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The Channel habitat atlas for marine resource management (CHARM): an aid for planning and decision-making in an area under strong anthropogenic pressure

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Abstract – The eastern English Channel, the narrow channel of water separating northern France and southeast England is an area of intense human use of the array of resources concentrated into its relative small area. The vulnerability of living resources and their habitats brought together French and British maritime experts within a common project (called CHARM): to create an atlas of marine resource habitats in the eastern English Channel so as to provide planners and decision-makers with the necessary information to help managing the use of its living and non-living resources. This multidisciplinary and richly illustrated atlas provides abundant information on the legal framework and physical environment; benthic invertebrates, fish and their habitats; fishing activities; and a first attempt at developing a trophic network model (using ECOPATH software) and a marine conservation planning exercise (using MARXAN software, at a spatial resolution of 25 km^2). Although most of the data used were collected elsewhere, some were collected especially for the project. Similarly, most of the analyses performed on the data where entirely original for this geographical area. The CHARM atlas has significantly improved the knowledge about the eastern Channel while contributing to the recognition that such holistic or multidisciplinary approaches to exploited marine systems are necessary to efficiently and durably manage their resources use.

Key words: Eastern English Channel / Dover Strait / Benthos / Fish / Habitat / Ecosystem / Marine spatial planning / Fisheries / Legislation / Trophic network / Food web / GIS / Geographic Information System

Résumé – La Manche orientale, ce bras de mer qui sépare l'Angleterre de la France, est une zone très riche d'un point de vue écologique et soumise à une forte utilisation anthropique d'une gamme de ressources concentrées sur une superficie relativement faible. La fragilité des ressources marines vivantes et leurs habitats a rassemblé des experts maritimes français et britanniques autour d'un projet commun (nommé CHARM) dans le but de réaliser un atlas des habitats des ressources marines de la Manche orientale. Cet atlas contient les informations nécessaires aux planificateurs et décideurs pour une meilleure gestion des ressources marines, vivantes ou non. Dans ce document pluridisciplinaire, richement illustré, on peut trouver des informations sur le cadre juridique et l'environnement, les invertébrés benthiques, les poissons et leurs habitats ; les activités de pêche ; et également sur le développement d'un modèle de réseau trophique

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(utilisant le logiciel ECOPATH) et un premier exercice de planification spatiale de la conservation (utilisant le logiciel MARXAN, à une résolution spatiale de 25 km^2). Bien que la plupart des données aient été collectées en dehors du projet, certaines l'ont été spécialement pour le projet. De même, la plupart des analyses faites sur ces données sont entièrement inédites pour cette zone géographique. L'atlas CHARM contribue de façon significative à une meilleure connaissance de la Manche orientale tout en démontrant la nécessité de développer ce genre d'approche intégrée ou pluridisciplinaire sur les milieux marins exploités, afin de fournir les connaissances scientifiques nécessaires pour gérer efficacement et de manière durable l'utilisation de leur ressources.

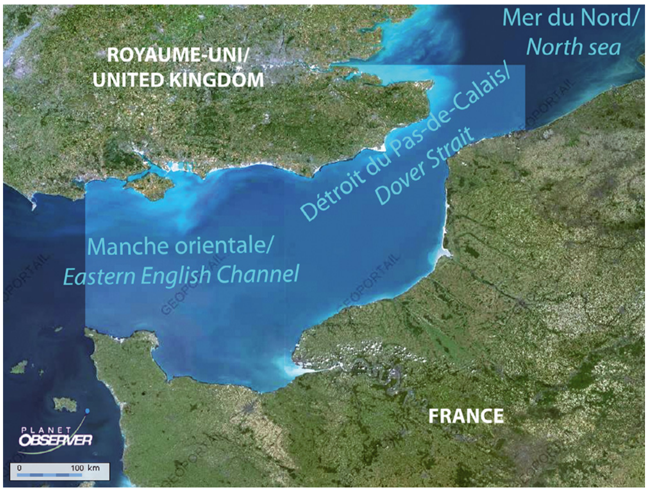

Fig. 1. The eastern English Channel. The study area of the CHARM project is highlighted. Background image courtesy of GEOPORTAIL (www.geoportail.fr, 2007).

1 Introduction

Project localisation

The eastern English Channel (Fig. 1) connects the North Sea to the western English Channel and Atlantic Ocean though the Dover Strait. This narrow channel of water separating northern France and southeast England is an area of intense use of a large array of resources concentrated into its relative small surface area. The eastern English Channel is one of the world's busiest straits for maritime shipping (20% of global maritime traffic) and a key economic area for numerous activities, such as leisure and tourism, international ports and the exploitation of living resources (e.g. fisheries, shellfish farming) or mineral aggregates (e.g. sand and gravel). This area is significant for fisheries because of the abundance of many commercial fish species and the presence of spawning and nursery areas and migratory routes linked to specific environmental characteristics. The vulnerable living resources and their habitats are subjected to strong anthropogenic pressure (e.g. from fisheries, mineral extraction, offshore wind farms, pollution threats from maritime accidents, etc.). This has brought together French and British maritime experts under a common project: to create an atlas of marine resource habitats in the eastern English Channel.

