

7. Conclusions and recommendations

There is now worldwide recognition that for their long-term sustainability, fisheries need to be managed as part of a wider ecosystem. This review has outlined how various moves towards implementation of EAF are being made and presents a number of cases studies.

This review primarily attempted to demonstrate how GIS can facilitate implementation of EAF, considering the key steps required for EAF planning and implementation and the importance of the spatial features of the fishery socio-ecological systems for successful EAF implementation. Knowledge of the distribution of key ecosystem components, such as fish, benthos, fishers and markets, as well as knowledge of key ecosystem processes and attributes, such as tides, currents, level of pollutants, spawning, migrations and fishing, are fundamental for EAF application. Also important is spatial information on social, economic and governance aspects such as geography of subsistence fishing, of legal access rights and market prices. For the relevant ecosystem attributes, components and processes, GIS can deliver maps but it can also perform additional functions such as data editing, manipulation, modelling and analyses. It is the final analytical function that gives GIS the vast potential to examine fisheries and EAF-related problems.

Despite its obvious advantages, utilization of GIS in fisheries management, and in particular in support of EAF implementation, is only at its infancy. EAF itself is at an early stage of application and it is important that GIS developments within institutions be closely linked to the information requirements in support of fisheries management planning and its implementation. A GIS team could provide useful inputs to the decision-making process, for example, in determining ecosystem boundaries, in mapping relevant stakeholder groups and in selecting indicators and reference points.

It seems that most matters at the core of EAF have a spatial component and thus will be susceptible to being incorporated into GIS analyses. In Section 5, examples were given of potential analyses that can be handled by GIS. For any specific analysis, a spatial boundary needs to be established, including a detailed consideration as to the spatial and temporal resolution for prospective analyses. Then much of the GIS-based work will involve modelling scenarios. Work needs to be done on devising or obtaining creditable models, to populate models with suitable data and algorithms, and to evaluate the outcome or outputs of modelling. Over and above these more direct GIS-based considerations, there needs to be intensive work on forging cooperation and working relationships with other teams of people who might, for instance, be working on projects in neighbouring thematic or geographic areas, or between different levels of governance, or among varied but interested stakeholder groups. To this end, the FAO Fisheries and Aquaculture Department is committed to developing synergies and opportunities between the spatial components of the EAF and the Ecosystem Approach to Aquaculture (EAA) in terms of sharing data and developing tools, methodologies and guidelines (see Aguilar-Manjarrez, *et al.*, in preparation). There are also practical matters concerning centres of GIS work, training, software preferences, financing of projects, GIS team composition, all of which can make a huge difference to project success. In order not to keep “reinventing the wheel”, avenues of information dissemination, reporting and communications need to be clearly established at the commencement of any project.

The following recommendations may be useful if GIS is to successfully be adopted as a key tool for EAF planning and implementation (the costs involved are not being considered but the authors *recognize* that projects will need to be very cognisant of them). The recommendations, not in any specific order, are shown in Box 7.1. Although not complete, the list indicates the major issues to be considered before embarking upon work with a GIS.

BOX 7.1

Recommendations to aid the adoption of GIS for EAF

- Define the spatio-temporal boundaries to any specific GIS task and define overall project objectives.
- Consider carefully the time and spatial resolution that is needed for each project component.
- Carefully explore the various software possibilities before finally deciding upon one. Remember that work will be done in cooperation with other partners.
- Establish data needs and sources, and identify any barriers to project implementation.
- Seek practical, working partners both within your physical project area and with neighbouring management areas.
- Clearly ascertain the principal stakeholders in the total fisheries ecosystem and establish a good working relationship with them.
- Consider carefully the “scale” of the GIS in terms of personnel and computing needs.
- Consider the various expertise and training needed for each project.
- Make certain that most members of the GIS team have a solid grounding in fishery ecology in its broadest sense.
- Build the capacity to undertake GIS carefully by seeking expert advice, for instance, and by exploring in-depth the GIS/EAF support that is now available.
- Look carefully at the GIS work being done elsewhere and learn from others.
- Start off with fairly simple projects, e.g. a small area and limited thematic coverage.
- Have frequent project meetings and make sure that everyone is aware of what is happening and can work well as a group member.
- Make strict time deadlines for project components.
- If possible, make sure that the project leader is competent and lines of authority are clear.
- Recognize the limitations of the project outputs and the fact that there may be considerable challenges to overcome before achieving success.
- Broadcast your successes as widely as possible. Are you actually saving/sustaining the fishery?

