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The CHARM Project: Defying the Channel's loss by improving communication on ecosystem knowledge across borders

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Abstract: The Channel Habitat Atlas for Marine Resource Management (CHARM) is a trans-border collaboration project between France and United Kingdom. It has become, since 2003, a growing network of scientists geared on investing in science through joint collaboration, communication and knowledge management. The initial objective of the project is to provide an atlas for the Eastern English Channel that will serve as significant support to stockholders and policy-makers towards sustainable exploitation and management of this ecosystem. The project started as a pilot program collecting information and "translating" these into comprehensive and integrated knowledge. The two published version of the CHARM atlas which focused on the Dover Strait and Eastern English Channel, respectively, feature a combination of map-based information and inventories on environment, living resources, exploitation and sensitive areas. Integrated studies were conducted in the second volume through construction of food web (ECOPATH) and systematic conservation planning (MARXAN) models. The project is actually in its third phase (2009–2012) which aside from providing map-based inventories of information covering the whole English Channel is geared towards a better understanding of this complex environment an ecosystem-based approach covering more aspects on integrated modeling such as trophic network dynamics, climate change effects, habitat map classification, economics and systematic conservation planning.

Keywords: *English Channel, ecosystem-based approach, ecosystem census, systematic conservation planning, transborder collaboration*

I. Introduction

The English Channel is facing major challenges due to human actions that are causing unprecedented impacts on ecosystem health [1]. This is a crisis that needs to be apprehended as it threatens the collapse of its living resources and the benefits to human society offered by this ecosystem.

The CHARM project aims to awaken consciousness and emphasize a commitment of a cross-section of international experts on the Channel to focus on how to better sustain and conserve this fragile ecosystem. It focuses on habitats which is an important factor especially in explaining the occurrence and distribution of living resources that lives in it. Studying habitats can also provide information about modifications in abundance of biological resources and identify the factors that can lead to these changes.

In 2003, French and English researchers from eight institutes were gathered to collaborate in establishing an initial protocol for collecting environmental and biological data along the Dover Strait [2]. During the second phase

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(2006–2008), scientific efforts were geared on exhaustive data collection and map-based representation of environmental, social and biological information of the Eastern English Channel (Fig. 1). Initial attempts were also done to describe and determine ecosystem state as well as defining better management and conservation options in order to slow down the system's degradation process [3]. Scientific experts assembled were devoted in developing synthesized data focused on specific issues and actions to achieve a better comprehension of system health and pin down current threats while outlining the consequences related to identified challenges and gaps. This is at the same time providing an opportunity for the popularization of information and approaches developed within the context of the project. Critical needs that were identified and covered by the project to date include: (1) provide information on biology and ecology of aquatic living resources, (2) establish ecological links and functioning, (3) comprehension of fisheries dynamics, (4) synthesis and distribution of available data (5) fishers' perception of marine environment and their socio-economic context (6) enhance comprehension and facilitate implementation of regulation in and between states and (7) knowledge on ecosystem management and conservation.

II. Documenting, mapping and modeling

In order to produce a comprehensive atlas, there is a need to provide a census of marine life. This means that it was necessary to identify the existing species, where they occur and what is their habitat. Information on environment (physical and hydrobiological features), living resources (fish and benthic organisms), fisheries and exploitations and existing regulations were collected for the first and second phases of the project were based on existing historical and newly collected data (Fig. 2). A summary of collected information are enumerated below. These along with data integration modeling techniques (habitat, food web and systematic conservation models) used in the atlas [3] can be found in the atlas and can be downloaded in this URL site : http://www.ifremer.fr/charm.

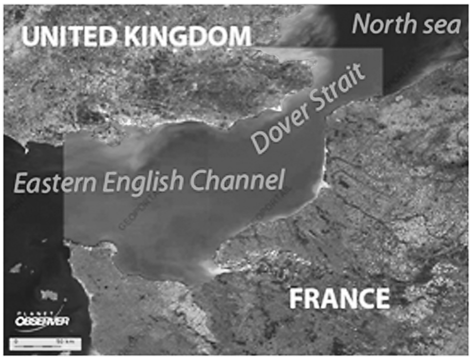

Fig. 1. The Dover Strait and the Eastern English Channel (Source: www.geoportail.com).

