Use of Geographic Information Systems (GIS) for Responsible Aquatic Resource Management

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INTRODUCTION

Aquaculture and fisheries play important roles in the global economy, in poverty alleviation, in fostering food security and in recreation. As recognized in the FAO Code of Conduct for Responsible Fisheries (CCRF), sustainability is a fundamental management and development requirement for both sectors. Sustainability has many important spatial elements.

A principal way through which the FAO Fisheries Department (FI) facilitates implementation of the CCRF is through its FishCode Programme of Global Partnerships for Responsible Fisheries (http://www.fao.org/fi/fishcode.htm). Amongst other activities FishCode promotes the use of manuals and applications like Geographic Information Systems (GIS) for fisheries monitoring and analyses, in line with the CCRF principles (http://www.fao.org/figis/servlet/static?xml=STF_proj.xml&dom=org&xp_nav=5).

Aquaculture spatial issues addressed most frequently include: development (siting and zoning, strategic planning), practice and management (inventory and monitoring of aquaculture and the environment, environmental impacts), and integration of aquaculture into other uses of lands and waters (management of aquaculture together with fisheries, multisectoral planning including aquaculture).

Inland fisheries spatial issues addressed most frequently include: status of fishery resources (habitat quality and quantity linked to fish abundance and distribution), fisheries (planning and potential), environment (impacts on fishes and habitats), and multisectoral planning and management including fisheries.

Marine fisheries spatial issues include: activities in support of management options (analysis of conflict areas, catch and effort spatial analysis), inventory and location of fishery resources (maps of distribution, bio-diversity analysis), modelling of fishing activities (through Vessel Monitoring Systems-http://www.fao.org/figis/servlet/static?dom=topic&xml=VMS_Home.xml), activities in support of ecosystem approach to fisheries, and location and impact assesment of marine protected areas (MPAs).

CURRENT IMPLEMENTATION AND ALLOCATION OF GIS ACTIVITIES AT THE FISHERIES DEPARTMENT

Six main GIS related activities are currently being carried out by different technical services of the FI, namely: (a) Methodologies, technical guidelines and technical papers, (b) Geo-referenced information systems, (c) Field projects and training, (d) New technologies, (e) Seminars, and (f) Standards and guidelines. The present article provides a brief on these activities with a specific focus on aquaculture. It is intended for administrators and technical staff of fishery departments of FAO member countries.

Inland Water Resources and Aquaculture Service (FIRI)

Programme Activities
The following activities will be completed in 2006 or will continue in 2007 and onwards like GISFish.

🌍 "GISFish" The Global Gateway to Geographic Information Systems (GIS), Remote Sensing and Mapping for aquaculture and inland fisheries to be released in late 2006. (By *Aguilar-Manjarrez, J. and Kapetsky, J.M.*).

GISFish is a "one stop" site from which to obtain the depth and breadth of the global experience on GIS, remote sensing and mapping as applied to aquaculture and inland fisheries. GISFish was created to: (a) promote the use of GIS, remote sensing and mapping; and (b) facilitate the use of these tools through easy access to comprehensive information on applications and training opportunities. Accordingly, GISFish targets a broad range of users.

GISFish sets out key issues in aquaculture and inland fisheries, and demonstrates the benefits of using GIS, remote sensing and mapping to resolve them. The global experience provided by GISFish is captured in databases of literature references, ongoing projects, training opportunities, activities, news and links.

GISFish provides access to case studies in order to: (a) call attention to a wide variety of applications that have contributed to solving important issues that affect the sustainability of aquaculture and inland fisheries and (b) provide information that is usually lacking from scientific papers and reports, particularly with regards to ways in which work has been completed and the commitment of time and specialized personnel involved.

Figure 1. Example of GISFish Web page illustrating case studies (GISFish is still under construction)

GISFish is powered by FAO's Community Directory Service (CDS) engine, which is compatible and has links to FAO's Fisheries Global Information System (FIGIS). A "marine fisheries" section will be developed for GISFish by FAO's Marine Resources service (FIRM) as soon as funds are made available.

⊕ GIS and Remote Sensing for the Development and Management of Offshore Aquaculture: A Reconnaissance - to be published in 2006. (By *Kapetsky, J.M and Aguilar-Manjarrez, J.*).

