9. Capacities to implement the ecosystem approach to aquaculture

9.1 INTRODUCTION

Chapter 5 on potential impacts of aquaculture on the environment and environmental impacts on aquaculture helps to gauge needs for spatial analyses to support the EAA at the country level. Complementary to that, the objective of this chapter is call attention to the need to identify, qualify and quantify capacities to carry out spatial analysis that could be brought to bear at country level in support of the EAA. The underlying requirement is to match training and technical support to the capacity to absorb them in relation to needs for spatial analyses in the EAA.

Capacity-building describes those programs designed to strengthen the knowledge, abilities, relationships, and values that enable organizations, groups, and individuals to reach their goals, in this case for the sustainable use of resources. It includes strengthening the institutions, processes, systems, and rules that influence collective and individual behaviour and performance in all related endeavours. Capacity-building also enhances people's ability to make informed choices and fosters their willingness to play new developmental roles and adapt to new challenges. Capacity is about more than potential; it harnesses potential through robust programs to make progress in addressing societal needs and is fundamental to fostering environmental stewardship and improving the management of areas and resources[1].

Carocci *et al.* (2009) indicate that an effective implementation of GIS to support the ecosystem approach to fisheries (EAF) largely depends on:

- The availability of an enabling environment, either at local, national or at international level or within a specific institution, including the availability of skills and competencies amongst personnel who have a clear understanding of its advantages and disadvantages.
- The availability of proper hardware, and adequate technological infrastructures and software are also important aspects of the capacity of an institution to deal with the complexity of collating, storing and analyzing spatial components of an ecosystem.
- Training opportunities and access to adequate support to promote the building of national capacities.
- The accessibility to suitable data. Data accessibility here will include practical cost considerations, data requirements, potential data sources, plus knowledge of data collection, storage and upkeep methods.

Carocci *et al.* (2009) also state that it is the above range of factors that collectively will build the capacity for GIS work. The same holds true for the EAA as does other material in their section on capacity building (Carocci *et al.*, 2009, Section 6.3).

This includes data (already covered herein in Chapters 3 and 4), technical support (covered in GISFish in terms of opportunities for formal and self-training including distance learning), software (covered in several ways in GISFish including freeware) and GIS configuration that, for reasons of economy will not be repeated here.

[1] Definition adapted from Committee on International Capacity-Building for the Protection and Sustainable Use of Oceans and Coasts, National Research Council, 2008.

Rather, the emphasis in this review is on defining in which countries and in which environments capacity building will be of the highest priorities.

Capacity to implement GIS, remote sensing and mapping in support of the EAA will depend on many factors, in various institutions at the national level:

- *Government policy on the EAA*
- *Awareness of the benefits of spatial analysis*
- *Finances and commitment for personnel, equipment and operations*
- *Experience in spatial analysis*
- *Internet access and speed*

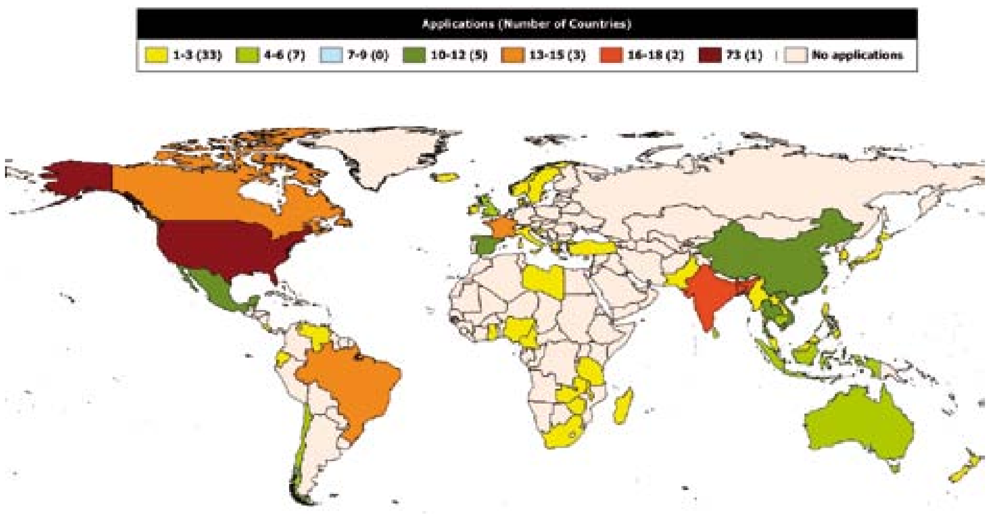
Of these, the first three are beyond the boundaries of this review. However, two of them, experience in spatial analysis as indicated by numbers of GISFish records per country and Internet access and speed, are the focus of the following sections.

9.2 AQUACULTURE GIS APPLICATIONS BY COUNTRY

In allocating effort to spatial analyses in support of the EAA it is important to know the level of experience in GIS in each country so that technical assistance and training, if required, can be allocated according to needs and capacities. One such indicative measure is the count of the number of applications by country in the GISFish aquaculture database. This is an indicative measure because some studies in targeted countries may have been carried out by expatriates or consultants without full involvement of nationals.

In, December, 2009, the GISFish database held 373 publications records pertaining to spatial analyses applied to aquaculture. Even though the content is biased towards publications in English, and there are no doubt many more examples of applications that have appeared in national languages, this compilation does indicate a strong background of experience with which to support the implementation of the EAA, but not one that is geographically homogeneous (Figure 9.1).

FIGURE 9.1
Geographic distribution of numbers of GIS applications in aquaculture in GISFish among 50 countries (December 2009)



Among the 373 applications there are a number such as reviews and manuals that did not geographically pertain to individual countries. Among the remaining applications some pertained to two or more countries and those were re-allocated to each individual country. Finally, there were 298 GIS applications in aquaculture that could be associated with a total of 51 countries (Figure 9.1).