A. Physical environment

Most of the data concerning the physical factors such as water temperature and salinity were from in-situ measurements provided by IFREMER's Channel Ground Fish (CGFS) [4] and Beam Trawl Surveys (BTS) [5]. These scientific sea surveys collect abiotic parameters aside from providing species abundance indices in the eastern Channel since 1988 and 2007, respectively. Chlorophyll-*a* concentration were derived from the Sea-viewing Wide Field-of-View Sensor (SeaWIFS) [6] satellite images and IBTS in-situ data. Remote sensing also provided complementary information on temperature and suspended particulate matter [7]. Hydrodynamic models were used to map bed shear stress (proxy data for tidal current pressure from Aldridge and Davies [8]) and depth. Sediment types were based from Larsonneur et al [9].

B. Biological species list

Three large biological groups were considered in the project: benthic invertebrates, cephalopods and fishes.

Information on benthic organisms were from two sources. A qualitative but exhaustive benthic community investigation collected during the early seventies through cooperative research program entitled "*Benthos de Manche*" (RCP Manche) [10]. These data were complemented by characterization studies of macrobenthic communities made under the MAcroBEnthos of the Eastern English Channel and the south of the North Sea (MABEMONO) programme from 2004–2006.

For fish and cephalopod species data were mainly based on CGFS and CEFAS' Beam Trawl Survey (BTS) from the period between 1988 until 2006 and 1986–2006, repectively. For fish species, data concerning different life stages were collected. For fish eggs were in-situ collections using a Continuous Underway Fish Egg Sampler (CUFES) employed during IBTS surveys. Larvae were from bongo net sample from two spring periods: 1995 and 1999. Juvenile and adult fishes were collected during summer and autumn annually in the eastern part of the Channel from 1989 until 2006. Complementary data on juveniles were collected at nursery areas (i.e., estuary mouth, coastal areas) from Young Fish Surveys (YFS) from 1977 until 2006 (see atlas for further information regarding sample collection during sea surveys).

C. Fisheries and dynamics

After identifying vessel types and gears used for commercial littoral, in-shore, artisanal or mixed fisheries, landings and fishing efforts by commercial fishing vessels were collected. French and English fishery data were taken from the national centre of statistical analyses (CNTS) and from the Department for Environment, Food and Rural Affairs (DEFRA), respectively. For other states exploiting the area, data were also collected but information were mainly based on European logbooks and from auction halls for vessels longer than 10 m and /or so at sea for more than 24 hours. For France, data are also collected for vessels less than 10m in length. Average landing per species and fishing frequency numbers per fleet were mapped at coarse resolution per International Council for the Exploration of the Sea (ICES) division cells (i.e., each cell is 1° longitude and 0.5° latitude grid).

D. Fishermen communities

A certain number of semi-structured interviews (20–100 minutes) among several fishing categories were carried out mainly focused on small-scale fishing communities. Questionnaires included information concerning fishing activities and methods, targeted species and distribution of fishing locations. Fishermen were interviewed regarding their life history in 10 English (Ramsgate, Folkstone, Rye and Hastings) and French (Calais, Boulogne-sur-Mer, Bay of Somme, Dieppe, Caen and Port-en-Bessin) cities. We also conducted the participant observation of various fishing practices. Information gathered from field interviews were then used to produce smoothed raster polygons which were then used to map fishing "hotspots" per species.

E. Acts of legislation

A thorough bibliographic and information research was made in order to compile relevant regulations on four major themes: fisheries, management, habitat conservation and marine pollution at the communal, international and state (UK and France) levels. Regulations collected were carefully validated by fishermen involved in the Channel management. In the atlas, regulations were listed and explained. Only a limited number of maps were produced and depicts only the most pertinent regulations in the Eastern English Channel.

