5. Case studies to illustrate ways to integrate GIS into EAF

5.1 INTRODUCTION

It is impossible to state precisely when GIS was first used explicitly as a tool in EAF management or research. This is because the GIS, by its very nature, is a tool that is frequently employed for aggregating and analysing related data sets concerning a topic that must be spatially-referenced. This bringing together of data usually implies that various facets of the ecosystem are under investigation and, of course, the wider the variety of parameters that are being integrated, the closer the project will be to a holistic EAF study. It is likely that few specific applications of GIS for EAF implementation were undertaken prior to 2000 and, indeed, St. Martin (2004) charts the rise of EAF itself as occurring only during the mid- to late- 1990s. St. Martin also presents a strong rationale for GIS being the obvious platform on which to house any EAF study, certainly in view of the essential spatio-temporal variations, intervariations and intravariations that characterize different ecosystems.

In this section, the authors examine three case studies, each of which takes a different approach to the implementation of EAF. The case studies cover marine areas that are different in terms of their scale, their resource base and their range of economic activities. In combination, the case studies have documented some useful experience of the challenges of EAF implementation and can, therefore, be used to formulate sound advice for EAF practitioners. The case studies were selected because they describe in detail many of the numerous considerations of EAF, thereby making it possible to formulate recommendations on how GIS might aid the EAF process as well as offering a range of potential EAF implementation strategies.

5.2 ECOSYSTEM-BASED FISHERIES MANAGEMENT IN THE BENGUELA CURRENT LARGE MARINE ECOSYSTEM OF SOUTHERN AFRICA

The Benguela current along the coast of southwest Africa is linked to an intensive upwelling area where high nutrient flow ensures high marine productivity. Many fisheries operate along this coast and these fisheries, plus oil extraction, ensure that social and economic factors are of high value and significance. If resource extraction is to be sustained, then high productivity can only be achieved with careful ecosystems management. The importance of this has long been recognized and a sophisticated ecosystem-based science research programme has been in operation in the Benguela waters since the 1980s (Payne *et al.*, 1987). Since 1996, a programme of strong cooperation among the three national governments (Angola, Namibia and South Africa) seeks to improve the fisheries as well as to look at traditional facets of the fishery ecosystem, i.e. factors concerning direct marine productivity.

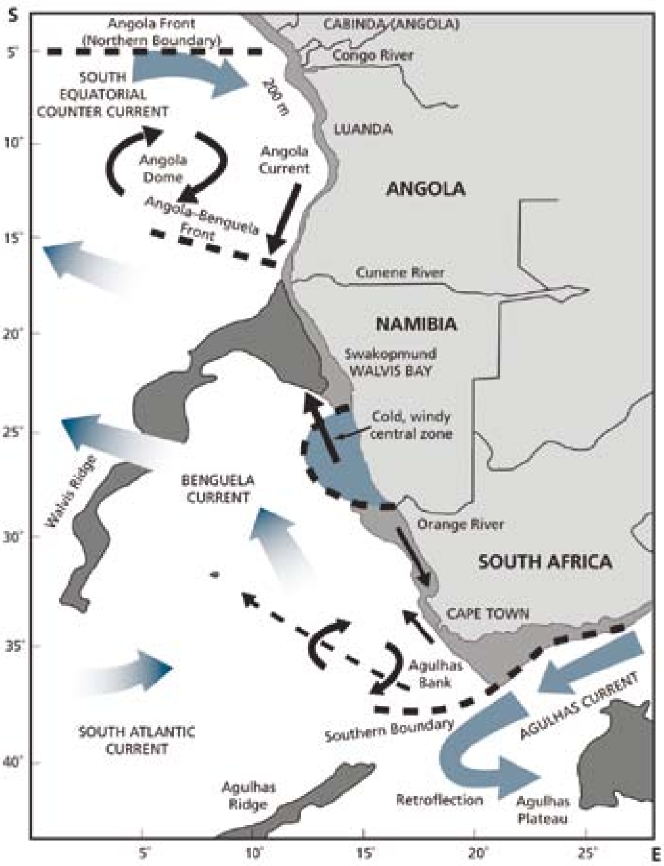
During the last decade, a programme led by FAO addressed the transboundary human impacts on the ecosystems, with a focus mainly on the fishery sector[9]. The FAO-coordinated work, reported in Cochrane *et al.* (2007), essentially "investigates the feasibility of using an ecosystems approach to fisheries management in the Benguela Current Large Marine Ecosystem (BCLME) region through examining the existing

