

11. Emerging themes or issues in fisheries and aquaculture GIS

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Although world marine fish production has reached a plateau of about 80 million tonnes annually, fish produced from aquaculture has increased by approximately 50 percent during the past decade. The combined total value of fish sold by fishers and aquaculturists is now likely to have reached US\$200 billion, and over 500 million of the world's population are supported directly or indirectly by fish production. These facts provide indicators that both fisheries and aquaculture are very significant activities and, as such, they will continue to need the input of both research and management. From the perspective of GIS and remote sensing, this recognition must be significantly bolstered because of all the world's production activities fisheries and aquaculture are the most spatially extensive, and a large range of production types takes place in hugely varied environments and at vastly differing scales. Because of this importance, it is vital to examine emerging themes or issues in both fisheries and aquaculture.

A number of preliminary considerations need to be made with respect to themes and issues:

- (i) Only issues having a spatial context are examined here, although in practice this is most issues.
- (ii) Although the terms “themes” and “issues” have distinct meanings, in the context of this chapter they are used almost synonymously. This is because GIS is being deployed as a spatially based problem-solving tool, and there is an implication that within specific thematic areas there must be an issue that needs to be addressed.
- (iii) The term “emerging” themes is used because there is already evidence that these themes are developing. Therefore, the term “future themes (or issues)” is avoided because of the degree of conjecture involved.
- (iv) It is important to be aware that many emerging themes or issues can be part of a related chain of issues, e.g. the issue of climate change can lead to changing water temperatures which in turn leads to range changes of fish species, etc.
- (v) Themes or issues themselves must arise from drivers or catalysts for change, and it is sometimes difficult to differentiate between a “driver” and an emerging “issue” or indeed an “emerging trend”.
- (vi) It may also be difficult to differentiate between “current issues” and “emerging themes or issues”. Here, emerging themes or issues are fields of study that are likely to become more important in the near future.

The rest of this chapter can be conveniently divided into three main sections. The first section looks at the drivers affecting spatial approaches to fisheries or aquaculture research or management-related work; the second section examines current issues and developments affecting work in GIS or remote sensing; and the third section discusses in some detail the emerging themes relating to spatial aspects of fisheries and aquaculture.

As there are many drivers that could affect the progress of fisheries or aquaculture, the concern here is only with identifying the main ones. The drivers are listed approximately such that they move from external towards internal, i.e. from those having indirect influences on the progress of fisheries or aquaculture towards those having more direct influences. Drivers themselves will be of differing importance according to local circumstances and, indeed, some drivers will be of no relevance at all in specific regions or areas. The main drivers identified are:

- Human population increases, and the consequent effects on food demand.
- Changes in atmospheric processes, mainly from climate change and its consequences.
- Contractually based supply chains, mainly for marketing, industry consolidation and quality control.
- Fuel and/or energy costs, which are increasing relatively rapidly.
- Education and information, which concern both the potential offered and how to accomplish the required activities best.
- Protein needs, food security and poverty alleviation, e.g. to help meet millennium development goals.
- Socio-economic development, including business opportunities and optimizing production locations and costs.
- Improving governance, relates to the need to improve the means by which fisheries and aquaculture are managed and controlled.
- Capital availability which may vary from time to time, from area to area, and between the public and private sectors.
- Changes in consumption preferences will impact upon production quantities among species.
- Ecosystem degradation and environmental awareness is linked to the recognition of sustainability and the essential need to improve many existing bio-physical systems.
- Freshwater access and availability, which throughout much of the world, is an increasing problem occurring at an accelerating rate.
- Stakeholder participation in decision-making meaning that, with an increasing move towards both EAA and EAF, a wider range of stakeholders will be involved in decision-making.
- Certification in fisheries and aquaculture is being applied in order to give certain quality guarantees in terms of sustainability, food sourcing, production fairness, etc.
- Genetic modification of aquaculture species is concerned with moves to develop species that have specific, desirable traits.