F. Data Integration

Data integration involves the use of data collected and analyzed in models. All data collected on species abundance and occurrence (presence-absence) were tested for normality using histograms, skewness and Kurtosis analyses. Based on skewness and Kurtosis values obtained, data were transformed if a normalizing function for data improvement is found. Kriging interpolation [11]was then

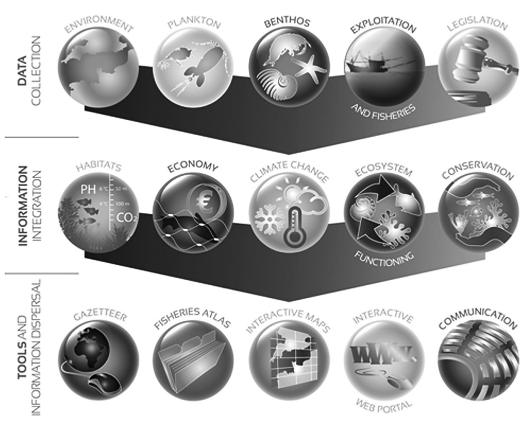

Fig. 2. Schematic representation of data collected and data integration approaches used during the second phase of the project.

used to produce most of the distribution maps.

Preferential and potential habitats were modelled using generalized linear model (GLM) [12] and Regression Quantile (RQ) [13] from abundance data while probable habitats were modeled using generalized additive model (GAM) [14] was used for presence-absence data [15, 16].

Aside from habitat spatial modeling, other modeling techniques were employed. In order to define and provide a snap-shot picture of ecosystem structure, a trophic model was built using the ECOPATH software [17]. The food web model represents the 1995 state of the eastern English Channel. This involves identifying functional groups from primary producers to top predators and establishing predator-prey interactions to depict biomass transfer from one trophic level to another.

Systematic conservation planning approach was also implemented in order to identify priority conservation zones using the MARXAN software . This involves defining planning regions as units and calculating conservation priorities or costs per unit. Based on the initial priorities specified in the model, the desired conservation targets are selected based on the minimized cost of planning units selected closely located to each other as to avoid conservation area fragmentation.

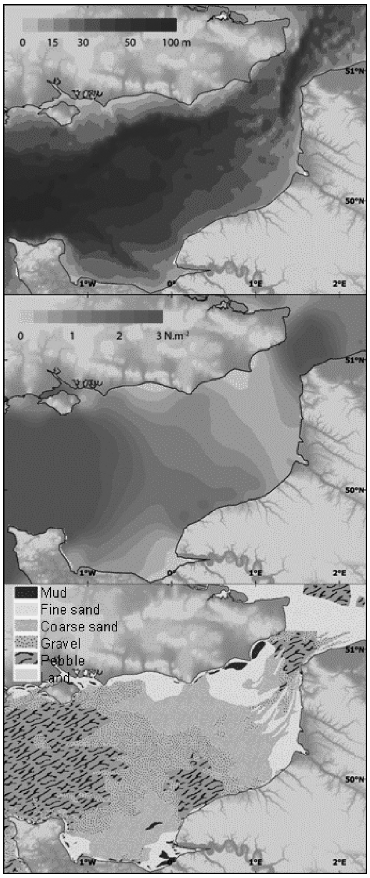

Fig. 3. Depth (above), bed shear data (middle) and bottom sediment type (below) maps of the Eastern English Channel.

III. Eastern english channel: a complex ecosystem

1. Physical environment

Several maps were produced showing the different physical and hydrological features of the Eastern English Channel. Mean average maps for depth, bed shear stress and seabed sediment types are some of the examples shown in Fig. 3. Environmental mapping of the Eastern English Channel shows that this ecosystem has diverse geomorphology. Water depth varies from 40 to 100 meters (Fig. 3 above). It is a macrotidal ecosystem. Elevated current intensities are located along the frontiers of the Eastern English Channel; the narrow area of the Dover Strait and the eastern-western channel border (Fig. 3 middle). As a result of an important hydrodynamic forcing (i.e., increasing current gradient both coast to offshore and west to east), sediments present a specific distribution with pebbles and coarse sediments in the zones of strong tidal currents and sandy muddy sediments in zones with weaker currents (Fig. 3).

2. Biological species description and habitats

The Eastern English Channel has an elevated species richness and biodiversity owing to diverse habitat features and adjacent estuaries. However, in the atlas only the most significant species in the food web and community structure and most abundant in scientific surveys were considered.

In the atlas we considered a total of 55 benthic invertebrate, cephalopod and fish species. These species were the most abundant and judged relevant in the ecosystem's structure. For a complete list of species considered, please consult the atlas [3].