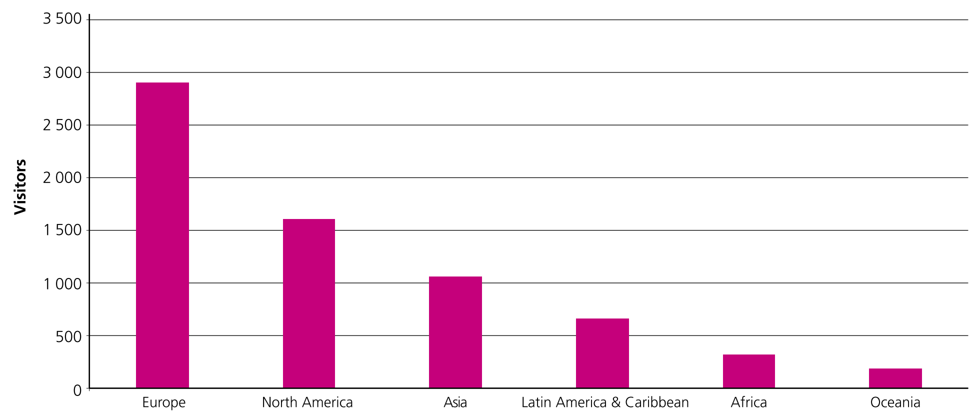
The United States of America accounted for 73 (24 percent) of the total, followed by India with 18 (6 percent), Bangladesh with 17 (5 percent) and, Brazil, Canada France each with 15 (5 per cent each), Thailand with 12 (4 percent) and China, Mexico Spain, and Viet Nam each with 10 (3 percent each).

Regarding the number of applications per country it is striking that there are many countries for which there are no aquaculture GIS applications at all. In summary, there were 298 applications among only 51 countries. In comparison, there were 163 countries having recorded aquaculture production in 2005 (FAO, 2007). The number of spatial analysis applications per country is underestimated for a number of reasons to do with language, how GIS applications are treated in publications and technical reports. Nevertheless, even though GIS has been applied to fisheries and aquaculture since the early 1980's, GIS applications in aquaculture cannot yet be said to be numerous and widespread. This poor geographic distribution of GIS usage indicates that training is likely to be a top priority for the implementation of GIS in support of the EAA. Further, in order to encourage a more widespread use of spatial tools applied to aquaculture and especially to the EAA it will first be necessary to promote GIS among administrators and decision-makers.

It is of concern that of those countries that practice aquaculture most intensively (Chapter 5), about half apparently are not represented in the GISFish Aquaculture Database. In contrast the numbers of visits to GISFish is encouraging in showing a widespread interest in GIS applications in aquaculture and inland fisheries (Figure 9.2).

The average number of visits to GISFish per country per month is 375, and the

FIGURE 9.2
Visitors to GISFish by continent from May 2007 to September 2009



average number of countries visiting GISFish per month is 66. The top 20 countries that visited GISFish during the period of May 2007 to August 2009 inclusive, is presented in Figure 9.3. Clearly, Italy and the United States of America standout as being the main visitors, however, there are many other countries that visit as shown in Figure 9.3 and 9.4.

9.3 ACCESS TO THE INTERNET AS A MEASURE OF CAPACITY FOR SPATIAL ANALYSES IN SUPPORT OF THE EAA

Access to the Internet and speed of access are extraordinarily important measures for gauging capacities to implement spatial tools in support of the EAA and for realizing that support. The Internet is a pipeline for communications and a data download pathway, as well as a backbone for training and technical support. In these regards the Internet is an essential element in providing the support required.

The number of Internet users within 220 countries and territories is tabulated in the World Fact Book (available at www.cia.gov/library/publications/the-world-factbook/rankorder/2153rank.html). Statistics vary but are mainly from 2007 and 2008

FIGURE 9.3
Top 20 countries visiting GISFish from May 2007 to September 2009

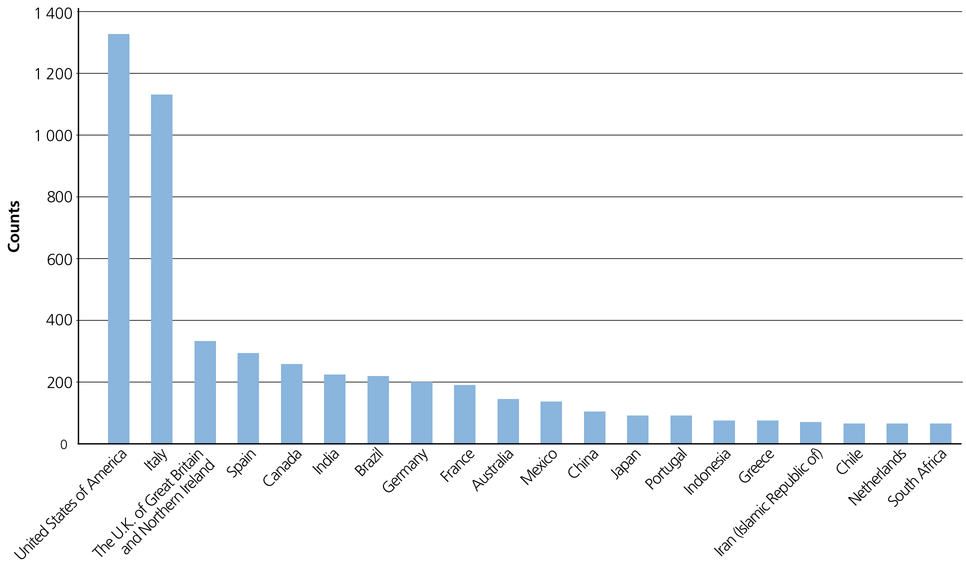
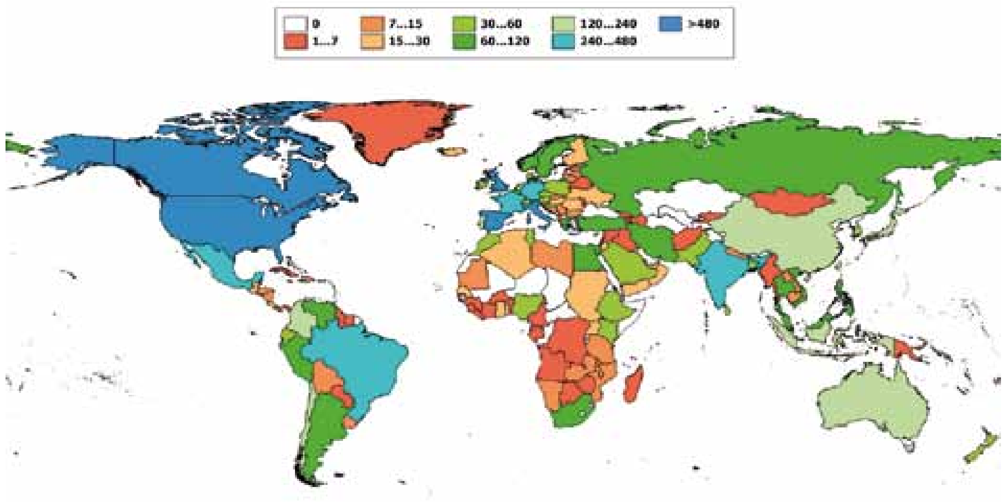


