Information Systems for the Co-Management of Artisanal fisheries

Final Technical Report

Volume I

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FINAL TECHNICAL REPORT

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1. DFID Summary

1.1 Executive Summary

The purpose of this project was to examine the feasibility of developing a generic (generally applicable) Fisheries Information Management System (FIMS) or database to improve the co-management and appropriate development of artisanal fisheries.

Generic information requirements to support the main co-management roles of fisheries departments were identified from literature reviews and case studies of fisheries in Bangladesh and the Turks and Caicos Islands. Generic inputs (fields) to support these requirements were identified from common data fields found in survey forms and databases.

Generic FIMS software to support the co-management roles and corresponding data and information requirements was developed using relational database and systems engineering theory. The system, designed to run under Microsoft ACCESS97, comprises a set of linked reference and survey tables, data entry forms, and predefined SQL queries. The system can store and process of a wide range of data and information collected using common methodologies. All the data and information contained within the database can stratified by more than 5 criteria, spatially referenced, grouped by 40 attributes and either plotted in a variety of formats or exported in Microsoft Excel spreadsheet format. A user manual has been produced to accompany the PISCES software.

The system has been successfully tested using catch and effort datasets provided by the two case study fishery departments, but the extent to which the PISCES system is generally applicable can only be objectively assessed after further attempts by fisheries departments to adopt the system. It is likely that certain elements of the system will be more generally applicable or generic than others. It is likely that outputs that can be explicitly defined including catch and effort, biological, environmental, and control and surveillance data, and information required for international management and reporting responsibilities will all be well supported by the software. Although some customisation will be inevitable, it is estimated that the PISCES software could be installed and working within six weeks compared to six months typically required to develop a bespoke system. Significant initial costs savings are therefore anticipated, although potential long-term maintenance costs remain uncertain. The system is complex and therefore institutional strengthening and training programmes may be required for successful adoption and uptake.

Further development of the PISCES software is required to provide the necessary fields and processing capacity to support the monitoring and evaluation of data relating to conflicts, the maintenance of traditional management practices, environmental data and employment in the harvesting (and processing) sectors. Further work is also required to improve the user interface and error checking functions. The system would also benefit from an expanded range of fields and processing functions for socio-economic data.

Nonetheless, this research has made a significant contribution to the development of improved strategies and plans for the management of capture fisheries important to poor people (RNRKS FMSP Purpose 1). Furthermore, fishery departments from both case study fisheries have expressed keen interest in the system and several requests for software and manuals have already been received including from members of SADC.

1.2 Background

Artisanal fisheries are fundamentally important in the developing world. It has been estimated that between 14-20 million people depend on these fisheries for their livelihoods, and about 1 billion rely on them for their main source of animal protein. Fisheries management is an integrated process involving information gathering, analysis, planning, consultation, decision-making, and the formulation and implementations of rules and regulations to govern fisheries activities to satisfy various objectives. Co-management, where the responsibility for management is shared between the major stakeholders is increasingly recognised as being an effective strategy to redress many of the paradigm failures associated with more conventional ‘top-down’ approaches to management. However, regardless of the nature of co-management arrangements, effective management relies heavily on processed information from the fishery. Fisheries Information Management Systems or databases provide an efficient means to hold and process information collected from fisheries (Chapter 2).

There are two main approaches to developing a FIMS; either by adapting or customising a commercially available (off-the-shelf) generic system to satisfy local requirements, or by creating a custom system from scratch. Generic systems have lower initial costs, but may be more costly in the long run because of higher maintenance costs. Significant (costly) modifications may also be required to satisfy local requirements. Custom (bespoke) systems are generally more costly to develop and require the continuing involvement of skilled system developers, but can be configured to match closely the data collection strategy so that the system will be more efficient and readily accepted (Chapter 2).

The Food and Agriculture Organisation (FAO) of the United Nations (UN) have developed their own generic FIMS. Although the system has been widely adopted in Africa, mainly for the management of artisanal lake fisheries, it is somewhat inflexible, orientated to the collection of catch and effort data, and contains no functions to support co-management (Chapter 2 & 7).

A wide demand for artisanal FIMS remains. Indeed, MRAG Ltd has received several requests for FIMS from fisheries Departments, particularly in Melanesia (Chapter 2).

1.3 Project Purpose

The purpose of this project was to examine the feasibility of developing a generic (generally applicable) Fisheries Information Management System (FIMS) or database to improve the co-management and appropriate development of artisanal fisheries. In addition to the generic database, other planned project outputs included:

(i) Guidelines and statistical procedures for a generic data collection system to support the FIMS software.
(ii) An evaluation of the cost of implementing the FIMS (both unit costs and national costs at case study sites).
(iii) Training workshops in the use of the generic FIMS and data collection strategy with supporting material/documents.
(iv) A description of the wider utility and applicability of the generic FIMS.

1.4 Research Activities

The outputs described in Section 1.3 were sought through a number of planned activities (Figure 1). It was intended to identify generic information outputs from the FIMS on the basis of a synthesis of government and community management objectives identified from the literature, company experience and from case studies of two diametrical artisanal fisheries (Volume II).

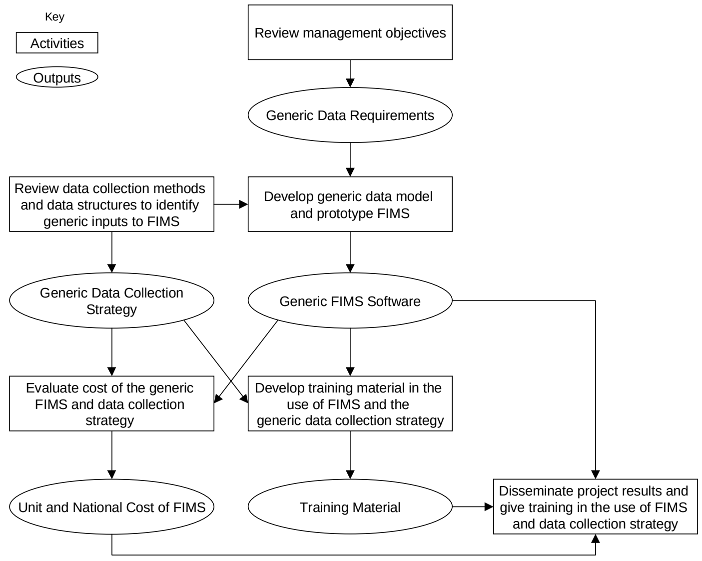

Figure 1 Planned Project Activities and Outputs

The raw data or *inputs* for storing and processing by the database to provide these outputs would be identified from a review of correspondingly appropriate data collection methodologies combined with a review of 'data structures'. This review of data collection methodologies was also intended to provide the basis for developing guidelines and statistical procedures for a generic data collection system to support the database component of the project. The computing hardware requirements for the FIMS software combined with and necessary resources and manpower to support the generic data collection system would then provide the necessary information to evaluate unit costs of the system, as well as the national costs of implementing the FIMS at the case study locations (Figure 1).

Shortly after the project began, it became evident that information requirements (outputs from the FIMS) to support co-management will be governed by more than just management objectives of governments and local fishing communities (Chapter 3). Instead, the information required from a co-management FIMS will be influenced by (i) the nature of the co-management arrangement which will determine which stakeholders are involved in the management decision-making process; (ii) the objectives of these stakeholders; (iii) the basis with which these stakeholders make decisions (eg custom/tradition, empirical or theoretical models, adaptive approaches...etc); (iv) their institutional capacity which will influence the types of decision-making methods and data collection approaches they can employ; (v) the type of management control measures they choose to employ to regulate resource exploitation, and of course: (vi) their preferences and the local conditions under which they operate (Chapter 3).

The continuous spectrum and evolutionary potential of co-management arrangements coupled with the inter-dependence among several of the factors listed above, presented a dynamic and multi-dimensional problem to identifying management information requirements and therefore designing a general database to support co-management (Chapter 3).

As a means of addressing the problem, idealised co-management arrangements based upon the work of Sen & Nielsen (1996) and Hoggarth *et al* (1999) were identified for the three main environmental regimes in which artisanal fisheries commonly operate. These arrangements effectively match the main stakeholders with the necessary motivation and institutional capacity to the main management roles that are heavily reliant upon data and information (Chapter 3).

It was also necessary to make explicit which of the main stakeholder groups should be the target of the FIMS. It was concluded that government fisheries departments should be the primary targets because they will usually have overall administrative responsibility for the (co-) management of national fisheries resources. They are also the most likely stakeholder group to possess the necessary institutional capacity and resources to formally monitor management performance and therefore are most likely to require such a system. Designing a system that could also support the needs of intermediaries (eg donor-funded projects, NGOs etc) was rejected. It would be impossible to anticipate their diverse range of remits and interests and potentially esoteric monitoring programmes commonly designed to satisfy donor-specified project impact indicators (Chapter 4). In spite of this, several NGOs delegates at the projects' dissemination workshop in Bangladesh believed the FIMS software could effectively be used in support of many of their community project monitoring and evaluation programmes (see later and Chapter 8). It was also concluded that whilst they are the ultimate target beneficiaries of the project, and may in contribute to the data and information contained within it, it would be unrealistic to expect local fishing communities to have any interest, motivation or the necessary institutional capacity to use such a system. Monitoring and evaluation at this level will typically be informal and often based on perception or common knowledge derived from the co-use of the resource under conditions where mutual observations are possible (See Chapter 4 and Project Memorandum Section 15d).

The system was therefore principally designed to support the following heavily-dependent co-management roles of fishery departments at each of the three nested spatial management levels identified as:

(i) Formulation of management plans.
(ii) National monitoring and evaluation, and control and surveillance for management plans for migratory[1] and state-owned sedentary resources[2].
(iii) National policy and development planning including the coordination of sectoral activities.
(iv) National and international management and reporting responsibilities.
(v) Coordination of community management plans to ensure complementarity.
(vi) Evaluation of community management plan performance and feedback of lessons of success and experiences to communities.

1.4.1 Identification of FIMS Outputs

Generic information requirements (outputs) from the FIMS to support these co-management roles were identified from an extensive synthesis of the literature (chapter 4):

Formulation of management plans

The main categories of information required for the formulation of management plans were identified as the stocks or fishery being considered and area of operation of the fishery; information on environments, habitats or locations critical for the life history of the stocks or species; potential catchment influences on the stock; information relating to the fishery; information relating to the fishers and other important stakeholders; the management objectives; decision-making arrangements including rules and regulations; and any external factors that may affect management (Section 4.2).

[1]Migratory resources cannot be effectively managed on a local scale.
[2]These refer to non-migratory stocks that are not managed on a local scale.

National monitoring and evaluation of management plans, and control and surveillance. Generic information requirements (outputs) from a FIMS to support national monitoring and evaluation activities were identified from a combination of management objectives (and their *status indicators*), technical management models (and their *reference points*) and adaptive management approaches, covering the full range decision-making methods that are employed to evaluate management performance (see above and Chapter 4).

Generic information requirements (outputs) from the FIMS to support biological or resource orientated management objectives, decision-aiding models and adaptive management approaches were identified as catches by species and gear type and corresponding fishing effort by gear type during a specified time period (commonly a year). Other requirements were identified as information to describe the population dynamics of the exploited populations (biological data) derived from the (sampled) catch including: the length or age composition of the catch and their life history characteristics, typically sex, fecundity, and reproductive condition in relation to length, and gonad weight in relation to somatic weight (Section 4.3). Spatially referencing these data and information significantly augments its' value allowing: (i) the development of spatial management models (Section 4.3.3); (ii) the identification of important areas for conservation and management (eg spawning locations or nursery areas...etc); (iii) the examination of the spatial and technical interactions among fleets or fishers, and stocks; and (iv) more effective management if the population dynamics of the stock varies significantly on a spatial scale.

Information requirements (outputs) from the FIMS to support common socio-economic management objectives and decision-aiding models were identified to include costs and earnings stratified by various criteria, economic rent, export revenue by species or product type, numbers of individuals employed in the fishery stratified by sub-sector, income stratified by FEU type, industry diversification data, indicators of food supply or security, information describing the extent and frequency of conflicts, information to monitor the existence/maintenance of traditional management practices or culture, and catch and effort information (Section 4.3.4).

Environmental information was also identified as being an important output from a FIMS, particularly to support the management of fisheries operating in environments sensitive to environmental stress or perturbation. General variables that should be available from a FIMS were identified in Section 4.3.5. Information requirements for control and surveillance were found to typically relate to vessel or gear ownership, identity, communications, fishing power and corresponding licence details (Section 4.4).

National policy and development planning
Information requirements from a FIMS to support national policy and development planning decisions, and reporting responsibilities were examined in Section 4.5. Three main categories of information requirements from the FIMS were identified: (i) resource and fishery related; (ii) socio-economic; and (iii) monitoring control and surveillance.

National and international management and reporting responsibilities.
Required outputs from a FIMS to comply with international management responsibilities including the FAO Code of Conduct for Responsible Fisheries and UNCLOS III were identified. Outputs required for international reporting responsibilities were also identified for the main commissions and conventions including the FAO Regional Fishery Commission; Convention for the International Trade in Endangered Species (CITES), and the Convention for Biological Diversity. However, it was recognised that membership to other regional bodies, agencies and organisations such as Organisation for Eastern Caribbean States (OECS) or the South African Development Commission (SADC) may carry with it additional obligations to supply specific information not required for the above (Section 4.7).

Coordination and performance evaluation of community management plans
Adaptive management is likely to be employed by local communities to achieve their objectives for their own *management unit*. However, identifying the best combinations of management tools and decision-making arrangements to achieve specific objectives by individual communities may take several years of (informal) monitoring and evaluation by the local managers. It was concluded that fishery departments or higher level managers have the potential to significantly accelerate this adaptive learning process by monitoring and comparing spatially, performance among individual management plans. The results and management recommendations arising from this approach can then be disseminated to local level managers via appropriate media such as regular radio transmissions, meetings, posters, workshops...etc. This spatial monitoring and evaluation approach also provides an effective means with which to spatially coordinate local management activities thereby promoting harmony and complementarity and helping to minimise conflicts.

Requirements from the FIMS to support this role were therefore identified as being all the information that is typically contained within a management plan and any other attributes that are believed to affect management performance or outcomes, as well as of course, indicators of management performance.

Co-management attributes and performance indicators were identified on the basis of the Oakerson Framework (Section 3.1), ICLARM's 'Institutional Analysis Research Framework' developed under their Fisheries Co-Management Research Project, DFID's Sustainable Livelihoods (SL) framework, and from inter-disciplinary comparative studies of African lake and coastal fisheries described by Preikshot *et al*. 1998 and Nielsen *et al*., 1995, respectively.

Performance indicators must be both relevant and palatable to local level managers if effective feedback and adoption of lessons of success are to be achieved. Whilst these indicators should ideally be selected by the local managers themselves, an extensive literature review discovered no documentation describing management performance criteria as selected and applied by the community itself. Nonetheless, it is recommended that these indicators be negotiated in collaboration with the communities themselves. The DFIDs' five main categories of desirable livelihood outcomes were identified as a useful basis with which to negotiate these indicators (Section 4.9).

The FIMS currently includes only a subset of attribute and performance fields for demonstration purposes. Further fields can be added when a commonly agreed or standard set of attribute and performance indicators/measures have been identified or developed (see below).

A statistical framework for identifying patterns or similarities between combinations of attributes (explanatory variables) and management performance indicators was proposed based upon Multi-dimensional Scaling (MDS). Using this framework, lessons of success, described in terms of combinations of attributes and levels of inputs that appear to give rise to desirable outcomes or objectives, can then be feedback to local level managers via appropriate media to help accelerate their own adaptive management activities (Section 6.6).

A DFID funded project ' Interdisciplinary Multivariate Analsysis for Adaptive Co-Management' (R7834) is currently developing, refining and attempting to validate this approach in collaboration with ICLARM, IFM, Reading University, DFID and independent consultants.

1.4.2 Identification of Generic Inputs for the FIMS (database fields)

As explained above, it was intended to identify generic raw data or *inputs* for storing and processing by the FIMS database to provide all the generic requirements (outputs) described above by identifying or formulating a generic data collection system. As a means of attempting to develop such a generic data collection system, factors affecting raw data and their collection and processing were examined in detail in Chapter 5. This included a review of potential sources of data for each required category of requirements, and appropriate data collection tools (eg questionnaires, interviews, direct observation...etc), sampling strata, and the appropriateness of sampling and complete enumeration in relation to the variable or data type in question. It was concluded that it was impossible and wholly inappropriate to design a generic data collection strategy. Effective and appropriate data collection strategies and data processing methods must be designed in accordance with the structure, operations and characteristics of the fishery (the local context), and the available institutional capacity, resources and preferences (see Chapter 5 and Figure 11).

Generic inputs for storage and processing by the FIMS to provide the required outputs were instead identified on the basis of corresponding commonly collected categories of data and information or *generic fields* (Chapter 6). Generic fields were identified by reviewing the types of raw data (example fields) that are frequently collected using commonly employed data collection tools and data sources to provide the main categories of information required from the FIMS.

This approach effectively aimed to develop a FIMS that could support a variety of common data collection strategies as opposed to designing a system around a single generic data collection strategy. In addition to increasing the complexity of the database design (and therefore the time and resources required for it's development), the inability to develop a generic data collection strategy also had the important implications with respect to delivering several of the expected/planned outputs (see later).

1.4.3 Development of the Generic FIMS

The generic FIMS to support the co-management roles and corresponding data and information requirements was developed using relational database and systems engineering theory. Various alternative designs and small working prototypes were examined. User defined stratification across the full range of attributes was achieved through dynamic creation of a series of linked SQL queries. This allowed a whole series of analyses to be partitioned according to values in each or a combination of these attributes. An architecture was developed that allowed the system to be support a variety of different catch and effort sampling strategies. Sample and frame surveys were combined through the use of new methods for common stratification and joining of results via relational operations (Chapter 7).

1.5 Outputs

1.5.1 Achieved Outputs

The project succeeded in fulfilling its primary purpose of examining the feasibility of developing a generic database to support the co-management of artisanal fisheries. Prototype software entitled 'PISCES - **P**roviding **I**nformation for **S**ocio-Economic **C**atch and **E**ffort Fisheries Surveys has been developed to store and process of a wide range of data and information collected using common methodologies to support fundamental co-management roles of fisheries departments described above (Chapter 7 and User manual).

The system, designed to run under Microsoft ACCESS97, comprises a set of linked reference and survey tables, data entry forms, predefined SQL queries, and plotting and export facilities. The PISCES software can:

- Store details of management plan documents with links to key information fields to aid the (spatial) coordination of inter and intra-sectoral management activites;
- Support the monitoring and evaluation of national management plans on the basis of a range of decision-making methods to achieve common management objectives by providing facilities to store and process:

    - Catch and effort data generated by a range of different sampling or enumeration strategies.
    - Biological data sampled by direct observation at the harvest level.
    - Cost and earnings (income) data collected from fishing units (FEUs) or households.
    - Data to help estimate economic rent from the fishery.
    - Sector diversity data (numbers of target species, numbers of different gears and vessel types).
    - Data to help estimate food supply and average per capita fish consumption.

- Support control and surveillance activities by storing information relating to vessel/fisher registration and identification details and licence/quota information. The system also includes facilities to automatically alert breaches to regulations or licensing arrangements.
- Provide information in support of policy and development planning activities.
- Potentially provide all the information required for international management and reporting responsibilities.
- Support the coordination and performance evaluation of community management plans.

All the data and information contained within the database can stratified by more than 5 criteria, spatially referenced, grouped by 40 attributes and either plotted in a variety of formats or exported in Microsoft Excel spreadsheet format. Several predefined analyses have been included in the PISCES software (see User Manual and Chapter 7).

A user manual has been produced to accompany the PISCES software. This contains sections describing installation, operation, data entry and data analysis.

1.5.2 Outputs not Achieved

Because no single generic data collection strategy to support the software could be identified (see above and Chapter 5) the following remaining planned project outputs were not achieved:

- Guidelines and statistical procedures for a generic data collection system to support the FIMS software.
- An evaluation of the cost of implementing the FIMS (both unit costs and national costs at case study sites).
- Training workshops in the use of the generic data collection strategy with supporting material/documents.

The actual activities and resulting outputs achieved are summarised in Figure 2.

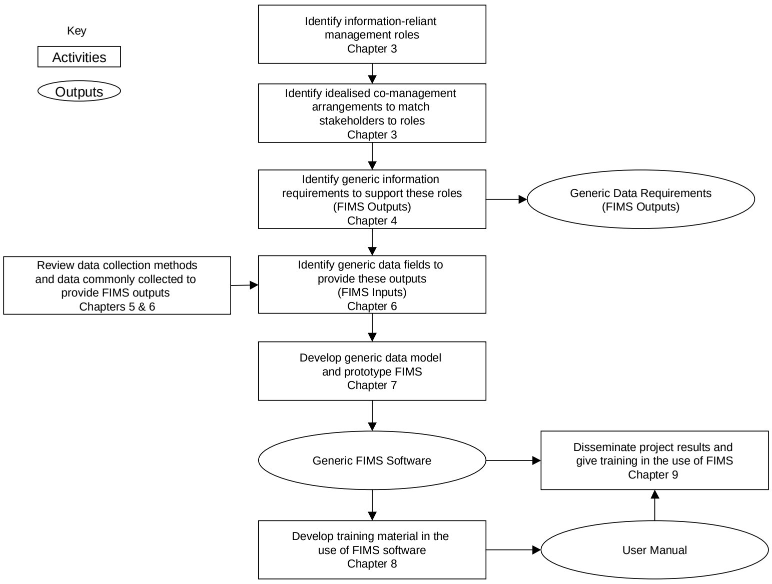

Figure 2 Actual Project Activities and Outputs

1.6 Contribution of Outputs

1.6.1 Contribution of Outputs Towards DFID Development Goals

This research has developed a potentially effective tool to help improve the co-management and appropriate development of artisanal fisheries and has, therefore, made a significant contribution to "...the development of improved strategies and plans for the management of capture fisheries important to poor people" (RNRKS FMSP Purpose 1).

The key question is how generic or general is the PISCES system? It is likely that certain elements of the system will be more generally applicable or generic than others depending upon the specificity of the required outputs and the corresponding range of potential data sources and collection methods.

Outputs that can be explicitly defined including catch and effort, biological, environmental, and control and surveillance data, and information required for international management and reporting responsibilities are all, therefore, likely to be well supported by the software.

Outputs required to support the evaluation of management activities geared towards achieving socio-economic objectives and for policy and development planning purposes are, on the other hand, typically more variable or less explicitly defined reflecting the use of a diverse range of measures, indicators and their proxies, and the wide range of available data collection methodologies and sources. For example, household income and fish consumption data may be monitored either on a routine (monthly) basis by means of a panel survey, or collected during socio-economic baseline/frame surveys. The PISCES software currently does not contain fields or the processing capacity to support the former. Instead fields are provided to record total annual income (from fishing and other activities) and total annual fish consumption generated by annual (ad hoc) surveys. However, fields and data processing facilities provided by the PISCES software for the more explicitly-definable socio-economic data requirements (outputs) such as income (costs and earnings) by FEU type are likely to be more generally applicable.

Data requirements for policy and development planning purposes are often drawn from the results of frame surveys. Frame surveys are also a very general way of collecting data and information about the fishery to help design data collection strategies, formulate management plans, provide baseline socio-economic and employment data, and indicators of poverty, industry diversification, and food security. The types of data and information collected during frame surveys are highly variable. More than 150 example data fields were identified from the literature ranging from answers to specific questions relating to sector support and infrastructure to data on literacy rates of village members (See Section 6.2.2). Whilst many frame survey fields exist in the PISCES software (via linked reference tables with the FrameTable) to record frame survey data, it is likely that significant changes may have to be made to accommodate further fields and to develop appropriate links and processing functions.

Indeed, it is very likely that additional fields may need to be added and existing broad generic fields re-named in several or all of the tables during installation in order to satisfy local requirements and existing data collection systems. In spite of this inevitable customization process, it is estimated that the PISCES software could be installed and working within six weeks compared to six months typically required to develop a bespoke system. Significant initial costs savings are therefore anticipated, although potential long-term maintenance costs remain uncertain.

Furthermore, whilst the database has been tested using catch and effort datasets provided by the two case study fishery departments (see Volume II), the extent to which the PISCES system it is generally applicable, particularly with respect to accommodating and processing socio-economic data, can only be assessed after further attempts by fisheries departments to adopt the system.

Other factors may influence adoption or uptake, beyond simply its potential applicability and cost-savings. The system as it stands is very complex and demands a high level of understanding of both data collection systems and relational database theory on the part of users (See Chapter 7 and User manual). Institutional strengthening and training programmes may well be required for successful adoption and uptake. Its robustness and reliability may also be important, particularly with respect to long-term uptake. Further testing of the system and error checking is required. Some participants at the dissemination workshop in Bangladesh believed that potential users may resist uptake because they might perceive an off-the shelf system as less desirable that a bespoke system that has been designed for them according to their own specifications and requirements. Notwithstanding these comments, both fishery departments collaborating on the project and members of SADC have expressed keen interest in the system (see below and Chapter 8).

1.6.2 Promotion of Outputs

Distribution of FTR, Software and User Manual

In addition to those required to satisfy DFID's contractual reporting requirements, it is intended, at least in the first instance, to send copies of the Final Technical Report, and the prototype PISCES software and User Manual to the following. Other copies will be made available on request:

DFID, Bangladesh
DoF, Bangladesh
CARE, Bangladesh
CNRS, Bangladesh

ICLARM, Bangladesh
MACH Project, Bangladesh
Fourth Fisheries Project, Bangladesh
EGIS Project, Bangladesh
SUFER Project, Bangladesh
Department for Environment and Coastal Resources, Turks and Caicos Islands
School for Field Studies (SFS), South Caicos.
Lake Uganda Project, DFID
SADC FIMS Project

Publications

No papers have yet been accepted for publication from this report. The following paper has been submitted for publication:

Craig, J.F., Halls, A.S., Barr, J. The Floodplain Fisheries of Bangladesh – A Review. Submitted to *Fisheries Research* October 2000.

The following paper is, at this time, in preparation:

Halls, A.S. and Lewins, R. The Fisheries of the Turks and Caicos Islands and Prospects for Co-Management.

Internal Reports

Two reports describing the case studies conducted in Bangladesh and the Turks and Caicos Islands referred to the main volume and appended in Volume II of this final technical report:

Information Systems for the Co-Management of Artisanal Fisheries. Field Study 1 - Bangladesh. MRAG Ltd, London, 1999, 337pp.
Information Systems for the Co-Management of Artisanal Fisheries. Field Study 2 - Turks and Caicos. MRAG Ltd, London, 1999, 115pp.

Dissemination Workshops

The results of the project were disseminated at the two case study locations between 4th and 19th December 2000 using a combination of workshops, presentations and demonstrations of the FIMS software aimed at target beneficiaries, other stakeholders, and the project's collaborators (Chapter 8).

The workshop in Dhaka, Bangladesh was attended by more than 25 participants representing NGOs, the academic community and international donor and development agencies. Overall, the project results were well received by all participants who expressed an opinion. Representatives of the EGIS project believed that the FIMS would be a valuable tool for the Department of Fisheries (DoF) in Bangladesh, and that the system's implementation should be encouraged.

Many participants supported the concept of learning lessons about (co-)management on the basis of spatial comparisons of standard, commonly-agreed management performance measures/indicators and those explanatory factors (co-management attributes) that are likely to affect performance (Section 6.6). Many participants representing NGOs recognised that whilst the FIMS is primarily aimed at fisheries departments, the system could also be used as a monitoring and evaluation tool to store and process data on local or small scale projects and studies. Most of the participants present requested to receive copies of the Final Technical Report and FIMS software so that they could explore the utility and applicability of the system for themselves in more detail.

A separate presentation and software demonstration was also given to the DoF at their headquarters. This was also well attended and received with many staff also expressing an interest to receive copies of the Final Technical Report and FIMS software. The department also expressed interest in being trained in the use of the software, and thought that the "best bits" of the software should be included in their future database systems.

Dissemination activities in the Turks and Caicos Islands (TCIs) were attended by staff from the Department for Environment and Coastal Resources (DECR) and other Government Departments. Unfortunately, stakeholders from the School for Field Studies (SFS), the processing industry, the Fisheries Advisory Committee (FAC) were not represented (Chapter 8).

The project results and outputs were well received by the participants, particularly those features relating to the automatic system to alert breaches to technical and licensing regulations. The DECR was also impressed by the flexibility of the FIMS with respect to meeting their reporting requirements and provision of data and information for stock assessment purposes. Some participants were sceptical about the appropriateness of co-management in the TCIs because they believe that communities have no interest in conservation and that resource boundary delineation would be problematic. Conditions to support co-management arrangements were believed only to exist in and around Salt Quay, a small, isolated island with few inhabitants and fishers (see Field Study 2 - Turks and Caicos Islands, Volume II). Others, on the other hand, were enthusiastic about the prospects for co-management and felt that the Department should consult the community more with a view to establishing co-management arrangements.

Mark Day, Director, DECR expressed considerable interest in installing the PISCES software in the Department to replace the existing, but no longer functioning, DataEase system (see Field Study 2 - Turks and Caicos Islands, Volume II). He intends to seek DFID development funds for a package to install and customise the FIMS, and to institutionally strengthen and train the Department in the use and application of the software. The prototype version of the PISCES software was installed in the DECR to provide an interim system to replace the DataEase system until a fully developed version of FIMS is installed at the Department.

1.6.3 Recommended Follow-Up Research

Further development of the PISCES software is required to provide the necessary fields and processing capacity to support the monitoring and evaluation of data relating to conflicts, the maintenance of traditional management practices, environmental data and employment in the harvesting (and processing) sectors. Further work is also required to improve the user interface and error checking functions. The system would also benefit from:

(i) some means of simplifying or automating the complex decision-making process surrounding the selection of the appropriate tables in the software for the four main catch and effort data collection scenarios,
(ii) an expanded range of pre-defined queries,
(iii) alternative file export definitions, and
(iv) an expanded range of fields and processing functions for socio-economic data.

The User Manual would also benefit from step-by-step tutorials to guide the user through each database table, feature and function. It is estimated that this further work would require approximately eight man-months of time to complete. No doubt further scope for improvements will be identified on the basis of feedback from users. An *FAO Fisheries Technical Paper* might be an effective medium to further disseminate the results of this research.

2. Introduction

2.1 Background

Artisanal fisheries are fundamentally important in the developing world. It is estimated that between 14-20 million people depend upon these fisheries for their livelihoods, and about 1 billion rely on them for their main source of animal protein (Pomeroy and Williams 1994). At the same time they are also tend to be very complex from resource, technical and institutional perspectives.

The management of artisanal fisheries resources to satisfy various objectives is an integrated process involving information gathering, analysis, planning, consultation, decision-making, and formulation and implementation of regulations or rules to govern fisheries activities.

Until recently, artisanal fisheries management has tended to focus upon maximising resource output using a suite of technical *operational rules* or regulations selected on the basis of deterministic (single-species) biological model-based predictions, set and enforced by a centralised (government) administrative authority.

Particularly in the developing world fisheries, where there is often a paucity of resources and institutional capacity to conduct (and interpret) formal assessments, and monitor and enforce rules and regulations among the widely dispersed resource users, this paradigm often fails to coordinate and restrain resource users, leading to depleted resources, inequity and conflict. Failure may also arise when the technical management models employed to guide decision-making processes are inadequate to capture the dynamic complexity of the fisheries.

Co-management, where the responsibility for resource management is shared between the government and user groups, is increasingly being seen as an effective strategy to redress these paradigm failures and thereby facilitate improved sustainable livelihoods. An adaptive or iterative approach to refining management strategies is often employed where resources and institutional capacity are scare, or where technical deterministic models are likely to fail due to the complexity and dynamic nature of the fishery.

Decision-making for fisheries policy-making, planning and (co-)management, relies largely upon processed information collected, in its raw form, from the fishery. Fisheries Information Management Systems (FIMS) or databases provide a means to hold and process these raw data, and facilitate flows of processed information.

A fundamental requirement of a FIMS is that they must hold all the data as they were collected in their primary, unprocessed form. This allows flexibility in the way the data can be processed (eg filtered, aggregated, sorted, transformed...etc) and ensure that all calculations are reproduced from source data incorporating all revisions. This also means that they should be integrated with the data collection strategy as far as possible (FAO 1999b).

Existing FIMS typically include information collected from the fishery itself but may also contain information required for implementing management instruments or administering the management strategy such as records of vessel details, surveillance information, and other information required for the general administration of the management system. There are two main approaches to developing a FIMS:

(i) Adapting a commercially available (off-the-shelf) system according to local requirements, or
(ii) Creating a custom system from scratch.

Each approach has own advantages and disadvantages. Adapting a commercially available system may have lower initial costs, but may prove costly in the long term because of increased maintenance requirements. Significant modifications may also be required to satisfy local conditions and requirements. These may cripple their intended function. Custom systems, on the other hand, are usually more costly to develop and require the presence and continuing involvement of skilled system developers, but can be configured to match closely the data collection strategy so that the system will be more efficient and easily accepted. Moreover, the use of common terminology and tools (data flow diagrams, task analysis...etc) during the development stage can be mutually beneficial to the design of both the database and data collection system (FAO 1999b).

The FAO have developed an off-the-shelf system for artisanal fisheries called ARTFISH. Although the system has been widely adopted in Africa for artisanal lake fisheries (for which it is particularly well suited), it is somewhat inflexible, largely geared to the storage and processing of catch and effort data, and contains no features to support co-management (Chapter 7).

A wide demand for artisanal FIMS's remains. Indeed, MRAG Ltd has received several requests for FIMS from fisheries departments, particularly in Melanesia. This may reflect limitations with respect to the suitability or adequacy of ARTFISH for the diverse range of fisheries that exist, or simply a reluctance to employ an off-the shelf product for the reasons described above.

2.2 Project Purpose and Other Outputs

As a means of attempting to satisfy this potentially large residual demand for off-the-shelf systems, this project was designed to examine the feasibility of developing a generic off-the-shelf FIMS that can support the (co-)management of a diverse range of artisanal fisheries exploiting both marine and freshwater systems. The project also sought to develop a generic data collection system to support the FIMS, estimate unit costs (and national costs at case study sites) of implementing the system, produce supporting documentation and training material, and conduct demonstration workshops in the use and application of the system.

It should be borne in mind that although fisheries departments are usually the main body responsible for collecting, processing and interpreting data to aid fisheries decision-making, other government departments or ministries may also have an important role in this respect. However, given that it would be impossible to anticipate the range of government structures that may exist among different countries or states and the roles and institutional capacity of their respective departments, the project was restricted to examining the feasibility of a system aimed primarily for use by fisheries departments or ministries.

2.3 Research Approach and Activities

Generic systems usually evolve through experience or on the basis of case studies. The project purpose and outputs were pursued on the basis of a combination of a literature review, company experience, and comprehensive case studies of two widely different fisheries (detailed in Volume II): the inland artisanal fisheries of Bangladesh, and the coastal marine fisheries of the Caribbean Turks and Caicos Islands. Six main research activities were planned:

(i) Identification of generic data requirements (processed outputs).
(ii) Identification of generic inputs (raw inputs/data for processing).
(iii) Development of the generic FIMS and testing with the case study fisheries data.
(iv) Evaluation of the unit costs of implementing the FIMS and the national cost of implementing the system at the case study sites.
(v) Production of training material and supporting documentation.
(vi) Dissemination of project results and training (demonstrations) in the use and applications of the generic FIMS software at the case study sites.

2.4 Institutional Collaborations

With a central project base at the Marine Resources Assessment Group, London, UK, collaborations were established with local research institutions, non-government organisations (NGOs) and relevant government departments and ministries at each case study site (See Field Study Reports 1 & 2 in Volume II of this report) to help identify co-management data and information requirements, provide administrative and fieldwork support, and to help disseminate the results of the project to target stakeholders.

In Bangladesh, formal collaboration was established with the Centre for Natural Resource Studies (CNRS), and CARE Bangladesh. Attempts were also made to establish informal collaboration with the Government of Bangladesh (GOB) Department of Fisheries (DoF). Logistic support and advice was also provided by DFID's Field Management Support (FMS) Office, and the British High Commission.

During the field visit, several other NGOs including; USAID (Dr William Collis); Caritas (Mr Nazmul Alam); ICLARM (Dr Paul Thompson; Mr Manjur Kadir); Proshika (Mr Abdur Rahman); BRAC (Mr Mokkarum Hossain) were visited in order to help identify community management objectives and data requirements.

In the Turks and Caicos Islands, formal collaboration was established with the Department for Environment and Coastal Resources (DECR), Grand Turk. Informal collaboration was also established with the School for Field Studies (SFS) and the Fisheries Advisory Committee (FAC).

2.5 Report Structure

This final technical report comprises two volumes and a software user manual. The main Volume I comprises nine chapters and six annexes. Volume II documents the two case studies conducted in Bangladesh and the Turks and Caicos Islands referred to the main volume.

Chapter 1 of this main volume provides a brief summary of the work, in the format required by DFID for Final Technical Reports. Chapter 2 provides the background and rationale for the study and an overview of the research approach and activities, including details of institutional collaborations, personnel and authorship of this report. Chapter 3 examines in detail how differences among co-management arrangements will influence fishery information requirements. It proposes an idealised co-management arrangement based upon a sharing of management responsibility for discrete 'management units', both spatially and hierarchically. This provides a meaningful basis upon which to develop the generic FIMS. Chapter 4 then identifies generic information requirements (outputs) from the FIMS to support the roles and responsibilities of the main stakeholders under this proposed arrangement including feedback mechanisms. Raw data and how they are processed to provide these data requirements dictate the design of a fisheries database. Chapter 5 therefore explores how these raw data (inputs) might vary among fisheries, and concludes that this will be dependent upon the data collection strategy which in turn will be dependent upon by local conditions. The design or identification of a generic data collection system/strategy as a means of identifying generic raw data, and thereby the generic database, was therefore rejected. Chapter 6 pursues an alternative means of identifying generic raw data on the basis of common 'data fields' used in artisanal fisheries data collection forms and databases for the main categories of required information. Having identified these fields, Chapter 7 describes the development of the generic datamodel and database and examines the utility and validity of the design using data collected from the case study fisheries. Chapter 8 describes the dissemination activities at the two case study sites. Finally, Chapter 9 summarises the project findings and draws conclusions about the utility and applicability of the system. Recommendations for further work are also discussed.

2.6 Personnel, Authorship and Acknowledgments

2.6.1 Personnel

This research was undertaken by the following personnel:

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Mr Crag Jones (Consultant IT Specialist)
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Government of Bangladesh, Department of Fisheries, Dhaka, Bangladesh

Dr Mokkamel Hossain (Director, Community-Based Fisheries Management Project)
Dr Nassurudin Ahmed (Director, Fisheries Resources Survey System, FRSS)
Dr Rhakal Chandra Banik (FRSS)

Department for Environment and Coastal Resources, Grand Turk, Turks and Caicos Islands

Mr Mark Day (Director, DECR)
Ms Michelle Fulford (Deputy Director, DECR)
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Mr Perry Seymour (Fisheries Officer)
Ms Linda Grinton (Database Clerk)

2.6.2 Acknowledgments

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2.6.3 Authorship

This Final Technical Report was written by Dr Ashley Halls, Mr Roger Lewins and Mr Crag Jones. The last two authors were responsible for all the socio-economic and IT sections, respectively, including:

Mr Roger Lewins	3.4	Co-Management
	3.4.1	A Typology for Co-Management
	4.3.2 B	Socio-Economic Objectives, Evaluation Criteria...
	4.3.4 B	Socio-Economic Objectives and Reference Points
	4.9.2	*Common Objectives & Management Performance*.... *Community Management Performance Indicators* *Negotiated Indicators*
	6.2.6	Socio-economic data
Mr Crag Jones	7	All Sections
	8.2.2	Software Demonstration at CARE
	8.2.3	Presentation and Demonstration at DoF
	8.3.3	One-Day FIMS Software Demonstration
	8.3.4	Interim System training
	User Manual	All Sections

3. FIMS Design Considerations

3.1 A Systems Approach to Design

In line with DFID's Natural Resources Systems Programme Strategy (DFID 1999), a *systems approach* is used here to help identify and address the design issues for a generic co-management FIMS in the development context. By taking full account of the technical, economic, social and institutional issues and their interactions, this approach will ensure an effective and meaningful design of a system to support and promote sustainable livelihoods in the artisanal fisheries sector.

A particularly useful and well established framework for studying common pool resource (e.g. fisheries) systems and their management is the Institutional Analysis and Development (IAD) framework developed by the Workshop in Political Theory and Policy Analysis at Indian University, USA. This framework has theoretical foundations on game theory, neoclassical microeconomics, institutional and transaction cost economics, political economy and public choice. The framework has been widely employed in the fisheries sector as a generic tool for documenting, evaluating and comparing artisanal fisheries management systems and co-management arrangements Berkes (1992); Nielsen *et al.* (1995); Pido *et al.* (1996).

The framework emphasises the relationship between the contextual variables (physical, biological and technical attributes) of the resource system and the institutional setting (decision making arrangements), how these affect patterns of interaction and incentives to cooperate and coordinate, and in turn, how this determines outcomes in terms of efficiency, equity and sustainability (Figure 3). Emphasises is given to the continuous and dynamic nature of the process (Oakerson 1992; Nielsen *et al.* 1995).

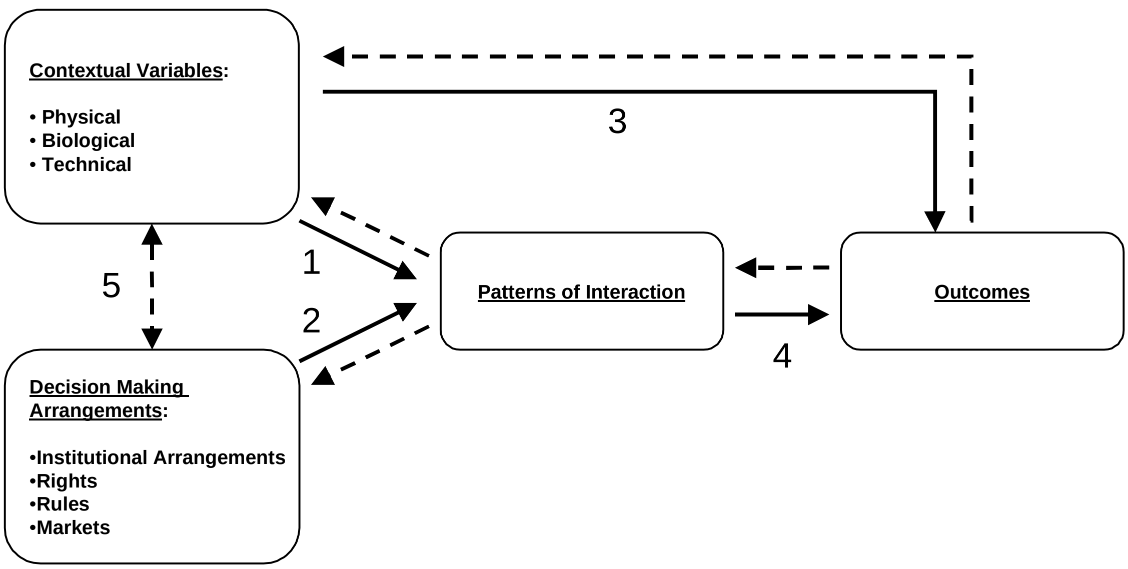

Figure 3 Framework for the analysis of common-pool resource management (adapted from Oakerson (1992) and Nielsen *et al.* (1995))

The following descriptions and explanations draw heavily from Oakerson (1992).