For each species, information provided includes species description for possible identification, biology, feeding behavior, habitat, geographical distribution (Fig. 4 middle).

These species were considered for habitat and fisheries modeling. Average abundance maps per species were also produced based on scientific surveys. An example is shown in fig. 4 for cod in two different periods: summer (July) and autumn (October).

3. Fisheries and dynamics

Fishing activity in the Eastern English Channel is economically significant. In 2005, a total of 90 763 tons were captured only by French commercial fishing vessels (614) and landed in 42 ports (landings declared to the French Maritime affaire). This generated about 218 million Euros. Demersal species are highly exploited, especially the flatfishes (common sole) and gadoids (whiting) as well as Scombroids and clupeids. Atlantic scallops are also highly exploited. In 2003, production reached up to 8500 tons sold at 24 017 Euros.

In the atlas, the French fishing gears and vessels are enumerated based on three main categories: littoral, inshore (<12 nm) and mixed (>12 nm) fisheries. Fig.ure 5 shows a bottom trawl used to catch demersal species and how this gear is put out at sea and taken back on-board. A complete description of each fishing gears is available in the atlas.

4. Fishing communities

Small-scale fishing communities interviewed in the project reacted well to the free-style form of survey. A total of fifty fishermen were interviewed in the 10cities/ports cited above, leading to about 1–4 fishers interviewed per port and per fishing gear. In the French side, mainly trawlers and netters were interviewed whereas in the English side, some longliners and potters were also interviewed aside from the trawlers and netters. Responses accumulated from the different fishers interviewed are mainly subjective and reflected the opinions and perception of the interviewee regarding the current state and the future of the fishing industry. Based on the results of our interviews and observations we can infer that the fishing activities in the study area are complex and diverse due to the fishing history and practices, number of fishing vessels, regulations, etc. that affects the fishing industry in different ports. Fishing zones are determined by the difference in the size and power of the fishing fleets between UK and France, which is the direct result of the regulation difference. In Boulogne-sur-Mer (France) with 1000 fishers employing medium-sized trawling fleets (120) with high mobility, fishing zones cover mostly the eastern part of the channel whilst for UK small ports, such as Ramsgate, with almost all under 10m netting boats (15–20 vessels), fish only along their coastal area (Fig. 6).

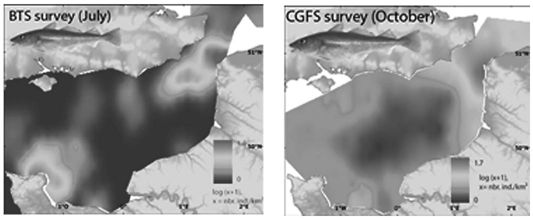

Fig. 4. Cod abundance distribution based on two scientific surveys.

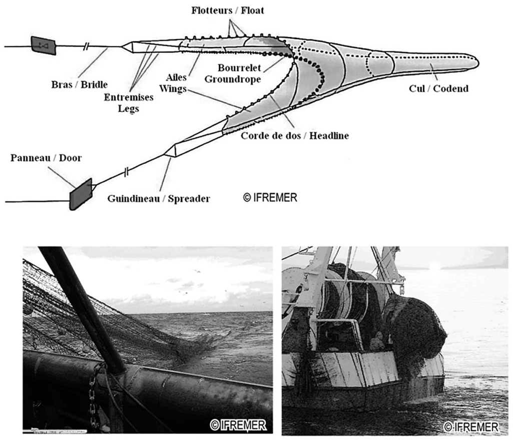

Fig. 5. Traditional bottom trawl (above). Below: Shoot (left) and haul (right) of the trawl at the stern (back) of the vessel.

5. Governance in the Eastern English Channel

A total of 216 regulations were compiled due to their relevance to the study site (Table 1). This part of the work was done in order to enhance the understanding, encourage the application and facilitate coordination of these

Table 1. Regulations compiled relevant to the Eastern English Channel on four major themes and at four application fields.