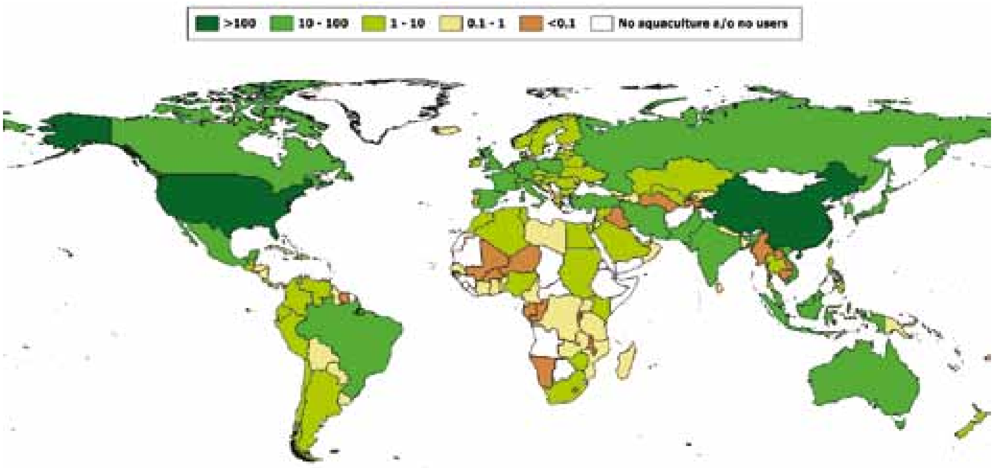
FIGURE 9.4
GISFish visitors map from May 2007 to September 2009



and may include users who access the Internet at least several times a week to those who access it only once within a period of several months. About 35 percent of the countries have one million or more users. The United States of America and China, Japan, India and Brazil rank first to fifth, respectively (Histogram: Statistics/Internet/InternetUsers&CIACC.xls).

Of the 163 countries recording some aquaculture production, there are data on the numbers of Internet users for 154 countries and territories (Figure 9.5). Numbers of Internet users vary greatly among countries spanning a range of less than one hundred thousand to more than 100 million. The only significant aquaculture producer not included is the Peoples Democratic Republic of Korea. Aquaculture producing countries with the least Internet users occur mainly in Africa. The number of Internet users in a country is not a guarantee that fisheries and aquaculture administrations are so equipped, yet this is an indicative means of evaluating training and equipment needs and for gauging the probability of success of technical interventions.

FIGURE 9.5
Internet users in each country (millions)



9.4 SYNERGIES BETWEEN THE ECOSYSTEM APPROACH TO AQUACULTURE AND THE ECOSYSTEM APPROACH TO FISHERIES, AND WITH OTHER SECTORS

One of the main outcomes from this review is the recognition that there are many issues, data requirements and analytical and decision-making developments that are common for both aquaculture and fisheries. More broadly, the same can be said for many other users of lands and waters. This is true not only in qualitative terms but also applies to all levels of organization and scale from global to sub-national. Taking advantage of these commonalities makes possible economic efficiencies (i.e. reduced costs) in data collection, data processing, spatial analyses and training. Moreover, the contacts and cooperation that result from a common or shared approach, or shared needs, pay additional benefits.

The following are some of the possible activities in which synergies could be sought between aquaculture and fisheries with regard to the implementation of the ecosystem approach to aquaculture (EAA) and the ecosystem approach to fisheries (EAF).

Activities with spatial components common to aquaculture in the EAA and to fisheries in the EAF in which synergies could be sought:

- Spatially and/or operationally defining ecosystem boundaries;
- Minimizing impacts on ecosystems (including societal impacts);
- Anticipating environmental and man-made impacts on aquaculture and fisheries;
- Facilitating integration of environmental, social and economic and administrative realms of aquaculture; and
- Anticipating and/or analyzing competing, conflicting and complementary uses of land and water.

Synergies should be sought and encouraged at all levels of the implementation of spatial planning tools for the EAA. Because training and technical assistance are going to be the major tasks, they are areas on which to concentrate searches for commonalties and competences. In practical terms, other specialized agencies of the UN family with strong training components (e.g. UNESCO) and well-developed capacities in spatial analyses (e.g. UNEP) as well as global NGOs (e.g. IUCN, WWF) with the same qualifications would appear to present good prospects for mutually beneficial cooperation.

