Shrimp trawl fisheries

Marine fish stocks are under increasing threat from a range of spatially based problems that might be natural or involve socio-economic factors. To best manage spatial problems, systems such as GIS and remote sensing are now being extensively deployed. For these systems to be effective, it is important that spatially based catch and fishing effort data can be recorded from electronic fisheries logbooks or via vessel monitoring systems. In many parts of the world, vessels such as this one are actively acquiring appropriate data.

Courtesy of John Mitchell

10. Current issues, status and applications of GIS to marine fisheries

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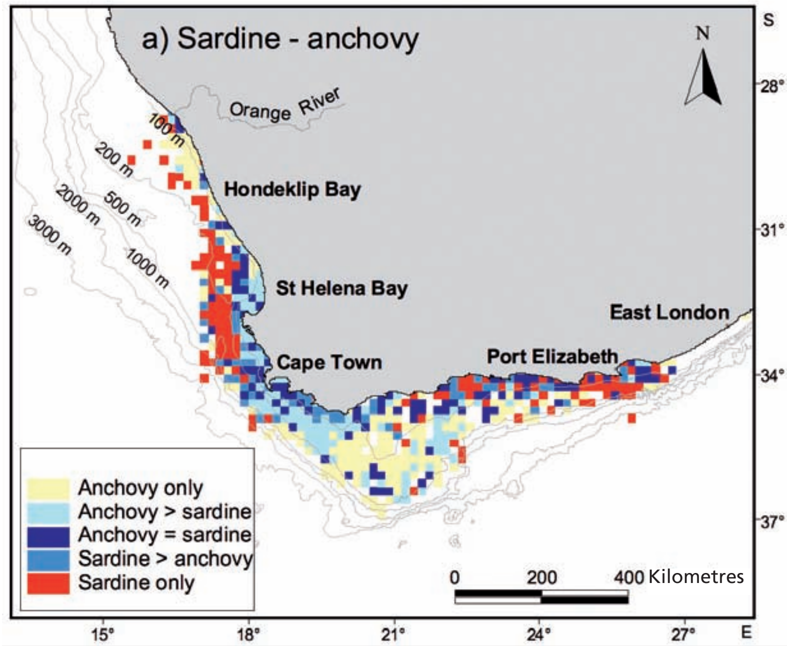
With respect to applying GIS as a tool for fisheries and aquaculture management or research, it is arguably more difficult to apply GIS in dynamic environments (e.g. marine fisheries, inland fisheries and offshore mariculture) compared with more static terrestrial environments. The reasons for this include the vastness and often remoteness of the areas being studied, the expense of obtaining suitable data from these areas, the fact that marine areas should be considered in terms of three or four dimensions, and the difficulties of mapping moveable objects – fish, for example – in moveable (non-static) aquatic environments. Along with these challenges, a number of factors such as overfishing, pollution, environmental degradation and resource competition, are causing large areas of the marine environment to be in spatial dis-equilibrium (out of a natural balance). As well as the main issues currently being addressed by GIS applications to marine fisheries, this chapter examines the spatial distribution of these analyses and concludes with three case studies illustrating a range of GIS usages.

There are a large number of ways in which GIS is presently being utilized to assist in marine fisheries management or research. The main ways (or themes) are

- **Distribution displays.** This is the construction of maps to show the distribution of any single theme or feature, or combination of marine and/or fisheries features. Distributions maps form the core of most modelling or GIS-based analyses.
- **Marine habitat mapping and analyses.** Establishing the essential components of fish habitats is an ideal way to utilize GIS, e.g. perhaps with a view to aquatic conservation designations.
- **Resource analyses.** These quantify and display the disposition and dynamics of any physical or biotic marine resource or combination of resources. For example, Figure 10 shows the potential interactions between two species having no predator/prey relationship (anchovy and sardine) that are competing for the same planktonic resources in South African coastal waters.
- **Modelling.** These functions include work on illustrating themes, often in a simplistic or general way, or there may be predictive modelling to show the outcome of potential decisions or actions. Modelling lies at the core of much marine GIS work.