Application fields Theme	Interna-tional	Com-munity	French	British
Conservation	7	5	16	8
Fisheries	13	29	68	23
Pollution & Security	7	17	7	9
Marine works	1	-	1	5

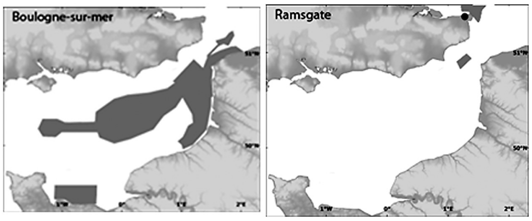

Fig. 6. Recorded fishing zones based on fishers interviewed at Boulogne-sur-Mer (France, left) and Ramsgate (UK, right) ports.

legislation. Among the four themes considered, regulations on fisheries are the most numerous totaling up to 133 laws (binding and soft), byelaws, directives, etc. at four application levels. Most international laws in fisheries are non-binding for contracting parties. State regulations complement community regulations and are put into applications when the latter is breached. The French fisheries have the highest number of regulations. Most technical measures (e.g., authorized gears, percentage of catches, etc.) related to fisheries are covered by the community regulations.

This is followed by pollution and security regulations (40) focused on environment protection. Measures are set up at the community level but cooperation at the international and between states are highly encouraged.

Regulations on conservation (36) focus on preserving marine habitats and species and protection involves the interdiction of some exploitation methods and practices. Conservation tools and establishment of conservation areas are established at the state and community levels, respectively.

For marine works, regulations (7) are established only at the international and state levels. A complete listing of these regulations as well as corresponding explanations can be consulted in the atlas [3].

6. Towards an ecosystem approach

6.1. Geostatistical analyses

6.1.1. Mapping species interaction with habitats

Several habitat maps produced for the 55 species were considered in the second volume of the atlas. This is especially true for the fish groups whose abundance distribution were mapped at different life stages: eggs, larvae, juvenile and adult. This includes 23 benthic invertebrates, 3 cephalopods and 29 fishes. Habitat modelings were done to predict probable, preferential and potential habitats for most of the species considered in the atlas. From the three modeling techniques utilized (GLM, GAM and RQ), it was observed that RQ-based models predicted the maximal response of species under ideal considerable conditions and are judged most suitable for precautionary conservation habitat planning [16]. An example using whiting is shown in fig. 6 where GLM and RQ-based map models are compared (Fig. 7). Compared with GLM analysis, RQ-based models consider the upper bounds of species-environment interactions thus providing a clearer description of how the environment is limiting species distribution.

6.1.2. Mapping fishing communities

Using interviews conducted in the fishing communities, fishing hot spot, seasonality and family history maps were created. Fishers drawings of popular fishing areas per species/-gear were used to create the shapefile polygons and once data are cumulated (overlay maps) will produce fishing hotspot maps. This is, however, a subjective snap-shot picture of favored fishing zones as the number of fishers (50) interviewed in the course of the project does not certainly represent the majority of fishers in the Eastern English Channel. In figure 8 hot spots for sole fishery along the Dover Strait zone is shown.

6.1.3. Mapping catch

Distribution of average annual landings from 2000–2006 for 25 of the most exploited fish and cephalopod species were mapped per ICES division. For each species, information on annual production by state as well as commercial value is also provided. Fig.ure 9 shows an example of fishing frequency numbers (trip numbers) of bottom trawls for stripped red mullet for every quarter of year. We can observe that the fishing activities occur considerably along the south of the North Sea during the third quarter and progress slightly to the middle of the eastern part of the Channel during the fourth quarter of the year. This species is of high commercial interest and is targeted mainly by French fleets capturing up to 97 % of annual landings. Exploitation started in 1990 with less than 300 tons and after 15 years, recorded landings had increased ten times.

6.2. Food web modeling

A total of 51 functional groups including detritus (1), primary producers (2), invertebrates (15), fishes (29), mammals (2) and seabirds (1) were considered in an ECOPATH [17] model. This type of modeling work provided a synthetic snap-shot representation of the ecosystem structure defined by food web links and energy transfers from one trophic level (TL) into another in the ecosystem [18]. The Eastern English Channel food web consists of four trophic levels: TLI consists of primary production and detritus, TLII include invertebrates such as bivalves, gastropods, small crustacean (i.e., zooplankton), small demersal fishes (i.e., stripped red mullet) and forage fishes (i.e., goby), TLIII is mainly occupied by large demersal, bentho-demersal and benthic fish species (i.e., cod, plaice, sole) and TLIV consists of high predators (i.e., shark, mammals, seabirds). It is a phytoplankton-based ecosystem owing to this primary production's contribution to support the upper TLs. Mean trophic level of capture is at TLII. TL V has very low exploitation level as functional groups belonging to this TL includes mainly marine mammals and seabirds (Fig. 10). Through this work, keystoneness [19] and important trophic roles of species were determined. Through this type of modeling, it was also interesting to see the combined trophic effects of fishing. This figure shows that the combined effects of fishing activites in the Eastern English Channel will have detrimental effects to most biomasses of functional groups.

