

13. Conclusions

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FAO's flagship fisheries publication "*State of the World Fisheries and Aquaculture*" (FAO, 2010b) addresses a range of contributing factors giving rise to the present global situation in fisheries and aquaculture. In its foreword, the publication highlights the encouragement of "actors at all levels in the (fisheries and aquaculture) sector to make better use of the Internet, GIS, remote sensing and other technological advances to safeguard biodiversity and ensure a sustainable future for the sector." To a great extent, it is these factors that are addressed by this publication. Thus, this technical paper has covered a range of material in the following subject areas:

- fisheries and aquaculture (in their broadest sense);
- the wider marine environment and ecosystems;
- the range of hardware and software that in combination constitutes the basis upon which spatial technologies function;
- the requisite digital data allowing the systems to function;
- GIS and remote sensing methodologies;
- and a range of parallel developments that are integral to the successful operation of GIS.

Within the context of these integrated fields, it has also been important to discuss how their integration occurs, how the GIS and remote sensing systems might best be initiated and implemented, the personnel that might be required, issues and challenges that might arise, where operational advice could be sought, as well as giving a large number of examples and case studies of the application of GIS and remote sensing to aquaculture, inland fisheries and marine fisheries. Additionally, it has been necessary to cover this material at a conceptual level allowing newcomers to the subject areas to readily comprehend what is being explained.

The predecessors of this technical paper (Meaden and Kapetsky, 1991; Meaden and Do Chi, 1996), published nearly two decades ago, arose from a perceived need to promote the new spatial technologies of remote sensing and GIS that were then beginning to "take-off", i.e. as a means to both promoting better management and to enable spatially based research to move forward. At that time, it was already clear that fisheries had reached a plateau with respect to marine landings, and that aquaculture might provide an alternative means of providing for the increasing demand for high-quality fish protein. Over these last two decades, both GIS and remote sensing have indeed contributed towards improvements in fisheries and aquaculture, with there being a wide range of "decision-related" output that could not otherwise have been obtained. However, during this period, it is also true to say that the overall situation with respect to the aquatic environments in which fish are produced has not improved.

In Chapter 1 the serious situation prevailing with respect to fisheries was outlined, but given the fact that the ecosystem approach to aquaculture (EAA) and the ecosystem approach to fisheries (EAF) strategies are now prevailing, it is necessary to think more broadly about the spatially based challenges to optimizing productivity from aquatic resources. Thus, as well as problems facing fisheries directly, the marine environment must contend with factors such as the imposition of additional rules and regulations, various kinds of pollution, disturbances along the coastal zone, disputes over resources, rapid changes in the natural environment, continuing human developments in the

marine space and species invasions. A way of realizing these challenges facing fisheries and aquaculture environments is seen in the recently perceived need for marine spatial planning. This planning can be exemplified by a new European Union document (European Commission, 2012; p. 13) noting that “The challenges and potential of the European seas, coasts and oceans are manifold and complex. Economic sectors active on or near the seas are interacting with other sectors in complex value chains. The list of sectors relevant from a maritime perspective is near endless. As a start, we can distinguish six maritime functions, each of them with a broad socio-economic value:

1. Maritime trade and transport;
2. Food, nutrition, health and ecosystems services;
3. Energy and raw materials;
4. Living, working and leisure in coastal regions and at sea;
5. Coastal protection and nature development;
6. Maritime monitoring and surveillance.

In many locations, it is likely that all future approaches to managing marine areas will be those that are required to integrate most or all of these functions, certainly in areas where conflicts are starting to emerge. A further recent document illustrating the large array of consideration in marine spatial planning is the ‘Atlas of maritime spatial planning’ covering all the Kingdom of Spain’s territorial waters (Suárez-de Vivero, 2011). This >300 page atlas portrays, at relevant scales, all the ways in which Spanish marine waters can be subdivided for different jurisdictional, physical, biological, and management purposes. There is no doubt that GIS will be the technological basis on which this marine spatial management will best function.