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Glossary

Abiotic	Non-living (resource) ^a .
Abundance	Degree of plentifulness. The total number or biomass of fish in a population or on a fishing ground. Can be measured in absolute or relative terms ^a .
Access rights	Permission from the holder to take part in a fishery (limited entry) or to fish in a particular location (territorial use rights or “TURFs”) ^b .
Adaptive management	A management process involving step-wise evolution of a flexible management system in response to feedback information actively collected to check or test its performance (in biological, social and economic terms). It may involve deliberate intervention to test the fishery system’s response ^a .
Bathymetry	The science of measuring and charting the depths of waterbodies to determine the topography of a lake bed or sea floor ^c .
Biodiversity	The variability among living organisms from all sources including, <i>inter alia</i> , terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems. Diversity indices are measures of richness (the number of species in a system); and to some extent, evenness (variances of species’ local abundance). They are, therefore, indifferent to species substitutions, which, however, may reflect ecosystem stresses (such as those due to high fishing intensity) ^d .
Biotic	Live and living (organisms) ^a .
Biotope	An area or habitat of a particular type, defined by the organisms (plants, animals, microorganisms) that typically inhabit it, e.g. coral reef, mangrove and deep sea hot vents or on a smaller scale a microhabitat ^a .
Bycatch	Part of a catch of a fishing unit taken incidentally in addition to the target species towards which fishing effort is directed. Some or all of it may be returned to the sea as discards, usually dead or dying ^a .

Catch	To undertake any activity that results in taking fish (<i>sensu lato</i>) out of their environment dead or alive. To bring fish on board a vessel dead or alive. The total number (or weight) of fish caught by fishing operations. Catch includes all fish killed by the act of fishing, not just those landed. The catch is usually expressed in terms of wet weight (or round weight). It should refer to the total amount caught but is sometime erroneously used to refer only to the amount landed. The catches that are not landed are called discards ^a .
Code of Conduct for Responsible Fisheries	The code, formulated by FAO in 1995, sets out internationally agreed Responsible Fisheries principles and international standards of behaviour for sustainable and 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 ^e .
Community	A social group of organisms sharing an environment, normally with shared interests. In human communities, intent, belief, resources, preferences, needs, risks and a number of other conditions may be present and common, affecting the identity of the participants and their degree of cohesiveness ^a .
Conventional fisheries management	The historical approach to fisheries management in which the interaction of the stock of the target species with other components of the ecosystem is not explicitly considered in the management actions ^d .
Cost-benefit analysis	Assessment of the direct or indirect economic and social costs and benefits of a proposed project for the purpose of project or programme selection. The cost-benefit ratio is determined by dividing the projected benefits of the programme by the projected costs. A programme having a high benefit-cost ratio may take priority over others with lower ratios ^a .
Discards	The components of a catch that are thrown back into the habitat after capture. Normally, most of the discards can be assumed not to survive ^d .
Ecoregion	An area of relatively homogeneous species composition, clearly distinct from adjacent systems. The species composition is likely to be determined by the predominance of a small number of ecosystems and/or a distinct suite of oceanographic or topographic features. The dominant biogeographic forcing agents defining an ecoregion vary from location to location but may include isolation, upwelling, nutrient inputs, freshwater influx, temperature regimes, ice regimes, exposure, sediments, currents and bathymetric or coastal complexity ^f .