9.5 SUMMARY AND CONCLUSIONS

Capacity-building describes programs designed to strengthen the knowledge, abilities, relationships, and values that enable organizations, groups, and individuals to reach their goals for the sustainable use of resources. The objective of this chapter was to call attention to the need to identify, qualify and quantify spatial analysis capacities that could be brought to bear at country level in support of the EAA. Prior information on capacity is vital in order to match training and technical support to the capacity to absorb them.

Several measures were employed to estimate capacities at the country level. These showed that the geographic distribution of the numbers of GIS-based applications in aquaculture did not cover all aquaculture countries and did not correspond with the intensity of aquaculture production. Because the Internet will have to serve as the backbone and pipeline for data, training and technical assistance in support of the EAA, Internet availability and access are essential. Many countries were shown to have limited numbers of Internet users.

This chapter also shows that information on which to gauge national capacity to undertake GIS, remote sensing and mapping in support of the EAA is generally difficult to come by and to evaluate remotely. Indeed, our experience shows that, even by concentrating on one country, searching the literature and the Internet for applications and for government and commercial entities, employing short-term national consultants and making site visits may give an incomplete picture, especially if the language of the country is not that of the investigators. This experience suggests that that small multidisciplinary teams of nationals of each country should evaluate their spatial analysis capacities as an essential step in planning for GIS in support of the EAA.

GIS support to the EAA depends on the general level of implementation of spatial tools in the country and more specifically on the interest of the fisheries and aquaculture administration, its finances, and the capacity and interest of staff. As regards GIS capacity and for efficiency in support of the EAA, direct contact should be made with the aquaculture administration in each country in order to make evaluations of the capacities of each to implement spatial tools and in order to be able to tailor technical assistance to the needs of the technical staff.

10. Advancing the use of spatial planning tools to support the EAA

10.1 INTRODUCTION

For brevity, the detailed conclusions synthesized from those set out at the end of each chapter of this review are assembled in the report of the workshop (pp 1-11) and not repeated here. Rather, the purpose of this chapter is to lay out several salient conclusions and to recommend activities to advance the use of spatial planning tools to support the EAA.

This review has established that there is an ample resource of technically broad spatial planning experience that can be tapped to support the implementation of the EAA through the use of GIS, remote sensing and mapping along with decision-making and modelling. This conclusion is based on an assessment of the availability of spatial data, and experience in addressing general issues in aquaculture at a broad range of scales and in a great variety of ecosystems that are relevant to the EAA, and in spatial decision-making and modelling. Specifically, the review has demonstrated that spatial planning tools easily encompass the three principles of the EAA and comprehensively cover the scales relevant to the EAA. The review has also shown that the experience is not homogeneously distributed globally as is the likely case with capacities to realize the benefits of applying spatial analyses to the EAA. Therefore, a major conclusion of this review is that the main tasks in support of the EAA are going to have to be promotion, training and technical assistance of GIS, remote sensing and mapping to ensure the timely and effective use of these tools.

The review has also employed methodologies to identify the countries which potentially make the most intensive use of freshwater, brackish- and marine environments for aquaculture as well as those in which the potential environmental impacts of other activities on aquaculture may be greatest. Some of those countries will be those most in need of awareness building of benefits, training and technical assistance.

With these challenges in mind, the remainder of this chapter is devoted to recommendations that are made mainly from the viewpoint of FAO Aquaculture Service (FIRA) that would be guiding the spatial planning initiatives in relation to overall EAA implementation at the global level. However, it is clear that spatial planning in support of the EAA will proceed best when it is tightly integrated temporally and geographically with the broader EAA effort.

10.2 FUTURE ACTIVITIES TO IMPLEMENT SPATIAL PLANNING TOOLS IN SUPPORT OF THE EAA

Filling gaps to lay a solid foundation for spatial planning tools in support of the EAA

Future activities in support of the EAA can be viewed as several major but related initiatives: (1) technical guidance for the development of innovative applications of spatial planning tools that can serve as core training materials that, in turn, can be deployed to EAA hotspots as needed, (2) capacity building that goes forward at all levels from global to sub-national, and (3) promotion of spatial planning tools at decision-making and technical levels. Of these, the first and third are expected to be closely managed by the FAO Aquaculture Service (FIRA) while opportunities for cooperative activities on capacity building should be explored with external organizations.

Development of spatial planning tools in-house and with external organizations
Implementation of the EAA can be viewed as somewhat akin to the development of the Code of Conduct for Responsible Fisheries. That is, implementation of the EAA will be a long, step-wise process that will include policy and technical guidelines as well as global, regional and national-level project activities. Therefore, a second important conclusion of this review is that, in order to ensure that planning for the use of spatial tools and analyses in support of the EAA is well founded, more specific and more detailed preparatory work will have to follow this review.

Innovative applications of spatial tools in the past have included strategic assessments of aquaculture potential at country, regional and continental levels. Presently new applications are aimed at mariculture with particular attention to off-the-coast and offshore aquaculture. Additionally, the development of the Africa Water Resources Database (AWRD) has opened up an opportunity for spatial analysis of waterbody ecosystems within larger terrestrial ecosystems. Analytical tools and comprehensive data are already at hand in the AWRD (Jenness *et al.*, 2007a; 2007b) that could be deployed for developing and testing EAA concepts and for implementing both the EAA and the EAF. Nevertheless, a number of topics should be pursued in order to address the gaps identified in this review. The topics are:

- Incorporating GIS-based social and economic analyses in aquaculture for the development of the EAA; what is needed are lessons learned from aquaculture, fisheries and other disciplines;
- Further exploration, documentation and synthesis of GIS-based decision support and risk analysis relevant to the EAA and catalogues of their respective tool boxes to follow the detailed survey already available herein as Chapters 7 and 8;
- Integrating spatial planning tools in the EAA via promotion, technical assistance and training: here are needed innovative ways to identify needs and capacities at all levels of administration; and
- Increasing capacities for training in spatial analyses via the Internet in the context of the EAA; and needed here are lessons learned from other disciplines and institutions that have been successful in reaching large audiences with low cost, effective solutions via the Internet.