- The demise of many commercial wild fish stocks will oblige fishers to change their target species, and it will encourage greater aquaculture production.
- Global growth in aquaculture production, i.e. in much the same way as terrestrial agriculture expanded in earlier times, will cause significant impacts in a variety of ways.
- Controls on recreational angling mean that more regulation is likely to be imposed because in some areas recreational fish catches are probably exceeding commercial catches.
- Changes in fisheries management, e.g. as EAF and marine spatial planning expand and as stocks dwindle further, the scale of fisheries management will significantly increase.

In sum, the drivers affecting fisheries and aquaculture development show that their combined impacts are likely to be large and they will initiate many spatially related changes. But these are not the only factors driving changes in the use of spatial tools in the fisheries and aquaculture spheres. An array of developments and issues in the spheres of GIS and remote sensing is also driving change. Because GIS and remote sensing both function in a highly diverse yet integrated technological field, it is often difficult to isolate individual “driver components” of GIS or remote sensing. Nevertheless, this has been attempted in this section. Again, only the main points are listed here, with more detail being provided in the technical paper.

- **Continuing advances in computing environments.** This is a “catch-all” issue encapsulating the advances that are continually ongoing in the world of computing, and that show no signs of declining. On a world scale, these developments increasingly make GIS and remote sensing more accessible.
- **The development of new spatial tools.** These comprise a wide range of proprietary and open source software, plus “add-on” programs capable of performing an almost infinite array of tasks that aid in mapping and spatial analyses.
- **Improvements in remote sensing imagery.** Future imagery will improve in terms of resolution, cost reduction, parameters surveyed, image processing capabilities and image delivery times.
- **Maps as an ideal medium for communication (geovisualization).** Significant improvements in map availability and visualization will continue through initiatives such as Google Maps, in-vehicle navigation and other cartographic improvements.
- **Interactive GIS via the Internet.** The use of GIS over the Internet is increasing exponentially, and the ability of integrated mapping functionality through “hotlinking” is greatly aiding the dissemination of spatially based data and information.
- **Data ownership and acquisition.** Although this may be a problem area in terms of data ownership and costs, undoubtedly the availability of mapping is increasing exponentially.

- **Data gathering instrumentation.** A proliferation of spatial data will occur through both a wider choice of handheld GPS-based devices and through more complex satellite technologies, as well as through fixed and mobile marine sonar technology.
- **Advances in geostatistics and data spatial modelling.** Further major developments in GIS applications to fisheries and aquaculture will come in the coupling (or integration) of geostatistics and spatial models to GIS functionality.
- **Mobile GIS delivery.** A host of developments will continue that combine to produce computing environments where most GIS tasks can be accomplished “on the run” or away from a desk. This is in terms of both the portability of the technology and the previously mentioned optimization of small-screen visualization.
- **Continuing standards improvements for data collection and data transfer.** These developments will continue as a means towards more universal interoperability of all computing systems. However, progress is quite slow because considerations here must operate across a wide range of associated fields.
- **The seamless integration of data sets.** Important advances are being made in developing formats or structures allowing for seamless data set integration or in developing simple algorithms that permit differently structured data sets to be integrated.
- **Accuracy, uncertainty and errors in GIS.** A range of measures are being implemented to ensure that fisheries or aquaculture data, which are often prone to error or uncertainty, can be confidently accepted.