Contextual Variables

The problems of common pool resource management are rooted in the constraints of the physical or biological resource and the available technology to exploit it. These variables directly and indirectly affect outcomes. Important attributes of the resource are (i) *subtractability*: the capacity of the resource base to support multiple users at the same time without reducing the yield of the resource available to all (e.g. how many fishers can fish with using different gear types without affecting each others, or the overall, catch?); (ii) *excludability*: the degree to which the resource permits the exclusion (control of access) to fishers (e.g. migratory and sedentary fish species) and (iii) *divisibility*: the extent or scale to which the resource can be, or should be, divided among fishers without impairing, or to achieve, effective management. For example, migratory fish stocks in lakes are indivisible and therefore may be best managed as an single resource. Lakeshore sedentary resources, however, could be divided into, and more effectively managed in, smaller *management units* (see later). These contextual variables ultimately limit outcomes (arrow labelled 3), independent of human action, but can simultaneously affect them through *patterns of interaction* (arrow 1).

Decision Making Arrangements

Decision-making arrangements are effectively the rules that structure individual and collective choices with respect to the exploitation of the (fishery) resource or *management unit* in order to achieve various management objectives or outcomes. These arrangements specify *who* decides *what* in relation to *whom* and include legal, political and economic factors *(external arrangements*) that will influence decision making. Oakerson sub-divides these arrangements into three hierarchical categories: (i) *operational rules*; (ii) *conditions for collective choice* and (iii) *external arrangements*. *Operational rules* are nested in *collective choice rules*, which are nested in *external arrangements*.

Operational Rules

Operational rules limit exploitation to maintain yield from the resource or meet other objectives agreed through collective choice (see below). In fisheries resource management, these operational rules set out how, where, when and by whom resources may be harvested. These rules have important implications for determining both the outcome of management objectives and the distribution of benefits. For example, banning the use a particular gear type may improve the overall yield from a fishery, but may displace certain groups or users from the fishery. Operational rules also include who should monitor and enforce rules and how, what sanctions will be applied for non-compliance and what information should be collected and exchanged. Operational rules are also the easiest facet of the decision-making arrangements to describe (and change) and therefore usually feature strongly in any prescriptive analysis of a resource system (Anderson *et al.* 1997).

Conditions for Collective Choice

The *conditions for collective choice* determine the rules for *how* decisions regarding the management of the resource are made. That is, who is eligible to make decisions and on what basis are they made. The specific form of these conditions will generally be determined by the cultural or social traditions. In some cases a single individual (eg village head or tribal chief) may hold responsibility for decision making (Anderson *et al*. 1997). In other cases, decisions may be made through a community management committee representing the interests of different stakeholders or ethnic groups, or by the fisheries department of a democratically elected government. In the latter case, decisions regarding the management of the fishery may be made on the basis of technical (theoretical) management models supported by detailed data and information collected through a formal monitoring system. At the other extreme, decision making within traditional or community-based management systems may simply rely on what is perceived to be successful, or on the basis of informal common-knowledge discussions among fishers (see later).

Who is involved in the decision making process is critical for compliance. Individuals not involved in the decision making process are less likely to comply if their aspirations are not represented in operational rules. Compliance may therefore be problematic in heterogenous communities, where consensus is difficult to achieve.

Given their often cultural context, conditions for collective choice normally relate not only to fishers, but to a wider arena and are, therefore, much harder to change than operational rules (Anderson *et al*. 1997).

External arrangements

Management objectives and the set of rules devised to achieve these objectives often cannot be perused or established in isolation of the wider political, legal, and market environment. External arrangements may determine who is eligible to make collective choice or operational rules and the types of rules that are permissible. They may also determine who has collective choice rights.

External arrangements may take the form of international conventions and codes of conduct (eg UNCLOS III, Code of Conduct of Responsible Fisheries) that define management obligations and therefore should be reflected in national and local policies. They may be the legislation necessary to establish the capability of local communities to engage in collective choice (eg the creation of local management committees), the enforcement of operational rules by external officers, or third-party arrangements (eg courts) to resolve disputes between resource users.

Markets arrangements will also be important in determining the economic parameters within which management of the resource is undertaken. For example, the seasonality of fish prices may greatly influence when a fishery might be ‘closed’ to conserve the resource.

Patterns of Interaction

Patterns of interaction describe the behavior of individuals when faced with the physical, technical and biological attributes of the resource system, and the decision-making arrangements (the rules) employed to govern its exploitation (arrows 1 & 2). Individuals perceived costs and benefits associated with rule compliance will determine their *incentives to cooperate* (or compete) and coordinate (or act alone). Incentives to cooperate may be influenced by many factors; (i) the availability of alternative livelihoods or sources of income; (ii) the opportunity costs associated with fishing; (iii) the effectiveness of enforcement measures and the severity of sanctions for non-compliance; (iv) support for the decision-making arrangements as determined by belief and degree of representation in the arrangements, and (v) the prevalence of free-riders (eg degree of poaching) or inequity in the distribution of benefits that can undermine collective effort (reciprocity) to comply with regulations. As illustrated above, patterns of interaction will also be affected by the biophysical nature of the resource (arrow1).

Outcomes

The patterns of interaction produce outcomes from the resource use (arrow 4). These outcomes include the yield from the resource, the distribution of benefits among stakeholders and the biophysical effects of fishing activities. These outcomes are typically the subject to human monitoring and evaluation, temporally and often spatially typically corresponding to issues of efficiency, optimality, sustainability, amelioration or deterioration and equity, and reflecting management objectives.

The hatched arrows in Figure 1 denotes that dynamic interaction exits among the four attributes. That is, outcomes may change the contextual variables and affect patterns of interaction. The former may occur due to resource depletion or environmental degradation, whilst the latter occurs with learning, causing individuals to modify their *operational rules* or management strategies to produce better outcomes on the basis of their objectives. Similarly, individuals may employ different technology, such as less destructive fishing gears or invest in stock enhancement programmes that would change the contextual variables. The achievement of dynamic congruence between the decision making arrangements and the contextual variables (arrow 5) in order to achieve desired outcomes or objectives is the essence of fisheries management.

3.2 Fisheries Management - the process, roles and responsibilities

The framework described above usefully identifies the overarching role of fisheries management and effectively demonstrates the complexity of the process. However, at this stage it is also convenient to summarise, in more formal terms, the process of fisheries management and the main roles and functions required to support it.

The fisheries management process has been defined by FAO (1997) as being: "The integrated process of information gathering, analysis, planning, consultation, decision-making, allocation of resources and formulation and implementation, with enforcement as necessary, of regulations or rules which govern fisheries activities in order to ensure the continued productivity of the resources and accomplishment of other fisheries objectives".

The process of fisheries management requires a number of roles to be performed:

1. Setting policies or objectives for each fishery, resource or *management unit* (see later). These must take into account as far as possible, the often conflicting biological, economic and social objectives of the various stakeholders who will be affected by the management of the resource and the overriding objectives of national planning and policy. For example, maximising economic returns from a fishery may be incompatible with maximising employment opportunities. A compromise may be required in order to achieve maximum compliance and cooperation from all stakeholders.

2. Formulation of management plans (MPs) for each fishery, resource or management unit to meet the management objectives. These are formal or informal arrangements between the management authority and other stakeholders which set out:

- Details of the stock, resource or management unit being considered.
- The agreed objectives.
- The decision making arrangements including:
    - (i) Stakeholder roles and responsibilities.
    - (ii) The management strategy - management rules and regulations (operational rules) applied to realise the objectives, including details of monitoring, control and surveillance (see below).
    - (iii) Decisions making methods; criteria upon which decisions and management regulations will be based, evaluated and adjusted as necessary (conditions for collective choice).
- Other relevant details about the fishery.

These management plans effectively serve as a reference and information source for those stakeholders involved in the management of the resource, summarising the state of knowledge of the resource, its environment and the fishery, and the management decision-making arrangements ie who may do what in relation to whom. The development and implementation of management plans for all resources or management units promotes a coordinated spatial approach to management, whereby interactions and externalities among units can be monitored, evaluated, and ultimately avoided.

The operational management plan may also detail the costs and benefits in order to justify the expenditure on the various components of the management system. Costs may include administration, and staff and capital equipment for monitoring, evaluation, control and surveillance. Benefits are often less easy to quantify, particularly where they result in social or conservation rather than economic returns (Mees 1998).

3. Implementing Management Plans (Monitoring, Control and Surveillance, MCS).
This involves the action and decision-making required to ensure that the management plan is put into operation and operates efficiently. These include monitoring (collecting), collating and analysing the data and information necessary to evaluate the performance of the management strategy in relation to the broader decision-making arrangements and contextual variables, and enforcing the control mechanisms (management regulations that control exploitation by controlling inputs or outputs) through surveillance operations.

4. Reviewing Management Plans
As illustrated in Section 3.1, both the contextual variables and the decision-making arrangements will change with time. This demands that the effectiveness and efficiency of the management plan be regularly evaluated with revisions as necessary. This review process in relation to desired outcomes and objectives forms the basis of adaptive management strategies (see later).

5. Other roles to facilitate and support the management process

Other roles required to facilitate the management process include:

- Develop national fisheries policy and coordinate planning decisions:

National fisheries policy describes the broad directions on how resources are to be utilised and the priorities to be given and criteria by which access to resources is granted. These decisions are made in the macro-policy and macro-economic (multi-sectoral) context and include the coordination of fisheries with other sectors of the economy having an impact on the fishery. It is therefore important that policy and planning decisions are made in the full knowledge of the role of fisheries in the regional, national and local economy, and the implications, costs, benefits and alternatives for use of the resources, before the best policy decisions can be made.

- (Inter-)national reporting responsibilities

The development of effective and efficient national fisheries policy therefore demands information to provide a clear understanding of the position and status of fishing in the regional, national and local levels. This information may include, for example, information on the catch, economic value (export duties, licence fees... etc) and employment opportunities for each fishery, social group or geo-political area. Information is also needed to assure the public at large that resources are managed responsibly and that management objectives are being achieved (FAO 1997). Information may also be required for organisations and conventions such as the United Nations Food and Agriculture Organisation (FAO), Convention for International Trade in Endangered Species (CITES) or Ramsar (Sections 4.6 & 4.7).

- Compliance with International Management Responsibilities

Governments often have international responsibilities for the management of resources. These *external arrangements* often take the form of international conventions and codes of conduct (eg UNCLOS III, Code of Conduct for Responsible Fisheries), which if ratified, define management obligations that should be reflected in national and local policies (Section 3.1).

- Establishment of an appropriate legal and institutional frameworks (conditions for collective choice) for management.
- Conflict Resolution

Fishery managers will often need to resolve conflicts by means of external arrangements (see Section 3.1), either between different fisheries or between fisheries and other sectors that have an impact on the fisheries (eg agriculture, transport, industry... etc).

- Conduct ad-hoc research

In addition to the routine collection of information collected under MCS programmes to evaluate the performance of the management strategy, *ad hoc* research or assessments may be conducted to improve the understanding of the fishery and to help develop management plans.

- Provision of technical advice

A technical understanding of a fishery can be gained through traditional knowledge (often detailed and specific to a particular area) and scientific knowledge gained through *ad hoc* research and MCS programmes. Technical guidance contributes to the assessment of the fishery and the development and implementation of management plans.

- Communication

Effective communication is required to build trust among stakeholders and encourage their continued participation in the co-management partnership. The exchange of information is also important to develop, maintain and improve the fisheries management process. A variety of different mediums of communication exist including meetings, posters, radio transmissions (Muthiah 1991), workshops, newsletters...etc.

3.3 Artisanal Fisheries

Artisanal fisheries are generally characterised by the small-scale use of low technology fishing gear, over a limited range, often, but not always for subsistence needs. This contrasts with industrial fisheries which generally employ higher technology over greater ranges, predominantly for commercial purposes. This division is often subjective, and what is considered artisanal in one country, may be considered industrial in another (Nielson *et al*. 1995).

Artisanal fisheries are mostly associated with developing countries. Developing countries are typically tropical or sub-tropical where species diversity is high and geographical range relatively small. Artisanal fisheries therefore tend to be based upon numerous small stocks and multispecies assemblages inhabiting diverse habitats (Mahon 1997). Some tropical river systems contain more than 200 species of fish and crustaceans with a range of different life histories and migratory behavior (Hoggarth *et al*. 1999). The diverse range of habitats and species are reflected by an equally diverse range of fishing gears and operations. For example, the inland fisheries of Bangladesh are exploited with more than 100 different types of gear (FAP17 1995), many specific to local conditions and (hydrological) seasons of the year. Fishers may be full-time professionals, often working as groups with expensive fishing gear, or only part-time, perhaps working on their own with more simple gear. Part-time fishers may alternate seasonally between fishing and other occupations, such as agricultural labouring. In poor, heavily populated countries where the opportunity costs of fishing are very low, the numbers of fishers can rise to exceptionally high levels (Hoggarth *et al*. 1999). Pomeroy and Williams (1994) estimate that in the developing world, between 14-20 million are directly involved in fisheries (and aquaculture), and about 1 billion rely on protein from aquatic products as their main source of animal protein.

In contrast with many temperate commercial or industrial fisheries, artisanal fisheries therefore tend to be very important from a socio-economic perspective, diverse, complex and dynamic.

3.4 Co-Management - the Search for better methods

The western (temperate) paradigm of fisheries management has tended to focus on maximising resource output using technical *operational rules* or regulations on the basis of quantitative (single-species) biological model-based predictions, set and enforced by a centralised (government) administrative authority. By largely ignoring *patterns of interactions* (fishermen behavior), *conditions for collective choice* and *external arrangements* (and their interactions), this paradigm has often failed to coordinate and restrain resource users, leading to depleted resources, inequity and conflict (Mahon 1997; Pomeroy and Williams 1994).

The failure of this paradigm is particularly prevalent in artisanal fisheries in developing countries; commonly exacerbated by the states paucity of resources and institutional capacity to conduct (and interpret) formal assessments, and monitor and enforce rules and regulations among the widely dispersed resource users. Often, the technical management models employed to guide decision-making process are inadequate to capture the dynamic complexity of the fisheries. Fisheries management experts now recognise that the underlying causes of fisheries resources over exploitation and environmental degradation are often of social, economic and institutional origins.

During the 1960’s and 1970’s, government and NGOs rural development programmes placed increasing emphasis on the role of the community in fisheries management. The incentives for this approach were numerous but government willingness to devolve difficult or expensive management responsibilities and the local-level desire for empowerment helped fuel the process (Hassett 1994). A huge literature has been developed reviewing past experiences and prospects for community-based management in agriculture, fisheries and forestry, together with a theoretical treatment of the benefits to be derived from a community approach. Frequently cited advantages of community management include:

- Increased sense of ownership encouraging more responsible exploitation.
- Policy and practice are sensitive to local socio-economic and ecological constraints;
- Appropriate and relevant policy is honed by local knowledge and expertise;
- Participation in decision making engenders a collective ownership ethic;
- Increased compliance through perceived legitimacy and local peer pressure; and
- Greater incentives for reliable monitoring via the user.

Community-based development projects often placed an emphasis on consolidating traditional management practices and the accompanying systems of use rights, but with the globalization of markets and increasing pressure on the resource base it was clear that government had a fundamental role to play in co-ordinating initiatives and representing rural needs nationally and internationally.

As the rural development debate of the late 1970’s placed greater emphasis on government/resource-user relations, the term “co-management” evolved to represent an idealised balance of rights and responsibilities between the State and stakeholder. Despite lacking a universal definition, co-management became a central theme in much of the fisheries policy literature regarding both developing and developed world scenarios (e.g. Pomeroy and Williams 1994; Phillipson 1996).

An Economic Rationale for Co-management

The study of common property predicts that resources such as fisheries, which are non-exclusive in nature, will suffer from problems of regulation and from subtractability (e.g. Feeny *et al* 1995). By definition, limiting access to the resource is difficult and costly and the behavior of each actor will detract from the welfare or utility of others. Management institutions evolve or are devised to regulate and control access to the resource and prevent an unacceptable dissipation of rent or benefits from the resource. Pomeroy and Berkes (1997) identify three basic regimes for this purpose: a) state ownership and governance where rights are controlled by government on behalf of all citizens; b) communal property where the resource is held by an identifiable group that can exclude others and can self-regulate; and c) private ownership where an individual or corporate body has the right to exclude and regulate resource use. Pomeroy and Berkes accept that overlapping combinations of all three systems are likely to be found but claim that the co-management relationship is based on interaction between a state system and communal system of management.

The rationale and functioning of state ownership and private ownership systems has been elaborated in the "theory of the state" Ostrom (1990) and the "theory of the firm" (after Coase 1937). As Ostrom indicates, in both systems the users are co-ordinated and impelled to maximise collective output from the resource, either through compulsion and coercion by the state or through voluntarily entering a contract with an entrepreneur. With respect to state management these gains and the performance of the fishery may be measured against a variety of predetermined criteria such as maximum economic yield, maximum employment or issues of social equity, while private management success is determined through the market performance of that firm. Ostrom illustrates how both systems suffer from the "problem of credible commitment" whereby the benefit to the actor in cheating within a functioning system will tend to outweigh net gains from compliance. Co-management can be viewed as an attempt to increase the incentive to comply by blurring this fundamental distinction between managers and the managed. Certain management responsibilities, together with their potential local benefits and risks, will have effectively been leased to the users but ultimately the resource will remain *res publica* and the state will hold the veto on any arrangements brokered.

3.4.1 A Typology of Co-management

Sen and Nielson (1996) provide a useful typology of co-management based on the level and mode of communication between government and the resource user (Figure 2). A spectrum exists between paternalistic "instructive" arrangements, with minimal exchange of information between government and user, to "informative" arrangements whereby users are delegated decision making power but inform government of change. Within this gradation Sen and Nielsen identify a "co-operative" mid-point as a desirable goal and loosely define fisheries co-management as:

"..an arrangement where responsibility for resource management is shared between the government and user groups."

A graded treatment of co-management is enlightening because it highlights the range of interactions that might be found and the probability that they will differ from country to country and even between fisheries or *management units*. In addition, while the focus of most co-management literature is the nature and shape of institutional hierarchies within countries, the above model approaches the relationships in terms of pathways and directions of information flow. Co-management might be supported by smoothing this flow of information - both of data and of dialogue or "conferral" information (see Alsop and Farrington (1997)).

Numerous fisheries (or aspects of fisheries) can be considered co-managed according to such an open definition and these systems of management can be well established. The inshore fishery of Japan is managed on a hierarchical and national system that has evolved gradually from institutional structures delineated during the feudal period (Balland and Platteau 1996). The legitimacy of the fishermen's guild as the body responsible for decisions regarding local access and fishing techniques was codified in law as early as 1719.

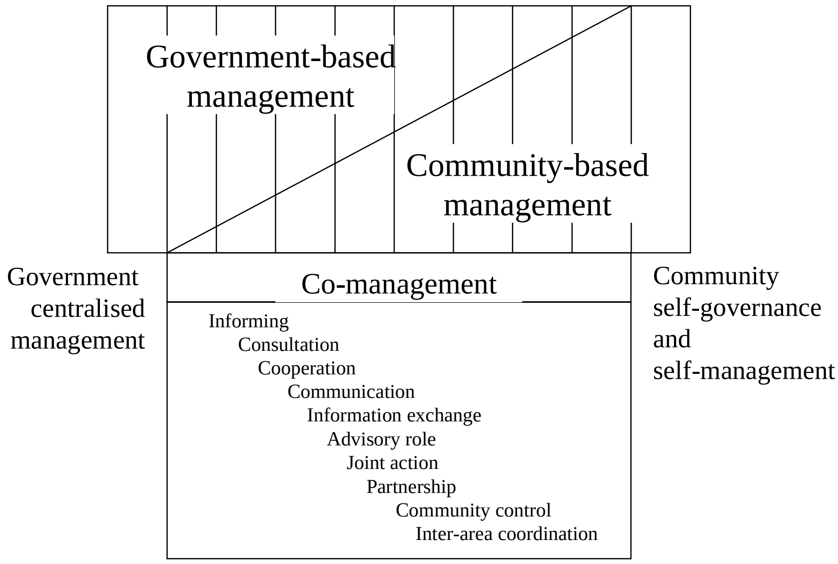

Figure 4 The 'Berkes hierarchy' of co-management arrangements (after Pomeroy and Williams 1994)

3.4.2 Co-Management of Artisanal Fisheries

The range of relationships between government and resource user reflect institutional and bureaucratic arrangements, user representation, political will and ultimately the desirability of partnership. For this reason co-management in the context of artisanal fisheries may involve quite different systems and patterns of interaction from those of industrial fisheries. Whereas these relations in the developed world tend to receive relevant bureaucratic and legal support and are contractual in nature, co-management in the developing world may be locally contained, piecemeal and a more ad hoc process. If politicised and unified user groups are absent, NGOs may play a critical role in articulating and representing local objectives and concerns by reacting to current policy, or through incorporation into national policy frameworks as in Bangladesh and the Philippines, respectively.

The constraints to achieving a co-management process in artisanal fisheries will reflect the current and historic nature of government and bureaucracy in the country in question. Both government and users may have to re-learn their roles and this process will be problematic where a top-down system of patronage has operated. Kuperan and Abdullah (1994) have ranked the prospects for successful co-management in eight south-east Asian countries by incorporating such factors as pre-existing local organisational capacity, ethnic diversity, geographic spread and the distribution of existing marine tenure systems. Significantly, government commitment was considered fundamental and the Philippines ranked first on the basis of that country's national mandate towards decentralisation and the legislation already in place to support a hierarchical and locally-inclusive frame for management (see Pido *et al* 1995).

3.4.3 Conditions for Successful Co-management

On the basis of research conducted during the last two decades, certain conditions emerge which appear central to developing and sustaining successful co-management arrangements (Pomeroy and Williams 1994):

- Clearly defined boundaries
- Membership is clearly defined
- Group Cohesion
- Organisational capacity exists
- Benefits of participation must exceed costs
- Individuals affected by management arrangements are included in decision-making
- Management rules are enforceable by resource users
- Legal frameworks exist that give users ownership over resources and authority to make management decisions.
- Cooperation and leadership at the community level exist
- Decentralisation and delegation of authority
- Coordination between government and local community.

3.5 Identifying Generic Co-management Information Requirements - a dynamic multi-dimensional problem

3.5.1 What information is required?

Management information is defined here as the information and data required to support management roles and responsibilities in order to achieve the dynamic congruence between the decision making arrangements and the contextual variables described in Sections 3.1 & 3.2. Arguably all management roles require information in one form or another since they all involve or support some form of decision making. However, four main roles, already introduced in Section 3.2, are particularly reliant upon data and information:

(i) The formulation of management plans;
(Ii) The implementation and review of management plans:
    Data and information collection (monitoring),
    Evaluating the performance of management strategy,
    Enforcement of management regulations
(iii) The development of national policy and the coordination of planning decisions
(Iv) (Inter-)national reporting responsibilities.

3.5.2 How might information requirements vary?

The actual information that is required to manage the fishery will depend upon *who* has responsibility for each role and on *what basis* decisions are made. Three major categories of *stakeholders* or individuals, groups, or organisations with an *interest* or *stake* in the fishery (Hoggarth *et al.* 1999) will usually take responsibility for one or more of these roles:

- Government departments eg Department of Fisheries
- Intermediary organisations eg NGOs; donor projects, research institutes etc
- Fisher communities

Government departments will invariably take on the (inter-)national reporting responsibilities, the development of national policy, and the coordination of planning decisions. However the formulation and implementation of management plans may be undertaken (to some degree or another) by all three stakeholders (Table 1).

Table 1 Potential roles and responsibilities for the main stakeholders of a fishery

Stakeholder	Management role					
				Implementation of MP		
	National Policy & Planning	Reporting Responsibilities	Formulation of MP	Monitoring	Evaluation	Enforcement
Government	✓	✓	✓	✓	✓	✓
Intermediaries			✓	✓	✓	
Fishers			✓	✓	✓	✓

Who actually takes on these respective roles is determined by the position of the fishery on the Berkes co-management spectrum (see above). To illustrate the complexity of the problem of trying to identify generic information requirements, there are more than 1000 combinations of stakeholder roles with respect formulation and implementation of management plans in Table 1 alone even before consideration is given to the type of information that may be employed among and within the stakeholder categories and the extent of their involvement! Moreover, these roles may well change with time as the co-management arrangements evolve.

Potential Variation in data and information requirements

Several factors affect data and information requirements to develop and implement management plans. To begin with, the objectives for the fishery set out in management plans will vary among and within stakeholder groups depending upon their interest or stake in the fishery. Government objectives and policies are usually broad-reaching taking account of international responsibilities and national aims such as the protection of biodiversity, the alleviation of poverty, or the amelioration of landings. Local fisher communities may have more defined objectives such as improved food security or income. These different objectives will demand different information to evaluate the success or extent to which they are being achieved. For example if the management objective was to maximise the catch of fish species X, then obviously it would be necessary to monitor the catch of species X (the outcome) or some proxy or *indicator* of catch such as the availability or price of fish, or the number of fish meals consumed by a villager each week. Similarly, if the objective was to conserve biodiversity, then it would be necessary to monitor the abundance of all fish species or some proxies. What is actually monitored, particularly with respect to proxies or indicators, will therefore also be closely related to management performance evaluation criteria or decision-making method.

The way in which the performance of a management strategy is evaluated, that is decisions about how best the operational rules, decision-making arrangements and contextual variables may be changed, improved, adjusted or enhanced to achieve desired outcomes or objectives, as set out in the MP, will also dictate data and information requirements. Arguably, information on all four of the attributes described above is necessary for this role.

At the simplest level are what may be termed *default* or *status indicators* and their *proxies*. These describe the basic outputs, outcomes or present states arising from a particular management strategy or policy, and can be used to monitor change or trends. Although measuring and monitoring such simple outputs or outcomes is necessary, they have limited value from an active management perspective. Such basic information cannot, by itself, inform managers whether or not the particular outcome can be improved or increased, or what measures could be taken to make improvements.

To reconcile this problem, decision-makers frequently employ frameworks or models which, in addition to the outcome (outputs), may also include information relating to inputs, and factors affecting both inputs and outputs to improve understanding and decision-making. These may take a variety of forms including (i) cognised (conceptual) models of the fishery[3] developed through perception, reasoning, intuition, or even superstition; (ii) empirical models developed on the basis of experience or *adaptive management*; and (iii) theoretical (technical) models of the fishery. These frameworks and models are expressed verbally, graphically, physically or quantitatively.

The technical models are typically quantitative and often based upon theories of population dynamics and economics (biometric and econometric models) . They attempt to generalize the fishery, often in terms of variables that can be controlled by operational rules or external arrangements(eg allowable fishing effort, mesh sizes, economic (dis) incentives), and outcomes (eg catch or economic rent). In this way they may be regarded as "theoretical laboratories" for exploring interactions in fisheries systems (Padilla and Charles 1994). However, as stated earlier, the utility of technical models from a management perspective is often limited by their failure to take account of *patterns of interaction* (fisherman behavior), *conditions for collective choice* and *external arrangements*, and their ability to successfully accommodate aspects of the contextual variables, particularly environmental affects, which can be both significant and complex in dynamic, heterogenous environments such as floodplain river systems. Many of these technical models demand large amounts of costly information or data generated through research or fishery assessments to estimate their, often numerous, parameters.

The different stakeholders will employ different decision-aiding models or frameworks depending upon their objectives, preferences and (institutional) capacity (their resources, skills, knowledge, motivation and legal rights). Their information and monitoring requirements will therefore vary accordingly. For example, local communities might employ informal cognised models, whilst fishery departments are more likely to have the capacity to collect, collate and analyse data and information to support a more formal technical models. On the other hand, intermediaries, such as NGOs, may have the capacity to employ frameworks such as Oakerson to examine patterns of interaction (fisher behavior) under various conditions for collective choice in order to provide advice to the other main stakeholders on the most appropriate organisational or institutional arrangements to achieve various outcomes.

In reality, it may be necessary or useful to employ a variety of these different models and frameworks together to gain a greater understanding of the fishery and to improve overall decision-making.

The choice of management control measures (Annex 1), to realise the management objectives will also affect data and information requirements, which are often optimised using technical management models. For example, management controls aimed at regulating fishing effort or total catch are often optimised using surplus production type models which have very different data and information requirements to that of age-structured models commonly employed to explore optimal technical regulations such as minimum mesh sizes to limit the age of fish at first capture (see later). Local conditions may dictate which control measures are appropriate and enforceable.

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[3]This category would include the Oakerson (1992) framework.

Information is also required to enforce operational rules (management regulations). When enforcement is the role of a fishery department, this information may be quite formal, such as lists or registers of vessels detailing who may fish where with what gear or vessel. Local communities would more likely enforce rules on the basis of common knowledge.

In summary the, information requirements to support the management process will therefore be largely influenced by:

- The position of the fishery on the Berkes spectrum (Figure 2) which will determine which stakeholders are involved in the development and implementation of management plans;
- the objectives of these stakeholders;
- the management control measures;
- their decision-making methods;
- their institutional capacity, and;
- their preferences and local conditions.

The continuous spectrum and evolutionary potential of co-management arrangements, coupled with the inter-dependence among several of the factors identified above, presents a potentially dynamic and multi-dimensional problem to identifying management information requirements and therefore to designing a FIMS.

3.6 Constraining the Problem - a potential solution

In order to provide some basis with which to begin to examine management information requirements for a generic co-management FIMS, there is clearly a need to constrain the independent dimension (variable) - that is, the position of the fishery on the Berkes spectrum.

Sen and Nielsen (1996) suggest that a co-operative mid-point along this spectrum is desirable where responsibility for resource management is shared between the government and user groups. Hoggarth *et al* (1999) propose a co-management system based around this position which effectively matches the main stakeholders, with the necessary motivation and institutional capacity, to the various management roles. This is achieved by sharing management responsibilities for *management units* both hierarchically and spatially. Although the system was originally conceived for the co-management of artisanal tropical floodplain-river fisheries, it's inherent flexibility permits a wider application to other environments and fishery types.

3.6.1 Management Units

Hoggarth *et al.* (1999) sub-divide river systems into four main categories of management unit based upon the spatial interactions between the environment, fishing communities and the fish stocks: (Inter)National Management Areas; Catchment Management Areas (CMAs), Village Management Areas (VMAs) and Intermediate Management Areas (IMAs) (Figure 5). This classification may be extended to the other two main categories of artisanal fishery : large lake[4] and coastal marine fisheries (Figure 6 & 7). For the latter, the CMAs may be replaced by Regional Management Areas (RMAs).

[4]Small lakes are common features of most river systems and can be managed as IMAs. Similar to river systems, much larger lakes, such as the African Great Lakes, may contain several different ecosystems and drain one or more whole catchment areas, with boundaries shared among several different countries.

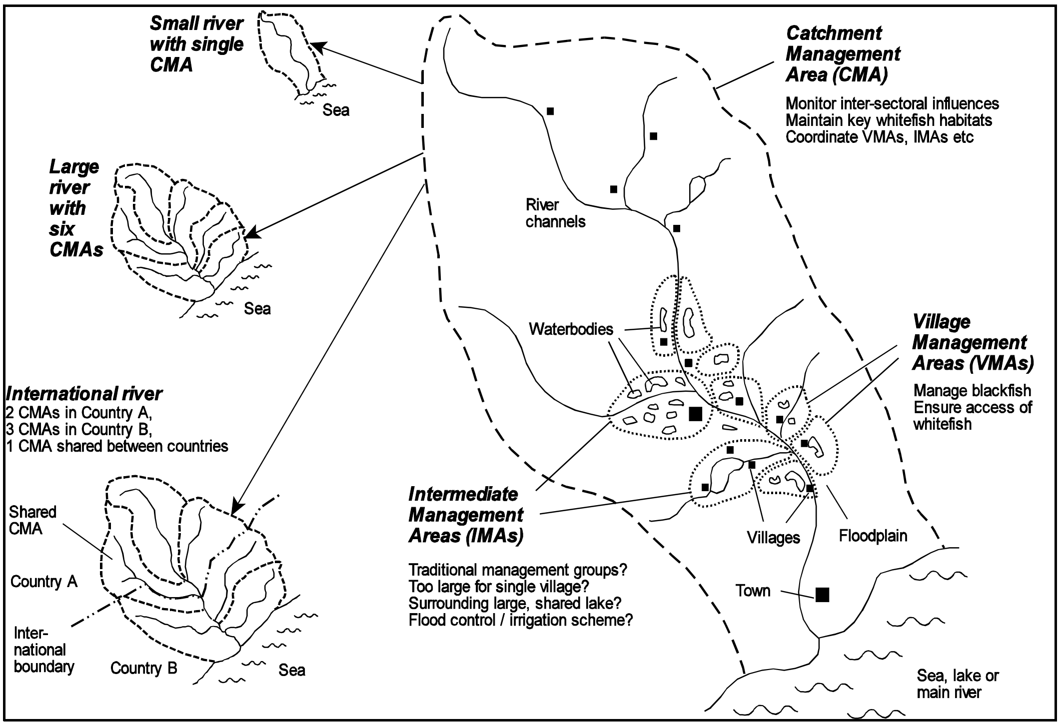

Figure 5 Floodplain-river management units (source: (Hoggarth *et al*. 1999)).

National Management Units.

Fisheries resources, particularly highly migratory species, often extend throughout a country, or a countries jurisdiction, or even between two or more countries[5]. National fisheries policy and planning decisions, including coordination of activities and conflict resolution among different sectors, must be made at this level (Section 3.2). The creation of legal frameworks for management, and the provision and sharing and information that will improve fishery management on a national scale should also be conducted at this level. National and international reporting responsibilities also exist at this level.

Catchment and Regional Management Units (CMAs and RMA's).

Catchment and regional management units represent the second tier in the nested arrangement of management units. These provide a rationale management perspective for migratory stocks confined to individual river/lake catchment areas or limited to coastal regions and an effective platform to coordinate the activities and resolve conflict among different sectors, or more local management units exploiting both sedentary and migratory stocks.

Village Management Units (VMAs)

Village management units form the lowest tear is this system of arrangements. The high spatial and temporal heterogeneity and variability within many river, lake and coastal (reef) systems and the communities that exploit them means that single overarching approaches to managing these systems are often inadequate, inappropriate or ineffective. Dividing aquatic resource systems into a number of small, local management units associated with cohesive social groups or communities such as villages, provides a potentially effective solution for the management of sedentary stocks.

[5] 'Straddling' or 'shared stocks'

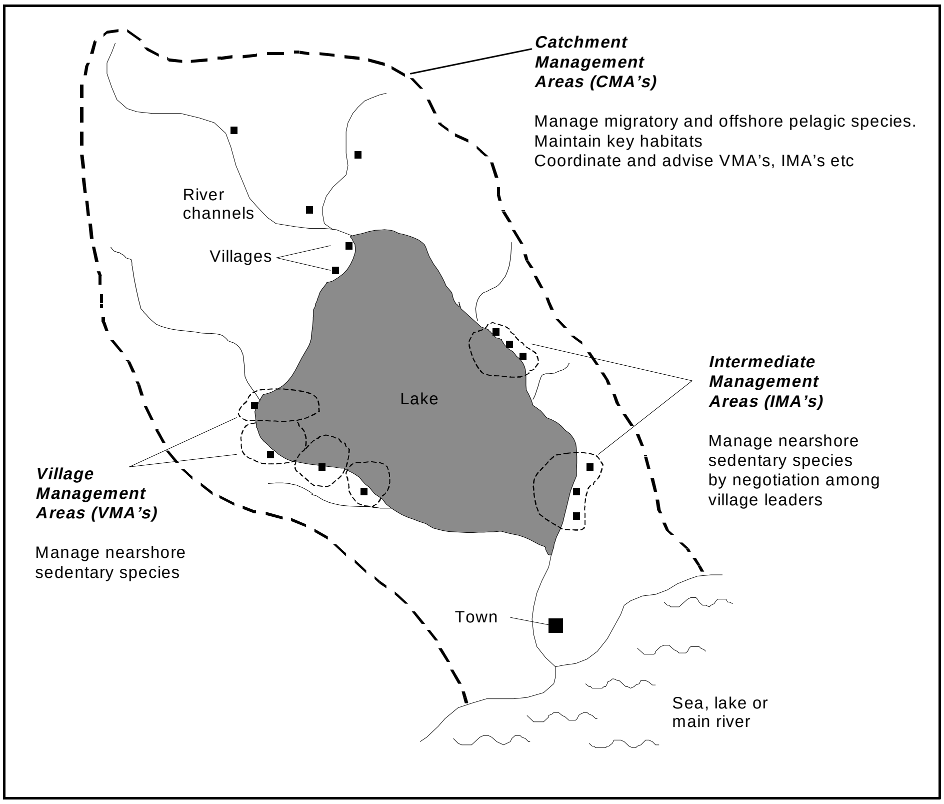

Figure 6 Lake System Management Units

VMAs should be based upon an ecosystem or some small spatial unit with well defined boundaries (Section 3.4.3) such as small floodplain waterbodies (*beels*, village ponds, small lakes...etc), small stretches of lakeshore or isolated reefs (Figure 5-7), where interactions between the environment, fishers and fish stocks can be monitored, understood and managed.

Intermediate Management Areas (IMAs)
It is not always possible or appropriate to divide aquatic systems into VMAs when the distribution of villages and resource sub units (ie waterbodies, lakeshores, reefs... etc) may mean that the catches in each village are largely dependent upon the activities of neighboring villages. This may occur when, for example, migration or transport rates of fish or progeny between isolated reefs, each under the tenure of different social groups (communities, villages...etc), is high, or when a single floodplain lake is shared between a number of villages. Under these circumstances, the management area may need to be extended to a size that is intermediate between VMAs and CMAs and RMAs in order to achieve maximum overlap between the range of authority of the social group and the distribution range of the resource.

3.6.2 Matching Stakeholders to Management Roles Hierarchically and Spatially - Who might do what?

No single group of stakeholders will have the capacity to take on all the roles necessary to manage all the levels described above. The full combination of capacities required may only be available in co-management partnerships involving representatives of different stakeholders at the appropriate levels (Hoggarth *et al*. 1999).

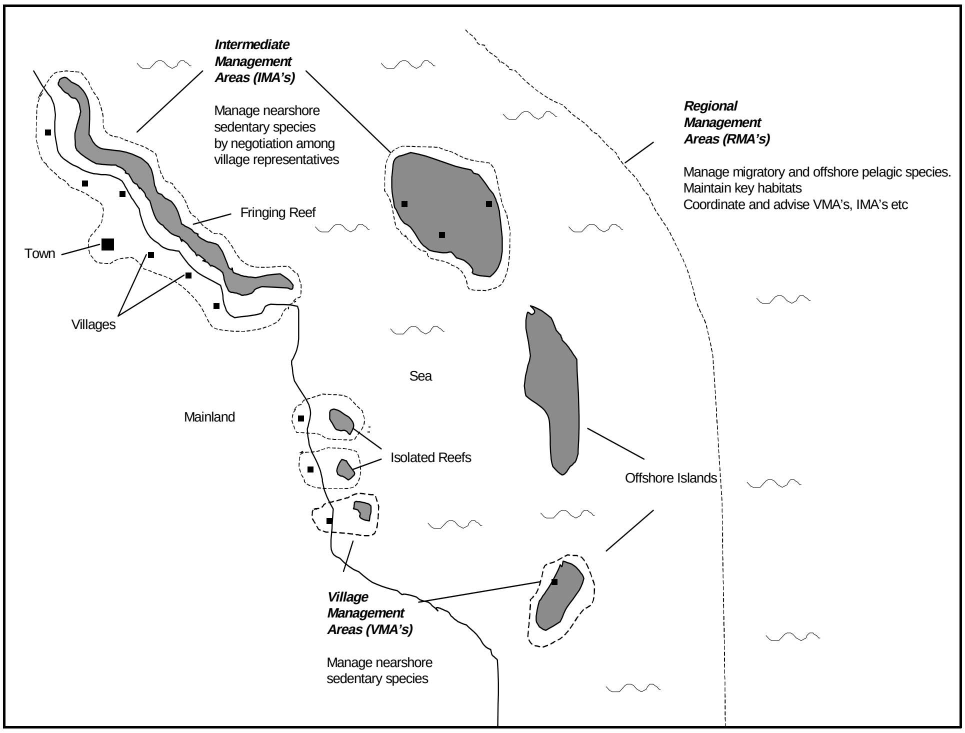

Figure 7 Coastal Management Units.

Although the stakeholders who should take on the management of the various management units will depend upon their respective capacities and other local factors, the following match is most likely to be appropriate:

Government Departments
Government involvement at all levels of management is both appropriate and necessary. Indeed, the administrative structure of ministries provides a complimentary nested structure (eg national, regional, district... etc) to support these layers of management units. At the national level, governments, as representatives of the state, will invariably be responsible for developing and evaluating national policy and planning decisions, monitoring and coordinating sectoral interactions and for ensuring compliance with (inter)national management and reporting responsibilities (Section 3.2). Governments are usually the only institution that can establish the necessary legal frameworks to support co-management arrangements.

Governments are also best positioned to take the necessary holistic perspective for the management of migratory stocks (MS) which may migrate throughout river catchments, lakes, coastal regions or even across international boundaries. They must also take responsibility for the management of sedentary resources not under the jurisdiction of local communities within VMAs and IMAs. These state owned sedentary resources (SOSRs) may correspond to extensive areas of a river and lake catchments or coastal regions, particularly during the initial stages of the creation of co-management arrangements, and may remain significant in those areas where the devolution of authority to local users is not possible because the necessary conditions or criteria for community-based management (see Section 3.4.3) simply don't exist or cannot be satisfied. At the national and CMA/RMA levels, governments would therefore be expected to have major roles in the management of these resources; establishing management objectives, and formulating and implementing overarching management plans with the support, local knowledge and technical advice from both local users and intermediaries.

Governments would primarily hold responsibility for implementing the MPs with respect to collecting and collating their information and data, conducting ad hoc research, evaluating the performance of the management plans and enforcing the management tools or regulations employed to achieve the management objectives.

A particularly important role for governments under these arrangements would be the coordination of management plans among VMAs and IMAs to ensure that management strategies are complementary, non-antagonistic and in line with government policy. This role would require full details of each VMA and IMA management plan.