Special attention is drawn to gaps in applications in aquaculture that deal with economics and social matters because of their close relationship with the EAA principles. A fundamental problem is that ecological and economic-social data are usually collected using political rather than geographic or ecosystem-based boundaries although, technically to a greater extent this can be overcome by GIS. A related and underlying problem lies in the basic education given to fisheries and aquaculture professionals, i.e. the lack of requirements for a solid foundation in economics and social sciences to accompany the natural sciences. There are several solutions to this, each with differing time horizons. The most rapid is to include economists and sociologists in spatial analyses, if no aquaculture specialists in these disciplines are available. Another, more medium term solution is to provide training on economic and social issues for technical staff with biological and ecological orientations. Finally, curricula preparing graduates for careers in aquaculture development and management need to be broadened to include not only natural sciences but also economics and sociology along with spatial awareness as required courses, or indeed graduates in ecosystem courses could have their courses broadened to include socio-economic elements as necessary. Aquaculture is very interdisciplinary and a good training programme will include aspects for all of the above components – and more.

Another gap is the lack of involvement of aquaculture with multisectoral planning. GIS, as is well known, can help to overcome this issue, but administrators and practitioners alike have to realize that they must go outside of their own disciplines to utilize the available expertise and to better understand competing and conflicting uses. This comes down to promotion through raising awareness of benefits and the inclusion of this solution in technical guidelines. One avenues in which to cover these topics is via expert reviews and case studies and eventually the preparation of technical guidelines that serve as core training materials. Another avenue is through workshops for managers and administrators to raise awareness about the capabilities of the tools and to formulate project proposals to implement them.

Cooperative training activities focused on the EAA

Training and post-training support of technical staff in fisheries and aquaculture departments, as well as departments and organizations involved in regulation or licensing will be required to implement spatial planning tools at the scales most pertinent to the EAA.

There is need to reach a large, globally dispersed audience. Accordingly, a broad strategy is required that takes advantage of common interests in the EAA principles and objectives and synergies that are shared by other organizations. Some of these could become potential partners and include:

- Universities (e.g. Stirling University in Scotland; The University of British Colombia in Canada, etc).
- The UN family of specialized agencies
- International and national NGOs involved with ecosystems and the environment
- International and national aquaculture associations and trade groups
- International and national aquaculture industries

Because spatial data is one of the principal shared needs among organizations, data collection and sharing could be one of the building blocks of cooperation that could eventually extend to joint projects.

Looking inward at FAO, there is a considerable body of organization-wide GIS experience and spatial data within the organization to implement spatial tools in support of the EAA. Other FAO-resident relevant experience already gained, readily available and highly pertinent is from the FAO Fisheries and Aquaculture Department EAF initiative. Additionally, there is untapped experience resident in the inland fisheries part of GISFish. While the resident experience is impressive in FAO, looking outside could also be fruitful. Common interests and skills reside in university programs and professors specialized in GIS for aquaculture and fisheries (e.g. Stirling University in Scotland) as well as in international NGOs with interests and competences in ecoregions and ecosystems and their conservation and management (e.g. World Resources Institute). The sources of ecosystem and other data listed in Chapters 3 and 4 provide an entrée to identify the latter organizations.

Gauging capacities to implement spatial tools in support of the EAA among countries

The countries likely to be most intensively impacting the coastal and inland environments through aquaculture activities have already been identified (Chapter 5), but their capacities to embrace the expert use of spatial planning tools are not generally known. Gauging capacities to implement spatial tools in support of the EAA is an essential step in providing the assistance required. At the country level this is very difficult and quite uncertain when done remotely. For example, the number of Internet users in a country is not a guarantee that fisheries and aquaculture administrations are well connected (Figure 9.3), yet this is an essential part of evaluating training and equipment needs and for gauging the probability of success of technical interventions. A well organized effort is required to gauge capacities. As a starting point, and in order to acquire this information quickly and inexpensively, the fisheries and aquaculture departments of FAO member countries should be emailed a brief questionnaire in order to identify the individuals and units using GIS and to request a summary of GIS activities and computer and Internet capabilities. The benefits of making such contacts are many and go beyond basic information collection itself. They include the opportunity for a dialogue that could reveal problems, potentials strengths and weaknesses that could eventually lead to improved and more efficient prescriptions for technical assistance. For example, opportunities for neighbouring countries to assist one another through networking or more formally through training and exchanges could result. Regional aquaculture networks such as the Network of Aquaculture Centres in Asia-Pacific (NACA); Network of Aquaculture Centers in Central and Eastern Europe (NACEE); Aquaculture Network of the Americas (RAA) and Aquaculture Network for Africa (ANAF) are important for the coordination of research, training and information exchange to promote aquaculture development on a regional basis, especially emphasizing the sharing of available resources (Aguilar-Manjarrez, 2008). It would be of utmost value if such centres were also able to provide operational information on GIS useful to support the EAA

Promotion

The EAA is holistic and therefore promotion of spatial awareness has to be not only at the ecosystem level but also all administrative levels. Additionally, promotion has to reach an audience much broader than practitioners of spatial planning tools for aquaculture alone. There are several potential audiences each with a need for a somewhat different approach in order to raise awareness of the need and benefits of applying spatial tools to the EAA. These include:

- aquaculture administrators;
- environmental regulators;
- coastal zone planners: decision makers with responsibilities broader than for aquaculture alone,
- aquaculture industry leaders and managers, including farmers, trade organizations, and financing institutions; and
- university professors in the fields of natural resource management, sociology and economics to orientate training and research; and
- private industry including farmers, trade organizations, and financing institutions; and
- NGOs with interests in conservation of natural resources.

