4. Implementation of GIS

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Now that background information has been given on the potential usefulness of GIS in fisheries or aquaculture research or management and on the potential hardware, software and data requirements, readers should be in a position to assess whether this IT system is likely to suit their future needs. If the decision is made to further investigate GIS capability, then the means of doing this is explained in this chapter. A full discussion is given here on the range of implementation decisions that are essential to the successful functioning of any GIS. It is important to mention that in the past many organizations made unsuccessful attempts at implementing GIS, and research has concluded that the lack of success was due to failures to:

- identify and involve all users when considering needs for the GIS;
- match GIS needs with the right hardware and software;
- identify the full range and extent of capital and operating costs;
- conduct a pilot study that would ascertain full operational requirements;
- operate the GIS within the right department, one that has geographical skills; and
- provide sufficient training, background support and hands-on GIS experience.

In addition, the adoption of a new and possibly complex technology such as GIS might have repercussions on existing working practices, including changes to work priorities, workflow patterns, product outputs, training needs, budgetary considerations, management priorities, and work and space allocation. Implementation of IT technology such as GIS needs to follow a recognized, though variable, set of procedures that are well described in sources listed in the full technical paper and these procedures will form the basis for the rest of this chapter.

Initiation of GIS as a valuable fisheries or aquaculture research or management tool is likely to come from an external source, perhaps a trade magazine, an exhibition stand or conference attendance, through networking with others in fisheries research or management, or perhaps as a recommendation from a consultant or a GIS software house. Whatever the source, there is likely to have been an individual within the organization who has perceived the likely benefits that GIS can provide and who has taken steps to recommend this. This person is frequently referred to as a "champion" because he or she is keen to "champion" a worthy cause – in this case GIS. It is clear that the champion has already recognized the full potential of GIS; he or she is likely to have discussed it with colleagues, and then the ideas would have been made known to those at decision-making levels. It may appear to readers that this is not the GIS initiation process that has occurred within their organization, i.e. they may simply have

had GIS use imposed upon them. This may not be a desirable situation, though it depends on how the imposition was made. It is vital that the introduction of new technology is undertaken with care, i.e. as it will inevitably involve disruptive changes in working practices. In order to best facilitate working practice changes, management should identify a suitable "champion", i.e. the person to nurture the future development of GIS within the organization.

Once the possibility of using GIS has been "championed", the feasibility of GIS adoption needs to be determined, i.e. is the use of GIS likely to be a sensible route to take. This feasibility will vary greatly between organizations according to such factors as needs, familiarity with IT, management skills and other resources available, plus the extent to which GIS will aid in meeting the organization's objectives. Four useful ways of conducting a feasibility study are through: (i) A GIS committee that may have been established precisely to work out the viability of GIS; (ii) questionnaires or interviews to determine the views of relevant people within an organization on the likely value of GIS; (iii) holding workshops or demonstrations that explore the idea of GIS adoption; and (iv) through use of an external consultant who can ascertain the likely needs and affordability of a GIS. Any combination of these approaches might be taken, and it would be useful for all GIS participants to update their familiarity with relevant aspects of GIS. The technical paper provides a list of questions that need to be asked in any feasibility study, and, based upon the answers, it might be recommended to proceed further with GIS adoption; or perhaps to seek alternative arrangements such as contracting out work to a specialist GIS contractor; or to share GIS work with another sympathetic co-user; or to abandon GIS plans for the present.

A final but important exploratory step to take on the route to possible GIS adoption is that of a cost–benefit analysis. This involves an exercise that attempts to balance the total costs of acquiring the system against the benefits that will be gained from deploying a GIS, that is, do the advantages of adoption outweigh the disadvantages? It is important to mention that costs and/or benefits may not be solely calculated in financial terms; some are likely to be measured in more nebulous values that largely relate to gaining information for better decision-making. In fact, with respect to any GIS implementation decision, it is likely that intangible costs or benefits will be more important than tangible, making the adoption decision possibly more difficult. Other problems are that benefits of GIS may take a long time to accrue, so initial costs will far outweigh benefits, and that cost–benefit ratios vary considerably between different GIS projects. Examples of costs and benefits are provided in the technical paper. It is suggested that the actual analysis should be carried out by an external organization or consultant, if only because these agents will be best placed to explain the results to senior management.