Given this broadening approach to fisheries and aquaculture management, at various places in this technical paper attention has been drawn to the facts that: (i) one of the most promising tools for analysing these spatial problems is GIS; and (ii) the great majority of the challenges faced by the marine, inland and other aquatic domains have a strong spatial component. A major proof of these claims lies in the extraordinary growth in the whole field of GIS³¹⁰, i.e. to the extent that it is now successfully deployed, and is thriving, across a wide range of applications areas. Chapters 8, 9 and 10 described in detail some of the means by which GIS are being successfully used to meet a variety of challenges faced by aquaculture, inland fisheries and marine fisheries and, as demonstrated in Chapter 11, the breadth of spatially based themes or issues that are now in need of urgent attention, or are presently “emerging”, has grown significantly, a trend that is likely to continue. However, although published work using GIS and remote sensing can demonstrate the utility of these tools, for the success and expansion of fisheries and aquaculture GIS-related work, it is essential that project results are disseminated to decision-makers and stakeholders in ways that are easily understood. For these reasons the reader can be confident that GIS will play a significant future part in addressing spatial issues.

GIS usage is concentrated within North America, particularly in the United States of America. Evidence has shown that an overwhelming number of GIS studies are carried out in this one country, and that the reasons for this might lie in the inherent advantages that this country offers. To an extent this is true. The United States of America undoubtedly has a wealth of resources with which to address research projects having high inputs of advanced technology-based methods, including people with the required expertise. This country is also where much of the research and development into GIS, remote sensing and the parallel technologies is carried out and is implemented. Other reasons why the United States of America dominance occurs are due to the number of conferences that take place there, the opportunities to publish the results of research studies, and the consequent ease of dissemination of knowledge about GIS.

³¹⁰ The ARC Advisory Group forecast that sales of GIS software will increase by 50 percent between 2010 and 2015 (www.arcweb.compress-center/2009-09-18/geospatial-information-systems-market-to-grow-50-over-next-five-years--1.aspx).

There is evidence, however, that other countries are now beginning to make rapid progress with respect to the application of spatial technologies to fisheries and/or aquaculture. This is especially true regarding the applications in the field of aquaculture. As has been mentioned before, one reason why aquaculture applications may be more widespread is the fact that this activity is often seen as another terrestrial farm-related activity, thus allowing terrestrial-type GIS analyses to be performed. Countries that are now emerging as newer GIS users are mostly the rapidly developing countries, especially those in east and south Asia. It is expected that a further significant expansion of GIS projects in these rapidly developing countries will occur mainly as a result of:

- the need to utilize GIS for EAA and EAF based projects, especially to confront problems arising from environmental degradation;
- an increasing awareness of the importance of the spatial perspective with respect to problem solving;
- the need for marine spatial planning in heavily populated coastal and marine environments;
- the increasing competition for freshwater in all food production sectors that supply high-demand products;³¹¹
- the need to ensure better food security for increasing populations, especially in areas where marine fish output is unlikely to grow;
- a dissemination process whereby information on the success of GIS is rapidly spread;
- the rapidly declining prices for GIS hardware, data gathering devices and remote sensing products;
- many Asian countries having strong cohorts of their population who excel in their interest and use of digital technologies, and there is an existing capacity to adopt GIS and other spatial tools.

Within those developing countries where economic growth is typically slower, there are indications that GIS use is now being taken up both for fisheries and aquaculture development.³¹² For instance, some African countries are already making good use of GIS. The case study by Asmah (2008) in Chapter 8 illustrates the use of GIS to assess the “development of potential and financial viability of fish farming in the Republic of Ghana”, and according to R. Asmah (personal communication, 2012), plans are currently under way in the Republic of Ghana to make practical use of GIS tools that are available for aquaculture development³¹³. In the Federal Republic of Nigeria, a national aquaculture strategy was published showing where GIS has been used to identify high potential aquaculture zones (Federal Ministry of Agriculture and Water Resources, 2008). However, much of the fisheries and aquaculture GIS work undertaken in developing countries is not being published,³¹⁴ and thus does not appear in FAO’s Aquatic Sciences and Fisheries Abstracts (ASFA) database. Given this emerging awareness on the usefulness of GIS, it is essential that the required capacity-building measures are in place allowing for easy and successful adoption of the range of expertise that GIS infrastructure require. Aguilar-Manjarrez, Kapetsky and Soto (2010) provide detailed information on additional considerations that might be deployed in order to enhance the capacity for pursuing GIS-based work in the

³¹¹ Freshwater availability on a per capita basis is rapidly dwindling, and in many cases, so is its quality.