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 ^d .
Ecosystem approach to fisheries (EAF)	An approach to fisheries management and development that strives to balance diverse societal objectives, by taking into account the knowledge and uncertainties about biotic, abiotic and human components of ecosystems and their interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries. The purpose of EAF is to plan, develop and manage fisheries in a manner that addresses the multiple needs and desires of societies, without jeopardizing the options for future generations to benefit from the full range of goods and services provided by marine ecosystems ^d .
Ecosystem functions	An intrinsic ecosystem characteristic related to the set of conditions and processes whereby an ecosystem maintains its integrity (such as primary productivity, food chain, and biogeochemical cycles). Ecosystem functions include such processes as decomposition, production, nutrient cycling, and fluxes of nutrients and energy ^a .
Ecosystem-based fisheries management	<i>(see Ecosystem approach to fisheries)</i>
Ecosystem-based management	An integrated approach to management that considers the entire ecosystem, including humans. The goal is to maintain an ecosystem in a healthy, productive and resilient condition so that it can provide the services humans want and need. It considers the cumulative impacts of different sectors; emphasizes the protection of ecosystem structure, functioning and key processes; is place-based in focusing on a specific ecosystem and the range of activities affecting it; explicitly accounts for the interconnectedness within systems, recognizing the importance of interactions between many target species or key services and other non-target species; acknowledges interconnectedness among systems; and integrates ecological, social, economic and institutional perspectives, recognizing their strong interdependences ^a .
Ecosystem models	Models that represent a wide range of technological, social, economic and ecological processes affecting the species and their use in the ecosystem (including multispecies and whole ecosystem). They are potentially important tools for providing broad scientific information on the impacts of ecosystem use (e.g. by the fishery) on the main ecosystem components and processes and to take into account changes in the ecosystem other than those caused by fishing, whether of natural or anthropogenic origin, that may be impacting the fishery ^d .

Ecosystem services	The benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services, such as spiritual and cultural benefits; and supporting services, such as nutrient cycling or waste degradation, that maintain the conditions for life on earth ^a .
Enforcement	In fisheries, a series of measures and action to constrain fishers to catch the right quantities and type of fishes as set by fishery laws or other regulations in order to achieve sustainable objectives over a stock and an area. Measures include: completion of fishery logbooks, equipping vessels with VMS, placing observers on board vessels, aerial or at-sea observation of the fishing fleet and inspections. These measures are usually backed up by the law.
Environmental impact assessment (EIA)	A set of activities designed to identify and predict the impacts of a proposed action on the biogeophysical environment and on man's health and well-being, and to interpret and communicate information about the impacts, including mitigation measures, that are likely to eliminate the risks. In many countries, organizations planning new projects are required by law to conduct an EIA. Usually it is carried out by three parties, the developer, the public authorities and the planning authorities.
Essential fish habitat (EFH)	Essential fish habitat can consist of both the water column and the underlying surface (e.g. sea floor) of a particular area. Areas designated as EFHs contain habitat essential to the long-term survival and health of a fishery. Certain properties of the water column such as temperature, nutrients, or salinity are essential to various species. Some species may require certain bottom types such as sandy or rocky bottoms, vegetation such as seagrasses or kelp, or structurally complex coral or oyster reefs. An EFH includes those habitats that support the different life stages of each managed species. A single species may use many different habitats throughout its life to support breeding, spawning, nursery, feeding and protection functions. An EFH encompasses those habitats necessary to ensure healthy fisheries now and in the future ^a .
Fish habitat (see also habitat)	The physical and biological environment in which the fish live, including everything that surrounds and affects their lives, e.g. water quality, bottom, vegetation and associated species (including food supplies) ^a .
Fish population	A group of interbreeding organisms that represents the level of organization at which speciation begins ^a .

Fisheries management	The set of measures affecting a resource and its exploitation with a view to achieving certain objectives, such as the maximization of the production of that resource. Management includes, for example, fishery regulations such as catch quotas or closed seasons. Managers are those who practice management ^a .
Fishing effort	The total amount of fishing activity on the fishing grounds over a given period of time, often expressed for a specific gear type, e.g. number of hours trawled per day, number of hooks set per day or number of hauls of a beach seine per day. Fishing effort would frequently be measured as the product of (i) the total time spent fishing and (ii) the amount of fishing gear of a specific type used on the fishing grounds over a given unit of time. When two or more kinds of gear are used, they must be adjusted to some standard type in order to derive an estimate of total fishing effort ^d .
Fishing fleet	The set of units (vessels) of any discrete type of fishing activity exploiting a specific resource. For example, a fishing fleet may be all the purse-seine vessels in a specific sardine fishery or all the fishers setting nets from the shore in a tropical multispecies fishery ^d .
Fishing vessel	Any vessel, boat, ship or other craft that is equipped and used for fishing or in support of such activity. For management purpose, particularly for monitoring and surveillance, may be considered to include any vessel aiding or assisting one or more vessels at sea in the performance of any activity relating to fishing, including, but not limited to, preparation, supply, storage, refrigeration, transportation or processing (e.g. mother ships) ^a .
Geographic Information Systems (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 they can be displayed and analysed ^c .
Geostatistics	A class of statistics used to analyses and predict the values associated with spatial or spatio-temporal phenomena. Geostatistics provides a means of exploring spatial data and generating continuous surfaces from selected sampled data points ^c .
GIS	<i>(see Geographic information system)</i>
GLM	<i>(see Generalized linear models)</i>
Generalized linear model (GLM)	A modelling process that attempts to accommodate variance heterogeneity and asymmetric, non-normal behaviour by offering a range of distributional types that cover at least the more common mean–variance relationships ^h .

