	0.525	158.38	0.545	Ve×Yr(M)
Yr(M)	2	130 686	46.040**	3196 591	53.937**	56.892	6.516	766.93	10.411*	Mo(Yr(M))
Ve×Yr(M)	8	15 032	4.649**	448 297	5.790**	25.093	8.857***	290.42	9.138***	Ve×Mo(Yr (M))
Mo(Yr(M))	4	2 839	0.964	592 65	0.772	8.731	4.294**	73.66	3.176*	Residual
Ve×Mo(Yr (M))	16	3 233	1.098	774 24	1.008	2.833	1.393	31.78	1.370	Residual
Residual	280	2 944		767 56		2.033		23.19		
Transform.		–		–		√(x + 1)		√(x + 1)		

Métier Red shrimp										
Sources of variation	D.f.	Total Catch				*Aristeus antennatus*				
		Biomass		Income		Biomass		Income		
		MS	F Value	MS	F Value	MS	F Value	MS	F Value	F versus
M	1	175 77	25.560*	1 444 982	0.351	3 936.8	0.375	934 705	0.102	Yr(M)
Ve	4	382 889	24.808***	7 968 429	4.757*	11 642.4	3.113	5 406 646	2.246	Ve×Yr(M)
M×Ve	4	148 12	0.959	3 079 655	1.838	5 154	1.378	3 794 867	1.576	Ve×Yr(M)
Yr(M)	2	688	0.022	4 109 784	1.440	10 478.5	7.529*	9 152 352	5.873	Mo(Yr(M))
Ve×Yr(M)	8	154 34	1.276	1 674 954	1.999	3 739.7	5.845**	2 407 194	3.347	Ve×Mo(Yr (M))
Mo(Yr(M))	4	311 63	2.777*	2 853 944	3.452*	1 391.6	1.757	1 558 216	2.203	Residual
Ve×Mo(Yr (M))	16	120 92	1.077	837 642	1.013	639.8	0.807	719 163	1.017	Residual
Residual	120	112 20		826 561		791.9		707 119		
Transform.		–		–		–		–a		

Table 3.2. Results of analysis of variance (ANOVA) with 3 factors (M: *Mesh*; Yr: *Year*; Mo: *Month*) for the total catch and the catch of the target species, by biomass and income, of métiers Norway lobster. D.f.: degrees of freedom; MS: mean square. Level of significance was *p <0.05. Dash (–) indicates that there is no transformation.

Métier Norway lobster										
Sources of variation	D.f.	Total Catch				*Nephrops norvegicus*				
		Biomass		Income		Biomass		Income		
		MS	F Value	MS	F Value	MS	F Value	MS	F Value	F versus
M	1	521 457	3.106	1 327.23	3.362	27 396.8	74.555*	1 058.45	4.262	Yr(M)
Yr(M)	2	167 843	5.842	394.74	1.139	367.5	0.217	248.35	1.001	Mo(Yr(M))
Mo(Yr(M))	4	287 29	0.433	346.29	1.602	1 686.4	0.424	247.88	0.972	Residual
Residual	104	662 90		216.12		3 972.5		254.98		
Transform.		–		√(x + 1)		–		√(x + 1)		

3.3.3. Effects of the mesh change in the structure of the catch assemblages

Assessing if mesh change caused significant differences in the structure of the catch assemblages, only the métier European hake showed in the nMDS (Fig. 3.5A) a clear separation between both meshes, however, the multivariate structure of the two meshes were not statistically different (P=0.17) (Table 3.3). On the other hand, the rest of the métiers did not show such differences, neither in the MDS (Fig. 3.5B, 3.5C, 3.5D) nor PERMANOVA (Table 3.3). Moreover, for métiers European hake, Red mullet and Red shrimp, significant temporal variability, depending on the *Vessel*, was observed at both, annual and month scales (Table 3.3). Similarly, métier Norway lobster showed significant temporal variation, but only among months (Table 3.4).

Table 3.3. Results of Permutational Multivariate Analysis of Variance (PERMANOVA) with 4 factors (M: *Mesh*; Ve: *Vessel*; Yr: *Year*; Mo: *Month*) for the biomasses of the species caught of métiers European hake, Red mullet and Red shrimp. D.f.: degrees of freedom; MS: mean square. Levels of significance were *p <0.05, **p <0.01 and ***p <0.001.

	Métier European hake			Métier Red mullet			Métier Red shrimp			
Sources of variation	**D.f.**	**MS**	**F Value**	**D.f.**	**MS**	**F Value**	**D.f.**	**MS**	**F Value**	**F versus**
M	1	39 197.118	1.668	1	16 099.106	0.942	1	6 767.398	1.198	Yr(M)
Ve	5	10 497.655	5.785***	4	12 656.692	3.441***	4	13 386.530	6.218***	Ve×Yr(M)
M×Ve	5	2 263.216	1.247	4	3 436.806	0.934	4	2 310.068	1.073	Ve×Yr(M)
Yr(M)	2	23 486.575	4.833**	2	17 075.751	3.735**	2	5 647.244	2.130*	Mo(Yr(M))
Ve×Yr(M)	10	1 814.483	2.133***	8	3 677.539	2.860***	8	2 152.736	1.644*	Ve×Mo(Yr (M))
Mo(Yr(M))	4	4 859.423	8.899***	4	4 570.831	5.626***	4	2 650.284	2.709***	Residual
Ve×Mo(Yr(M))	20	850.680	1.557**	16	1 285.791	1.582***	16	1 308.893	1.338**	Residual
Residual	432	546.047		280	812.400		120	978.120		

Table 3.4. Results of Permutational Multivariate Analysis of Variance (PERMANOVA) with 3 factors (M: *Mesh*; Yr: *Year*; Mo: *Month*) for the biomasses of the species caught of métier Norway lobster. D.f.: degrees of freedom; MS: mean square. Level of significance was ***p <0.001.

Métier Norway lobster				
Sources of variation	**D.f.**	**MS**	**F Value**	**F versus**
M	1	7 593.536	1.780	Yr(M)
Yr(M)	2	4 266.000	1.051	Mo(Yr(M))
Mo(Yr(M))	4	4 058.893	3.023***	Residual
Residual	104	1 342.255		

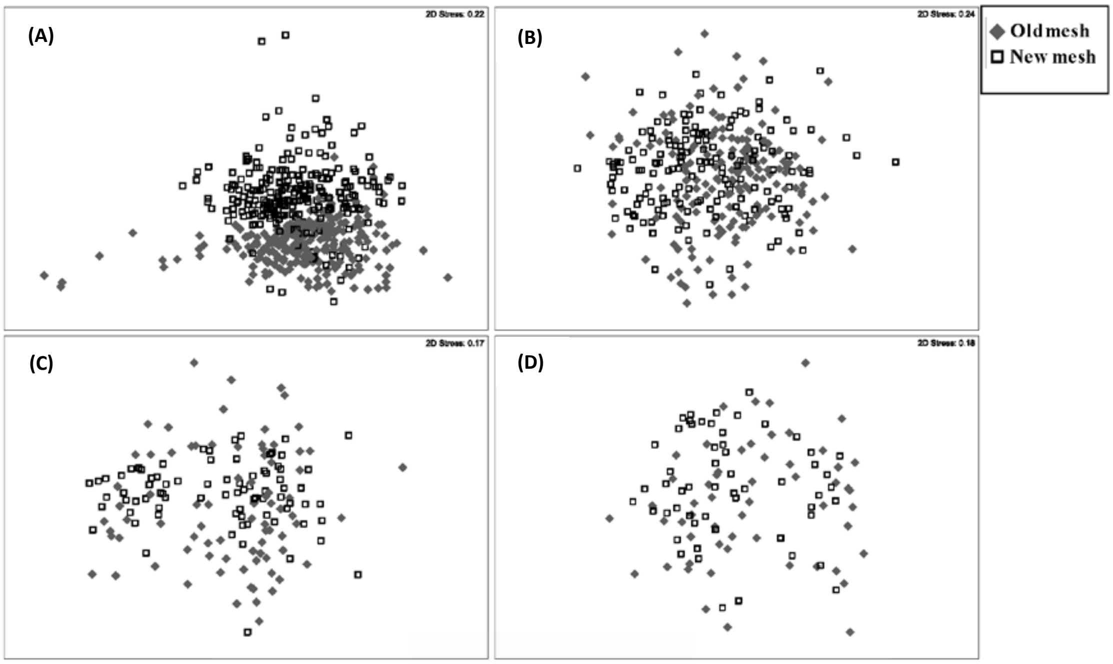


Figure 3.5. Two dimensional nMDS ordination of biomasses of the species caught at each vessel·day^{-1} using the old mesh (solid diamonds) and new mesh (empty squares), for métiers (A) European hake, (B) Red mullet, (C) Red shrimp, and (D) Norway lobster.

Following this further, analysing métier European hake, the species that most contribute in the dissimilarity between meshes, SIMPER results indicated an average dissimilarity of 43.48 %. There were seven species that contributed in more than 5% of this dissimilarity (Fig. 3.6); *M. merluccius* contributed with more than 20%, while morralla, *Liocarcinus depurator* (Linnaeus, 1758) and *Lophius* spp. (Linnaeus, 1758) contributed with almost 8% (Fig. 3.6). Accordingly, the biomass of *M. merluccius* and Morralla decreased after applying the new mesh, while *Liocarcinus depurator* and *Lophius* spp. increased.

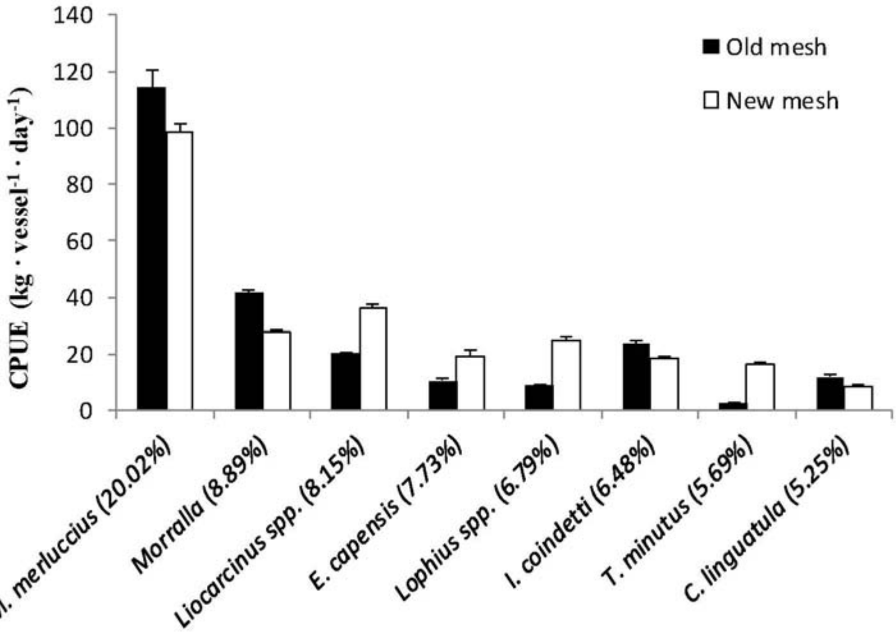


Figure 3.6. Mean catch biomass of species that contributed in more than 5% of dissimilarity between two meshes of métier European hake. Error bars show the standard error. Percentage contribution to dissimilarity of these species is provided between brackets according to a SIMPER analysis. *Morralla* is a Spanish category that refers to a mix of low-valued small fishes (mainly Sparidae and Labridae).

3.4. Discussion

Our results revealed some short-term effects (after 14 months) due to the mesh change, which were manifested in an increase of the total biomass of métier Red shrimp and the biomass of *N. norvegicus* of métier Norway lobster. However, on the economic revenue, no changes were observed as a consequence of inserting the new mesh. Moreover, no differences in the structure of the catch assemblages were detected among the two meshes, except for métier European hake, where some slight -not significant- changes were observed. Additionally, some significant variability was observed between vessels and at different temporal scales.

In this work, four métiers were identified in the fishery: European hake, Red mullet, Norway lobster and Red shrimp. In accordance with other works in the western Mediterranean (e.g. Ordines *et al.,* 2006, Guijarro and Massutí, 2006; Samy-Kamal *et al.,* 2014), and in the light of the catch composition of each métier observed in this study, the trawlers directed mainly to the Red mullets resources are fishing at the littoral zone between depths of 50 to 100 meter, while other trawlers directed to the European hake resources are fishing at the beginning of the slope, at depths of 100 to 200 meter. For trawlers targeting crustaceans, some directed to Norway lobster at depths of 200 to 400 meter, while the rest are fishing the Red shrimp on the slope between depths of 400 to 800 meter. Furthermore, according to the number of samples obtained after métiers separation, it was clear that the main métier used by the fishery was the European hake. Additionally, as *M. merluccius* was species most caught, hence it is the most important species for the studied fishery.

Technical measures, such as modifying the mesh shape or size, are normally associated with substantial biological and economic loss, as predicted by models on the short time (Lleonart *et al.*, 1996; Suuronen, 2005; Suuronen and Sardà, 2007). In the western Mediterranean, previous empirical studies addressed the efficiency of the square-mesh to improve selectivity (Bahamon *et al.*, 2006; Guijarro and Massuti, 2006; Ordines *et al.*, 2006). Guijarro and Massuti (2006) and Ordines *et al.* (2006) concluded that the use of square-mesh would not lead to a significant difference or a reduction of the yields of the main target species; meanwhile, Bahamon *et al.* (2006), addressed relatively high economic losses due to the substantial loss in biomass. In agreement with Guijarro and Massuti (2006) and Ordines *et al.* (2006), the results of the present study showed that the new mesh did not lead to a significant difference in biomass and income of both métiers European hake and Red mullet. This might be because escaping individuals are relatively small to produce a significant loss in biomass or income, or because selectivity just affected to individuals previously discarded (when using the old mesh size), and such decrease in discards is not reflected in landings data. It must be stressed, that discard reduction is a priority in the new common fishery policy and this could be achieved by using more selective gears (Sardà *et al.*, 2013). On the contrary and against predictions, the total biomass of métier Red shrimp and the biomass of *N. norvegicus* were significantly higher after inserting the new mesh. Therefore, this study did not reveal the expected substantial loss due to the high escapement ratio of small species and, hence, did not point towards the short-term effect. It is also noteworthy that the previous studies compared differences between 40-mm diamond and 40-mm square-mesh. However, in our study, the change was from 40-mm diamond to either 50-mm diamond or 40-mm square-mesh. Nevertheless, this does not explain the increased catches obtained here because both 50-mm diamond or 40-mm square-meshes are more selective than 40-mm diamond (Guijarro and Massuti, 2006; Tosunoğlu *et al.*, 2008).