Open ocean aquaculture is in its very early stages. Currently available technologies are limited to operations in exposed offshore sites. Exploiting open ocean sites will require new designs for tethered and free-floating structures. Nevertheless, a number of factors provide incentives for such developments. Among them are an increasing demand for fish products, escalating competition for space along with problems of pollution in inland and coastal areas, and the perception that the world's oceans offer an almost unlimited capacity for growth. Meanwhile, nearshore aquaculture is well developed in many countries but there are important issues regarding sustainability. Whether offshore or nearshore, GIS, remote sensing and mapping have important roles to play in resolving the issues that are entirely spatial or that have spatial components. The purpose of this reconnaissance study is to document the role of available tools to support the development and management of marine applications in places where good potential exists. The study, to be published as an FAO Fisheries Technical Paper includes a global in-depth review of the issues, concepts, data needs and availability, techniques, and capacity.

At first glance assessing open ocean aquaculture potential appears simple and straightforward compared to land-based and inshore aquaculture. In reality, it is complex. Two case studies use GIS and remote sensing to assess the open ocean aquaculture potential of two species - Cobia, a warm water finfish, and the blue mussel, a cold water mollusc - within the Exclusive Economic Zones (EEZ) of the east coast of the USA and Puerto Rico/Virgin Islands. The criteria broadly include suitability for the organism and the culture system, and access (Figure 2). Guidance for the identification of relevant data sources is provided by FIRM.

Figure 2. An example of Cobia culture suitability map for nearshore and offshore aquaculture
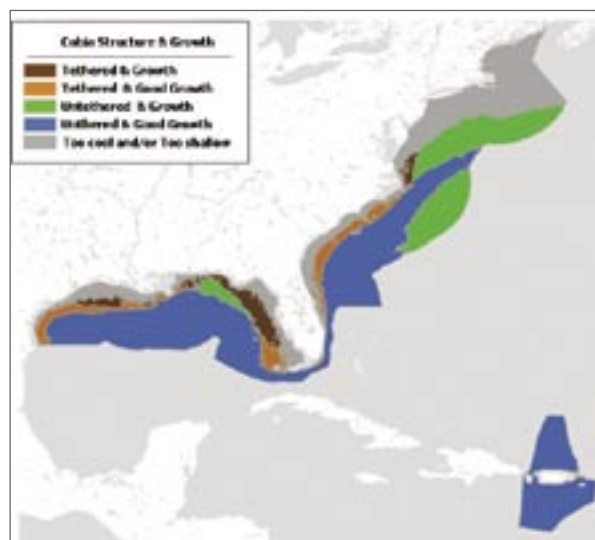
⊕ African Water Resource Database (AWRD) – to be published in 2006 (By *Jenness, J.; Dooley, J.; Aguilar-Manjarrez, J., and Riva, C.*).

The African Water Resource Database (AWRD) represents the follow-up activities based on the recommendations of the Committee on Inland Fisheries for Africa (CIFA). AWRD is a GIS analytical framework supporting inland aquatic resource management with a specific focus on inland fisheries and aquaculture. AWRD database includes: surface water bodies, watersheds, aquatic species, rivers, political boundaries, population density, soils, satellite imagery and many other physiographic and climatological data types. AWRD contains an assortment of new custom-designed applications and tools to display and analyze these data. The Database allows integration of different types of information (e.g., fishery statistics) into a cohesive programme that, because of its visual nature, is easy to understand and interpret. Systems such as AWRD are excellent means to attract and direct investments in aquaculture and fisheries development. Further explorations and applications of AWRD data could deepen our understanding of inland aquatic resource management and be of immediate value in addressing a wide variety of issues raised at recent CIFA sessions. These include, for instance: improving status and trends reporting in inland fisheries and aquaculture, co-management of shared inland fisheries resources, transboundary movements of aquatic species, and increased participation of stakeholders in watershed use decision making processes.

AWRD offers an effective way of dealing with transboundary issues, such as assessing the risks and benefits from the use of alien species (i.e. introduced or exotic species) in fisheries and aquaculture. Use of alien species may impact areas very far removed from the target locality. Figure 3 shows the area that the introduced Silver carp species could potentially access once introduced into the Limpopo drainage in southern Africa. A local introduction into coastal Mozambique or Zimbabwe highlands would provide access to four countries. International codes of practice on alien species, such as the ICES codes of practice (ICES 1995) and the FAO Code of Conduct for Responsible Fisheries, call on users of alien species to notify States that may be impacted by their introduction. AWRD would provide clear indication of which countries should be notified and which waterbodies may be impacted.