[9] Additional information available at www.bclme.org

issues, problems and needs related to EAF, and considering different management options to achieve sustainable management of the resources at an ecosystems level". The project, which was managed by various fisheries agencies with assistance from FAO, covered marine areas of South Africa, Namibia and Angola (see Figure 5.1) and took place from January 2004 to December 2006. Ten major fisheries in the three countries were examined. The project used a structured and participatory approach designed to engage the various stakeholders in identifying and prioritizing gaps in the existing approach to fisheries management and to generate potential management actions needed to address these gaps. The project also used cost-benefit analyses to evaluate the importance of each of the potential objectives and actions identified to improve the management of each fishery. There is no need here to detail all of the methods and approaches used in this lengthy study – this information can be obtained from Cochrane *et al.* (2007) and from Fletcher *et al.* (2002), whose work provided the basis for the current study. In this section, the authors intend only to identify thematic areas in which GIS could be used as part of the EAF process and they briefly describe the EAF process followed. It should also be acknowledged that the project as designed and implemented by FAO had no intention to explicitly utilize GIS to secure its aims.

At the outset, the project team agreed to adopt the FAO (2003) definition of the purpose of EAF (see Section 2.1) but noted that this definition was just one of several. They then noted that ideally an EAF should start from a holistic viewpoint in the sense that it should be implemented across all fisheries within an area. Because this would be a major and somewhat unrealistic task, an early decision was taken that EAF should be "implemented incrementally according to opportunities and crises". Hence, the major fisheries in the three countries were selected rather than all fisheries and included artisanal and subsistence fisheries.

FIGURE 5.1
The main physical features associated with the Benguela current system



Source: Reproduced with permission from Cochrane *et al.*, 2007.

Because the EAF being adopted was to take a "human" inputs viewpoint, the starting point for the EAF was for the stakeholders of the ten fisheries to identify perceived issues and problems in the various fisheries. Therefore, a series of workshops were held in each of the three countries. They were attended by stakeholders who included managers, decision-makers, fishing industry members, conservationists and scientists. The workshop participants generated a list of issues for each country and for each fishery. Between 150 and 200 issues were identified, although many of the issues were duplicated for different countries or fisheries. For each issue a "risk score" (denoting perceived importance) was then derived by multiplying a "consequence" by a "likelihood", whereby consequence equates to the severity should the issue not be resolved and likelihood equates to the likelihood of the issue occurring. It is in the resolving and managing of these issues that GIS can best form an invaluable input to the EAF process.

Table 5.1 ranks 50 of the most important issues in which GIS could play an analytical part either directly or indirectly. Note that the "risk scores" shown are indicative only because of the variability in risk assigned to the different fisheries in the different countries. How each issue with regard to the EAF may be addressed by GIS in terms of mapping, modelling and/or managing is indicated. For some of the issues, the participants were not able to assign only one exact use for GIS, so for those issues more than one category is indicated. For many of the issues GIS would be of limited use in the absence of suitable data-gathering systems. In addition to the issues listed in Table 5.1, there were many issues that may have relevance but are beyond a more immediate EAF-GIS concern. These included economic, well-being and social issues concerning the fishery and its wider structure, plus a number of management and governance issues.

TABLE 5.1
The major EAF issues identified by stakeholders in ten different southern African fisheries that may be addressed by GIS

Issue	Indicative "risk" score	GIS mapping	GIS modelling	GIS managing
Impact of small-scale fisheries on inshore stocks	30	X	X	X
Stock status (variability and uncertainty of)	30	X	X	X
Size composition of the stock (average size of fish caught is declining)	30		X	X
Need to redevelop infrastructure (roads, bridges, etc.)	25	X	X	X
Fishing activity taking place in nearshore areas (impact on stocks and environment)	24			X
Utilization of high-value species for fishmeal	24	X		X
Impact of bottom trawl fishery on species abundance	24	X		X
Allocation of fishing rights (often seen as unfair)	24	X	X	X
Inadequacy of monitoring and control systems	24	X		X
The negative impact the hake fishery may be exerting on the sustainable use of monkfish	24	X	X	X
Decreased food availability for fish predators	24	X	X	X
Affect of short-term climatic anomalies, e.g. El Niño events	24		X	
Poor understanding of decadal-scale fluctuations in abundance of primary species	24		X	
Dependence of a large number of the families on small-scale or semi-industrial fisheries	20		X	
Lack of management plans for all species	20			X
Open access in small-scale fisheries (attracts too many entrants)	20			X
Improvement of communication among scientists, managers and industry representatives	20			X
The barrier represented by oil exploitation areas to the distribution of sardinella	20	X	X	X
Climate anomalies affecting recruitment (uncertainties surround this)	20		X	

TABLE 5.1 (cont)