Both 50-mm diamond and 40-mm square meshes produce less resistance (Lin, 1998).That could explain the observed increase of catches in the short term. In this sense, this might contribute to increase the efficiency and performance of the gear. In other words, less resistance in water with the new mesh allows the same trawler to sweep more area in the same time than before and, hence, offset the catch without retaining the small species. That might compensate the expected short-term substantial loss due to the improvement of selectivity. This is an optimum scenario as it helps the sustainability of the fishery by increasing the selectivity. This would be favoured by fishers as they are selective by nature; they do not want to catch small fishes that cannot be sold and could achieve this without diminishing their catch.

Positive effects depend on the willingness of fishermen to accept these technical measures, such as the new mesh, that reduce earnings on short term (Suuronen *et al.*, 2007; Bellido *et al.*, 2011). Hence, it is unattractive to fishers who have a consistent economic goal of maximising short-term profits. Probably when the new mesh came into force in 2010 and when it provoked short-term catch losses, fishermen would unlikely be able to increase effort to such an extent. Instead, they might try to circumvent the regulation by intentionally decreasing the selectivity of their gear, i.e. by gear manipulation (Suuronen, 2005; Suuronen *et al.*, 2007; Bellido *et al.*, 2011), which may explain the observed increase in the short term. These types of compensatory actions may have negative overall consequences before the estimated short-term effects had been properly addressed.

With regard to the structure of the catch assemblages, Ordines *et al.* (2006) observed differences in catch composition between both meshes. However, Guijarro and Massutí (2006) concluded that no differences in catch composition could be attributable to mesh change. In accordance with Guijarro and Massutí (2006), in the present study, no differences in the structure of the catch assemblages were observed among the two meshes, except for some slight -not significant- changes in métier European hake. In multi-species fisheries of the Mediterranean, it is clear that the same mesh opening is not suitable for all species to escape (Bahamón *et al.,* 2006); it will always be too large for some species and too small for others. Accordingly, this could explain why such changes were observed in the structure of the catch assemblages of some species in métier European hake.

Concerning the variability observed among vessels, it responded to the difference in the technical characteristics of vessels as well as different experience and fishing tactics used by each skipper; this variability was also observed in other studies (Sampson, 1991). In addition, temporal variability was observed at both temporal scales studied, years and months. Temporal variations in biomass were already evidenced for these fishing resources by other works (Aldebert and Recasens, 1996; Sbrana *et al.,* 2003; Abella *et al.,* 2005). The temporal variability in income is simply because of the change in market prices. Prices are a function of supply and demand and are influenced by fish size, species, consumer preferences and fish quality, and the catch quantity-demand function. Hence, these factors (*Vessel* and temporal) should be taken into account to adequately assess management measures.

Despite these assumptions and doubts, obviously, there is an immediate effect on the short term. This effect (increase in captures) in the short term could be negative or positive, it all depends on whether this increase occurs with or without retaining small individuals; the former, due to the gear manipulation, and the latter, due to the increase of efficiency. Some suggestions would be useful to improve such type of assessment for other studies to be made. For instance, analysing discards and size structure of the catches would be ideal to test the effectiveness of the management regulation. However, it has not been possible to collect such data for this study. It is also important to assess fishing effort using more accurate units such as swept area in order to test the mentioned hypothesis that the square-mesh offers less resistance and, therefore, they would increase effort that may offset the catch.

Taking into account these results, it can be concluded that the introduction of a 50-mm diamond or 40-mm square-mesh codend in a trawl fishery of SW Mediterranean, does not show the expected effect on short term as predicted by previous studies. Probably, this could be related with a higher performance of the new gear that may compensate the lower retention of smaller sizes. However, if this assumption is true, some positive effects are expected on the long term, without diminishing the economic profit just after applying the new mesh. Otherwise, the anticipated long-term benefits will not be realised.

Chapter 4: Effects of seasonal closure

Abstract

In input-controlled multi-specific fisheries, seasonal closure has little biological justification as a management measure, because it is difficult to adjust such closure for many target species and, in most cases, they are adopted for economic purposes. We aimed to determine effects of closure in biologic and economic terms, using 10-year landing data from two representative trawling ports of the western Mediterranean: Dénia and La Vila Joiosa. Analysis of Variance (ANOVA) was used to detect significant differences, before and after the closure, in standardized catch per unit effort (CPUE) at different seasons and sale prices at home and neighbour ports. ANOVAs showed significantly higher CPUE of *M. merluccius* and the total CPUE of Norway lobster métier after the closure in early summer in some of analysed years. On the contrary, significant lower values for total CPUE and *A. antennatus* CPUE were observed in early summer for Red shrimp métier. Similar CPUE was observed at all levels when the closure took place in late summer. In economic terms, market prices of target species have decreased or shown no changes after the closure at home and neighbouring ports. The only exception was the significant increase of the price for *A. antennatus* in Dénia during the closure in La Vila Joiosa. Depending on its timing, the closure would highlight some positive biological effects on some target species. However, closure leads to an unavoidable reduction in most of target species prices. An alternative management measure that is based on effort reduction in input-controlled multi-specific fisheries, could ban one day per week when market prices of target species are lower.

Keywords: Catch per unit effort (CPUE), Effort reduction, Evaluation of closures, Ex-vessel fish price, Input-control management measures and western Mediterranean trawling fishery.

4.1. Introduction

A large number of fish stocks are overexploited in Mediterranean multi-specific fisheries, and reductions of fishing mortality on these stocks are often recommended (FAO, 2011). Fishing mortality is normally reduced through effort reductions, which can mainly be done by decreasing the number of vessels or the fishing days. The adoption of closed fishing seasons is one of the simplest measures used in the management of fisheries. Closure means a complete cessation of fishing activity for a certain period, which results in a reduction of annual effort (Lleonart and Franquesa, 1999). This management strategy is mainly based on effort control which reduces fishing intensity and protects target stock from mortality at a specific stage of the life history, i.e. when a species aggregates in an area or in a specific season to spawn (Horwood *et al.,* 1998; Dinmore *et al.,* 2003). This approach also can help reproductive success and support recruitment (Arendse *et al.,* 2007). However, it is well known that in multi-species fisheries, such as the Mediterranean Sea, there are many target species with different recruitment and reproduction periods, thus a particular period may be of benefit to only a recruitment period or the reproduction of certain species and not others (Lleonart and Franquesa, 1999). Therefore, in Mediterranean multi-specific fisheries, the adoption of closure, in most cases, is based on economic purposes in agreement with fishermen (Lleonart and Franquesa, 1999).

From an economic perspective, a temporary/seasonal closure may have short-term benefits to fishermen: (i) benefit arising from the reduction of operating costs; (ii) financial compensation arising from the recovery of stocks where fishing is ceased now in order to catch more later; and (iii) the third benefit derived from compensation subsidies (if the administration funds the closure) (Lleonart and Franquesa, 1999). However, ceasing the fleet for long periods (e.g. monthly closure) provokes serious logistical and economic problems, namely: (i) unemployment, fishermen may need to seek alternative work during the closure period; (ii) "border effect", the result of imbalances between the fleet activity belonging to adjacent ports where there may be no closure (Lleonart and Franquesa, 1999); (iii) the market for some luxury species becoming devoid of a highly appreciated local product (Guillen and Maynou, 2014); (iv) imbalances in market price due to the irregular supply of fish to the market (Guerra-Sierra and Sánchez-Lizaso, 1998); and (v) additional costs on the administration in the form of state subsidies.

Closure in Mediterranean multi-specific fisheries, in most cases, does not have a biological sense because it is very difficult to adjust the closure to reproductive periods of many target species; as well, in some cases, it generates some logistic problems. The closures are not intended to protect spawning stock at a vulnerable point in their life cycle, thereby enhancing the probability of sustaining recruitment; rather, they are adapted generally for economic purposes and reducing effort intensity. Closures can be justified in multi-specific fisheries if it results in substantial biological or economic benefits, other than effort reduction. These benefits can be seen by increases in landings (e.g. in kg or in first sale price) that compensate some of the previously mentioned problems. Otherwise, effort reduction can be achieved by adopting other less-problematic management measures rather than closure, i.e. reduction of fishing days or hours.

Temporary/seasonal closures are widely studied in many fisheries throughout the world (e.g. Ye, 1998; Pipitone *et al.,* 2000; Arendse *et al.,* 2007; Shih *et al.,* 2009). Studies in the western Mediterranean are limited to ecological effect on epibenthic communities (Demestre *et al.,* 2008) and on catch composition in the Catalan Sea (Sánchez *et al.,* 2007). The effectiveness of specific temporary/seasonal closures as the most applied management measure for multi-specific fisheries should be rigorously evaluated in both biological and economic terms using long-term landings data. In addition, there are many target species with different recruitment and reproduction periods; thus the timing of the closure should be taken into account as suitable timing may or may not benefit particular species.

The aim of this work was to determine the effects of implementing a seasonal closure in biological (total landings and landings of target species) and economic (ex-vessel price "first sale price" of target from a commercial Spanish trawling fishery, derived from two representative fishing ports (Dénia and La Vila Joiosa) in the western Mediterranean.

4.2. Material and Methods

4.2.1. Study area

This study was conducted in two ports, Dénia and La Vila Joiosa, located in the southwestern Mediterranean Sea off the coast of Spain (Fig. 4.1). Along the gulf of Alicante, there are 12 fishing ports that have traditionally been important fishing activity locations. According to the number of trawlers, these two ports represent about 41% of the total trawlers operating on the Alicante coast (BOE, 2013). They can be considered quite representative of this area, given the similarity of the characteristics of the trawlers, and also have features similar to those operating in other areas of the western Mediterranean (Samy-Kamal *et al*., 2014). The Mediterranean trawl fishery in Spain is an input-controlled fishery, where effort is controlled by limiting the time at sea: fishing is permitted for 12 hours/day from Monday to Friday, stopping the fishing activity completely on weekends (Maynou *et al.*, 2006). The fishing activity is ceased normally for one month per year as seasonal closures, alternating the northern ports (e.g. Dénia) with the southern ports (e.g. La Vila Joiosa) to avoid the closure of the whole gulf at once (Table 4.1). The species *Mullus* spp. (Linnaeus, 1758), *Merluccius merluccius* (Linnaeus, 1758), *Nephrops norvegicus* (Linnaeus, 1758) and *Aristeus antennatus* (Risso, 1816), are the most targeted by fishermen and accounted for almost 60% of the total income of the fishery (Samy-Kamal *et al.*, 2014).

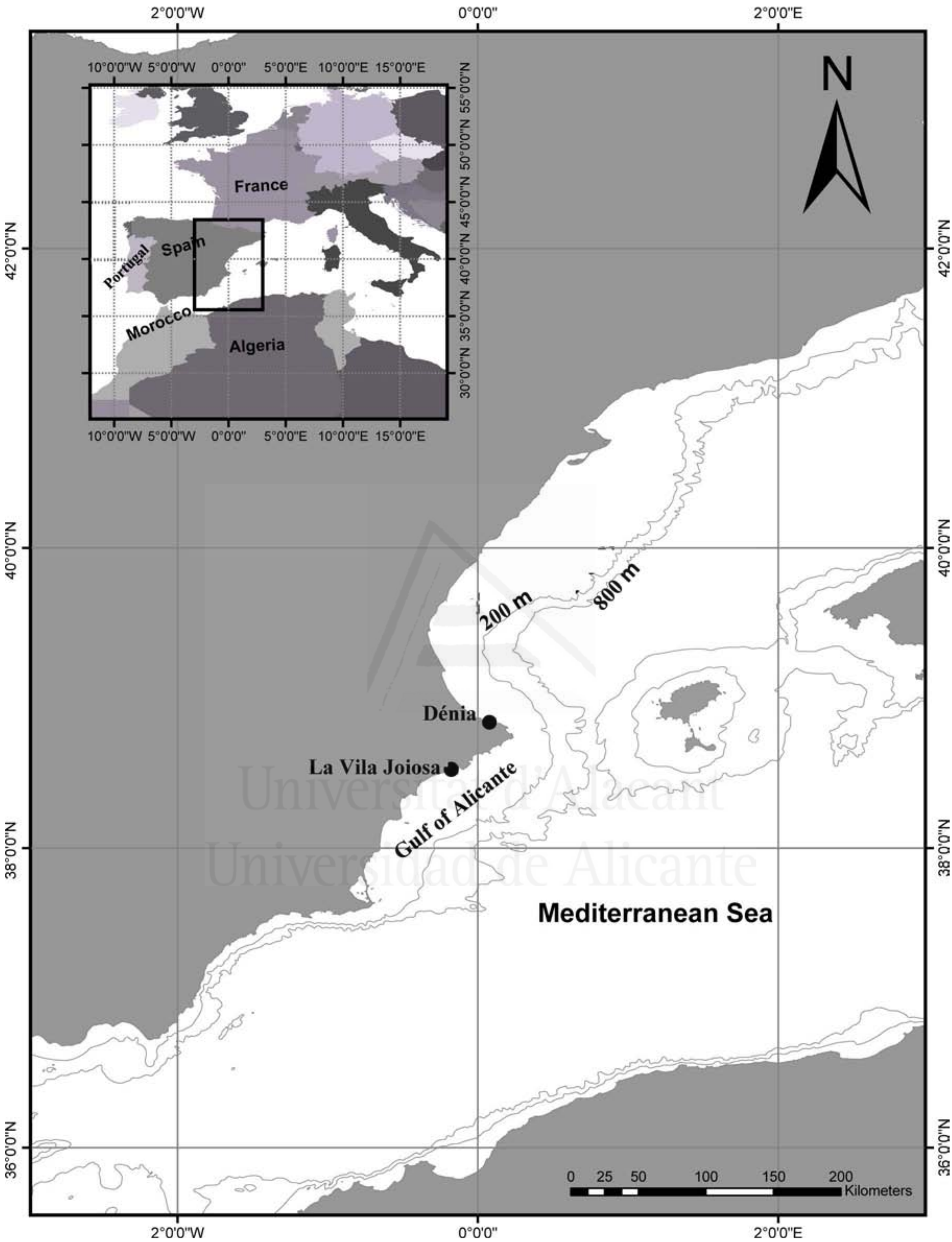


Figure 4.1. Map of the study area (SW Mediterranean) showing the location of the two trawling ports: La Vila Joiosa and Dénia (Spain).

Table 4.1. Seasonal closures of trawling fisheries in Dénia and La Vila Joiosa ports during the studied 10 years (2002-2011). Shaded years were used in the analysis of variance (ANOVA).

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Dénia	June	June	Sep.	June	Sep.	Sep.	15th Sep. to 15th Oct.	Jan.	Sep.	15th Jan. to 15th Feb + Oct.
La Vila Joiosa	May	May	June	May	June	June	June	June	June	Sep.

