12. Overcoming the challenges to fisheries or aquaculture GIS work

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Given the range of thematic areas that are encapsulated within the broad areas of "GIS", "fisheries" and "aquaculture" and the spectrum of knowledge that must be utilized, it is unsurprising that there will be challenges to working within any of these areas. Challenges are exacerbated by the requirement to be working in a three-dimensional environment that may be in constant motion and where the scale of the data needs is extremely large, certainly when compared with the majority of terrestrial GIS work. This chapter describes the nature of the main challenges and provides clues as to how these challenges might be overcome. Although challenges may be broadly considered as being intellectual or theoretical, practical or organizational, economic, or social and cultural, here they are considered in subsections derived from these headings.

(i) **Mapping moveable variables.** In aquatic environments, not only do most of the objects being mapped move, but the environment itself (the water) also moves. This creates obvious challenges for mapping, but they are reduced for aquaculture as most mapping is of fixed or permanent features. Attempts, however, must be made to map moveable species or objects because without doing this little marine-based GIS work could be achieved. For many marine-based movements there are degrees of regularity, many of which can be estimated, e.g. diurnal or seasonal migrations or large-scale ocean currents and tides, and therefore generalized maps can be drawn. The real challenge is to map chaotic movements, though even these can often be modelled such that at a coarser scale they can be tentatively mapped. Alternatively, data for mapping may be gathered at short time intervals allowing temporal mapping. Advances in data gathering, such as the use of tagging to gather data movements against time, now contribute significantly to the development of movement prediction models. However, considerable thought must always be given by the GIS user to the optimum resolution or scale at which GIS-based work involving movements is best carried out.

(ii) **Multiple scale and resolution.** Scale is concerned with the relationship between the mapped distance or area and the corresponding real-world size or area, whereas resolution is concerned with the smallest size of a feature that can be mapped or measured. Both should incorporate a spatial and temporal dimension. The movement and size of aquatic environments or objects takes place across a large spectrum of scales and resolutions, and there is a long history of discussion on the appropriateness of the scale of study. For marine-based GIS work, data may be gathered at a range of scales or resolutions, and throughout the technical paper examples of work at varying scales have been given. Finding the optimum scale or resolution for a particular project may only be obtained by trial and error (experience), though the geographic area and the marine processes involved will provide obvious clues. Caution is given about the use of data for a single project that has been gathered at highly variable scales, i.e. because when data sets are integrated the value of the results may only be as good as the coarsest data used. With the advent of increasing EAF or EAA work, it is likely that scale or resolution challenges will be enhanced because a greater range of data inputs will have been gathered according to mixed spatial criteria.

(iii) **Handling 2.5D, 3D and the 4th dimension.** Whereas most terrestrial GIS work is confined to two dimensions (plus the 4th time dimension), for marine-based work it may be necessary to consider both the 2.5 and the third dimension. The difference between these is that in the 2.5D objects are fixed to the marine seafloor, which can be of varying depth, whereas in 3D objects can be of any variable depth on the z axis. While many GIS have the capacity to operate within these dimensional variations, the main challenge is to obtain mapped output that can be meaningfully interpreted in all dimensions. There are also other significant challenges with respect to the large data requirements for 2.5D or 3D work. The technical paper provides examples of how 2.5D and 3D mapping is being achieved and, in many cases, this is best accomplished by sequential spatial or temporal "animated mapping", i.e. as used in cine-films.

(iv) **Application of spatial models and statistics.** What is being considered here is the use of GIS as a software platform or activity surface on which numerical models, usually in the form of equations, may be conceived, evaluated or tested. Once established, a model can be used again in similar situations (or at different times), having been, for example: (i) suitably adjusted to suit perhaps different species; or (ii) through changes in geographic area; or (iii) with the addition of extra variables; or (iv) with adjustments to the weighting of variables. Models can be run on specialized software and then integrated into most GIS, or they can be run directly within a GIS. The challenges to model use can be in their requirements for the use of advanced mathematics and statistics, in identifying the best combination of variables to be included in the model or the problem of spatial and temporal autocorrelations and the identification of true dependence or independence between variables, and in securing statistical significance of the data being used. To overcome challenges relating to modelling, it is recommended that familiarization with, and use of, some of the spatial analysis tools be made.