Project objectives

The project "Channel Habitat Atlas for marine Resource Management" (CHARM) focused on the Dover Strait (2003-2005) and was extended to the whole eastern English Channel (2006-2008). The primary aim was to produce a descriptive atlas of this marine ecosystem providing planners and decision-makers with the space-based information needed for the management of the use of its living and non-living resources. The approach was both descriptive and process-oriented, developing management-support information systems and tools for planning and decision-making. The project aimed at promoting a common vision in France and the United Kingdom on the conservation of this fragile ecosystem and its shared marine resources presently suffering from declining abundance. Both phases actively contributed to the dissemination of the knowledge gathered into two successive atlases (Carpentier et al. 2005; Carpentier et al. 2009) to the stakeholders of this cross-border zone and to the public at large to increase their awareness of its value and of the importance of its proper management and conservation.

Project outputs

Habitat conservation is an essential condition for populations and communities to survive and for an ecosystem to function. Hence, the project's primary output was a richly illustrated atlas of marine habitats, focusing largely on biological resources because of their ecological and economic importance in this geographical area. In the latest atlas (Carpentier et al. 2009), a great number of maps can be found, representing: (1) the spatial distribution of key hydrologic (e.g. temperature, salinity), physical (depth, sediment type) and biological (e.g. benthic invertebrates, fish and cephalopods, at various developmental stages) features; (2) the results of habitat modelling for a selection of species, based on physical and environmental predictors; (3) information on human activities, such as French and UK fisheries and fishing communities (collected through a social-anthropological approach) and, (4) a synthesis of international, EC and national regulations relevant to this maritime area and its resources. The atlas ends with two examples of data integration: (i) a first attempt at developing a marine foodweb (or trophic network) model and (ii) a preliminary marine-conservation planning exercise.

The development of a multidisciplinary approach in the Channel was justified by the importance of this marine area and by its socio-economic and ecological potential, and it was tailored for the European maritime strategy which, through a holistic approach to the seas and oceans, aims at achieving a good ecological status of the marine environment by 2021 (Commission of the European Communities 2007). The European maritime strategy is clearly geared toward an ecosystem management based on scientific knowledge under the premise that, if ecological and socio-economic capacities are to last in the longer term, we must first understand how the ecosystem functions.

2 Materials and methods

Each chapter of the atlas included methodologies developed according to data sources and collection methods and analyses performed on these data. In a number of chapters, data collected outside of the CHARM project, notably from historical and ongoing long-term scientific surveys, were used for analysis. In parallel, additional data were collected within the framework of the project, particularly data from recent benthic invertebrate surveys and socio-anthropological data on fishing communities. The analyses of the data and the two examples of data integration mentioned above (i.e. the trophic network model and the marine conservation planning exercise) were developed and carried out specifically for inclusion in the atlas.

Summaries of data sources, collection methods and analyses are made available below for each chapter of the atlas and it is hoped that the present article will make the reader want to find out more about them by accessing the atlas itself (downloadable freely at http://www.ifremer.fr/charm/). Maps are shown in the atlas at various spatial resolutions, which depended on the resolution of the original data. For esthetical reasons, some maps were further 'smoothed' to a resolution of 1 km^2, by interpolation within a Geographic Information System (GIS).

2.1 Legal framework

This chapter had three main objectives: (i) enhancing the understanding of current legal systems, (ii) encouraging a better application of regulations, and (iii) facilitating coordination between French and British legal systems. The methods followed consisted in searching for relevant regulations using different means (libraries, contacts with the structures at the origin of the regulations, e.g. International Maritime Organisation, French maritime affairs, French and British sea fisheries committees). Regulations were carefully examined and discussed with fishers involved in the management of the English Channel marine ecosystem. For each selected regulation, the main points were then summarised and explained. Where relevant, maps illustrating the information given in the body of the regulation were produced and presented together with the text of the regulation.

2.2 Physical environment

This chapter introduced the marine physical environment of the eastern English Channel through maps compiled using data from various sources that are detailed in Carpentier et al. (2009). It is important to note that the data came from: (1) in situ measurements during sea surveys taking place at different seasons of the year: e.g. temperature/salinity/chlorophyll-*a*/fluorescence; (2) hydrodynamic models: e.g. for bed shear stress (a proxy for the pressure applied to the seabed by tidal current; Aldridge and Davies 1993), mean sea level used in the production of the depth map); and (3) remote sensing by a sensor onboard a satellite: e.g. temperature, chlorophyll-*a* concentration, suspended particulate matter (Gohin et al. 2002 and 2008; Saulquin et al. in press). Some of the environmental maps were used as part of the modelling procedures to create the species' habitat maps presented in the following chapter (Species and habitats). They included maps of temperature, salinity and chlorophyll-*a*/fluorescence, depth, bed shear stress and seabed sediment types (Larsonneur et al. 1979),

2.3 Species and habitats

This chapter concentrated on two of the main compartments of marine organisms living in the eastern English Channel: benthos (specifically benthic invertebrates, from annelid worms, molluscs and arthropods to echinoderms) and nekton (large cephalopod molluscs as well as cartilaginous and bony fish). In total, more than 50 species (or groups of species) were considered and their spatial distributions mapped and/or their habitats modelled.