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 United States Department of Defence, the system is used in navigation, mapping, surveying and other applications in which precise positioning is necessary ^c .
GPS	(see <i>Global positioning system</i>)
Governance	The formal and informal arrangements, institutions, and norms which determine how resources or an environment are utilized, how problems and opportunities are evaluated and analysed, what behaviour is deemed acceptable or forbidden, and what rules and sanctions are applied to affect the pattern of resource and environmental use ^a .
Ground truthing	The process of assessing the accuracy or validation of remotely sensed or mathematically calculated data based on data actually measured in the field ^c .
Habitat (see also Fish habitat)	The place where an organism lives or the place one would go to find it. The habitat is the organism's address, and the ecological niche its profession, biologically speaking.
Hardware	The physical equipment in a computer system ^a .
Hatchery	A facility used for the artificial and controlled breeding, hatching and rearing of aquatic organisms, on a commercial or experimental basis, through their early life stages. A hatchery is usually closely associated with a nursery facility where the cultured organisms are grown to the appropriate size before being released to the wild or an ongrowing structure.
Index of abundance	A relative measure of the weight or number of fish in a stock, a segment of stock (e.g. the spawners) or in an area. Often available in time series, the information is collected through scientific surveys or inferred from fishery data ^a .
Indicator	A variable pointer, or index, of the state of a system. Its fluctuation reveals the variations in key elements of a system. The position and trend of the indicator in relation to reference points or values indicate the present state and dynamics of the system. Indicators provide a bridge between objectives and actions ^a .

Integrated management	A continuous process through which decisions are made for the sustainable use, development and protection of areas and resources. Integrated management acknowledges the relationships that exist among different uses and the environments they potentially affect. It is designed to overcome the fragmentation inherent in a sectoral approach, analyses the implications of development and conflicting uses, and promotes linkages and harmonization among various activities ^a .
Landings	Weight of the product landed at a landing site. Landings may be different from the catch (which includes the discards) ^a .
Landsat	A series of United States polar orbiting satellites, first launched in 1972 by NASA, which carry both the multispectral scanner and thematic mapper sensors ⁹ .
Large marine ecosystem	Large area of ocean space of approximately 200 000 km ² or greater, adjacent to the continents in coastal waters, that has distinct bathymetry, hydrography, productivity and trophically dependent populations ^a .
Logbook	A detailed, usually official record of a vessel's fishing activity registered systematically on board the fishing vessel, usually including information on catch and its species composition, the corresponding fishing effort and location. Completion of logbooks may be a compulsory requirement for a fishing licence ^a .
Management measures or regulations	Specific controls applied in the fishery to contribute to achieving the objectives, including some or all of the technical measures (gear regulations, closed areas and time closures), input controls, output controls and user rights ^d .
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 ^c .
Map 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 000th of the same unit on the earth ^c .