The salient question is how to most effectively reach this varied audience. This is recommended as one of the future activities above on"Filling gaps to lay a solid foundation for spatial planning tools in support of the EAA."

An important aspect of promotion is raising awareness of the benefits and constraints of spatial tools as applied to the EAA. The GISFish portal already provides an avenue to this kind of information, but it is mainly aimed at those who are already somewhat familiar with GIS and who may be actual practitioners. If spatial tools for the EAA are to attain their potential, then administrators and decision-makers at the national level have to be made aware of the alternatives (e.g. contracted investigations vs. developing in-house capabilities) for their implementation. Facts pertaining to their benefits and costs in terms of capital investments, personnel and operating costs need to be disseminated. A new FAO Technical manual on "Geographic information systems and remote sensing in fisheries and aquaculture" is currently in preparation. This manual aims to address this need using selected case studies from different regions, environments, species and culture systems to illustrate the range of uses of spatial planning tools to support EAA and EAF implementation . Along the same lines, one of the follow-ups to the present review, especially Chapter 7 on decision-making modelling, will serve as one of the key background documents to assist a multidisciplinary team of 12 experts to prepare a much broader review entitled "Progressing aquaculture through virtual technology and decision-making tools for novel management" (Ferreira *et al*., 2010). This will be presented at the Global Conference on Aquaculture 2010 (www.aqua-conference2010.org/). This review will broaden and enrichen the present review. As a complement to this, advantage can be taken of the GISFish portal which contains many applications and case studies. The case studies presented in GISFish can be viewed as potential models for gauging the benefits accruing from future investigations as well as the time and personnel required in order to achieve results.

Technical assistance

Technical assistance for spatial planning tools in support of the EAA can take many forms such as missions and regional and in-country projects, as well as manuals and reviews and the GISFish Web portal. Access to the Internet particularly with country level client EAA practitioners is going to be essential for Email communications, as a spatial data and tools pipeline, and for delivering promotion and training. Relatively inexpensive initiatives could yield great benefits such as the activity on inventory of aquaculture outlined below.

Spatial inventory of aquaculture

As mentioned in Chapter 5, much of the implementation of the EAA will depend on defining aquaculture's impact on the environment and environmental impacts on aquaculture. Fundamental to defining these potential impacts are two kinds of information: (1) the boundaries of ecosystems and, (2) the locations of aquaculture and its characteristics. For the implementation of the EAA and for the use of spatial tools in support of the EAA, there is no substitute for a spatial inventory of aquaculture with follow up monitoring in order to detect changes in distribution and attributes. In short, the locations of various kinds of aquaculture installations including production sites, storage, transport and marketing facilities, along with their attributes, are indispensable for two purposes: (1) placing the aquaculture industry locationally within an ecosystem context, and (2) establishing administrative responsibilities for management and development in geographic terms. Fully developed spatial inventory should become a priority and for a relatively inexpensive initiative, the benefits can be great, delivering essential data for spatial analyses in support of the EAA. Thailand already provides one example of such an implementation (Suvanachai, 1999). Satellite remote sensing has already been shown by FAO and others to be efficient for aquaculture inventory and examples are included as GISFish case studies (www.fao.org/fishery/gisfish/id/1014).

The FAO Aquaculture Service (FIRA) is in the process of mapping aquaculture as part of the National Aquaculture Sectors Overviews (www.fao.org/fishery/naso/search/en). There is ample justification for amplifying and accelerating this activity due to its fundamental importance to the EAA as well as side benefits including the improvement of aquaculture statistics. An amplification of the NASO effort should include the preparation of a simple manual aimed at national level aquaculture departments on the methods to inventory and attribute aquaculture using image processing and GIS freeware. Remotely sensed data can be obtained from freely downloadable sites such as TerraLook and satellite images for base maps and other layers from earth browsers such as Google Earth and Microsoft Virtual Earth as indicated in Chapter 4. A part of this manual could include methods for field verification carried out by local personnel with inexpensive GPS units to collect the attribute data and to provide the spatial verifications. The GIS would then become the information backbone of the inventory by containing the spatial data, by placing the inventory in other spatial contexts and by holding the attribute data. To this end, there will be a need to create and/or strengthen information systems to keep the national aquaculture inventories up-to-date that will require more sophisticated training. Work already carried out in Thailand provides a template for further refinement (Suvanachai, 1999). FIRA can assist by perfecting and disseminating the methodology as appropriate for various levels of aquaculture development. Dissemination can be through manuals and training courses that can be direct or online. For the latter, GISFish should be further developed to serve as a training materials pipeline.

Practical implementation

Practical guidelines for GIS to support the EAA need to be developed. The present review and the FAO Technical manual on "Geographic information systems and remote sensing in fisheries and aquaculture" (in preparation) should be used as a base or starting point. GISFish is a portal to many additional resources upon which to build the manual, these include, literature, internet training opportunities, freeware, and data, a first step is to filter these resources for their usefulness.

Figure 7.1 in Chapter 7 illustrates a schematic representation of the phases in a GIS project which is still useful in a generic sense to any GIS project. However, a more specific example of GIS implementation to support the EAA is UNESCOs initiative on marine spatial planning (MSP) because the MSP process and tools could be adapted to, or adopted by the EAA.

Many steps in the MSP process (Ehler and Douvere, 2009) require or are facilitated by the use of software tools or other well-defined spatially-explicit methodologies (collectively referred to as "tools"). The present review aims to promote awareness, use, and development of GIS–based tools that can help implement the EAA. The review also provides a knowledge base of tools for EAA. As MSP is a means of implementing EAA, virtually all of the GIS-based tools presented in this review are relevant to MSP.