(v) **Optimizing visualization and mapping methods.** GIS output is conveyed via tables, graphs and dominantly maps. In order that these illustrative methods convey a clear message, it is important that the message is accurately depicted and perceptually easy to synthesize. Good quality maps should follow basic rules concerning, for example, legend construction and content, scale delineation, number of classes used, word placement, etc, though there is freedom to accommodate individual mapping styles and preferences. The challenge for GIS workers is in achieving cartographic output having acceptable and comprehensible visual qualities. Most GIS have a range of acceptable output styles, but GIS workers have to use discretion with regard to factors such as classification ranges, font style and placement, colour mixes and the range of data to convey. A problem to achieving success with visualization is that individuals have widely varying perceptions as to what constitutes good quality mapping. The technical paper gives suggestions on mapping considerations and advice on where additional guidance can be obtained.

(vi) **Integration of socio-economic considerations.** The need to integrate social and economic considerations into EAA- or EAF-based management means that a sustainable future for fisheries or aquaculture can only be achieved if recognition is given to matters such as the provision of employment, the availability of labour, the benefits of sustaining local communities, dietary advantages of secure food supplies, and the achievement of equity in the use of marine space. This integration of socio-economic data presents additional challenges to GIS work because much of the data is difficult to classify, values may be hard to measure, social data are scarce in many areas, participants in projects may be reluctant to divulge data, mapping boundaries to social or economic classes is difficult, and some data can only be subjectively evaluated. It is likely that initial EAF or EAA work will be "exploratory,"in the sense that experimentation or conjecture will be needed with "trial-and-error" techniques being used. This being the case, it will be useful if early projects can be undertaken where there is some degree of certainty about GIS results, i.e. until such time as experience has been acquired. It will also be useful if experience can be shared between groups, and if alliances with other GIS groups can be formed so as to share learning and information in social and economic concepts, issues, methods and resources.

(vii) **Data gathering and assembling.** Although data acquisition has long been a challenge to GIS work, it still remains a prime challenge. There are a number of reasons for this, including: (i) the relatively large costs involved; (ii) uncertainty on the exact nature of some data requirements; (iii) the difficulty in acquiring exact data requirements; (iv) the uncertain quality of data accessed; (v) the precision of the data available; (vi) the standards required in terms of structure, format, projections and classifications; and (vii) can statistically valid data be provided? Further details on problems associated with adequate data acquisition are given in Chapter 3 and in Box 12.1 of the technical paper. There is little doubt that significant advances are being made in data acquisition, with data gathering systems and data sources growing at an exponential rate. But with the growth in the range of requirements for GIS work occurring at ever-increasing scales and resolutions, then for some time the challenge of data provision may continue to be one step ahead of meeting data needs.

(viii) **Subject breadth and organization.** Although each of the areas of "GIS", "aquaculture" and "fisheries" are clearly identified subject areas, their existence is essentially linked to other main subject areas, including oceanography, marine ecology, climatology, agriculture, biology, remote sensing and branches of information technology and marine construction. Working in this breadth of applications areas increases the complexity of the work undertaken in terms of the overall knowledge required, the linkages and communications channels, and the range of information and data that might be required. Added to this there are now considerations relating to marine spatial planning and EAF and EAA. Most of the GIS-based work being pursued in fisheries and aquaculture is small-scale and undertaken in scattered private and public companies and institutions, and these conditions are not always conducive to optimizing the chances of successful and well-tested applications. Chapter 4 of the technical paper provides significant detail on the range of support being offered in the disparate subject areas. The various technologies associated with the Internet as a vehicle for information acquisition, for data exchange, and for interactive GIS also serve to reduce the challenges of subject breadth, fragmentation and isolation that were previously more prevalent.