4.2.2. Data collection

Two different data sets were used, one for each port. Data records of daily auctions were obtained from the fishing guild of each port for 10 years (2002 to 2011). For each fishing day, data on species landing weight (kg) and its first sale value (€) were available by vessel. Sale value (revenue) is the result of quantity landed (kg) and ex-vessel fish price (price obtained by fishers per kg of landed fish). The sale value (€) of each target species was divided by its landings (kg) to calculate the first sale price per kg (ex-vessel fish price). Vessels with sporadic landings events within the ports were excluded from the analysis, considering only those vessels registered in the studied ports (home port) to avoid possible biases in the data. Most of the included sets of vessels have had activity throughout the considered period. The total number of collected samples (vessel·day^{-1}) was 102187 fishing days. Technical characteristics of vessels within the analysis were obtained from the Census of Fleet Operations of the General Secretariat of Maritime Fisheries of Spain (BOE, 2013). Over the 10 years studied, a total of 93 different fishing vessels were listed in the official fleet register of Dénia and La Vila Joiosa (34 and 59 vessels respectively). The bulk of the fleet is composed of vessels up to 23-25 m length, 40-80 GT, 40-60 GRT and 200-400 registered HP (Samy-Kamal *et al.*, 2014).

4.2.3. Data standardization

For multi-specific fisheries, a preliminary analysis of the fishing tactics in the fishery is essential to clearly determine the real effort directed at the species under study (Maynou *et al.*, 2003). Four principal métiers, Red mullet, European hake, Norway lobster and Red shrimp, were identified using the multivariate analysis: hierarchical cluster, non-metric multi-dimensional scaling (nMDS) and the Similarity Percentage Analysis (SIMPER) routine (Samy-Kamal *et al.*, 2014). Catch rates were standardized to separate that large percentage of the variability of data not directly attributable to variations in abundance. To standardize the catch per unit effort (CPUE), generalized linear models (GLM) were used (Maynou *et al.*, 2003; Maunder and Punt, 2004; Murawski *et al.*, 2005). A minimum threshold of effort by vessel of 100 fishing days per year was considered; also, a selection of vessels operating in the fishery for more than 4 years was carried out with the intention of standardizing CPUE data from vessels that would be representative of the fishery. Once the selection of representative vessels was undertaken, a data matrix by métier was constructed with the variables required for analysis. The initial set of explanatory variables considered was: temporal variables (*Year*, *Month* and *Date*) to capture temporal variations; technical (vessel's total length "*TL*" and gross tonnage "*GT*") to capture differences between vessel characteristics; and the "individual *Vessel*" was also used as an alternative in case if technical factors were not significant. The initial model applied contains all factors, as well as the interactions between factors year and month: CPUE ~ *Year* + *Month* + *Date* + *Vessel* + *TL* + *GT* + (*Year* × *Month*).

The GLM was conducted on the total CPUE (kg · vessel^{-1} · day^{-1}) as well as the CPUE of each target species (*Mullus* spp., *M. merluccius*, *N. norvegicus* and *A. antennatus*) in their respective métier. When the data was asymmetric, log transformation was made to correct the extreme data and the constant K was added to the catch rate to account for zero observation, where: K is 10% of the mean CPUE. For each case, i.e. CPUE total and by each target species, the significance of the factors in the model, and also of interactions, were fitted with a stepwise selection procedure by exact Akaike Information Criterion (AIC; Akaike, 1974). Factors that were not significant were eliminated from the model. The AIC determines between adding or excluding each variable, creating a balance between the variability explained by each factor and the degrees of freedom introduced in the model (Akaike, 1974).

4.2.4. Data analysis to test the effect of closure

To analyse the biological and economic effect of closure at the home port, data of five years, where the closure occurred in early and late summer, were selected for the analysis (Table 4.1), in which two weeks before and two weeks after the closure were used. For the economic effect at the neighbour port, two weeks before, two weeks during and two weeks after the closure data were compared. Analysis of Variance (ANOVA) was used to test for significant differences in total standardized CPUE (kg · vessel^{-1} · day^{-1}) and standardized CPUE of target species by métier (biological effect), and first sale price of target species (euro · kg^{-1}) at home and neighbour port (economic effect) (Underwood, 1997). The experimental design for the biological analysis consisted of three factors: *Closure* (fixed); *Season* (fixed and orthogonal); and *Year* (random and orthogonal). The same experimental design was used for the economic analysis, replacing the factor *Season* by the factor *Port*. An even numbers of samples were randomly selected to maintain balanced data within each level of the factors considered in the experimental design. However, métiers are known to exhibit seasonality, in many occasions “disappearing” in some years (during the studied two weeks before and after the closure). Therefore, levels number of factor *Year* and minimum samples used to balance the model varied (Table 4.2). The temporal factor *Year* was considered as orthogonal to separate the inter-annual variations from the effect of the Closure. Factor *Season* was used to separate the effect of season from closure, while factor *Port* accounted for the relation between both ports and first sale price of target species. When the ANOVA F-test was significant, post hoc analyses were conducted using Student-Newman-Keuls (SNK) multiple comparisons (Underwood, 1981). Before ANOVA analysis, Cochran’s test was used to test for homogeneity of variance (Cochran, 1951).

When significant heterogeneity was found, the data were transformed by √(x + 1) or ln(x + 1). When transformations did not remove heterogeneity, analyses were performed on the untransformed data, with the F-test α-value set at 0.01, since ANOVA is more restricted to departures from this assumption, especially when the design is balanced and contains a large number of samples/treatments (Underwood, 1997). ANOVA was conducted by R statistical computing software (R Development Core Team, 2010) and the R's package GAD (Sandrini-Neto and Camargo, 2011).

Table 4.2. Number of samples and levels per factor used in analysis of variance (ANOVA). Dash (–) indicates that the factor was not used in the analysis, because of the lack of data to balance the model.

The analysis		Levels per factor			Number of Samples	
	Métier	***Closure***	***Season* or *Port***	***Year***	**Random samples per level**	**Total samples**
Biologic effect	Red mullet	2	2	–	9	36
	European hake	2	2	3	24	288
	Norway lobster	2	2	3	3	36
	Red shrimp	2	2	5	29	580
Economic effect	Red mullet	2	2	–	10	40
	European hake	2	2	3	24	288
	Norway lobster	2	2	4	3	48
	Red shrimp	2	2	5	29	580
Border effect	Red mullet	3	2	3	4	72
	European hake	3	2	2	25	300
	Norway lobster	3	2	2	3	36
	Red shrimp	3	2	5	38	1140

4.3. Results

4.3.1. Data standardization

The GLMs were able to separate the large percentage of data variability that do not account for abundance: between 53.4% and 80.1% for total CPUE and target species CPUE of Red mullet, European hake and Norway lobster métiers (Tables 4.3 and 4.4). The factor *Date* contributed to separate the highest percentage of deviance in CPUE (i.e. 59.2% of *N. norvegicus* in Dénia), which clearly captured the temporal variability in the catchability of the target species. In addition, factors *Year* and *TL* were highly significant in most cases. In contrast, the explained variation in Red shrimp métier was about 39% (Tables 4.3 and 4.4). This suggests that factors other than *Year*, *Date*, *TL* and *Vessel* cause most of the variability within the CPUE data. In this métier, the factor *Vessel* accounts for 10% of the explained variability.

Table 4.3. Analysis of deviance table for generalized linear models (GLMs) fitted to total CPUE and target species CPUE for the four métiers, from 2002 to 2011, in Dénia. D.f.: degrees of freedom; Res. D.f.: residual of degree of freedom; Resid. Dev.: residual deviance; Dev. ex (%): percentage explained of deviance; F: F value; AIC: Akaike Information Criterion. Levels of significance were *p <0.05 and ***p <0.001.

Métier	Model	D.f.	Deviance	Res. D.f.	Resid. Dev	Dev. ex (%)	F	AIC
Red -mullet Dénia	Total CPUE					46.91447		12602.26
	NULL			9643	2678.422			
	Year	9	102.7709	9634	2575.651	3.836993	62.61809***	
	Date	1812	825.517	7822	1750.134	30.82102	2.498275***	
	TL	25	328.2796	7797	1421.855	12.25645	72.00725***	
	Mullus spp. CPUE					42.70007		25573.15
	NULL			9643	9523.876			
	Year	9	453.334	9634	9070.542	4.759974	71.96734***	
	Date	1812	3022.879	7822	6047.663	31.74001	2.383539***	
	TL	25	590.4887	7797	5457.174	6.200089	33.7467***	
European hake Dénia	Total CPUE					53.41639		9102.191
	NULL			7650	2051.795			
	Year	9	180.7233	7641	1871.072	8.808056	126.0537***	
	Date	1614	655.6045	6027	1215.467	31.95273	2.549896***	
	TL	26	259.044	6001	956.4233	12.62524	62.5438***	
	Vessel	1	0.623003	6000	955.8002	0.030364	3.910879*	
	M. merluccius CPUE					54.97712		16498.34
	NULL			7650	5581.645			
	Year	9	509.5253	7641	5072.12	9.128587	135.1921***	
	Date	1614	1713.19	6027	3358.93	30.69328	2.534721***	
	TL	26	845.9125	6001	2513.017	15.15525	77.6927***	
Norway lobster Dénia	Total CPUE					80.13371		2484.285
	NULL			1579	640.7356			
	Year	9	105.9978	1570	534.7378	16.54315	54.68225***	
	Date	953	375.7251	617	159.0126	58.63965	1.830498***	
	TL	25	29.57875	592	129.4339	4.616374	5.493281***	
	Vessel	1	2.14352	591	127.2904	0.33454	9.952209**	
	N. norvegicus CPUE					77.57166		3552.741
	NULL			1579	1116.067			
	Year	9	167.1011	1570	948.9655	14.97232	43.91078***	
	Date	953	661.6807	617	287.2848	59.28685	1.642064***	
	TL	25	36.96958	592	250.3152	3.312488	3.497348***	
Red shrimp Dénia	Total CPUE					39.63861		25173.14
	NULL			15373	5757.755			
	Year	9	190.0031	15364	5567.752	3.29995	80.01849***	
	Month	11	100.1541	15353	5467.598	1.739465	34.51028***	
	Date	2153	928.6656	13200	4538.932	16.12895	1.634886***	
	TL	26	987.4272	13174	3551.505	17.14952	143.9475***	
	Vessel	1	76.04378	13173	3475.461	1.320719	288.2278***	
	A. antennatus CPUE					39.46414		25002.94
	NULL			15373	5677.951			
	Year	9	309.9029	15364	5368.048	5.458006	131.9664***	
	Date	2164	1186.641	13200	4181.406	20.89912	2.101564***	
	TL	26	692.5874	13174	3488.819	12.19784	102.0896***	
	Vessel	1	51.62238	13173	3437.196	0.909173	197.8419***	

Table 4.4. Analysis of deviance table for generalized linear models (GLMs) fitted to total CPUE and target species CPUE for the four métiers, from 2002 to 2011, in La Vila Joiosa. D.f.: degrees of freedom; Res. D.f.: residual of degree of freedom; Resid. Dev.: residual deviance; Dev. ex (%): percentage explained of deviance; F: F value; AIC: Akaike Information Criterion. Level of significance was ***p <0.001.

Métier	Model	D.f.	Deviance	Res. D.f.	Resid. Dev	Dev. ex (%)	F	AIC
Red mullet La Vila Joiosa	Total CPUE					70.38269		2561.132
	NULL			5778	1161.802			
	Year	9	95.15197	5769	1066.651	8.19003	139.7391***	
	Date	1183	458.7234	4586	607.9271	39.48377	5.125176***	
	GT	38	263.8325	4548	344.0946	22.70889	91.76716***	
	Mullus spp. CPUE					66.35898		9714.118
	NULL			5778	3526.621			
	Year	9	341.9471	5769	3184.674	9.696168	145.6495***	
	Date	1183	1572.312	4586	1612.363	44.58408	5.095025***	
	GT	38	425.9712	4548	1186.391	12.07873	42.97235***	
European hake La Vila Joiosa	Total CPUE					50.48909		13768.89
	NULL			34877	7026.398			
	Year	9	958.9942	34868	6067.403	13.64845	1000.666***	
	Date	2148	1042.01	32720	5025.394	14.82993	4.555678***	
	TL	39	1401.249	32681	3624.144	19.94264	337.4165***	
	Vessel	11	145.3114	32670	3478.833	2.068079	124.0574***	
	M. merluccius CPUE					58.35841		27955.71
	NULL			34877	16764.8			
	Year	9	997.8627	34868	15766.94	5.95213	518.8618***	
	Date	2148	3336.923	32720	12430.02	19.90434	7.270014***	
	TL	39	5054.67	32681	7375.346	30.15049	606.529***	
	Vessel	11	394.2161	32670	6981.13	2.351451	167.7124***	
Norway lobster La Vila Joiosa	Total CPUE					71.45246		7448.967
	NULL			3571	2970.989			
	Year	9	455.1861	3562	2515.803	15.32103	140.0747***	
	Date	1182	1542.055	2380	973.7475	51.90377	3.613232***	
	TL	21	84.52888	2359	889.2186	2.845143	11.14806***	
	Vessel	10	41.07445	2349	848.1441	1.382518	11.37588***	
	N. norvegicus CPUE					61.05505		8062.583
	NULL			3571	2586.922			
	Year	9	206.1951	3562	2380.727	7.970673	53.44034***	
	Date	1182	1200.073	2380	1180.653	46.39002	2.36823***	
	Vessel	30	173.1778	2350	1007.475	6.694357	13.46494***	
Red shrimp La Vila Joiosa	Total CPUE					42.31832		23718.87
	NULL			11424	6418.899			
	Year	9	62.63351	11415	6356.265	0.975767	17.55924***	
	Date	2043	1949.994	9372	4406.271	30.37895	2.408276***	
	Vessel	30	703.7424	9342	3702.529	10.9636	59.18803***	
	A. antennatus CPUE					39.65501		25578.98
	NULL			11424	7220.321			
	Year	9	181.872	11415	7038.449	2.518891	43.32769***	
	Month	11	205.5284	11404	6832.921	2.846527	40.06095***	
	Date	2032	1768.109	9372	5064.811	24.48796	1.865639***	
	Vessel	30	707.7092	9342	4357.102	9.80163	50.57963***	

4.3.2. Biological effect

In general, trends in CPUEs were not always higher after the closure. For total landings and *Mullus* spp. of Red mullet métier, similar CPUEs were observed before and after the closure (Fig. 4.2A). ANOVA did not show significant differences at both total and species levels (Table 4.5).