6.3. Systematic conservation planning

The Eastern English Channel is an interesting area for designing marine protected area

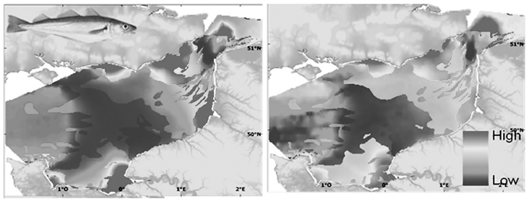

Fig. 7. Preferential (GLM-based, left) and potential (RQ-based, right) habitat models based on the interpolated mean abundance data from October 1988–2006 surveys (whiting photo courtesy of IFREMER).

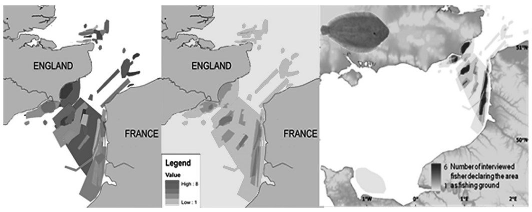

Fig. 8. Mapping of fishers' interview responses in fishing communities. Mapped fishing locations for the common sole (left) made from raster maps (middle, orange) and shapefile polygon hot spot maps (right). (common sole photo courtesy of IFREMER).

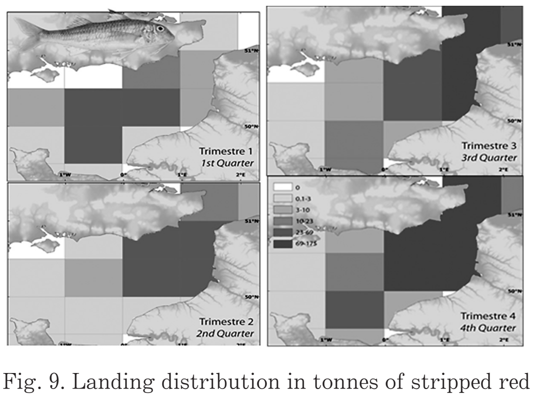

Fig. 9. Landing distribution in tonnes of stripped red mullet mapped per ICES division (stripped red mullet photo courtesy of IFREMER).

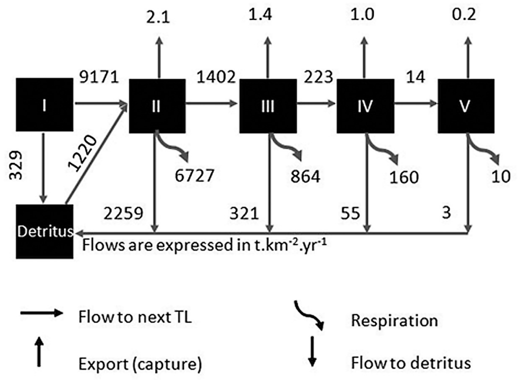

Fig. 10. A simplified representation of energy fluxes per trophic level of the Eastern English Channel.

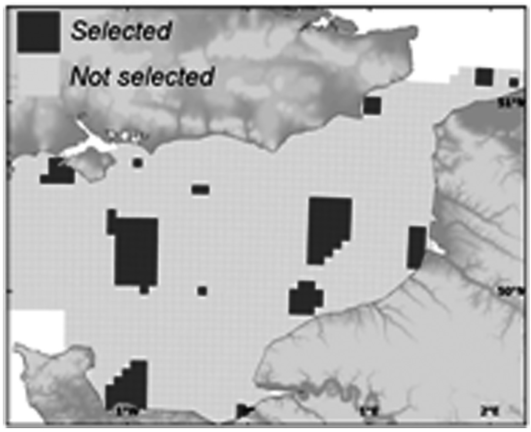

Fig. 11. Best conservation portfolio using a BLM of 500.