³¹² See, for instance, articles by Aguilar-Manjarrez (2011) and Crespi, *et al.* (2011) in the FAO Aquaculture Newsletter, No. 48, December 2011 (www.fao.org/docrep/015/i2647e/i2647e.pdf). During the training courses reported by Aguilar-Manjarrez (2011) for the Network of Aquaculture of the Americas and by Crespi *et al.* (2011) for the Aquaculture Network for Africa, the participants informed that the Member Countries of these networks are either already using GIS or planning to use GIS for the development and management of aquaculture.

³¹³ See also Mensah (undated), who reports on the need for, and a justification of, the implementation of remote sensing, GIS and an aquaculture spatial database in the Republic of Ghana to be hosted by the Fisheries Commission of the Ministry of Food and Agriculture.

³¹⁴ Publications may also not be in English and these have less chance of getting international recognition.

emerging economies. It will be increasingly important that the use of GIS can be made in conjunction with multidisciplinary teams whose expertise includes knowledge of EAF and EAA. This technical paper is a significant contribution to these needs.

For the least developed or more remote regions of the world, it may be some time before the widespread use of spatially based technologies for fisheries and aquaculture development and management is achieved. Thus, except in a few core urban locations, these areas are unlikely to have the infrastructure allowing the essential technologies to be available; there will be little access to necessary information needs; data will be scarce or, indeed, absent; and many areas will in any case be inhospitable and sparsely populated. Therefore, for the most part, there will be little necessity for problem-based spatial analyses in these areas.

For GIS to be successful, under most circumstances it is essential that the whole system has been carefully and correctly implemented; indeed, this is why the technical paper devotes a considerable amount of detail to GIS implementation in Chapter 4. In this chapter, guidance and advice is given on a step-by-step basis to all the major facets that must be considered to enable GIS operational success. Chapter 12 described a wide range of challenges and attempted to provide useful clues as to how the challenges might be overcome. To this end, and on a wider note, it is relevant to conclude this technical paper with a table that provides main answers to the questions “What do I need to consider in order to get my fisheries or aquaculture projects started?”, or alternatively, “What is the way forward to successful GIS work?” Table 13.1 offers important clues not only to tasks that need to be thought about but also indications of the “activators” who might best accomplish these tasks.³¹⁵ Tasks have been differentiated between “Establishing the existing situation” and “Establishing an enabling capability”. Varying situations in different workplaces mean that tasks cannot be exactly ordered or prioritized.

Each of the questions posed in Table 13.1 is likely to initiate a whole sequence of further questioning and research, some of which might involve external help and perhaps weeks of investigation. This technical paper clearly indicates where additional support can be obtained. The dissemination of appropriate information mentioned in the table might be through various media, such as the Internet, leaflets, workshops, conferences, training manuals, and this dissemination should be appropriately pursued at more senior levels among not only those working directly in fisheries and aquaculture but also among workers in associated activities, such as other stakeholders. Wherever GIS or remote sensing methods are to be deployed, it is essential to remember that these applications can be designed to work at a wide variety of scales. “Scales” can best be viewed in two main contexts:

- Functional or operational – which relates to the financial and personnel inputs into the whole system, or in terms of the volume of, or degree of sophistication of, the outputs achieved by the system. A valid functional GIS or remote sensing output can be obtained by one person working in comparative isolation at a small single-site workstation, while at an intermediate scale there can be institutions or consultancy companies working probably in a single “cluster” of workers, and at a large scale a group of multidisciplinary experts will probably be achieving high levels of sophisticated output at a national or international operational level.

This huge range in system operating capabilities represents a significant bonus for GIS, as does the easy ability to upgrade the systems whenever the means or needs to do so are available. Therefore, there is no need for large expenditures or for sophisticated spatial work to make good use of GIS or remote

³¹⁵ It is likely that management will be involved in almost all activities, but the amount of involvement will vary considerably according to local circumstances.