Issue	Indicative "risk" score	GIS mapping	GIS modelling	GIS managing
Climate anomalies affecting fish availability (uncertainties surround this)	20	X	X	
Seasonal migrations, particularly of shared stocks	20	X	X	X
Impact of bottom trawling on bottom substrate	20	X	X	X
Lack of models and indicators for multispecies assessments	20		X	
Open-access nature of a small-scale fishery	20	X		X
Pollution resulting from oil exploitation activities	20	X	X	X
Variability in resource availability that makes planning difficult	18	X	X	X
Fishery statistics – variable status of data gathered	18	X	X	X
Removal of grazers, which leads to accumulation of plankton biomass and possibly to sulphur eruptions and low-oxygen events	16	X	X	X
Shared resource – could be between countries or fishing groups	16	X		X
The conflict between increasing oil exploitation and the development of industrial fisheries	16	X		X
Lack of distribution networks – transport and markets	16	X		X
Impact of the small-scale fishery on the horse mackerel fishery	15	X		X
Impact of the artisanal fishery on the sardinella fishery	15	X	X	X
Current high fishing mortality	15		X	X
Poor understanding of the knowledge of life history	15	X	X	
Low selectivity of the trawl fishery is affecting natural-size structure	15	X		X
Removal of biomass (especially top predators), which may alter the trophic structure and functioning of the ecosystem	15		X	X
The longline fishery is affecting natural-size structure by catching larger fish	12	X		X
Reduction or changes in geographical distribution of the species due to fishing activity	12	X	X	X
Lack of processing plants and job opportunities	12	X	X	X
Pressure on coastal ecosystems, e.g. destruction of mangroves	12	X	X	X
Lack of knowledge about round herring, gobies and chub mackerel	12		X	X
Amount of bycatch being taken (uncertainty surrounds this)	12		X	X
Overexploitation of demersal resources with a further decline expected if no management measures are taken	9		X	X
Conflicts between the small-scale and the industrial fisheries	9	X		X
Preference of inland communities for small, pelagic fish	8		X	
Changes in community structure (could refer to fish or human community)	8		X	
Biomass estimation methods are variable among countries and stocks	6	X	X	X
Licence allocation to purse seiners (not always seen as fair)	6	X		X
Impacts of factory and other effluents	5	X	X	

Source: Adapted from Cochrane *et. al*, 2007.

As can be noted from the table, many issues of relevance to EAF, such as dealing with shared stocks and improving fisheries data and statistics, and information on bycatch, should already have been addressed under a conventional fisheries management framework. Thus, theoretically, they should have received low risk scores, indicating they were of little concern, but as the table shows, in some cases they were considered important issues. Furthermore, this southern African study very clearly showed considerable concern for wider ecosystem issues such as interactions between fish species, disturbance of trophic structures, pollution and impacts of fishing on the other ecosystem components.

Another important finding showed the relationship between the state of the stocks and type of issue mentioned. Thus, the fisheries that were overexploited had concerns (issues) that were overwhelmingly related to social, economic, management and governance matters, and it is with these matters that arguably GIS is the least able to be of help. The implication of this is that the lack of a well-managed fishery is likely to shift the balance of concern from the fishery itself towards more general societal issues. Overall, approximately 45 percent of all issues raised by the ten fisheries examined would lend themselves to analyses by GIS, these issues for the most part being more directly fishery-related. Given the implication that a poor fishery leads to strong socio-economic concerns, a good case can be made for adopting GIS within an EAF as a means of initially preventing problems from arising in the fishery industry.

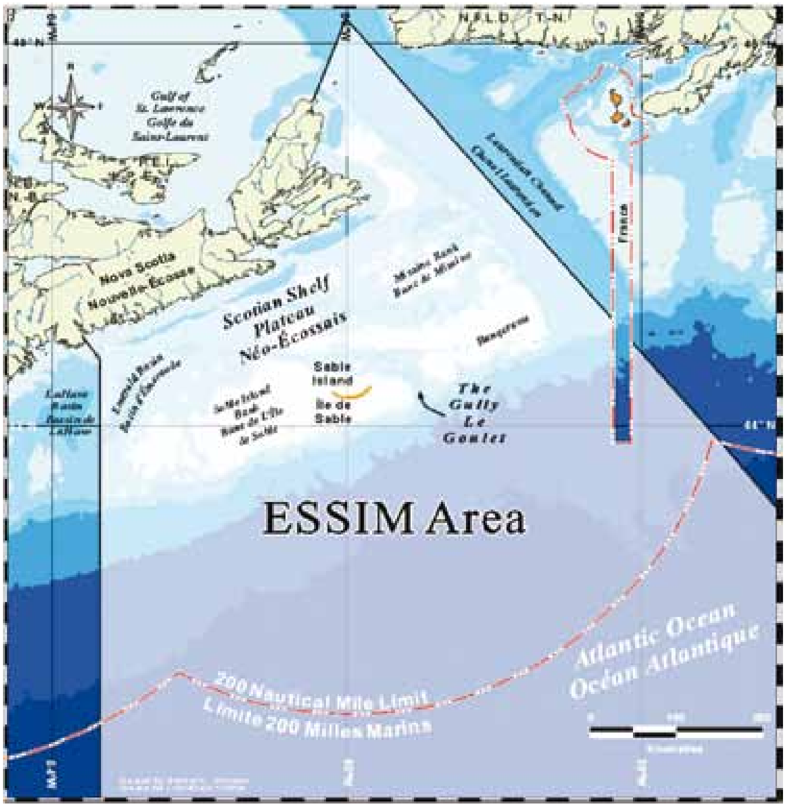
The activities that concluded this EAF study were as follows. Workshop participants prepared a "Performance Report" that contained the issues that the participants had ranked as high priority on the basis of the risk scores together with the potential management responses (measures) designed to reduce the high risks. Because the workshops had been so important in identifying issues, establishing risks and agreeing management responses, as articulated in the performance report, Cochrane *et al.* (2007) stressed the importance of good stakeholder representation as the basis for fisheries management under EAF.