If it is agreed that GIS adoption is feasible and that likely benefits outweigh likely costs, then GIS implementation can move to a system design stage. The outcome of this will be a "GIS system design" document that provides answers to the feasibility questions and that demonstrates the conceptual design of the

complete GIS, including the likely hardware, software, system architecture, personnel needs, main data sources and management requirements. This is, therefore, a comprehensive guide to management showing that all implementation considerations have been covered. Compilation of this document is likely to be a major task, one that is likely to involve external advice and contributions. Only in cases where it is considered best to develop GIS capability as a slow incremental growth from an existing small-scale facility will the system design document be minimal in scope and content. Additional guidance is given in the technical paper to system design, especially to the requisite sectional headings for such a document.

If the decision is made to proceed with GIS implementation, there are frequently standard procurement and installation procedures that organizations are obliged to follow. In practice, it is often the case that an implementation plan is drawn up as part of the "system design" document described above, though additional information might now be considered, including any timing for the installation plus other organizational matters such as support and training needs, system maintenance and security arrangements. The implementation plan might be devised by a "GIS committee", which might be in place to oversee overall GIS developments, and which might expect advice from management and from external consultants. The technical paper provides examples of implementation plans that could be useful for supplying content headings, plus a checklist of important issues when actually implementing a GIS and a guide to the varying staff roles of groups or individuals who might be involved. The implementation itself may follow one of four main models:

- An "in-house" development using a slow-growth approach whereby the GIS is incrementally built up over an extended period, allowing easy adaptations to occur.
- An "in-house" development using a "big-bang" approach whereby the GIS is developed in a non-working environment, with the date announced beforehand indicating when the GIS will become operational and thus ready to use.
- All GIS work is contracted out, which is often a good policy if the amount of future GIS work is thought to be minimal.
- The purchase of a "turnkey system" whereby all work on developing the system is carried out by an external GIS supplier, and the complete tested system is delivered for immediate use at a preselected date.

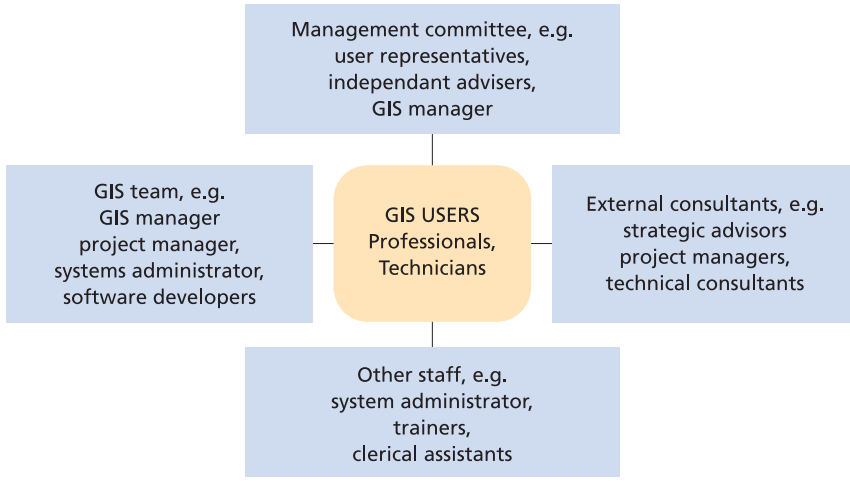
The last of these implementation models might require a tendering process for which there are probably official organizational policies and procedures. From the beginning, it will be important that the implementation has management approval and that it will be in the hands of a competent individual. Any implementation plan will need to be prepared for flexibility in the sense that many changes are likely to occur during the development and adoption period. During the possible long and difficult implementation process, personnel involved will need to be aware that there are likely to be effects on the organization, some of which may

be profound, including institutional restructuring, job insecurity, rationalization and possible redundancies.

Once the GIS has been implemented (installed), there are a number of immediate concerns and procedures that must be in place to ensure that the system will work proficiently. Initially, it is useful to subject the system to a few small "pilot" projects designed to test a range of system functionality. These tests should include not only GIS output but also items of hardware, data access, formatting and structure, and that staff are aware of their roles. This work should be overseen by the GIS committee and at least some members of management. It is almost certain that this pilot work will reveal challenges that need addressing, and a good implementation plan will have allowed for this, probably under "contingency planning". Because it is likely that the first few months of GIS operation will produce many technical problems and/or adjustments, it is essential that reliable contacts are available for a range of possible emergencies or system failures.