Figure 3. Use of AWRD data and tools to assess the distribution of Silver carp through four countries
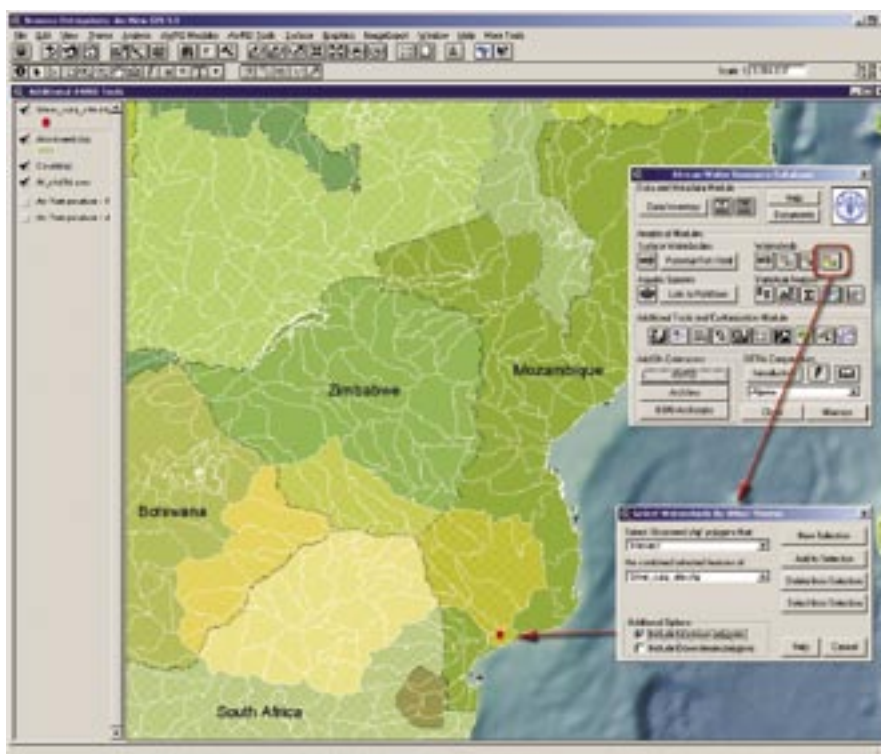
🌐 Distribution and characteristics of the main aquaculture production sites by administrative units for the National Aquaculture Sector Overviews - to be published in NASO in 2006. (By Crespi, V.; Dessi, A.; Franceschini, G.; and Aguilar-Manjarrez, J.).

The National Aquaculture Sector Overview (or NASO) collection, a concise and comprehensive cross-domain product, provides synthesis of aquaculture and culture-based fisheries at the national level (Figure 4).

Figure. 4 Example of NASO GIS produced map for Brazil*

*http://www.fao.org/figis/servlet/static?dom=countrysector&xml=naso_brazil.xml

NASO maps, supported by line drawings, illustrations and charts, provide a quick overview of aquaculture site locations and offer links to summary tables on aquaculture production. These maps are being produced for globe coverage and when finalized could represent what is likely to be the most comprehensive geo-referenced database on aquaculture site locations ever compiled.

🌐 Inventory and monitoring of coastal aqua-culture and fisheries structures by Satellite Aperture Radar (SAR) (By Travaglia, C.; Kapetsky, J.M.; Profeti, G., and Aguilar-Manjarrez, J.).

Satellite Aperture Radar (SAR) data can be used for inventory and monitoring of coastal aquaculture and fisheries structures which are important baseline data for decision-making in planning and development, including regulatory laws, environmental protection and revenue

collection. Publications produced by FIRI in 1999 and 2004 using SAR data include studies for Sri Lanka (Environment and Natural Resources Working Paper No.1) and the Lingayen Gulf, the Philippines (FAO Fisheries Technical Paper. No. 459). Provided funds are available in the future, SAR analysis could be applied in similar environments around the globe and could help create a comprehensive inventory of aquaculture structures, thus enhancing NASOs and the statistics compiled by FIDI.