Slightly increasing trends of CPUEs were observed after the closure in total landings and *M. merluccius* of European hake métier, especially in early summer (Fig. 4.2B). For total landings, significant seasonal and inter-annual variations were detected, while no effects were observed for the closure (Table 4.6). *M. merluccius* CPUE showed significant two-way interactions between *Closure* and *Season*, as well as between *Closure* and *Year* (Table 4.6). In SNK comparisons, significant higher CPUE after the closure were detected in early summer, while no significant differences were observed in CPUE in late summer. In addition, CPUE increased significantly after the closure in both 2006 and 2007.

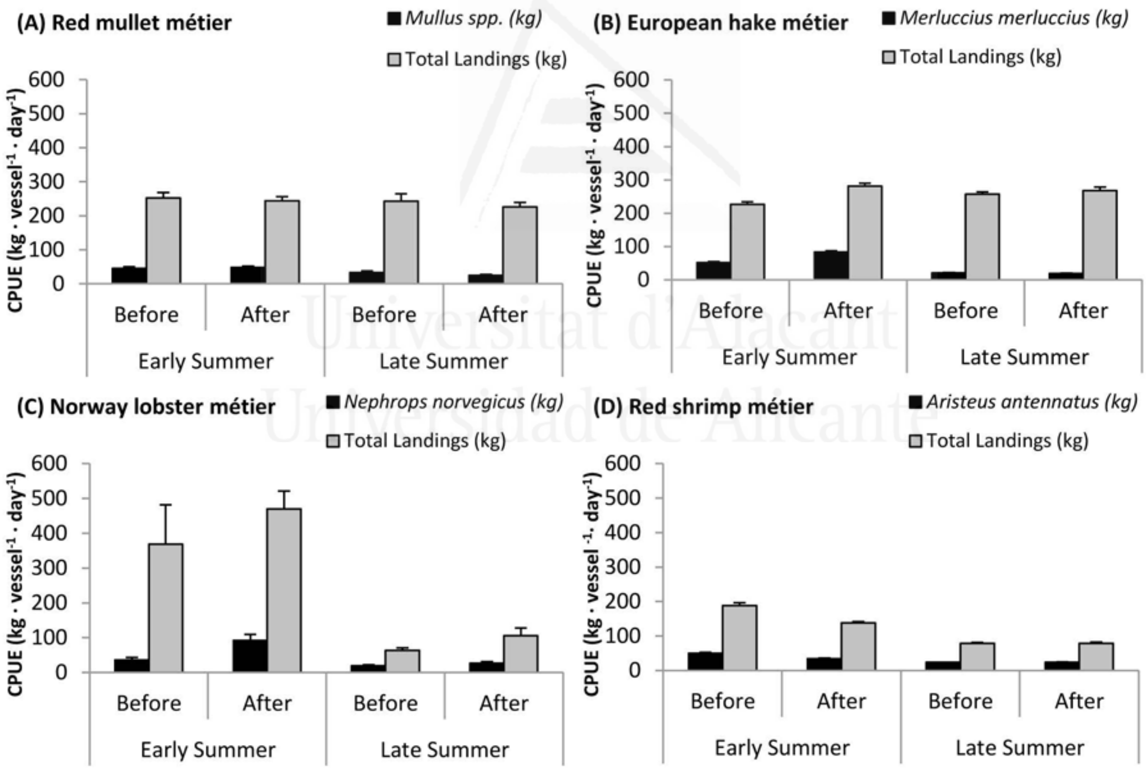


Figure 4.2. Mean CPUE (kg · vessel $^{-1}$· day^{-1}) and standard error of the total landings (grey) and target species (black) of the four métiers: (A) Red mullet, (B) European hake, (C) Norway lobster), and (D) Red shrimp during two seasons before and after the closure.

Table 4.5. Results of analysis of variance (ANOVA) with 2 factors (C: *Closure*; S: *Season*) for biologic effect (the total CPUE of Red mullet métier and *Mullus* spp. CPUE), with 2 factors (C: *Closure*; P: *Port*) for economic effect (price at home port) and with 3 factors (C: *Closure*; P: *Port*; Yr: *Year*) for price at neighbour port. D.f.: degrees of freedom; MS: mean square; F: F value. Dash (–) indicates that there is no transformation. (a) indicates that there is no homogeneity of variance, the levels of significance being *p <0.01; **p <0.001.

	Red mullet m®tier							
	Total landings				***Mullus* spp.**			
Biologic effect	**Sources of variation**	**D.f.**	**MS**	**F**	**D.f.**	**MS**	**F**	**F versus**
	C	1	81384.82	6.65	1	276.78	0.37	Residual
	S	1	1802.88	0.15	1	2162.05	2.88	Residual
	C×S	1	604.13	0.05	1	10.85	0.01	Residual
	Residual	32	12242.58		32	750.55		
	Transform.		–a			–		

	***Mullus* spp. Price**									
	Home port					**Neighbour port**				
Economic effect	**Sources of variation**	**D.f.**	**MS**	**F**	**F versus**	**Sources of variation**	**D.f.**	**MS**	**F**	**F versus**
	C	1	3.10	1.19	Residual	C	2	67.67	11.67	C×Yr
	P	1	192.93	74.40**	Residual	P	1	45.00	3.12	P×Yr
	C×P	1	59.56	22.97**	Residual	Yr	2	58.86	12.98**	Residual
	Residual	36	2.59			C×P	2	48.06	2.84	C×P×Yr
	Transform.		–a			C×Yr	4	5.80	1.28	Residual
						P×Yr	2	14.44	3.18	Residual
						C×P×Yr	4	16.91	3.73*	Residual
						Residual	54	4.53		
						Transform.			–a	

For Norway lobster métier, clear increasing trends were observed after the closure at both total and target species levels (Fig. 4.2C). Three-way way interaction, *Closure*, *Season* and *Year*, was significant for the total landings (Table 4.6). In SNK, significant higher total CPUE was obtained in early summer after the closure in both 2004 and 2010, while in late summer, such significant differences were absent. At target species level, *N. norvegicus* did not show any significant differences (Table 4.6).

On the contrary, decreasing trends of CPUEs in Red shrimp métier were observed after the closure (Fig. 4.2D). There was three-way interaction between *Closure*, *Season* and *Year* in both, total and target species CPUE (Table 4.6). For the total landings, significant lower CPUEs were obtained after the closure in early summer of 2004, 2007 and 2008, while CPUEs in late summer were similar. The same trend was evident at species level, as *A. antennatus* CPUEs significantly decreased after the closure in early summer of 2006, 2007, 2008 and 2010. Such differences were absent in late summer.

4.3.3. Economic effect

For the first sale price of *Mullus* spp. at the home port, a slight decrease was observed in Dénia in contrast to a slight increase in La Vila Joiosa (Fig. 4.3A). In ANOVAs, the two-way interaction of *Closure* and *Port* was significant (Table 4.5). In SNK comparisons, price decreased significantly after the closure in Dénia, while no differences were detected in La Vila Joiosa. At neighbour port, a mild decreasing trend was observed by the closure at both ports (Fig. 4.3B). In ANOVAs, the three-way interaction was significant (Table 4.5), where the price in La Vila Joiosa was significantly higher before the closure (in Dénia) than during and after the closure in the 3 years studied (Fig. 4.3B). In Dénia, the same differences were detected but only in 2010.

For *M. merluccius*, home port prices showed a small reduction in Dénia and similar prices in La Vila Joiosa (Fig. 4.3C). ANOVAs indicated that the interaction between *Closure* and *Year* was significant (Table 4.6), showing higher price before the closure only in 2006. Inter-annual variation was detected as the interaction between *Port* and *Year* was also significant. At neighbour port, slight increase of prices during the closure was observed at both ports (Fig. 4.3D), although ANOVA did not show any significant differences (Table 4.6).

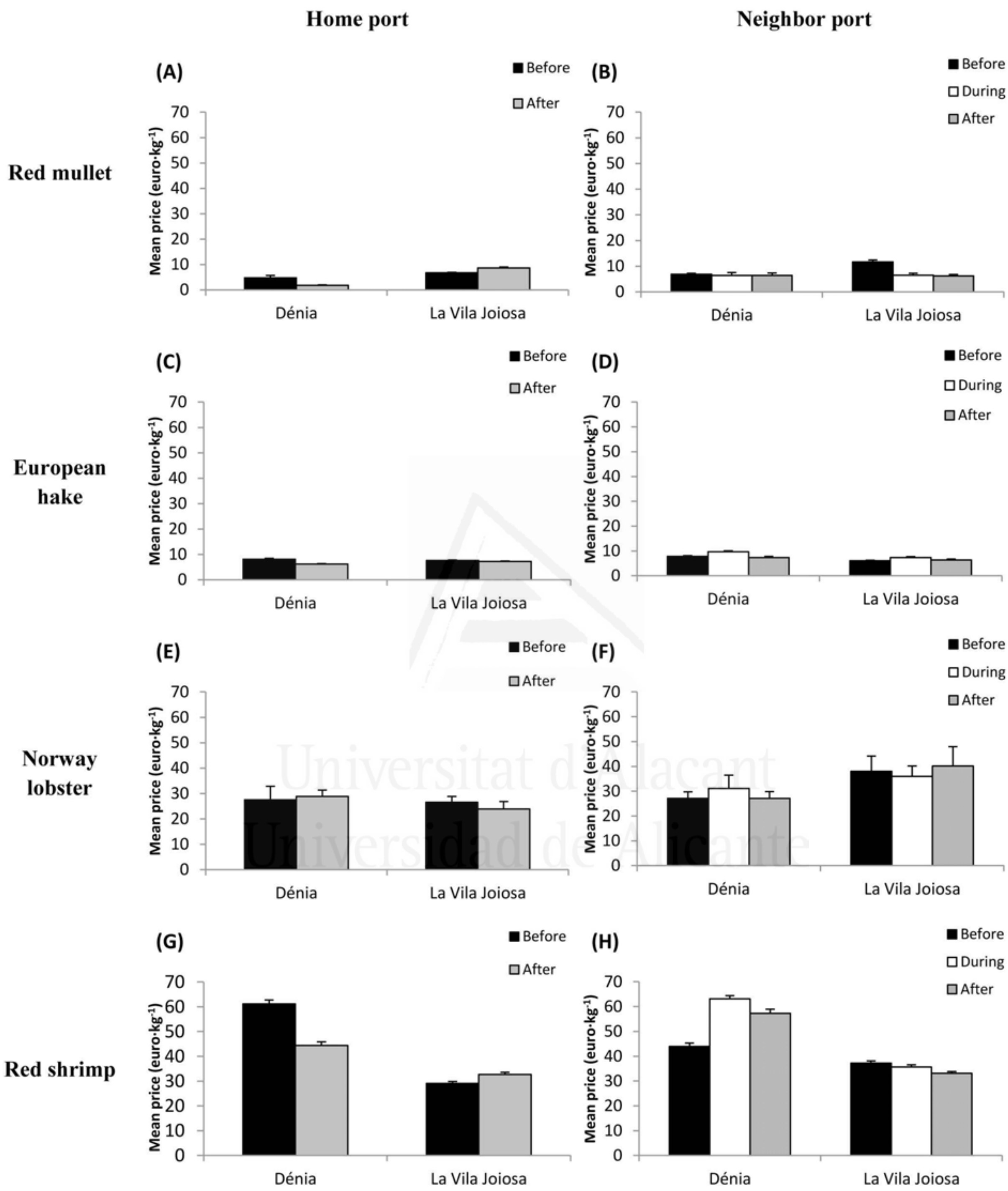


Figure 4.3. Mean first sale price (euro · kg^{-1}) and standard error of the main target species: (A, B) *Mullus* spp., (C, D) *Merluccius merluccius*, (E, F) *Nephrops norvegicus* and (G, H) *Aristeus antennatus* of the four métiers: Red mullet, European hake, Norway lobster, and Red shrimp in the two ports before and after the closure (left) and their mean prices at neighbour port before, during and after the closure (right).

Table 4.6. Analysis of variance (ANOVA) results with 3 factors (C: *Closure*; S: *Season*; Yr: *Year*) for biologic effect (total CPUE by métier and target species CPUE), and with 3 factors (C: *Closure*; P: *Port*; Yr: *Year*) for economic effect (the first sale price at home and neighbour ports) of the target species *Merluccius merluccius*, *Nephrops norvegicus* and *Aristeus antennatus*. D.f.: degrees of freedom; MS: mean square; F: F value. Levels of significance were *p <0.05, **p <0.01 and ***p <0.001. Dash (–) indicates that there is no transformation. (a) indicates that there is no homogeneity of variance, the levels of significance being *p <0.01; **p <0.001.