At the VMA and IMA levels, governments could help local managers formulate and implement MPs for sedentary resources on the basis of their knowledge and lessons gained through (i) *ad hoc* research; (ii) the management of migratory stocks and SOSR; and (iii) from monitoring, evaluating and comparing, on a spatial and temporal scale, the performance of individual management strategies or plans employed by local VMA and IMA managers to meet different objectives. The latter would also require full details of each management plan as well as strategy performance indicators. This provides a particularly powerful means of facilitating adaptive management at the local level (see later).

Governments may also have a role in funding or providing credit to local users or local management groups to purchase gears, fishing licences or raw materials for stock enhancement programmes such as seed fish, fertilizer...etc.

Local Communities

As described above, the spatial and temporal heterogeneity and complexity within many river, lake and coastal (reef) systems and the users that exploit them, combined with the paucity of resources and capacity faced by most fisheries departments (Sections 3.3 & 3.4) suggests that management decisions and activities should be flexible and made at a very local level with respect to sedentary resources. This is because management objectives are most likely to be achieved when management rules (decision-making arrangements) are well adapted to both the physical characteristics of local resources and to the social priorities of local users. With their intimate knowledge of their resources, and their capacity for mutual monitoring and enforcement, local communities or social groups are best placed to manage sedentary stocks at the local VMA level. The application of management strategies at this local level may result in improved local output, and give benefits to the local community. Communities thus have an *incentive* to sustainably manage their local sedentary species, particularly where they have local ownership rights'.

Where independent management by one village may be negatively affected by the actions of other villages then spatial VMAs would not be appropriate, but instead, village leaders control the fishing activities of their own local people. An umbrella committee may be formed with representatives of each village to negotiate and agree rules to be followed at an IMA level (eg Beach Village Committees (BVC) in Lake Malawi/Malombe - see Hara (1996)). Simpler management strategies are required for IMAs due to the increased difficulties of roles such as monitoring, communication, co-ordination and enforcement within larger areas and among potentially less cohesive larger social groups or communities.

VMA and IMA managers would be responsible for setting objectives and developing management plans for their local sedentary resources, but under the auspices of government representatives to ensure that they are in line with government policy and to minimise interaction among neighboring VMAs/IMAs. VMA and IMA managers may choose to draw upon the knowledge, advice and support from intermediaries and governments departments when formulating management plans, particularly with respect to selecting, establishing and refining appropriate institutional and decision-making arrangements and management strategies.

At the same time, VMA/IMA managers may reciprocate support be providing local knowledge to help governments both formulate management plans and interpret the performance of their management strategies. They may also help governments implement their management plans for migratory stocks and SOSR by aiding data collection, and enforcement by reporting rule breaking.

Intermediary Organisations
This category covers a range of organisations, such as NGOs, international projects, aid agencies, extension and development projects. Such organisations are often active in rural areas and may help to improve linkages between government and communities. These groups often have a poverty focus which includes resource management and may extend to environmental protection. Projects are often research-based, aiming to understand the nature of the resource systems to improve management. These organisations usually have strong skills in training extension and communication which can assist both governments and communities with their responsibilities for fisheries management.

At the national and CMA/RMA levels, these intermediary organisations, have the capacity to conduct research to help governments formulate and implement their management plans, and evaluate the performance of their management strategies for migratory stocks and SOSR. At the VMA/IMA level, they can help governments evaluate the performance of local VMA/IMA management strategies by assisting with the analysis and interpretation of spatial and temporal comparisons of different VMA/IMA management plans described above.

They are also usually well equipped to help VMA/IMA managers formulate management plans for their sedentary resources during the evolution of co-management arrangements by providing technical knowledge and helping to establish effective institutional and organisational arrangements to engender collective decision-making. They are also likely to have an important role in providing credit, training and extension, developing skills, and in helping local managers evaluate the performance of, interpret, and revise, their management plans. In particular, they are critical in clarifying roles, introducing management methods and procedures, encouraging stakeholders to take on new management responsibilities, helping to identify the benefits of participation, and reinforcing the relationship between stakeholder groups (Hoggarth *et al.* 1999).

Table 2 below summaries this idealised spatial match between the main stakeholders and key management roles and activities.

Table 2 Idealised co-management arrangement summarising the spatial match between stakeholders and management roles and activities.

	Management Unit		
Stakeholder	National	CMA/RMA	IMA/VMA
Government Departments eg. Department of Fisheries	• Develop and evaluate national policy and planning. • Meet national and international management and reporting responsibilities. • Ensure compliance with International management responsibilities. • Establish necessary legal frameworks for management, including mechanisms to enable resource users to manage local resources. • Monitor and co-ordinate sectoral interactions (including conflict resolution). • Set management objectives for MS and SOSR in consultation with local resource users. • Formulate MP's for MS and SOSR with help (eg provision of technical advice) from, and by consulting with, intermediaries and local communities. • Implement MP's for MS and SOSR: collect information and data and conduct research to evaluate performance of, and review, management strategy; enforce management regulations.	• Monitor and co-ordinate sectoral interactions (including conflict resolution). • Set management objectives for MS and SOSR in consultation with local resource users. • Formulate MP's for MS and SOSR with help (eg provision of technical advice) from, and by consulting with, intermediaries and local communities. • Implement MP's for MS and SOSR: collect information and data and conduct research to evaluate performance of, and review, management strategy; enforce management regulations. • Co-ordinate management plans among IMAs,VMAs and ensure that local objectives and management strategies are complementary and non-antagonistic.	• Help VMA/IMA managers formulate and revise MP's and strategies for sedentary resources with results from: (i) ad hoc research; (ii) Management of MS and SOSR at CMA and RMA level; and (iii) Monitoring (spatial and temporal) and analysis of the performance of individual management strategies (plans) employed by local VMA and IMA managers. • On the basis of (iii) Communicate lessons and experiences of management among VMA and IMA managers regarding appropriate MP's to meet different objectives. • Fund or provide credit support for local users for stocking, buying fishing gear, licences...etc.
Intermediaries eg. NGOS's, Research Institutes, Donor Organisations	• Conduct research to help governments formulate and implement MP's for MS and SOSR. • Help governments evaluate the performance of management strategies for MS and SOSR.	• Conduct research to help governments formulate and implement MP's for MS and SOSR. • Help governments evaluate the performance of management strategies for MS and SOSR. • Help governments and local communities coordinate IMA/VMA management plans and resolve conflicts by encouraging dialogue and communication.	• Conduct research (eg stock assessments, institutional analysis...etc) to help local communities formulate and implement MP's for sedentary resources. • Help governments evaluate the performance of IMA/VMA management strategies for sedentary resources (eg stock assessments, institutional analysis or assisting with spatial analysis, including profiling IMA/VMA MP's - see above). • Help governments communicate lessons and experiences of management to VMA and IMA managers regarding appropriate MP's to meet different objectives. • Help VMA/IMA managers formulate MP's for sedentary resources by helping to build capacity and establish effective institutional and organisational arrangements to engender collective decision-making. • Help VMA/IMA managers implement MP's for sedentary resources by providing credit, training and education.
Local Communities eg Village communities, User Organisations	• Provide local perspective and technical advice (local knowledge) and any other information to help governments formulate MP's and evaluate and interpret the performance of management strategies for MS and SOSR. • Where incentives exist, help governments implement MP's for MS and SOSR by aiding data collection (monitoring) and enforcement (reporting rule breaking).	• Provide local perspective and technical advice (local knowledge) and any other information to help governments formulate MP's and evaluate and interpret the performance of management strategies for MS and SOSR. • Where incentives exist, help governments implement MP's for MS and SOSR by aiding data collection (monitoring) and enforcement (reporting rule breaking).	• Set management objectives for sedentary resources. • Formulate MP's for sedentary resources. • Implement MP's for sedentary resources. • Provide local perspective and technical advice (local knowledge) and any other information to help governments formulate MP's and evaluate and interpret the performance of management strategies for MS. • Where incentives exist, help governments implement MP's for MS by aiding data collection (monitoring) and enforcement (reporting rule breaking).

4. Generic Information Requirements

4.1 Introduction

The previous chapter introduced the concepts and process underlying fisheries management and the problems associated with identifying generic information requirements for the co-management of artisanal fisheries. As a means of addressing the problem, idealised co-management arrangements have been proposed for the main environmental regimes under which artisanal fisheries commonly operate. The data and information flows to support this framework are summarised in Figure 6 below.

It is important at this stage to re-emphasise that this research is directed towards developing computer database software for use by government fisheries departments who will usually have overall administrative responsibility for the (co-)management of national fisheries resources. It is not intended as a tool for the diverse range of intermediaries which often have an equally diverse range of interests and remits, but, at the same time, may contain information and data generated from studies and projects undertaken by them. Similarly, it is not intended for use by local communities who are unlikely to have any interest, or the necessary institutional capacity to use such a system, but will ultimately be the main beneficiaries of the system and, like intermediaries, may also contribute to the data and information contained within it. In other words, the software is principally aimed at supporting the heavily information-dependent management roles of fishery departments at each of the three nested spatial management levels identified in Section 3.6 and summarised in Table 2:

(i) Policy and development planning including coordination of sectoral activities.
(ii) Meeting national and international reporting responsibilities.
(iii) Compliance with International management responsibilities.
(iv) Formulation of management plans for migratory and state-owned sedentary resources.
(v) Implementation of management plans for migratory and state-owned sedentary resources
(vi) Coordination of management plans among IMAs and VMAs.
(vii) Evaluation and synthesis of the performance of individual VMA and IMA management plans and dissemination of lessons and experiences.

This chapter identifies common types of data and information required to support each of these roles. It should be borne in mind, however, that the FIMS must have realistic limits. For example it is not intended as a tool to store, collate and process data and information collected by, what has been termed here, ‘*ad hoc* studies’ undertaken in support of the management process. These studies are often unique, esoteric or specific to different fisheries. Examples of *ad hoc* studies may include a study to examine the dependence of fish biomass on their growth rates, or a tagging study to examine the migratory behaviour of key species. Besides being potentially inappropriate, it would be impossible to anticipate all the types and formats of data and information that may be collected under such studies in order to be able to design appropriate data structures within the database. The processed data may, however, be an important integral part of the database.

The information required to support the seven roles listed above will overlap considerably and may be interdependent or simply summaries or aggregations. However, many of the roles are distinct and occur on different time scales and require different information to different levels of detail.

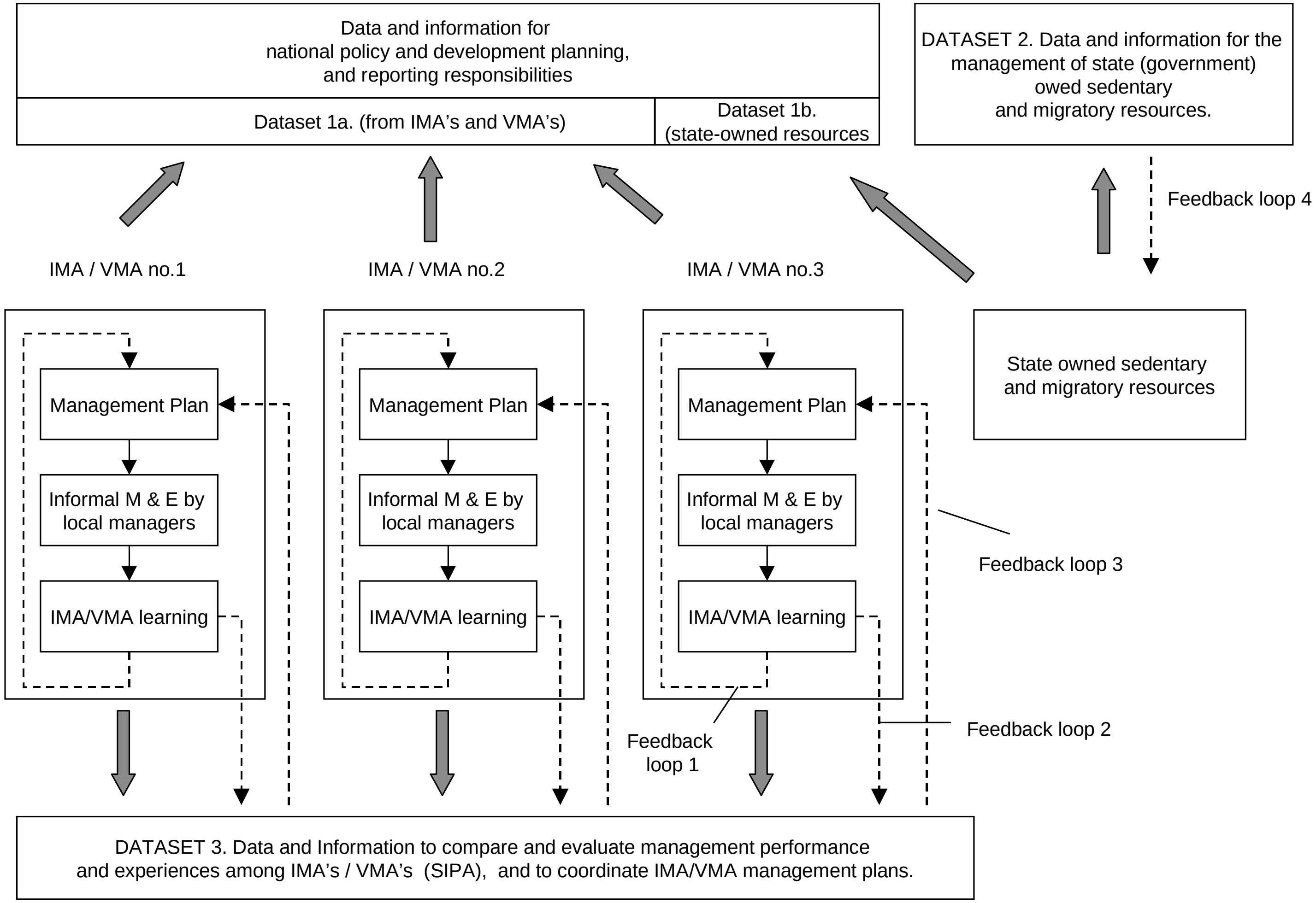

Figure 8 Summary of the proposed data flows and feedback loops for the co-management FIMS (see text for further explanation).

For example, at the management implementation level, details of local catch rates may be extremely important. At the other end of the spectrum, policy makers may need, for example, information of the average economic value of all fishery exports for the last ten years (FAO 1997).

4.2 Data and Information Requirements to Formulate Management Plans for State Owned Migratory and Sedentary Resources (Dataset 2)

The concept of management plans was first introduced in Section 3.2. Management plans translate and reference how the broad directions and priorities stipulated within fisheries policy are translated to specific fisheries or stocks profiled in the plan.

Management plans should be formulated iteratively between the management authority, and the users, in this case the state and local communities, respectively. Much of the information required to formulate MPs may be collected directly from local users, and they will often know what actions or management control measures would sustain local catches. Intermediaries are likely to have a significant role in collecting or providing much of the socio-economic and institutional data and information. In addition, formal stock assessments or the application of analytical frameworks may be employed where feasible and appropriate to investigate the biological, social and economic implications of different harvesting strategies and control measures (and their combinations) designed to control fishing mortality.

Information and data requirements to formulate management plans have been examined, among others, by FAO (1997); Hoggarth *et al.* (1999); Sen and Nielsen (1996); Mees (1998); Mees *et al.* (1998). Common data and information requirements synthesised from this work have been identified below under each of the key attributes of a fishery. These data and information may be presented in a report format or electronic format within the FIMS database.

4.2.1 Resource and Environment*:*

(i) *The stocks or fishery being considered and the area of operation of the fishery*. In the case of a multispecies fishery, this would include information on the relative importance of each species measured in terms of catch weight or value. This information could be obtained from routine sampling or enumeration programmes (see Chapters 5 & 6). Attempts should be made to categorise species according to their migratory behaviour (eg. sedentary or migratory), on the basis of *ad hoc* studies such as mark-recapture programmes, by consulting local users, or by examining spatially referenced species abundance through time collected under routine sampling or census programmes.

(ii) *Information on environments, habitats or locations critical in the life history* of the stock or species, including the location of spawning and nursery areas, migrations routes and pathways, waterbodies where fish survive during the dry season…etc. This information could be generated from a combination of *ad hoc* studies, consultations with local users, maps or satellite images, and the examination of spatially referenced data of the age structure, maturity and gonadosomatic indices of fish through time collected under the routine sampling/census programmes.

(iii) Potential catchment influences on the fishery or stock, identified from maps or satellite images indicating sectoral resource use.

4.2.2 Fishery

A fishery on a given stock may simply comprise a number of homogenous fishermen operating similar gears in one location, as is the case in the Turks and Caicos Islands conch and lobster fishery (see Field Study 2, Volume II). In other cases, such as the inland fisheries of Bangladesh (see Field Study 1, Volume II), the fishery may be much more, complex, consisting of one gear but operated by a team of fishermen belonging to different socio-economic categories; or different types of boats or vessels operating different gear types in different locations. A management plan and its evaluation needs to consider the effects of these different categories of *fishing economic units (FEUs)* [1] on the resource and the impact of the management plan on them (FAO 1997; FAO 1999b).

In relation to the fishery and its operations, the management plan should, therefore, contain the following information for each category of FEUs:

(i) Total numbers
(ii) Gear types and technology employed
(iii) The selectivity of the gears with respect to the species of fish caught and their length at first capture or Lc_{50}.
(iv) Seasonality of fishing
(v) Location of fishing
(vi) Landing locations
(vii) Socio-economic categories of fishermen and other stakeholders associated, coinciding or dependent on the different categories of FEUs (see below).

With the exception of (iii) and sometimes (iv), these data and information are commonly collected with frame surveys or as part of enumeration-based data collection programmes (see later). The selectivity of fishing gears with respect to length at first capture or the length at which 50% of the population is caught (Lc_{50}) is commonly examined under *ad hoc* studies (See Sparre and Venema (1992); King (1995); Quinn and Deriso (1999) for details). The seasonality of fishing may be investigated by examining (monthly) time series of total effort estimates for each gear type, generated under routine sampling programmes (for example Hoggarth *et al.* 1999).

4.2.3 Fishers and Other Stakeholders

Resource users will generally be heterogeneous in structure, and management actions may have a different impact (eg the distribution of income) on one category than on another. It is therefore necessary to identify the distinct socio-economic categories of fishers (professional, subsistence etc), their sub-categories (eg women, children) and other stakeholders (fish traders, leaseholders etc) associated with the different FEUs. This profiling will usually be undertaken as part of a frame survey or may be constructed on the basis of population censuses or even periodic fisher or socio-economic surveys. It should indicate which groups are associated or coincide with, or directly or indirectly dependent upon, the different FEUs operating within the fishery which may be affected in different ways by management control measures (see above). Particularly in floodplain system, this profiling may be severely complicated by seasonal variations in gear use and labour markets, and multiple livelihoods. Therefore, the implications (costs and benefits) of different management control measures will become increasingly difficult (and therefore costly) to assess beyond the primary resource users associated with the different FEUs.

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[1] The Fishing Economic Unit (FEUS) typically comprises the fishing craft (if any), the fishing gear, and the fishermen to carry out fishing operations Bazigos, G. P. (1983). Design of Fisheries Statistical Surveys. *FAO Fisheries Technical Paper* **133**: 122 pp.

.

4.2.4 The Outputs/Outcomes:

- The agreed biological, social and economic objectives for the fishery.
- The current performance of the management plan in realising these objectives, and the impact on the resource and its users (biological, economic and social impact).
- Data and information concerning non-compliance.

Management objectives and information requirements to assess the performance of the management plan are considered in detail in Section 4.3 below.

4.2.5 Decision-making Arrangements:

The importance of institutional information for understanding and evaluating management systems was emphasised in Section 3.1, particularly with respect to understanding user behaviour such as non-compliance. The management plan should contain the following information:

Operational rules:

(i) The management control measures (eg closed seasons, mesh size regulations, effort restrictions etc) employed to realise the management objectives, including details of user or access rights, existing legislation and sanctions for non-compliance.

(ii) Details of exiting monitoring, control and surveillance (MCS) systems for the fishery, including who is responsible, what information is collected, and how when and where. Known strengths and weaknesses of the existing system and the potential for greater user participation. The MP should also include the number of personnel and costs involved with the MCS programme.

Conditions for collective choice:

(i) Stakeholders (homogeneity/heterogeneity of users – based upon socio-economic groups, ethnicity, wealth, residency, religion, gear types etc) and their respective roles, rights (including access rights) and responsibilities particularly with respect to decision-making processes.

(ii) The basis with which decisions, including the performance of management control measures are made/revised eg technical models adaptive management, IAD etc. In other words, how the data should be analysed and what management action should be taken on the basis of the results of the analysis. This should include the extent to which users are represented or participate in rule making.

(iii) Existence of, and possible solutions to, any conflicts between user groups.

(iv) Conflict resolution mechanisms.

(v) User attitudes.

(vi) Procedures for consultation and joint decision-making.

4.2.6 External Arrangements:

These may relate to the existence or otherwise of enabling legislation or cultural factors that may affect how users engage in local collective choice and enforcement of operational rules. This category will also include factors such as the existence and magnitude of markets for the exploited resources, trade arrangements, the economic value (market price) of the resource, price seasonality, as well as the frequency and predictability of natural disasters, population, economic and technological trends, and the presence of donor assistance. All these factors have the potential to affect fisher behaviour and ultimately outcomes.

4.2.7 Other Information:

This includes the results of previous stock assessments and any information and data that may be appropriate to help determine and interpret the impact of the management strategy.

4.3 Data and Information Requirements to Implement (and evaluate) Management Plans for State-Owned Migratory and Sedentary Resources (Dataset 2).

As introduced in Section 3.2, the implementation of the management plan involves all the actions and decision-making required to ensure that the management plan is put into operation and operates efficiently. With respect to identifying data and information requirements, these include monitoring (collecting), collating and analysing the data and information necessary to evaluate the performance of the management strategy to meet specific management objectives set out in the management plan. It also includes enforcing the management measures (Annex 1) that control the exploitation of the exploitation and revising or refining the plan as necessary.

As identified in Section 3.5 the information required to support the management plan will depend upon both the management objectives and the models or frameworks (decision-making methods) that are employed to evaluate the performance of, and to guide, management activities or control measures to achieve the desired objectives.

4.3.1 Management Plan Objectives

Fisheries management objectives have received only modest attention in the literature (Hilborn and Walters 1992). They are usually categorised into three main groups: biological, economic and social. Traditionally, the main objective of fisheries management has been the maximisation of catch or yield on a sustainable basis in support of the notion that more catch is better. The other main objective of management is the conservation of fish stocks by maintaining minimum (spawning) stock sizes (King (1995); Sylvia and Enriquez (1994);Hilborn and Walters (1992); Charles (1988)). Management objectives may also extend to the conservation of biodiversity, maintenance of ecosystem integrity or prevention of ‘Ecosystem or Malthusian Overfishing’ (Caddy and Mahon 1995). The latter describes the progressive loss of large, high value (predatory and migratory) species and a shift towards assemblages predominated by small, low value plantivorous/herbivorous species, with increasing fishing effort (Pauly (1994); Regier (1977); Regier and Henderson (1973)).

Economic objectives of fisheries management include maximising the net profit from the fishery for revenue generation, export earnings, poverty reduction and contribution to GDP (Hoggarth *et al*. (1999); Hilborn and Walters (1992)). Social objectives are usually inherently linked to economic objectives and typically include the provision or maximisation of food and employment, ensuring equitable distribution of benefits or income from the fishery, conflict resolution and the maintenance of traditional lifestyles.

Fishery managers are increasingly required to meet equity and distributional objectives of government in addition to pursuing the more traditional emphasis on restraint and biologically efficient resource use (Campbell *et al* 1996). This may be particularly true of fisheries management in the developing world where the social and economic value of the sector in providing livelihoods to rural poor is obvious. However, a shift from the biological approach to the bioeconomic approach depends on the successful identification of appropriate socio-economic criteria and this may be more easily achieved in the developed world (Caddy 1997).

Government objectives also extend to development issues including increases to production, employment and fishermen's income, industry diversification, skills development, and the encouragement of both exports and domestic consumption (Charles 1988).

Unlike community objectives on a local or individual scale, national management objectives must take account of all the often conflicting objectives of the various stakeholders in the fishery (CDS 1995). Moreover, several international conventions and codes of conduct exist which, if ratified, define management obligations that should also be reflected in national policies (Mees *et al.* 1998).

The screening of more than 2000 published papers, reports and newsletters concerning artisanal fisheries revealed few explicit statements of management objectives. Those found, all related to broad, overarching national objectives, policies and plans or the desired course of action for the fisheries sector:

> "Increase fish production; alleviate poverty by expanding employment opportunities and improving socio-economic conditions of fishers; fulfil the demand for animal protein; achieve economic growth through foreign exchange from fish exports; maintain ecological balance, conserve biodiversity, ensure public health and provide recreational facilities"
>
> (Inland fisheries of Bangladesh; Ministry of Fisheries and Livestock, 1998).

> "To optimise the financial and social benefits to the TCIs from the sustainable management of all renewable and non-renewable natural resources, particularly those found within protected areas and coastal waters".
>
> (Turks and Caicos Islands marine fisheries, DECR, 1995)

> "...rational use and conservation of fisheries resources".
>
> (Inland Fisheries, Nigeria; (Neiland 1997))

> "...manage all fisheries according to internationally recognised codes of conduct.; establish adequate monitoring, resource assessment and control systems, and as more information becomes available, develop detailed biological management plans for each fishery".
>
> (Mauritius marine fisheries; (Anon 1997))

> "...to ensure that all fishing is undertaken with due regard and concern for the stability of the fish stocks, conservation of biodiversity and appropriate management of the resources for the long term benefit of users".
>
> (British Indian Ocean Territory marine fisheries; (Mees *et al.* 1998))

> "To manage and regulate the exploitation of fishery resources with a view to realizing the optimum production of fish and fishery products to meet national needs... to increase the productivity, income and socio-economic level of fishermen and fish farmers".
>
> (Malaysian marine fisheries; (Mohamed 1991))

> "Increase national production and reduce massive imports of frozen fish responsible for an important outlow of currencies...meet partly the demand for fish which remains high and create new jobs and maintain existing ones in the fields of fish processing and marketing, which employ a large number of nationals especially women".
>
> (Cote d'Ivoire artisanal marine & freshwater fisheries; (Doumbia 1993))

> "To ensure that the income from the utilization of the fish resources benefit the local population and the economy of the region...to increase local employment...utilize the fish resources to improve the nutritional

condition of the community around the lake...to promote export trade where possible".

(Lake Victoria Fisheries, Kenyan; (Ogari 1992)).

"Increase production to ensure self-sufficiency; create jobs to fight unemployment and rural exodus; increase fisherman's income and welfare; preserve resources; improve technology Increase foreign currency earnings and reduce fish imports by increasing domestic production".

(West African marine fisheries; (Horemans 1998))

"To enhance its contribution to nutrition; the creation of the maximum amount of work opportunities; the maximisation of foreign exchange earnings; the creation of optimum linkages with other sectors; the insurance of stable development in the industry and the conservation of marine resources to ensure the long term viability of the industry".

(Seychelles marine fisheries; (Mees *et al*. 1998))

"...to ensure maximum yield or maximum economic value of the yield...to ensure maximum employment..."

(Coastal lagoon and estuarine artisanal fisheries; (Kapetsky 1981))

"The fisheries will be managed to ensure that the maximum sustainable yield is not exceeded; all fish catches will be landed in Bahrain with the principle aim of supplying national food requirements, although export of fish shall be allowed when it is economically feasible; no constraint shall be placed on the domestic or international trade in fish or fish products; the Government will ensure that opportunities for training, apprenticeships, international vessel attachments or other forms of education are available to increase the awareness and knowledge of the skills in the fisheries sector and the government will adopt a programme of localisation of labour input in cooperation with the private commercial fisheries sector. Such as programme will adopt a flexible timetable but with the ultimate aim of localisation by the year 2005".

(Bahrain marine fisheries; (RDA 1991))

"Ensure an optimally sustainable flow of economic, social and environmental benefits from the coastal zone and resources; limit overexploitation of renewable coastal resources within their natural regenerative capacity; promote equitable distribution of benefits from utilization of the coastal zone and resources in a manner than prevents or minimises incompatabilities and conflicts; undertake conservation and protection measures to maintain or enhance the functional integrity, aesthetic quality and biodiversity of the coastal zone; develop viable and responsive laws and legal/institutional structures and capabilities; and generate and utilize sound and appropriate scientific knowledge and technology"

(Brunei Darussalam coastal marine fisheries, Department of Fisheries, Brunei Darussalam, 1992).

"...ensure the sustainable development of these resources for multiples uses; maintain brackish water habitats while accommodating other users".

(Coastal Resources, Sri Lanka; (Samarakoon 1991)).

"Ensure the sustainability of subsistence fisheries and maintain an adequate supply of protein"

(Pacific Island Countries and territories; (Anderson and Gates 1996))

"To effect a rational long-term utilisation of marine and inland fisheries resources; to use local fish as a means of improving nutritional standards of the population; to increase and expand the participation of private Gambian entrepreneurs in the fishing industry; and to increase employment opportunities and net foreign exchange earnings in the sector".

(The Gambian Marine and Inland Fisheries; (Horemans *et al*. 1996))

No specific management plan objectives relating to, for example, reference points or other indicators (see below), for individual fisheries or stocks were found within the artisanal fisheries literature. This paucity of explicitly stated management plan objectives probably reflects the less formal management procedures adopted by most artisanal fisheries managers compared with fisheries in the developed world.

Common data and information requirements to evaluate the performance of artisanal management activities and to support decision-making were therefore implicated from the broad management objectives identified above and also from reference points and indicators applicable to most fisheries.

The majority of reference points used in fishery management relate to biometric (population) and econometric models. This probably reflects both the complexity and infancy of multi-objective or multi-criteria bio-socio-economic modelling (see below), and the traditionally biological stance adopted within fisheries management strategies. FAO (1999a) emphasise that a broader set of reference points needs to be developed and agreed covering all the dimensions of fisheries resource systems such as the environment, poverty, conflict, development, employment etc.

The data and information required to evaluate many of the socio-economic objectives, particularly with respect to artisanal fisheries are therefore frequently the default indicator type, and simply monitored alongside the results of biological models and assessments or analysed within non-deterministic models or frameworks such as (Oakerson 1992).

However, less formal reference points may also be adopted. The choice of these reference points will depend upon policy objectives and long-term and short-term goals. Suitable historic reference points fix the magnitude of fisheries attributes to one point in time so that performance is gauged by movement above or below this marker. These reference points can be set just prior to changes in export policy, co-management arrangements, international law or any factor that could influence the nature of the fishery. As such, reference points must be selected according to realistic management objectives and goals, and these will vary between nations and fisheries. Where global guidelines are established for minimum basic needs these may be used directly as reference points (eg. the World Bank's *World Development Indicators 1999* provides 600 indicators of health, nutrition and poverty, and tailors reference points for these to 148 nations). Within the FAO guidelines and literature socio-economic reference points were non-specific ("*realistic policy target", "selected historical level*") and presumably this reflects the generic nature of FAO's output on this subject.

4.3.2 Data and Information Requirements Identified from General Management Objectives

Decision-making with respect to management objectives can, at its simplest level, be made on the basis of the *default* or *status indicators*, based upon relevant criteria which describe the basic outputs, outcomes or present states arising from a particular management strategy or policy, and can be used to monitor change or trends. For example if, the objective of the management plan is to increase catch, then the default indicator (and the evaluation criteria), would, of course, be catch.

Clearly, without making assumptions about appropriate decision-making methods, models or frameworks, data and information in support of these broad management objectives will be confined to default or status indicators, or basic performance evaluation criteria.

Particularly with respect to socio-economic objectives, indicators must be developed according to the range and types of data that are available. In the context of artisanal fisheries, and especially developing world fisheries, the accumulation of appropriate and limited data may have to be improvised where systematic census or monitoring does not occur. Consequently, the literature has tended to focus on the sustainable management of developed world fisheries and emphasised social and economic criteria and indicators that appear unmeasurable or inappropriate in the developing world context. This review revealed no national or institutionalised use of development indicators in the context of artisanal fisheries. The use of socio-economic indicators has largely been restricted to specific and geographically discrete development programmes and projects (see Field Study 1, Volume II). These may be *a priori* indicators designed by NGOs and development agencies to gauge project performance against project goals or may be developed in participatory processes to formulate "negotiated indicators" (see Section 4.9). In either case, it may be impractical, costly or inappropriate to scale these approaches to the national level. In any context, the indicators chosen should provide information on appropriateness (how objectives match community and government requirements), effectiveness (how well management achieves stated objectives) and efficiency, that is, how well management inputs are maximised to achieve desired outputs (Staples 1997).

Evaluation criteria and default indicators for the main categories of management objectives are identified below:

A. Biological and Ecological Objectives, Evaluation Criteria and Data Requirements

Biological or resource orientated objectives of management centre upon, maintaining or sustaining, increasing or maximising catch. Catch is often referred to as yield or production. Catch objectives are usually evaluated over the period of one year, and therefore indicators are expressed on a per annum basis. Although many proxy indicators (functions) of catch potentially exist eg fish prices, fishing effort, fisher income ...etc they are likely to be unreliable or misleading and therefore not recommended. The other main ecological objectives centre upon conserving the absolute and relative abundance or biomass of the fish or species assemblages associated with the fishery to maintain system integrity and ecological balance (Table 3)

Abundance (numbers and biomass) may be estimated using VPA or depletion methods, or *ad hoc* trawl or acoustic surveys (see Section 4.3.3). Catch per unit effort (CPUE) is a common proxy indicator of abundance, although the underlying assumption that CPUE is proportional to abundance is not always satisfied[2].

Diversity indices are often used to quantify biodiversity. Common univariate indices include species richness (S), which is simply the total numbers of species present, and the Shannon-Wiener diversity index, H' which requires information on the relative abundance of each species (See Clarke and Warwick (1994) for further details).

[2]See discussion on hyper-depletion and hyper-stability in Hillborn & Walters (1992)

Table 3. Summary of basic information requirements to evaluate management activities to meet common biological and ecological government objectives.

Objective	Criteria	Indicator (Data Requirements)	Index or Proxy Indicator
Maintain/sustain/increase/ maximise catch/yield/production	Catch by species	Annual catch by species	Fish prices, fishing effort, fisher income...etc
Conservation/Preservation/ stability of fish stocks	Abundance or biomass of each species	Abundance (*N*)or biomass (*B*)of each species	CPUE of each species
Conservation of biodiversity	Biodiversity	Abundance (*N*) or biomass (*B*) of all species affected by fishery.	Species richness (*S*); Diversity indices eg *H'*.
Maintenance of ecosystem integrity or ecological balance	Ecosystem Integrity/ Ecological Balance	See mass balance and tropic level models below (Section 4.3.3)	
Rational use of fisheries resources / limit overexploitation	Reference points (see below)	see Section 4.3.3 below	

B. Socio-Economic Objectives, Evaluation Criteria and Data Requirements

Socio-economic objectives focus upon issues of profit maximisation, export earnings, poverty alleviation, improved food security and equity. Field reviews of community management objectives (see Volume II) revealed an interest in precisely the same criteria at the primary level (provision of food and income) and at a secondary level (employment, industry diversification, conflict etc.).

Profit/Income

Profit and income related management objectives are typically evaluated on the basis of data on costs and earnings.

Costs and earnings data relate to the utilisation of resources and the consequent production over the year at the household, community or fishery level. They provide data directly relevant to both national and community management objective – specifically the improvement of fisher income. While detailed coverage at the household level may be costly and logistically challenging, an understanding of household economies provides a useful indicator of how changing policy, catches or markets will impact fishers and how they may react to this change. Costs are treated as *fixed costs* or *variable costs.* Fixed costs are considered as expenditure related to capital (such as investments in gear and vessel) and may be independent of the level of output. Variable costs are continuous expenditure relating to everyday running costs (including fuel, repair, ice, food and crew costs etc). Variable costs would usually include some payment for the right of access to the resource. These costs may include traditional taxes or offerings collected for church/temple/village funds and utilised for social and religious purposes or those funds paid to leaseholders and other formal or informal owners or middlemen. The costs identified below in Table 4 should be quantified.

Table 4. Summary of common costs of operating artisanal fishing units. Source: Kurien (1982) and Caddy and Bazigos (1985).

Cost Category	Costs
Fixed costs	Gear, vessel investment Insurance Depreciation
Variable costs (owner operating)	Repair and maintenance of craft Repair and maintenance of gear Food Materials Others
Variable costs (common operating costs)	Food Traditional taxes and offerings Materials Commission Repair of craft and gear Remuneration to other owners Repayment of loans Others

The following categories of earnings should be quantified.

- Fresh fish sales
- Processed fish sales
- Sales of fishing inputs
- Rental of gear
- Sale of fishing rights
- Investment

Ideally, cost and earnings surveys would incorporate all flows into and out of the economic unit under scrutiny (fishing unit owner, household, community etc). These guidelines have reduced sampling requirements to that information crucial to monitoring income production only from the fisheries sector.

Changing investment levels is a good proxy indicator of changing economic performance and output (FAO 1999b). Investment can involve the acquisition of greater capacity through additional fishing units or improvements in efficiency of existing fishing units. Relevant data include number of licensed vessels by vessel class and sales recorded by secondary support sectors such as gear-repairers and sellers.

Other proxy indicators of socio-economic status might be utilised if these are designed in preparatory phases of the monitoring programme. Realistic checklists for information requirements can only be established and refined through these preparatory phases and interview or survey strategies must adopt suitable protocol for the sampling of sensitive information. Caddy and Bazigos (1985) recommend the survey of simple proxy indicators of economic well-being e.g., “are incomes high enough to allow fishers, to repair or purchase boats and gears?”, “are sources of credit readily available?” Poate and Daplyn (1990) question the reliability of cost and earnings surveys within the agricultural sector and suggest the adoption of suitable proxies;

“….*it is prudent for the survey designer to question the wisdom of even trying to collect income, expenditure and consumption data, before embarking on design and exploratory surveys.*

Unless very high standards of enquiry are achieved the results are likely to be unreliable, and potentially damaging if the users of the data are not aware of their shortcomings. An alternative approach is to avoid the problem of measuring total income or expenditure by concentrating on physical production, which can then be modelled using price and marketing data. Proxy measures of wealth, and access to or participation in social activities such as education, may convey sufficient information about economic well-being. If a survey is unavoidable, we suggest that a small (case) study of a few households under good supervision will provide more reliable and usable data than a large-scale sample survey. Expenditure data are likely to prove more reliable than income data." (Poate and Daplyn 1990)

Export Revenue

Changes to export earnings are usually expressed in terms of annual export revenue by species or product type, often as a proportion of gross domestic product (GDP). Monitoring net earnings from foreign exchange would also require data on sectoral investment in foreign and imported gear such as engines or vessels, and foreign exchange earnings from fish and fish product exports (Caddy and Bazigos 1985)

Where statistics are lacking, fish export GDP may be estimated from export duties charged and received by unit value or unit weight. Macro-economic indicators of export revenue are typically available from the relevant trade ministry.

Employment

Artisanal fisheries within the developing world often provide livelihoods for the most vulnerable groups within society. The opportunity cost of fishing may be near zero and displaced or landless groups may use the fishery as a supplementary or last resort source of income and nutrition. Information regarding changes in the total number of people employed in the sector overtime (on a seasonal basis and across sub-sectors) would provide a useful indicator of the value of the fishery to local communities.

There are few examples of reliable statistics regarding fisheries employment in the artisanal sector. Ideally, this information should be generated through routine national census or statistical collection and reporting systems, or failing this through periodic frame or *ad hoc* survey exercises (Seki and Bonzon 1993). Estimating employment is complicated by the diversity and seasonality of economic activities within artisanal fishing communities but classification of fishers could follow the FAO Fisheries Information, Data, and Statistics Service (FIDI) categorisation of "full-time", "part-time" and "occasional fishers"[3].

Information on secondary employment such as trading and processing is less likely to be available. Estimates of secondary employment can be made with fixed conversion factors suitable for the fishery and the surrounding economy in question. Seki and Bonzon (1993) recommend separate conversion factors for African inland and marine fisheries (inland fishers x 5, and marine fishers x 3). Similarly, if each fisher is assumed to support 4 dependents on average an estimate of the total population directly or indirectly dependent on the fishery can be made.

Poverty Reduction

Indicators of poverty have typically been macro-economic statistics regarding growth, investment, balance of payments...etc, but these have failed to represent distributional aspects

[3] FIDI classify "full-time" fishers as those receiving at least 90% of their in
come form, or spend at least 90% of their time in fishing. "Part-time" fishers receive between 90 and 30% of their income, and spend between 90 and 30% of their time in fishing. "Occasional" fishers receive less than 30% of their income form fishing and spend less than 30% of their time in that occupation.

of development. Fields (1994) defines poverty as:

"…the inability of an individual or a family to command sufficient resources to satisfy basic needs."

The poverty line is the reference point by which to gauge development and is defined by standards set by that country and according to its particular stage in economic development. Once the reference point is set, the extent of poverty can be gauged by the shortfall between desired and actual income. In acknowledging that the costs of living may differ between regions, some countries have set separate rural and urban poverty lines (eg. India and Costa Rica).

Fields (1994) suggests the sampling of larger economic units – that is, sampling of households as opposed to the individual. The household unit quickly encompasses more individuals and accounts for the sharing of family income. The frequency of sampling is also critical. Long reference periods are more appropriate for capturing long-term trends but data quality suffers from long recall periods. Ideally, sampling would occur on a monthly basis.

Poverty lines have been constructed as some fraction of average wage (as in Brazil) but this overlooks access to basic needs and commodities. The most common way to set reference points is to estimate the cost of a basic food basket (the cost of nutritional necessities as defined by calorific and protein content). Most developing nations have established poverty lines according to this type of criteria and will be unique form country to country.

With regards to quantifying the attainment of these reference points the simplest measure is an income head count in relation to this level of poverty. This does not, however, provide information on the distribution of poverty or, in fact, to what degree sections of society are poor. The generation of this level of information requires data on incomes by strata of interest.

Ideally, data requirements for poverty evaluation would be derived from household income surveys (see above) conducted on a national scale. Alternatively it may be possible to employ a case study approach (see above) or obtain levels refined measures of income from a national census (Fields, 1994).

Following the work of Amartya Sen and the emphasis on poverty as lacking access to social capital or *entitlements*, there has been a re-appraisal of the financial treatment of poverty. The sustainable livelihoods approach adopted by DfID acknowledges the complexity of the poverty issue. Ideally, a checklist analogous to the sustainable livelihoods approach would be adopted where human, social, natural, physical and financial capital are monitored but recognised as inter-dependent. The problem here, however, is to understand the processes by which these attributes influence one another and the problem of capturing the essence of abstract concepts such as "social capital" (see Serra (1999)). Access to (or exclusion from) basic infrastructure and services provides alternative poverty indicators. Hundreds of indicators have been developed and applied such as "distance to doctor", "distance to clean water", "proportion of children in primary education" etc. As with the design of poverty lines, proxy measures can be global but are more suitably developed nationally or on a regional basis.