The purpose of the UNESCO initiative on MSP is to help countries operationalize ecosystem-based management by finding space for biodiversity conservation and sustainable economic development in their marine environments. One way to do this is through marine spatial planning. UNESCOs work focuses on moving marine spatial planning beyond the conceptual level by:

- Developing a step-by-step approach for implementing marine spatial planning;
- Documenting marine spatial planning initiatives around the world;
- Analyzing good practices of marine spatial planning;
- Collecting references and literature on marine spatial planning;
- Enhancing understanding about marine spatial planning through publications;
- Developing capacity and training for marine spatial planning.

Most of the 10 steps for MSP are relevant to GIS for EAA and are listed here:

Step 1 Defining need and establishing authority
Step 2 Obtaining financial support
Step 3 Organizing the process (pre-planning)
Step 4 Organizing stakeholder participation
Step 5 Defining and analyzing existing conditions
Step 6 Defining and analyzing future conditions
Step 7 Developing and approving the spatial management plan
Step 8 Implementing and enforcing the spatial management plan
Step 9 Monitoring and evaluating performance
Step 10 Adapting the marine spatial management process

A modified version of these MSP steps as required for GIS to support EAA implementation (also see Figure 2.1 in Chapter 2) could be:

Step 1 Defining ecosystem boundaries
Step 2 Identifying issues and potential stakeholders
Step 3 Organizing stakeholder participation
Step 4 Defining operational objectives
Step 5 Developing and approving the spatial management plan
Step 6 Obtaining financial support
Step 7 Defining legal issues and their spatial context
Step 8 Implementing and enforcing the spatial management plan
Step 9 Monitoring and evaluating performance
Step 10 Adapting the marine spatial management process

Finally, it is important to note that the ecosystem approach to aquaculture (like the ecosystem approach to fisheries) is about people. It is in their interest to develop aquaculture in an environmentally and people-friendly way and it is people who will be implementing the EAA (C. Brugère, personal communication, 2010). Likewise, it is entirely up to aquaculture decision-makers and spatial analysts as potential EAA implementers to make sure that GIS tools are used responsibly, and it is the creative use that they make use of these tools which will make them effective.

11. Glossary

GIS-RELATED TERMINOLOGY

Cell. The smallest unit of information in raster data, usually square in shape. In a map or GIS dataset, each cell represents a portion of the earth, such as a square meter or square mile, and usually has an attribute value associated with it, such as soil type or vegetation class.[a]

Fuzzy classification. Any method for classifying data that allows attributes to apply to objects by membership values, so that an object may be considered a partial member of a class. Class membership is usually defined on a continuous scale from zero to one, where zero is nonmembership and one is full membership. Fuzzy classification may also be applied to geographic objects themselves, so that an object's boundary is treated as a gradated area rather than an exact line. In GIS, fuzzy classification has been used in the analysis of soil, vegetation, and other phenomena that tend to change gradually in their physical composition and for which attributes are often partly qualitative in nature.[a]

Geographic Information System (GIS). An integrated collection of computer software and data used to view and manage information about geographic places, analyse spatial relationships, and model spatial processes. A GIS provides a framework for gathering and organizing spatial data and related information so that it can be displayed and analysed.[a]

Geodatabase. A database or file structure used primarily to store, query, and manipulate spatial data. Geodatabases store geometry, a spatial reference system, attributes, and behavioral rules for data. Various types of geographic datasets can be collected within a geodatabase, including feature classes, attribute tables, raster datasets, network datasets, topologies, and many others. Geodatabases can be stored in IBM DB2, IBM Informix, Oracle, Microsoft Access, Microsoft SQL Server, and PostgreSQL relational database management systems, or in a system of files, such as a file geodatabase.[a]

Global Positioning System (GPS). A system of radio-emitting and -receiving satellites used for determining positions on the earth. The orbiting satellites transmit signals that allow a GPS receiver anywhere on earth to calculate its own location through trilateration. Developed and operated by the U.S. Department of Defense, the system is used in navigation, mapping, surveying, and other applications in which precise positioning is necessary.[a]

Keyhole. **Markup Language.** XML grammar and file format for modelling and storing geographic features such as points, lines, images, polygons, and models for display in Google Earth. A KML file is processed by Google Earth in a similar way that HTML and XML files are processed by web browsers. Like HTML, KML has a tag-based structure with names and attributes used for specific display purposes. Thus, Google Earth acts as a browser of KML files.[b]

Landsat. A series of US polar orbiting satellites, first launched in 1972 by NASA (National Aeronautics and Space Administration), which carry both the multispectral scanner and thematic mapper sensors.[d]

Maps. Graphic representation of the physical features (natural, artificial, or both) of a part or the whole of the Earth's surface, by means of signs and symbols or photographic imagery, at an established scale, on a specified projection, and with the means of orientation indicated.[f]

Map Projection. A method by which the curved surface of the earth is portrayed on a flat surface. This generally requires a systematic mathematical transformation of the earth's graticule of lines of longitude and latitude onto a plane. Every map projection distorts distance, area, shape, direction, or some combination thereof.[a]

Metadata. Information that describes the content, quality, condition, origin, and other characteristics of data or other pieces of information. Metadata for spatial data may describe and document its subject matter; how, when, where, and by whom the data was collected; availability and distribution information; its projection, scale, resolution, and accuracy; and its reliability with regard to some standard. Metadata consists of properties and documentation. Properties are derived from the data source (for example, the coordinate system and projection of the data), while documentation is entered by a person (for example, keywords used to describe the data).[a]

Modelling. The representation of a system by a mathematical analogue, obeying certain specified conditions, whose behaviour is used to simulate and interpret a physical or biological system.[f]