FIGURE 10
The interaction between anchovy and sardine stocks in South African coastal waters



Source: Drapeau *et al.* (2004).

- **Monitoring management policies.** Fisheries management involves many spatially based decisions, e.g. in order to sustain fish yields fishing effort needs to be optimally deployed, and perhaps recorded via data obtained from electronic logbooks or vessel monitoring systems.
- **Ecosystems relationships.** Large numbers of marine relationships can be usefully delimited by GIS use, e.g. seeking predator/prey relationships, or relationships between fish distributions and any environmental parameter.
- M**arine protected areas (MPAs).** GIS can assist in identifying suitable areas for species or habitat protection or for the exclusion of fishing, and for analysing the results achieved through the designation of these areas.
- **Marine spatial planning.** This involves determining marine allocations so that all competing users of the marine space can best function sustainably. This may be complex given the number of the often conflicting parties involved, the frequent need to cross international boundaries, and the variety of spatial considerations.
- **The creation of economic surfaces.** Allowing researchers to model the likely income derived from fishery products based on alternative management and resource extraction scenarios.

- **Ecosystem approach to fisheries.** GIS is the ideal tool to assist in identifying ecosystems dis-equilibrium, and to predict and depict scenarios for improved management practices.

In each of the above thematic areas, examples of GIS are provided and further details are given. Over the past decade, the range of these themes has not expanded greatly, but the sophistication of the work has increased and current work is more likely to include complex modelling, geostatistics, animations, 3D and 4D analyses, and other processes.

Four other indicators concerning the recent and/or current status of GIS work are then reviewed:

(i) A breakdown of the number of records appearing, under various thematic headings, in FAO's GISFish database between 1990 and 2012 showed that most of the 360 records were for GIS applied in the context of ecosystems (i.e. approaches to fisheries, modelling, ecoregions) – 140 records; followed by management (i.e. integrated, regulations, systems and planning) – 67 records; marine protected areas – 30 records; habitats – 27 records; and species distributions – 20 records.

(ii) Using FAO's ASFA database, 207 records were obtained showing the geographic location where marine fisheries GIS work was conducted between 1996 and 2010. Of these records, 57 cited no specific location, and of the remainder more than half of the work was based in the United States of America, with much of the rest carried out in developed countries. This is unsurprising given the potential complexities and costs associated with undertaking GIS work that relies on data collected from a widespread and often hostile physical environment. It may be some time before much GIS-based work appears from many developing countries, but at least they will have existing work from which to obtain project ideas and methods.

(iii) An examination was made of the locations of a selection of the main institutions where marine fisheries GIS is being pursued. Because nearly all of this work is research oriented, it is again unsurprising to see that most of this work is undertaken in developed countries.

(iv) Finally, as a means of demonstrating progress that is being made in respect to GIS applications, Box 10.3 in the technical paper shows insights into some of the perceived trends and/or status in GIS as ascertained from individual observations made at the conclusion of the 2008 Rio de Janeiro GIS/Fisheries Symposium. These comments demonstrate the progress since the previous symposium in 2005.

In order to exemplify recent work being undertaken in respect to GIS applications to marine fisheries, three case studies are described. The first case study is entitled "Towards the use of GIS for an ecosystems approach to fisheries management: CHARM 2 – A case study from the English Channel" (Meaden *et al.*, 2010). This sophisticated example comes from a developed world area where up to 12 researchers worked over a six-year period. Although the case study exemplifies advanced GIS functionality and output, this is valuable for establishing the wider possibilities of the system. The aims of the CHARM project were to develop materials for a series of atlases and a Web site to help with resource management of the busy marine area (the English Channel) lying between the French Republic and the United Kingdom of Great Britain and Northern Ireland. Resource management included the incorporation of EAF considerations, the creation of a wide range of newly mapped resources, developing habitat models, and suggestions for locating marine conservation areas. Although work on the CHARM project was allocated so as to make best use of individual institutional strengths, maximizing the integration of activities was also fundamental to project success. Data inputs came from disparate sources, including national and local government offices, local university studies, specially commissioned marine benthic surveys, a range of existing specialist surveys including annual or semi-annual fishery surveys by national fishery agencies, GIS-based modelling, and remotely sensed data. All GIS work was performed using ArcView V.9.2. The technical paper briefly describes a selection of the output achieved, for example, the distribution of some benthic species, the mapping of fisher's perceptions as to the location of their main exploited commercial fishing grounds, and the use of Marxan software to establish potential marine conservation areas according to specified criteria. All project outputs can be seen on the project Web site at www.ifremer.fr/charm. The authors acknowledged the many challenges encountered during the implementation of the projects, but the results achieved by the CHARM team allowed for a vastly increased knowledge of the Channel's ecosystems and resource distributions.