Diversification

National objectives of fisheries diversification may relate to the increased utilisation of under-exploited or unpopular species for subsistence fishers[4], the extension of exported species and products and the development of new secondary industry and firms such as processors and

[4] A public awareness campaign by the Ministry of Food and Agriculture in Ghana successfully promoted catches of underexploited triggerfish species (D. Abodo, pers. com.).

gear manufacturers. Evaluation criteria will therefore be based upon some diversity measures of the gears operated within the fishery, the species caught and the processing activities. Basic data requirements may therefore include the total numbers of gears operated, species landed and categories of processed products. Species can be tallied or more simply treated within distinct “economic species groups” as defined by the International Standard Statistical Classification of Aquatic Animals and Plants (ISSCAAP). This classification groups together species with similar economic values and uses. Alternatively, the World Customs Organisation maintain a Harmonised Commodity Description and Coding System database which classifies traded fisheries commodities (FAO 1999b). Proxy indicators include:

- Number of species (or economic species groups) traded domestically
- Number of species (or economic species groups) traded internationally
- Number of processing firms / processing licences
- Number of firms in supporting sectors (engineering, transport)

Food provision and security

Fish is a major source of animal protein to people in the developing world. It is important to monitor if changing management, export policy or environmental change is impacting access to fish protein and its contribution to diet. Significant trends in per capita fish consumption and fish consumption as a proportion of total protein consumption can be indicative of the ability of fisheries performance in meeting the primary objective of human nutrition.

Total national food supply (tonnes/year) is a product of total domestic production and fish imports minus exports. Fish consumption can be expressed as kg/capita/year but does not provide an indicator of distribution within the population. Ideally, a Gini coefficient should be calculated for fish consumption - that is, the deviation between observed cumulative consumption as described by a Lorenz curve and the cumulative consumption expected from equal distribution (see below).

Average fish consumption per capita may be estimated from the total annual national consumption (AFC) divided by the estimated total population (N_{pop}) where:

AFC (kg y^{-1}) = annual domestic fish production + (annual fish imports minus annual fish exports)

Annual domestic fish production is the sum of the total annual catches all food fish species. The term “food fish” here is taken to represent all catch and cultured products excluding mammals and aquatic plants (FAO 1991). Import and export data are available from the relevant trade ministry records (see Section 4.5).

Where annual domestic fish production estimates are not available, fish consumption, measured in terms of numbers of fish meals consumed per week derived through household surveys/fisher interviews, may provide a proxy.

Equity of distribution

The Gini coefficient (G) is a useful means by which to quantify the distribution of benefits, such as income and nutrition among individuals or groups or categories of individuals:

$$G = 1 + \frac{1}{n} - \left[\frac{2}{n^2 \overline{y}} \left(y_1 + 2y_2 + 3y_3 ..... + ny_n \right) \right]$$

where

$y_1 \ldots ny_n$ represent incomes or annual fish consumption of individuals of each group or category in decreasing order of size

$\bar{y}$ is the mean income or annual fish consumption of all the groups or categories combined

n is the number of socio-economic groups or categories under examination.

Distribution equity may be quantified in terms of the deviation in the observed value for G from the expected or desired value (Lorenz 1905).

Sen (1976) combined the three aspects of head count, average shortfall from the poverty line, and inequality into a comprehensive and commonly used poverty index:

$S = H\,[I + (1 - I)\,G\mathrm{p}]$

where H is the poverty headcount ratio, I is the average income or fish consumption shortfall of the poor in percentage terms, and Gp is the Gini coefficient of income or fish consumption inequality among the poor.

The calculation of Gini coefficient for income distribution requires fisher household cost and earnings data monitored by panel survey methods (iterative sampling of identifiable model households see Section 5.1). Calculation of the Sen poverty index (S) would rely on an identical set of household data.

The distribution of wealth and income form the fishery is likely to be closely linked to access arrangements (Caddy and Bazigos 1985). This is especially true in heavily exploited fisheries, where the expansion of fishing effort by one group is likely to impact negatively on other groups. Within the artisanal context, there is often a polarisation of effort and technological input as semi-industrial vessels compete with traditional gears and users, for instance.

Calculation of the Gini Coefficient (G) to quantify the distribution of nutritional benefits would require detailed information of diet for as many households or groups as possible but stratification according to sub-sector or management unit, and with reference to an appropriate proxy such as fish meals/week, could more realistically be sampled.

In this instance $y_1..ny_n$ represent individual, group or category annual fish consumption in decreasing order of magnitude; $\bar{y}$ is the mean individual fish consumption across all individuals, groups or categories; and n is the number of individuals, groups or categories.

To determine the distribution of nutritional benefits from fisheries a panel survey equivalent to that for income should be designed. Representative households must be sampled iteratively to record “number of fish meals” consumed annually and number of dependants (y and n, respectively).

Conflict Resolution

Conflict-resolution was identified as a general concern and role for government from literature review, while field survey revealed conflict to be common and a major concern at the community level (see Field Studies 1&2, Volume II).

Conflicts within artisanal fisheries occur between the whole range of stakeholders, at a range of geographical levels and manifest themselves in a variety of ways. Although conflict is not an exclusively modern characteristic of fisheries, its study and quantification in this context has only recently been attempted (Neiland and Bennett 1999). The DfID project ”Management of conflict in tropical fisheries” (R7334) is currently developing a typology of conflict which will help document change in the nature or severity of conflict within the fishery sector. The project will also develop methods to identify conflict and its frequency of occurrence.

The characteristics of conflict between fisheries will differ according to setting. Which conflicts are seen as key and particularly disruptive by government and community may also be unique. However, disputes tend to focus on issues of access and exclusion (eg. ethnicity, in the case of Muslim and Hindu river fishers in Bangladesh and, in the Turks and Caicos Islands, access rights granted to foreign fishers). Where conflicts such as these are persistently disruptive it should be possible to record the incidence of disputes. Sometimes, an arbitration process might be formalised and institutionalised (as is the case with Ghana's Community-Based Fisheries Management Committees), and process documentation in the form of minutes must be made available for all cases heard by the committee or mediating body concerned. Where such a process has not been formalised, sources of conflict data may have to be improvised. In the Turks and Caicos Islands, the Fisheries Advisory Committee is required to document grievances and disputes identified by fishers within Fishery Management Plans draw up for each fishery. Where *ad hoc* monitoring programmes are devised in relation to ongoing development projects, information is often collected regarding conflict. Impact monitoring is designed to record if conflicts have increased, decreased or, in fact, been introduced by programme activities themselves. For instance, within ICLARM's Community-Based Fisheries Management Project in Bangladesh, historic records of ongoing disputes and dialogue will be available through Local Management Committee minutes (see Field Study 1, Volume II).

If this process documentation needs to be reduced further to simplify the process of data collection, then key events could take the form of proxies. Suitable proxy indicators of conflict include:

- Verbal confrontation
- Physical confrontation
- Injuries or deaths
- Incidents of gear damage
- Incidents of vessel damage
- Legal / tribunal cases (including both formal and informal / traditional village courts)

Maintenance of traditional management/lifestyles
The management arrangements in many artisanal fisheries are a reflection of both formal, *de facto* rules, and informal rules derived from local and traditional systems of control. These traditional systems tend to focus on issues of access and distribution and as such they impact on several attributes of the management system (access arrangements, fee payments, gear controls and target species through taboo etc.). The value of these traditional systems in establishing compliance and the control of effort through local knowledge of the resource has been recognised by government and researchers (with respect to the design of co-management arrangements, for example) and has been expressed by fishing communities, themselves. The stability of traditional access arrangements, taboos...etc may prevent deterioration to *de facto* open access. The loss of traditional practice, regulations or rules may be indicative of a fishery undergoing sudden change with respect to external market pressures, ethnic makeup or population pressure.

The quantification of the maintenance of traditional management and culture must rely on proxy indicators. Information on traditional fisheries practice and management can be obtained by interview with head fishers or community leaders. Suitable proxies might include:

a) Maintenance of traditional management system:
- Local access rules set by chief fisher or village head
- Access payments to chief fisher or village head

- Rule-breaking payments to chief fisher or village head

b) Maintenance of traditional belief system / culture:
- Cultural reference to fishing in art / song
- Changing number of mosques, temples, churches

Table 5 Summary of basic information requirements to evaluate management activities to meet common socio-economic management objectives

Objective	**Criteria**	**Indicator (Data Requirements)**	**Index or proxy indicator**
Maximise / increase net profit / income	Profit or income	Monthly revenue and costs by FEUS strata	Market price, unit costs of production
Maximise / increase export earnings	Export revenue	Annual export revenue by species or product type	Duty received; Volume and unit value of exports
Maintain / increase employment	Employment	Total no. fishers in catch sector by fishery etc.	Total no. vessels, gears and average crew sizes
Poverty alleviation or reduction	Poverty	Household headcount below national poverty line	Level of primary education, access to services... etc
Equitable distribution of benefits/income	Gini coefficient of income / fish consumption	Income / fish consumption by household strata	Income / fish meals by sub-sector
Industry diversification	Diversity of gears, target species, processing activities	No. gear types, no. target species, no. processing activities	No. species traded domestically; No. products types exported
Provide food / improve food security	Fish consumption per capita	Total domestic fish consumption, total population	No. fish meals consumed per unit time.
Resolution of conflict among stakeholders	Conflict	Number of disputes, Number of incidents of damage and injury	Recorded disputes (local courts and informal judiciary)
Maintenance of traditional lifestyles	Traditional management / culture	Nos of villages: (i) operating payments to traditional head; (ii) adhering to traditional sanctions; (iii) operating traditional conflict arbitration	Maintenance of traditional customs, access arrangements, religion

4.3.3 Data and Information Requirements Identified from Management Models and Decision-Making Methods.

Although measuring and monitoring the simple default indicators for the criteria implicated from the objectives identified above is obviously necessary, they have limited value from an active management perspective. As stated above, such basic information cannot, by itself, inform managers whether or not the particular outcome can be improved or increased, or what measures could be taken to make improvements. Three categories of decision-aiding models are used to reconcile this problem were identified as; (i) cognised or conceptual models of the fishery (eg Oakerson Framework), developed through perception, reasoning, or intuition; (ii) theoretical (technical) models of the fishery; and (iii) empirical models developed on the basis of experience or *adaptive management* (see later).

Cognised or conceptual models are generally informal and non-deterministic. It is therefore impossible to be prescriptive about specific the data and information requirements to support them. However, the holistic frameworks (eg Oakerson) provide a useful means to identifying and ordering the types of data and information to understand systems, possibly on the basis of non-parametric multivariate pattern analysis (see Sections 4.9 & 6.6.3 below). Much of the data and information required to support this type of approach is included in the management plan (see above).

Technical models and management objectives
The technical models are typically quantitative and often based upon theories of population dynamics and economics. They attempt to generalize the fishery, in terms of variables that can be controlled by operational rules or external arrangements(eg allowable fishing effort, mesh sizes, economic (dis) incentives), and outcomes (eg catch or economic rent). Detailed descriptions and explanations of these models, together with the plethora of methods to estimate their parameters are covered in several excellent textbooks and manuals dealing with fish stock assessment including Gulland (1983); Sparre and Venema (1992); Hilborn and Walters (1992); and Quinn and Deriso (1999).

These management models typically have *specific target* or *limit reference points* (TRP's or LRP's, respectively) which may be regarded as criteria which capture, in broad terms, the management objective for the fishery or management unit (Caddy and Mahon 1995). Reference points are therefore often embedded in policy statements and more specific operational management plans. Several of the international conventions and codes of conduct also make specific reference to them (see Section 4.6).

Several of these technical management models and reference points demand data and information over and above that required for simple default indicators. Often this is because they contain several sub-models such as growth models for which additional data is required to estimate their parameters. Data and information requirements to estimate the common reference points described below are illustrated in Figure 9 with respect to the various sub-models and stock assessment methodologies for resource and biological orientated management objectives.

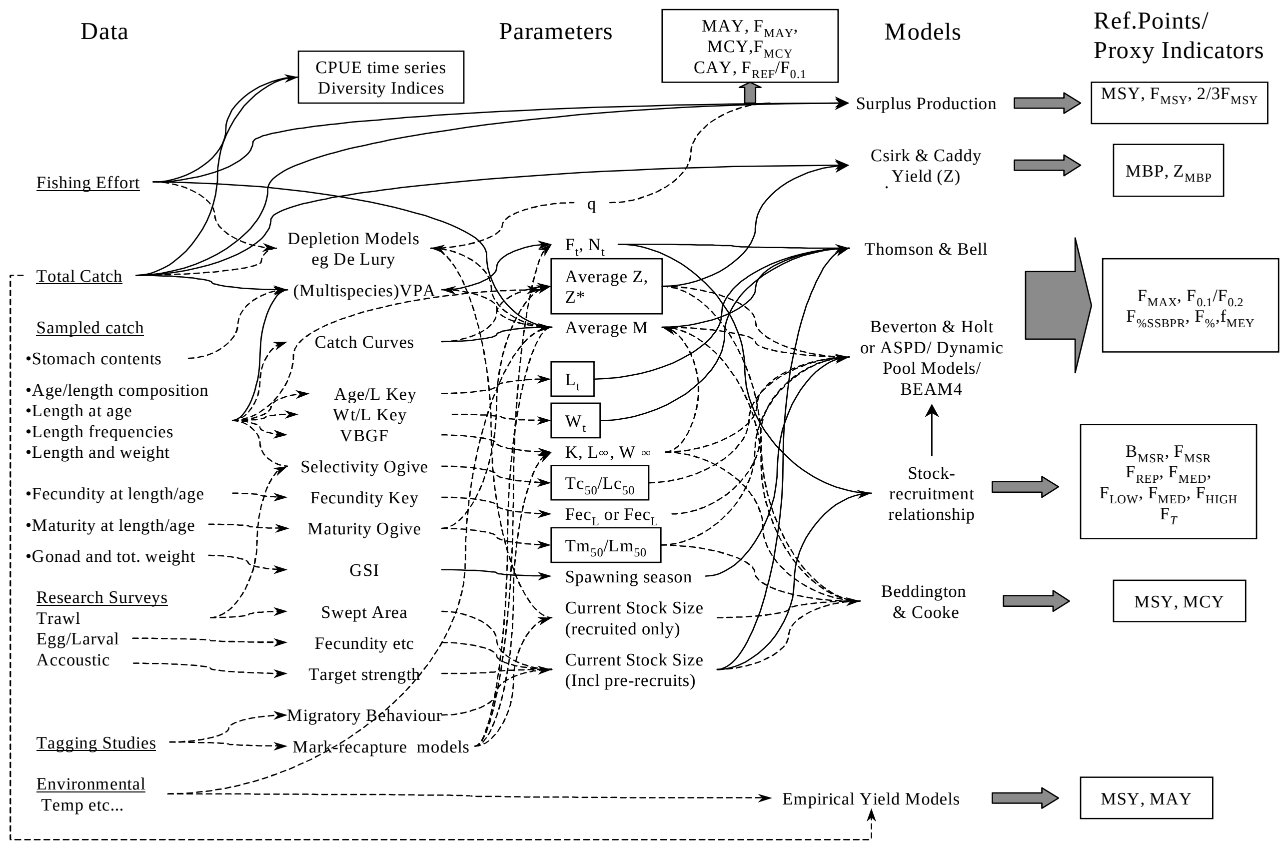

Figure 9. A conceptual flow diagram of key fisheries methodologies, assessment techniques and information requirements. Solid lines indicate a requirement for a time series or multiple sample of the data or parameter estimates (modified from (MRAG 1992)). Reference points in boxes.

The Underlying Population Models
The foundation for the majority of the biological (and some economic - see later) technical models and reference points is the relationship between Yield (Y), fishing mortality, F and mean stock biomass (B) (Caddy and Mahon (1995); (Figure 10)). F and B are the basic *reference variables*. Reference points on these variables are established using various criteria described below, for example the F which maximises average yield equivalent to Maximum Sustainable Yield (MSY) or the F which maximises yield-per recruit. Fishery management seeks to control F or sustain B at levels which correspond to target values, using a variety of management instruments or control measures (Annex 1) such as effort control and minimum size at first capture. Other variables which influence, relate to, or reflect the basic reference variables are also used as proxies for reference variables eg mean size at capture and effort (assuming constant catchability *q*) can be used as proxies for F respectively (Caddy and Mahon 1995).

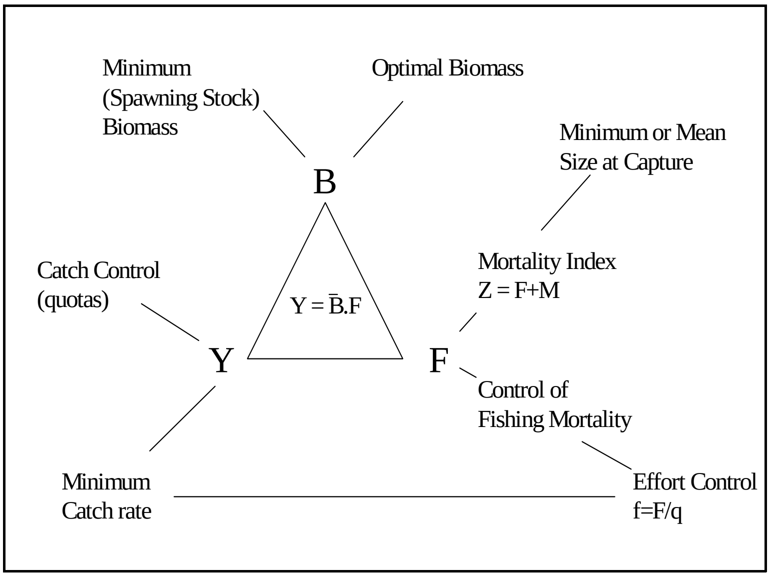

Figure 10. The main population, reference and control variables used in defining biological reference points. In addition to the three primary measures of the state of an exploited population (Y,B and F), other secondary measures shown may also be used as reference variables. Redrawn from (Caddy and Mahon 1995).

Reference points as targets or limits
Technical reference points are categorised, in terms of their application, in two categories: Target Reference Points (TRP's) and Limit reference Points (LRP's). Traditionally TRP's have been considered as indicators of stock status desirable for management eg MSY. Management involves monitoring and adjusting the fishery inputs until one or more of the primary or secondary variables (eg F or effort respectively) corresponds to the TRP. An LRP corresponds to some minimum condition (eg dangerously low spawning stock biomass) or some maximum condition (eg a high mortality rate or mean size at capture) at which point a management response is triggered (Caddy and Mahon 1995).

Below is a brief description of the commonly employed TRP's and LRP's under the three main categories of management objectives drawing heavily from Caddy and Mahon (1995) and Smith *et al.* (1993).

Biological / Resource Reference Points

(i) Maximum Sustainable Yield Criteria: eg F_{MSY} and $2/3F_{MSY}$

Maximum Sustainable Yield (MSY) is a descriptive term for the highest point on the parabola describing the relationship between annual standard fishing effort and yield under equilibrium conditions, based upon various surplus production models formulated among others by Schaefer (1957); Fox (1975); and Pella and Tomlinson (1969), and requires statistical fitting of historical catch and standard effort data. The effort level f_{MSY}, or F_{MSY} (if the catchability coefficient *q* is known) are the TRP's corresponding to MSY. $2/3F_{MSY}$ has been proposed as a more cautious TRP in an attempt to reconcile the problems associated with equilibrium assumptions and the accuracy of estimates of F_{MSY} but has been criticised for being arbitrary, empirical and insensitive to changes in recruitment. For the same reasons, F_{MSY} has also been proposed as a LRP rather than a TRP, providing greater flexibility in choosing a more cautious F-based TRP taking account of uncertainty surrounding the estimate of the current F (F_{NOW}).

Other TRP's in this category include Maximum Average Yield (MAY) and corresponding F_{MAY}, and Maximum Constant Yield (MCY) defined as "the maximum constant catch that is estimated to be sustainable with an acceptable level of risk, at all future levels of biomass" implies a much lower level of fishing mortality (F_{MCY}). This is extended further by means of a dynamic TRP called Current Annual Yield (CAY) which is defined as the annual yield calculated by applying a reference fishing mortality (F_{REF}) to an estimate of the fishable biomass at the start of the year. F_{REF} (which is often set equal to $F_{0.1}$ (see below)) is the fishing mortality rate that, if applied every year, would within an acceptable level of risk, maximise the average catch from the fishery.

(ii) Yield per-recruit (YPR) criteria eg F_{MAX}, $F_{0.1}$.

Yield per recruit (YPR) criteria were some of the earliest benchmarks for fisheries management derived from analytical age-structured (dynamic pool) models. F_{MAX}, the level of fishing mortality for a given age or size at first capture which maximises the average yield (the reference variable) from each recruit entering the fishery, is a frequently used TRP's. However, for many species there is no clear maximum to the curve of YPR against F, and therefore the fishing mortality level $F_{0.1}$ has been proposed as an alternative, more conservative, TRP. $F_{0.1}$ is an arbitrary criterion defined as the fishing mortality rate at which the slope of the YPR curve as a function of F is 10% of its value at the origin. In South Africa, a more conservative value ($F_{0.2}$) is used.

Although the use of YPR as a reference variable does not take account of the effect of fishing on recruitment, Deriso (1987) as cited by Hilborn & Walters (1992) has shown that for a broad range of models of stock dynamics, $F_{0.1}$ does not unduly reduce spawning stock abundance.

Population parameter estimates for basic YPR models include instantaneous natural and current fishing mortality rates (M and F), von Bertalanffy growth parameters (L_∞, K, t_0), length-weight model parameters (a and b), and length (age) at first capture (l_c). Depending upon the method employed to estimate their values, these parameters estimates will have their own suite of data requirements (Figure 9).

(iii) TRP's and LRP's based upon the size of fish caught

The YPR models described above indicate the mean age/size at first capture that provides the maximum YPR for a given set of population parameters and given F. When data required to estimate F are not available, the mean size of fish in the catch can be used with other data as a proxy TRP. Other data include the age or length at first capture (Tc_{50}/Lc_{50}) estimated from gear selectivity ogives in relation to the size at first maturity (Lm_{50}). Rational targets and LRP's would include those which aim for an exploitation rate such that the average size of fish is equal to, or greater than, the average size at maturity, thereby ensuring that at least 50% of individuals would have a chance to spawn.

The average length at maturity (Lm_{50}) can be substituted into Beverton and Holt's equation relating the instantaneous total mortality rate Z to mean size in the catch to estimate a corresponding reference value for total mortality Z* (Figure 9).

(iv) TRP's based on the natural mortality rate, M

A family of empirical models exist to estimate MSY from the generalised formula MSY = x.M.$B_{0,}$ where B_0 is an estimate of the virgin unexploited biomass and x takes the value of 0.1 to 0.5 depending upon stock characteristics (Caddy and Mahon (1995); Kirkwood *et al.* (1994); Gulland (1983); Beddington and Cooke (1983)).

The foundations of the model descend from the surplus production model, and that at MSY, the fishing and natural mortality rates will be equal. In New Zealand, a more precautionary reference point is used, where MCY = $0.25F_{0.1}B_0$.

(v) TRP's based upon the total mortality rate, Z_{MBP}, Z*.

It is often difficult or impracticable to partition mortality into natural and fishing components and hence reference points may be expressed in terms of total mortality Z and where Z_{MBP} is the total mortality rate corresponding to Maximum Biological Production. For the Schaefer model, Z_{MBP} and F_{MBP} correspond to a fishing mortality consistently below F_{MSY}.

(vi) TRP's and LRP's based upon recruitment considerations

In addition to size-based reproductive TRP's (iii), due to the demonstrated dependence of recruitment on the spawning stock size, other TRP's are used to ensure that the spawning capacity of stocks is conserved and thereby prevent stock collapse through recruitment overfishing. TRP's based upon recruitment considerations are derived from stock-recruitment relationships (SRR's) and an extension of YPR analysis which incorporates age/size at maturity in calculating spawning-stock-biomass-per-recruit (SSBPR) corresponding to different levels of F.

For SRR, derived from fitting various types of curves to time series of stock and recruitment data, the SSB corresponding to maximum recruitment or Maximum Surplus Reproduction (B_{MSR}) corresponds to a level of fishing mortality F_{MSR}. Because, recruit and hence SSB is also influenced by natural environmental variation, in practice, F_{MSR} must be updated annually to achieve a constant B_{MSR}. Whilst this approach is useful for salmon which can be counted annually during their spawning migrations, its information requirements are too great for most species.

Evans & Rice (1988) and Getz & Swartzman (1981) as cited by Caddy & Mahon (1995) describe other approaches to the use of SRR to generate reference points.

Reference points based upon SSBPR are often employed in the absence of historical data on stock and recruitment if information on maturity/fecundity at size/age is available. SSBPR decreases monotonically with increasing F, and SSBPR is usually expressed as a percentage of SSBPR (%SSBPR) under unfished conditions (ie at virgin spawning biomass, B_0). Reference points are expressed in terms of levels of F which produce particular %SSBPR designated

$F_{\%SSBPR}$ or just $F_{\%}$. Goodyear (1989) as cited by Mace and Sissenwine (1993) suggested that a critical minimum of $F_{20\%;}$ the fishing mortality at which SSBPR is 20% of the maximum, be maintained for stocks where the SRR cannot be determined. Mace (1994) found that the validity of $F_{20\%}$ is highly dependent on the life history characteristics of the stock, particularly the degree of density dependence in the SRR. She therefore recommends that $F_{40\%}$ be adopted as a target reference point when the SRR is unknown and that %SSBPR be related to the estimated or assumed degree of density-dependence in the SRR. Clarke (1991) suggested that a target of $F_{35\%}$ should be capable of achieving high yields for a wide range of SRR's.

Reference points based upon SSBPR or %SSBPR have also been defined on the basis of the relationship between SSBPR and survival ratios (Recruits per spawner (R/S)) obtained from pairs of stock-recruitment relationships. For any level of F there is corresponding straight line through the origin of the S-R scatterplot. The slope of this line is the inverse of the SSBPR which corresponds to the F level. The S-R plot can thus be used to select a survival ratio for use as a reference point, which can be translated back in SSBPR values and projected onto the F scale to determine the corresponding F level. The reference point F_{REP} or F_{MED} corresponds to an average survival ratio, S/R=1, at which the stock relaces itself. Similarly, F_{LOW} and F_{HIGH} are defined to leave 90% and 10% of the data points for recruitment above the line through the origin corresponding to that level of fishing mortality. These reference points are interpreted as follows:

F_{LOW} Low probability of stock decline, and some likelihood of stock increase.
F_{MED} Likely that current stock levels will be sustained
F_{HIGH} Likely that fishing at this level will result in stock declines.

LRP's have also been derived from SR considerations, for example F_{MED} has been proposed as a LRP (Caddy and Mahon 1995). The extreme LRP for SSB is F_T, which is based upon the the slope of the SRR at the origin. When $F > F_T$, effective stock extinction is assured. F_T may be estimated from the 90th percentile of the observed survival ratios (S/R) equivalent to F_{high}. For most SR scattergrams, data points relate to the ascending linear part of the curve and hence F_T will be more closely approximated by the 50th percentile of the S/R ratios equivalent to F_{med}, hence F_{med} may be regarded as a more rational LRP. Other proposed LRP's include $100._T.B_0$ <0.05. More generally, for stocks considered to have average resilience, $F_{20\%}$ is recommended, whilst for little known stocks $F_{30\%}$ is recommended (Figure 9).

The importance of stochastic environmental factors on recruitment success is widely recognised (Pitcher and Hart (1982); Welcomme (1985); Le Cren (1987); Cushing (1988); Eckmann *et al*. (1988) and has been attributed to obscuring density-dependent affects (King 1995). Mills and Mann (1985) used environmental variables alone to explain variation in year class strength. However, recruitment cannot be entirely independent of spawning stock biomass (Salojarvi (1991; Hilborn and Walters 1992). Therefore several workers including Stocker *et al*. (1985) have incorporated environmental factors into extended stock recruitment models. Therefore in addition to annual estimates of stock size and subsequent recruitment, management objectives and strategies based upon stock recruitment considerations may need to be supported by environmental data.

(vii) Other biological LRP's

In developing countries in particular, where adequate information is absent or imprecise several other warning signals or LRP's may be adopted. These include: (a)When total mortality (Z) rises above some agreed value such as that corresponding to Zmbp or Z* for the stock; (b) when the proportion of mature individuals in the stock falls below some agreed percentage of the virgin stock; (c) when catch per unit effort (CPUE) falls below some agreed level, and (d) when annual recruitment remains poor for a predetermined number of consecutive years. Caddy and Mahon

(1995) also list two other “robust” indices of low stock size and hence reduced intra-specific competition which may be employed as LRP’s: increases in mean weight at age and reduced size at maturity (Lm_{50}).

(viii) Reference points for new or developing fisheries

Reference points for new or developing fisheries will usually be derived from exploratory or survey biomass estimates using the empirical approaches described in (iv) above.

When estimates of M are unavailable or unreliable, or when considering the potential yield from multispecies assemblages, empirical ‘spatial-replicate’ models are frequently employed which assume that each spatial replicate is independent but ecologically similar. Surplus production models based on spatial replicates have been used in coral reef fisheries to estimate MSY; the classic example being (Munro and Thompson 1983). Simple linear regression models have been widely used to predict potential yield (MSY) from inland (river, lake, reservoir and lagoon) fisheries Halls (1998); Halls (1999); Welcomme (1985). Explanatory variables include fishing effort, fishing intensity, morphoedaphic, hydrological and other environmental variables. These models also assume that each spatial replicate is independent but ecologically similar and, for those models that do not include fishing effort as an explanatory variable, that yield corresponds to MAY or MSY.

(ix) Reference points for stock rebuilding

For stock rebuilding, F must be below Fmed (vi), the level at which the stock replaces itself. For extremely depressed stocks, F_{LOW} may be employed.

(x) Simulation Modelling

In addition to the use of reference points, management actions are often explored and guided by means of age-structured population dynamics (ASPD) simulation modelling. Pitcher & Hart (1982) describe some management applications of these simulation models with particular emphasis on optimal control and risk assessment. These models tend to be data intensive requiring, in their most basic form, time series of stock and recruitment data in addition to the same parameter estimates required for YPR models.

(xi) Multispecies and ecosystem considerations for management - models and reference points.

Fisheries management has traditionally examined each species and fishery as separate entities to be analysed and managed, ignoring potential interactions among species and fishing gears (Hilborn & Walters (1992); Sparre & Venema (1992)). Several reasons for this stance exist:

- Species interactions may be insignificant
- Parameter describing species interaction may be difficult or prohibitively expensive to estimate
- Controlling species interactions may not be possible.

However, the need for more holistic multispecies, multigear and ecosystem perspectives has been frequently noted (see Caddy & Mahon, 1995) and therefore whilst still at relatively early stages of development and sophistication, a number of management models (both technical and theoretical) and reference points have been developed to help deal with these interactions. These, together with their data requirements for the main categories of interactions, species interactions, technical interactions and ecosystem interactions, are briefly described below.

Species Interaction

Multispecies stock and recruitment
The reference points based upon recruitment considerations described above can implicitly account for the effects of predation and competition caused by other species by adding additional terms to standard SRR's (eg Ricker and Beverton and Holt) which represent variation in juvenile survival, in the same way as including the effects of environmental factors (Hilborn & Walters, 1992). The additional data requirements being the spawning stock biomass of the putative competitor/prey species.

Multispecies Surplus production models
Surplus production models can be similarly modified to account for competition and predation interaction between species, again with additional terms that describe how much a unit biomass of species X reduces the relative growth of species Y. The additional data requirements are corresponding time series of catch and effort for the putative competitor/prey species. However, the need for strong contrast in the abundance of the species under consideration make the approach unrealistic as a management tool (Hilborn & Walters 1992).

Aggregated production models
More successful variants of the multispecies surplus production model are aggregated production models which simply lump several or all species together and treat them as a single stock to be analysed using surplus production models. Relevant reference points are simply multispecies analogues of those described in (i). Practical applications of this approach include Medley *et al.* (1993) and Ralston and Polovina (1982).

Multispecies Virtual Population Analysis (MSVPA)
MSVPA is a variation on single species VPA (Pope 1972). VPA is not a management model (with reference points) per se, but more of an analytical approach for estimating (spawning) stock biomass, recruitment and age dependent fishing mortality. For this reason, it is often an important sub-model to many of the management models described above (Figure 9). The multi-species version attempts to account for species interaction (predation) in species and age dependent natural mortality rates based upon the analysis of stomach contents. Therefore, in addition to the basic requirements of single species VPA (catch (numbers) at age data and estimate of M), MSVPA also requires reliable annual estimates of the proportion of each cohort consumed by each species from stomach contents analysis to estimate the species and cohort natural mortality matrix. Such demanding data requirements make this approach beyond the scope of most management authorities.

Technical Interactions

Technical Interactions are caused by non-selective fishing of multispecies stocks where effort cannot be targeted on a species-by-species basis. The effect is most pronounced when the assemblage contains species with very different life-history characteristics and consequently different responses to exploitation. Thus an overall single species F- or sized-based reference point will overexploit some species and under-exploit others (Caddy & Mahon, 1995; Hilborn & Walters, 1992; Sparre & Venema 1992).

A number of multispecies models have been developed to explore technical interactions and various management strategies. The majority are extensions to YPR or age structured population dynamics (ASPD) simulation models (eg Murawski, 1984), involving summing yields from each species, calculated from species specific parameter estimates for growth, mortality, length at first capture, vulnerability (catchability) to different gear types, and fishing effort by gear type. Species specific recruitment is either (i)expressed as relative recruitment estimated from surveys, (ii) estimated by 'tuning' the model to minimise the sum of squares between the observed and predicted catches, or (iii) modelled using a SRR estimated by VPA (length or age-based). Economic (interactions) and spatially structured extensions include (Pikitch 1987), MIXFISH (in LFSA; (Sparre 1987)) and FAO's BEAM 4 ' Analytical Bio-economic Simulation of Space-structured Multi-species and Multi-fleet Fisheries' (Sparre and Willman (1991); Hoggarth and Kirkwood (1996)). Reference points include f_{MAX}, $f_{0.1}$, and f_{MEY} (see below), though more general management strategies can also be explored in detail including the effects of changes to fishing effort by gear type, location and time period, and mesh size, on total yield and revenue.

Ecosystem Interactions

Ecosystem effects of fishing are widely documented (Caddy & Mahon, 1995; Pauly 1994; Regier 1977; Regier & Henderson 1973) and describe changes in species composition characterised by the progressive loss of large, high value (predatory and migratory) species and a shift towards assemblages predominated by small, low value plantivorous/herbivorous species with increasing fishing effort.

Quantitative descriptors of fishery induced changes to exploited assemblages which could be used as reference variables include (i) the slope of the assemblage size spectra (plot of $\log_e$ numbers against $\log_e$ length of each species) which decreases linearly with the level of exploitation (Gislason and Rice 1998) and is easily monitored; (ii) diversity indices and (iii) the results of multivariate trend analyses (see Jongman *et al*. 1995) describing how the assemblage changes in response to exploitation. Measures (ii) and (iii) require estimates of abundance (numbers or CPUE) or biomass for each species in the assemblage.

Mass balance or trophic level models such as ECOPATH (Polovina 1984); can provide insights into ecosystem functioning. The approach employs a system of linear equations through which the biomasses of different consumer groups within an ecosystem can be estimated, along with the trophic fluxes among them. Some of the data required to construct these ecosystem models form the basis of many stock assessments, such as fish catch, natural mortality rates etc. However, the remaining information requirements relating to the non harvest components of the ecosystem will generally not be the concern of most government fisheries departments.

Socio- Economic Reference Points

(i) Maximum Economic Yield Criteria: F_{mey}

Maximum Economic Yield (MEY) is central to basic fisheries economics theory and based around the Gordon-Schaeffer surplus production model (see Cunningham *et al*. 1985). MEY describes the maximum difference between the landed value and the harvesting costs and occurs at a level of effort F_{mey}- the TRP for MEY. In most cases, costs are assumed to increase linearly with increasing effort. Costs comprise fixed costs (eg cost of gear, boat, annual license fee) and variable costs (eg fuel, bait, crew, opportunity cost, interest payments etc). Fixed costs are generally independent of fishing effort, whereas variable costs do. Landed value is assumed proportional to landings, so that the landed value less the total costs are the economic rent (profits). Rent is also maximised at a lower fishing effort (F_{mey}) than F_{msy} and hence the use of F_{mey} as a TRP is less likely to result in biological overfishing than F_{msy}. Data requirements are as for MSY criteria in addition to the total costs and landed value. The economic rationale for the rent maximisation objective is that the harvesting of fish requires society's resources such as fuel, labour and materials, and that this is optimised at F_{mey}.

The value of a unit weight of landed catch may vary according to the size of individual fish or with species composition, in the case of multispecies fisheries. Both fish size and species composition are functions of fishing mortality (see above) and therefore based on purely economic criteria, may be used as TRP's. Even if the target F value cannot be estimated (due to insufficient institutional capacity or resources), in theory F could be adjusted until the catch value is maximised.

Social and Multi-Objective Reference Points

Maximum Social Yield (MScY) is an amalgamation of various social preferences and objectives such as income distribution, employment and the maintenance of traditional heritage...etc as identified in Table 5 (Section 4.3.2 B) . Similarly, Optimal Social Yield (OSY) and Optimal Yield (OY) represent the idealised attainment of pre-arranged "…*economic, social and biological values*" ((Wallace 1975)) and as such, are not considered technical and fixed reference points but as guidance to manageable and safe practice (Caddy & Mahon (*ibid.*).

The concepts of MScY, OSY and OY remain abstract are not derived from any formal model, but are used primarily to shift the management debate away from that of a purely biological one. If, however, desirable social and economic targets are identifiable by stakeholders and government it may be possible to model appropriate policy options through multiple-criteria decision-making (MCDM) techniques (see Mardle and Pascoe 1999) for a comprehensive review of applications in fisheries). This approach seeks optimal or "best-fit" solutions by weighting the various general management objectives and identifying Pareto efficient combinations, that is, solutions where no goal can be improved without degrading others. However, these techniques are still being developed and have only been deployed on an experimental basis where management options are tightly framed and where large sets of quantitative data are available. The potential of MCDM techniques in the context of artisanal fisheries is currently limited.

Pitcher & Hart (1985) advocate that the best policy is to place greatest emphasis upon biological objectives and then introduce economic and other considerations as a way of selecting the best stratagies to achieve optimal biological objectives. In their words "To run things the other way round seems a path fraught with dangers, since only by putting the stock biology first can we be sure of continuing to use the valuable naturally renewable resources of fisheries".

Hannesson (1981) as cited by Charles (1988) argues that the best, though not obtainable, single-objective ideal is rent maximisation and therefore improvements or second best solutions should be sought, given the institutional constraints. One such important constraint is fishery employment as a common means of supporting rural communities, and thereby a measure of social stability.

4.3.4 Summary of data and information requirements in relation to general management objectives, formal management models and reference points

A. Biological / Resource orientated objectives and reference points

The performance of resource orientated management objectives for a fishery, both in terms of default indicators to meet general management objectives, and the array of commonly employed reference points described above are evaluated on the basis of estimates of catches by species and the corresponding fishing effort employed to catch it during a given period of time, commonly a year, and information on population dynamics (growth, mortality and reproduction) of the exploited populations derived from the (sampled) catch.

Total Catch
For management purposes, catches should be measured in terms of gross catch which relates to the total live weight of fish caught prior to any discarding or processing. Estimates of nominal catch, required for and International responsibilities (Sections 4.6 & 4.7), refer to the live weight equivalent of the fish retained after discarding whether it is gutted, filleted, or processed in anyway. Conversion factors are used to convert retained landings to nominal catch (Brander 1975).

Obtaining data on the catch of each individual species is not always possible due to resource constraints or problems of identification. Catches of different species are therefore often combined in various different categories such as families, guilds, demersal/pelagic, mixed fish...etc.

In most cases, it is useful to obtain catch information in terms of both weight and numbers. Conversion between the two measures is made possible with an estimate of the mean weight of individual fish caught[5].

Fishing Effort
Fishing effort (*f*) is most commonly monitored in relation to catch to provide estimates of CPUE (CPUE = Abundance x *q*) - an index of fish abundance (Section 4.3.2 A) and to provide a proxy of fishing mortality, F (*F=fq*) for use in surplus production models (Section 4.3.3) where *q* is the *catchability coefficient*; a measure of the efficiency of the gear, gear/vessel combination or FEUs.

Catchability varies among gear types employed by the FEUs according to their attributes and characteristics. For example, a large monofilament gillnet will have a greater efficiency or fishing power than a single hook and line. The units used for measuring fishing effort are therefore critical. Generally, measures of fishing effort need to indicate how many units of the gear were used, their size, and how long they were fished for. Standard units of effort for different gear types are given in Annex 2.

When vessels form part of the FEUs, catching power will also depend upon various attributes and characteristics of the vessel including its size, tonnage, engine power, hold capacity ...etc. These attributes or characteristics provide a basis for categorising vessels to both help standardise fishing effort (see below) and to provide *strata* for catch and effort sampling programmes (see Section 5.1.1).

Measures of fishing time for this type of FEUs may be less straightforward to monitor than a

[5]Mean weight (or length) is also a useful proxy or relative fishing mortality (Section 4.3.3)

simple gear operated by an individual fisherman. The actual time spent fishing by some types of these FEUS's, for example, tuna seiners, may account for only a small proportion of the total time available for fishing. Significant proportions of the total time spent fishing may be devoted to time spent travelling to the fishing grounds, time spent searching for the best places to deploy the gear eg around shoals of tuna, and the time required for handling and processing the catch (Total time spent fishing = travel time + search time + setting time + handling time). Measures such as the total number of days at sea are unlikely to provide a useful indicator of abundance when combined with the corresponding catches for the period. For this type of fishery, it is therefore necessary to monitor each component of the total time spent fishing so that more relevant measures of effort to estimate abundance can be calculated, such as the search time and/or the actual time spent fishing (see Annex 2).

Methods to standardise fishing effort across different vessel categories to allow the calculation of total or overall effort (and CPUE) for all vessels during a period are described, among others, by Hilborn & Walters (1992) and Sparre & Venema (1992). This task is, however, much more complex in mulitgear fisheries such as those in Bangladesh (see Field Study 2, Volume II) where more than 100 gears may be used during the course of the year, but where the types of gears used and their catchability varies seasonally in response to dynamic hydrological conditions. This type of standardisation problem has also been reported for small-scale marine fisheries in the south Pacific: "...the fact that most tropical fisheries are multigear fisheries makes the derivation of any but the crudest expressions of overall (combined) fishing effort almost impossible" (Munro and Fakahau 1993). Such crude measures of effort might include the overall numbers of fishers or canoes/boats, or the numbers of different types of gear in use (Hoggarth *et al*, 1999). However, these coarse measures make it impossible to detect subtle changes in effort or catchability, caused by for example, improvements in gear technology.