Project-based activities
In terms of Technical Cooperation, the following projects have a GIS component:

- TCP/RAF/3101 (F) "Project formulation for fisheries-related technical assistance components of the Regional Programme for Integrated Management of Lake Tanganyika.
- "UTF/BRA/066/BRA on Coastal Communities Development" (Aguilar-Manjarrez, J. Lead Technical Unit Officer). Using the GIS analytical framework developed by the previous TCP on seaweed farming TCP/ BRA/0065, the UTF project will collect and enter the required information to pre-select 15 new sites per state for further analysis. The establishment of GIS for integrated mariculture and artisanal fisheries would include the training of the operators and the programming of the system which should also be used for monitoring of project impact (Figure 5).

Figure 5. An example of potential areas for seaweed culture in Paraíba as indicated by the GIS analysis (green areas indicate high potential whilst orange areas indicate medium potential)

Marine Resources Service (FIRM)

GIS activities at FIRM contribute to different areas of analysis and management of fishery resources. In the last biennium 2004-05, FIRM has played an important role in:

- production, maintenance and updating of distribution maps of marine species of commercial importance;
- preparation of electronic fact sheets of selected fishery resources as inputs to FIGIS and other regional and global databases;
- ecosystem analyses and monitoring in support of Ecosystem Approach to Fisheries (EAF);
- updating of the "Review of the state of world marine fishery resources" (available at ftp://ftp.fao.org/docrep/fao/007/y5852e/y5852e00.pdf); and
- global and regional reviews of tuna and tuna-like fisheries and fishery resources.

Programme activities

FIRM is involved in the development of methodologies and applications for the analysis of fishery information:

- Simulation and modelling of spatial distribution of small-scale fishing activity through a dedicated GIS application called FAST (Fishing Activity Simulation Tool). The application and documentation is available through the FAO COPEMED Project at http://www.faocopemed.org/en/activ/research/gis/eff_network.htm (Figure 6).

Figure 6. An example of application of FAST in the Caribbean region: preliminary analysis of the distribution of local fishing activities modelled according to "scoring" functions applied to distance from landing sites and depth zones
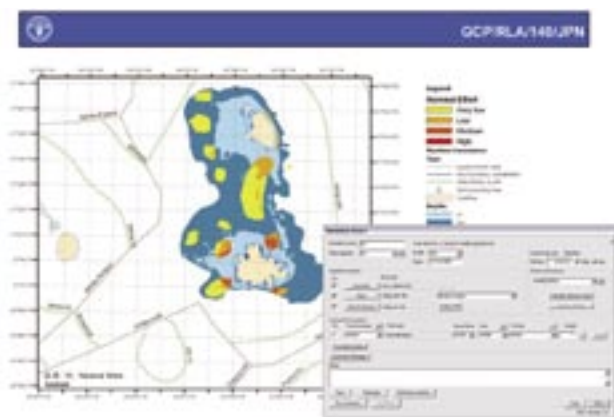
- Application "Resources" for the management and spatial analysis of data collected by scientific fishing surveys. The application includes a data-entry interface and assists the user for mapping catch statistics. A GIS project is automatically built by the application for each selected set of fishing operations, including one layer for each computed statistics (Figure 7). Further documentation is available through the FAO COPEMED Project at http://www.faocopemed.org/en/activ/research/gis/app_trawl.htm.

Figure 7. An example of the "Resources" application: map of catch statistics extracted from the module for spatial analysis and compared to depth zones
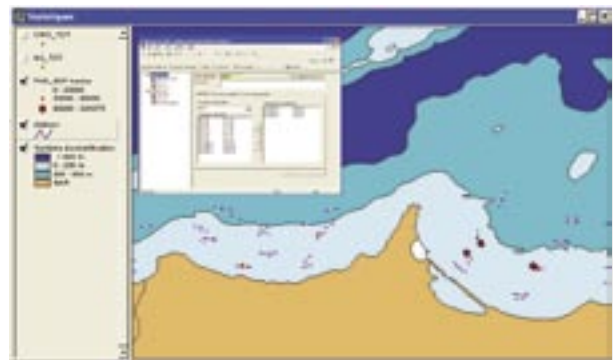

- In addition, GIS is pursued by FIRM as a valuable tool in the development and use of indicators and reference points for assessing and monitoring the status of marine fishery resources in the context of their ecosystem.