Benthic invertebrates

Several sea surveys, during which data were collected, were presented in the atlas, notably historical surveys that took place in the 1970s, collecting 1 495 samples across the eastern English Channel (Cabioch and Gentil 1975; Cabioch and Glaçon 1975 and 1977). In order to partially update this historical dataset, new data (469 sites) were collected for the CHARM project during 1998-2007, some of which were used for comparison with the historical dataset. Traditional sampling gears such as Rallier du Baty dredge, Hamon grab or van Veen grab were used specifically to collect benthic invertebrates. Beam and bottom trawls, targeting primarily fish and cephalopods, can also capture benthic invertebrates representatively: such data were also used for the atlas.

Fish and cephalopods

This chapter focused on spatial distribution and modelled habitats of fish and cephalopod species. Where data were sufficient, the different stages of their life cycle were presented, though data on the early life stages (eggs, larvae) were relatively limited, compared to data on other developmental stages (juveniles and adults). Data came from various French and British scientific surveys. Eggs were collected using a continuous underway fish egg sampler (CUFES; Checkley et al. 1997) during the International Bottom Trawl Survey (IBTS) in January 2007. Larvae were collected using a bongo net in April/May 1995 and 1999. Fish (mainly juveniles) were collected using a beam trawl in September at coastal nursery sites during the period 1977 to 2006, Young Fish Survey (YFS). Finally, fish of all ages (though mainly juveniles and adults) were collected across the eastern English Channel (1989-2006) in July using a beam trawl (Beam Trawl Survey, BTS; Parker-Humphreys 2005) and in October using a very high vertical opening trawl (VHVO trawl), also known as GOV trawl (Channel Ground Fish Survey, CGFS).

Further details on these surveys (and on the ones targeting benthic invertebrates) are available in the atlas, along with maps of the sampled locations.

For the two biological compartments considered, continuous spatial distribution maps were produced using geostatistics and kriging interpolation (Webster and Oliver 2001) applied to the survey data. This approach was also used for environmental survey data on, e.g. data on temperature and salinity. For a selection of species, -mainly fish and cephalopods-, generalised linear modelling (GLM; McCullagh and Nelder 1989) was used to produce maps of the mean probable/preferential habitat, whilst regression quantile modelling (RQ; Cade and Noon 2003; Vaz et al. 2008) was used to produce maps of the maximum potential habitat. The detailed methodologies are provided as an annex to the atlas.

2.4 Fishing activities

Gears, vessels and exploited species

In the countries neighbouring the eastern English Channel and southern North Sea, landings and fishing effort by commercial fishing vessels are mainly monitored using data collected at auction halls and from European logbooks (for vessels longer than 10 m and/or out at sea for more than 24 hours). French fishery data (fishing effort and landings) were obtained from the national centre for statistical analyses (CNTS), whilst UK data originated from DEFRA (Department for Environment, Food and Rural Affairs) and its Fisheries Activity Database (FAD). Data resolution was that used by the statistical divisions of the International Council for the Exploration of the Sea (ICES), i.e. a grid of 1° longitude by 0.5° latitude. Maps were hence shown at that relatively coarse resolution.

Fishing communities

Based on a previous study (Ota and Just 2008), this chapter described (mainly) small-scale fishing communities active in the eastern English Channel and southern North Sea. Data were collected during interviews with a total of 50 fishers from Ramsgate, Folkestone, Rye and Hastings in the UK, and Calais, Boulogne-sur-mer, Dieppe and Port-en-Bessin in France. Interviews were semi-structured, and a number of key questions were asked in all interviews. Each interview lasted between 20 and 100 min, during which the researcher attempted to guide the interviews in a way that would elicit the particularities of each fisher's fishing activities and family background. Such a socio-anthropological approach was innovative compared with previous studies in this geographical area that used mostly questionnaires (e.g. Walmsey and Pawson 2007). Maps of fishing zones, for example, could be produced based on drawings by the fishers themselves.

2.5 Trophic network

In the context of an ecosystem approach to resource management, there is a need to understand how perturbations caused by anthropogenic activities impact the ecosystem, modifying species abundance, biodiversity or foodweb structure and function (Christensen and Pauly 1997; Hewitt et al. 2008). An Ecopath model of the eastern English Channel was hence constructed for the 1995-1996 time period. The model was a static representation of biomass flows in the food web, and this modelling approach intended to provide a synthetic description of the foodweb structure and reveal some of its fundamental properties. For instance, modelling predator-prey interactions is useful because it provides a synthetic manner of establishing trophic links and carbon fluxes between functional groups in the ecosystem (Pascual and Dunne 2006). Ecopath with Ecosim with Ecospace (EwE) software (Christensen et al. 2005) was used, in which functional groups were formed based on their common eco-biological characteristics, i.e. demography, diet preferences and spatial distribution.