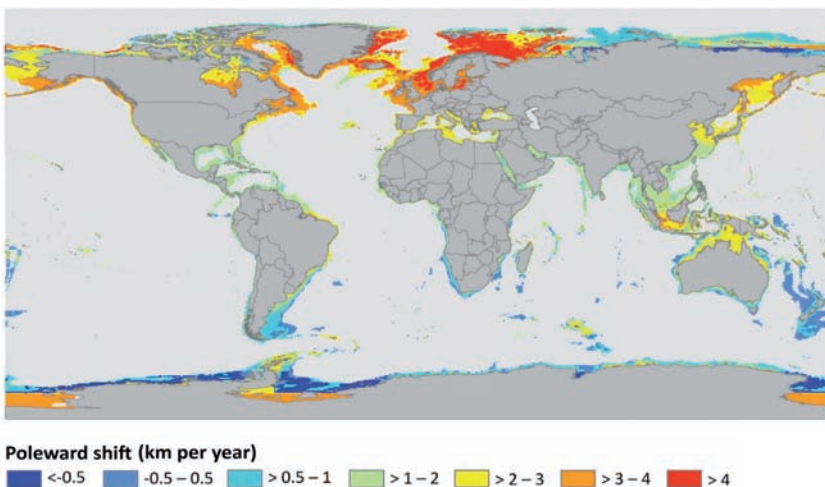
As a result of the previously described drivers, forces are continually driving change with respect to spatial factors relating to the broad subject areas of fisheries and aquaculture. Here, an attempt is made to identify and classify the main themes that are emerging as a result of these changes. It is of course difficult to precisely identify these themes and to speculate on the degree to which a theme can be said to be “emerging”. However, it is likely that in many cases themes will be an extension of current work and that they will form the core of future spatially related work. Discussion of themes that have already been described in Chapters 8, 9 and 10 are omitted, and again emerging themes are simply listed in no particular order.

- **The production of different aquaculture species.** There are currently three lines of debate with respect to the optimum species for aquaculture production: (i) should farmed production concentrate on higher trophic level species with the food resources coming from the sea; or (ii) should production concentrate on lower trophic level herbivorous species, thus reducing energy inputs and losses; or (iii) should consumer food preferences alone determine aquaculture production choices? Whatever thinking prevails, there will be strong spatial implications for production location choices and for future fish marketing, both of which will provide opportunities for GIS modelling and analyses.

- **The potential impacts of aquaculture on the environment.** Although an older issue, this subject will become increasingly important as aquaculture continues to expand and intensify, and as the need for environmental controls become more stringent and diverse. It must also be recalled that this is a two-way process, with the environment affecting aquaculture and aquaculture affecting the environment, and both processes can operate over wide spatial areas. The technical paper gives details on the range of environmental disturbances that may occur, the means that farmers can use to reduce environmental impacts, and some ways in which GIS can be utilized in helping to achieve this impact reduction.
- **Management of freshwater resources for aquaculture.** Because of climate change, increases in human population and the consequent need to increase food production, the availability of freshwater in many regions is a rapidly increasing challenge. As water security is a top priority for inland aquaculture, planning for the constant availability of this is a task that GIS can assist in, especially with respect to the modelling associated with spatial differentiation in water supply availability. If aquaculture gradually adopts methods that use water recirculation systems, then this too will have repercussions on alternative location preferences for fish farming.
- **Offshore mariculture.** Recent technological developments are now allowing mariculture to be successfully accomplished in what were previously relatively hostile environments for aquaculture, i.e. open coastal waters. The opportunities for production expansion here are very large indeed, but in view of the number of human, biological, physical and meteorological variables involved, locations will need to be carefully optimized through marine spatial planning and GIS-based analyses (Kapetsky, Aguilar-Manjarrez and Jenness, 2013).
- **Growth of inland fisheries and recreational angling.** Inland fisheries and recreational angling show a number of similar characteristics. They are both extremely widespread activities, often practised in relatively remote areas, usually practised on a small-scale, have relatively limited management constraints, and little reliable data are available on the scale of the activity in terms of fish catches and production uses. However, it is reliably surmised that the activities are increasing and fish restocking is more frequently necessary. Given the very obvious spatial components associated with these activities, it is clear that the future opportunities (and indeed necessity) for spatially based management are hugely significant.
- **The consolidation of the fishing and aquaculture industries.** Although there are some moves towards a reduction in scale of both capture fisheries and aquaculture activities, when examined holistically both sectors are witnessing production consolidation and a growth in enterprise size. This is largely being achieved through various horizontal and vertical integration movements designed to achieve economies of scale. Clearly, these movements will have a strong influence on the spatial dispersal of various sectors of both the fishery and aquaculture industries, and the direction of these movements may best be optimized through spatial analyses.