Once the management responses had been agreed for each fishery, a benefit-cost analysis was undertaken during a separate workshop to establish the relative advantage of each management measure identified in the performance report. Scores were allocated on a scale of 0–4 to each management measure. Scores could be positive or negative according to the broad objectives of the fishery and two sets of scores were obtained, i.e. one for short-term objectives and one for long-term objectives. The benefit-cost results for all of the ten southern African fisheries studied are contained in the report of Cochrane *et al.* (2007). Interestingly, the report noted that many of the short-term benefit-cost ratios were negative to the extent that if the management measures were to be implemented, socio-economic hardships to the fishery community would result. In contrast, the long-term benefit-cost ratios were overwhelmingly positive. The short-term negativity would create a substantial problem for policy or decision-makers and strategies will need to be developed to mitigate any undesirable consequences. The report also stressed that all fisheries should be included in the benefit-cost analyses (and indeed the whole EAF procedure) and that all issues should be considered, not just the high priority ones dealt with at the workshop. Overall, it noted that "the benefit-cost analysis process was found to be very informative and an important step in the implementation of EAF" and that the EAF "is far preferable to the fragmented and reactive approach to addressing problems that typifies fisheries management decisions around the world at present".

5.3 THE EASTERN SCOTIAN SHELF INTEGRATED OCEAN MANAGEMENT PLAN IN CANADIAN ATLANTIC WATERS

The Eastern Scotian Shelf Integrated Ocean Management Plan (ESSIM) is a recent initiative of the Canadian federal government and is designed to generate a multiyear, strategic-level plan to provide long-term direction and commitment for integrated, ecosystem-based and adaptive management of all marine activities in or affecting

FIGURE 5.2
The Eastern Scotian Shelf management area



Source: Reproduced from O'Boyle, Sinclair, *et al.*, 2005.

the waters of the Eastern Scotian Shelf (ESSIM, 2005). The ESSIM area, covering 325 000 km^2, lies in a broad arc to the south and east of the northern part of Nova Scotia (Figure 5.2). The management area stretches seawards to the limit of the Canadian exclusive economic zone (EEZ). Because this plan is very much a first for Canada and because management problems faced in the offshore area are very different from the problems of the inshore zone, at present the ESSIM project is concentrated almost exclusively on offshore waters beyond the 12 mile territorial sea limit. At a later stage, complementary plans for the inshore zone will be developed in conjunction with the province of Nova Scotia and other interests. The ESSIM (2005) document outlines the characteristics of the marine environment and of the human uses for this area and much useful documentation regarding this eastern Scotian shelf management scheme[10] is available on the Internet.

The ESSIM Plan focuses on the management needs and priorities related to multiple ocean use, ecosystem management, and conservation and collaborative planning. These issues are broader than the issues relating to fisheries management alone but the same principles apply. Thus, EAF can be considered a subset of the ecosystem-approach (EA) for multiple-use marine planning, as encapsulated by ESSIM. For example, with regards to stakeholder engagement, "the [ESSIM] Plan is being developed through a collaborative and inclusive planning process involving all interested and affected government departments, sector groups and individuals", the goal being to develop a plan that is accepted by all interested parties. The EAF has similar goals. In the case of ESSIM, interested parties comprise the following institutional components: (a) an ESSIM Forum; (b) a stakeholder roundtable; (c) a government sector structure; and (d) a planning office. The whole ESSIM Plan is enshrined in a vision statement and guiding principles. It provides an objectives-based approach to ocean management, setting out long-term, overarching ecosystem and human-use objectives to support agreed outcomes for environmental, social, economic and institutional sustainability in the ESSIM area.