(ix) **Work management and control.** Challenges associated with work management and control mainly occur at the scale of an individual GIS worker or smaller organization. Because so much GIS work in fisheries or aquaculture is pursued in smaller organizations, it means that GIS project groups will be small, with workers being obliged to carry out all or most of the many necessary tasks and to have a high degree of initiative. The challenge here then is in keeping up with developments, scheduling the work, getting access to support, and usually dealing with a wide range of people and possible problems. Challenges are helped if robust management support is available, and by having formed links with other GIS groups engaged in similar aims, having a good knowledge of avenues for external advice and having the time and resources to attend courses, conferences, and workshops plus other forms of networking. If the optimum working milieu cannot be established, then other solutions to obtaining GIS functioning may be sought through linking with other institutions or departments or through contracting out any GIS work.

(x) **Promotion of GIS output.** There is concern that the use of GIS does not receive the promotion that it deserves, i.e. with respect to the utility of the software and the scale of the spatially based problems associated with worldwide fish production. Reasons for this include: (i) the specialized nature of the work; (ii) GIS output is usually only promoted in the grey literature; (iii) there are few conferences or workshops to showcase GIS work; and (iv) because GIS is only a problem-solving tool for spatial analyses, then it is the problem itself that attracts most attention. Additionally, the majority of GIS output is only passed on to decision-makers and thus it may receive little recognition. Given the potential scale of problems confronting aquaculture and fisheries, it is vital that these challenges to adequate promotion are met. Although there are relatively few hard copy publications or relevant conferences and workshops, it is likely that the growth of the Internet will be the significant spur to promoting GIS, and, indeed, this is already happening through FAO's GISFish Web site, through interactive fisheries and other biological data mapping, through numerous online videos and through interactive aquaculture-based simulations. Additional spurs to GIS work in fisheries and aquaculture will come through the increased needs for marine spatial planning and for EAF and EAA related projects, through the spread of suitable spatial and geostatistical models, and through the establishment of marine conservation zones.

(xi) **Expenses associated with fisheries and/or aquaculture GIS.** A theme occurring throughout the technical paper is that the implementation and pursuance of fisheries or aquaculture GIS might be an expensive applications area. Thus, apart from initial capital costs of establishing the system itself and securing trained personnel, there are likely to be significant costs associated with data acquisition. Data costs could be high owing to the expense of gathering data in widespread marine aquatic environments, plus the costs of acquiring satellite imagery and other digital data sets. Continuing operating costs can also be high, especially in developing countries that might have to pay "western prices", and, indeed, high costs could be proving a barrier to even acquiring knowledge about GIS. Challenges associated with costs can be overcome by implementing GIS at a low and/or relatively simple scale, sharing computing facilities with other compatible users, obtaining free and open source software (FOSS), seeking data sets on the Internet, and approaching companies, public authorities, or universities for any free or low-cost digital data.

(xii) **Obtaining funding.** Though fisheries are an extremely widespread activity, supporting hundreds of millions of people worldwide, the fact that they mostly take place on a small-scale or as semi-subsistence activities mean that surplus funding is seldom generated. Any funding obtained is unlikely to be on a large scale, and the future of funding may depend on the perceived output results from the GIS project. The likelihood of GIS and/or remote sensing work proliferating (and thus being funded) will probably be much higher if these tools can be integrated as essential elements of wider projects. Funding for fisheries GIS must usually be obtained from government sources or through various types of donor support. In recessional times, this funding may dry up completely. Because cost–benefit analyses showing the value of GIS work are difficult to substantiate, this too prevails against easy access to funds. The challenge for the GIS enthusiast might therefore be to convince his or her organization that GIS is very much more than a "luxury, peripheral add-on". The challenge can be met through the production of high-quality visual output that is well appreciated and understood, and through an added appreciation that most problems derive from an imbalance in the spatial domain and that the needs for marine spatial planning, EAA and EAF are a tacit recognition of this. The financial outlay on GIS may be a small price to pay compared with the enormous challenges faced from rapidly dwindling fish stocks.