- **Rebuilding depleted marine and freshwater stocks.** Although freshwaters in many regions have a long tradition of being restocked when necessary, this has not been common in marine waters because of factors relative to costs, uncertainty, the scale required and the difficulty of measuring success. However, as marine stocks especially become increasingly endangered, the incentive towards restocking grows. But the spatial complexities of doing this, and in calculating the necessary carrying capacity of waters concerned, may be extremely complex and indeed are becoming more so with increasing ecosystem changes and with the effects of climate change. For example, Pereira *et al.* (2010) predict latitudinal range shift for demersal marine species of up to 4 km per year from 2005 to 2050 (Figure 11), and that pelagic species will migrate even faster because of higher surface water temperatures. Success for restocking might only be achieved through the fairly sophisticated use of both remote sensing and GIS techniques.
- **The recording of fishing vessel activities.** In an era when both overfishing and illegal fishing are commonplace, there are a number of reasons why fishing vessel activity might be recorded. The technical paper describes a variety of reasons and methods for collecting fishing activity data. Thus, as well as basic vessel monitoring systems that rely on satellite recordings of vessel locations, there are now moves in many countries to instigate fisheries electronic logbooks. These can provide detailed data on catches by species, fish landings, fishing methods, locations of activities, etc., and these data represent very useful inputs to GIS for both research and management purposes.

FIGURE 11
 Predicted latitudinal shift of demersal marine organisms between 2005 and 2050 as caused by climate change (excluding areas > 2000 m in depth)



Source: Pereira *et al.* (2010).

- **Evaluating fisheries management practices, including sustainability.** Over the past half century, the management of capture fisheries has become an increasingly complex subject. This has partly arisen because management has too often been unsuccessful, with many stocks continuing to decline, and thus there has been the need to incorporate ever more management measures. Because these measures almost all involve spatial considerations, then in an electronic era it is unsurprising that GIS has materialized as a potentially useful tool. For the present, most evaluation of management practices occurs in the form of government directed research, but increasingly the use of GIS is permeating down so that it becomes a useful tool at fishing company level, or even at individual vessel level. In many cases, it is sustainability issues that are promoting these more sophisticated management practices.
- **Threats and changes to marine and freshwater ecosystems.** Continuing human population growth allied to rising resource consumption is having a negative impact on a range of aquatic ecosystems. The main threats to such ecosystems include: (i) vast accumulation of plastic within large oceanic gyres; (ii) severe oxygen depletion in assorted aquatic systems and areas; (iii) an increasing range of biosecurity problems; (iv) climate change and the threat of rising sea levels, increased storminess, marine acidification, species home-range shifts, and marine invasions of exotic species; (v) various forms of pollution; and (vi) flow modifications in rivers. All of these perturbations have a strong spatial component, thus allowing for GIS-based investigations or management.
- **The standardization of habitat (and other) classifications.** Because the world in which fisheries or aquaculture functions is so complex in terms of social, economic and environmental considerations, then in order to research any specific theme or issue the researcher is obliged to utilize simplification through the classification of virtually all data held. In order to give any classification used more utility, there is a move towards the standardization of data descriptions and classification classes. Two examples of standardization are in the categorization of marine habitats and of bottom sediment classes. There are many debates in progress aiming to agree to international data standardization, and when agreements are reached then the usefulness of GIS analyses will be greatly increased.
- **Working at variable scales and resolutions.** Data on aquatic environments are now being collected and accumulated at an accelerating rate; the tendency is for such data to have a greater range of resolution, with more emphasis being given to data at a smaller resolution, i.e. because data can be usefully converted from small to large resolution, but not in the other direction. With improvements in resolution, which is also associated with data collection from a wider range of parameters, the field opens up for a far broader range of potential studies and therefore of GIS-based analyses. These developments will be especially important to increasing EAF and EAA work that must consider parameters whose data collection scales are likely to be highly variable.

- **Studies of temporal change in fisheries and aquaculture thematic areas.** It seems highly likely that considerable efforts will be made in the immediate future to study temporal changes with respect to both fishery and aquaculture themes. This becomes increasingly possible now that data sets covering comparatively long time periods are accumulating. There is much value to be had from studies examining changes through time or that can assess the validity of some of the early GIS and/or remote sensing work in terms of its methodology and outcomes.