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 subpopulation (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 ^d .
Marine spatial planning (MSP)	A process of analysing and allocating parts of 3D 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 ⁱ .
Modelling	The construction of physical, conceptual or mathematical representation of the real world. Models help to show relationships between processes (physical, economic or social) and may be used to predict the effects of changes in, for instance, marine ecosystems ^a .
Monitoring	The collection and analysis of information performed for the purpose of assessment of the progress and success of a management plan. Monitoring is used for the purpose of assessing performance of a management plan or compliance scheme and revising them or to gather experience for future plans ^a .
MPA	(see <i>Marine protected areas</i>)
Non-retained species	(see <i>Discards</i>)
Population dynamics	The part of fishery biology which studies the abundance of biological populations (including fish) and their changes ^a .
Quota	A share of the total allowable catch (TAC) allocated to an operating unit such as a country, a community, a vessel, a company or an individual fisher (individual quota) depending on the system of allocation. Quotas may or may not be transferable, inheritable and tradable. While generally used to allocate total allowable catch, quotas could be used also to allocate fishing effort or biomass ^d .
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 a single 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 or measurement ^c .

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, acoustic sonar and satellite imaging ^c .
Restocking	The release of cultured juveniles into the wild to restore the spawning biomass of severely overfished stocks to levels at which they can once again provide sustainable yields. Restocking requires some level of management to protect the released animals and their progeny until replenishment has occurred ^d .
Retained species	(see <i>Landings</i>)
Satellite imagery (see also Remote sensing)	Imagery acquired from satellites and aircraft, including panchromatic, radar, microwave and multispectral satellite imagery ^c .
Seamounts	A large isolated elevation characteristically of conical form. Seamounts are undersea mountains whose summits lie beneath the ocean surface. They are usually volcanic in origin and are generally defined as having an elevation of greater than 1 000 m from the sea bed ^a .
Spatial patterns	Recognition of regularities in the geographic distribution of natural phenomena or human activities on which the prediction of successive or future events may be based.
Spatial scale	(see <i>Scale</i>)
Species	Group of animals or plants having common characteristics, able to breed together to produce fertile (capable of reproducing) offspring, and maintaining their "separateness" from other groups ^a .
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 ^d .

Stock	<p>A group of individuals of a species occupying a well-defined spatial range independent of other stocks of the same species. Random dispersal and directed migrations due to seasonal or reproductive activity can occur. Such a group can be regarded as an entity for management or assessment purposes. Some species form a single stock (e.g. southern bluefin tuna) while others are composed of several stocks (e.g. albacore tuna in the Pacific Ocean comprises separate northern and southern stocks). The impact of fishing on a species cannot be fully determined without knowledge of the stock structure^d.</p>
Stock assessment	<p>The process of collecting and analysing biological and statistical information to determine the changes in the abundance of fishery stocks in response to fishing, and, to the extent possible, to predict future trends of stock abundance. Stock assessments are based on resource surveys; knowledge of the habitat requirements, life history, and behaviour of the species; the use of environmental indices to determine impacts on stocks; and catch statistics. Stock assessments are used as a basis to assess and specify the present and probable future condition of a fishery^a.</p>
Sustainable development	<p>Development that meets the needs of the present without compromising the ability of future generations to meet their own needs^d.</p>
Target species	<p>Those species that are primarily sought by the fishers in a particular fishery. The subject of directed fishing effort in a fishery. There may be primary as well as secondary target species^d.</p>
Territorial waters	<p>The area beyond the tidal baseline of the open coasts of a country over which that country exercises full control except for innocent passage of foreign vessels. Set at a maximum of 12 nautical miles in breadth by the 1982 Law of the Sea Convention, its width depends on countries^a.</p>
Total allowable catch (TAC)	<p>Total amount of resource allowed to be taken in a specified period (usually a one-year period) for a specified area, as defined in the management plan. TAC may be allocated to the stakeholders in the form of quotas as specific quantities or proportions^d.</p>
Vector	<p>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^c.</p>

Vessel monitoring system (VMS)	A part of modern monitoring, control and surveillance systems (MCS) the VMS is a vessel tracking system (usually satellite-based) which provides management authorities with accurate information on a fishing vessel's position, course and speed at time intervals. Detail of VMS approved equipment and operational use will vary with the requirements of the nation of the vessel's registry and the regional or national water in which the vessel is operating ^a .
Vulnerable habitats	(see <i>Vulnerable marine ecosystems</i>)
Vulnerable marine ecosystems (VME)	Marine areas where a population, community or habitat will experience substantial alteration from short-term or chronic disturbance, and will require some time to recover after a disturbance. The vulnerabilities of populations, communities and habitats must be assessed relative to specific threats. Some features, particularly ones that are physically fragile or inherently rare, may be vulnerable to most forms of disturbance, but the vulnerability of some populations, communities and habitats may vary greatly depending on the type of fishing gear used or the kind of disturbance experienced ¹¹ .
Zoning	Dividing an area in zones or sections with different characteristics, or reserved for different purposes or uses, or conditions of use such as no-take zones or reserves (see MPAs), biodiversity corridors, non-trawling areas and areas for exclusive use by small-scale fisheries or aquaculture. Ocean zoning is an element of marine spatial planning.