2.6 Marine conservation planning

Systematic conservation planning is seen as the most appropriate approach for identifying priority areas for conservation whilst minimising impacts on other sectors (Margules and Pressey 2000). As many people rely on marine resources for their livelihoods, it is widely recognised that Marine Protected Area (MPA) systems must balance the needs of people and biodiversity (Klein et al. 2008). The systematic conservation planning approach often uses software to identify priority areas, and the most widely used software is MARXAN which has been used to design marine and terrestrial protected area networks in a number of countries (Ball and Possingham 2000). This involves dividing the planning region into a number of planning units (here cells of 5 km^2 surface area, a good trade-off between software computing time and result quality) and calculating the amount of each conservation feature within each unit. Marxan then selects groups of planning units that meet the representation targets, though considering two other factors in the selection process: (i) the cost of the planning units selected (so as to minimise cost) and (ii) their location relative to each other (so as to minimise fragmentation of the protected areas). The cost can be a measure of any aspect of the planning unit, such as its area, the risk of being affected by anthropogenic impacts, or the opportunity costs resulting from its protection (Stewart et al. 2003; Wilson et al. 2005).

3 Results

3.1 Legal framework

The regulations studied in this chapter of the atlas were divided into four main themes: (i) conservation of marine habitats and species, (ii) fisheries, (iii) marine pollution and maritime security, and (iv) marine works. A total of 216 regulations (and groups of regulations) were judged relevant to the eastern English Channel (Table 1); the corresponding 216 summaries and explanations are available on the CD-ROM provided with the atlas. The next step in this analysis would be to directly compare these texts, so as to establish their level of compatibility and detect potential conflicts.

Table 1. Regulations (and groups of regulations) that were judged relevant to the eastern English Channel marine environment.

Themes	Application fields	Types of regulation	Regulations
Conservation	International	Binding law	5
		Soft Law	2
	Community law	Other	1
		Directives	2
		Regulations	2
	French law	*Arrêtés*	7
		Lois	9
	British law	Acts of Parliament	5
		Byelaws	1
		Statutory instruments	2
Fisheries	International	Binding law	3
		Soft Law	10
	Community law	Directives	1
		Regulations	28
	French law	*Arrêtés*	52
		Circulaires	3
		Décrets	12
		Lois	1
	British law	Acts of Parliament	4
		Byelaws	3
		Statutory instruments	16
Pollution & security	International	Binding law	6
		Soft Law	1
	Community law	Other	2
		Directives	13
		Regulations	2
	French law	*Arrêtés*	6
		Lois	1
	British law	Acts of Parliament	2
		Statutory instruments	7
Marine works	Community law	Directives	1
	French law	Other	1
	British law	Acts of Parliament	2
		Non statutory system	1
		Statutory instruments	2

3.2 Physical environment

The marine environment of the eastern English Channel was approached from different perspectives: physical (depth), sedimentary (seabed sediment type), hydrodynamic (bed shear stress), and hydrological (temperature and salinity, chlorophyll-*a* concentration, fluorescence, and suspended particulate matter). Two of the maps presented in this chapter, in which a description of the eastern English Channel environment was given, are shown in Fig. 2. Seasonal patterns of a number of parameters (e.g. temperature, salinity, chlorophyll-*a* concentration, etc.) were highlighted and explained, along with long-term evolution of remotely-sensed sea surface temperature for the period available (1986-2006).

3.3 Species and habitats

A total of 23 species (or groups of species) of benthic invertebrates were presented in the atlas (Table 2). Special attention was given to species having a specific importance in the food web or the community structure. With regard to fish and cephalopods, a total of 33 species (or groups of species) were presented in the atlas (Table 3), and examples of maps are shown in Fig. 3 (benthic invertebrates) and Fig. 4 (fish and cephalopods). For each of the these two faunal compartments, and depending on available data, a number of interpolated (continuous) maps were produced, either by pooling several years of data together or by mapping each year separately to produce time series. Where data were poor -e.g. in the case of infrequent observations of the species and/or when the sampling gear catch of the species was not representative-, probability of presence was mapped instead of abundance (i.e. density). When enough data were available, several developmental stages of fish, as well as different seasons, were shown. The GLM-based habitat models predicted the mean response of the species to environmental factors, whilst RQ-based models predicted the maximal response of the species (under ideal environmental conditions) and hence were considered more favourable for the species (e.g. resulting in a wider predicted spatial extension) and hence more suited for precautionary habitat management (Vaz et al. 2008). This chapter was the most extensive of the atlas, accounting for a third of its content.