The overarching objectives are:

- to integrate the management of all measures and activities in or affecting the planning area;

[10] See www.dfo-mpo.gc.ca/Library/286215.pdf

- to manage for conservation, sustainability and responsible use of ocean space and marine resources;
- to restore and/or maintain natural biological diversity and productivity; and
- to contribute to social, cultural and economic well-being of stakeholders and coastal communities.

A recent study (Charles *et al.*, 2009) provides invaluable background to the problems in the ESSIM area and concentrates particularly on the social and economic factors involved, offering indicators that can and should be monitored and applied on a regular basis to evaluate the well-being and sustainability of fisheries and the marine environment.[11]

High-level objectives are supported by operational objectives for which specific indicators and targets can be set. The plan also provides an area-based approach whereby planning, management and decision-making for multiple human use and ecosystems conservation can be undertaken at appropriate spatial scales. The whole plan has to be carefully integrated into existing management plans, jurisdictions, responsibilities and objectives, and the plan itself is embedded in recently enacted federal legislation, i.e. the Oceans Act, 1996. A series of Action Plans will be developed for two- to three-year periods as part of the implementation process. As the planning process evolves, monitoring and performance measuring mechanisms will be established to enable regular evaluation and reporting on the plan's objectives. It should be mentioned here that, as with the case study reported in Section 5.2 above, this plan contains no specific reference to the use of GIS.

The authors use the plan objectives as the basis for illustrating where GIS can fit into an EA to management. Table 5.2 lists the objectives, and again they are categorized as relative to mapping, modelling or management in the GIS context. As with the Benguela EAF programme, it can be seen with ESSIM that there is a far greater potential to use GIS to meet objectives relating to more direct fishery ecosystem issues and that GIS is of particular relevance to matters relating to basic mapping and modelling.

The ESSIM Plan specifically mentions that GIS has already been used to create an atlas showing the extent and location of the major human activities in the area, including various management zones (ESSIM, 2005). The atlas will soon be extended to cover the mapping of ecological components. Data sets contributing to the atlas will form the basis of a spatio-temporal framework to assess risks associated with human activities, including ecosystem impacts and sector activity interactions. Figure 5.3 illustrates the type of detailed mapping data that is available for this location (from O'Boyle *et al.*, 2005b). It is important to note that the ESSIM Plan discusses the types of marine planning work that will be possible and describes the tools that will be available to pursue the project objectives. The ESSIM Plan concludes with a consideration of the various management strategies and potential actions available, allocating lead authorities and time lines for this as well as looking at project implementation and review procedures.

5.4 CHANNEL HABITAT ATLAS FOR RESOURCE MANAGEMENT (CHARM) IN THE EASTERN ENGLISH CHANNEL

The English Channel, the stretch of water separating France from England, is one of the world's busiest shipping lanes. The waters of the channel also support locally important fisheries, are an important source of aggregates, provide numerous leisure and tourist facilities, and are crossed daily by numerous passenger ferries. Because of the potential for resource conflict, efforts began in the late 1990s to consider options for resource utilization in a limited transboundary geographic zone. Following the success of this project, in 2003 the European Union agreed to fund a similar but larger project called CHARM, covering the eastern quarter of the English Channel (Figure 5.4).

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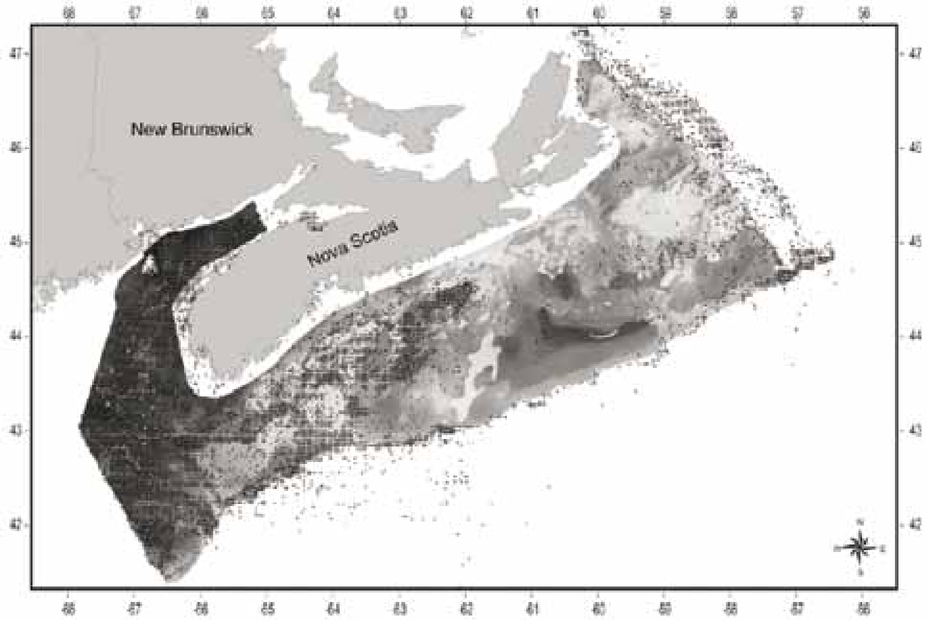
[11] See www.gpiatlantic.org/pdf/fisheries/fisheries_2008.pdf for the Charles *et al.* (2009) study.