Alternatively, if estimates of CPUE are simply required for monitoring relative species i abundance in period k, then the effort corresponding to a single gear type j may be used:

$$CPUE_{i,j,k}\text{ (kg / unit effort)} = \frac{\text{Total catch of species } i\text{, taken by gear } j\text{, in period } k}{\text{Fishing effort of gear } j\text{, in period } k}$$

Where several different CPUE estimates are available for a single gear type in a given period (eg from different fishers), an average CPUE figure may be calculated. However, CPUE's should never be averaged across different gear types.

For monitoring species abundance where catchability varies seasonally, such as in floodplain fisheries, CPUE estimates for the current year must only be compared with those for the same periods in previous years. Since the timing of the seasons varies between years, CPUE's may best be estimated as the average for each season (eg the floodseason, the falling-water season and the dry-season) rather than for individual calender months (Hoggarth *et al*, 1999).

Fish abundance is generally not uniform over the range of fishing operations. This may give rise to imprecise catch and CPUE estimates, which can only be remedied by spatially stratifying the sampling programme to a more local level and/or collecting larger sample sizes (Section 5.1). This problem is often acute in the floodplain environment where gear catchability may vary significantly on a very local spatial scale due to variations in hydrological or morphological conditions or fish abundance associated with, for example, local fish migration routes. For most floodplain fisheries, the measures described above to improve the precision of catch and CPUE estimates may be prohibitively costly.

Spatially referencing data and information collected from the fishery may also provide managers with a means of: (i) developing spatial management models (see Section 4.3.3); (ii) identifying important areas for conservation and management eg spawning locations, nursery areas...etc; (iii) examining spatial and technical interactions among fleets or fishers, and stocks (iv) managing the fishery more effectively on the basis of fishery sub areas if the population dynamics of the stock varies significantly on a spatial scale.

Sampled Catch
Sampling the catch is one of the major ways of collecting data about fish populations:

(i) *Length/age composition*
Continuous sampling of the catch for age (scales, otoliths and other hard structures) or length composition is required for age- and length-based VPA, respectively. The age composition of the catch, sampled either continuously or periodically, may also be used to estimate total mortality rates. Continuous or periodic sampling of the catch for the age of fish in relation to their length or weight is required to estimate the parameters of growth models (typically the von Bertalanffy growth function, VBGF: K, L_∞, or W_∞).

Ageing tropical fish species using growth checks in hard parts is generally more difficult and costly than for temperate species because seasonal variations in food availability are less pronounced and because many species have a protracted spawning season or spawn more than once per year. Since age is related to length, length sampling or length frequency sampling is used in many tropical fisheries to derive the same types of information using the array of available length frequency distribution analysis (LFDA) techniques (see Sparre & Venema, 1992; Gulland and Rosenberg, 1992). LFDA of periodically or continuously sampled length frequencies can provide VBGF parameter estimates, estimates of total mortality, gear selectivity (length/age at first capture, Lc_{50}/Tc_{50}) and relative recruitment or year class strength.

Even without the use of sophisticated LFDA techniques, simply monitoring the average size of the species landed provides a useful proxy indicator of exploitation rates (Figure 10). When monitored in conjunction with estimates of CPUE, also a proxy indicator, further inferences can be made. For example, a decline in mean size in the catch, coupled with an increase in the catch of juveniles is an indicator of better than average recruitment compared with recent years. An increase in mean size and CPUE may indicate that effective effort has declined in recent years, however, if accompanied by a decline in catch rate, it may indicate that recruitment levels have declined to lower than average levels.

Continuous or periodic sampling of length and corresponding weight is required to construct length weight relationships (keys) to covert length to weight.

(ii) *Life history characteristics*
In addition to length and age, the catch of a species is often sampled (often regularly over a period of a single year) for its sex and reproductive condition in relation to its length to construct maturity ogives showing the cumulative percentage of mature individuals from which an estimate of the mean length at sexual maturity (Lm50) can be made. The estimate of Lc50 (see above) in relation to a species Lm50 provides a simple limit or target reference point (Section 4.3.3).

Similar sampling regimes are used to estimate the spawning period or locations of species from sampling gonad weight in relation to their total or somatic weight (King, 1995). Having identified, the spawning period, catches of species may be sampled for fecundity to construct length- or age-fecundity relationships which may be required to construct stock recruitment relationships or for some age-structured models (Figure 9).

(iii) *Stomach contents*
Stomach contents sampling is required for multi-species VPA and for Ecosystem models. However, neither of these approaches are likely to be of practical use for most artisanal

fisheries. Data and information generated by research surveys and tagging programmes are considered too specific here to be included in the design of the FIMS, and therefore are not considered further.

B. Socio-economic orientated objectives and reference points

In summary, the performance of socio-economic orientated management objectives for a fishery, both in terms of default indicators to meet general management objectives and the commonly employed reference points described above may be are evaluated on the basis of the following broad categories of data described below. Monitoring fisheries performance with respect to broad groupings also has practical advantages. As Gustavson *et al* (1999) state:

"It is important to link sustainable development goals to movements of a small slate of individual indicators as single indicators can rarely be linked to any specific sustainable development goal…In contrast to much of the current indicator work, which relies on selecting a large number of detailed specific indicators, it would be more fruitful and less costly to focus attention on a small number of indicators within selected indicator classes (economic, social, environmental or human health indicators)."

Costs and Earnings
Costs and earnings data should relate to the FEUs under scrutiny. FEUs may be stratified according to ownership of the unit, employment status of the fishermen, religion, ethnicity, age time spent fishing, fishing gear, type of fishing vessel/craft etc. Data on costs and earnings for each FEU category should include:

Fixed costs
- Gear, vessel investment
- Insurance
- Depreciation

Variable costs (owner operating)
- Repair and maintenance of craft
- Repair and maintenance of gear
- Food
- Materials
- Others

Variable costs (common operating costs)
- Food
- Traditional taxes and offerings
- Materials
- Commission
- Repair of craft and gear
- Remuneration to other owners
- Repayment of loans
- Others

Earnings
- Fresh fish sales
- Processed fish sales
- Sales of fishing inputs
- Rental of gear
- Sale of fishing rights
- Investment

Economic Yield (Rent)
The generation and maximisation of resource rent (yield) is one of the main economic objectives of management (see Maximum Economic Yield, MEY - Section 4.3.3). Economic rent in relation to fishing effort is estimated as the difference between revenues and all costs associated with exploiting the resource. This includes total catch, prices, harvesting, processing, management and opportunity costs, and management revenues generated from licensing, access restrictions, quotas etc.

Export Revenue
Annual export revenue by species or product type. For foreign exchange earnings, data on investment in foreign and imported gear/vessels, engines etc would also be required, together with foreign exchange earnings from fish and fish product exports.

Employment
Employment is typically expressed in terms of the number of individuals involved in the fishery sector stratified by a primary (harvest) and secondary (post harvest) sub-sectors, season, fishery type, region, socio-economic categories...etc.

Poverty
Income from fishing (costs and earnings data) by FEU of interest, and the nationally adopted poverty (income level) or cost of basic food basic. Numerous other proxies may be used including distance to clean water, material possessions...etc.

Industry diversification
A variety of data may be employed to assess or monitor industry diversification including: the total numbers of supporting sectors, total numbers of different gear or vessel types, and the total numbers of target species.

Food Provision/Security
On a macro scale, data would be required on the total national fish production (sum of total annual catches/landings of all species), total national fish imports, total national exports, and total population number. On a micro scale, household fish consumption per unit time period (eg kg/year), appropriately stratified, for example by region, fishery, fisher category...etc, would be required.

Conflict
Conflict monitoring requires tallies of conflict incidents by category (injuries/deaths, gear/vessel damage, legal and tribunal cases...etc) stratified by desired strata eg sector, region...etc)

Maintenance of traditional management/culture
Data requirements might include the numbers of villages operating access payments to chief fisher or village head, or the numbers of villages operating sanctions set by chief fisher or village...etc.

Catch and Effort
In addition to cost and earnings data, estimates of total annual catch and fishing effort (see above) will also be required to estimate F_{MEY}.

4.3.5 Environmental Monitoring
Fisheries operating in certain environments, for example floodplain-river systems, coral reefs, mangroves etc are particularly sensitive to environmental stress. Environmental degradation in the form of hydraulic engineering, sedimentation, poor-land use practices etc, is often more of a threat to these fisheries than over-exploitation. The importance of environmental factors has

been well recognised in the marine environment where historical records have provided strong evidence that environmental factors can be as important as fishing mortality in determining the dynamics of fish populations (Section 4.3.3). Environmental monitoring in parallel with fisheries monitoring is paramount under these circumstances (FAO, 1999b).

The major problem in recording environmental data is deciding what should be recorded. There are potentially hundreds of different factors that could be recorded alongside fisheries data. There is also the danger that it is almost impossible to make sure that apparent correlations with fisheries data are not simply spurious (Hilborn & Walters, 1992). General variables include:

Environmental Regime	**Example Variables**
Riverine, lakes and floodplains	Water level, area flooded, pH, bioloimiting nutrient and oxygen concentration, temperature, topographical information.
Mangroves:	Salinity gradients, temperature.
Coastal areas	Rainfall, temperature, current speed and direction, sea state, sea colour, salinity.

4.3.6 Adaptive Management and Empiricism - Basic Data and Information Requirements

It has already been emphasised that the more technical or formal models, that many of the reference points described above are based may have limited utility for the management of many significant artisanal (floodplain-river) fisheries, particularly inland fisheries in Asia, because:

- They are often inadequate to capture the spatial and temporal complexity and variability of the environment and the fisheries.
- They are often inappropriate in terms of providing relevant management recommendations eg reductions in fish effort in situations where effort controls cannot be enforced.
- They fail to take account of the simultaneous, and often interacting, affects of important attributes of the fishery such as fishermen behaviour, institutional arrangements and external factors which have been shown to have a significant impact on the outcomes of management.

At the same time, however, it has also been emphasised that only monitoring default data and information requirements with respect to management objectives has limited value since this information cannot inform managers whether or not the particular outcome can be improved or increased, or what measures could be taken to make improvements.

Adaptive management offers an intermediate, non-deterministic or 'black-box model' approach which recognises that the outcome of management actions often cannot be predicted hence:

(i) actively monitors and evaluates management intervention or change;
(ii) compares the outcome with that in other places or in previous times; and thus
(iii) develops appropriate management strategies to achieve specific objectives.

Adaptive management is effectively an experimentation and learning process, is possible at all the spatial levels (RMAs, CMAs, IMAs, VMAs), and intended to increase knowledge of the effects of resource, environmental, technical and institutional attributes of the fishery or fisheries in relation to achieving specific management objectives (Hilborn & Walters, 1992; Hoggarth *et al*., 1999).

It is simple process whereby adjustments are made to these attributes, typically the operational rules (institutional arrangements) such as the level of regulation or management tool, or the mixture of tools used, with the intention of improving the outcome from the fishery. If it is found, for example, that a new reserve designed to protect spawning 'whitefish' does not increase the catch of 'species X' as much as hoped, it may be decided to introduce another reserve, or to add a ban on a certain type of gear in the next revision of the management plan. Further iterations to the management plan may be required until the desired outcome is achieved.

The adaptive management process is likely to be the most suitable approach for IMA and VMA managers to adopt for the management of sedentary resources since it can be applied to any local conditions and institutional arrangements without any *a priori* understanding of the fishery or formal monitoring and evaluation (Hoggarth *et al*, 1999). At the same time, it may offer higher level managers such as government fishery departments a practicable or more appropriate means by which to manage SOSR and MS at the national, RMA and the CMA levels.

Adaptive management may be difficult to apply to short lived *r*-selected type species whose abundance may respond both rapidly and significantly to environmental variation such as flood strength or up-welling. In these cases, it may to difficult to separate out these environmental effects from the effects of management. Similarly, the approach may not be suitable for very long-lived, slow growing *K*-selected type species, such as certain species of reef fish, where the effects of management intervention may not be manifested in fishery benefits for many years.

4.3.7 Data and Information Requirements to Support Adaptive Management of SOSR and MS by Government Fishery Departments

As well as monitoring the outcomes of management in relation to management objectives, it is necessary to monitor factors (inputs) that are likely to affect the outcomes (outputs).

Data and information requirements in relation to common management objectives have already been identified in Section 4.3.2 above. Data and information concerning many of the inputs, for example, the decision-making arrangements, or numbers of different gear types may remain fixed or change slowly with time and are already included in the management plan (see Section 4.2 above). Data and information concerning these inputs can therefore be updated as the management plan is adapted in accordance with the periodicity set out in the plan. Other more variable inputs that require more regular monitoring include the amount of fishing (fishing effort), both legal and illegal, and environmental conditions (see Sections 4.3.4 & 4.3.5).

Since the achievement of nearly all management objectives depends upon the health of the fish stocks, it is generally useful to always monitor the ecological state of the fish stocks. Estimating the absolute abundance (numbers or biomass) of fish stocks is often impracticable for many fishery managers. Monitoring *relative* abundance, measured in terms of CPUE (see Section 4.3.4) provides a more practical alternative, particularly for a single gear type. Other basic reference points, such as mean fish length, may also provide useful indicators of the relative state of the stocks (Section 4.3.3).

4.4 Data and Information Requirements for Control and Surveillance (Dataset 2)

Management control measures are often based upon limiting or restricting access to resources or by means of catch quotas allocated to licensed individual fishers, gears or vessels (see Annex 1). In order to effectively enforce such measures, it is necessary to maintain up-to-date registers of these licensed fishermen, vessels or other FEUs. Based upon company experience, literature reviews including: Mees (1998); FAO (1997); FAO (1996a); FAO (1996b); FAO (1996c); Flewwelling (1994); Carrara and Ardill (1989); Caddy & Bazigos (1985); Brander (1975) and the two field studies (Volume II), these typically include information relating to the ownership, identity, communications and fishing power[6] of each FEU. Corresponding licence details of each FEU, which are normally held in a separate table (and related by means of a allocated fishing unit identification number), include details of the licence holder, the licence fee which is required to estimate revenues derived from the fishery (Section 4.3.4), quota allocations where applicable, and the period of validity:

(i) Name and address of each fisher, owner, skipper or charter agent of each fishing vessel or unit.
(ii) Address or port of registry of each vessel or fishing unit.
(iii) Details of mortgages, maritime liens and other encumbrances.
(iii) Identification and communication details (particularly for larger fishing vessels).
(vi) Information relating to fishing power and operations.
(vii) Details of the licence and/or quota.

4.5 Data and Information Requirements for Policy and Development Planning (National Reporting Responsibilities) - Datasets 1a and 1b.

The significance of fisheries with respect to the regional, national and local economy must be understood before the best policy decisions are made in relation to other sectors of the economy. This demands a clear understanding of the position or status of the fishing in the national socio-economy. The provision of this information may be regarded as a national reporting responsibility. Policy and development planning decision-making therefore requires information relating to the benefits generated from the fisheries in terms of economic return, employment and food production, and sometimes in terms of recreational opportunities. Information relating to the costs generated by the fisheries, in particular monitoring, control and surveillance, subsidies and the opportunity cost of the fishery in relation to competing sectors, is also required (FAO, 1997).

FAO (1997; 1999b) identify three main categories of data and information desirable for policy and planning decisions. This has been augmented by reviewing the common types of data and information that are presented in annual fisheries reports or statistics which are often published by fishery departments (e.g. Cook (1988); Horemans (1998); Moussalli and Bouhlel (1988); Anon (1991); Chemonics (1992); Mees *et al.* 1998) for policy makers:

4.5.1 Resource and Fishery Related

The structure of a country's fisheries is often complex. Different groups of fishers may target different resources in different locations using different gears or vessels and land at different sites. Effective management therefore demands that fisheries are divided into sub-sectors (and management units - see Section 3.6) according to similarities in one or more of the

[6] This information is often required to standardise fishing effort (see Section 4.3.4) and calculate licence fees or quota allocations.

aforementioned characteristics, and managed under their own appropriate management plan. For example, country's coastal marine fishery may be sub-divided into an inshore subsistence and an offshore commercial fishery comprising three different vessel categories; gillnetters, 'baby trawlers' and large trawlers.

Policy level decision-making requires information on the relative importance of each sub-sector, typically in terms of total catches or landings, economic value and employment. This information is often presented in terms of the current year (CY) and annual time series (TS) in the reports of most fishery departments.

Biological, technical and social interactions are common among sub-sectors. Fisheries managers need to advise policy makers on the potential implications of policy changes on each sub-sector. This may require special studies or spatial multigear, multifleet, bioeconomic stock assessment models such as BEAM 4 (Section 4.3.3) which employ routinely monitored data and information from the fishery. Spatial monitoring of fishery activities between sub-sectors or fishing units in relation to performance, perhaps with the aid of GIS techniques, may provide a simple alternative.

National fisheries policy decisions must take account of their implications for the environment of the different life-stages of resources important to fisheries. This requires spatial evaluation of environmental and ecosystem impacts on the fishery arising from both the activities of the different sub-sectors of the fishery and other competing sectors of the economy such as industry or agriculture in order to develop and coordinate integrated management policies (FAO 1999a). These environmental impact assessments will invariably require special studies. More generally, managers should provide policy makers with the history of management performance in relation to previous management strategies to help learn lessons.

4.5.2 Socio-economic Information

Humans are an integral part of fisheries and their social, cultural, institutional and economic characteristics have an important bearing upon management outcomes (Section 3.1). Management decisions made at any level will invariably impact on peoples livelihoods. Socio-economic information is therefore required to help predict the nature and extent of these impacts. At the policy level, decision-makers require the following data and information for each sub-sector:

- The stakeholders and their features and interests in the fishery.
- The social and economic dependence of the different stakeholders on the fishery.
- The costs and benefits from the sub-sectors.
- The role of each sub-sector in providing employment to different stakeholders and alternative sources of employment.
- Details of decision-making arrangements including access and ownership rights and the historical roles of different stakeholders.

4.5.3 Monitoring, Control and Surveillance (MCS)

At the policy level, information is required on previous successes or failures in MCS for each sub-sector of the fishery to help develop new policy. Information on the costs of MCS is also important since they can be substantial. It is often the case that the costs of MCS exceed the value of the fishery to users or society. In these situations, alternatives need to be developed.

4.5.4. Summary

Because of the heterogeneity of fisheries and their management and policy institutions, it is difficult to prescribe generic policy-level data and information requirements, their formats and sources beyond those given in Table 6 below and described above. Some of these requirements will potentially be available directly from a FIMS generated by routine monitoring programmes (RMP) or contained within management plans (MP) or from frame surveys (FS) whilst others may need to be generated from a number of sources not included in the proposed FIMS such as fishery department accounts, special environmental studies, or information potentially available from other government departments or ministries eg Department of trade, Bureau of Statistics (BS)...etc. Outputs from the FIMS for policy level decision-making and planning, will therefore be restricted to (processed) data and information collected under the RMP, FS and MP and may need to be tailored to meet local circumstances and requirements.

Data and information for policy and development planning decision-making will, of course, be required from both the locally- and government-managed (SOSR and MS) sectors of the fishery. Although information available from frame surveys and management plans are likely to be common between the two sectors, routinely monitored data may be very different (see Section 4.9.2 'Monitoring IMA/VMA Management Plan Performance') to that collected for implementing management plans for state-owned migratory and sedentary resources (Section 4.3).

However, examination of Table 6 indicates that the most important source of data from RMP's for this management role are catches and market prices by species[7]. Since, market prices for fish caught by the two sectors are likely to be similar, then monitoring catch by species from both sectors should ensure that the data and information requirements for policy and development planning decision-making are satisfied. Data on catch by species is also required for international reporting responsibilities (Section 4.7). Catches by species could be negotiated as one of the indicators of IMA/VMA management plan performance (Dataset 3, Figure 6 and Section 4.9) or simply monitored by the state.

[7] Alternative sources exist for other data collected under Routine Monitoring Programmes (RMP's).

Table 6. Desirable data and information requirements for policy and development planning. Modified from FAO (1997 and 1999b). FS - Frame surveys; MP's - Management Plans; RMP- Routine Monitoring Programmes, SS- Special Studies; BS - Bureau of Statistics, ER- Export records; SA - stock assessment. [1] Monthly breakdown frequently included to demonstrate any intra-annual variability.

Field	Data and Information Requirements	Source
Resource Related	Summary of recent landings[1] (total catches and catch per unit area by species and all species combined) by fishery, location or habitat	RMP
	Inter-annual variability in yield (annual time series of total catches by species and all species combined) by fishery, location or habitat	RMP
	Summary of potential yields by fishery, with options of possible alternative approaches	RMP and SA
	Details on environmental constraints and sensitive habitats	FS & MP& SS
Fishery Related	Summary of types of fishery and gear characteristics for each fleet/fishery	FS & MP
	Number of fishing units for each fishery, fleet, location/ habitat	FS & MP
	Key fishing grounds and their characteristics	FS & MP
	Summary of number and distribution of landing sites	FS & MP
	Details of the costs of fishery management (eg salaries, operational costs, capital expenditure...etc)	Fishery Department accounts
	Total revenue generated from the management of the fishery (eg Licence fees & export duties, sales of ice...etc)	Licence registers & gov.depts
	The impact of fishing gear and practices on the environment and on the ecosystem	SS
	Extent and importance of recreational fisheries, where applicable	FS & MP
Socio-Economic	Characteristics of, and trends in, markets (time series of average market price by species, catch category or product).	RMP
	Contributions to national GDP or local economy (landed value of catch by species and all species combined) by fishery/fleet, location or habitat)	RMP
	Exports (earnings)/Imports by species/product weight/numbers, value and destination/source	RMP & ER & Customs
	Duties paid on exports	ER & Duty
	Employment characteristics by fishery and fleet and possible alternative sources of employment	FS/BS
	Time series of per capita fish consumption (by main socio-economic groups?) and dependency on fish as a food source	RMP, SS & BS & Customs
	Existing institutional structures related to the fishery, including traditional institutions	FS & MP & SS

	Major stakeholders and likely policy implications	FS & MP & SS
	Summary of existing user rights systems of each fishery and fleet	FS & MP & SS
	Implications of State macro-economic policies which could influence fisheries	Various
	Existing or likely developmental activities and their implications for fisheries	Various
	Any trends influencing or likely to influence fisheries, e.g. demographic changes, political changes, migrations, etc.	BS
	Details on any existing or possible conflicts between fisheries or fleets, including the causes	FS & MP & RMP & SS
	Details of any subsidies being paid to fishers and estimated costs of reducing over- capacity	FS & MP & SS
Monitoring, Control & Surveillance	Summary of successes or problems in monitoring and control by fishery and fleet	MP & SS
	Financial and institutional implications of different policy options for monitoring and control	Various
	Details of existing arrangements and potential for partnerships or co- management with user or interest groups	FS & MP & SS

4.6 Data and Information Requirements for Compliance with International Management Responsibilities

The FAO Code of Conduct for Responsible Fisheries (CCRF) (FAO 1995) sets out a number of obligations on States to conserve stocks and avoid over-exploitation. To achieve this, they are required to collect data so that decisions are based upon the best scientific evidence available (FAO, 1999b). Rather than being prescriptive about the data and information that should be collected, broad obligations are set out:

" Conservation and management decisions for fisheries should be based on the best scientific evidence available, also taking account traditional knowledge of the resources and their habitat, as well as environmental, economic and social factors. States should assign priority to undertake research and data collection to improve knowledge of fisheries". (CCRF 6.4).

The *precautionary approach* to fisheries management requires managers to be cautious when the state of the resource is uncertain, for example when fishery data are insufficient or unreliable (FAO, 1999b). This precautionary approach is embodied in the CCRF as well as the 1995 United Nations (UN) Fish Stocks Agreement. The latter is a binding instrument which applies the precautionary approach both on the high seas and within Exclusive Economic Zones (EEZ's) for straddling and highly migratory stocks. Annex 1 of this agreement specifies the minimum data requirements that Flag States are obligated to collect (and share) for the management and conservation of these resources (See Annex 3 of this report). Revisions or elaborations may be made to these requirements for scientific or technical reasons (FAO, 1999b). The basic requirements include:

- Catch numbers or nominal weight by species, and fishing effort by fishery, fleet and location,
- where appropriate, length, weight, age and sex composition of the catch, and other biological information supporting stock assessments eg growth, recruitment, distribution and stock density, and make available the results of relevant research including abundance surveys, and oceanographic and ecological studies, and
- vessel data and information for standardising fishing effort (see Sections 4.3.4 & 4.4).

Because of the characteristics of these resources (highly migratory with poorly defined boundaries) they are not suited to local (community) management. These resources are therefore likely to be most effectively monitored and managed by the state (Section 3.6.2). These data will form part of Dataset 2 in Figure 8.

4.7 Data and Information Requirements for International Reporting Responsibilities

International reporting responsibilities usually exist as a result of either membership to one or more commissions set up to harmonise and promote rational and responsible management of fisheries resources on a regional or global level, or ratification and compliance with international conventions or codes of conduct.

Membership to many of the regional bodies, agencies, organisations and commissions such as the Organisation of Eastern Caribbean States (OECS), Integrated Development of Artisanal Fisheries (IDAF) programme; South African Development Commission (SADC)...etc, often requires the provision of data and information. These data may be specific, determined by a combination of the nature and structure of the local or regional fisheries and the objectives for management and development.

More generic information requirements to meet the reporting responsibilities of the main international commissions and conventions are described below:

4.7.1 FAO Regional Fishery Commission Requirements

Countries that are members of FAO regional fishery commissions including the:

- Asia Pacific Fishery Commission (APFIC);
- Fishery Committee for the Eastern Central Atlantic (CECAF)
- Committee for Inland Fisheries of Africa (CIFA)
- Commission for Inland Fisheries of Latin America (COPESCAL)
- Indian Ocean Fishery Commission (IOFC)
- Indian Ocean Tuna Commission (IOTC)
- Western Central Atlantic Fishery Commission (WECAFC)

established to promote management of fish stocks in the commission or convention area and other members of FAO are required to report to the FAO Fisheries Department the following information (FAO, 1999b):

(i) *Nominal (liveweight) catch statistics* for the countries' flag vessels that fish in the area[8]. These should be broken-down by species classified in accordance with the FAO Common and Scientific names (See Section 5.3). Routine monitoring programmes (RMP's) are the main sources of these data.

(ii) *Annual production of fishery commodities, imports and exports*. These should be expressed in terms of country, volume, value and processing method in accordance with the FAO International Standard Statistical Classification of Fishery Commodities (ISSCFC) (See Section 5.3 and FAO, 1999b for further details). The production of these data is likely to be the responsibility of a country's customs and export department, and therefore will not be an output from the FIMS.

(iii) *Fleet statistics*
Member countries are also required to complete a questionnaire each year detailing their fleet statistics. These refer to the "...number and total tonnage of fish catching, processing, and support vessels utilised in commercial, subsistence and artisanal fisheries by size of vessel measured in gross register tons (GRT) and by type of vessel according to the International Statistical Classification of Fishery Vessels (ISCFV)" (FAO, 1999b). These data are generally available from frame surveys (Section 4.2; 5 & 6.2.2) and or vessel registers (Section 4.4) and included in management plans (Section 4.2).

(iv) *Employment statistics*
Employment statistics are also requested each year by means of a questionnaire. These refer to the number of workers according to the time devoted (full-time, part-time, occasional) to fishing and aquaculture, by gender (FAO, 1999b). Employment statistics are typically collected by means of frame surveys and population censuses undertaken by government statistics such as Bureaus of Statistics (BS) (Table 6) and should be included in management plans.

4.7.2 Convention for the International Trade in Endangered Species (CITES)

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is an international treaty which was drawn up in 1973 to protect wildlife against over-exploitation and to prevent international trade from threatening species with extinction. Member countries (146) act by banning commercial international trade in an agreed list of endangered species and by regulating and monitoring trade in others that might become endangered.

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[8] Data concerning the nominal catch of fish included within FAO species group 36 (tunas, bonitos and billfishes) are reviewed in collaboration with regional tuna agencies ICCAT, IATTC, IPTP, SPC etc.

Exports of endangered species (see Appendix I - III of the Convention) require a valid export permit containing the information set out in Resolution Conference 10.2 (formerly Appendix IV of the convention). See Annex 4 of this report for full details.

The production of these data is likely to be the responsibility of a country's customs and export departments, and therefore will not be an output from the FIMS.

4.7.3 The Convention on Biological Diversity

The convention on Biological Diversity was established in 1993 in response to the the world community's growing commitment to sustainable development. The objectives of the convention are "...the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources, including by appropriate access to genetic resources and by appropriate transfer of relevant technologies, taking into account all rights over those resources and to technologies, and by appropriate funding".

Countries that have ratified the agreement are obliged to identify and monitor through sampling and other techniques "...components of biological diversity important for its conservation and sustainable use" and "Maintain and organize, by any mechanism, data, derived from identification and monitoring activities" (Article 7). However, no advice is given with respect to required measures or indicators of diversity. Several measures or indicators are likely to be appropriate to the fisheries sector based either upon catches (eg species richness, presence/absence etc) or abundance data (eg CPUE data) (Section 4.3.4).

4.7.4 Summary

Similar to national reporting responsibilities (Section 4.5), the data and information collected to comply with these international management responsibilities must also refer to both the locally- and government-managed (SOSR and MS). Similarly, these data are potentially available from routine monitoring programmes (RMP) or from frame surveys (FS) of the two sectors. Catches or CPUE by species will need to be negotiated as one of the indicators of IMA/VMA management plan performance (Section 4.9) in order to satisfy the requirements on biological diversity for the locally-managed sector.

4.8 Data and Information Requirements to Support Adaptive Management of Sedentary Resources by Local IMA/VMA managers.

Formal data collection by local users adopting the adaptive management strategy (Feedback loop 1, Figure 8) is likely to be unnecessary for decision-making by IMA and VMA managers. Management learning at this level will more likely be based on 'common knowledge', derived from co-use of the resource under conditions where mutual observations is possible and secrets hard to maintain (Hoggarth *et al*, 1999).

However, monitoring the performance of individual IMA or VMA units in relation to their management plans(Dataset 3 and feedback loop 2, Figure 8) by higher level fishery departments provides the opportunity to rapidly accelerate the adaptive management learning processes (feedback loop 3, Figure 8) at this local level (See Section 4.9). Formal monitoring of these units (at least for catch by species data) is also required (Dataset 1a.) for national policy and development planning purposes (Section 4.5.4), and to satisfy international reporting responsibilities (Sections 4.7.4).

4.9 Information Requirements to Coordinate, and Evaluate the Performance of, Individual VMA and IMA Management Plans (Dataset 3)

Adaptive management may be employed by IMA and VMA managers to achieve their individual management objectives. Identifying the best combinations of management tools and decision-making arrangements to achieve specific objectives may, however, take several years of (informal) monitoring and evaluation by the local IMA/VMA managers. Fishery departments or higher level management departments have the potential to significantly accelerate this process by monitoring and comparing spatially, performance among individual management plans (Dataset 3). The results and management recommendations arising from the analysis can then be disseminated (Feedback loop 3) to local level managers via appropriate media such as regular radio transmissions, meetings, posters, workshops...etc (see Section 3.2).

This type of spatial comparison approach has been used by Munro & Thompson (1983) for the Jamaican coral reef fishery. However, for that study, only data on catch and fishing canoe density (a proxy of fishing effort) relating to a single year but from several different reef sites (spatial replicates) fished at different levels of effort, were used to construct a 'spatial surplus production model' which provided an estimate of canoe density to achieve maximum sustainable yield. The approach proposed here would not only include information on fishing effort, but also data and information across the full range of attributes identified in the management plan that have the potential to affect outcomes (objectives) to permit a 'spatial inter-disciplinary pattern analysis' (SIPA). This approach would require fishery departments to record the management plans (profiles) of each IMA/VMA, as well as to periodically monitor the performance of each plan (Dataset 3) possibly with the aid of NGOs.

4.9.1 Monitoring IMA/VMA Management Plans

Establishing and describing the management plan for each IMA/VMA could be conducted with the assistance of intermediary organisations such as NGOs as each new IMA/VMA is created. The description of each management plan should be as comprehensive as possible and contain all same types of information as those already described in Section 4.2 for SOSR and MS. For easy reference, these management plans could be entered in the FIMS or simply recorded in standard (paper) report form and appropriately referenced in the database.

Periodic revisions of each management plan will be required as they are adapted by the local VMA/IMA managers in accordance with the periodicity set out in their plans. Maintaining a log of these revisions will allow managers at all levels to monitor the progress of individual IMA/VMA management plans and ensure that the spatial inter-disciplinary pattern analysis (SIPA) is based upon up-to-date data and information.

Maintaining these up-to-date profiles will also enable fishery departments to identify potential interactions among individual management plans, and thereby coordinate or harmonise the activities of local level managers, particularly if the details of each plan are referenced using some form of geographical information system (GIS).

4.9.2 Monitoring IMA/VMA Management Plan Performance

As already discussed in Section 4.8, local communities are unlikely to monitor the performance of their management plans in a formal manner. Therefore, if higher level management authorities, such as fishery departments, wish to monitor the performance of individual IMA/VMA management plans or employ spatial pattern analysis (SIPA) to accelerate the adaptive management process, then, in addition to monitoring the details of each IMA/VMA management plan, they must also monitor the indicators of management plan performance. These indicators or evaluation criteria must be both relevant and palatable to local level managers if effective feedback is to be achieved and adopted. Ideally, the indicators should be selected by the local managers themselves[9] (Abbot and Guijt 1999). However, for the reasons already discussed in Section 4.3.1 there are "...literally thousands of indicators already in use in fisheries and thousands of others of others that could be used..." (FAO, 1999a & 1999b). Significant differences in the indicators employed among local level managers may complicate or even preclude the spatial comparisons of management performance (Abbot & Guijt, 1998). Ideally, therefore, a common set of indicators corresponding to the range of different management objectives that exist, should be negotiated with local level managers[10] (see below). These indicators may not, however, be upwardly compatible with higher level monitoring and evaluation concerns (Abbot & Guijt, 1998) particularly with respect to international reporting responsibilities and national policy and planning development (Dataset 1a) (Sections 4.6 & 4.7). Monitoring these community-selected or negotiated indicators may therefore require their own discrete parallel programmes.

In order to help design the prototype datamodel for this generic FIMS in the light of this uncertainty, the following section reviews and attempts to identify potentially appropriate indicators of management performance as identified by community managers themselves in relation to their management objectives.

Community objectives and management performance evaluation criteria
An extensive review of the artisanal and community-based fisheries literature revealed very few direct references to community objectives. The numerous in-depth commentaries of traditional and community-based fisheries management outline the access arrangements, sanctions and technical attributes of local fisheries but the objectives of these controls is rarely alluded to.

Community management tools have generally been regarded as well-designed solutions to the same problems of over-harvesting and effort control inherent to the management of industrial fisheries in the developed world. However, there is an increasing recognition that it is simplistic to infer community objectives from observable practice. It should not be assumed that limiting access to the resource through payment arrangements and exclusion through physical confrontation equate to motives of conservation, for instance (see Rettig *et al.* 1989) and Klee 1980) for a treatment of "intentional" versus "inadvertent" practice). Similarities with Western management tools and methods must be balanced with an acknowledgement of the very different “cultural matrices” within which they evolved (Wilson *et al.* 1994).

The significance of conservation and stock protection to communities has not been overlooked, however. Morrell (1989) documents how local management arrangements by the Gitskan and Wet’suwet’en people of north-central British Columbia emphasise the protection of spawning stocks and the clearing of obstacles to aid fish migration, for example. More generally, (Pinkerton 1993) identifies a common concern for ecological health and viability;

“Habitat is an overriding (stakeholder) concern because fish as a common pool resource are always situated within another common pool resource, water.”

Although many community management tools may impact biology directly (through gear control, seasonal rules and food taboos, for instance), the link between stock health, harvests and community objective is not a simple one. Malvestuto (1989) draws attention to the range of community concerns met by the fishery that may fall outside of the scientific emphasis on

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[9]Indicators derived by individuals, households or communities are often referred to as ’grassroots indicators’ or ’bare-foot indicators’.

[10]Experiences of community based environmental monitoring in Australia indicate that participants are often willing to adopt national standard indicators (Abbot & Guijt, 1999)

biology and production;

"*Most fisheries management proposals that I have read openly state that the ultimate goal of the project is to increase benefits to people. The specific objectives, however, usually only address traditional fishery management endpoints, such as to increase fishing success for particular species, to insure large sizes of fish in the harvest, to increase or decrease rates of exploitation, or to enhance reproduction and recruitment. In the majority of cases, whether enhanced benefits to people truly are realised via the traditional management objectives, cannot be evaluated – social accounts (objectives), though implied, are not explicitly addressed. Fisheries managers have found it convenient to assume that "good" biology translates into positive social benefits.*"

More recent treatments of community management objective have augmented the focus on "traditional fisheries endpoints" with attempts to understand the social and political impacts of local management tools from economic or anthropological perspectives. Neiland (1997) comments on the complexity of local management rules with regards to mapping their ultimate objective, actual impacts on the resource, and their socio-economic effects on the community. With regards to the artisanal fisheries of N.E. Nigeria, the extraction of rent was seen as a consistent theme;

"The objectives of control and authority over fishing grounds were not seemingly explicit. It was concluded that there were three major objectives of traditional systems. The securing of acknowledgement by outsiders of local community culture and authority (and therefore the defence of community resources and the control of fishing rights), the generation of revenue relevant to securing a minimum level of income for the community, and at a secondary level, the conservation of fish stocks.

Although the precise characteristics of the systems varied between villages and locations, in terms of management measures, management structure and level of application, the major objectives were similar, usually the generation of revenue for the regulators."

In acknowledging the complexity of community management objectives much of the recent literature has emphasised what (Charles 1992) refers to as the social/community paradigm or "world view". Traditional and artisanal fisheries management reflects an emphasis on local community relations and patterns of access and consumption as issues of equity and fairness are seen to take precedence. Crean (1999) has commented on how these incentives to management will change overtime as traditional practices, markets and cultures are subsumed by global markets, external policy and ultimately, changing world views. Management objectives can be classified by their intended impact (Neiland, *ibid*). First order or primary objectives relate to fundamental, universal and socio-economic needs such as nutrition and income provision. Secondary objectives may impact on how effectively these basic needs are met but may be shaped by cultural and political concerns that are site-specific, and these objectives may evolve as fisheries are developed[1]. As Crean (*ibid*) states;

"In the early 1980's it was clear that the balance of objectives for the planning, development and management of coastal resources had undergone a significant shift consequent with the expansion of commercial activities. The traditional exploitation activities were dominated by what we might term "social" objectives: aimed at food security and sustainability. Furthermore they were geared to the reinforcement of cultural norms and equity. Implicitly there were also biological, technological and other targets – but these were of secondary importance. However, the commercial imperatives of the agribusiness culture brought the coastal communities under

[1]Field Studies 1& 2 in Volume II detail the primary nature of fisher objectives in Bangladesh and their more secondary nature in the Turks and Caicos Islands.

the influence of wider objectives, and centralist influences of the nation: creation of employment; generation of foreign exchange; contribution to gross national product; and regional development."

There have been several interesting exercises in identifying and documenting community objective in British Columbia (see Pinkerton 1989). In an attempt to incorporate local management systems into modern co-management arrangements with the state, fisheries researchers, lawyers and indigenous communities have prepared formal declarations of community management objectives. Doubleday (1989) identified the objectives of the Inuvialuit as:

- to preserve Inuvialuit cultural identity and values within a changing northern society;
- to enable Inuvialuit to be equal and meaningful participants in the northern and national economy and society; and
- to protect and preserve the Arctic wildlife, environment and biological productivity.

If Doubleday summarises these objectives as "…(maintenance of) *cultural identity, integration and, conservation"*, then Richardson and Green (1989) have identified a more specific and technical articulation of community objective with the fishers of Haida Nation. The objectives here were to:-

1. improve the management of, and yields from, specific stocks;
2. to develop the technical, biological, and resource management skills of our people in order that we might develop effective fisheries management programmes in the future
3. to create new wealth as a result of increased yields from managed stocks, and from the harvesting of the stocks which it has not been possible to harvest with traditional open access fisheries, and to use this wealth for the economic development of our communities and other communities in Haida Gwaii and British Columbia – a very important objective
4. to create employment for Haida people and other residents of Haida Gwaii in fish harvesting and processing and fisheries management
5. to provide a unique opportunity to experiment with approaches to fisheries co-management, and particularly with possible mechanisms for resolving the title dispute

Community Management Performance Indicators

Although monitoring is considered a key activity within any management system (see Ostrom's (1990) seven design principles) this review discovered no documentation of indicators or proxies relating to management performance criteria as selected and applied by the community itself. It may be that having established community objectives, the monitoring of management success or failure was assumed self-evident[2]. However, community monitoring is likely to occur with respect to compliance to the set of operational rules in use which, in turn, are a combination of external arrangements and local operational rules as outlined by Oakerson (1992). At the local level, violations of access arrangements are likely to be the most visible and vigorously enforced management tool because issues of access and exclusion relate to many of the community objectives identified in Table 7. With respect to monitoring the condition of the resource itself, communities may have unique cognised models and "mental maps" (Section 4.3.3) to explain or predict the impact of fisher behavior on stocks (eg. Zerner (1994)) for a discussion of the Sasi world view in Indonesia).

[2] Most community interviewees were confused by discussions of "how is success shown or made visible?" See Field Studies 1 & 2 in Volume II.

Table 7. Summary of Community Management Objectives

Category	Community Objective	Location / Community	Reference
Biological	Increase yield	Global Haida Gwaii	Malvestuto (1989) Richardson & Green (1989)
	Increase yield of target species	Global	Malvestuto (1989)
	Conservation/rehabilitation of stocks	N.E. Nigeria Inuvialuit Gitskan & Wet'suwet'en Papua New Guinea Melanesia	Neiland (1997) Doubleday (1989) (Morrell 1989) (Johannes 1982) MRAG (1999)
	Conservation of habitat	Global	Pinkerton (1993)
Economic	Increase income	N.E. Nigeria	Neiland (1997) Richardson & Green (1989)
	Maintain food security	Global	Crean (1999)
	Maintain livelihoods	Haida Nation Melanesia	Richardson & Green (1989) MRAG (1999)
	Equitable distribution of benefits	Global Global Inuvialuit	Crean (1999) Wilson *et al* (1994) Doubleday (1989)
Social	Maintain cultural norms / belief systems	Global N.E. Nigeria Inuvialuit	Crean (1999) Neiland (1997) Doubleday (1989)
	Social/political inclusion/ exclusion	Inuvialuit Melanesia	Doubleday (1989) MRAG (1999)
	Ceremonial	Melanesia	MRAG (1999)

Negotiated indicators

Recent drives by NGOs such as CARE and Oxfam have addressed the uniqueness of community perceptions of success by designing "negotiated indicators" in collaboration with communities themselves. Within the participatory monitoring and evaluation (PME) approach, such as that operated by CARE, negotiated indicators are adopted to monitor project performance. These indicators are site-specific and are developed in consultation with prospective beneficiaries. Community proxies for improved catches, for instance, include "number of fish meals" to even simpler indicators such as "number of cans of cooking oil bought" (Desilles, pers. com.) and ideally, the monitoring is co-designed so that it can be easily incorporated into everyday routines (Guijt 1999). Stakeholders participating in current development projects such as NOPEST are ascribing themselves to specific sectors of the community, each with its own collection of "well being variables". These variables include family size, number of children in school, frequency and composition of meals, house ownership, business or livelihood, assets, savings, income...etc, and are monitored overtime to track the performance of programme activities in delivering community objectives (see Ashley and Carney (1999)). For this approach to be sustainable it must be participatory in the sense that the collection of information and its processing is carried out as locally as possible to establish community ownership of data.