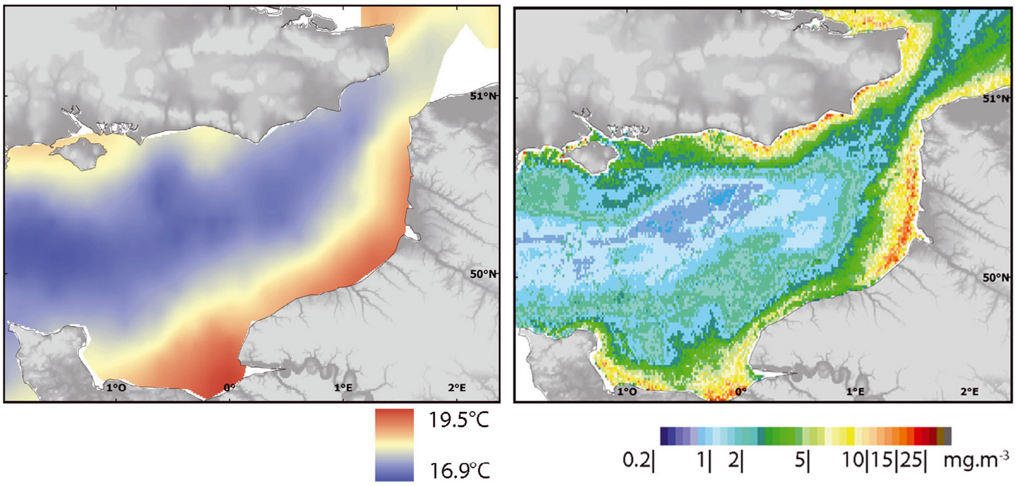

Fig. 2. Mean surface temperature in July for the period 1989-2006 (left), and chlorophyll *a* concentration in May for the period 1998-2006 (right), from chapter "*Physical environment*".

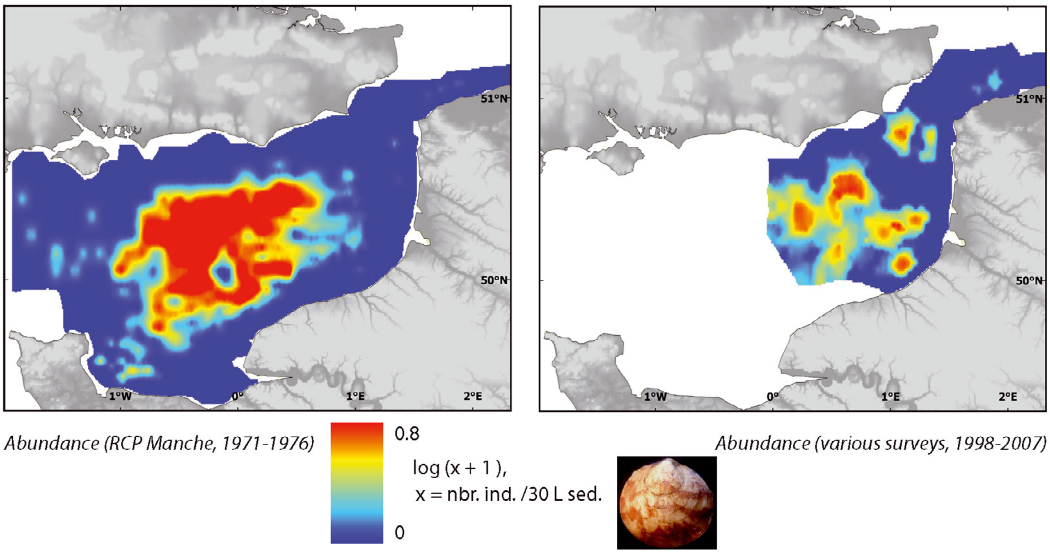

Fig. 3. The temporal evolution of dog cockle (*Glycymeris glycymeris*) spatial distribution for two time periods (photo A. Foveau), from chapter "*Species and habitats (benthic invertebrates)*".

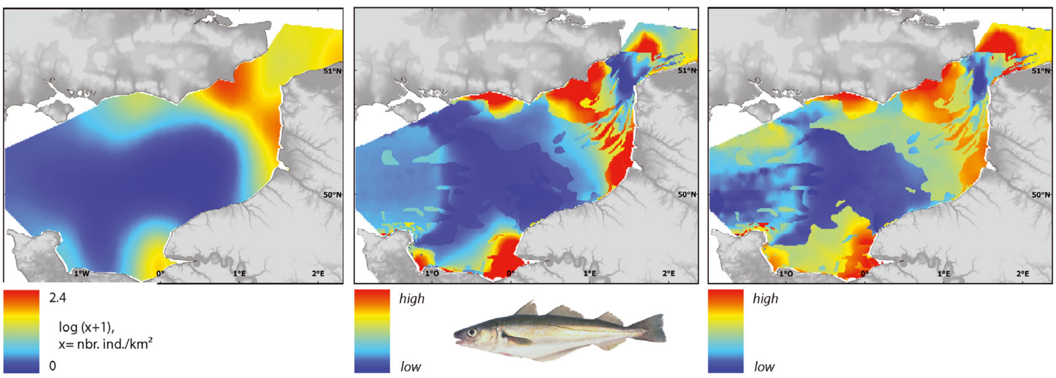

Fig. 4. Mean spatial distribution of whiting (individuals older than one year) in October; *left*: interpolated from survey data for the period 1988 to 2006, preferential; *centre*: GLM model, and potential; *right*, RQ model, habitat maps based on survey data from the same period (photo Ifremer), from chapter "*Species and habitats (fish and cephalopods)*".

Table 2. Benthic invertebrate species considered in the chapter "*Species and habitats*" of the atlas. [1]: habitat model available; [2]: also considered in the chapter "*Fishing activities*".