TABLE 13.1
Suggested main tasks for taking fisheries or aquaculture GIS work forward

Tasks	Activators		
	Managers	Operative	External
Establishing the existing situation			
How much knowledge is there about GIS use or its potential in my workplace or country?	X		X
What is the existing GIS capability in my country?	X		X
Is GIS being used for existing fisheries or aquaculture work, and is this information being published?	X		
What type of spatial problems might exist in fisheries or aquaculture in my country or in any local areas?	X		
What back-up resources are available locally to support GIS work?	X	X	
What is the spatial distribution (or inventory) of support facilities for fisheries or aquaculture, e.g. fishing ports, processing plants, farming ponds, transporters, main markets, etc.?	X	X	
What are the possibilities for collaborative GIS projects with other regions, or other users of the marine or aquatic space?	X		
What knowledge exists on developing trends in fisheries or aquaculture such as EAF, EAA, and marine spatial planning?	X	X	
Establishing an enabling situation			
Disseminate information on the importance of optimizing locations for aquaculture facilities.	X		X
Disseminate information on the fact that "spatial disequilibrium" lays at the root of most problems confronting aquaculture and/or fisheries, i.e. the environment is often out of balance.	X		X
Disseminate information on the value of GIS and other spatial technologies and tools.	X		X
Disseminate information on important emerging issues such as EAA, EAF and marine spatial planning.	X		X
Investigate and then implement the appropriate capacity to operate GIS at selected sites, including hardware, software, personnel, back-up and support, etc.	X		X
Ensure that at each selected GIS site someone is there to "champion" the GIS work (see Chapter 4).	X	X	
Ensure access to appropriate GIS-related training, experience, knowledge, information, conferences, workshops, etc.	X		
Put into place rigorous data collection, storing, security, and updating methodologies.	X	X	
Provide or develop examples or case studies of successful GIS projects in fisheries or aquaculture and make them available to share (perhaps through FAO's GISFish).		X	X
With respect to fisheries or aquaculture, identify spatially related problems and prioritize GIS-based projects.	X	X	
Establish collaborating networks in terms of communications, but more importantly of physical working (effort sharing).	X	X	
Investigate opportunities for any cost reductions via the use of freeware GIS and the sharing of expertise with other departments.	X	X	
Develop time line or workflow patterns for all GIS project work.	X	X	
Have in place multidisciplinary back-up teams who can advise, for instance, on matters not directly related to fisheries or aquaculture, such as the social and economic issues implicit in EAA and EAF.	X		

Note: External activators are likely to be GIS consultants, FAO Web sites such as GISFish, or a range of other relevant Web sites.

sensing tools, and the work undertaken can certainly involve considerations relating to both EAF and EAA and other important emerging areas.³¹⁶

- The geographic area covered by a project – which could range from a world scale to a highly localized scale. At a large scale, the work of Aguilar-Manjarrez and Nath (1998) shows the use of GIS to illustrate the large potential that exists for inland aquaculture in most parts of Africa, and Kapetsky and Aguilar-Manjarrez (2007) have shown the potential for mariculture in most countries having access to marine waters. At the other extreme, small-scale GIS-based work in this technical paper has illustrated studies that were focused on a small reach within a single stream (Le Pichon *et al.*, 2006), or on a small marine area where various management problems needed resolving (Purroy Albet, 2010). The ability of utilizing GIS and remote sensing across vastly different spatial domains is enormously useful in terms of data resource inputs to GIS, in terms of geographic cognition, and as a means of initiating collaborative working with neighbouring regions or countries.

In summary, GIS and remote sensing have much to offer in the fisheries and aquaculture fields. The production of fish demanded in a more affluent world, whose population is increasing by 80 million per year, will be an accelerating challenge to meet. Meeting this challenge will require radical improvements in fisheries and aquaculture management, and these improvements are beginning to be adopted through approaches that involve spatial planning and an ecosystem approach to both fisheries and aquaculture. Given these facts, it is easy to envisage that GIS in developed world scenarios will, in the not too distant future, be linked to a suite of fisheries and/or aquaculture management tools, whose principle outputs will be easily comprehended by decision-makers because the outputs will frequently be in graphical, tabular and mapping formats. Though GIS and remote sensing technologies are mainly associated with developed countries, this paper has shown that the situation is rapidly changing. Because GIS is extremely flexible with respect to its degree of sophistication, developing countries will have numerous options to benefit from systems that are designed to match their needs or capacities. It is, therefore, incumbent upon the GIS users to make certain that this unique technology is promoted with considerable robustness and enthusiasm.

³¹⁶ It can be envisaged that relatively suitable GIS-based work would be addressing questions, such as “Where can aquaculture facilities best function?”; “Where is fish protein most urgently needed?”; “How accessible is expertise or extension facilities?”; “Where might processing or markets be located?”