(DFID 1999) identify five main categories of desirable livelihood outcomes (objectives) that may form the basis to negotiate basic indicators:

- more income (eg household income)
- increased well being (eg health status, access to services, maintenance of culture... etc)
- reduced vulnerability (eg alternative livelihoods, market seasonality, disease...etc)
- improved food security (eg infant mortality, dietary diseases, body mass index, frequency and composition of meals...etc)
- more sustainable use of the natural resource base (sustained catches, number and size of species caught).

Arguably, these categories of livelihood outcomes encompass all the management objectives identified in Table 7. Indicators for some outcomes such as increased well being may be extremely difficult to identify. Criteria proposed to identify suitable indicators include: specificity, acceptability, measurability, attainability, relevance, timeliness, validity, verifibility, cost effectiveness, simplicity and sensitivity (Abbot & Guijt, 1998). Practical guidelines for developing indicators for fisheries management and development purposes are discussed in detail by FAO (1999a).

4.10 Chapter Summary

The generic data and information requirements for each dataset identified in Figure 8 are summarised in Tables 8 a & b below:

Table 8a Summary of data and information requirements to manage state-owned sedentary resources and migratory stocks (Datasets 1b & 2)

Purpose	Data and Information requirements
(i) Management plan formulation for SOSR and MS	*Management Plan Information for each stock, fishery, resource or other management major strata* : The stocks being considered and area of operation (boundaries etc) Information on environments Potential catchment or regional influences on the stock The fishery (for each FEU category): Total numbers Gear types and technology The selectivity of the gears with respect to the species of fish caught and their length at first capture or Lc_{50}. Seasonality of fishing Location of fishing Landing locations Socio-economic categories of fishermen and other stakeholders associated, coinciding or dependent on the different categories of FEUs. Fishers and other stakeholders Management objectives/desired outcomes Decision-making arrangements Operational rules Conditions for collective choice External arrangements
(ii) Management plan implementation and performance evaluation	Catch by species and by gear (and location) Effort by gear (and location) Biological data Length/age composition by species (and location) Sex, reproductive condition by species (and location) Environmental data eg area flooded, temperature, salinity etc. Costs and Earnings (Incomes) Fixed Costs Variable Costs Economic Rent Total revenue Total costs Poverty indicators other than income (above) eg levels of education, access to clean water etc. Local fish consumption per capita Numbers of fishers employed Tally of conflicts by category Tally of villages operating local/traditional management arrangements Other data to meet research/management goals in the context of local conditions.

(iii) Control and surveillance and effort standardisation	Name and address of each fisher, owner, skipper or charter agent of the fishing vessel or production (fishing) unit Address or port of registry of each vessel or fishing unit Details of mortgages, maritime liens and other encumbrances Details of the licence and/or quota Identification and communication details (particularly for larger fishing vessels Information relating to fishing power and operations (often used for effort standardisation calculations Details of the licence and/or quota
(iv) (Inter)national reporting/management responsibilities and policy planning	Catch by species (and by gear type and location if possible) Other data available from (i)-(iii) above, frame survey, stock assessments, special studies, other government departments

Table 8b Summary of data and information requirements to support and coordinate co-management of locally managed resources (Datasets 1a and 3)

Purpose	**Data and Information requirements**

(i) IMA/VMA Management plan formulation and Coordination	*IMA/VMA Management Plan Information* :
	IMA/VMA ID number
	The stocks being considered and area of operation (boundaries etc)
	Information on environments
	Potential catchment or regional influences on the stock
	The fishery (for each FEU category):
	    Total numbers
	    Gear types and technology
	    The selectivity of the gears with respect to the species of fish caught and their length at first capture or Lc_{50}.
	    Seasonality of fishing
	    Location of fishing
	    Landing locations
	    Socio-economic categories of fishermen and other stakeholders associated, coinciding or dependent on the different categories of FEU's.
	Fishers and other stakeholders
	Management objectives/desired outcomes
	Decision-making arrangements
	    Operational rules
	    Conditions for collective choice
	External arrangements
	Other data available from stock assessments, special studies, other government departments.

(ii) SIPA to support adaptive management	IMA/VMA Management plan and relevant frame survey data and information to profile each IMA/VMA (see above), and Negotiated indicators based upon income, well-being, vulnerability, food security, resource sustainability...etc.
(iii) (Inter)national reporting responsibilities and policy planning	Catch by species (minimum requirement) Other data available from (i) & (ii), stock assessments, special studies, and other government departments.

5. Data Collection & Processing Factors

The previous chapter identified generic information requirements from a FIMS, and desirable feedback loops to support the co-management arrangements described in Chapter 3. The fundamental principles of a fisheries database are to (i) hold raw data as they were collected in their primary (unprocessed) form, and (ii) to provide an efficient and reliable means to process these raw data to meet these data and information requirements for management. Factors affecting raw data, and their collection and processing are therefore fundamental to the design of the FIMS.

This chapter examines factors affecting raw data and their collection and processing based mainly upon recently published FAO data collection guidelines[3] (FAO, 1999b), but also drawing heavily from earlier FAO guidelines and technical papers, including Brander (1975); (Bazigos 1983); Caddy & Bazigos (1985); Sparre & Venema (1992); Flewwelling (1994). Potentially appropriate data collection methodologies for the data and information requirements identified in the previous chapter are also examined.

5.1 Factors Affecting Raw Data and their Collection and Processing

The factors and their *interactions* affecting the raw data, and their collection and processing that will dictate fisheries database design have been summarised graphically in Figure 9. The figure illustrates that the raw data contained within the database, and their collection and processing will ultimately be determined by two main factors:

(i) *The structure, operations and characteristics of the fishery* and
(ii) *The required data and information* (Chapter 4), referred to here as the *variable or data type* (Figure 9),

but will also be *constrained* by institutional capacity, for example financial and human resources. The raw data, and their collection and processing will, therefore, vary among fisheries (FAO, 1999b).

5.1.1 The Structure, Operations and Characteristics of the Fishery

As described below, the structure, operations and characteristics of the fishery have significant affects on the raw data and how it is collected and processed. Describing these characteristics by census or *frame surveys* (see later) is therefore the first stage in designing any data collection programme. The frame survey also helps to identify appropriate sampling strata, sampling methods/tools and provides the basis for raising sampled data (raising factors), and for directly providing important information to formulate management plans.

The structure, operations and characteristics of the fishery determine:

- ***Available sources of data*** and thereby the choice of data collection methods/tools (see below). FAO (1999b), identify six main sources of data and information:

[3]These guidelines have been prepared in consultation with experts from Asia with skills in anthropology, biology, economics, data processing and statistics.

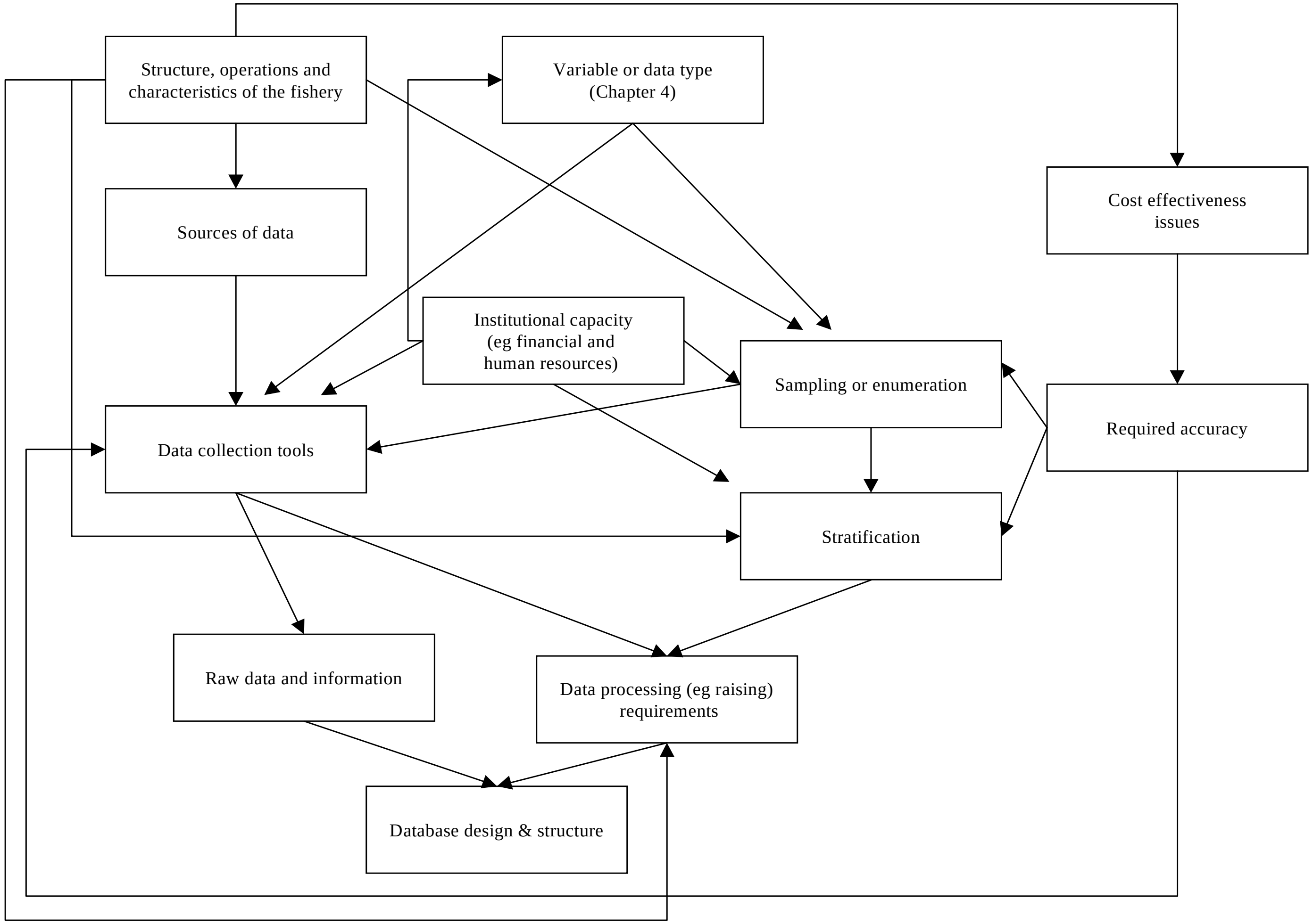


Figure 11 Data collection and processing factors affecting the design of a fisheries database.

(i) *Harvest:* The level where fish are caught or landed, and the most direct approach to the fishery data.

(ii) *Post Harvest:* The levels through which fish are prepared for market, including fish traders, auctions, processing centres and transport of products.

(iii) *Market:* All levels where fish are commercially transferred, including primary fish markets and transaction (secondary markets) eg between processors and consumer markets.

(iv) *Consumers:* The level where the products are finally consumed.

(v) *Government agencies:* Agencies or institutes forming part of government eg, customs & exports department, coast guard, meteorological department etc.

(vi) *Support Industry*: Includes industries which provide materials and services for fisheries (eg ship building, fishing gear suppliers etc.).

In, the TCI for example, the fisheries are centred around a well organised processing sector. The few processing plants upon the islands are, therefore, the main source of fisheries information and data. In Bangladesh, by contrast, subsistence operations dominate the fishery, and therefore fishers and primary landing centres are the main sources of data (Volume II).

On the basis of the FAO (1999b) guidelines (particularly, Table 6.1), the following Table 9 summarises the potential sources for the data and information requirements of the FIMS identified in the previous chapter:

- ***Data Collection Tools***

FAO (1999b) identify five main categories of data collection methods or tools:

(i) Registration

A register is a depository of information, typically related to fishing vessels, companies, gears, licences or individual fishers. Registers are frequently used to support vessel/fisher licensing, quota management, effort standardisation and for the purposes of monitoring, control and surveillance. Registers typically contain information on vessel, type, size gear, engine horsepower, fish hold capacity, license type, holders' details...etc (see Section 4.4).

Companies, particularly processing companies, are also often included in registers in circumstances where they must hold a valid processing licence or have other legal obligations (see Field Study 2, Volume II).

Although registers usually serve as references rather than for collecting data, they may provide important information useful in the design and implementation of a data collection system, for example providing criteria to stratify FEUs. They may also provide important information on licence revenues generated from the fishery for the calculation of economic rent.

Generally, registers must be designed so that they can capture new records, indicate when a record is inactive (eg when a processing company has ceased operations), or record changes in vessel or company details, and indicate when licences are due for renewal.

Table 9 Potential sources for the data and information requirements of the FIMS. Modified from FAO (1999b).

	Potential Sources					
Data Requirements	**Harvest**	**Post Harvest**	**Markets**	**Consumers**	**Government depts**	**Support Industry**
To Support IMA/VMA Co-Management (Datasets 1a and 3)						
Management plans	●	●	●	●	●	●
Effort	●				✚	✚
Other inputs (eg compliance poaching/illegal fishing)	●	❍	✚			
Catch by species	●	●	❍			
Negotiated Indicators	●					
Other data eg imports/exports trade					●	
To Manage State-Owned Sedentary Resources and Migratory Stocks (Datasets 1b & 2)						
Management plans for each stock, fishery or other strata	●	●	●	●	●	●
Total catch by species, FEU and gear type	●	●	❍			
Total effort by FEU and gear type	●				✚	✚
Biological Data (length/age composition, sex, reproductive condition etc)	●	●	●		●	
Environmental data	❍				●	
Vessel/licence/quota data/fleet statistics	●				●	✚
Other data eg imports/exports, commodities, employment etc					●	
Costs and Earnings (Incomes)	●	●	❍		✚	✚
Economic Rent (Total Revenue & Total Costs)	●	●	●		●	✚
Poverty indicators other than income (above) eg levels of education, access to clean water etc.	●	●		●	●	
Local fish consumption per capita	●	●		●	●	
Numbers of fishers employed	●	●			●	❍
Tally of conflicts by category	●				●	
Tally of villages operating local/traditional management arrangements	●				●	

● Strong linkage: major relation ❍ Secondary linkage: secondary or important validation source ✚ Possible source or secondary validation

(ii) Questionnaires

Questionnaires are commonly used to collect regular, or infrequent data, and data for special studies. Examples of data that may be collected through questionnaires include demographic characteristics, fishing practices, catch and effort data, opinions of stakeholders and general information on fishers and household food budgets, although information on almost any data variable may be collected. The data and information obtained from questionnaires is always subjective and not direct measurements, and therefore subject to serious errors.

A questionnaire requires respondents to fill out some type of structured, pre-defined form. This demands a high level of literacy, and therefore may not be appropriate for many artisanal fisheries. Multiple or regional languages are common and may complicate the use of questionnaires.

Similar to interviews (see below), questionnaires can contain either structured questions with blanks to be filled in, multiple choice questions, or they can contain open-ended questions which can be replied to more subjectively and at length, but requires subsequent interpretation. Generally, questionnaires short be designed to be a simple and as short as possible, with targeted sections and questions.

(iii) Interviews

For interview methods, data and information are obtained by inquiry and recorded by enumerators. Structured interviews employ pre-designed survey forms, whereas open interviews are notes taken while talking to respondents and subsequently interpreted for further analysis. Although structured interviews can be used to collect almost any information, the responses obtained will be also subjective and therefore prone to large errors due to poor estimates or intentional errors to disguise sensitive information. Open-ended interviews generally involve focus groups comprising representatives of important stakeholders or panel surveys involving a random selection of individuals who agree to be available for interview over an extended period of time.

Structured interviews form the basis of much of the data collection in small-scale fisheries. Although more expensive than questionnaires, more complex information can be obtained, and data may be validated as they are collected, thereby improving data quality. For sampling catch, effort and price data, enumerators work according to a schedule of landing site visits to record data on landings, effort, prices from all FEUs that are expected to operate on the sample day. The sample should be as representative as possible of FEU activities. Additional data relating to fishing operations may be required for certain types of FEUs, such as beach seines or boats making multiple fishing trips in one day.

For sampling boat/gear activities, enumerators work according to landing site / homeport visits to record data on boat/gear activity. Generally, the objective is to determine the total number of FEUs and fishing gears based at the landing site/homeport, and the number of those that have been fishing during the sampling day.

Data relating to boat/gear activities is commonly obtained by means of interview and direct observations. The latter may be used to identify inactive FEUs. Panel survey interview approaches are also common, where a predetermined sub-set of fishing units have been selected for sampling. The enumerator traces all the fishers (respondents) on the list to find out those that have been active during the sampling day, or on days prior to the interview. The additional information increases the sample size significantly with little extra cost resulting in more precise estimates of total fishing effort.

Structured or open-ended interviews are an integral part of most socio-economic surveys of artisanal fisheries. Semi-structured interviews may be more appropriate during initial survey stages, particularly for frame surveys, and when establishing attitudinal information regarding conflict or governance issues.

(iv) Direct Observations

Direct observations of the fishery are most often made by observers, inspectors, data logging or through scientific research (special studies/surveys and stock assessments). Data logging generally involves the use of sophisticated technology such as Automatic Location Communicators (ALC) and Vessel Monitoring Systems (VMS). The use of this technology is usually confined to industrial/oceanic fisheries and therefore will not be considered further here.

Observers

Observers can make direct measurements on fishing vessels, at landing sites, processing plants, or in markets. Data that are collected include catch, effort, FEU operations, environmental variables, biological variables and values and quantities of landings and sales. However, observers may also be required to conduct interviews and surveys. The use of 'on-board' observers is usually restricted to industrial/oceanic fisheries. For artisanal, fisheries, observers obtain data and information at landing sites, processing plants and markets. Frame surveys are often conducted by direct observation supported with formal interview methods.

Inspectors

Inspectors are involved in law enforcement and surveillance of vessels, at landing sites and processing factories and at markets. The role of inspectors in data collection is generally restricted to verification.

Scientific Research

Scientific research or *ad hoc* research on the fishery may be undertaken independently of fishing operations to measure variables related to fish populations and the environment. This may include research to quantify the selectivity of a particular gear type, or improve the understanding of the migratory behavior of a species by means of a tagging programme.

For the reasons described in Section 4.1, it is unlikely that data and information collected from *ad hoc* studies can be accommodated in an generic FIMS.

(v) Reporting

Reporting is frequently employed for the complete enumeration of data and information or for validating data collected by some other means eg direct observation. Reporting is usually undertaken by stakeholders other than the fisheries department staff such as fishing companies, processors, market operators...etc. Such methods are almost exclusively used for semi-industrial and industrial fisheries. However, this approach is fundamental in the fisheries of the Turks & Caicos Islands and may be appropriate for IMA/VMA monitoring, and therefore is included here.

This approach is prone to risks of under- or mis-reporting and therefore should be validated by observers or inspectors.

Harvest

In most industrial fisheries, vessels are required to report a variety of data and information as a condition of licencing or quota agreements. Data is usually submitted in the form of logbooks or landing declarations containing details of fishing operations including position, fishing grounds, type and duration of operation, gear type, effort, catch by species (including by catch) and environmental variables.

Community Participatory Monitoring
Fishing communities have been enlisted to collect data for on going research or to monitor longer term development projects such as the Community Based Fisheries Management project in Bangladesh (see Field Study 1, Volume II). Ticheler *et al*. (1998) describe the participation of local fishers in data collection for special stock assessment studies. Large quantities of high quality length-frequency data were collected cheaply and effectively by the community. Ticheler suggests that this collaborative approach to monitoring could provide a basis for the adoption of further local management responsibilities in the future. However, unless the choice of data is identified in collaboration with the community and a degree of local ownership is established, these activities are unlikely to be sustained. Similarly, requiring users to collect information that is not directly relevant to them may demand (financial) incentives (Abbot & Guijt, 1998). FAO (1999b) state that "Compliance with data supply and willingness to assist in data collection are the two biggest administrative problems for management". Fishers often see "...the provision of data as time-consuming, pointless and/or a release of information that would be beneficial to others".

Post Harvest
Data from post harvest operations, in particular processing factories, can provide information on landings (eg quantity and value of fish received), biology, markets, costs and earnings, and conversion factors (see Field Study 2, Volume II). Factories may also maintain information on their output and sales such as destination and price. Data forms require customisation to the type of processing and factory management system.

Sale
Market transaction records (eg sales slips, tallies or invoices) may offer a means of collecting landings data, particularly where vessels land in central locations. This approach has been proposed for non-processed lobster and conch landings in the Turks & Caicos Islands (see Field Study 2, Volume II).

Market transaction records should include the name of the vessel that sold the catch, the date or trip number and total weight by species or commercial group, and price received. Further desirable data include the fishing ground or location and details of fishing effort, although generally this is not possible to collect. More general sales records, such as volume and prices by product type provide useful information for bioeconomic analysis (eg construction of demand curves).

Trade
Trade data refers to information from customs/export departments. These data are used for socio-economic indicators. (See FAO 1999b for further details).

Other Ministries
Several socio-economic data requirements may not require special survey and sampling designs but may be accessed from existing records and sources. This type of information will include demographic, trade and employment data routinely collected by the ministries or departments responsible. However, data will be categorised according to the reporting responsibilities and remits of the departments in question, and appropriate raising factors may have to be applied to the statistics e.g. dried fish exports to fish production exported, vessel licence holders to total population of crew etc. (FAO, 1999b).

- ***The appropriateness of sampling or enumeration approaches to data collection***. Data may be collected either by complete *enumeration* where all population units (eg fish in a lake), and their characteristics (eg sex, weight, length) are measured, or by *sampling* where only a known proportion of population units are counted or measured.

Enumeration approaches to data collection may be appropriate in small scale fisheries with few landing centres such as the lobster and conch fisheries of the Turks & Caicos Islands (See Field Study 2, Volume II). In larger, inland fisheries, such as those found in Bangladesh where fishers and landing centres are widely dispersed (See Field Study 1, Volume II), sampling will be the only practicable approach for most data types.

The characteristics of the fishery, particularly in terms of the value of the resource relative to the costs of management (ie cost effectiveness issues surrounding monitoring, control, surveillance etc) will determine the required accuracy of the data, and therefore will also have a bearing on whether enumeration or sampling approaches are employed, and sampling strata (see below). Institutional capacity (eg available human and financial resources) will also affect the choice between the two approaches.

- ***Stratification*** of sampling programmes. Stratification is employed to reduce the error (variance) in sample estimates by systematically removing data variability through sampling design. Estimates of population units and their characteristics (variables) are always calculated at the lowest stratum level. Totals at major stratum are simply aggregations of estimates and counts from the minor strata involved (FAO, 1999b).

  Appropriate sampling strata will be dictated by the structure, operations and characteristics of each fishery. In floodplain fisheries, for example, catch and effort sampling must be stratified by hydrological season, gear type and habitat type to take account of variations in gear catchability, fish density and species habitat preferences. For marine fisheries, fishing grounds and vessel type may be more appropriate strata.

  It is impossible to predefine appropriate, or identify generic, sampling strata. FAO (1999b) list more than 35 examples of sampling strata across a wide range of categories (spatial, temporal, trade, vessels/gear, landings, household types...etc). As well as the individual characteristics of the fishery, the number of strata employed will also be dictated by the institutional capacity (operational constraints) of the management authority. Stratification based upon administrative, geographical or temporal criteria that are imposed on the data collection programme for reporting purposes may also exist.

5.1.2 The Variable or Data Type

The variable or data type determines:

- ***The appropriateness of sampling or enumeration*** approaches to data collection. Complete enumeration approaches are commonly required to describe the basic structure and operation of the fishery eg numbers of fishing vessels, employment, infrastructure...etc required for frame surveys. Complete enumeration approaches are also often required for data collected for compliance with international management and reporting responsibilities such as fleet statistics or exports of endangered species, or to meet statutory obligations eg vessel registration/licence details.

- ***Data collection tools****.*
  Some types of data collection tools are unsuitable for certain variables or data types, whereas for other types of data, some collection tools may be more appropriate than others. For example, interview methods are generally unsuitable for collection biological information, but appropriate for cost and earnings data. Table 10 illustrates potential match between the information requirements of the FIMS identified in the previous chapter and the various collection tools.

Table 10a The FIMS data and information requirements that can be collected by *complete enumeration* with the various data collection tools (Modified from FAO, 1999b, Table 6.3).

			Interviews		**Direct Observations**				**Reporting**				
	Registration	Question naires	Open ended	Structured	Observers	Inspectors	Scientific research	Data logging	Harvest	Post harvest	Sales	Trade	Other Ministries
To support IMA/VMA Co-Management (Datasets 1a & 3)													
Management plans	●	●	●	●	●	●	●	●	●	●	●	●	●
Effort		●							●				
Other inputs (eg compliance poaching/illegal fishing)		●							●				
Catch by species		●							●				
Negotiated Indicators		●							●				
Other data eg imports/exports trade												●	●
To Manage SOSR and MS (Datasets 1b & 2)													
Management plans for each stock, fishery or other strata	●	●	●	●	●	●	●	●	●	●	●	●	●
Total catch by species by FEU and gear type		●			●	❍		✚	●	✚[1]	●		
Total effort by FEU and gear type		●			●			●	●	✚[1]			
Biological Data (length/age, sex, repro. condition...)					✚				❍	✚[1]			
Environmental data								✚	❍				
Vessel/licence/quotastatistics/mcs	●	●			❍	❍		✚	●				
Other data: exports, employment.. etc											●	●	●
Costs and Earnings (Incomes)									●	●	✚		●
Economic Rent (Total Revenue & Total Costs)									●	●	●	●	●
Poverty indicators other than income		❍	❍	●									●
Local fish consumption per capita		❍	❍	●									●
Numbers of fishers employed		❍	❍	●	●								●
Tally of conflicts by category													
Tally of villages traditional management arrangements				●	●								

Questionnaires/reporting - Requires high level of literacy and motivation/incentives. However, ability of fishery departments to process this quantity of data unlikely.
[1] - Employed in Turks & Caicos Islands lobster and Conch fishery (See Field Trip Report 2).

Table 10b The FIMS data and information requirements that can be collected by *sampling* with the various data collection tools (Modified from FAO, 1999b, Table 6.3).

			Interviews		Direct Observations				Reporting				
	Registration	Question naires	Open-ended	Structured	Observers	Inspectors	Scientific research	Data logging	Harvest	Post harvest	Sales	Trade	Other Ministries
To support IMA/VMA Co-Management (Datasets 1a & 3)													
Management plans	●	●	●	●	●	●	●	●	●	●	●	●	●
Effort		●	❍	●	●				●				
Other inputs (eg compliance poaching/illegal fishing)		●	❍	●	●				●				
Catch by species		●	❍	●	●				●	❍			
Negotiated Indicators		●	❍	●	●		●		●				
Other data eg imports/exports trade												●	●
To Manage SOSR and MS (Datasets 1b & 2)													
Management plans for each stock, fishery or other strata	●	●	●	●	●	●	●	●	●	●	●	●	●
Total catch by species by FEU and gear type		●	❍	●	●	❍			✚	✚	✚		
Total effort by FEU and gear type		●	❍	●	●	❍		❍	✚				
Biological Data (length/age, sex, repro. condition...)					●	✚	●		✚	❍			
Environmental data					●		●	❍	✚				
Vessel/licence/quotastatistics		●	❍	●	●	❍			✚				
Other data: exports, employment.. etc											●	●	●
Costs and Earnings (Incomes)		❍	❍	●					●	●	✚		
Economic Rent (Total Revenue & Total Costs)		❍	❍	●					●	●	●	●	●
Poverty indicators other than income		❍	❍	●									
Local fish consumption per capita		❍	❍	●									
Numbers of fishers employed		❍	❍	●	●								
Tally of conflicts by category		❍	❍	●									
Tally of villages traditional management arrangements		❍	❍	●									

The choice of variable or data type may also be constrained by institutional capacity. For example, where capacity is low catches may have to be aggregated into broad categories, eg major carps, weedfish, mixed fish etc, or effort may have to be expressed in terms of crude measures eg numbers of fishers.

The structure, operations and characteristics of the fishery will also determine, directly, the data held within the database and processing requirements. This may be illustrated with two hypothetical fisheries. One comprises FEUs (eg vessels) which land once per day, the other comprises vessels and gears that make multiple fishing trips or hauls. The former may be sampled once for catch, effort and price..etc to obtain an estimate for the day. The latter, however will require additional data (and data processing) relating to the fishing operations, for example covering the planned fishing operations, as well as the activities already completed.

5.2 Frequency of data collection

The frequency of data collection is dependent upon their rates of change and the costs of measurement. Most variables require a natural data collection frequency which often becomes apparent when the dynamics of the fishery are understood (FAO, 1999b):

Daily: From logbooks, processing records etc covering catch, effort and processing rates.
Vessel Trip: At the end of a vessel trip, data can be reported on landings, effort, fishing locations, prices, trip costs and other operational data.
Monthly: Monthly collection of data is appropriate for variables that change slowly and those that have a seasonal pattern. This would include biological sampling of the catch for length or age structure, reproductive condition etc (Section 4.3.4).
Annual: Annual collection of data is used for slowly changing variables such as the decision-making arrangements of IMA/VMA management plans, or fishermen density, or vessel and gear characteristics recorded for licensing or quota purposes.
Infrequent: This category might include household or demographic data which may be collected every 3-5 years by other government (statistical) departments eg Bangladesh Bureau of Statistics.

5.3 Standardisation

Standardisation allows for the integration of data and information between different data collection systems. This is important in the context of shared-stock or regional management and for national and international reporting responsibilities. International standard classifications for vessel and gear types are given in *Definition and classification of fishery vessel types* (FAO Fisheries Technical Paper No. 267, and *Definition and classification of fishing gear categories* (FAO Fisheries Technical Paper No. 222), respectively. Species are commonly classified using a 3-alpha species code in accordance with the FAO Standard Common Names and Scientific Names of Commercial Species which it updates annually (scientific names[4] are used when codes are not available). The World Customs Organisation maintains a classification for traded fishery products- the Harmonised Commodity Description and Coding System (Customs Co-Operation Council, 1992). The United Nations, the World Health Organisation and other international and regional organisations have standards for census categories and nutritional and health values (FAO, 1999b).

[4]Taken from FAO species Identification guides or FishBASE

5.4 Identification of Generic Data Inputs for the FIMS - Theory

The large number of interacting factors affecting the types of data that may be collected from a fishery make it impossible to design a generic data collection strategy. Since the database must hold the data collected from the fishery in its raw, unprocessed form, the only alternative for developing a generic database is to attempt to identify commonly collected categories/items of data or information or 'generic fields'. This is pursued in the following chapter.

6. Generic Data Fields

The previous chapter examined data collection and processing factors that will influence the data that is contained within any database. It was concluded that generic data collection strategies cannot be designed and developed principally because of variations in the structure, operations and characteristics exhibited among fisheries and the institutional capacities of their managers.

Since the database must hold data collected in its raw unprocessed form, this chapter attempts to identify commonly collected or stored categories (*generic fields)* of data and information as an alternative basis for designing a generic FIMS. These generic fields are identified by reviewing the data fields frequently collected using commonly employed data collection tools/methodology and data sources to provide the general data and information requirements identified in Chapter 4. A summary of the documents reviewed for this excercise are summarised in Annex 5. The chapter begins by identifying generic fields to manage state-owned sedentary resources and migratory stocks (Datasets 1b & 2) before identifying those to support co-managed resources (Datasets 1a &3).

6.1 Generic Fields to Formulate Management Plans for State-Owned Migratory and Sedentary Resources (Datasets 1b & 2)

As described in Section 4.2, management plans reference how the broad directions and priorities stipulated within fisheries policy translate to specific fisheries, management units (IMAs/VMAs), or stocks profiled in the plan.

Data and information contained within management plans are often central to the evaluation of management performance in relation to management objectives, policy, planning and intra and inter-sectoral coordination. Indeed, much of these data and information is central to the proposed SIPA approach to support co-management (IMA/VMA) units (see later). Despite extensive searches, no examples of management plans for artisanal fisheries were found in the literature. The general categories of data and information that should be included in management plans have already been identified in Section 4.2. Locally, these guidelines may need to be modified to support SIPA (see later).

These data may be collected and assembled from an indefinite number of scattered sources using a variety of data collection tools including combinations of frame surveys (see below), routine monitoring programmes, PRAs, stock assessments, special or *ad hoc* studies surveys, and consultation with local users...etc.

The potential heterogeneity of management plans in terms of their structure and content, coupled with the fact that some information (eg figures, lengthy text descriptions...etc) contained within them is often not efficiently stored in electronic format, suggests that management plans should not be included in the generic FIMS database design. However, referencing the data contained in the FIMS to the respective management plan document would aid the coordination of management activities both inter- and intra-sectorally if the data could be spatially referenced.

6.2 Generic Fields for Management Plan Implementation and Evaluation for State-Owned Migratory and Sedentary Resources (Datasets 1b & 2)

Before attempting to identify generic data fields for this management role, it would be useful to first examine and identify the types of data and information (including example and generic fields) that are collected as part of frame surveys, and some basic principles, terms and ideas behind sampling theory design, particularly for catch and effort data. Frame survey data and information are also often drawn upon for socio-economic assessments, policy and development planning purposes (see later) and for the formulation of management plans (see above).

6.2.1 Sampling Theory and Design

The first stage of any data collection programme is to define the units to be included in the survey, and their geographical context. Two main *sampling units* are usually employed:

1. Primary sampling units (PSUs) - Landings centres, beaches, households...etc, and
2. Secondary Sampling Units (SSUs) - Fishing economic units (FEU's) also referred to as *survey units*.

Items of information (fields) are collected from the survey units. Data may be collected from the survey units either by (i) complete enumeration (census) or (ii) by sampling a fraction of the survey population. Statistical theory for (ii) is given in Annex 6. Expressions for variance estimation have been omitted for brevity. Full details are available in Bazigos (1983) and Caddy & Bazigos (1985).

6.2.2 Frame Surveys

Frame surveys are the first stage in the design of data collection strategies or *sampling frames*, and dictate the field operations that follow. Typically, frame surveys contain a inventory of all the fishery waterbodies or areas and descriptions of the fisheries operating within them, including:

- Important landing centres, places and ports, fishing villages (PSUs), their location, patterns of fish distribution and accessibility.
- numbers and types of *FEUs* and information on their composition including fishing gears, fishers, fishing craft and distribution in relation ports and landing places.
- fishing activity and landing patterns of the different FEUs including seasonal, diurnal and geographical operations and any switching between fisheries.
- Supply centres for supporting services, material...etc.
- Fish distribution routes, utilisation, processing and marketing practices, trade, local consumption, number of processors...etc.

The information recorded in the frame survey helps identify appropriate PSUs, FEUs and sampling strata, and provides the fundamental data for raising sampled data to give the total population estimates (see later). Frame surveys also provide a potentially important source of information to formulate management plans and for policy planning and development purposes, and socio-cultural analyses (see later).

In common with management plans, frame surveys also typically draw upon data collected and assembled from an indefinite number of scattered sources including vessel registers, harbor radio logs, ports, market sales, transport and administrative records, population census, maps, aerial photographs, or images, fishing charts and other information using an equally diverse range of methodologies including questionnaires, 'water and aerial approaches', pilot monitoring programmes, PRAs, stock assessments, special or *ad hoc* studies surveys, consultation with local users...etc (for example see Horemans, 1998). Obviously the choice of data collection methods and sources will largely determine the types of information that are collected.

The data and information collected from the frame survey are commonly presented in the form of a map or chart, or annotated table. Detailed guidelines for conducting frame surveys are given in Bazigos (1983) and Caddy & Bazigos (1985).

Generic fields identified on the basis of examples of data fields collected from more than twenty frame surveys conducted on artisanal fisheries (see Annex 5) are summarised in Table 11 below. The majority employed interviews or direct observations at the harvest level.

Table 11 Generic fields identified from examples of data (fields) and information commonly collected for artisanal fisheries frame surveys.

Generic Fields		**Example Data (Fields)**	**Units**
Form Number		Form number Serial number	Alpha-Numeric or Number
Enumerator ID		Name of recorder/observer Team number Recorder team ID Observers ID	Text Number Alpha-Numeric Alpha-Numeric
Major Stratum		Region Strata I-XII Stratum ID	Text Roman Numerals Alpha-Numeric
Minor Stratum		Area Stratum Province Island name Location/locality Island ID	Alpha-Numeric or Text
Minor Stratum Descriptors		Latitude Length of shoreline % of shoreline District	Degs.Mins.Secs km % Text
Survey Date/Period/Time		Date Month Time	Date Text Time
PSU ID		Landing site Fishing camp Village name/code Code of fishing site Fishing site ID/serial number Name of fishing Site Beach name	Alpha-Numeric or Text
PSU Descriptors		Geographical location Left bank, right bank Distance from 'X' Fishery habitat Type of fishing site Environment Accessibility Description of boundaries Permanent landing /fishing site	Text Text km Text Text Text Text Text (Y/N)
FEU's at PSU's	FEU ID	Vessel ID number Vessel Name Name of owner Home port Registration number Fisher name & address	Alpha-Numeric Text Text Text Alpha-Numeric Text

FEU's at PSU's	FEU Descriptors	Numbers of FEUs of type t operating gear g (Collectively for whole PSU**)	Number
		Gear type	Text
		Numbers of fishers operating gear	Number
		Boat type	Text
		Type of vessel	Text
		Engine make/HP	Text/Number
		Numbers of engines	Number
		Engine condition	Text
		Fuel type	Text
		Year of construction	Year
		Place of construction	Text
		GRT	Tonnes
		NRT	Tonnes
		Vessel condition	Text
		Propulsion method (Oar/Paddle/Sail)	Text
		Material of construction (GRP/Wood etc)	Text
		Age of boat	Years
		Operational status (Active/Inactive)	Text
		Crew size	Number
		Length/beam/draft	Number
		Number of lamps	Number
		Fishing equipment	Text
		Type of fishing	Text
		Main types of gear	Text
		Mesh sizes	Number
		Gear sizes	Number
		Materials of construction	Text
		Numbers of gears	Number
		Numbers of fishers in household	Number
		Fishing aids/equipment:	Text
		Processing facility	Text
		Fisher category (Full- /part-time)	Text
FEU's at PSU's	Activity Data	Species caught	Text
		Time of landing	Time
		Number of landings per day	Number
		Seasonality	Text
		Diel patterns	Text
		Fishing grounds/habitats	Text
		Gear used by habitat	Text
		Fishing locations	Text
		Landing sites	Text
		Time spent fishing	Days/Hours
		Time spent traveling to fishing ground	Days/Hours
		Trip frequency	Number
		Average days at sea per month	Days
		Average days worked per week	Number
		Catch rates per day and gear use by season	Number
		Major/minor fishing seasons	Text
		Historic trend in catch rates	Text
		Closed seasons	Text
		Festival activities	Text
		Number of weeks fisherman remain at home	Number
		Holidays	Text
		Days fished last week	Number

FEU's at PSU's	Fishers (Socio-Economic)	Number of inhabitants/fishers	Number
		Nationality of inhabitants	Text
		Nationality	Text
		Residential status	Text
		Origin of boat owners	Text
		Marital status	Text
		Number of dependents	Number
		Ethnicity / number of ethnic groups	Text
		Religion	Text
		Literacy	Text
		Age	Years
		Alternative livelihoods	Text
		Other economic activities (eg farming)	Text
		Experience	Years
		Range of fishers	km
		Boat owner?	(Y/N)
		Gear owner?	(Y/N)
		Enumeration (salary only, Salary with % etc)	Text
		Sharing % by owner/skipper/crew	%
		Fuel consumption per year	Tonnes
		Fisher salaries per month	Number
		Cost of fish transportation to market	Number
		Purchase price of boat	Number
		Value of boat	Number
		Gear costs	Number
		Maintenance costs per year	Number
		Access to essential services	Text
		Home Ownership	Text
		In house equipment	Text
		Transport	Text
		Investment costs	Number
		Prices of species	Number
		Sale price of fish	Number
		Womens roles (traders, processors etc)	Text
		Gear/boat ownership by demographic group	Text
		Household possessions eg oven	Text
		Fish meals and quantity per day	Number
Disposition of Catch at PSU		Sale to consumers/traders etc	Text
		Own consumption	Text
		Proportion processed	Number
		Destination of products	Text
		Buyer frequency	Number
		Buyer transport	Text
		Origin of buyers/traders	Text
		Distance to market	km
		Fish products	Text
		Main markets (Names)	Text

Sector Support and Infrastructure at PSU	Community HQ? Market places Access road exists? Boat transport exists? Transport of fish Public transport Numbers of processors Preservation/processing methods/facilities (eg Kiln, smokers etc) Electricity? Sources of raw materials (gear/boats) Village oven? Repair facilities?	(Y/N) Text (Y/N) (Y/N) Text Text Number Text (Y/N) Text (Y/N) (Y/N)

The table illustrates that frame surveys may generate a broad range of data. As stated above, much of the information that is commonly collected is used for subsequent planning and design of data collection programmes, creating inventories or registers of vessels, MCS purposes, socio-economic baseline data, and policy and development planning purposes, or a combination of these. Identifying exactly what frame survey fields and corresponding data should be included in the FIMS will depend on the overall data collection strategy, institutional capacity, preferences...etc. For example, much of the socio-economic identified above might instead be collected under routine cost and earnings surveys (see below). Similarly, employment and fish consumption data may be collected under the frame survey if they are not available from alternative sources such as population census data collected by other government departments.

It is therefore impossible to be prescriptive about the types of frame survey data that should be included in the FIMS beyond the minimum requirements needed to raise sample estimates of catch and effort to total estimates (catch assessment Scenario C - see below) if sampling as opposed to complete enumeration (census) methods are employed. These basic requirements are identified as:

(i) Major Stratum
(ii) Minor stratum
(iii) Survey Date
(iv) PSU ID
(v) total numbers of operational FEU's of type *t*, deploying gear type (*g*) at each PSU ($FEU's_{t,g,PSU}$).

6.2.3 Total Annual Catch by Species and Effort by Gear Type

Catch and effort data are collected either using census or sampling approaches:

(i) *Census Approaches*

The collection of catch and effort data by census (complete enumeration) approaches is generally confined to industrial fisheries (not considered here) where the numbers of PSU's and FEUs are low and fishing activities easily monitored, or where detailed reporting by the FEU is a condition of some access or licence agreement. Exceptions to this include, for example, the artisanal TCI lobster and conch fishery (Field Study 2, Volume II) and the BIOT Inshore fishery.