Scientific name	Common name
Abra alba	White furrow shell
Aequipecten opercularis	Queen scallop
Ampelisca spinipes	-
Asterias rubens	Common starfish
Branchiostoma lanceolatum	Lancelet
Buccinum undatum	Whelk
Ebalia spp.	Nut crabs
Echinocardium cordatum	Sea potato, heart urchin
Echinocyamus pusillus	Pea urchin
Galathea intermedia	Dwarf squat lobster
Gastrosaccus spinifer	Opposum shrimp
Glycymeris glycymeris	Dog cockle
Homarus gammarus[2]	European lobster
Maja brachydactyla[1, 2]	Spider crab
Ophelia borealis	Ophelia
Ophiothrix fragilis	Common brittlestar
Ophiura spp.	Serpent star, brittlestar
Pecten maximus[1, 2]	King scallop
Pisidia longicornis	Long-clawed porcelain crab
Pomatoceros spp.	Tubeworms
Psammechinus miliaris	Green sea urchin
Thia scutellata	Polished crab
Upogebia deltaura	Great mud shrimp

Table 3. Fish and cephalopod species considered in the chapter "*Species and habitats*" of the atlas. [1]: egg stage; [2]: larval stage; [3]: nurseries; [4]: separation between less/more than one year old; [5]: fish of all ages; [6]: separation between male/female; [7]: also considered in the chapter "*Fishing activities*".

Scientific name	Common name
Ammodytidae[2, 5]	European sand eels
Aspitrigla cuculus[4, 7]	Red gurnard
Buglossidium luteum[5]	Solenette
Callionymidae[1, 2, 5]	Dragonets
Clupea harengus[4, 7]	Atlantic herring
Dicentrarchus labrax[3, 5, 7]	European seabass
Engraulis encrasicolus[5]	European anchovy
Gadus morhua[1, 3, 4, 5, 7]	Atlantic cod
Galeorhinus galeus[5]	Tope
Gobiidae[2, 5]	Gobies
Limanda limanda[1, 2, 3, 4, 7]	Common dab
Loligo forbesi[5, 7]	Northern squid
Loligo vulgaris[5, 7]	European squid
Lotidae[1, 5]	Rocklings
Merlangius merlangus[1, 2, 3, 4, 7]	Whiting
Microstomus kitt[3, 4, 5, 7]	Lemon sole
Mullus surmuletus[4, 7]	Red mullet
Platichthys flesus[1, 2, 3, 4, 5, 7]	European flounder
Pleuronectes platessa[1, 3, 7]	European plaice
Raja clavata[6, 4, 5, 7]	Thornback ray
Raja montagui[5, 6]	Spotted ray
Sardina pilchardus[5, 7]	European pilchard
Scomber scombrus[5, 7]	Atlantic mackerel
Scyliorhinus canicula[4, 5, 6, 7]	Lesser spotted dogfish
Scyliorhinus stellaris[5, 7]	Nursehound
Sepia officinalis[5, 7]	Common cuttlefish
Solea solea[1, 2, 3, 5, 7]	Common sole
Spondyliosoma cantharus[4, 5, 7]	Black bream
Sprattus sprattus[2, 3, 5]	Sprat
Squalus acanthias[5, 7]	Spurdog
Trachurus trachurus[4, 7]	Horse mackerel
Trisopterus luscus[2, 3, 5, 7]	Pouting
Trisopterus minutus[5]	Poor cod

3.4 Fishing activities

This double chapter aimed at reviewing fisheries and their associated fishing communities in the eastern English Channel. Examples of atlas maps are shown in Fig. 5. First, the atlas provided an illustrated account of the fishing vessels and gears for both sides (French and UK) of the Channel, followed by information on landings for a number of exploited species, both benthic invertebrates (three species, see Table 2) and fish and cephalopods (30 species, see Table 3). Maps showing the numbers of fishing trips for different fishing vessels (e.g. netters, longliners, inshore trawlers and dredgers, mixed trawlers, etc.) and gear type (e.g. beam trawl, bottom pair trawl, otter trawl, etc.) were produced and shown by ICES division, along with maps of landings (in tonnes of fresh fish equivalent) for exploited species at the same resolution. For exploited species, medium-term temporal trends (1989-2006) in total landings for the study area were also provided. This represented a major contribution to available knowledge in this field and for this geographical area. (e.g. Pawson 1995; Guitton et al. 2003).

Then, the atlas moved from a methodological description of fishing towards a primary socio-anthropological perspective on the fishing industry and those who work in it. It focused on fishing activities, including fishing methods, targeted species and the spatial distribution of fishing zones. It also discussed contemporary social and technological changes affecting fishers. Finally, this chapter analysed the correlation between the practical and the social aspects of fishing activities.