Project-based activities

In terms of Technical Cooperation the following Projects have included a GIS component:

- GCP /RLA/140/JPN on Scientific Basis for Ecosystem-Based Management in the Lesser Antilles including interaction with Marine Mammals and Other Top Predators.

- TCP/GAB/3001 on Support for the formulation of a development plan for the industrial fishery in Gabon.

- TCP/SEY/2902 on Capacity Building in the Resource Assessment and Management of the Seychelles Holothuria Fishery (Figure 8).

Figure 8. GIS analysis for the optimal allocation of sampling sites using multi-criteria and randomly allocated stratified sampling scheme
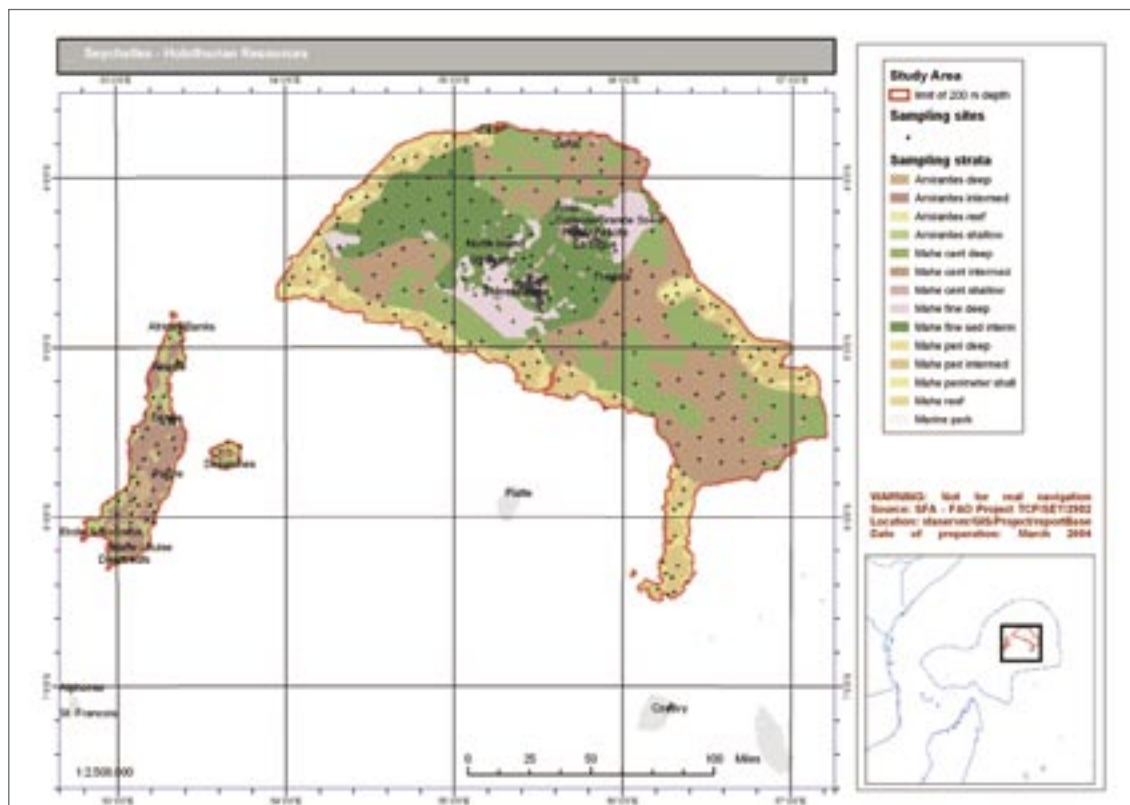
Fishery Information, Data and Statistics Unit (FIDI)

Thanks to a mixed support of extra budgetary and Regular Programme inputs, FIGIS has supported the integration of geo-referenced data and applications through implementation of standards and integration of web-based applications. To date, six dynamic mapping applications built on KIDS (Key Indicator Data System developed by FAO) core GIS software are disseminated through the FIGIS platform:

- Species distribution maps (Species Identification Data Programme - SIDP) in collaboration with Marine Resources Service;
- Tuna Atlas catch statistics by 5 degree square (in collaboration with Marine Resources Service);
- Aquatic Sciences Fisheries Abstract (ASFA) geographic query tool;
- Fishery Resources Monitoring System (FIRMS) geographic query tool;
- Dynamic mapping of Stocks and Fishery resources (FIRMS); and
- Dynamic mapping of RFB competence areas (FIRMS).