^a From or adapted from FAO Fisheries and Aquaculture Department Glossary. www.fao.org/fi/glossary/default.asp

^b From or adapted from Cochrane, K.L. (ed.). 2002. *A fishery manager's guidebook. Management measures and their application*. FAO Fisheries Technical Paper 424. Rome. 231 pp.

^c From or adapted from the ESRI GIS Dictionary. <http://support.esri.com/index.cfm?fa=knowledgebase.gisDictionary.gateway>

^d From or adapted from FAO. 2003. *Fisheries management. 2. The ecosystem approach to fisheries*. FAO Technical Guidelines for Responsible Fisheries No. 4, Suppl. 2. 112 pp.

^e From or adapted from FAO Fisheries and Aquaculture Department Aquaculture Glossary. www.fao.org/fi/glossary/aquaculture/default.asp

^f From or adapted from Spalding, M.D., Fox, H.E., Allen, G.R., Davidson, N., Ferdaña, Z.A., Finlayson, M., Halpern, B.S., Jorge, M.A., Lombana, A., Lourie, S.A., Martin, K.D., Mcmanus, E., Molnar, J., Recchia, C.A. & Robertson, J. 2007. Marine ecoregions of the world: A bioregionalization of coastal and shelf areas. *Bioscience*, 57(7): 573–583.

^g From or adapted from Habitat Protection Division of NOAA National Marine Fisheries Service (NMFS), Office of Habitat Conservation. www.nmfs.noaa.gov/habitat/habitatprotection/efh/index_a.htm

^h From or adapted from Venables, W.N. & Dichmont, C.M. 2004. GLMs, GAMs and GLMMs: an overview of theory for applications in fisheries research. *Fisheries Research*, 70: 319–337.

ⁱ From or adapted from Meaden, G.J. & Do Chi, T. 1996. *Geographical information systems: applications to marine fisheries*. FAO Fisheries Technical Paper 356. Rome. 335 pp.

^j From or adapted from Ehler, C. & Douvère, F. 2007. *Visions for a Sea Change*. Report of the First International Workshop on Marine Spatial Planning. Intergovernmental Oceanographic Commission and Man and the Biosphere Programme. IOC Manual and Guides No. 48. IOCAM Dossier (pdf, 3.01 MB) No. 4. Paris, UNESCO.

^k Adapted from FAO. 2009. *Report of the Technical Consultation on International Guidelines for the Management of Deep-sea Fisheries in the High Seas, Rome, 4–8 February and 25–29 August 2008*. FAO Fisheries and Aquaculture Report 881. Rome. 86 pp.