The second case study, though very specific in content, covers a wide geographic area. This was a two-year project that used GIS and remote sensing as tools to help delimit suitable habitat for humphead wrasse throughout the Republic of Indonesia, Malaysia and Papua New Guinea (Oddone *et al.*, 2010). This species is in severe decline throughout its Indo-Pacific range, and it is important that the habitat distribution is identified with a view to future stock enhancement and conservation. Previous evidence has shown that more than 95 percent of the species live within 100 m of coral reef edges. This study evaluates the use of freely available Landsat-7 satellite imagery, collected between 1999 and 2003, for the mapping of shallow reef areas in order to locate suitable humphead wrasse habitats. The first phase of the project established that the Landsat imagery was of sufficient resolution to identify inner and outer reef edges and that buffers could be reliably drawn on either side of the reef edge so as to depict 200-m wide "corridors" of reef habitat. Once the methodology had been tested and approved, the second phase of the project involved obtaining all 279 of the freely available Landsat images covering the appropriate marine areas in the three study countries. All reef edges in these images were then digitized in order to capture locational data for all 20-m wide reef-edge habitat zones. Using the GIS methods described, the total reef areas suitable for humphead wrasse were 11 892 km^2 in the Republic of Indonesia, 941 km^2 in Malaysia, and 5 254 km^2 in Papua New Guinea. Based on previous reef estimate work, it is likely that these estimates are reliable. A knowledge of reef area and typical wrasse densities might give clues as to the species yield potential and thus to economic productivity for this species. The authors also described some of the challenges facing this work, but further noted that similar methods could be easily replicated and applied in estimating habitat potential in shallow marine waters for other species.

The final case study in this chapter is entitled "Spatial assessment and impact of artisanal fisheries activity in Cap de Creus". The study was carried out over a two-year period by a Master's degree student (with academic staff assistance) and concentrates on a small area of the Mediterranean Sea northeast of the Kingdom of Spain (Purroy *et al.*, 2010). As with many European marine waters, this area suffers from intensive and extensive overfishing from commercial, artisanal and recreational sources, which has led to severe stock depletions and widespread habitat degradation. There is also a major problem with the lack of fishery monitoring and enforcement. As there is a strong recognition that steps must be taken to reverse stock depletions, this study aims to provide information that helps to catalogue problems in the area, which also aids in defining an expanded MPA in the area and which thereby contributes to a long-term fishery future, especially for the local artisanal fishers. The marine environment here is interesting in that the wide coastal shelf is penetrated by a major marine canyon, which offers contrasting ecosystems, a rich species biodiversity, highly variable bottom substrates and a range of ecological niches. The specific objectives of this project were to accumulate detail on the numbers of fishers, the main areas fished and the species targeted, plus the varied fishing methods used. Data on fishing-related matters were obtained from government fishery departments and from FAO, and other data came mostly from the national mapping agency. For GIS purposes, the 1 145 km^2 study area was divided into 500 m^2 cells, and a range of relevant raster-based mapping layers was constructed from the data using ArcView and ArcCatalog GIS software. The range of GIS-based output achieved is described, including maps showing fishing methods deployed, gear types used according to the fisher's home port, and the fishing impact in terms of the variety of gear used in each 500 m^2 cell. The latter map shows a relationship between the number of gear types employed and the distance from the coast; most areas considered valuable for conservation were those where the least number of gear types had been used. The study concludes with a clear recognition of ways in which the whole GIS-based project could usefully be extended.