3.5 Trophic network

The model presented in the atlas consisted of 51 functional groups including marine mammals (2), seabirds (1), fish (29), invertebrates (15), primary producers (2), and discard and detritus (1) compartments. This work was an initial step towards the comprehension of the interspecific links and biomass fluxes among biological groups that underlie the food web of the eastern English Channel. An example of use of this model can be seen in Fig. 6, which presents the potential consequences of a 10% increase in fishing effort of a selection of fishing methods (or "métiers") to some functional groups. This modelling study provided a synthetic overview of the different phenomena affecting the food web, and the results will then serve as the basis for simulating the spatio-temporal dynamics of the food web using Ecosim and Ecospace. This type of study can reveal a lot of information regarding the state of the ecosystem and how its biological components are affected by environmental perturbation or change. The results aim at providing the basis for the future evaluations of management options for sustainable exploitation and conservation of marine resources considered as necessary for providing essential livelihood to human societies and meeting increasing food demand (Charles 1994; Barange 2003).

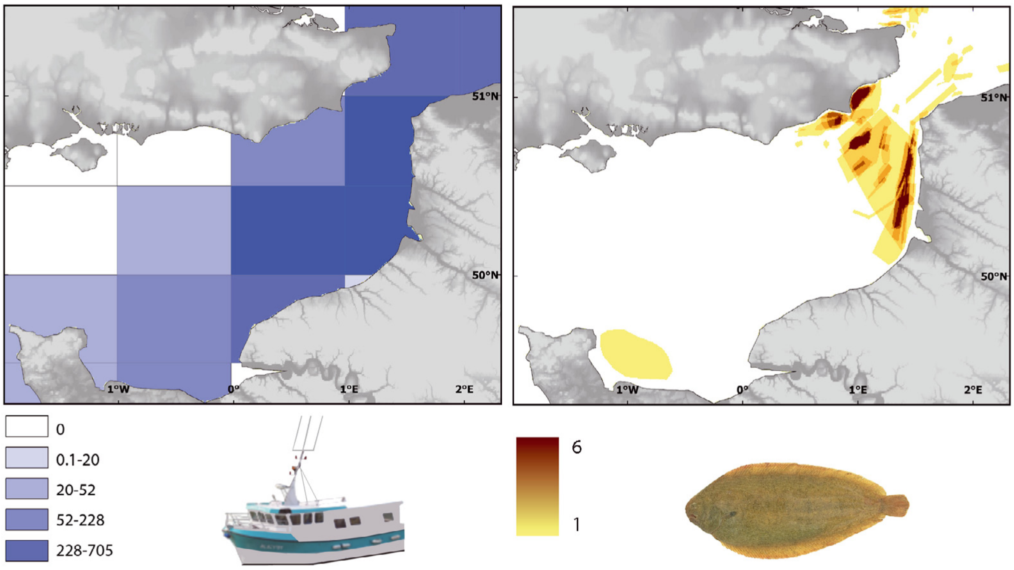

Fig. 5. French netters spatial distribution in 2006 (left, in number of fishing trips per ICES division) and Common sole fishing zones of interviewed fishers (right, in number of interviewed fishers declaring this area as fishing ground) from chapter "*Fishing activities*".

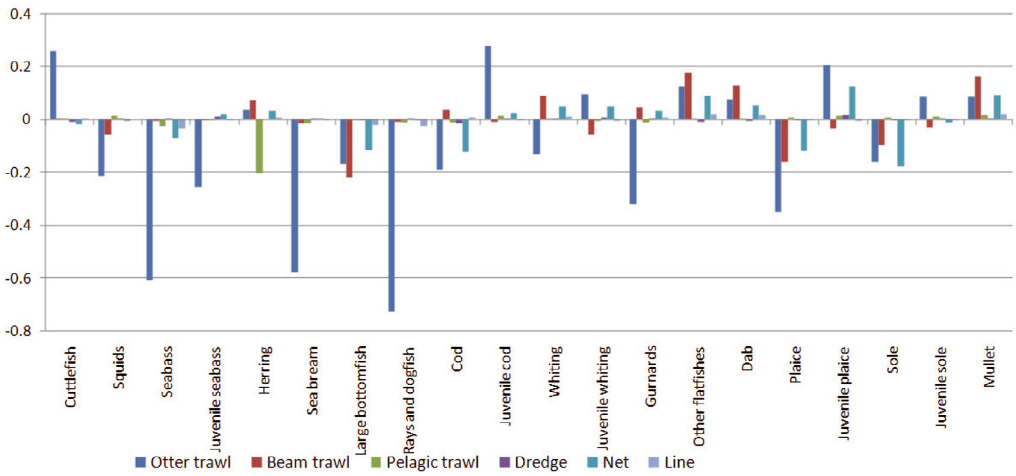

Fig. 6. Mixed trophic impacts of principal métiers on functional groups considered. Positive impacts are shown above the baseline while negative impacts are shown below.