TABLE 5.2
Objectives to which an EA might aspire for the eastern Scotian Shelf area and which have the potential for GIS-based mapping or analyses

Issue	Objective	GIS mapping	GIS modelling	GIS management
Important benthic communities	Identify and protect important benthic communities, e.g. unique, diverse or productive	X	X	X
Sensitive benthic communities	Identify and protect coral and other sensitive communities	X	X	X
Important pelagic communities	Identify and protect important pelagic communities	X	X	X
Sensitive pelagic communities	Identify and protect sensitive pelagic communities	X	X	X
Conservation of communities	Maintain/restore identified pelagic, benthic and demersal communities or assemblages	X	X	X
Conservation of communities	Maintain/restore identified seabird communities or assemblages	X	X	X
Commercially harvested species	Maintain/restore species, populations and productivity	X	X	X
Endangered species	Protect and rebuild species stocks	X	X	X
Ecosystem structure and function	Maintain/restore bycatch of non-target species within acceptable limits		X	X
Invasive species	Limit and monitor invasive species	X		X
Ecosystem resilience	Maintain/restore genetic diversity		X	
Ecosystem structure and function	Monitor the base of the food chain to detect changes that may affect other ecosystem components	X	X	
Ecosystem structure and function	Monitor environmental conditions that may influence productivity at the base of the food chain	X	X	
Trophic structure	Preserve trophic structure, including forage species for higher-level predators		X	X
Trophic structure	Preserve traditional role of top predators		X	X
Diversity of habitats	Identify and protect rare habitats	X	X	X
Bottom habitat	Maintain/restore physical characteristics of sediments that are conducive to resident biological populations	X	X	X
Processes in sediments	Maintain/restore geochemical conditions necessary for functioning of resident community	X	X	
Toxic chemical contamination	Maintain concentrations of toxic chemicals below levels harmful to local biota	X	X	
Eutrophication	Maintain/restore oxygen levels sufficient for productive biota growth	X	X	
Water column	Maintain/restore the chemical quality of the waterbody	X	X	
Non-biodegradable debris	Maintain amounts of solid wastes within acceptable limits	X		X
Health of resident biota	Maintain/restore marine environmental quality conducive to healthy biota	X	X	
Contaminant levels in fish	Prevent chemical or biological contamination of species for human consumption	X		
Community well-being	Ensure access by local people to sustainable livelihood opportunities derived from the sea	X		X
Community well-being	Enhance ocean-related services and infrastructure	X	X	
Economic well-being	Generate wealth from the ocean by fostering new opportunities and enhancing existing opportunities	X	X	
Economic well-being	Ensure efficiency of resource use and open space		X	
Industrial capacity and assets	Balance multisectoral use on the Scotian Shelf and reduce resource use conflict	X	X	X
Industrial capacity and assets	Promote stewardship and best practices		X	
Integrated management processes	Ensure policies, plans, programmes and measures are applicable to ocean users	X		X
Integrated management processes	Promote adaptive management in response to change			X

Source: Adapted from ESSIM, 2005.

FIGURE 5.3
An example of the type of mapping data available to the ESSIM Plan



Source: O'Boyle, Sinclair, *et al.,* 2005.

Note: Dots indicate location of bottom trawling during 1999–2003. Base map shows benthic community sensitivity where white equals most sensitive and black equals least sensitive.

This project resulted in the production of a hardcopy resource atlas of the area (Carpentier *et al.*, 2005). The project involved small teams of researchers from seven institutions (academic and research) located on both sides of the English Channel. Although fisheries were at the core of the project, the study included numerous other important ecosystem properties, both physical and biological, within the water column and the sea bed. In so doing, the project moved towards some core facets of EAF and GIS was used extensively for mapping and modelling[12].

Following Phase 1 of CHARM, Phase 2 was initiated in 2006 and completed in September 2008. This phase had a similar partnership but substantially increased funding, allowing a broader range of work to be accomplished, and the project itself looked at the whole of the eastern English Channel (Figure 5.4). The objectives of CHARM Phase 2 were to develop an integrated system of marine management for the evaluation of living resources and to identify important species habitats in the eastern English Channel. Figure 5.5 provides an illustration from Charm Phase 2 and shows how the surveyed distribution of a species (executed by the IFREMER Channel Ground Fish Survey [CGFS]) compares with outputs from predictive habitat modelling for that same species. Information from CHARM Phase 1 was integrated into additional Charm Phase 2 data so as to create ecosystem and conservation planning models for the wider area. In the Charm Phase 2 project, a wider variety of species were examined and many more stakeholders were involved.