Annex

Major fisheries and marine data providers on the Internet

FISHERIES DATA¹

Organization	Description and Web site URL
Alaska Fisheries Science Center	Fisheries data for the Alaska marine areas www.afsc.noaa.gov/databases.htm
Australian Government	Various fishery datasets www.daff.gov.au/fisheries
CEFAS – Centre for Environment, Fisheries and Aquaculture Science, United Kingdom	A wide range of fisheries for mainly UK waters www.cefasc.co.uk/products-and-services/data-and-technology/fisheries-management-systems.aspx
CEPHBASE	Extensive database on cephalopods www.cephbase.utmb.edu/
Coastal and Ocean Information Network Atlantic (COINAtlantic)	Metadata records covering Atlantic Canada http://coinatlantic.ca/
CCAMLR – Commission for the Conservation of Antarctic Marine Living Resources	Fisheries data for the Antarctic region www.ccamlr.org/pu/E/sc/dat/intro.htm
European Commission (Eurostat)	Comprehensive Fisheries data http://epp.eurostat.ec.europa.eu/portal/page/portal/fisheries/introduction
European Union (FIDES)	A “one stop” shop that automates the management of fishery data http://ec.europa.eu/idabc/en/document/2254/5926
FAO, Rome	Statistical data available from FAO Fisheries and Aquaculture Department www.fao.org/fishery/statistics/en
FishBase	www.fishbase.org/home.htm A global information system on fishes
GISFish – FAO, Rome	A “one stop” site from which to obtain the global experience on Geographic Information Systems (GIS), Remote Sensing and Mapping as applied to Fisheries and Aquaculture. www.fao.org/fishery/gisfish/index.jsp
ICCAT – International Commission for the Conservation of Atlantic Tuna	Fishery statistics for all fisheries in the Atlantic www.iccat.int/en/
ICES – International Council for Exploration of the Seas	A range of fisheries data covering the North Atlantic www.ices.dk/datacentre/index.asp
INTUTE	Portal to detailed archives including marine biology www.intute.ac.uk/cgi-bin/browse.pl?id=117967
Marine Life Information Network for Britain and Ireland	Marine environmental data www.marlin.ac.uk/marinedata.php
National Biological Information Infrastructure	Extensive biological information www.nbio.gov/portal/server.pt
National Oceanographic Data Center of NOAA	Access to indexing and abstracting databases covering a wide range of fisheries related topics www.lib.noaa.gov/researchtools/journals/databases.html
NOAA Fisheries – Office of Science and Technology	Fisheries statistics for USA www.st.nmfs.noaa.gov/st1/index.html
Northeast Fisheries Science Center	List of worldwide fisheries databases www.nefsc.noaa.gov/nefsclibrary/dbs.html
NAFO – Northwest Atlantic Fisheries Organization	Supplies data on fisheries catches and landing for 12 North Atlantic countries www.nafo.int/fisheries/frames/fishery.html
United States Geological Survey (USGS) – Fisheries Data Center	List of fisheries data servers in the USA www.umesc.usgs.gov/data_library/fisheries/fish_page.html
Woods Hole Institute, United States of America	Library search facilities for databases on fisheries www.mblwhoilibrary.org/databases/index.php?search=fisheries
WRI – World Resources Institute	Searchable database on coastal and marine ecosystems http://earthtrends.wri.org/searchable_db/index.php?theme=1

¹ All Internet addresses correct as of 14 October 2009.

MARINE DATA	
Organization	Description and Web site URL
APL Ocean Remote Sensing	Wide range of satellite data http://fermi.jhuapl.edu/
Australian Government – Bureau of Meteorology	Meteorological and marine data for Australia and Antarctica www.bom.gov.au/
Australian Government – Department of the Environment, Water, Heritage and Arts	Marine data products for Australia www.environment.gov.au/erin/index.html
Australian Ocean Data Centre	Marine data from a multi-agency distributed data system www.aodc.gov.au/
Baltic Sea Region GIS	Regional datasets for the Baltic Sea www.grida.no/baltic/
British Antarctic Survey	Various marine data for the Antarctic waters www.antarctica.ac.uk/bas_research/data/index.php
British Oceanographic Data Centre	Worldwide marine data sets www.bodc.ac.uk/
BSH, Germany	Marine data and data holding centres in Germany www.bsh.de/en/index.jsp
Centre National D'Etudes Spatiales (CNES), France	Various microwave satellite altimetry data products www.aviso.oceanobs.com/en/data/index.html
CISL Research Data Archive	A range of collections of oceanographic observations http://dss.ucar.edu/catalogs/free.html
CSIRO – Marine and Atmospheric Research, Australia	Marine datasets for Australia www.marine.csiro.au/datacentre/
CSIRO – Observing the Ocean, Australia	Marine satellite data for Australia www.marine.csiro.au/~lband/
DLR – Applied Remote Sensing Cluster	German satellite remote sensing data www.dlr.de/caf/en/desktopdefault.aspx
EOWEB – Earth Observation on the web	Various remote sensing data sets http://eoweb.dlr.de:8080/servlets/template/welcome/entryPage.vm
EPIC – Pacific Marine Environmental Laboratory	Access to earth observation data www.epic.noaa.gov/epic/
European Commission – Sea-Search	Gateway to oceanographic and marine data for Europe www.sea-search.net/
Fisheries and Oceans Canada (DFO) – Ocean and Ecosystem Science	Oceanographic data for eastern Canada www.mar.dfo-mpo.gc.ca/science/ocean/sci/sci-e.html
IFREMER, France	Access to French oceanographic data www.ifremer.fr/sismer/index_FR.htm
INFORAIN	Searchable database of geographic data for western USA and Canada www.inforain.org/dataresources/datalayers.cfm
Integrated Science Data Management (ISDM), Canada	Marine buoy and satellite data for Canada www.meds-sdmm.dfo-mpo.gc.ca/isdm-gdsi/index-eng.html
IRI/LDEO Climate Data Library	Various historical marine and atmospheric datasets http://iridl.ldeo.columbia.edu/
Lamont-Doherty Earth Observatory	Wide range of datasets at global and regional level www.ldeo.columbia.edu/research/databases-repositories
MarineGIS, Canada	List of marine data centres www.marinegis.com/
MARIS – Marine Information Service, Netherlands	Oceanographic and marine data and information in Europe www.maris.nl/
NASA – Earth System Science Data and Services	Listing of NASA's satellite data archives http://nasadaacs.eos.nasa.gov/about.html
NASA – Goddard Earth Sciences Division	Various NASA's satellite data http://disc.sci.gsfc.nasa.gov/
NASA – Goddard Space Flight Center	Various worldwide oceanographic datasets http://gcmd.gsfc.nasa.gov/
NASA – Goddard Space Flight Center	Worldwide SeaWiFS data http://oceancolor.gsfc.nasa.gov/SeaWiFS/