3.6 Marine conservation planning

In the atlas, a preliminary English Channel conservation planning system was developed, and a sensitivity analysis was conducted to investigate the impacts of uncertainty regarding the input parameters on the spatial pattern of priority areas identified for conservation. Three parameters were chosen which focused on: (1) level of fragmentation of the area levels; (2) target conservation levels, i.e. how much of the area should be conserved, and (3) the type of cost data used in the analysis, e.g. fishing pattern and catch, distance to port, etc. (Fig. 7). It was found that all three factors had an impact on the priority areas identified and that the cost metric selected had a particularly large influence. This analysis successfully incorporated biological, economic, legal and anthropological data – some of which collected as part of the CHARM project – in a preliminary conservation assessment. This was an important first step in the development of the English Channel conservation planning system; however, additional steps, some of which involving stakeholders in the implementation strategy (Knight et al. 2006; Ban et al. 2009), need to be taken before this system can be used to make management decisions.

4 Discussion

The atlas (626 pages, with 1 800 colour maps) is the result of four years of in-depth study of the Dover Strait and the eastern English Channel conducted by a dedicated and interdisciplinary team working from both sides of the Channel. It is freely available for download in two languages (English and French) on the project's Internet site (www.ifremer.fr/charm).

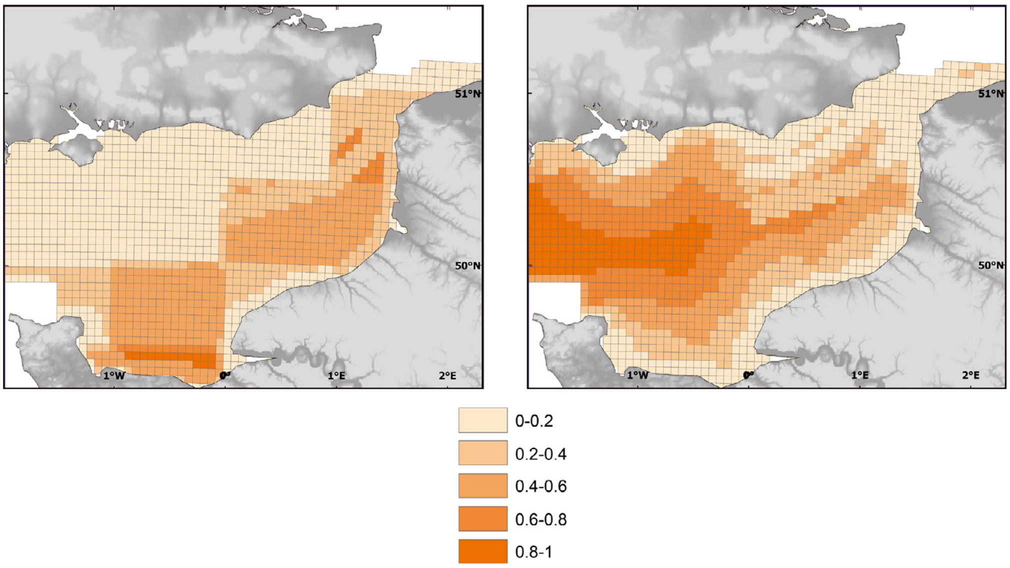

Fig. 7. Planning unit cost maps showing two of the four metrics used in the analyses; *left*: cost = fishing catch, and *right*: cost = distance to port) from chapter "*Marine conservation planning*".

The atlas is written in a way that can be easily comprehended by a wide range of users (from scientists and other researchers, to decision-makers and planners, but also by the wider public such as conservation agencies, industries, students, etc.). By accessing this detailed document, everyone can gain knowledge of the eastern English Channel, its regulations, environmental characteristics, biological richness, but also aspects of its exploitation by human activities, the food web and the tools to sensibly and hence durably manage the use of this fragile ecosystem.

A few aspects of the original work presented in the atlas may be highlighted. Firstly, viewing fisheries activities from the fishers' perspective is a novel approach, for this geographic area and possibly for any marine resource atlas. This was achieved by asking the fishers to tell their own stories of what to them is often a lifelong interest – an interest which they have every reason to respect and to maintain. The development of trophic network models in the eastern English Channel was also an innovative aspect of the project. Who eats what? What are the interactions between species and with humans? What is the role of each component in the ecosystem? This initial work highlighted that each element of the ecosystem (exploited or not, and of any size) contributes significantly to the richness of this maritime zone. It showed that any human intervention, albeit small, can have direct or indirect consequences, of ecological and/or economical importance. Another innovative aspect of the project was the pilot study using a "marine spatial planning" tool to support decision-making for the conservation of marine biodiversity. The works initiated in this project will be further developed to allow for testing of various scenarios based on a range of conservation targets and political and societal constraints. The question "where should [MPAs] be located to [. . .] enhance surrounding fisheries?" was indeed recently identified as one of the "100 ecological questions of high policy relevance [. . .]" (Sutherland et al. 2006).

5 Conclusion

The CHARM atlas has made a huge contribution to knowledge about the eastern English Channel but also towards the recognition that such holistic or multidisciplinary approach is necessary to efficiently and durably manage global marine resources. A lot of work still needs to be carried out; the European Union (through the INTERREG 4a programme) approved in 2009 the extension of the project to the whole English Channel (2009-2012). This will be achieved through widening CHARM activities to investigate topics such as plankton, fishery bio-economics and the effects of climate change. With this added focus on the human or wider social dimension, all parties who presently utilise the Channel will gain an enhanced appreciation of the need to work in harmony.

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