It is impossible to conceive that any GIS work will be successful without enthusiastic support from either the GIS champion and at least someone at management level. Longley *et al.* (2005) identify the following management support areas that are critical to successful GIS outcomes: (i) customer support in terms of both "upstream" or "downstream" GIS work; (ii) operations support in terms of system administration, maintenance, security, technology acquisitions, etc.; (iii) data management support to ensure that access is available to the best data possible; (iv) applications development and support to ensure that future software needs are enabled; (v) project management to oversee all important decisions with

FIGURE 4
Varying staff roles of groups who might be involved in GIS implementation



Note: Figure 4 could apply to most types of GIS adoption approach, although only a large organization is likely to have all of these groups.

respect to GIS progress; and (vi) human resources support to maintain harmonious working relationships among people having a wide range of competencies and experience. Figure 4 illustrates the wide range of staff both within and external to the organization who might be involved in the adoption of GIS.

In a more direct or specific sense, there are a number of other supervisory tasks that are of major importance and that are most likely to be performed by the "GIS champion". These comprise:

- **Working patterns and task allocation.** Where a fisheries or aquaculture GIS is operating at a small-scale, with perhaps only one or two people, there are rarely work allocation decisions because it is likely any worker will be in a position to master most tasks or to come to an agreement on task allocation according to skills, time availability, etc. In larger GIS groupings, it may be essential to have a leader who is reasonably multifunctional, but who also manages workflow, liaises with customers, supervises data processing and writes-up reports. Other workers would typically take on specific roles. Maintaining a constant workflow is often a difficult task, one that takes on significant planning, especially because it must be combined with numerous unknown contingencies, e.g. hardware breakdown, staff sickness, emergency work or staff redeployment. It is common to build in a 25 percent time contingency when estimating project timing.
- **System safekeeping and security.** Data security is a vital ingredient in most computing environments, and the costs or consequences of a security breakdown can be large in terms of data losses, time wasted, leakages of information, and in monetary terms. Causes of problems include electrical failures, insufficient data back-up, deliberate illegal activities, unintentional data deletions and system operational faults. To safeguard the system, measures should be put into place, such as regular password changes, use of back-up power supplies, the regular back-up of data and files, and perhaps limited access to certain files.
- **System maintenance.** Like most other practical systems, GIS needs to be maintained in optimum working order, and system maintenance refers to sustaining the ability of the system to function as required. It is normal for any organization to build system maintenance routines into the GIS work schedule. The approach to maintenance may be reactive, whereby the GIS team knows exactly what to do or how to cope with any system emergency, or it may be proactive, where procedures are in place allowing for regular servicing or maintenance of equipment plus the provision of software upgrades. Data are also in constant need of maintenance in terms of their quality, timeliness, seeking additional sources and metadata upkeep, plus maintaining data storage capacity.
- **Coping with organizational change.** The introduction of GIS will almost inevitably bring about change within the organization, and Heywood, Cornelius and Carver (2006) report the following changes that may occur following GIS introduction: (i) changes in job descriptions as employees are

obliged to take on different roles; (ii) levels of responsibility will be affected, which may negatively influence some employees; (iii) the functioning of GIS often positively acts to break down barriers within an organization; (iv) GIS can foster increased contacts with the wider external IT community; (v) relationships between groups or departments within an organization may strengthen as GIS takes on an expanded role; and (vi) if GIS really "takes off", then sometimes the inevitable internal restructuring can have positive or negative repercussions. The technical paper sets out principles for introducing new technology into an organization.

With respect to the discussion on GIS implementation, the stage is now reached where GIS may have been adopted, is fully installed and is able to function as required. But the account cannot finish here because the GIS system must be expected to continue to function into the indefinite future. In order that this happens, attention now turns to the range of support and training that is available and necessary. Support and training is examined in terms of its needs, its main sources, the mediums for delivery and the range available. The concern here is mostly with GIS-related support and training, but it may also be important to keep up to date with major developments occurring in the fisheries or aquaculture fields. The technical paper gives numerous leads to the wide variety of support and training that are available.