The standard GIS framework is currently being extended with the national sub-administrative levels boundaries (Global Administrative Unit Layers or GAUL), a FAO GIS corporate product.

Considering the experience gained by the FIGIS framework, FIDI intends to continue to provide the know-how and infrastructure to develop new mapping applications. The FIGIS framework should continue to play an important role to:

- expand dynamic mapping web interfaces through application of data standards and customization of existing tools, e.g. integrate the African Water Resource Database with relevant information, dynamically power NASO maps, etc. ;
- implement inter-operability with statistical mapping tools and trade flow maps developed by FAOSTAT2;
- integrate mapping applications of stocks and species distribution;
- develop other geo-referenced fisheries data and applications; and
- contribute to the development of metho-dologies for elaboration of new global/regional geo-based fishery indicators.

CROSS-CUTTING ISSUES/APPLICATIONS AND PLAN OF ACTION FOR THE GIS USAGE IN FI

As part of FI's medium term plan of action, three main activities are currently underway:

🌐 Training course on GIS for FI staff. The objective of the course is to train interested FI Staff in the use GIS and applications of GIS in fisheries and aquaculture management. A one week training course is proposed, up to 36 hours in September or October 2006 for about 10-15 staff members. The training course will be based on FAO Fisheries Technical Paper No 449. The trainers will be from FI/FishCode (de Graaf/Bensch), FIRI (Aguilar-Manjarrez) and FIRM (Carocci). The programme of the course is being prepared and interested staff of FI will be requested to apply.

🌐 Seminars on applications of GIS in fisheries and aquaculture. A series of seminars, to be held during 2006-2007 with the support of FishCode, will set out some of the key issues in fisheries and aquaculture and demonstrate the benefits of using GIS, remote sensing and mapping to resolve them. Three seminars are planned for 2006 whilst seven are proposed for 2007. Each seminar will focus on one or two key issues and will be targeted at different FI divisions/services. The seminars are grouped into six main categories: (a) GIS work at FI; (b) GIS applied to fisheries management; (c) GIS applied to the ecosystem approach; (d) GIS as a mapping and dissemination tool for fishery statistics; (e) GIS applied to aquaculture; and (f) Case studies.

🌐 Project proposals. Proposals for projects under the FishCode umbrella are being developed in order to complement and strengthen core GIS activities under FI's Regular Programme. Project topics and issues areas under consideration include the following:

- Ecosystem approach to aquaculture and fisheries
- Statistical representations of world and regional resources and fisheries and related monitoring through geo-based indicators
- High seas resources and fisheries mapping and management
- Marine protected areas
- Analysis of shared stocks management
- Area-based fisheries management
- Climate change scenarios – including risk and productivity
- Explorations of decision-rule approaches for aquaculture development and management
- Applications of risk analysis
- Environmental safety
- Disease - epidemiology, risk mapping, disease surveillance and control
- Estimates of aquaculture carrying capacity
- Spatial modelling of aquaculture related to development poverty and needs issues.
- Integrated watershed or coastal area management
- Poverty/livelihoods targeting using market chain data
- Marketing – global trade fluxes

GIS TO ASSIST WITH YOUR FUTURE MANAGEMENT TASKS

GIS is aimed at a broad range of users. Potential beneficiaries include researchers, planners and managers in national, regional and international organizations, scientific institutes and universities. Other beneficiaries are in the commercial sectors of aquaculture and fisheries.

GIS is most frequently applied as a decision-making tool for development, but increasingly it will be used for the tasks of administration and regulation. Potential applications include allocation of sites in a context of administrative jurisdictions, and environmental carrying capacity. Also, GIS can be used administratively and operationally to relate locations of individual culture sites or clusters to optimize extension efforts.

The authors continuously seek opportunities to cooperate with other organizations in the realm of GIS, remote sensing and mapping, training to improve the sustainability of aquaculture and fisheries is of particular interest. To explore cooperative activities, please contact:

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