MARINE DATA (cont.)	
Organization	Description and Web site URL
NASA – Goddard Space Flight Center	Various colour and thermal satellite products http://oceancolor.gsfc.nasa.gov/
National Geophysical Data Center	World shoreline and coastline data http://geodiscover.cgi.ca/gdp/index.jsp?language=en
Naval Research Laboratory – Ocean Sciences Branch	Marine satellite data for selected areas http://www7240.nrlssc.navy.mil/
NEODASS – Dundee Satellite Receiving Station	Archived AVHRR, Modis and SeaWifs satellite data www.sat.dundee.ac.uk/auth.html
NOAA – Comprehensive Ocean Atmosphere Datasets	Worldwide satellite images http://icoads.noaa.gov/
NOAA – National Data Buoy Center	Worldwide Meteorological and oceanographic buoy data http://seaboard.ndbc.noaa.gov/
NOAA – Shoreline Data	Worldwide shoreline data http://shoreline.noaa.gov/
NOAA – Tropical Atmosphere Ocean Project	Ocean buoy data for the central Pacific www.pmel.noaa.gov/tao/
NOAA – Global Drift Program	Worldwide drifter buoy data www.aoml.noaa.gov/phod/dac/gdp.html
NODC – National Oceanographic Data Center, USA	Worldwide marine biological and physical data www.nodc.noaa.gov/
NODC – National Oceanographic Data Center, USA	Global ocean temperature and salinity data www.nodc.noaa.gov/GTSP/gtspp-home.html
OBIS – Ocean Biogeographic Information System	Worldwide marine biogeographic data www.iobis.org/

The ecosystem approach to fisheries (EAF) has been developed over the last decade in response to perceived and actual deficiencies in previous methods of management. The EAF recognizes that fish are only one albeit important part of a much wider ecosystem incorporating an array of physical and biological components that humans interact with and exploit. Rather than managing single fish stocks, an EAF is concerned with the impacts of fisheries on the marine ecosystem, the interactions between different fisheries, of fisheries with the aquaculture sector, as well as with other human activities. Geographic Information Systems (GIS) are considered an ideal platform upon which to perform necessary information management and decision-support analysis for the implementation of an EAF. This technical paper is intended to be a guide to methods that readers could adopt for their own use of GIS for an EAF. The planning considerations for appropriate GIS in terms of objectives, scope and geographical area are outlined. The practical considerations are discussed and include hardware architecture, various software possibilities, sources and types of data that will be needed, and the array of backup and support that is available.