To assess the project in the context of EAF, it is valuable to highlight the specific actions that were undertaken – these are listed in Box 5.1. It can be seen that the CHARM Phase 2 project is less wide ranging than the previous two case studies in that it maintains a focus on fish and their habitats and tends to ignore wider social and economic

[12] Additional information available at http://charm.canterbury.ac.uk and at www.ifremer.fr/charm

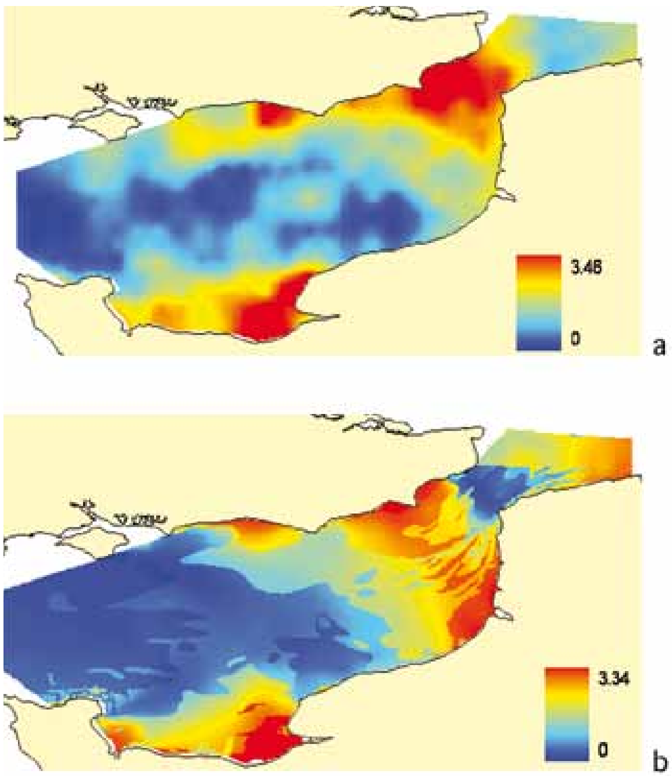
FIGURE 5.4
The areas covered by Phase 1 and Phase 2 of the CHARM project

Source: Carpentier *et al.*, 2005.

considerations. However, unlike the other case studies, the CHARM project had a definite intention to utilize GIS as the platform for all of its mapping and for most of the modelling[13].

The CHARM project benefited from access to both substantial bodies of data for the study area and to a strong team of specialists in habitat modelling, spatial geostatistics, conservation modelling, and web development. However, the approach adopted by the CHARM team was not

FIGURE 5.5
A comparison of survey data and habitat modelling output for the Callionymidae family in the eastern English Channel from the CHARM Phase 2 project



Source: The IFREMER Channel Ground Fish Survey (CGFS).

Note: (a) Mean spatial distribution (number per km2) of fish, 1988 to 2006 (October, CGFS). (b) Preferred habitats (modelled using Generalized Linear Models (GLMs)) for fish, e.g. reticulate dragonet, 1988 to 2006 (October, CGFS). Significant predicators: bed shear stress, salinity, temperature, sea-bed sediment type.

[13] Examples of the GIS output can be seen at http://charm.canterbury.ac.uk and www.ifremer.fr/charm

BOX 5.1

The main actions undertaken as part of the CHARM Phase 2 project

- Develop fish species distribution maps for input to ecosystem modelling and management planning (under actions 5 and 6).
- Develop a sea bed habitat map using the best available data.
- Gather primary data from local fishing communities to be used as inputs to models developed under actions 5 and 6.
- Complete a bilingual comparison of French and United Kingdom policies in the context of marine resource management.
- Develop a model of the eastern English Channel ecosystem functioning using mass-balance food-web models (Ecopath with Ecosim) and habitat models developed under action 1 (Ecospace) in order to evaluate management scenarios driven by inputs from stakeholders.
- Develop a conservation planning system for the eastern English Channel based on the Marxan spatial planning software.
- Use the outputs from the atlas and modelled scenarios in Ecopath and Marxan to develop a draft management strategy that can be reviewed by stakeholders.
- Deliver all outputs through an interactive atlas on the project's Web site.
- Produce the final report.

without problems or challenges. The problems can be basically summarized as the following:

- Data was not available for all ecosystem components and collection of needed data would have been beyond the funding possibilities of the project.
- Most of the biological resource data represented only a snapshot in time – this would give it very poor statistical validity under most testing regimes.
- Allied to the above, it was sometimes difficult to establish an optimum resolution at which to work.
- Different aspects of the ecosystem function at different spatial and temporal scales greatly influenced data collection and analysis strategies.
- The approach adopted by the project team could be considered as top down. Thus, although stakeholders were involved, their participation was minimal. Most decisions and actions were based on the project team's perceptions of what might be desirable aims for an optimum functioning marine ecosystem in the English Channel area.
- It was difficult to establish the most appropriate thematic areas (and boundaries to these areas) to be covered. All research projects are resource and time limited so inevitably some important aspects of the total ecosystems cannot be included.