	Sources of variation	European hake métier						Norway lobster métier						Red shrimp métier						F versus
		Total landings			*Merluccius merluccius*			Total landings			*Nephrops norvegicus*			Total landings			*Aristeus antennatus*			
		D.f.	MS	F	D.f.	MS	F	D.f.	MS	F	D.f.	MS	F	D.f.	MS	F	D.f.	MS	F	
Biologic effect	**C**	1	75696.67	17.59	1	3.79	2.96	1	79.12	2.62	1	4.31	5.39	1	93285.19	2.61	1	8764.70	6.23	C×Yr
	S	1	4947.49	0.07	1	103.10	16.76	1	1019.12	58.01*	1	5.73	8.76	1	1040506.46	53.64*	1	48518.22	9.08	S×Yr
	Yr	2	125856.35	32.41**	2	0.26	1.54	2	90.83	7.41**	2	0.84	2.50	4	5952.67	1.70	4	3604.23	14.75**	Residual
	C×S	1	35732.19	2.72	1	4.69	19.23*	1	6.01	0.08	1	0.97	3.01	1	92838.27	4.34	1	9918.29	6.99	C×S×Yr
	C×Yr	2	4303.47	1.11	2	1.28	7.67***	2	30.22	2.46	2	0.80	2.37	4	35718.98	10.18**	4	1405.78	5.75**	Residual
	S×Yr	2	72989.23	18.79**	2	6.15	36.82***	2	17.57	1.43	2	0.65	1.94	4	19397.93	5.53**	4	5343.55	21.87**	Residual
	C×S×Yr	2	13132.04	3.38	2	0.24	1.46	2	75.16	6.13**	2	0.32	0.96	4	21384.02	6.10**	4	1419.24	5.81**	Residual
	Residual	276	3883.64		276	0.17		24	12.26		24	0.34		560	3507.10		560	244.36		
	Transform.		–a			Ln(x + 1)			√(x + 1)			Ln(x + 1)			–a			–a		

	Sources of variation	*Merluccius merluccius* price						*Nephrops norvegicus* price						*Aristeus antennatus* price						F versus
		Home port			Neighbour port			Home port			Neighbour port			Home port			Neighbour port			
		D.f.	MS	F	D.f.	MS	F	D.f.	MS	F	D.f.	MS	F	D.f.	MS	F	D.f.	MS	F	
Economic effect	**C**	1	96.45	3.20	2	84.87	89.51	1	4.82	0.01	2	4.05	0.04	1	6335.52	4.67	2	7326.20	8.48	C×Yr
	P	1	6.22	0.22	1	213.03	41.42	1	103.02	1.79	1	831.44	9.52	1	69405.43	34.59*	1	107541.92	21.71*	P×Yr
	Yr	2	89.51	23.54**	1	207.34	30.15	3	824.02	14.55***	1	1539.35	15.77***	4	982.10	5.13**	4	2796.53	10.15**	Residual
	C×P	1	41.42	16.00	2	10.03	27.79	1	48.87	0.16	2	53.64	0.17	1	15113.25	23.56*	2	11666.11	10.66*	C×P×Yr
	C×Yr	2	30.15	7.93**	2	19.72	89.51	3	349.46	6.17**	2	92.19	0.94	4	1356.09	7.08**	8	863.44	3.13*	Residual
	P×Yr	2	27.79	7.31**	1	313.37	41.42	3	57.56	1.02	1	87.32	0.89	4	2006.75	10.48**	4	4952.58	17.98**	Residual
	C×P×Yr	2	2.59	0.68	2	19.78	30.15	3	306.03	5.40**	2	308.15	3.16	4	641.51	3.35	8	1094.36	3.97**	Residual
	Residual	276	3.80		288	4.83	27.79	32	56.64		24	97.63		560	191.47		1110	275.45		
	Transform.		–a			–a			–			–			–a			–a		

For *N. norvegicus,* at home port, similar mean prices were observed in Dénia before and after the closure, in contrast to a slight decrease in La Vila Joiosa (Fig. 4.3E). In ANOVAs, the three-way interaction was significant (Table 4.6). Mean prices were significantly higher in Dénia before the closure only in 2007 and 2010, while in La Vila Joiosa such differences were not significant (Fig. 4.3E). At neighbour port, higher mean price in Dénia was observed during the closure in La Vila Joiosa (Fig. 4.3F). The opposite was evident in La Vila Joiosa, as prices decreased during the closure in Dénia. No effect was detected in ANOVA for closure or port, while inter-annual significant differences were present (Table 4.6).

Finally for *A. antennatus*, at home port, a clear price reduction was observed in Dénia after the closure, while a small increase was observed in La Vila Joiosa (Fig. 4.3G). In ANOVAs, there were significant two-way interactions between *Closure* and *Year*, as well as between *Closure* and *Port* (Table 4.6). Three years showed significant lower mean price after the closure. Price also decreased after the closure in Dénia, while no significant differences were detected in La Vila Joiosa (Fig. 4.3G). At neighbour port, a clear higher mean price in Dénia was observed during the closure in La Vila Joiosa (Fig. 4.3H), while a small decreasing trend was detected in La Vila Joiosa. The three-way interaction was significant (Table 4.6). Higher mean price in Dénia was observed during, after and before the closure in La Vila Joiosa, in all years (Fig. 4.3H). However, prices in La Vila Joiosa did not show any effect by the closure in Dénia.

4.4. Discussion

The resumption of fishing activity, in both study ports, did not always result in higher CPUE after the closure. Generally, increasing trends were observed in European hake and Norway lobster métiers at both total and target species CPUEs. However, the statistical analysis revealed significant differences only for *M. merluccius* CPUE and the total landings of Norway lobster métier. Both showed a positive effect with higher CPUE after the closure in early summer in some years. On the contrary, Red shrimp métier showed a negative effect of significantly lower

CPUE at both total landings and *A. antennatus* CPUE also in early summer. However, similar CPUEs were observed at all levels in late summer. The most evident effect of the closure was in economic terms, where market prices of the main target species have decreased or shown no changes after the closure at home and neighbour ports. The only exception was the increased *A. antennatus* price in Dénia during the closure in La Vila Joiosa.

Standardized catch rates assumes that the explanatory variables used were able to separate that a large percentage of the variability of the data is not directly attributable to variations in abundance. GLM models were applied to the total catch rates and different target species using the factors *Year*, *Month*, *Date*, gross tonnage "*GT*", total length "*TL*" and individual *Vessel*. Factors *Year*, *Date* and total length "*TL*" mainly explained the total variance percentages ranging between 39% in the case of Red shrimp métier and 80% in Norway lobster métier. Nevertheless, these percentages are very high despite considering daily CPUE data instead of monthly average. The high percentages obtained by the models reflect the suitability of the selected factors. One way to decrease the variability of the data, and therefore increase the variability explained by the model, is to aggregate the data on a temporary basis; for example, monthly (Goñi *et al.,* 1999; Maynou *et al.,* 2003). However, when using the factor *Date*, it was able to account for daily changes in the CPUE with a high explained proportion of deviance. Regarding the "individual *Vessel*" factor in the analysis of Mediterranean fisheries CPUE, various authors have used vessel factor, grouped into categories according to their technical characteristics (Goñi *et al.,* 1999), while others have used the "individual *Vessel*" factor (Maynou *et al.,* 2003; Sbrana *et al.,* 2003). In the Mediterranean small and medium-scale fisheries, the experience and skills of the fishermen determine and influence the result of fishing operations. This fact justifies that it is more appropriate to include the factor "individual *Vessel*" in the models separately, rather than grouped into categories (Maunder and Punt, 2004). The "individual *Vessel*" factor includes other factors that are not directly related to the technical characteristics of the vessels, but that may influence catch rates (Maynou *et al.,* 2003). This is evident in the case of Red shrimp métier in La Vila Joiosa, where the factor *Vessel* explains about 10% of variability.

Table 4.7. Spawning (grey cells) periods of the main target species: *Mullus* spp. *Merluccius merluccius*, *Nephrops norvegicus* and *Aristeus antennatus* by month.

Target species	January	February	March	April	May	June	July	August	September	October	November	December	Reference
***Mullus* spp.**					■	■	■						(Relini *et al.,* 1999; Voliani, 1999; Sieli *et al.,* 2011)
Merluccius merluccius	■	■	■	■	■	■	■	■	■	■	■	■	(Martin *et al.,* 1999; Domínguez-Petit, 2008)
Nephrops norvegicus								■	■	■	■	■	(Sardà, 1991)
Aristeus antennatus					■	■	■	■	■	■			(Demestre, 1995; García-Rodríguez and Esteban, 1999)

Fishing closures during spawning season, can most likely reduce fishing mortality if the spawning stock is more aggregated during the spawning season than at any other time of the year; however, in a multi-specific fishery, this not the case of all target species. The spawning seasons of the four main target species are summarized in Table 4.7. Adjusting the closure to benefit all target species in multi-specific fisheries is difficult. Changes were observed in the CPUE of two main target species, as *M. merluccius* increased after the closure, while *A. antennatus* decreased. A rise in total landings of Norway lobster métier has been also observed. These changes were mainly in the early summer, while no effects were detected in late summer. The European hake *M. merluccius*, represents a spawning period extending almost throughout the year, that is interpreted as an adaptive strategy to maximize the survival of early life cycle stages (Martin *et al.,* 1999; Domínguez-Petit, 2008). This large-scale spawning period has favoured the benefits observed in the early summer. In contrast, the spawning period of *A. antennatus* occurs between the months of May to October, but is more intense in July and

August (Demestre, 1995; García-Rodríguez and Esteban, 1999). Although the spawning period concurs with the closure in early summer, decreased catches have been observed.

Moreover, a short closure period (one month) cannot substantially raise biomass due to an increase of the abundance of individuals; while it could be solely due to the increase of fish weight. An explanation of the increased CPUE after one month of closure is linked to rapid-growing species, observed in *M. merluccius* (Piñeiro and Sainza, 2003) and total landings of Norway lobster métier, where species such as *M. poutassou* and *P. blennoides* are abundant (Samy-Kamal *et al.*, 2014). But these closures are too short to affect benthic communities, where these processes, recruitment and growth, take place much more slowly (Demestre *et al.*, 2008). From another perspective, Bas (2006) argued that the effect of closure, reflected in an increase of catches following resumption of the activity, is more likely due to species' behaviour. The absence of fishing activity changes the species' behaviour to move around freely, thus occupying more places, having previously been accustomed to escaping into marginal places during the fishing activity (Bas, 2006). After reopening the fishery, it is likely these species are more susceptible to being caught. This is more evident in limited fisheries, such as continental-shelf métiers, especially for fishes (e.g. *M. merluccius*) as they are more mobile than benthic communities which could be another explanation of the results obtained here.

In the short term, a closure may also involve losses, such as those derived from a reduction in sales or loss of markets (Lleonart and Franquesa, 1999). Prices are a function of supply and demand, and are influenced by fish size, species, consumer preferences, fish quality and the catch quantity-demand function (McClanahan, 2010). Prices of most target species decreased by the closure, which may be related to loss of market due to shortage in the supply after a month of closure. The economic effect of closure at the neighbour port was not so evident, except for the increase of *A. antennatus* price in Dénia during the closure in La Vila Joiosa. This is explained as closure might produce more demand on the market at Dénia where *A. antennatus* is the main target species.

According to the results obtained here, the closure has one apparent benefit, which is the overall reduction of fishing effort for that specified period. Despite this, choosing the suitable timing to schedule closure during the spawning season of the main target species is difficult; it (i.e. early summer in our case of study) would bring up some biological positive effects on some target species (e.g. *M. merluccius*). In any event, these increases in catches after the closure are so far to compensate the lost catches by stopping the activity for a whole month. In addition, closures more likely lead to unavoidable reduction in market prices of many target species. An effective management measure should be easily applied, as in the case of seasonal closure, and be able to ensure enough net contribution to the income of fishers. At the same time, an economically consistent closure should be applied without subsidies and be accepted by the fishing community; otherwise, it will convert into a structural compensation and will lose its economic sense (Lleonart and Franquesa, 1999). Despite these reductions in prices, the wide acceptance of seasonal closure as a management measure by the fishing community is mainly because it is subsidized by the administration. An alternative management measure, based on effort reduction in input-controlled western Mediterranean multi-specific fisheries, could target an additional day per week (other than weekend), when market prices of target species are lower (Guillen and Maynou, 2014). This would result in the double annual amount of effort reduction than in the one moth seasonal closure, as well minimize the short-term negative economic effect of on market prices and, therefore, on fishers' income. Also, it is more acceptable by the fishing community to stop fishing for one day than a whole month, and can be easily applied without additional costs of subsidies.

Chapter 5: Daily variation of ex-vessel fish prices

Abstract

In input-controlled multi-specific fisheries, the evaluation of alternative management strategies is needed as the effectiveness of the current management measures is quite low. For recommendation purposes, the daily variation of ex-vessel price was analysed to determine which day of the week will be better to ban the fishery as an alternative management measure to the one month seasonal closure. Thus, 10-years landings data were used from two representative trawling ports of the western Mediterranean: Dénia and La Vila Joiosa. Analysis of variance (ANOVA) was used to detect significant differences in daily ex-vessel price of the main target species. The lowest mean prices for most target species were on Tuesday and Wednesday, and were higher on Monday and Friday. Banning one day per week (Tuesday or Wednesday), when market prices of target species are lower, would reduce the double of effort than one month of seasonal closure, and likely without subsidies.

Keywords: Effort reduction, Ex-vessel fish price, Input-control management measures.

5.1. Introduction

For many reasons multispecies multi-gear fisheries (e.g. Mediterranean fisheries) present an immensely more difficult challenge for fisheries management than single species fisheries, combining management complexity, scientific uncertainty and political sensitivity (Ulrich *et al.*, 2012). Due to the diversity of both, the characteristics of fleet and the catch composition, the GFCM (General Fisheries Commission for the Mediterranean) has placed emphasis on the direct control of fishing capacity and effort rather than catch limitation as an effective way to reduce fishing mortality (Alemany and Álvarez, 2003; Samy-Kamal *et al.*, 2014). Measures to regulate fishing effort are the main measures used for the management of Mediterranean multi-specific fisheries, in combination with other technical measures, i.e. minimum mesh and landing size or spatio-temporal closures (Cacaud, 2005). The objective is trying to reduce the pressure on fish stocks by limiting the overall size of the fleet as well as the amount of time that the fleet can spend fishing. This includes: limiting the number of vessels (fishing license), limiting fishing capacity (total and individual power), and limiting the fishing time (seasonal closure, days in a week or hours in a day) (Cacaud, 2005).

The effectiveness of some current management measures is arguable (Samy-Kamal *et al.*, in press; submitted). The successful management of fisheries must take into account biological and economic considerations, including the evaluation of alternative management strategies. In the western Mediterranean, a recent surge of studies has discussed to reduce effort by banning fishing one more day a week (other than the week end) instead of seasonal closure (Guillen and Maynou, 2014; Samy-Kamal *et al.*, submitted). This would result in the double annual amount of effort reduction (obtained by one month of closure); as well minimize the short-term negative economic effect of seasonal closure on market prices and therefore on fishers income (Samy-Kamal *et al.*, submitted). Also it is more acceptable by the fishing community to stop fishing one day than a whole month, and can be easily applied without additional costs of subsidies. It is important to note that trawl fisheries in the area of study are not managed separately from other trawl fisheries in Spanish Mediterranean; hence reducing the number of fishing days for the trawling fleet will affect most of western Mediterranean fisheries. However, the selection of which day to be banned is still under discussion. Daily variation in prices of the main target species are important to be considered, in order to select the most suitable day to be banned.

This study was conducted in two important ports (see Samy-Kamal *et al.,* 2014), Dénia and La Vila Joiosa, located in the south-western Mediterranean Sea off the coasts of Spain (Fig. 5.1). The aim of this work was to analyse, for recommendation purposes, the daily variation of ex-vessel price to determine which day of the week is better to ban the fishery. As an alternative management measure, based on effort reduction, could target one more day per week instead of the one month seasonal closure.

5.2. Material and Methods

5.2.1. Data collection

Data records of daily auctions were obtained from the fishing guild of each port for 10 years (2002 to 2011). For each fishing day, data on species landing weight (kg) and its first sale value (€) were available by vessel. Data were arranged in a two-way matrix of daily landings per vessel as samples (rows) and species landed as variables (columns). Sale value (revenue) is the result of quantity landed (kg) and ex-vessel fish price (price fetched by fishers per kg landed fish). The sale value (€) of each target species was divided by its landings (kg) to calculate the first sale price per kg (ex-vessel fish price). Vessels with sporadic landings events within the ports studied were excluded from the analysis, considering only those vessels registered in the studied ports (home port) to avoid possible biases in the data. Most of the included set of vessels have had activity throughout the period considered. The total number of collected samples (vessel·day^{-1}) was 102187 fishing days.