(MPA) networks due to the significant ecosystem services (i.e., jobs, gravel extraction, windfarming, etc.) it offers. Preliminary systematic conservation planning [20] was done in the Eastern English Channel. This involved identifying a set of conservation features (i.e., species, jobs, ecological processes, etc.) then setting numerical targets for conservation. Once this is done, the planning region is divided into planning units (PU) then simulation runs are made using annealing techniques to estimate a large number of near-optimal sets (or portfolio) of PUs. A total of 1466 PUs were created and about 17 conservation features were identified. From the identified PUs, 47 were considered as "conserved" while 123 were classified as scenario-excluded for cost metrics simulation runs. One of the hypotheses tested was the estimation of the total perimeter length of the planning unit portfolio multiplied by a boundary length modifier (BLM). MARXAN [21] minimizes the boundary length cost by choosing patches over isolated PUs. From our analyses, we chose a BLM of 500 to ensure that the conservation portfolio patches formed (dark blue patches) were generally large enough to be ecologically viable (Fig. 11) based on the metric costs used. In this scenario, establishing several discontinued MPAs seemed efficient in increasing biodiversity and mitigating effects of diverse anthropogenic activities. Modifying metrics of cost from the one considered here, however, may give other results and may require BLM adjustments. Other analyses include testing different metric costs and target values on resulting priority area spatial pattern.

IV. Reaching beyond scientific borders

This project has been carried out in four years (two phases). The amount of results generated throughout this period is considerable owing to the motivation and dedication of scientists who collaborated together to produce the atlas. Producing the atlas was not an easy task. Scientific partners working on this since its conception have overcome several challenges in order to accomplish this work. Results obtained are innovative in the sense that compiling fragmented data from different fields into a user-friendly, concise and freely-distributed tool has provided an opportunity to safeguard and revalorize existing information.

The success of scientific initiatives launched in the project since its conception is the increasing scientific recognition reflected by the ongoing growth, in terms of collaborations and scientific productions, of the Charm Consortium. It provided an opportunity of bridging the gap between scientists, managers, stockholders, policy-makers, fishermen and the grand public, creating a social-learning institution among different sectors that are concerned with marine management. The atlas has become a significant reference material of knowledge on the Eastern English Channel and its living resources. The main force relies on efficient communication of simplified, concise and useful information to different sectors. It was initially dedicated to providing contemporary map-based inventories of habitats and living resources in the Eastern English Channel [22] and is actually moving towards a greater ambition of implementing an ecosystem-based approach. Since 2009, the third phase of the project has begun covering more scientific themes and challenges. Scientific French and English research institutes and laboratories participating in this phase doubled. Currently, the whole English Channel is being covered and more integrative modeling work dealing on habitat classification, economics and climate change are considered aside from the trophic network and systematic conservation plan modeling during the second phase.

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References

[1] S. Vaz, A. Carpentier, F. Coppin (2007): Eastern English Channel fish assemblages measuring the structuring effect of habitats on distinct subcommunities, ICES J. Mar. Sci., 64.

[2] A. Carpentier, S. Vaz, C.S. Martin, F. Coppin, J.-C. Dauvin, N. Desroy, J.-M. Dewarumez, P.D. Eastwood, B. Ernande, S. Harrop, Z. Kemp, P. Koubbi, N. Leader-Williams, A. Lefèbvre, M. Lemoine, C. Loots, G.J. Meaden, N. Ryan, M. Walkey (2005): Eastern Channel Habitat Atlas for Marine Resource Management (CHARM), Atlas des Habitats des Ressources Marines de la Manche Orientale,, in, IFREMER, pp. 225 pp.

[3] A. Carpentier (2009): Atlas des habitats des Ressources Marines de la Manche Orientale, In I.A. Programme (Ed.), IFREMER, Boulogne-sur-Mer, pp. 626 pp + CD-rom.

[4] A. Carpentier, F. Coppin (2000): Campagnes exp érimentales de chalutage en Manche orientale. Les campagnes C.G.F.S. 1997 et 1998, in, IFREMER, Boulogne-sur-Mer, pp. 174.