Catch (and effort) is summed across each boat or fisher type (FEU_t), sampling (data collection) days in the month (*sd*), months of the year (*m*), and PSU (eg processor or mother ship) to give annual estimates:

$$Total\ Annual\ Catch_{s,t} = \sum_{PSU=1}^{PSU=n} \sum_{m=Jan}^{m=Dec} \sum_{FEU=1}^{FEU=n} \sum_{sd=1}^{sd=31} Catch_{s,sd,FEU_t,PSU,m}$$

where *Total Annual Catch* $_{s,t}$ is the total annual catch of species *s,* from (or effort deployed by) all FEU's of type *t* and *Catch* $_{s,sd,FEUt,PSU,m}$ is the catch of species *s*, landed (or effort deployed) on day *sd* of month *m* at *the PSU* by fishing units of type FEU_t. This is a general expression applicable to most census-based data collection systems.

(ii) Sampling Approaches

Stamatopolous (1993), identify three main categories of sample-based surveys for the collection of catch and effort data, referred to as Scenarios A, B and C (Table 12). They are the most frequently recommended approaches to fishery administrations with limited manpower and resources, typical of many artisanal fisheries.

Table 12 Methodological and operational characteristics of fishery surveys for the collection of catch and effort data. 1=Most accurate, 4=Least accurate. Source: Stamatopoulos (1993).

Type	**Census in Space**	**Census in Time**	**Sampling in Space**	**Sampling in Time**	**Frame Survey Required**
1. Census on Catch and effort	YES	YES	NO	NO	NO
2. Scenario A					
Catch	NO	NO	YES	YES	NO
Effort	YES	YES	NO	NO	NO
3. Scenario B					
Catch	NO	NO	YES	YES	NO
Effort	YES	NO	NO	YES	NO
4. Scenario C					
Catch	NO	NO	YES	YES	YES
Effort	NO	NO	YES	YES	YES

All three statistical scenarios are based upon the following basic expression:

$$Catch = CPUE\ x\ Effort$$

Scenario A

For Scenario A, fishing effort of FEU's (boats/fishers/(boats + fishers)/ Households...etc) of type *t* (eg canoes/outriggers etc) is completely enumerated from all PSU's (landing sites / clusters of households (villages)...etc), for the entire survey period, usually a calender month, *m*. Depending upon the precision required for data on fishing effort, records on fishing operations (gear types (*g*) /hours, numbers of hauls, crew size etc) are collected. In some cases the detailed data on effort are collected only through sub-sampling.

Catch per unit effort is sub-sampled from FEU's, at a sub-sample of PSU's, during a sub-sample of days (sampling day, *sd*) in the calender month for each species, *s* to give:

$$Total\ Catch_{FEU_t,g,m,s} = \sum_{PSU=1}^{PSU=n} \sum_{FEU_t=1}^{FEU_t=n} Effort_{g,m,PSU,FEU_t}\ x\ Sample\,CPUE_{FEU_t,t,g,m,s}$$

where

$$Sample\,CPUE_{FEU_t,g,m,s}=\frac{\sum_{sd=1}^{sd=n}\sum_{PSU=1}^{PSU=n}\sum_{FEU_t=1}^{FEU_t=n} Sample\ Catches_{g,m,s,PSU,FEU_t,sd}}{\sum_{sd=1}^{sd=n}\sum_{PSU=1}^{PSU=n}\sum_{FEU_t=1}^{FEU_t=n} Sample\ Effort_{g,m,PSU,FEU_t,sd}}$$

Sample CPUE should be as representative as possible of the fishing activities at the different PSUs and monthly fishing activity and be of sufficient size as to provide good estimates for the population CPUE.

Where the estimation does not involve details of the species composition directly, the catch of species *s* is estimated on the basis of the observed composition of the catch at the PSU or markets. For example if species *s* is y% of the total sample catch from gear *g*, in month *m*, then the estimated catch of species *s* is simply:

$$Catch_{FEU_t,g,s,m}=y\%\ x\ \frac{(Total\ Catch_{FEU_t,g,m})}{100}$$

This scenario requires no frame surveys since effort is censussed and used directly for the estimation of total catch. It is the most accurate sample-based survey, but also the most costly because it requires the collection of effort data of all FEUs from all PSUs on a daily basis. Its feasibility depends upon the number and accessibility of the PSUs, the mobility of the enumerators, patterns of fishing operations, numbers of daily landings and willingness of the fishermen to participate.

Scenario B

In this type of sample-based survey, fishing effort is completely enumerated from all FEUs for at all PSUs, but only during a limited period of randomly selected sample days. Thus collection of data on fishing effort is censussed in space and sampled in time (Table 12).

Fishing effort is estimated over the entire period eg a month by first determining the mean daily effort and then raising to a monthly total by applying a time raising factor:

$$Total\ Effort_{FEU_t,g,m}=\sum_{sd=1}^{sd=n}\sum_{PSU=1}^{PSU=n}\sum_{FEU_t=1}^{FEU_t=n} Effort_{g,m,sd,FEU_t,PSU}\ x\ \frac{R}{n}$$

where *n* is the total number of sampling days, and *R* is the ' time raising factor'. The definition of the raising factor is crucial in this approach. If fishing activity occurs each day of the month, then *R*= number of calender days in month (28-31). *R* must be adjusted to take account of days in the month (eg Sundays) when little or no fishing occurs.

Total catch of species *s* by gear type *g* in month *m* is then estimated from:

$$Total\ Catch_{FEU_t,g,m,s}=Total\ Effort_{FEU_t,g,m}\ x\ Sample\,CPUE_{FEU_t,g,m,s}$$

where

$$Sample\,CPUE_{FEU_t,g,m,s}=\frac{\sum_{sd=1}^{sd=n}\sum_{PSU=1}^{PSU=n}\sum_{FEU_t=1}^{FEU_t=n} Sample\ Catches_{g,m,s,PSU,FEU_t,sd}}{\sum_{sd=1}^{sd=n}\sum_{PSU=1}^{PSU=n}\sum_{FEU_t=1}^{FEU_t=n} Sample\ Effort_{g,m,PSU,FEU_t,sd}}$$

Scenario B provides good estimates of total catch and effort and does not require frame surveys. Although less costly than Scenario A, it still requires that all PSUs are sampled.

Scenario C

For Scenario C, both catch and effort of FEUs are sampled in space from PSUs and time (days of the month), and then raised using information on the numbers of FEUs at each PSU, and for the fishery or stratum as a whole, collected as part of a frame survey:

$$Total\ Effort_{FEU_t,g,m} = \sum_{sd=1}^{sd=n} \sum_{PSU=1}^{PSU=n} \sum_{FEU_t=1}^{FEU_t=n} Sample\ Effort_{FEU_t,g,msd,PSU}\ x\ \frac{R}{n}\ x\ \frac{\sum_{sd=1}^{sd=n} \sum_{PSU=1}^{PSU=n} No.s\ FEU's_{t,g,sd,PSU}\ Landing\ (Active)}{\sum_{sd=1}^{sd=n} \sum_{PSU=1}^{PSU=n} No.s\ FEU's_{t,g,sd,PSU}\ Sampled}\ x$$

$$\frac{Total\ No.s\ of\ operational\ FEU's_{t,g}\ within\ Fishery/Stratum\ (Recorded\ by\ frame)}{\sum_{PSU=1}^{PSU=n} Number\ of\ operational\ FEUs_{t,,g,PSU}\ observed\ at\ the\ time\ of\ sampling}$$

and

$$Sample CPUE_{FEU_t,g,m,s} = \frac{\sum_{sd=1}^{sd=n} \sum_{PSU=1}^{PSU=n} \sum_{FEU_t=1}^{FEU_t=n} Sample\ Catches_{g,m,s,PSU,FEU_t,sd}}{\sum_{sd=1}^{sd=n} \sum_{PSU=1}^{PSU=n} \sum_{FEU_t=1}^{FEU_t=n} Sample\ Effort_{g,m,PSU,FEU_t,sd}}$$

and

$$Total\ Catch_{FEU_t,g,m,s} = Total\ Effort_{FEU_t g,m}\ x\ Sample CPUE_{FEU_t,g,m,s}$$

Scenario C is the least accurate sample-based survey method because assumes that the numbers of FEUs recorded at each site between each frame survey remain constant, and that the FEUs activity coefficient is representative of all landing sites or (clusters of) households within the fishery or stratum. Numbers of operational FEUs at the PSUs can potentially be updated each month or sampling period, and thereby also be used to partially update the total numbers of operational FEU's in the fishery or stratum recorded during the frame survey.

It is, however, the least costly, and frequently the only viable, approach in manpower and resource limited situations. It's effectiveness depends largely upon the representativeness and number of PSUs and FEUs selected for sampling, the accuracy of the frame survey, the number of daily landings, the willingness of fishers to participate and the validity of the time raising factor selected.

There are a number of variants on these basic scenarios, mostly relating to the selection of FEUs and PSUs, for example with PPS methods (see Annex 6). Stratification is also common according to region, location, fishing area etc. In these cases, an extra subscript denoting the strata would be added. All estimates are made at the minor stratum. Total estimates are made by simply summing the estimates for each stratum.

These algorithms were used to as a basis to identify generic (fields) and corresponding examples of data (fields) collected under each scenario (Table 13 below) from more than 20 artisanal fisheries (See Annex 5). The majority of these data collection systems reviewed were based upon interview, direct observation (or combination of the two) at the harvest level, and logsheet reporting at the harvest and post harvest levels.

Table 13 Summary of generic fields identified from examples of data and information fields collected for catch/effort sampling surveys (Scenarios A-C) and Census Approaches. *From frame survey ** From frame survey or updated during survey period (eg month).

Generic Fields	**Example Data (Fields)**	**Units**
Enumerator Details	Recorder name/ID Initials	Text/ Number/Code
Major Stratum	Province name River name Stratum code Habitat type	Text Text Code Text
Minor Stratum	Municipal Name Code Area name District name	Text Text Number/Code Text Text
Time/Date	Year Month DD/MM/YY Time	Year Month DD/MM/YY Time
PSU Identification	Landing site name Beach name Location Station name Code Village name Name of beel Baor Processing plant name Mother vessel ID	Text/ Number/Code
FEU Identification	Boat/vessel name Skipper name Boat ID Fisher ID Registration number Name of head of household (& location in village) Name of head fishermen Respondents name Dory number	Text /Number/Code
FEU Type (FEU_l)	Canoe? Outrigger? Pirogue? Outboard? Vessel type Gear type	Y/N Y/N Y/N Y/N Text Text

FEU Descriptors	Gear dimensions Gear code Mesh Sizes Material Of Construction Gear Name Vessel Length	Number Code mm Text Text m
$Sample\ Effort_{FEU_r,g,msd,PSU}$	Hook hours Numbers of gears/hauls Reel hours Hours fishing /days Fishing Number of bundles of gillnets Soak hours Days at sea	see Annex XX
Additional Effort/Activity Data:	Number of Fishers/Crew Day or Night Fishing Fishing location/grounds Depth Area Habitat type FAD fishing? Echo sounder? Trip number Departure time Arrival date & time Bait Distance from MV Numbers of fishers in household	Number Text Text/ Lat,Long m Text/Code Text Y/N Y/N Number Time Date and Time Text km Number
$No.s\ FEU's_{t,g,sd,PSU}\ Landing\ (Active)$	Number of boats landed by gear type Numbers of gears fished	Number Number
$No.s\ FEU's_{t,g,sd,PSU}\ Sampled$	Number of boats sampled by gear type	Number
$Total\ No.s\ of\ operational\ FEU's_{t,g}\ within\ Fishery/Stratum*$	Number of boats by gear type	Number
$Number\ of\ operational\ FEUs_{t,g,PSU}**$	Number of existing boats by gear type	Number
$Sample\ Catches_{g,ms,PSU,FEU_r,sd}$	Catch landed by boat gear code	Number/ weight / % of total
Environmental Data	Sea condition/ Wind Strength/Direction Current Strength Cloud Cover Pressure	Sea state Beaufort ms-1 Ordinate mB

All the generic fields, identified in Table 13 above should be included in the FIMS with options to allow the user to select one or more of the example fields determined by the local context.

6.2.4 Biological Data

The purposes of recording biological data and information, including measures of interest are described in details in Section 4.3.4. Biological data are most commonly sampled using direct observations at the harvest level where fish are caught and landed (Chapter 5). Generic data and information fields identified from examples of biological data (fields) collected for nine artisanal fisheries (See Annex 5) and presented in Table 14. These were based mainly on direct observations, and logbook reporting at the harvest level.

Table 14 Generic biological data fields identified from examples of data and information fields collected for biological sampling surveys.

Generic Fields	**Example Data (Fields)**	**Units**
Enumerator Name	Measured by Recorder	Text / Code
PSU ID and/or Relational Information (links to other datasets eg catch/effort)	Sampling point Station Vessel name Cruise Processing Plant Mother vessel code Dory name/number	Text /Code
Date Sampled	Date sampled	Date
Date Caught	Date caught	Date
Time Caught	Time landed Time of fishing Time in	Time
Species Name	Species Code	Text Code
Location of Capture	Locality Place caught Fishing location Location of capture Position Depth Habitat	Text Text Text / Code Text / Code/ Lat/Long Text / Code/ Lat/Long m Text/Code
Method of Capture	Gear type Fishing method	Text / Code
Gear Descriptors	Mesh size	mm
1.Total Numbers of units available for sampling	Number of traps set Number of boxes/baskets	Number
2. Numbers of units sampled	Number of traps sampled Number of baskets/boxes sampled	Number
Raising Factor (or 1./2.)	Proportion of the catch measured	Number / %
Length	Fork length	(mm)
Weight or...	Total weight	g / kg
Class Interval (length or weight) and...	Length/ weight class Class interval	g / mm

Numbers/Count (males/females/with/without eggs) in Class Interval	Count in class interval Class interval count by males, females (eggs/no eggs) Counts	Number
Sex	Sex	Male/Female
Maturity	Immature/mature/ripe/spent	Text / Code
Gonad weight	Ovary weight	g
Stomach Fullness	Stomach fullness	Ordinate Scale
Food Type	Food type	Text
Food Percentage	Food percentage	Ordinate Scale / %
Number of envelop/container containing samples eg scales, otolith, gonads etc.	Hard parts envelop number	(Alpha Numeric) Code
Contents of Envelope / Container	Scales/ otoliths/gonads etc	Text / Codes

6.2.5 Environmental Data

In common with biological data, environmental monitoring often occurs in parallel with catch and effort monitoring.

Commonly recorded environmental fields identified from the literature review were sea condition, wind strength and direction, current strength, cloud cover, atmospheric pressure, sea surface temperature (Table 13). Other potential variables for monitoring include water heights, flood area, pH, salinity, rainfall...etc (Section 4.3.5). Because these data are commonly collected in parallel with catch and effort data, data collection systems reviewed were also based mainly upon interview, direct observation (or combination of the two) or logsheet reporting at the harvest level.

The relevance of these different fields (and their combinations) will be dependent upon several factors including: local conditions and environments, the characteristics and operations of the fishery, available resources...etc. It is therefore impossible to be prescriptive about which fields should be included in the FIMS. In common, with catch and effort data, some means of allowing the user to select one of more of these fields would therefore appear necessary. Also in common with biological data, some means of linking these environmental fields to individual catch and effort records is fundamental.

6.2.6 Socio-Economic Data

General Sampling Guidelines

Several of the social and economic objectives outlined can be monitored with reference to overlapping sets of information and it is important that survey approaches streamline the data-gathering process to avoid replication of data sets – the integration principle (Caddy & Bazigos, 1985). For example, the outputs from cost and earnings surveys, in particular, can contribute to the calculation of net export earnings and poverty line headcounts (see later).

Most socio-economic data pertinent to government and community management objectives could be derived from a combination of vessel and gear inventory through licensing, combined with a cost and earnings survey for major fishing units and supplemented by special studies for minor gear or complex aspects of fisheries management (Caddy & Bazigos, 1985).

Where licensing systems are operational they can provide a source of basic information regarding the fishing unit, it's harvesting capacity and other baseline data. Other information sources may have to be improvised. Fisheries departments generally have little influence regarding census design but useful data is often available through national surveys developed by other government agencies such as planning departments, trade departments and the national statistical office (Caddy & Bazigos, 1985).

In the developing world where manpower and coverage is limited, sampling may have to be concentrated at nodal points that capture key activity. The geographic distribution of markets, and their ability to capture production from surrounding fisheries make these centres obvious sampling targets. Economic and revenue ministries may be better placed and have greater incentive to monitor markets than fisheries departments, but information on the value of production by fishery and it's availability to poor can be derived from market prices.

(i) Cost and Earnings

The need for cost and earnings data has already been discussed in detail in Section 4.3.2 B. Profitability is a vital micro-economic indicator of fishery or processing sector performance. To remain viable, fishers and processors must be able to cover all their costs. Measures of financial profitability of different vessel or FEU types and processing facilities provides an indication of short-term sustainability (FAO, 1999b).

Sources and Data Collection/Sampling Methods
Cost and earnings data are collected using cost and earning surveys (CES), applied either to FEUs (eg vessel and crew) operating from PSUs eg landing sites, or directly to PSUs in the case of household surveys where the PSU is also the FEU.

Caddy & Bazigos (1985) recommend stratified two-stage sampling (see Annex 6) with structured interview methods using pre-designed survey forms where FEUs or PSUs are sub-sampled from those selected for the catch assessment survey (see Section 6.2.3). This 'integration principle' improves efficiency, reduces the overall data collection costs and improves the utility of the results obtained. Before any selection is made, the sample units are stratified according to various strata, for example, region, fishery, socio-economic groups, fishing gear/vessel type (sub-sector), investment by unit of gear...etc. A few sampling units are then selected, with equal probabilities, from each strata of interest. Stratifying in this way also allows the calculation of Gini coefficients of income distribution among categories of interest.

Most cost and earnings survey forms are detailed. Targeting the same model households between surveys is preferable as data quality and recall by respondents is likely to be higher and the process of scaling up is simplified (Poate and Daplyn 1990). Such panel survey methodologies are regularly deployed to monitor long-term trends in income (see Dercon and Krishnan 1998).

For efficient data-handling it is recommended that a suitable system of codification is developed to identify fishery, sub-sector, village, respondent and enumerator. The cost and earnings survey will require the allocation of extra time to statistical officers carrying out catch assessment surveys. It should be borne in mind that CES provide only average, not total, values of attributes of interest eg average monthly costs, average gross revenue etc. Some costs data (eg fuel and gear costs) may be available from support industries.

Generic and example cost and earnings data fields identified from the literature are summarised in Table 15 below. Many of these fields will be common to catch and effort sampling if the two surveys are integrated.

Table 15. Generic and example cost and earnings data fields

Generic Fields	**Example Data (Fields)**	**Units**
Enumerator Details	Recorder name/ID Initials	Text/ Number/Code
Major Stratum	Province name River name Stratum code Habitat type	Text Text Code Text
Minor Stratum	Municipal Name Code Area name District name	Text Text Number/Code Text Text
Time/Date	Year Month DD/MM/YY Time	Year Month DD/MM/YY Time
PSU Identification	Landing site name Beach name Location Station name Code Village name Name of beel Baor Processing plant name Mother vessel ID	Text/ Number/Code
FEU Identification	Boat/vessel name Skipper name Boat ID Fisher ID Registration number Name of head of household (& location in village) Name of head fishermen Respondents name Dory number	Text /Number/Code
FEU Type (FEU_l)	Canoe? Outrigger? Pirogue? Outboard? Vessel type Gear type	Y/N Y/N Y/N Y/N Text Text

Costs	Fixed costs (monthly/annually)	Insurance Depreciation (vessel/gear) Loan repayments (principal & interest) Storage Leases Gear/vessel maintenance costs Licence / Access fees Household expenditure	Local Currency
	Variable Costs (by trip/month/annually)	Fuel Oil Bait Ice Water Food (Total) crew costs Crew share formulae Taxes and offerings Selling costs (transport etc)	Local Currency
Earnings (by trip)	Variable Earnings (by trip/month/annually)	Earnings from fish sales Species price & quantity sold Fresh fish sales Processed fish sales Mean selling price	Local Currency
	Fixed Earnings (monthly/annually)	Rental of gear Sales of fishing rights Investments	Local Currency
Cost and Earnings combined (by trip/month/annually)		Income	Local Currency

Cost and earnings data may also be generated by one-off socio-economic baseline studies often conducted in conjunction with frame surveys, or by *ad hoc* surveys to provide a 'snap-shot' of incomes from fishing. The same types of information identified above are commonly included.

A further complication arises in the fact that the periodicity at which these cost and earnings data are collected will vary according to how rapidly each variable changes with time, the structure and operations of the fishery, and local institutional capacity and resources. Fishers could be asked for any, or all, of the data in Table 15 for each trip they make, or asked to estimate their average values for, say, the last month, or for the entire year or a combination of these.

(ii) Economic Rent

The estimation of economic rent requires information on the total revenue and costs associated with a particular fishery. Total revenues are calculated as the product of the landed weight of fish (available from catch and effort surveys) and market prices of landed species. Market prices should be available from appropriate government agencies (FAO, 1999b), or from cost and earnings surveys which should be included in the FIMS (see above). Total revenue should also include the revenue obtained from quotas, licence fees...etc. These data should be available from fishery department/administration control and surveillance database records and included in a FIMS (see Section 6.3 below). Total costs of production include:

(i) Harvesting costs (fuel, ice, bait, repair, maintenance...etc).
(ii) Processing costs (unprocessed product, power, water, packaging, transport...etc).
(iii) Opportunity costs (interest rates, rates of return on capital from other sectors, wage rates in alternative employment sectors, unemployment rates...etc), and
(iv) Subsidy and management costs (subsidies, administration, MCS costs).

Harvesting and processing costs are available from cost and earnings surveys, support industries, or *ad hoc* frame/socio-economic baseline surveys. Data to estimate opportunity costs would generally not be included in a fisheries database. FAO (1999b) suggest several alternative sources for these data. Similarly, subsidy and management costs would be available from relevant government economic ministries or fisheries administrations but would generally not be included in a FIMS.

(iii) Export Revenue Data

Export revenue is an indicator of foreign exchange earnings from fisheries related exports (see Section 4.3.2 B). When combined with the value of imports, balance of trade may be calculated. Information on fish imports and exports value and volume is usually obtained from the responsible financial authority or ministry monitoring international trade. These data would generally not, therefore, be included in a FIMS for fisheries departments.

(iv) Employment Data

Employment data are useful for policy and development planning purposes (Section 4.5), particularly with respect to determining the relative importance of fisheries or the various sectors of the industry (fishing, processing, marketing, manufacturing..etc) to the regional or national economy. This data may be obtained from one or a combination of (i) Frame/Socio-economic baseline surveys (see above); (ii) population census; (iii) *ad hoc*; and (iv) catch and effort surveys (see above). Population census data are generally available from other government departments or ministries. Population census and *ad hoc* study data are generally not stored in fishery department databases (also see Section 4.3.2 B).

(v) Poverty Data

Poverty is a reference point used to gauge levels of income in relation to basic living costs, often among different types of fishing units, fisheries or sectors (Section 4.3.2 B). Generic data fields for income data have already been identified above (see cost and earnings data). Numerous proxies may be substituted for income data such as gear/vessel ownership, savings, investments, assets, access to services and credit, material possessions, household assets...etc.

Proxy indicators are usually collected infrequently (once every 1-10 years) as part of frame/ socio-economic baseline surveys (see above), *ad hoc* surveys (not covered by the FIMS), or may be available from population census data (see above), or combination of these. These proxy indicators may, however, also be collected as part of cost and earning surveys.

(vi) Industry Diversification Data

Data to assess and monitor industry diversity (Section 4.3.2 B) are available directly from the catch and effort (total numbers of target species), and frame survey (total numbers of different gear and vessel types and supporting sectors) elements of the FIMS.

(vii) Food Provision/Security Data

The calculation of fish supply and trends in average per capital consumption requires information on total national: (i) landings; (ii) imports and exports; and (iii) total population. Landings data are available directly from the catch estimation elements of the FIMS. Imports and exports are available from the relevant government trade ministry and population estimates should be available from national census data, also from the relevant government ministry. Household fish consumption surveys may also be employed to gather the data, either as part of a frame/socio-economic baseline survey (see above), or as a separate survey. For household fish consumption surveys relevant generic data fields identified by Caddy & Bazigos (1985) include:

Enumerator ID (see above for example fields)
Major Strata (see above for example fields)
Minor Strata (see above for example fields)
Date (see above for example fields)
PSU ID (eg Name of head of household and household address)
Number of persons in household
How many fish meals in the last week?
What quantity of the following fish did you eat: Crawfish, Turtle, Snapper, Grouper...etc?
Did you or your family catch it yourself?
Trade it for other commodities?
Buy it from a fisher/store?
Locally produced?

For distribution of fish consumption and calculation of the Gini coefficient, fish consumption surveys (and frame surveys) would need to collect fish consumption data, as well as corresponding demographic variables or categories of interest such as age, ethnicity, income groups, fishery sub-sector, region...etc.

(viii) Conflict Data

The incidence of each conflict by strata of interest (eg FEU type, fishery, region...etc) should ideally, be determined on a seasonal basis since movements of fisher groups into and out of the fishery may follow seasonal patterns and dictate the nature of fisher-fisher interaction.

Conflict data may be available from NGOs facilitated community group/project records and minutes, or from local court records. Alternatively, the data could be collected with *ad hoc* studies employing semi-structured interview techniques. PSUs might typically include villages, or representatives from informal village courts (*matbors* in Bangladesh). No example fields relating to the collection of these types of data were identified from either existing data collection forms or databases. Relevant generic fields might include:

Enumerator ID (see above for example fields)
Major Strata (see above for example fields)
Minor Strata (see above for example fields)
Date (see above for example fields)
PSU ID (Local Court Name and see above for further example fields)
Sampling period (see above for example fields)
FEU ID (see above for example fields)
FEU Type (see above for example fields)
Total number of incidents of gear damage
Total number of injuries or deaths
Reasons / Explanation for dispute

(ix) Maintenance of Traditional Management and Culture Data

Data to assess and monitor the maintenance of traditional management and culture (see Section 4.3.2) would typically include the numbers of villages operating access payments to chief fisher or village head, or the numbers of villages operating sanctions set by chief fisher or village. This information would best be collected as part of a frame (see above) or *ad hoc* survey. Such a survey may comprise semi-structured interviews of village heads or chief fishers at a sub-sample of PSUs (villages) stratified by variable of interest (eg region, fishery, ethnicity...etc):

Enumerator ID (see above for example fields)
Major Strata (see above for example fields)
Minor Strata (see above for example fields)
Date (see above for example fields)
PSU ID (Village or community ID)
Access Payments Made?
Sanctions set by village head or chief fisher?
Number of mosques/churches or other culture indicators present

6.3 Generic Fields for Control and Surveillance (MCS) (Datasets 1b & 2)

Reviews of Mees (1998); FAO (1997 & 1996a-c); Flewwelliing (1994); Carrara & Ardill (1989); Caddy & Bazigos (1985); Brander (1975) and the two field studies (Volume II) identified the following generic information fields:

(i) Name and address of each fisher, owner, skipper or charter agent of each fishing vessel or unit
(ii) Address or port of registry of each vessel or fishing unit;
(iii) Details of mortgages, maritime liens and other encumbrances.
(iii) Identification and communication details (particularly for larger fishing vessels):
- Name of vessel or registration number;
- Allocated Identification number for licensing purposes, colours, profile etc.
- Port of registry/home port;
- ITU International Radio Call Sign 6 ;
- Length overall, as used to measure length for the purpose of the International Regulations for Preventing Collisions at Sea, 1972;
- Registered length, as defined in the Torremolinos International Convention for the Safety of Fishing Vessels, 1977, as modified by the Torremolinos Protocol of 1993 relating thereto;
- Date of build; Lloyd’s Register number (where applicable);
- INMARSAT number (where applicable);

(vi) Information relating to fishing power and operations:
- Vessel type;
- Details of fishing gear and method(s);
- Gross registered tonnage as defined in the International Convention on Tonnage Measurement of Ships, 1969;
- Material of build;
- Hold capacities in cubic meters;
- Processing equipment
- Freezing equipment
- Number of crew;
- Horse power of main engine(s) in kW or HP;
- Endurance (maximum trip length)

(vii) Details of the licence and/or quota including:

Allocated FEU identification number for licensing purposes (see above) or
Licence holder name and address
Licence type
Licence number (serial) allowing for two or more licences to be allocated to one FEU)
Date and place of issue
Period of validity (Starting and expiry dates)
Licence fee
Permitted fishing locations or areas and gears
Quota allocation by species and areas
Terms and conditions of licence (eg access agreements)

6.4 **Generic Fields for Policy and Planning Purposes** (Datasets 1a & 1b).

As already discussed in Section 4.5.4, the heterogeneity of fisheries and their management and policy institutions makes it very difficult to identify generic policy-level data and information requirements, their formats and sources beyond those already identified in Table 6. Outputs from the FIMS to support this role will be restricted to (processed) data and information either collected under routine monitoring programmes (eg catch and effort, biological, environmental, socio-economic...etc), information for control and surveillance (C&S) purposes and frame surveys, or drawn from management plan documents which themselves are often heavily based upon frame survey data and information.

Given that management plans may not be included in the FIMS (only referenced), the frame survey data fields (Table 11) that are included in the FIMS will therefore, along with the data collected under the routine data collection programmes, C&S records and other government departments or ministries, largely dictate the system's capacity to provide the necessary data and information required for this role.

6.5 Generic Fields for Compliance with International Management and Reporting Responsibilities (Datasets 1b & 2)

The basic information required for compliance with international management responsibilities, identified in Section 4.6, relates mainly to catch and effort and biological data, and vessel data for standardising fishing effort. Generic fields for these data and information have already been described above.

Most of the information requirements for International reporting responsibilities with respect to the main international commissions and conventions (Section 4.7) are also covered by catch and effort surveys or may be obtained through other government departments, for example, imports and exports data from a customs and excise department.

Fleet statistics may be available from vessel registers (see Control and Surveillance above) or included in the frame survey element of the FIMS, for example in the form of number of FEUs required for estimating total annual catch and effort using sampling programmes (see Section 6.2.2 above). Generic fields to provide employment statistics are identified above.

6.6 Generic Fields to Support and Coordinate Co-Managed Resources (Datasets 1a and 3)

This next Section 6.6 attempts to identify generic fields of data that are required to support and coordinate the management of locally managed resources at the IMA or VMA level (Datasets 1a and 3)

6.6.1 Generic Fields for IMA/VMA Management Plan Formulation and Coordination (Data set 3)

As concluded in Section 6.1 above, the heterogeneity of management plans in terms of their structure and content and format will almost certainly preclude their inclusion in the FIMS database. However, referencing individual management plans to their respective IMAs and VMAs will be essential to monitor and coordinate their management activities.

6.6.2 Generic Fields to Support SIPA (Dataset 3)

The concept of Spatial Interdisciplinary Pattern Analysis (SIPA) was first introduced in Section 4.9 as a means of accelerating the adaptive learning process among IMAs and VMAs. The basis for the approach is to attempt to establish patterns or similarities among individual IMA/VMAs attributes and inputs (explanatory variables) identified from the management plan (and any other sources) in relation to management performance evaluation criteria indicators (outputs). To support SIPA, generic fields describing these attributes, inputs and performance indicators must, therefore, be included in the FIMS.

It is difficult to be prescribe generic attributes that should be included in such an analysis since many may be unique or more relevant than other among different fisheries. At the bare minimum, they should include all the information categories contained within the management plan and any other inputs that are believed to affect outcomes or management performance. As was concluded in Section 4.9 , a common set of management plan performance indicators should be negotiated with the local IMA/VMA managers. However the main categories of performance indicators, identified by DFID (1999), may provide a useful starting point.

Potentially appropriate generic and example fields describing these attributes, inputs and performance criteria are given in Tables 16a & b. These fields have been identified on the basis of the Oakerson Framework (Section 3.1), ICLARM's 'Institutional Analysis Research Framework' developed under their Fisheries Co-Management Research Project, and from inter-disciplinary comparative studies of African lake and coastal fisheries described by Preikshot, Pitcher *et al*. (1998) and Nielson *et al*. (1995) respectively.

These fields can be easily and objectively scored on a ordinal or presence/absence score, or quantified using interval or ratio scales if available. Basic ranked scores could be replaced later by more precise values. Selecting generic fields to include in the FIMS will require discussion, negotiation and refinement and may be largely dictated by data availability.

Statistical Analyses and Feedback

Similarities among IMA/VMA attributes and inputs may be identified using multivariate methods such as ordination. This method attempts to construct 'maps' of samples or sites (in this case IMA/VMAs), usually in two or three dimensions, such that their relative placement in the ordination space reflects the overall similarity of, in this case, their attributes and inputs. Points in close proximity to each other have very similar attributes and inputs, whilst samples that are far apart have few common features. In essence, this technique allows the data and information to "...tell its own story..." (Clarke 1993).

Several multivariate ordination techniques exist (see Jongman *et al*. (1995) for review). Non-parametric Multidimensional Scaling (MDS), developed by Shepard (1962) and Kruskal (1964) for use in social sciences[5] where measurement scales are often arbitrary, is particularly suitable for the types of data and information under consideration here where little is known of the probability distributions underlying most of the attributes.

The method constructs an ordination where the relative distances between samples or sites are based upon their rank (dis)similarity calculated from a matrix of similarity or dissimilarity coefficients (Figure 10). The coefficient is usually a simple algebraic measure of how close the scores are for each attribute under consideration. The MDS algorithm employs an iterative procedure to construct the ordination, successively moving the positions of the points until they satisfy the dissimilarity relations between the samples. The success of the ordination is measured in terms of 'stress'. Successful ordinations have stress levels less than 0.2. The ordination is then interpreted in terms of relative similarities, for example, "site A is more similar to site B than it is to site C" (Clarke, 1993). Attributes may be given equal weighting by standardising their scores, typically so that they have a zero mean and unit standard deviation.

Null hypotheses regarding attributes and inputs in relation to single or multi-criteria outcomes or management performance criteria listed in Table 16b, for example, "there are no differences in IMA/VMA attributes and inputs with respect to fisher income" (Figure 10), can be tested using a non-parametric permutation (analysis of similarity or ANOMSIM) test based upon the difference in the average rank similarity within and between groups of replicate sites *r* statistic).

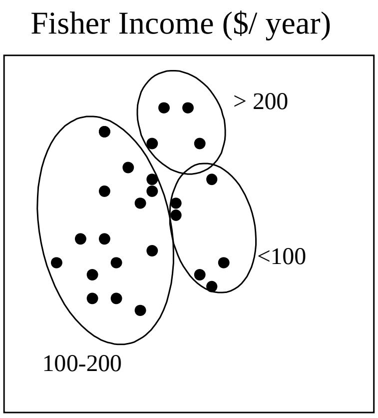


Figure 12. A hypothetical ordination illustrating similarities in fishery attributes and inputs for 25 individual IMA/VMA's. The three ovals superimposed on the ordination indicate three different levels of fisher income (outcomes) for hypothesis testing using ANOSIM (see text for further explanation).

The significance level of the test is calculated by referring the observed value of the *r* statistic to its permutation distribution generated from randomly selected sets of permutations of site labels. The attributes and inputs most responsible for statistically significant different site groupings can be determined by computing the average contribution of each attribute and input to the overall dissimilarity between all pairs of intergroup sites (Clarke & Warwick, 1994).

[5]MDS has also been extensively used in a large number of published ecological studies (Clarke, 1993).

Table 16a Potentially appropriate generic and example fields describing the attributes of, and inputs to, individual IMAs/VMAs

Category	Generic Fields	Examples of Data Fields	Units
IMA/VMA Identification and Reference	IMA/VMA ID	IMA/VMA ID	Text/code
	IMA/VMA Management Plan ID	IMA/VMA Management Plan ID	Text/code
Resource: (Natural capital)	Production potential of resource	Bioloimiting nutrient concentrations Water transparency (Secchi depth) Primary Production	µg l^{-1} m g /C/m^2/year
	Resilience of resource	Mean (Unexploited) Longevity/size or Mean Lm50/Lmax of species present	Years/cm 0 - 1
	Rule enforcement potential	Clearly defined boundaries Boundary perimeter length or site area Distance to fishing ground Fisher density	0;1;2 (low, med, high) km km N km^{-2}
	Divisibility of resource	Migratory or sedentary resources	0;1
Environmental: (Natural capital and shocks)	Environmental health of fishery habitat		0;1;2 (low, med, high)
	Connectivity of inland water body	Stream order association	1 - 6 (stream order)
	Nutrient recycling	Waterbody depth	m
	Natural variation	Coral cover	%
	Upwelling		0;1;2 (none, seasonal, constant)
	Anthropogenic effects (Adjacent land use)	Agriculture Forestry Industry	0;1 (No; yes) 0;1 (No; yes) 0;1 (No; yes)
Technological: (Inputs / physical capital)	Exploitation methods (Predominant gears)	Gillnet Poison FADs traps ...etc	0;1 (No; yes) 0;1 (No; yes) 0;1 (No; yes) 0;1 (No; yes)
	Exploitation intensity	Nos. of fishers/boats/gears per unit area	N km^{-2}
	Poaching/illegal fishing/compliance	Incidence of poaching/illegal fishing	0;1;2 (low, med, high)

	Preservation facilities	Ice Smokers Drying	0;1 (No; yes) 0;1 (No; yes) 0;1 (No; yes)
	Transport and infrastructure		0;1;2 (low, med, high)
Decision making arrangements & Factors affecting fishermen behavior: (Transforming structures and processes, livelihood strategies, human and social capital)	Management Plan	Present/implemented	0;1 (No; yes)
	Management (Operational rules)	Effort control Catch control Reserves Closed seasons...etc	0;1 (No; yes) 0;1 (No; yes) 0;1 (No; yes) 0;1 (No; yes)
	Mechanisms for enforcement	Rules monitored by resource users	0;1 (No; yes)
	Representation of users in rule making		0;1;2 (low, med, high)
	Relevance of rules		0;1;2 (low, med, high)
	Level of user information/knowledge	 Years of education Number of years fishing Literacy rate	0;1;2 (low, med, high) Years Years %
	Sanctions for non-compliance		0;1 (No; yes)
	Graduated Sanctions for non-compliance		0;1 (No; yes)
	Effective conflict resolution mechanisms		0;1 (No; yes)
	Homogeneity of users:	Ethnicity, Age, Gender, Religion...etc	0;1 (single/mixed) Years 0;1;2 (Predominantly male; female; mixed) 0;1 (single/mixed)
	Dependence on the fishery for livelihood (Motivation of users)	Alternative livelihoods Income from fishing as a % of total income Commercial/Subsistence fishers	0;1 (No; yes) % 0;1
	Attitudes towards collective action, risk, innovation...etc		0;1;2 (low, med, high)

External Factors: Transforming structures and processes, vulnerability	Economic value of resource	Mean unit value of species present	Price/kg
	Market Demand	Local market population size	Numbers
	Natural disasters (eg cyclones, extreme floods)	Frequency	0;1;2 (low, med, high)
	Population, economic, technological trends		0;1;2 (declining, static, rising)
	Price seasonality		0;1;2 (low, med, high)
	Donar assistance	Expenditure	$/year

Table 16b Potentially appropriate generic and example fields describing management performance of IMAs/VMAs

Generic Field	**Examples of Data Fields**	**Units**
Reference period	Year Season (dry season / flood season etc)/YY Month/YY Week/MM/YY DD/MM/YY	Year Text Month/YY Week/MM/YY DD/MM/YY
Income (financial capital)	Average fisher earnings / savings	$/day
Well-being	Infant mortality Access to services (health/water etc)	Number per thousand births 0;1;2 (low, med, high)
Vulnerability	Catch variability	0;1;2 (low, med, high COV)
Food security	Numbers of fish meals/week Days per month without fish meals Body mass index	Number Number Index
Exploitation status	Mean length of target species Mean trophic level of catch Catch per unit effort with standard gear	cm 2-4 kg/hr
Sustainability	Catch trends (time series or fisher opinions)	0;1;2 (Developing, mature, senescent)
Conflict	Numbers of conflicts	0;1;2 (low, med, high)
Equity	Gini coefficient of benefit/income distribution	Index
Biodiversity	Diversity indices eg *H'* ; species richness (*S*).	Index or Number of species in catch

On the basis of the results of these tests, IMA/VMA managers can, using appropriate media (see Section 4.9), be informed of which combinations of attributes and levels of inputs appear to give rise to desirable outcomes or objectives (management performance) that they may be pursuing (feedback loop 3, Figure 8). For example, it may be found that a combination of medium sized reserves with closed seasons and effective enforcement arrangements tend to give rise to the highest fish production. However, it may also be found that a different combination of attributes such as homogeneity of users, graduated sanctions for non-compliance and representation in rule making are more important for achieving a more equitable distribution of benefits.

A DFID funded project ' Interdisciplinary Multivariate Analysis for Adaptive Co-Management' R7834 aims to develop, refine and validate this approach.

6.6.3 Monitoring Guidelines to Support SIPA

The majority of the attributes and inputs listed in Table 16a will remain fixed or change very slowly with time. Monitoring these variables could, therefore, be undertaken annually or with each iteration of the management plan, which may occur, say, 1-3 years. Performance indicators (Table 16b) could be monitored more frequently to capture seasonal effects, or simply monitored with the same frequency as the attributes and inputs. Some form of 'reference period' indicating the period in time to which the performance data relates should also be recorded. This would ensure that valid comparisons of performance indices are made if they exhibit significant seasonal variation. For example, in floodplain fisheries, where catchability varies seasonally with the hydrological conditions, catch rates during any one month or season must only be compared with those recorded for other IMA/VMA's for the same month or season (See Section 4.3.4).

Management plan formulation and revision, and the subsequent (re-)profiling of each IMA/VMA according to the attribute and input indicators listed in Table 16a could be achieved with the assistance of intermediary organisations such as NGOs as each new IMA/VMA is created, or with each iteration of the management plan.

Monitoring of IMA/VMA performance indicators could either be also assigned to this type of intermediary, or simply monitored by the state in parallel with it's own monitoring programme for state owned sedentary resources and migratory stocks.

NGOs could also have an important role in documenting the establishment and development of co-management units. This process documentation could provide valuable lessons and insights for establishing further IMA/VMAs. However, its typical narrative nature in the format of diaries or logs would preclude its inclusion in a electronic FIMS.

6.6.4 Generic Fields to Comply with International Management and Reporting Responsibilities, and for Policy and Development Planning (Dataset 1a)

All the information required from IMA/VMAs with respect to these roles can be obtained from: (i) including IMAs/VMAs in the state's routine monitoring programmes for catch and effort (the generic PSU ID field in the catch and effort table would simply have to include an appropriate IMA/VMA ID field); (ii) IMA/VMA management plans (see above); and (iii) other data from other sources not included in the FIMS including special studies, export records and other government departments or ministries.

7. The PISCES Fisheries Information Management System

This chapter describes the development of the FIMS software (entitled 'PISCES' - **P**roviding **I**nformation for **S**ocio-Economic **C**atch and **E**ffort Fisheries Surveys) to satisfy the requirements identified in the previous chapters. Please refer to the accompanying User Manual for details on the operation of the software. The 'Technical Reference' chapter in that User Manual also repeats the material in this chapter with further detailed discussions on various design considerations for the software.