5.2.2. Data analysis

To select the day to ban fishing, Analysis of Variance (ANOVA) was used to test for significant daily differences (daily variation) in the ex-vessel price (euro · kg^{-1}) of the main target species using the whole set of data (10 years). The experimental design consisted of two factors: *Day* (5 levels, fixed) and *Port* (2 levels, fixed and orthogonal). An even numbers of samples were randomly selected to maintain our balanced data within each level of the factors considered in the experimental design. Thus, for métiers Red mullet, European hake, Norway lobster and Red shrimp with n = 2925, 5576, 2038 and1809 replicates respectively; there were a total of 29250, 55760, 20380 and 18090 observations.

When the ANOVA F-test was significant, post hoc analyses were conducted using Student-Newman-Keuls (SNK) multiple comparisons (Underwood, 1981). Before (ANOVA) analysis, Cochran's test was used to test for homogeneity of variance (Cochran, 1951). When significant heterogeneity was found, the data were transformed by $\sqrt{(x + 1)}$ or $\ln(x + 1)$. When transformations did not remove heterogeneity, analyses were performed on the untransformed data, with the F-test α-value set at 0.01, since ANOVA is more restricted to departures from this assumption, especially when the design is balanced and contains a large number of samples/treatments (Underwood, 1997). ANOVA was conducted by R statistical computing software (R Development Core Team, 2010) and the R's package GAD (Sandrini-Neto and Camargo, 2011).

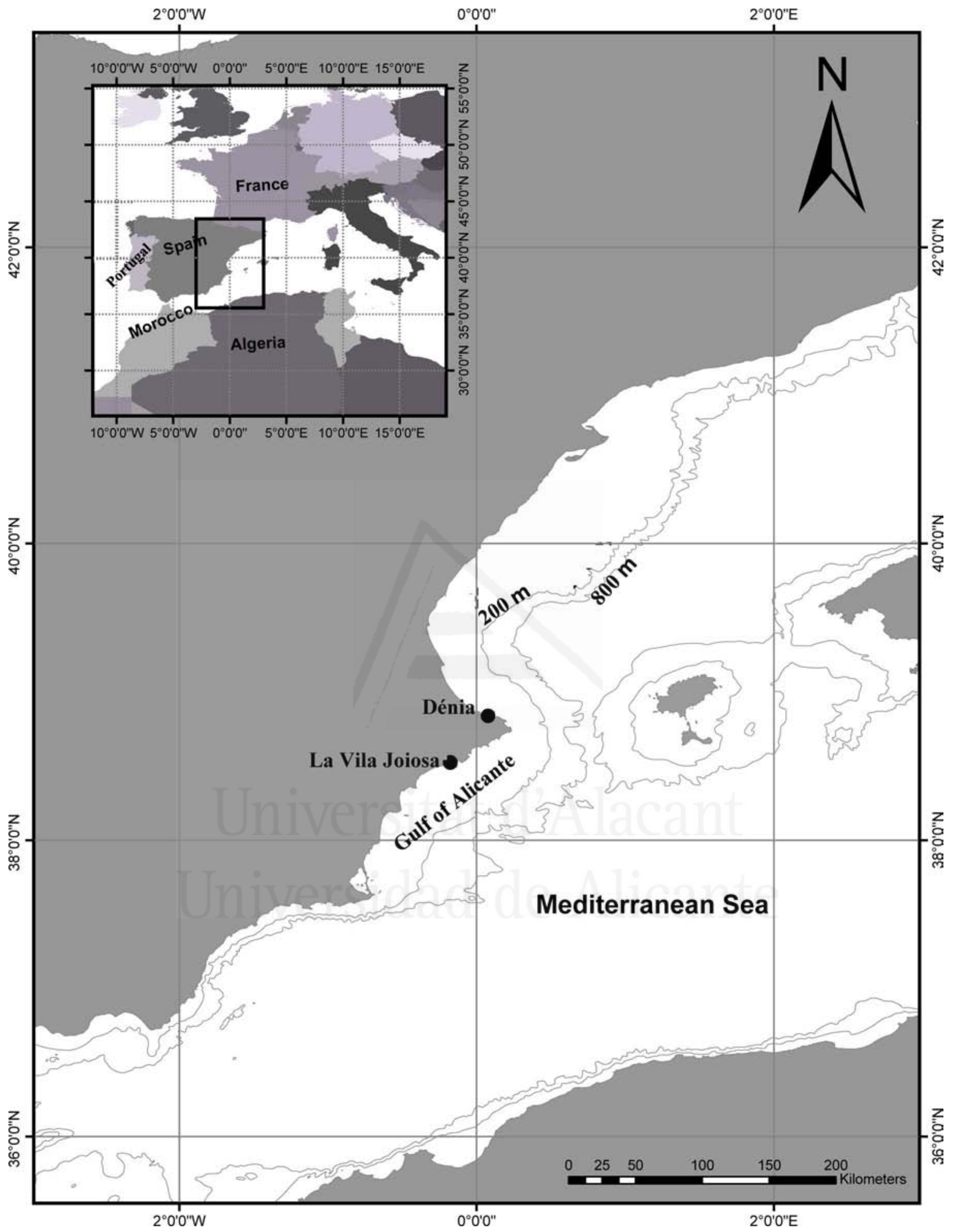


Figure 5.1. Map of the study area (SW Mediterranean) showing the location of the two trawling ports La Vila Joiosa and Dénia (Spain).

5.3. Results

Daily variation was observed in the mean ex-vessel price of all target species with quite similar patterns at both ports (Fig. 5.2). Generally, the lowest prices were observed in the middle of the week, while the highest were observed in Monday (in case of fishes) and Friday (in case of crustaceans). In ANOVAs, the two-way interaction *Day* and *Port* was significant in all cases (Table 5.1). In Dénia, SNK comparisons detected significant lowest prices on Friday for *Mullus* spp. (Fig. 5.2A); Friday then Wednesday for *M. merluccius* (Fig. 5.2C); Wednesday, Tuesday then Monday for *N. norvegicus* (Fig. 5.2E); and Tuesday for *A. antennatus* (Fig. 5.2G). In La Vila Joiosa, significant lowest prices observed on Tuesday, Wednesday then Friday for *Mullus* spp. (Fig. 5.2B); Tuesday, Friday then Wednesday for *M. merluccius* (Fig. 5.2D); Thursday then Wednesday for *N. norvegicus* (Fig. 5.2F); while no significant differences was observed between days for *A. antennatus*. However, quite similar pattern of *A. antennatus* prices was evident between both ports showing the lowest price on Tuesday followed by Wednesday (Fig. 5.2H).

Table 5.1. Results of analysis of variance (ANOVA) with 2 factors (D: *Day*; P: *Port*) for mean ex-vessel price by target species: *Mullus* spp., *M. merluccius*, *N. norvegicus* and *A. antennatus*. D.f.: degrees of freedom; MS: mean square; F: F value. Dash (–) indicates that there is no transformation. (a) indicates that there is no homogeneity of variance, the level of significance being **p <0.001.

Sources of variation	***Mullus* spp.**			***Merluccius merluccius***			***Nephrops norvegicus***			***Aristeus antennatus***			**F versus**
	D.f.	**MS**	**F**	**D.f.**	**MS**	**F**	**D.f.**	**MS**	**F**	**D.f.**	**MS**	**F**	
D	4	378.85	38.17**	4	1318.83	228.93**	4	6304.03	24.03**	4	9121.21	26.60**	Residual
P	1	6295.72	634.29**	1	5442.10	944.68**	1	4454.43	16.98**	1	786331.31	2293.05**	Residual
D×P	4	80.56	8.12**	4	116.97	20.31**	4	4734.50	18.05**	4	3432.60	10.01**	Residual
Residual	29240	9.93		55750	5.76		20370	262.34		18080	342.92		
Transform.		–a			–a			–a			–a		

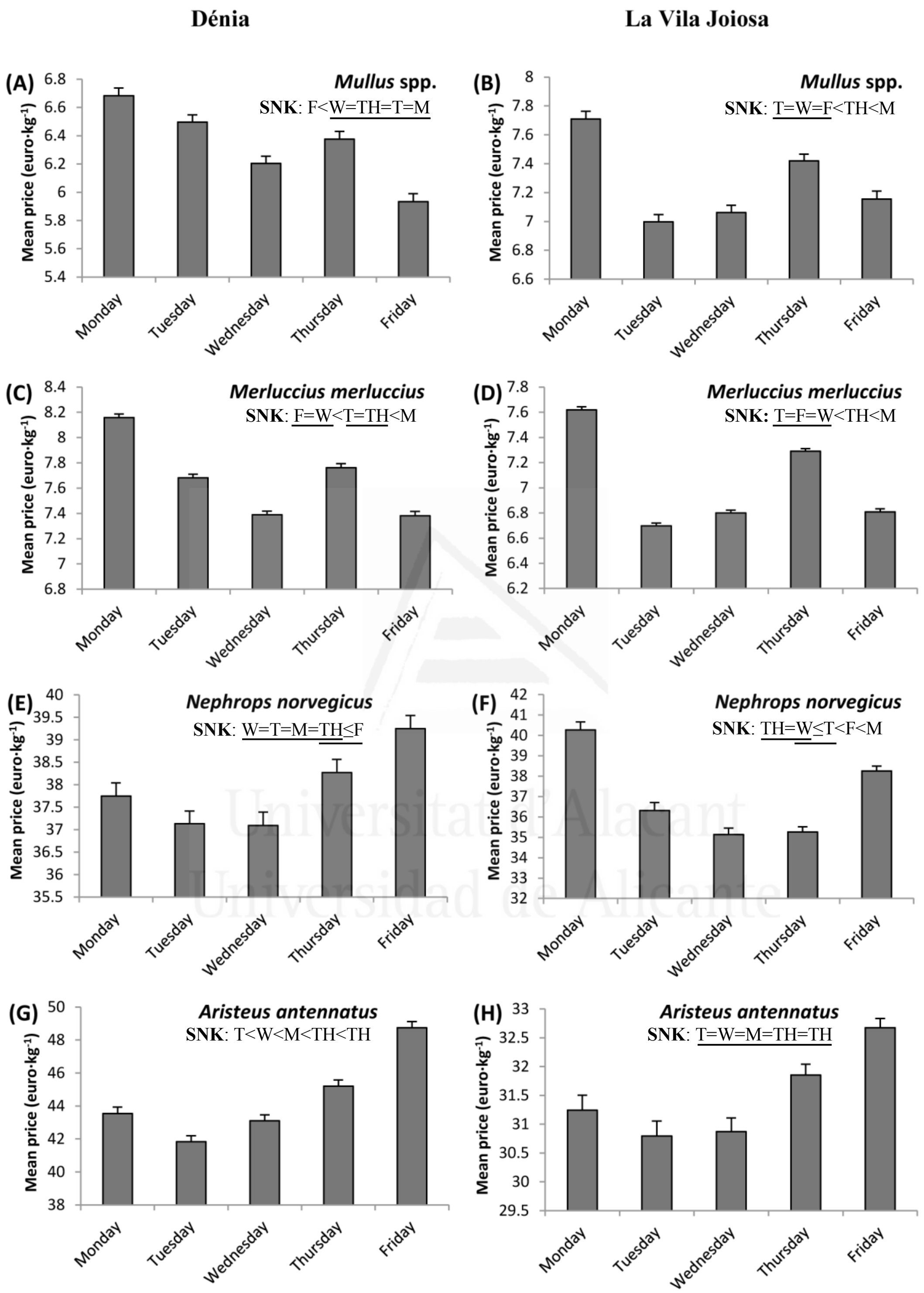


Figure 5.2. Mean ex-vessel price (euro · kg^{-1}) and standard error of the main target species: (A, B) *Mullus* spp., (C, D) *Merluccius merluccius*, (E, F) *Nephrops norvegicus* and (G, H) *Aristeus antennatus* in the two ports: Dénia (left) and La Vila Joiosa (right). Student–Neuman–Keuls (SNK) pairwise comparisons among days of the week (Monday: M, Tuesday: T, Wednesday: W, Thursday: Th, and Friday: F).

5.4. Discussion

The significant daily variation in prices could be related to variations in daily catch rates as price-quantity relationship. The lowest mean ex-vessel prices for most target species were on Tuesday and Wednesday, and were higher on Monday and Friday, with some exceptions. Likewise other works in western Mediterranean, for *A. antennatus*, Guillen and Maynou (2014) considered than in Tuesday is the lowest price of the week, while in Friday is the highest. Similarly, Sardà and Maynou (1998) observed higher fishing effort targeting the Red shrimp fishery on Fridays because prices are higher. The conformity of these results, in case of Red shrimp, may be related to a higher consumption on restaurant during the weekend. On the other hand, higher prices on Monday are related with no fishing during the weekend. This may induce fishermen to devote more or less effort to a certain target species on specific day, resulting to daily difference in effort, subsequently catch rates and therefore price-quantity relationship.

According to the results obtained here, an alternative management measure based on effort reduction in input-controlled western Mediterranean multi-specific fisheries could target on a day per week (other than week-end) Tuesday or Wednesday when ex-vessel prices of target species are lower. Moreover, if the reduction is produced on Wednesday it probably increase the price of the previous and next day, and compensate the lower catches in the short term with a reduction of cost and an increase of average prices for the remaining days. This will reduce fishing effort in 52 days per year what may reduce overfishing in demersal stocks in the Mediterranean Sea, instead of the 20 days that fishery stop in the seasonal closure. In addition, this will remove the burden of subsidies on the administration; as such measure could be adopted without subsidies. Meanwhile this amount of money can be used in other efficient measures such as MPAs.

Chapter 6: General discussion and conclusions

General discussion

6.1. Data and analysis

The different approaches taken in this thesis have allowed analysing the long-term (2002-2011) evolution of fishing effort, as well as its temporal distribution between the identified métiers and explore the resulting catch profiles in three trawling ports of the western Mediterranean. In addition, these approaches permitted to analyse the effect of the seasonal closure and the improvement of selectivity as two of the main management measures applied in the fishery. Finally, to analyse daily variation in market prices of the four main target species to select the appropriate day with the lowest prices to be banned as an alternative management measure to one month seasonal closure.