[5] Y. Verin, F. Coppin, J.-P. Delpech, J.-L. Dufour, A. Carpentier (2001): Campagnes d'évaluation des ressources halieutiques en mer de nord et manche orientale: Présentation des campagnes IBTS & CGFS- Volume 1, in, IFREMER, Boulogne-sur-Mer, pp. 47.

[6] S.B. Hooker, W. Esaias, E. Feldman, W.W. Gregg, C.R. McClain (1992): An overview of SeaWiFS and Ocean Colour, *In* NASA Technical Memo 104566, Volume 1, NASA Goddard Space Flight Center, Greenbelt, Maryland, S.B. Hooker, E.R. Firestone (Eds.)

[7] F. Gohin, J.N. Druon, L. Lampert (2002): A five channel chlorophyll concentration algorithm applied to SeaWiFS data processed by SeaDAS in coastal waters, Int. J. Remote Sensing, **23** 1639–1661.

[8] J.N. Aldridge, A.M. Davies (1993): A high-resolution three-dimensional hydrodynamic tidal model of the Eastern Irish Sea., Journal of Physical Oceanography, **23** 207–224.

[9] C. Larsonneur, P. Bouysse, J.-P. Lauffret (1982): The superficial sediments of the English Channel and its Western Approaches, Sedimentology, **29** 851–864.

[10] L. Cabioch, R. Glaçon (1975): Distribution des peuplements benthiques en Manche Orientale, de la Baie de Somme au Pas-de-Calais, CR Acad Sci, **280** 491–494.

[11] R. Webster, M.A. Oliver (2001): Geostatistics for Environmental Scientists, Wiley, Chichester,

[12] P. McCullagh, J.A. Nelder (1989): Generalized linear models, monographs on statistics and applied probability 37, Second Edition, Chapman and Hall, London.

[13] B.S. Cade, B.R. Noon (2003): A gentle introduction to quantile regression for ecologists, Front. Ecol. Environ., **1** 412–420.

[14] J. Oksanen, P.R. Minchin (2002): Continuum theory revisited: what shape are species responses along ecological gradients? , Ecological Modelling, **157** 119–129.

[15] S. Vaz, C.S. Martin, F. Coppin, B. Ernande, A. Carpentier, P. Koubbi (2006): Analyses géostatistiques dans le cadre des campagnes CGFS, in, IFREMER, pp. 73 p.

[16] S. Vaz, C. Martin, P.D. Eastwood, B. Ernande, A. Carpentier, G.J. Meaden, F. Coppin (2008): Modelling species distributions using regression

quantiles, J. Appl. Ecol., **45** 204–217.
[17] V. Christensen, C.J. Walters, D. Pauly (2005): Ecopath with Ecosim: a User's Guide., in, University of British Columbia, Vancouver, pp. 154 p.
[18] B. Ernande, S. Mackinson, M.C. Villanueva (2009): Food web modeling, pp 548–562, In Channel habitat atlas for marine resource management, IFREMER, Boulogne-sur-Me, A. C arpentier, C.S. Martin, S.V. (Eds.)
[19] S. Libralato, V. Christensen, D. Pauly (2006): A method for identifying keystone species in food web models, Ecol. Model., **195** 153–171.
[20] C.R. Margules, R.L. Pressey (2000): Systematic conservation planning, Nature, **405** 243–253.
[21] I.R. Ball, H.P. Possingham (2000): MARXAN (V1.8.2) : Marine reserve design using spatially explixit annealing, a manual., in, Brisbane, Australi, University of Queensland.
[22] C. Martin, A. Carpentier, S. Vaz, F. Coppin, L. Curet, J.-C. Dauvin, J. Dalavenne, J.-M. Dewarmez, L. Dupuis, G. Engelhard, B. Ernande, A. Foveau, C. Garcia, L. Gardel, S. Harrop, R. Just, P. Koubbi, V. Lauria, G.J. Meaden, J. Morin, Y. Ota, E. Rostiaux, R. Smith, N. Spilmont, Y. Vérin, C. Villanueva, C. Warembourg (2009): The channel habitat atlas for marine resource management (CHARM) : an aid for planning and decision-making in an area under strong antropogenic pressure, Aquat. Living Resour., **22** 499–508.

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