(xiii) **Overcoming inertia relating to the cultural ambience.** The social or cultural ambience of a country, region or even a workplace can have a major effect on the acceptance of technological innovations. For instance, in inward looking or closed societies or in circumstances where outdated or entrenched attitudes may persist, there may be very few people emerging who are able to act as "champions for GIS" and who can therefore promote the use of these digital systems. So, there may be little familiarity with GIS or, indeed, the circumstances where it might prove to be useful. Also, there is often reticence about passing on or accumulating data with regard to fish catches and capture locations. So, in some areas information systems still have little relevance to existing cultural norms. These challenges might best be met by a "top-down" approach, where senior management, or experts from external agencies, brief a workforce on advantages that a technology offers, and in turn this information is disseminated throughout an organization or working group. Alternatively, a "bottom-up" approach may be adopted, whereby a demand for change is engineered from within an organization, perhaps by a middle-level employee who has gained access to GIS knowledge via education or through the Internet. A further alternative is through getting fishers or aquaculturists to work with scientists as a means of appreciating their often opposing perspectives on the management of their activities.

(xiv) **Gaining support and advice.** Support for GIS and/or remote sensing work will be much higher if these tools: (i) can be integrated as essential elements of wider projects (e.g. on climate change implications for fisheries and aquaculture, or strategic planning for offshore mariculture development); (ii) can focus on issues/themes that illustrate the many benefits that GIS can provide to support problem solving and decision-making; or (iii) can be designed to match the needs, interests, finances and capacities of the target users or stakeholders.

(xv) **Transcending political or international boundaries.** It is clear that there will be little relationship between areas demarcated by designated political boundaries and those areas in which fish species inhabit. This duality of marine space division (political jurisdiction versus natural ecosystems) may lead to challenges with regard to resource management, especially where more mobile marine species are concerned. Important implications for GIS work occur in terms of setting spatial boundaries for analyses, acquiring funds for joint projects, for the management and content of projects and for data resourcing. Many attempts have been made to achieve regional fisheries cooperation between neighbouring countries or within groups of neighbouring countries, for example, the European "Common Fisheries Policy"or the 17 regional fisheries management organizations controlling the high seas. However, most of these attempts at cooperation have been unsuccessful. The challenges of transcending political differences are likely to be ameliorated through the necessity of collective working, e.g. on EAA, EAF or marine spatial planning projects.

(xvi) **Developing geographic cognition and spatial awareness.** This challenge refers to an appreciation of geographic thinking and perception. Thus, a person with good geographic cognition is able to recognize factors such as: (i) spatial patterns in the landscape, e.g. clustering, ubiquity, adjacency; (ii) they can visually discriminate the implications shown by any mapped distributions; (iii) has a sound knowledge of local geography and geographic relationships; (iv) is aware of the locational suitability for various types of activity; or (v) is aware of spatially variable production functions that might control fisheries or aquaculture production. These kinds of abilities allow GIS workers to have an instinct for the type of work that a GIS project could best accomplish, or they may get a feel for whether GIS output is likely to have validity. Related to this is the appreciation that problems affecting fisheries or aquaculture are likely to be rooted in spatial differentiation, i.e. that different locations have favourable or unfavourable abilities to provide for the essential factors of production, with location being the key to business success. This challenge must be met through workshops, conferences, reports, books, etc., all placing a greater emphasis on spatial awareness and geographic understanding, and, indeed, these ideas are slowly emerging through concepts such as marine spatial planning and through the rapid spread of geographic technologies such as Google maps, in-vehicle navigation systems, global positioning systems and the emergence of the GeoWeb environment, i.e. a relatively new term that implies the merging of geographical (location based) information with the abstract information that currently dominates the Internet.