Regarding the quality and the utility of the data used in this thesis, which are based on daily landings (weight in kg and sale value in euros) by species and fishing effort, obtained from the fishing guilds of the ports under study. These data were provided by species local names, where some species has more than one common name (e.g. in Spanish or in Valencian). However these common names were identified and their corresponding scientific names of the main species are listed in annex I. These data were crossed by the characteristics of vessels which were extracted from the Census operational fleet of the General Secretariat of Maritime Fisheries, Ministry of Agriculture and Fisheries (http://www.mapya.es). Many authors have pointed out the difficulty in obtaining data in the Mediterranean (Lleonart *et al.,* 1998) and the importance of landings and catch data (Kimura, 1981; Fox and Starr, 1996; Pauly *et al.,* 2013). Although these data seem to be very simple, it is very valuable, due to the difficulty in obtaining such long-time trends of unbroken period (2002-2011) in Mediterranean fisheries. In addition, it provides very detailed information of the fishing activity, on biological, economic terms and the exerted fishing effort. The analysis of these data came up with a comprehensive overview of the fishery and its evolution. Also it provides essential information for the multivariate techniques used to identify different métiers and fishing tactics in the fishery. These data also afford a remarkable chance to evaluate changes in the fishery under different management measures. By contrast, the nature of the available data does not reveal a fundamental aspect of the fishery which is the spatial distribution of fishing effort.

6.2. Identification and analysis of k étiers

The identification of métiers was a preliminary objective of the thesis that helps to undergo the rest of analysis (e.g. analyse the temporal trends and seasonality of fishing effort exerted on different métiers or evaluate different management measures). However we were not able to identify approximately 9700 fishing days (approximately the 8% of the fishing days analysed, mostly in the port of Dénia) within their corresponding fishing tactics. During these days the same vessel could have used more than one fishing tactic. Palmer *et al.* (2009) developed a methodology capable to classify those days where the same vessel used more than one fishing tactic during the same fishing day, identifying which fishing tactics were carried out. However, our objective was not to classify all the data, as mentioned it was a preliminary step to conduct the main objectives of the thesis. We believe that including these days will introduce a bias in the rest of analysis (e.g. temporal distribution of fishing effort or evaluation of management measures). The estimate will be more realistic if we consider only those individual fishing days that are expressly directed to the species. Of course, we would prefer to have the data disaggregated by trawl hauls (fishing sets) and not aggregated by day, but such data were not available. In this sense we believe that it is more accurate to discard some data (less than 8%) than to artificially separate those fishing days in which the vessel use more than one fishing tactic.

The results of the comparison between different métiers have shown that, even though trawling fishing effort in the study area extended on homogeneous soft bottom of the continental shelf and upper slope, each métier act in a heterogeneous way in their characteristics, temporal dynamics and spatial distribution (chapter 2). The use of specific métier is an adaptive response of fishers that provides the flexibility to increase, or at least maintain, their catch and income.

In the Mediterranean, although trawling exploitation is directed at a restricted number of target species, the total landing and its economic value are also generated from several species belonging to the so called "accessory species" and, for this reason, the Mediterranean trawl fishery has been classified as multi-specific (Caddy, 1993). The dominant species in the landings within the same métier were generally similar between ports, however they were different among métiers (see chapter 2). The most abundant high value species were the main target species, that exhibited seasonal variation in their abundance and market value and therefore, this was the main reason to use a métier or another (see chapter 2). The prevailing role of depth, with a secondary role of seasonal influence on the demersal resources in the Mediterranean, has already been documented by different authors (e.g. Cartes and Sardá, 1992; 1993; Cartes, 1993). According to our knowledge, this is the first work that analyse the annual and seasonal variation in the fishing effort of different métiers in the western Mediterranean using long-time data series. Since fishing effort regulations are the main management measures in the Mediterranean fisheries, the analyses of effort distribution between different métiers at different ports, is useful for designing management plans based on effort control. The patterns observed in the distribution of effort, can indicate when is the most suitable time to reduce the overall effort (e.g. to set a seasonal closure). For example, closing the fishing ground during months of lower activity would have fewer effects on fishing sector and may be easily accepted, but it will produce a lower reduction in fishing mortality than if the closure was established in months with higher activity. On the other hand, closure can be set in months of the most intense fishing effort directed on certain métier, when there is a need to protect a specific target species or accessory species of this métier.

6.3. The current situation

This study allowed us to analyse fishing effort evolution of trawling fleet of the three ports understudy. The fishing effort of a vessel is defined by two factors, time and fishing power, being the total fishing effort exerted by fleet the sum of the individual efforts of its component vessels. In the Mediterranean, the activity of a trawler (fishing time) is limited to 12 hours per day. Most of trawlers try to maximize the fishing time (about 10 hours of real fishing effort) to approximate the allowable time. This can justify that trawl effort can be measured in a day as a u nit of time. However, this differs from one métier to another, where slope métiers need more time (navigating) to reach fishing grounds than continental shelf métiers. On the other hand, the power or fishing capacity is a complex and hardly measurable function, which depends on the characteristics of the vessel, fishing gear and skills of the crew. Generally the most considered factor of the fishing capacity of trawlers is the engine power; however, in western Mediterranean this factor is of a little use, as it is known to depart from real values because vessel power is regulated (Goñi *et al.,* 1999, Sánchez Lizaso, 2002). Therefore, it was more convenient to determine the fishing capacity using tonnage (GT or GRT) and vessel size (total length). The analysis of long-time series of effort data, revealed the annual decline in the fishing effort, expressed in total number of vessels, fishing days, total length and gross tonnage in the two most important ports studied, La Vila Joiosa and Dénia (chapter 2). Reductions in vessel mean horsepower and GT, indicated that the most powerful vessels have been withdrawn from the fishery. This removal was probably linked to the higher fuel prices that make fishing for this fleet segment less profitable. This gives more attention to socio-economic management measures, as it would be more effective in reducing the fishing effort when external factors (i.e. fuel price) affect the net profits of fishers. This is closely based on pioneer researches in fisheries economics presenting models of entering and exiting common property fisheries (Gordon, 1954). A profitable fishery attracts additional effort (vessels enter), eventually leading to overcapacity and less profit. Similarly, fishing vessels exit depending on their economic viability (or reduced expectations of future benefits).

The trawling fleet in the three ports understudy provide about 3000 tonnes annually (chapter 2), which corresponds to about 0.2% of the total Mediterranean landings (about 1.5 million tonnes). This can be consider a high percentage for only three ports taking into account the huge number of ports and fishing gears in the Mediterranean Sea. Regarding the total landings, CPUE and income, they generally remained more or less stable throughout the study period (chapter 2), although it is appreciated two increments in 2006 and 2011 in La Vila Joiosa. This stability of landings linked to the previously discussed decline of the fishing effort and fishing capacity, produced very mild positive changes observed in an increase of CPUE (chapter 2). The power of fishing vessels has increased considerably over the decades of eighties and nineties. However in the past decade, the common fisheries policy for the European Union member countries, has adopted some approaches whose main priorities were: first, the target support for the modernization of the fleet in all its forms and, secondly, the adjustment of fishing effort by reducing the capacity of fishing fleet. Probably, most investments made by fishermen have focused on a renewal of fishing equipment, rather than size, have allowed an increase in productivity due technological improvements (e.g. GPS, Sonar, etc.) that facilitate fishing operations. In general, the modernization may have increased effort efficiency despite the withdrawal of vessels. Nevertheless, in recent years the tendency has reversed and seems that more powerful vessels have been withdrawn more than smaller ones. However, the general overall stability of catches can be interpreted that, in general, stocks in the study area show signs of overexploitation. Fishermen always tend to change between different métiers in order to optimize the catches and therefore their economic yields. This takes the total landings to their maximum limits, which explains the overall stability of the total landings. This could perhaps be linked to an ‘‘overfishing steady state’’ situation that has been debated for the whole Mediterranean (Lleonart and Maynou, 2003).

The evolution in the landings of the main target species, based on standardized CPUE by treating disaggregated métiers over a long-time series data, is presented in annex 2. The standardized catch rates were separated from large percentage of the variability of the data, that is not directly attributable to variations in abundance. Despite the overall stability of total landings, the observed temporal variation of some species suggested that the populations are not relatively stable. Some of ANOVA results have shown significant temporal variability at different scales (annual and monthly). This temporal variability is common in fisheries and has been studied in several works including different temporal replication (Abella *et al.,* 2005; Forcada *et al.,* 2007; Valle *et al.,* 2007). The incorporation of a suitable temporal replication in the experimental design, as applied here (chapter 3 and 4), is very important to distinguish the differences and effects caused by the management measure (e.g. closure or selectivity) of those caused by other sources of variability. In this sense, having a detailed long-time series of data was very helpful to adequately substantiate the effects of the two management measure analysed.

Improving selectivity in trawling codends by modifying the shape or size of the mesh has been proved by many experimental works (e.g. Guijarro and Massutí, 2006; Ordines *et al.,* 2006). In the present study (chapter 3), the effectiveness of selectivity by the increase of mesh size (from diamond-mesh 40 to 50-mm) or modification of shape (to square-mesh 40-mm) was evaluated through the landings rates. The fishermen in the area of study have changed their gears at the last month (May 2010, see chapter 3) before the deadline. This unique opportunity has allowed comparing landings before and after the mesh change to verify the effect of this measure. Contrary to what was expected, the change in selectivity caused a si gnificant increase in landings of some métiers. Therefore, the results obtained showed an improvement of short-term fishing yield, indicating that this technical measure has unexpected impact on fish stocks of commercial interest. As discussed (in chapter 3) this increase could be related to either, improvement in the performance of the new gear or manipulation of gears by fishermen, that both may compensate the lower retention of small sizes. Although the study area has certain particularities, fishermen could tend to adapt their fishing effort and performance to optimize their economic yields; such circumventions were observed in other areas after the application of mesh change (Suuronen 2005; Suuronen *et al.,* 2007; Bellido *et al.,* 2011). Size structure of the catches will be necessary to confirm that improved of the catches is produced by a lower mortality of smaller size and a higher proportion of larger fish.

In this input-controlled fishery, the seasonal closure is a management measure based on effort reduction, and it could be an effective short-term management measure if the closure has been set in a suitable timing and for longer period. However, it provokes unavoidable market loss manifested in short-term reduction in the first sale prices of the main target species. Similarly, various authors have addressed that tying-up the trawl fleet for long periods (e.g. monthly bans) implies important logistic problems, as well as economic problems of different natures (see chapter 4) (Guerra-Sierra and Sánchez-Lizaso, 1998; Lleonart and Franquesa, 1999; Guillen and Maynou, 2014). An alternative management measure is to reduce the number of allowed fishing days from 5 to 4 per week. This would avoid negative economic problems of seasonal closure, while at the same time permitting a double reduction of fishing effort obtained by a month of seasonal closure (Guillen and Maynou, 2014). As recommended (see chapter 5) that banning the activity on Wednesday may increase ex-vessel fish prices of previous and next days. It is important to note that, this measure probably can be done without subsidies and therefore remove its burden on the administration. Lagares and Ordaz (2014) have reported that Spain is the highest (about 25%) among EU countries in receiving subsidies from European Fisheries Fund. The overcapacity of the fishing fleet relative to available resources, combined with the significant increase in operational costs (especially fuel, previously discussed) endangers the profitability of fishing vessels, which in some cases are only profitable by EU fishing subsidies. Therefore, many of these subsidies have been transformed to structural compensation which contradicts the initial intention of management measures. Subsidies that should be maintained are only those enhance the growth of fish stocks through conservation, and the monitoring of catch rates through control and surveillance measures to achieve a biological optimal use (Sumaila *et al.,* 2010).

6.4. Recommendations and future improvements

Despite the actions that have been undertaken to mitigate the fishing impact on the ecosystem and rebuild exploited populations, fisheries management regulations are still arguable in the Mediterranean (Mora *et al.,* 2009). The management of Mediterranean fisheries is based on control of fishing effort along with additional technical measures, such as minimum sizes of the species landed, mesh sizes and gear, etc. Lleonart (1999) pointed out that Mediterranean fisheries are a good example to use management based on an ecosystem approach, as data and knowledge are scarce, resources are highly exploited by decades of intense fishing activity, and the complexity of fisheries makes the classic management approaches unrealistic.

Colloca *et al.* (2013) demonstrated that under the current fishing regime in the Mediterranean, stock productivity and fleet profitability are generally affected by a combination of high fishing mortality and poor selectivity featuring the main fisheries. They also emphasized that, a simple reduction in the current fishing mortality, without changing selectivity, will not allow neither to maximize the stock biomass nor the fisheries yield and revenue. While this can be achieved only through a radical change in fisheries selectivity, shifting the size of first capture towards the size at which unexploited fish cohorts achieve their maximum biomass, the so-called optimal length (Colloca *et al.,* 2013).

Although the fishery management agencies attempt to ensure selectivity more effectively to enhance yield, some of Mediterranean fisheries still depend on young and small fishes as target species, which mostly are caught before they can reproduce (Colloca *et al.,* 2013). This pattern occurs for some important Mediterranean species, such as hake. The improvement of the selectivity in Mediterranean fisheries is challenging because of their multi-specific nature. Although for some stocks, such as red mullet, swordfish, small pelagics and the giant red shrimp, the current critical length (L_{cur}) is not so far from the optimal (L_{opt}), for hake, bluefin tuna, blue and red shrimp or striped red mullet stocks, the achievement of L_{opt} needs a strong increase in length at first capture, which is estimated between 1.5 and 4 times of L_{cur} (Colloca *et al.,* 2013). Colloca *et al.* (2013) also suggested a set of technical improvements that can be adopted to reduce the impact of the trawl on vulnerable species or juveniles, such as grid, escape panel, modified separator trawl and modified codends and minimize the impact on the seabed (Colloca *et al.,* 2013). The multi-specific nature of the Mediterranean trawl fisheries also complicates the adoption of other management measure such as seasonal closure (chapter 4).

In the sound of métier-based measure, closure also can be adjusted on the month of the most intense fishing effort directed on certain métier to decrease fishing intensity (as recommended in chapter 2). The existence of a single fishery management in the area in which four main target species are exploited, assumes that any change in fishing pressure or selectivity will be applied to all target species equally. The reality of the bottom trawl fleet activity in the Mediterranean is more complicated: the four target species are not caught simultaneously. As we have seen (chapter 2), each métier operated at different fishing grounds and different season during the year. It is evident that a reduction of overall fishing effort, as well as selectivity, will not affect all target species equally, unless characteristics of target species and the activity of vessels in each of the métiers were taken into account.