Instruction and exercise manuals are the first major source of support. Most manuals are originally supplied as hard copy or as CD–ROMs, though they can often be downloaded from software houses or other sources. Manuals are aimed at providing both the instructions on the use of GIS and for resolving problems that users might experience while attempting specific functions. Under this heading, four main categories of manuals are identified:

- GIS hardware and software manuals that provide instructions on how the hardware or software can be used. Sometimes this information is available via a "Help" facility within the software, or online instructions are given from the providers showing where help is available.
- Some GIS software providers have developed a range of "illustrative manuals" that provide case studies on a range of ways in which their software can be used. Sometimes similar exemplar material is available from Internet sites that specialize in particular thematic areas.
- More specifically, some GIS software houses provide exercise or tutorial manuals allowing users to work through exercises on various areas of GIS functionality or analysis.
- A few GIS manuals and exercise manuals have appeared specifically covering marine-, fisheries- or aquaculture-related topics. Examples of "how to use GIS software" for fisheries or aquaculture work are given, i.e. rather than more general information "about" fisheries or aquaculture GIS.

A second major source of support is "hands-on" practical training. Degree-level courses are not discussed here because there are now a large number of full- and part-time courses available and they can readily be found by using Web-based searches. With the boom in GIS over the last two decades, the range of hands-on

courses has greatly increased, such that all aspects of practical GIS are covered. However, most of these courses relate to the general use of GIS, i.e. rather than being fisheries or aquaculture specific, for which there is still insufficient general demand. When enrolling on training courses, participants need to be careful of the level at which they are pitched. Practical training is available either on a face-to-face basis or by "distance learning", which usually involves online tuition. Face-to-face provision is normally only available in major cities, so courses are often "residential" (i.e. the attendee on a training course may have to stay for a period of time in a city and thus incur accommodation costs). These courses have an advantage in that a high degree of individual attention may be obtained, though they may have the disadvantages of being both expensive and the fact that too much knowledge is imparted over a short time, making the retention of material difficult.

As well as instruction and training manuals, there is a range of other published material, which makes up the third source of support. This material may be available in either hard copy or digital formats, and it can be briefly described under three headings:

- **General GIS books.** Unlike the situation two decades ago when only about a dozen GIS books were available, today such books are numbered in the thousands, and the subject matter of these books has moved from general GIS towards being topic specific in terms of application or methodological areas. A range of introductory texts is recommended in the technical paper and all GIS users should be generally familiar with this level of content.
- **Fisheries or aquaculture GIS publications.** These are far more specialized publications, but they are very relevant to workers in these areas. The technical paper lists all 20 of such publications published during the last decade.
- **Journals and trade magazines.** These periodicals originate from a variety of sources, though most are produced by academic publishers or software houses. Unfortunately, many are rather technical, as they are often aimed at promoting new progress in GIS development. There are no specific "fisheries and/or aquaculture GIS" journals or magazines, though a list is given of major magazines in which GIS information pertaining to aquaculture may be published.

A fourth route to support and training can be attained through attending conferences, workshops or exhibitions. This is a more verbal or visual method of support, one that includes a great deal of flexibility and thus attractive for many GIS participants. Unfortunately, events specific to fisheries and/or aquaculture GIS are rare, but there are many general GIS events that can prove useful, though most of these only take place in developed countries. Conferences, workshops and exhibitions all allow opportunities for networking and thus the exchange of knowledge and ideas. The technical paper provides information on Web sites that describe a range of GIS conferences, and details are provided on a major series of fisheries and aquaculture symposia organized by the Fishery-Aquatic GIS Research Group, based in Saitama, Japan.

The final source of support and training concerns the various persons or groups who specifically aim to offer advice either freely or on a paid basis. This miscellaneous group comprises: (i) consultancy services, where expert advice can be purchased on a range of GIS-based issues, though these would rarely be directly related to fisheries and/or aquaculture; (ii) user support groups who operate freely over the Internet and who specialize either in discussions in groups or forums on particular subject areas or who specialize in particular GIS software; (iii) software houses that might offer a range of support, including time-limited advice that accompanies many software licences, sponsored user groups, and various training materials that they publish; (iv) professional organizations that operate in many countries and that aim to promote GIS via conferences, publications and reports, consultancy and advice to governments. Joining such a professional body can be advantageous from career, influence and participation viewpoints.