Based on the experience gained from CHARM Phase 2, a Phase 3 will commence in late 2009. It is intended that this phase will take the project further towards a full EAF implementation. It is also clear that opportunities are many for the integration of GIS into most facets of EAF work. Box 5.2 sets out the main objectives for this new phase of the project.

5.5 CONCLUSIONS

The three case studies provide an assessment of potential uses of GIS in the EAF adoption process. Undoubtedly, had the authors looked at further studies, other uses for GIS would have been found. Both Boxes 5.1 and 5.2, and more especially the actual texts of Cochrane *et al.* (2007) and ESSIM (2005), show that ecological issues are predominant in the EAF analysis and planning in these case studies. However, there

BOX 5.2
The main tasks and objectives for a proposed Phase 3 of the CHARM project

- Include also the western English Channel (doubles the project area).
- Carry out a detailed data review and inventory.
- Incorporate plankton to space/time mapping and modelling.
- Better identify fish spawning areas.
- Better identify the role of benthic organisms in the English Channel.
- Classify marine habitats using European Union habitat directives.
- Set up a "fisheries exploitation" database.
- Identify the "fisheries culture" (the place and impact of fishing in coastal areas).
- Carry out further habitat and trophic network modelling (for the whole of the English Channel area).
- Analyse socio-economic changes in the fishery scene.
- Reinforce collaboration between fishery ecologists and economists to advance development of an EAF.
- Explore the prospects for the diversification of marine activities.
- Explore the impacts of climate change on the English Channel.
- Provide necessary inputs to conservation planning.
- Develop GIS interface tools for better geospatial modelling.

is reason to believe that this is not a general characteristic of EAF and that in other situations (e.g. small-scale fisheries) the human dimensions of the fishery system and relative issues may be predominant. GIS is expected to be of use in both situations.

As a contribution towards the process of linking GIS with EAF, FAO compiled two databases, which will eventually form part of the GISFish Internet site[14]. The first database provides a list of papers which address spatial aspects of EAF and the second database provides a list of Web sites containing information on the uses of GIS and spatial analyses in the EAF. In Table 5.3 below, the papers are categorized by the EAF application area addressed, e.g. biodiversity, and by the main GIS role discussed, i.e. "mapping", "modelling", "management" and "communications" (refer Section 4).

The table shows that the various categories of publications devoted to the use of GIS for EAF are remarkably well distributed among mapping, modelling, management and communication, indicating that within the context of these roles a broad range of issues are currently being addressed. The 52 papers in the "Communications" category convey in a more general sense the linkage between EAF and GIS. This area is very well represented in the literature. However, many important areas such as "Mapping the impact of fisheries", "Mapping catch and effort distributions" and "Modelling of spatial stock assessment" are receiving very little attention. As mentioned earlier in this section, GIS applications for EAF are rarely shown to address wider social and economic issues but this may be a reflection on the process used to select the 214 papers for inclusion in the FAO database. For instance, the search for these papers was conducted using the Aquatic Sciences and Fisheries Abstracts (ASFA)[15] bibliographic database and perhaps this database itself is not being furnished with a wide enough array of papers to account for the holistic EAF approach as perceived by Cochrane *et al.* (2007).

[14] See www.fao.org/fishery/gisfish/index.jsp
[15] See www.fao.org/fishery/asfa for additional information.

TABLE 5.3
Categories of GIS publications relating to EAF

Main GIS role	Main EAF application area addressed	No. of papers
Mapping	Impact of fisheries	2
Mapping	Catch and effort distributions	1
Mapping	Ecosystems or ecoregions	19
Mapping	Biodiversity	4
Mapping	Habitats	6
Mapping	Species distributions	7
Mapping	Management regulations	1
Mapping	Multispecies analysis	9
Mapping	Social and/or economic impact studies	1
Mapping	Indicators	13
Modelling	MPA (design, implementation, monitoring)	21
Modelling	Ecosystem modelling	26
Modelling	Spatial stock assessment	4
Management	Integrated marine management and planning	32
Management	Fisheries management systems	15
Management	Fisheries development	1
Communications	Principles, practices, case studies and issues which constitute the foundation for EAF	52
Total papers		**214**

Source: www.fao.org/fishery/gisfish/index.jsp)