The degree of compliance to any management measure depends on an effective surveillance system that prevents the circumvention by fishermen. However, this is a weak point in the Mediterranean, because it is difficult to perform effective surveillance at sea for these approaches. Control and surveillance at sea, a crucial step of any management process, has not been efficient in enforcing the adopted measures. From the point of view of surveillance, it is easier to control effort measures such as limiting access (via VMS) than technical regulations of selectivity (through inspections). Currently, the means that are available to control the fishing fleet from the ports in the gulf of Alicante do not ensure effective monitoring, so it does not seem that some regulations (e.g. improving selectivity or maximum motor power) can be met. This is also because fishermen are not usually included in decision processes, and the new regulations enforced are often not fully implemented. In general, there is a lack of communication among the three main groups of stakeholders for an adaptive management: managers, fishermen and scientists (Lleonart and Maynou, 2003). Incorporate the fishing sector in the process of management is fundamental, to understand community priorities and behaviors, and to adapt management tools adequately with their needs (Helvey, 2004; Pita *et al.,* 2011; Gelcich *et al.,* 2008; 2009). Integrate fishers into management decision making processes, will increase the understanding of their reactions under management changes and how those changes could affect the fishing community. Increased fishers collaboration should also reduce conflict, which helps to improve their compliance and results to overall management success. There are also calls for more local management (with a r educed emphasis on centralised control), and co-management, with increased participation of the fishing community. The Castellón Trawling Plan, which took place from 1961 to 1966, was a unique experience and appears as a highly useful model of an exactly co-management. The incorporation of the fishing sector in decision making and, especially, in the tasks of surveillance and control of compliance with the regulations, was the basis of its success (Agrafojo *et al.,* 1999).

There is an obvious need to improve fisheries management tools in the Mediterranean trawl fisheries. Adopting an ecosystem-based, instead of single species, approach to fisheries management has been promoted worldwide (Pauly *et al.,* 2002; Leslie and McLeod, 2007; Levin and Lubchenco, 2008). The future of fisheries in the Mediterranean requires the formulation of new management strategies in the sound of ecosystem based approach. The ecosystem approach to fisheries requires new tools to enable the manager to implement management measures to protect the integrity of the environment affected by the activity at the lowest possible operating cost. In the absence of information on the environmental situation or certain fishery's resources, as well as management uncertainty, there is an increasing emphasis on the use of spatial restrictions by means of marine protected areas (MPAs). This tool can preserve and restore biodiversity, promote ecosystem resilience, maintain fisheries sustainability and contribute to the ecosystem-based approach (Pauly *et al.,* 2005;

Roberts, 2012). One of the main objectives of MPAs is to decrease the fishing mortality by prohibiting extractive use in a limited space, and therefore a resulting spillover effects (Forcada *et al.,* 2009). However, most of MPAs in the Mediterranean are established in coastal areas, mainly to preserve some vulnerable ecosystems and benefits artisanal fisheries. Meanwhile deep fishing grounds are areas of common trawling rarely protected in the Mediterranean. Deep slope areas of soft bottoms are the main fishing ground for trawling and are the habitat of many important marine resources should be protected. Spatial restriction of deep fishing grounds for trawling fisheries was implemented in many cases (Mazzini, 2013), with the intention of overcoming limitations that had traditional fisheries management measures. Likewise MPAs, spatial restriction acts as refuge area for species in concern, sites for their recover as well as restoration of their habitat. It showed that there is a clear concentration of effort around the closed areas that is consistent with the occurrence of export of biomass (spillover effect) to adjacent fishing grounds (Mazzini, 2013). More analysis should be done to study the spatial distribution of the fishing effort, directed to different métiers and to be linked with the distribution pattern of the target species to adequately select sites (e.g. with intensive effort) for closure.

Conclusions

1. Desegregated long-term series of daily landings and effort data provides very detailed information of the fishing activity, on biological and economic terms, and the exerted fishing effort, and also afford a remarkable chance to evaluate changes in the fishery under different management measures. It would be very useful to provide direct access to fishing guild's data for different institutions and scientific groups involved in fisheries management, to collect disaggregated catch and effort data based on the daily landings by vessel, as it can provide important information on possible changes in the fishery.
2. The methodology used to assign catch profiles and effort to one of the main métiers, based on long-time series of landings data, has been useful for our analysis. However, for different purposes, disaggregated fishing sets are more useful to deal with days when fishers use more than one métiers.
3. In the Mediterranean, although trawling exploitation is directed at a restricted number of target species, the total landing and its economic value are also generated from several species belonging to the so called "accessory species", and for this reason, the Mediterranean trawl fishery has been classified as multi-specific. Despite the large number of species, around 80% of landings were represented by just 15. The dominant species in the landings of western Mediterranean trawl fishery are: European hake *Merluccius merluccius*, blue whiting *Micromesistius poutassou*, red shrimp *Aristeus antennatus*, mullets *Mullus* spp., *Octopus vulgaris* and Norway lobster *Nephrops norvegicus*.
4. Four main métiers underpinning the trawling fishery of the western Mediterranean: Red mullet, European hake, Norway lobster and Red shrimp, are directing to the most abundant high value species and their accessory species.
5. Variation in fishing effort was found in the use of different métiers at seasonal and annual scales. The change between the various métiers depends on the abundance of

resources and their life cycles as well as economic factors (e.g. market value). The use of specific métier is an adaptive response provides the flexibility to increase or at least maintain their catch and income. This is useful for designing management plans based on effort control. For instance, when is the most suitable time to reduce the overall effort (e.g. to set a seasonal closure).

6. The analysis of long-time series of effort data revealed an annual decline in the fishing effort, expressed in total number of vessels, fishing days, total length and gross tonnage, in the two most important ports, La Vila Joiosa and Dénia. Also reductions in vessel mean horsepower and GT, indicated that more powerful vessels have been withdrawn from the fishery in last years.
7. The annual fluctuations in standardized CPUE suggest that variations in resource abundance are relatively unstable, probably due to natural fluctuations in environmental conditions. However the general overall stability of landings could perhaps be linked to an ‘‘overfishing steady state’’ situation in the Mediterranean.
8. The introduction of a 50-mm diamond or 40-mm square mesh cod-end in a trawl fishery of western Mediterranean did not show the expected decrease of catches on the short term. Probably, this could be related with a higher performance of the new gear that may compensate the lower retention of smaller sizes. However, if this assumption is true, some positive effects are expected on the long term, without diminishing the economic profit just after applying the new mesh. Otherwise, the anticipated long-term benefits will not be realised.
9. The seasonal closures have shown successes and failures dependent on the target resources and season. The management measure has one apparent benefit, which is the overall reduction of fishing effort for that specified period. Choosing the suitable timing to set closure during the higher catchability or higher recruitment period of the main target species (i.e. early summer in our case of study) would bring up biologic positive effects. However, it provokes market loss manifested in short-term reduction in the first sale prices of the main target species.

10. An alternative management measure to the one month seasonal closure could target one additional day per week (other than weekend) with the lowest market prices (Tuesday or Wednesday), to avoid negative economic consequences and reduce the double of effort.
11. The future of fisheries in the Mediterranean requires the formulation of new management strategies in the sound of ecosystem-based approach and métiers-based measures; because the complexity of fisheries makes the classic management approaches unrealistic.

Conclusiones

1. Los desembarques diarios desagregados y datos de esfuerzo, proporcionan información muy detallada sobre la actividad pesquera, en términos económicos, biológicos y sobre el esfuerzo pesquero, y también dan una oportunidad extraordinaria para evaluar los cambios en la pesquería bajo diferentes medidas de gestión. Sería muy útil proporcionar un a cceso directo a los datos de cofradías de pescadores para las diferentes instituciones y grupos científicos involucrados en la gestión de la pesca, para recoger así los datos de desembarques diarios desagregados por barco y esfuerzo, ya que puede proporcionar información importante sobre los posibles cambios en la pesquería.
2. La metodología utilizada para asignar perfiles de captura y esfuerzo a uno de los principales métiers, basada a series históricas de datos de desembarques, ha sido útil para los análisis. Sin embargo, para propósitos diferentes, los datos desagregados por lances serían más útiles para analizar aquellos días donde los pescadores utilizan más de un métier.
3. En el Mediterráneo, aunque la pesca de arrastre está dirigida a un número restringido de especies objetivo, los desembarques totales y su valor económico también se generan de varias especies pertenecientes a las denominadas "especies accesorias", y por esta razón, se ha clasificado la pesquería de arrastre del Mediterráneo como multi-específica. A pesar del gran número de especies, alrededor del 80% de los desembarques están constituidos por sólo 15. Las especies dominantes en los desembarques de la pesca de arrastre del Mediterráneo occidental son: *Merluccius merluccius*, *Micromesistius poutassou*, *Aristeus antennatus*, *Mullus* spp., *Octopus vulgaris* y *Nephrops norvegicus*.
4. Cuatro métiers principales sustentan la pesquería de arrastre del Mediterráneo occidental: el salmonete, la merluza europea, la cigala y la gamba roja, estando dirigidos a las especies de alto valor más abundantes junto a sus especies accesorias.

5. La variación temporal en el esfuerzo de pesca se evidencia en el uso de los diferentes métiers a ambas escalas, estacionales y anuales. El cambio entre los distintos métiers depende de la abundancia de los recursos y sus ciclos de vida, así como los factores económicos (por ejemplo, el valor de mercado). El uso de un métier específico es una respuesta adaptativa que proporciona la flexibilidad para aumentar, o al menos mantener, sus capturas y los ingresos. Esto es útil para el diseño de planes de gestión basados en el control del esfuerzo. Por ejemplo, para decidir cuándo es el momento más adecuado para reducir el esfuerzo general (por ejemplo, para establecer un cierre de temporada).
6. El análisis de la serie histórica de los datos de esfuerzo a largo plazo, reveló la disminución anual en el esfuerzo pesquero, expresada en número de barcos, días de pesca, eslora total y arqueo bruto (GT), en los dos puertos más importantes, La Vila Joiosa y Dénia. También las reducciones observadas en la potencia media de motor y GT, indicaron que los barcos más potentes se han retirado de la pesquería en los últimos años.
7. Las fluctuaciones anuales de la CPUE estandarizada, sugieren que las variaciones en la abundancia de recursos son relativamente inestables, probablemente debido a las fluctuaciones naturales de las condiciones ambientales. Sin embargo, la estabilidad global de los desembarques tal vez podría estar vinculado a un "estado de sobrepesca sostenible" en el Mediterráneo.
8. La introducción de una malla rómbica de 50 mm o cuadrada de 40 mm en el copo en una pesquería de arrastre del Mediterráneo occidental, no mostró la reducción de las capturas prevista a corto plazo. Probablemente, esto podría estar relacionado con un mayor rendimiento de la nueva malla, que puede compensar la menor retención de tamaños más pequeños. Sin embargo, si esta suposición es cierta, se esperan efectos positivos al largo plazo, sin disminuir el beneficio económico justo después de la aplicación de la nueva malla. De lo contrario, los beneficios previstos a largo plazo no se conseguirán.

9. Las vedas temporales han mostrado tendencias positivas y negativas que dependen de las especies objetivo y la temporada. La medida de gestión tiene un beneficio aparente, que es la reducción global del esfuerzo pesquero para ese período de tiempo determinado. Elegir el momento adecuado para establecer la veda durante la epoca de mayor capturabilidad o reclutamiento más alto de las principales especies objetivo (es decir, a principios de verano en nuestro caso de estudio), podría traer efectos positivos en termino biológicos. Sin embargo, provoca la pérdida de mercado que se manifiesta en la reducción a corto plazo en los precios de primera venta de las principales especies objetivo.
10. Una medida de gestión alternativa a la veda temporal de un mes, podría ser prohibir la pesca un día adicional de la semana (que no sea el fin de semana), que coincida con los precios de mercado más bajos (martes o miércoles), para evitar así las consecuencias económicas negativas y reducir el doble de esfuerzo.
11. El futuro de la pesca en el Mediterráneo requiere la formulación de nuevas estrategias de gestión, con un enfoque basado en el ecosistema y medidas dirigidas a l os métiers, porque la complejidad de la pesca hace que los enfoques de gestión clásicos sean poco realistas.

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Annexes

Annex 1: Local names and their corresponding scientific names of the most landed species by the trawling fleet in the three ports Dénia, Xàbia and La Vila Joiosa.

Common Name	Scientific Name
BACALADILLA/BACALLAR	*Micromesistius poutassou* (Risso, 1827)
BRÓTOLA DE FANGO/ FURO	*Phycis blennoides* (Brünnich, 1768)
BOQUERON	*Engraulis encrasicholus* (Linnaeus, 1758) Or *Engraulis capensis* Gilchrist, 1913
CABALLA	*Scomber scombrus* Linnaeus, 1758
CALAMAR	*Loligo vulgaris* Lamarck, 1798
CIGALA	*Nephrops norvegicus* (Linnaeus, 1766)
CRANC/CANGREJO	*Geryon longipes* Milne Edwards, 1881
CANGREJO BLANCO	*Liocarcinus depurator* (Linnaeus, 1758)
DORADA	*Sparus aurata* Linnaeus, 1758
FANECA/CAPELLÁN	*Trisopterus minutus* (Lacepéde, 1800)
GALLINETA	*Helicolenus dactylopterus* (Delaroche, 1809)
GALERA	Squilla mantis (Linaeus, 1758)
GAMBA	*Aristeus antenatus* (Risso, 1816)
GAMBOSÍN	*Pleisonika* spp.
JUREL/ SORELL	*Trachurus* spp. Rafinesque, 1810
LISA	*Liza aurata* (Risso, 1810)
MOIXINA	*Scyliorhinus* spp.
MOLLERA	*Gadus capelanus* Lacepède, 1800
MORRALLA	a mix of low-valued small fishes of mainly Sparidae and Labridae
MUSOLA	*Mustelus mustelus* (Linnaeus, 1758)
PAGEL/PAJEL	*Pagellus erythrinus* (Linnaeus, 1758)
PALAYAS	*Citharus linguatula* (Linnaeus, 1758)
PASSAMAR	*Illex coindetti* (Verany, 1839)
PESCADILLA/MERLUZA	*Merluccius merluccius* (Linnaeus, 1758)
PLATERO/BURRO	*Argentina sphyraena* Linnaeus, 1758
PULPO BLANCO/POLP BLANC	*Eledone cirrhosa* (Lamarck, 1798)
POTA	*Todarodes sagittatus* (Lamarck, 1798)
PULPO	*Octopus vulgaris* Cuvier, 1797
RAPE	*Lophius* spp. (*L. piscatorius* Linnaeus, 1758 and *L. budegassa* Spinola, 1807)
SALMONETE/CABUT/MOLL	*Mullus* spp. (*M. barbatus* and *M. surmuletus*) Linnaeus, 1758
SEPIA	*Sepia officinalis* Linnaeus, 1758
SOPA	a mix of high-valued medium-sized fishes of mainly Sparidae and Labridae
TOTENA/VOLADOR	*Cheilopogon heterurus* (Rafinesque, 1810)

Annex 2: Standardized CPUE of the main target species (a) *Mullus* spp.,(b) *M. merluccius*,(c) *N. norvegicus*,(d) *A. antennatus*.