Multi-Criteria Evaluation (MCE). Decision support tool for Multi-Criteria Evaluation. A decision is a choice between alternatives (such as alternative actions, land allocations, etc.). The basis for a decision is known as a criterion. In a Multi-Criteria Evaluation, an attempt is made to combine a set of criteria to achieve a single composite basis for a decision according to a specific objective. For example, a decision may need to be made about what areas are the most suitable for industrial development. Criteria might include proximity to roads, slope gradient, exclusion of reserved lands, and so on. Through a Multi-Criteria Evaluation, these criteria images representing suitability may be combined to form a single suitability map from which the final choice will be made.[c]

Raster. A spatial data model that defines space as an array of equally sized cells arranged in rows and columns, and composed of single or multiple bands. Each cell contains an attribute value and location coordinates. Unlike a vector structure, which stores coordinates explicitly, raster coordinates are contained in the ordering of the matrix. Groups of cells that share the same value represent the same type of geographic feature.[a]

Remote sensing. Collecting and interpreting information about the environment and the surface of the earth from a distance, primarily by sensing radiation that is naturally emitted or reflected by the earth's surface or from the atmosphere, or by sensing signals transmitted from a device and reflected back to it. Examples of remote-sensing methods include aerial photography, radar, and satellite imaging.[a,e]

Resolution. The detail with which a map depicts the location and shape of geographic features. The larger the map scale, the higher the possible resolution. As scale decreases, resolution diminishes. The dimensions represented by each cell or pixel in a raster.[a]

Scale. The ratio or relationship between a distance or area on a map and the corresponding distance or area on the ground, commonly expressed as a fraction or ratio. A map scale of 1/100 000 or 1:100 000 means that one unit of measure on the map equals 100 000 of the same unit on the earth.[a]

Shapefile. A vector data storage format for storing the location, shape, and attributes of geographic features. A shapefile is stored in a set of related files and contains one feature class.[a]

Vector. A coordinate-based data model that represents geographic features as points, lines, and polygons. Each point feature is represented as a single coordinate pair, while line and polygon features are represented as ordered lists of vertices. Attributes are associated with each vector feature, as opposed to a raster data model, which associates attributes with grid cells.[a]

FISHERIES AND AQUACULTURE TERMINOLOGY

Code of Conduct for Responsible Fisheries. FAO-formulated code, which sets out principles and international standards of behaviour for responsible aquaculture and fisheries practices with a view to ensuring the effective conservation, management and development of living aquatic resources, with due respect for the ecosystem and biodiversity.[i]

DEPOMOD. A particle tracking model used for predicting the sinking and resuspension flux of particulate waste material (and special components such as medicines) from fish farms and the benthic community impact of that flux.[g]

Ecosystem. An organizational unit consisting of an aggregation of plants, animals (including humans) and micro-organisms, along with the non-living components of the environment.[j]

Ecosystem Approach to Aquaculture. The ecosystem approach to aquaculture is a strategic approach to development and management of the sector aiming to integrate aquaculture within the wider ecosystem such that it promotes sustainability of interlinked social-ecological systems. This is essentially applying an ecosystem based management as proposed by CBD (UNEP/CBD/COP/5/23/ decision V/6, 103-106) to aquaculture and also following Code of Conduct for Responsible Fisheries (CCRF) indications.[l]

Large Marine Ecosystem. Large area of ocean space of approximately 200 000 km² or greater, adjacent to the continents in coastal waters, that has distinct bathymetry, hydrography, productivity and trophically dependent populations.[k]

Mariculture. Cultivation, management and harvesting of marine organisms in their natural habitat or in specially constructed rearing units, e.g. ponds, cages, pens, enclosures or tanks. For the purpose of FAO statistics, mariculture refers to cultivation of the end product in seawater even though earlier stages in the life cycle of the concerned aquatic organisms may be cultured in brackish water or freshwater.[f]

Marine protected area (MPA). A protected marine intertidal or subtidal area, within territorial waters, EEZs or in the high seas, set aside by law or other effective means, together with the overlying water and associated flora, fauna, historical and cultural features. It provides degrees of preservation and protection for important marine biodiversity and resources; a particular habitat (e.g. a mangrove or a reef) or species, or sub-population (e.g. spawners or juveniles) depending on the degree of use permitted. The use of MPAs for scientific, educational, recreational, extractive and other purposes including fishing is strictly regulated and could be prohibited.[j]

Marine Spatial Planning (MSP). A process of analysing and allocating parts of three-dimensional marine spaces to specific uses, to achieve ecological, economic, and social objectives that are usually specified through the political process; the MSP process usually results in a comprehensive plan or vision for a marine region. MSP is an element of sea use management.[h]

Stakeholder. Any person or group with a legitimate interest in the conservation and management of the resources being managed. Generally speaking, the categories of interested parties will often be the same for many fisheries, and should include contrasting interests: commercial/recreational, conservation/exploitation, artisanal/industrial, fisher/buyer-processor-trader as well as governments (local/state/national). The public, the consumers and the scientists could also be considered as interested parties in some circumstances.[j]

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The potential of spatial planning tools to support the ecosystem approach to aquaculture

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Attention is presently turning to the processes, methods and tools that allow practical implementation of the ecosystem approach to aquaculture (EAA). This will require the use of various tools and methodologies, including environmental impact assessments and risk analysis. Ecosystem-based management involves a transition from traditional sector-by-sector planning and decision-making to the more holistic approach of integrated natural resource management at different scales and for ecosystems that cross administrative boundaries. An essential element for the implementation of the EAA will be the use of spatial planning tools including Geographic Information Systems, remote sensing and mapping for data management, analysis, modelling and decision-making. These proceedings focus on the status and process of implementing these tools which, in turn, necessitate the development of capacity building, training and promotion of spatial planning among decision-makers and technical staff. The document is organized in two parts. The first, the workshop report, deals with the background of the EAA effort and the genesis of the workshop. Most importantly, it captures the salient contributions of participants from their formal presentations and general discussions. The main conclusions of a review of the status and potential of spatial planning tools, decision-making and modelling in implementing the EAA are also included. The review itself, along with an abstract, forms the second part.

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