7.1 Introduction

A recurring problem in the field of fisheries research has been a lack of uptake of the professional techniques for information management despite there being the demand for this from the management sector. Techniques that were state of the art ten years ago and were profitably embraced by business and commerce have still yet to be widely applied in fisheries.

We have instead, either been floundering in an attempt at adapting to general information management a morass of third generation programming approaches that originated from specialised research interests, or indulged in amateur attempts at producing information management systems based only on the terms of any particular package an interested party had experience in. The net result of this lack of awareness of, and training in, the available methods among researchers and managers, has been a proliferation of inappropriate and incompatible systems instead of a coherent and unified approach to the common requirements. The information management perspective of this project attempts to address this problem in conjunction with producing a generic FIMS for co-management.

On a strategic level database initiatives in various projects should be co-ordinated as much as possible to share identified needs and design ideas. This would improve the usage and compatibility of systems allowing improved sharing and comparison of information between projects.

The main reasons for using a relational database are that in the first place it allows a clear and realistic way of defining a real world system, and how its parts interact. This in turn results in much more efficient and reliable collection, entry, storage, manipulation and analysis of data arising from any such real world system. Advantages that then become manifest in the management process itself, in this case for fisheries.

A comprehensive discussion of the underlying theory of database structuring and manipulation is beyond the scope of this report but it is important that the reader is aware of the utility of this theory and that it has been rigorously considered in this work wherever possible. The interested reader is refereed to the first 6 chapters of 'Access Databases, Design and Programming' (Roman 1999) for a practical introduction to the concepts involved and to 'Database Systems Engineering' (Whittington 1988) for a thorough treatment of the underlying principles.

The following sections concentrate on describing how this body of underlying theory has been applied to produce a fully working prototype generic FIMS for use in co-management. The reader is also referred to the accompanying user manual which also describes some of the additional design considerations.

This initial overview concentrates on describing some of the core concepts of the system namely the generic handling of effort catch costs and earnings data. The later sections describe other related facilities for generic handling of information for control and surveillance purposes, and for storing and processing biological and socio-economic data.

The principles applied, particularly those concerning the generic nature of the system, are applicable to most kinds of management. Co-management issues are dealt with by providing the means to record the factors identified as being relevant to co-management with every entity and process in the database. Thus any analysis can explicitly take these factors into account as defined by the user.

It is important to stress at this early stage that the customisation period required at each site where PISCES is installed is intended not so much to alter the PISCES software but most importantly to explain where their own data should be entered in the system. This will make it clear to users how the system relates to their particular situation and aid their understanding of how to use the system to find the answers to their particular questions. The 'customisation' will also transform a site's historic data into a PISCES format so that they can have an uninterrupted time series for analysis using historic, current and future data via a single system.

The entire principle on which the system is based is that any activity can be described as having taken place under a set of circumstances recorded as fields within basically a single table. The value for each of these circumstances is recorded for the activity. The set of circumstances or in technical terms the 'attributes' that describe the situation may include the time and place of the activity along with all the other conditions pertaining to it. These 'attributes' (fields) would describe the conditions pertaining in a household or whilst fishing. Such attributes would be both, the inputs and outputs in terms of physical data, measures that profile management areas and measure the performance of management areas.

A range of performance attributes can be analysed against any of the physical or management attributes or any number of combinations of these according to the user's choices. This allows a choice of analyses from the traditional physical kinds all the way through to a comparison between different co-management arrangements.

The choice of whether any one attribute is regarded as an 'input' or 'output' is an arbitrary one based on the investigators assumption of cause and effect for each of the analytical queries provided. The distinction can thus be ignored, (in the terms of information structuring that is) which means that data structures do not have to confine the range of possible analyses but allow more to be added as required.

For example the species attribute could be used as a 'generic input' for catch analysis but as a performance indicator where used in the analysis of species diversity. The analogous viewpoint is also applicable to such things as exploitation methods and exploitation intensity.

The following figure illustrates this general principle. Bear in mind that what are called inputs and outputs are not data inputs and outputs but fishery inputs and outputs; things that that effect and result from the operation of the fishery. They are the attributes that describe the fishery, the circumstances under which it operates. As mentioned earlier what constitutes an input or output to the fishery is somewhat arbitrary and any one attribute can change from one category to the other depending on the 'model' of cause and effect the analysis is assumed to be operating under. Both the general and specific cases are given in the example figures. Thus attributes labelled as 'i' (input) or 'o' (output) could all just be labelled 'a' (attribute) since their definition as either inputs or outputs only happens at the time of analysis when a particular type of analysis is selected by the user. Thus, the attributes to be processed (o) and the result of the analyses are to be partitioned (grouped) according to the list of attributes (i) chosen by the user.

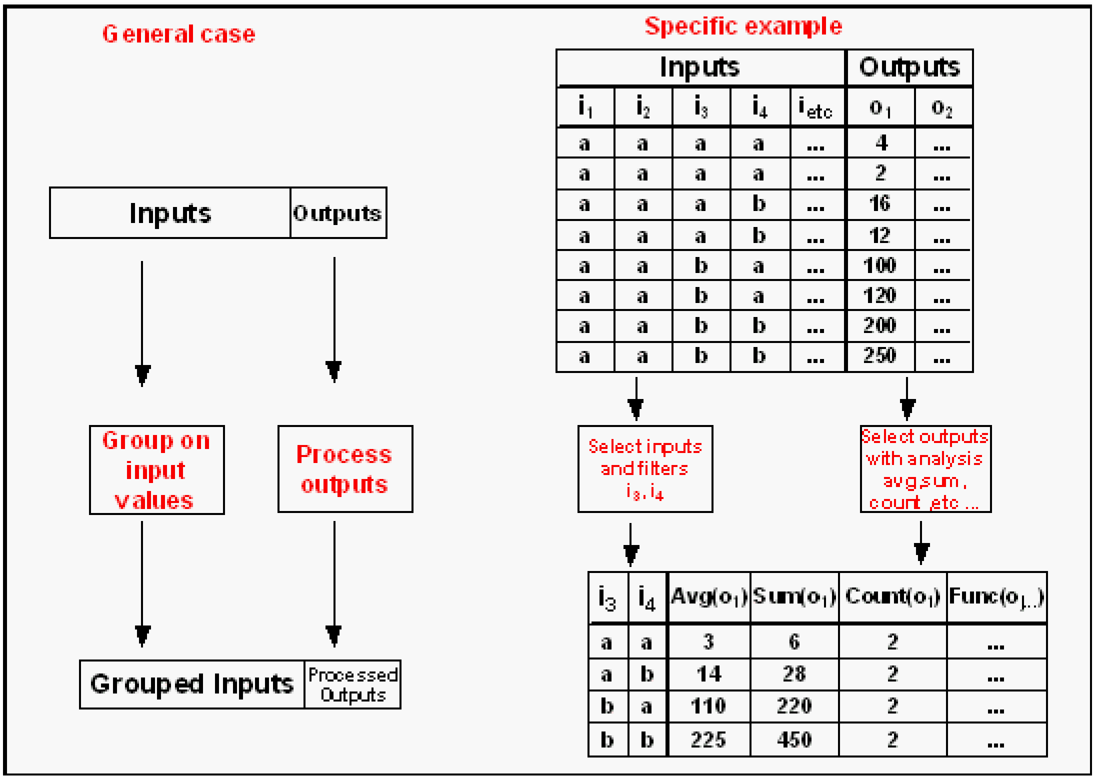


Figure 13 Illustration of allocation of attributes to groupings and analytical processes.

7.2 Design and Operation

The fundamental principles used in the design that address the problems of generification across fisheries are:

7.2.1 Encapsulating complexity in the data rather than via data structures
7.2.2 Reification (spreadsheet -> to table design mentality)
7.2.3 Use of grouping clauses for stratification and categorisation purposes
7.2.4 Dynamic generation and linking of suite of related SQL queries
7.2.5 Variable scaling of the data
7.2.6 Estimation of CPUE by outward joins of effort and catch tables
7.2.7 Overview of Analysis in Relation to Data Structures
7.2.8 Software design options. Complexity in structures or processes?
7.2.9 Survey design options and the database structure

Since all of these principles as applied in the PISCES software interact to provide the solution, it is somewhat artificial to describe them in sequence. It is best if the reader bears in mind the importance of this interaction and their combined effect in arriving at an efficient and flexible solution to the challenge of providing a database system that handles a complete range of fisheries situations. Section 7.2.7 'Overview of Analysis in Relation to Data Structures', attempts, with a simple example, to illustrate the overall effect of applying these principles.

7.2.1 Encapsulating Complexity in the Data rather than via Data Structures

The central point here is that widely differing situations can perfectly adequately be described under the same table structure providing that you choose the suitable range of attributes (fields) to compose that table at the design stage. The following figure illustrates how increasingly complex fisheries are described within the same data structure. The complexity is catered for by an increase in data and not an increase in the number of data structures.

Region	FEUtype	Habitat	Catch
a	a	a	8

Region	FEUtype	Habitat	Catch
a	a	a	4
a	a	b	4

Region	FEUtype	Habitat	Catch
a	a	a	2
a	a	b	2
a	b	a	2
a	b	b	2

Region	FEUtype	Habitat	Catch
a	a	a	1
a	a	b	1
a	b	a	1
a	b	b	1
b	a	a	1
b	a	b	1
b	b	a	1
b	b	b	1

Increasingly complex fisheries

Represented by an increase in data and NOT an increase in data structures or their complexity. (7b)

Figure 14 Complexity as data.

The first situation is a very simple fishery composed of only one region with only one type of boat operating and there only being one type of habitat. The second table of exactly the same structure can illustrate a more complex situation where there are now two types of habitat. The next situation is further complicated by there being two types of FEU operating in both the habitats. Again this is represented in the same structure *ad-infinitum*. Though these simplified examples are concentrating on physical attributes of the fishery, the same principles apply to all other attributes e.g. those of particular relevance to co-management. The following section on table design reinforces this point.

7.2.2 Reification (spreadsheet -> to table design mentality)

In designing the kind of table alluded to in the previous section the principle of reification must be applied without mercy! This is most simply explained as the switching from a spreadsheet design mentality to that of a database table. Thus if you wished to express the catch of two species in say two different habitats instead of having a table like,

Habitat_A Species_A Catch	Habitat_A Species_B Catch	Habitat_B Species_A Catch	Habitat_B Species_B Catch	***Habitat_A Species_C Catch***	***Habitat_B Species_C Catch***
5	8	2	11	***15***	***23***
7	3	4	9	***17***	***19***

we instead have a table designed as follows,

Habitat	Species	Catch
A	a	5
A	a	7
A	b	8
A	b	3
B	a	2
B	a	4
B	b	11
B	b	9
A	***c***	***15***
A	***c***	***17***
B	***c***	***23***
B	***c***	***19***

The advantage of the latter approach is that whenever you encounter a new habitat or new species it simply becomes more data whereas with the spreadsheet type design of the first table you actually have to alter the structure of the table before any data can be entered by creating more columns in the first place. With this former approach it is not long before your number of columns becomes unmanageable and you have a spreadsheet that extends out of the building.

Apart from having to alter the structure each time a new type of thing pops up you also have to alter any analytical code to take account of the new thing.e.g. for the first type of structure

Sum(Habitat_A/Species_ACatch),Sum(Habitat_A/Species_BCatch),
Sum(Habitat_B/Species_A Catch), Sum(Habitat_B/Species_B Catch),

Has to become:

Sum(Habitat_A/Species_A Catch), Sum(Habitat_A/Species_B Catch),
Sum(Habitat_A/Species_C Catch), Sum(Habitat_B/Species_A Catch),
Sum(Habitat_B/Species_B Catch), Sum(Habitat_B/Species_C Catch),

Whereas with the second type of design the data for the new species slots into the existing table without any modification of it; and the analyses of the form:
Sum(Catch) GROUP BY Habitat, Species
will continue to work whatever new habitats or species appear in the data.

7.2.3 Use of Grouping Clauses for Stratification and Categorization Purposes

Note the use of the GROUP BY operator in the analytical code of the previous section to partition the sum of catch by every unique combination of habitat and species.It would result in the following relation:

Habitat	Species	Catch
A	A	12
A	B	11
B	A	6
B	B	20
A	***C***	***32***
B	***C***	***42***

In fisheries terms the results have been stratified by habitat and species. It is probably best to use the term categorise rather than stratify in order to avoid confusion with the overlapping concept of ‘stratification’ as applied to sampling design. Though, where data collection has been stratified in such a way it is the GROUP BY operator that is used there as well to dis-aggregate the results during analysis. In reality, the terms have been used interchangeably and their significance can be gauged from the context in which they are used.

The user is free to choose whichever attributes they wish and in whatever combination on which to categorise their results. They can also choose how many as well, up to the artificial limit of 8 as imposed by Access. Fortunately in practical terms this limit does not impose any problem since all possible combinations of values under 8 different attributes would produce a result set way beyond what is usually required for now.

The maximum number of results produced by such groupings is calculated as the product of the maximum number of different values of each of the attributes grouped on. So in this example if you have a maximum of two possible habitats and three possible habitats we can have a maximum of 2 x 3 = 6 sets of results. Of course if all possible occurrences do not in fact occur then the results set is reduced accordingly.

7.2.4 Dynamic Generation and Linking of Suite ofRrelated SQL Queries

As the limited example above illustrates what we are doing is essentially creating a new table (the results) either as a physical table or a virtual one based on combinations of the underlying base tables. Such a virtual table is in database terminology known as a view or in Access terminology as a query. The resultant queries can then themselves be combined, queried to give further results. E.g. the calculation of CPUE is produced as a query, this itself is then queried in conjunction with the frame table to give an estimation of raised catch.

There are two basic approaches to forming such queries. Procedural ones based on ‘Relational Algebra’ and logical ones based on the ‘Relational Calculus’ This project is based around the use of SQL which is an implementation of the concepts of relational algebra.

At the core of the PISCES system is a method to allow the user the flexible choice of both the type of analysis and how this analysis is to be applied. For example are we to calculate effort, catch, CPUE, costs, earnings, net income, length frequency distributions, species diversity etc? Are we going to calculate these from census data or from sample data only or a combination of both? And finally whatever of the above choices we make are we going to look at differences in the results according to other factors e.g. habitat, or management area etc? These last ‘other factors’ can be chosen in isolation or in any combination from the following possibilities:

Table 17 Choice of attributes for grouping results of analysis

Fields	
Country	StartMonth
FrameSet	StartDay
PSUtype	DepthZone
PSUid	Disasters
RMA	EnvironHealth
IMA	LandUse
VMA	Exploit
ManagementPlan	Enforcement
Fishery	Compliance

Licence	Representation
LocationType	Relevance
LocationID	Knowledge
FEUtype	Sanctions
FEUid	Resolution
Village	Homogeneity
TripNo	Dependence
GearType	Infra
GearID	ExStratum1
DisposalSite	ExStratum2
StartYear	ExStratum3

The last three fields are for extra strata that have not been explicitly anticipated in the list. For example in the Bangladesh field study ExStratum1 held district codes and ExStratum2 held River Names but in the Turks and Caicos they held Island Names and the split season year respectively. As a specialised example the user could decide to analyse say the fishers costs in terms of the relevance of the regulations.

Under each effort and catch record there would be a required value for this 'Relevance' attribute being either, in this case, High Medium or Low. The costs analysis would thus be broken into three records, one each corresponding to the possible states of relevance of the regulation.

The user can also state a filter value for the states that are being analysed across thus if you wanted to analyse by habitat across regions for example you could specify only the habitat type you are interested in be analysed for, ignoring the data for the others.

Such flexibility of defining the queries is achieved by picking which fields you want to group (or 'stratify') by from the above list. These are then stored in a temporary table along with any additional filter values specified

e.g.

ChosenField	FieldValue
Country	TCA
ExStratum2	
StartMonth	

This allows analyse data by country, ExStratum2, and StartMonth but only for the Turks and Caicos. (FAO code) This isolates the ExStratum 2 values as being for Season. Because that is what it is used for in TCA.

This temporary table is then used with the choice of analysis to build up the necessary conditions in an SQL statement. A piece of code loops through each record in the table adding its name into the various selection, grouping and joining clauses that need to be constructed as part of the queries that form the skeleton of the analysis.

In this way that 'skeleton' can be rebuilt each time. So though we have a generic way of structuring and storing our data and a generic way of defining the analysis we are in no way stuck with only one way of doing things. In fact this approach confers the maximum amount of flexibility imaginable.

The same chosen attributes are chosen in the same order to build up queries for frame data, sample effort and sample catch data, biological sampling data, biological measurement data, household survey data etc. This ensures that the results sets produced are compatible and can then be dependently compared and combined as required. I.e. we can be sure that the summed catch is that resulting from the correct sets of summed effort, that the costs and earnings are similarly matched.

Once these queries are constructed they are your answer and will always reflect any changes in the underlying data. You simply open the query to check on the current results values, providing tour choice of groupings has not changed.

One cosmetic drawback of having this entirely flexible way of defining your analysis is that it is impossible to output them via preformatted reports because the content can constantly change. The results have to therefore be first presented in the format of simple tables. The user is then given the choice of graphing these via a generic plotting routine. This automatically scales and labels axes and allows the results to be visualised in a choice of formats. There are also facilities to export the original and processed results to either spreadsheets or a word processor so the user can then format them further to their taste.

Please refer to the code documentation for the exact details of how all this is achieved. Though the theory is a simple and strong one, the implementation is extremely complex particularly when having to take into account the possibility of either missing data and variably scaled data i.e. a mixture of summary and detailed data in the same database. All of the code combined runs to several thousand lines.

7.2.5 Variable Scaling of the Data

The other critical principle underlying the system is the way the calculation of effort is handled whilst allowing very variable degrees of detail in the data. The following explains how this is done.

Note that the principles discussed here apply equally to both the frame and sample tables for whether the effort is being used as a census figure, for use in estimating CPUE or being applied as a raising factor to estimate overall catch.

- **Management of variably scaled data**

Generic effort structure

FEU type	Nos of Units	FEU id	Year	Month	Day	Active Days	Effort hrs
a	3	""	00	1	""	2	7.5
a	1	z	00	1	""	2	6
a	1	z	00	1	1	1	5
a	1	z	00	1	2	1	7

Generic effort process

```
Sum(NosOfUnits*ActiveDays*EffortHours)
Group By [FEUtype[,FEUid][,Year][,Month][,Day]
```

Figure 15 Demonstrating how both detailed or summary data can both be held in the same data structures and processed by the same programs.

Detailed and summary data can even be combined during an analysis PROVIDING that the analysis in question only proceeds to the level of detail available in the summary data.

If you attempt to analyse combined data down to the level of the detailed data then the summary data will be automatically left out and only the detailed data will be included in the analysis.

Please see the following Section 7.2.7 'Overview of Analysis in Relation to Data Structures' for a further example and explanation of how the representation and processing of variably scaled data can be treated in a generic fashion.

There are three separate groups of records illustrated above in Figure 15 the first two are composed of single records the last group has two records. Each group is separated by a clear line simply to aid clarity. Note that the attributes chosen to illustrate the principles, FEUtype, FEUid. Year, Month and Day are arbitrary. Other attributes are handled in precisely the same way e.g. ManagementPlan, EnvironmentalHealth, RelevanceOfRegulations etc.

The first record illustrates the most summarised form of data. It only states the type of boat the numbers of these that were active the average number of days per month they were active and the average number of hours per day spent by these boats. Note that if these latter two averages were not available then either an informed guess can be made or they are left at their default values of 1 so that the effort units are no longer in hours but automatically become an index of effort based on the lowest level of detail available 'Nos of Units' in this example. However if you wish to combine summary data of this kind with more detailed data in a single analysis then you have to provide estimates of the average values so that the same units are used throughout your data set.

Note that for this first record neither the detail of FEUid or the particular day in the month the FEUs were active is available. Values for these are left as their default values of "" a 'zero-length-string' which the user can not see. This means that this data can only be sensibly used in an analysis that is based on FEUtype. It can not be used in an analysis for individual FEUs or particular days in a month.

The second record holds a little more detail. Individual FEUs (boats) are identified so note that in such a case the NosOfUnits automatically becomes 1 because we are by definition dealing with a single FEU. Particular days in the month are not identified so the Day field is still a "" zero length string and the ActiveDays field can be one or more.

In the final group (two records) both the individual boat and particular days are identified thus both NosOfUnits and ActiveDays become 1. Such records as these could be included in any analysis i.e. either a general one down to FEU type or a very detailed one including individual FEUs and the daily pattern of behaviour.

Note that in the analysis query the user would in reality be free to choose to what combination of groupings to use. The sum function always calculates a product of all the scaling attributes of effort. Where these are not known their values always default to 1 so as not to effect the outcome of the calculation and prevent multiplication by 0.

7.2.6 Estimation of CPUE by Outward Joins of Effort and Catch Tables

Most of the examples so far have concentrated on the structures and queries for the handling of effort data. If we were only measuring total catch or three was only ever one species in a catch then life would be much simpler. You would simply require a catch attribute alongside your effort attributes and all could be stored and handled together. However we have the old problem of multi-species catch which automatically makes the correct estimation of effort over aggregate queries, e.g. catch by gear or island or whatever grouping, problematical.

Say we had the following results for a single 10 hour fishing event structured as follows.

Island	Effort	Species	Catch
A	10	x	20
A	10	y	10

This set up is fine for estimating CPUE per species but calculating the CPUE across species would immediately cause an error as would estimating effort by island, both resulting in an erroneous doubling of the result.

The usual desperate escape solution illustrated below, temporarily solves the problem but we are then stuck with a structure and analysis query that cant handle any new species and require constant amendment whenever anything unanticipated turns up. This problem was described in detail before.

Island	Effort	Species_x_Catch	Species_y_Catch
A	10	20	10

The correct solution is to separate the effort and catch tables.

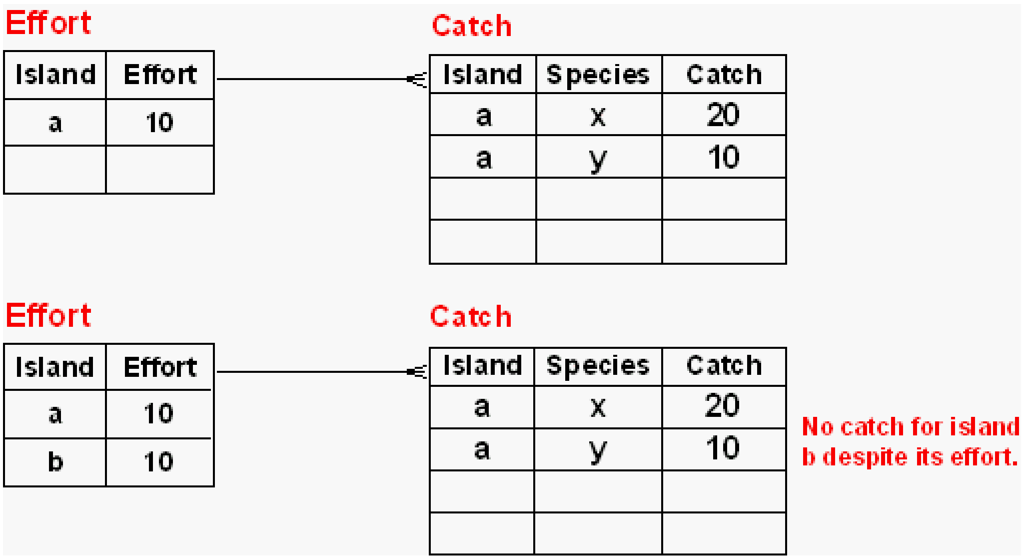


Figure 16 Effort and catch tables

Such a solution works very well. The requirement is that whenever you wish to perform any calculation involving the two tables you always have to join them using a relational operator so that the correct records from each table are matched up. However in the case of fisheries databases there is the scope for a major error at this juncture which will often catch novice or even experienced developers unaware. If you were trying to estimate catch per unit effort across Islands i.e. disregarding the distinction between islands a and b but summing both effort and catch across both islands. Then if you use a simple ‘inner join’ it will give the correct results in example 1 but will underestimate the effort in example 2 by leaving out the effort portion from island b because no catch was recorded as a result of that effort. This is potentially a very serious error arising from the convenient but inappropriate use of a database operator. To prevent this happening you should always use OUTER JOINS in expressions that relate effort and catch tables.

The application of the following code to example 2

```
SELECT Species, SUM (Catches.Catch) / SUM(Efforts.Effort) AS CPUE
FROM Efforts LEFT OUTER JOIN Catches
ON Efforts.Island = Catches.Island
GROUP BY Species
```

would result in:

Species	CPUE
X	1
Y	0.5

Note that all the effort has correctly been taken into consideration regardless of whether this resulted in a catch or not.

You can specify ‘left’ or ‘right’ with the ‘outer’ clause to indicate which of the two tables in the join should have all of its records taken into account even where there are not matching fields in the corresponding table. In this case ‘left’ is used because we wish to sum all examples of effort from the efforts table which happens to be on the left of the join expression.

7.2.7 Overview of Analysis in Relation to Data Structures

These principles apply in the estimation of effort whether they are being applied to the Frame or sample table.

In a census fishery the product of all the effort fields is summed for each of the unique combinations of values under the strata fields selected. The same is done for the catch fields with total catch per combination being divided by total effort per combination to give CPUE per combination. Correct estimation of effort in the calculation is maintained by having the effort and catch data in separate related tables and performing the arithmetic via an outward join.

In a frame-sampling survey with raising applied to estimate catch then the CPUE per combination values under the selected strata is calculated in exactly the same way. The difference is that this CPUE figure calculated from the sample and catches table is then multiplied by the to sum of the product of all the effort fields in the frame table which has been partitioned according to exactly the same combinations of strata values.

A crucial feature of the system is the way it matches up the CPUE results from the sample table with the sum of effort from the frame table. It does this by comparing the combinations of values across the selected strata from each of the two tables via an inner join operation.

For example if you had data that included LocationType and FEUtype in both sample and frame data. Then the system would work out the CPUE per unique combination of LocationType and FEUtype in the sample table. The results would thus be in a set of four records if for example there were two types of region each with the same two types of FEU operating in them. The system then checks the frame table to sum the overall effort again grouping the results according to each unique combination of LocationType and FEUtype. It then matches the two results sets multiplying them where both the values for LocationType and FEUtype match one another to give the third set of results of estimated raised catch. It is up to the user to ensure that there is representative data under each of the strata chosen for the analysis.

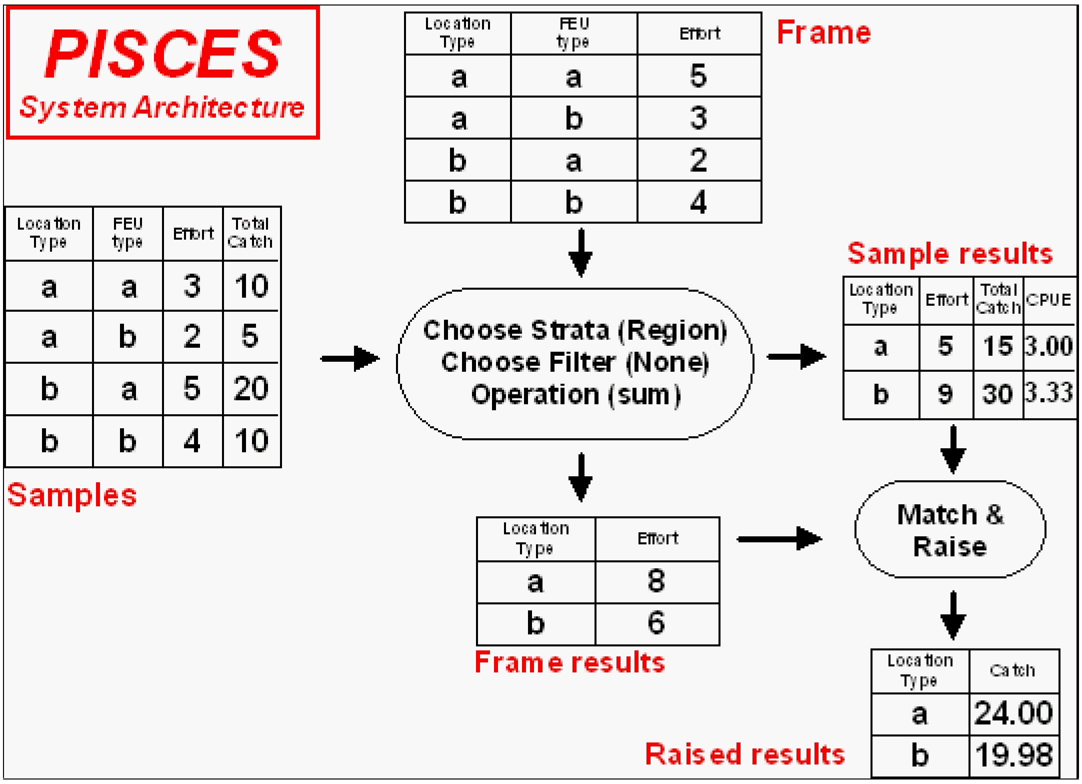


Figure 17 Simplified illustration of central data structures and processing principles.

The use of relational database operations such as the crucial join and grouping clauses as the core of the system are the key to its flexibility and speed. This approach also helps ensure data integrity and helps understanding of the system by presenting a unified and coherent method of structuring and processing the data.

The design is such that it can cater for (in this example) any unanticipated new type of Location or FEU without having to alter the structure of the database or analysis programs.

Though this example is for only two fields the user is in theory free to choose as many fields as they like to stratify by. However an internal feature of the Microsoft Access development environment limits the combination of fields used to 8 which imposes an artificial limit on the logic of the system. However in reality a user would be unlikely to even use this number of fields in defining strata because the combinatorial explosion of results sets would be so complex as to render them useless.

The user has total flexibility which fields and which combination they choose to stratify by. The number of result sets produced depends on the numbers of columns chosen and the number of different combinations of values under each column. In the example cited if there were say 3 LocationTypes instead of two and the extra type of location also had the same two types of FEU operating on it then obviously the re would be six results in the set. If there were 3 FEUtypes operating in each of the three location types there would be 9 results in the set etc.

The scenario ('B') where there is a census of effort but a sampling of catch is logically identical to the frame-sampling-raising situation and is handled by the same set up with allowances for variation in the way time series information is handled.

The following figure gives an overall view of the whole process involved in the catch effort estimation components of the PISCES system.

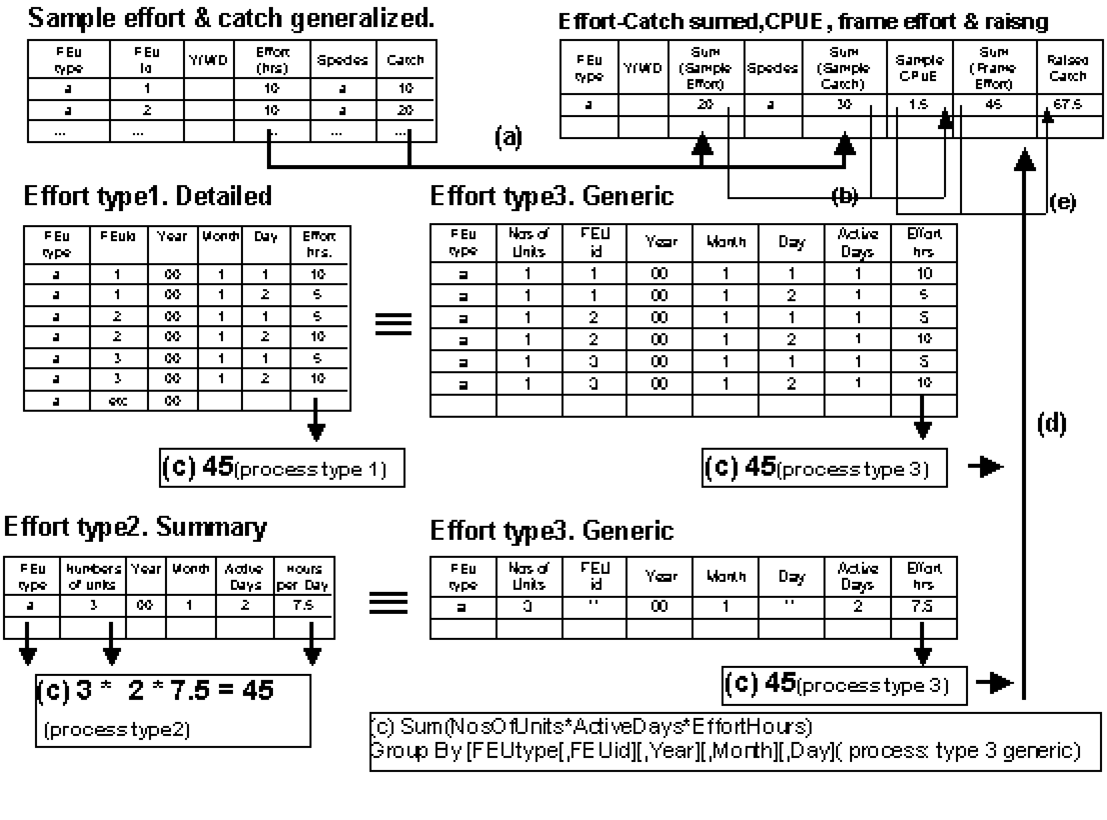


Figure 18 Structure and processes for variably scaled data and how these relate between sample and frame data.

This also shows how detailed effort data (Effort type 1) and summary effort data (Effort type 2) that require different data structures can both be equally well expressed in a single generic data structure (Effort type 3) without any loss of information.

It also shows the two different types of process for calculating effort (process type 1 and process type 2) from the different effort structures can also be generified into a single form (process type 3) and produce the correct results whatever the source.

The figure also illustrates how this handling of overall effort data (usually from the frame survey) is related to the effort and catch data from sampling surveys.

The same principle applies to all other attributes all the way up the hierarchy e.g. gear types at the lowest level to countries at the highest level. Care must be taken when summary data is used as input data to correctly allocate the proportion of effort to each grouping

The third, generic, type of effort calculation is a generalisation of types 1 and 2. I.e. it can cope with both detailed and summary data with both the same data structure and the same analysis code. It assumes the data has been entered in the correct format. It also assumes that any analysis carried out is done so with a knowledge of the limits of a particular data set i.e. down to what level of detail it goes. Thus you should not try to analyse to a finer level of detail than the coarsest grouping in the data.

You can aggregate up to any higher levels you wish. It is only on the 'downward' dissagregation that you are limited.

The figure also indicates the order in which the procedures take place, labelled as a,b,c,d,e.

First of all the selected groupings (and any filter values) are chosen.
Process (a) is the summing of effort and catch from the sample table according to the selected groupings.
Process (b) is the calculation of CPUE from these groupings
Process (c) is the calculation of overall effort (from the frame) according to the same groupings.
Process (d) is the pairing up of sample and frame results via matching value sets in the selected groupings.
Process (e) is the calculation of raised catch by multiplying the sample CPUE by the frame effort for each grouping.

In summary then this design offers a simple approach that can answer either a census type or frame/sampling/raising requirement and the variations on these. It addresses all the stratification requirements in as flexible a way as possible and as defined by the user. It is a generic design that has great utility over the widest possible range of fisheries situations.

With the frame/sampling single table approach, the trick is to make practical use of the built in redundancy of the design. Such redundancy would normally be considered an inefficient design. However by only having two core tables much of the inefficiency in terms of data storage is regained by the reduction in repeated complex keys required if everything is split up into smaller tables. The real gain though is that the same analysis procedures can be applied whatever the level of stratification. This is all achieved by having both tables composed of the finest detail possible but structured such that any of this detail can be left out. The only requirement for a frame or sample record is that the values in it must be capable of uniquely identifying that record in order for it to be tied to its matching partner from the frame/sample pair.

The outline of the process is:

Survey Design
Decide whether you are going to monitor via a census or frame / sampling survey approach. Choose whatever fields you wish to include for your survey from the complete detailed list.

This choice is based on the initial level of stratification you wish to implement.
Conduct a frame survey, if required, on these down as far as the finest indicator of effort in your sub-set of fields
Based on the frame results choose which strata to conduct a detailed sampling survey for CPUE and the proportion of sampling for each type within the strata (refine the frequency of sampling for each type depending on the data variability)
OR conduct a census

Data Entry
Enter the data filling the missing field types with zero-length strings (default values)

Data Processing
Choose the sub-set of fields from the sample survey results. Its level of detail can not be any finer than that actually contained in the data!

Calculate the average CPUE into a AverageCpuePerGroup field as
summed catch/ summed effort grouping across the same chosen field list.

IF you are also using a frame survey as a measure of overall effort THEN:

> sum the overall effort into a new TotalEffortPerGroup field grouped according to the same list of fields chosen for the sample data.
>
> match the pairs of these frame and sample survey calculated results on the corresponding in their field lists.
>
> Estimate the overall catch as TotalEffortPerGroup x AverageCpuePerGroup per matched pair grouped again across the field list.

.

This whole process is both very simple but very powerful. The user can survey to a very fine level of detail or at a very general broad level. Whichever is chosen the same data structures and data analysis processes can be applied.

Figure 19 overleaf illustrates the operations required and the intervening data storage.

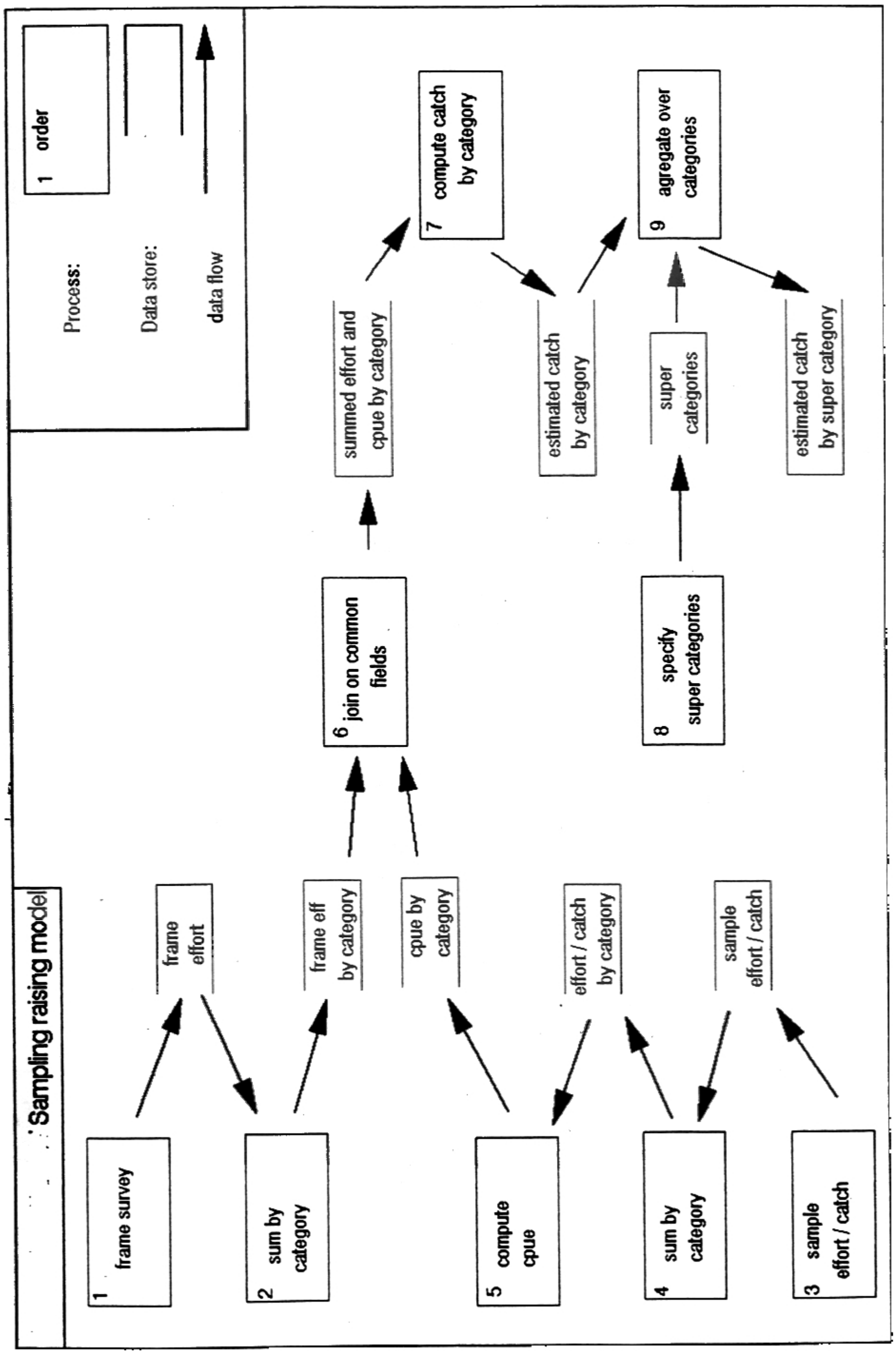


Figure 19 Representation of data processing for frame and sampling surveys and subsequent raising operations.

7.2.8 Software Design Options. Complexity in Structures or Processes?

Investigations during this project have revealed two possible solutions. These are labelled for convenience as 'Autonumbered Keys' and 'Large Natural Keys' respectively. The pros and cons of each approach are discussed below. Both are valid and worthy of further investigation. The 'Large Natural Key' design is the most favoured because of it being simpler, more robust and not dependent on the structure of a fishery and therefore applicable to the widest range of situations. The software required to support it will not be as widely available as the Microsoft Access used to develop the present prototype. That disadvantage will be outweighed by the improved design that can be implemented 'Large Natural Key' approach.

The design described in the previous sections is the one on which a successful system has been built. Experience gained during the project has shown though that there is a central conflict at the core of the design about how 'flat' the data model should be. Flat means that all of the fields are included in as few tables as possible.

Normally the flatter a data model the greater, in technical terms, is its 'redundancy' i.e. the needless repetition of data. This in turn leads to all of the related issues of 'Multiple-value Problems', Update Anomalies', 'Insertion Anomalies', Deletion Anomalies'.

A richer layering of the data model into a series of related tables that are correctly 'normalised' does away with these problems. However, such relations between tables depend on unique primary and foreign keys.

For a conventional fisheries relational database model such keys can be reliably formed from a combination of between one to five of the natural attributes whose values can uniquely describe any one instance of a particular entity.

Such keys normally have to have values though some systems can cope with null values or (in the case of Access) zero-length strings being allowed as part of the key where there is missing data providing that the combination of all the key fields is still unique.

A feature of a generic database is that for it to be truly generic and flexible in its application then it must be able to cope with a lot of missing data or empty fields where the data is irrelevant to a particular usage.

In order to meet the necessity of satisfying both of these last two points and to also maintain the keys from natural attributes then the keys have to be made very large and all of the attributes have to be grouped in a single large flat table. This is to maintain the requirement that any one record is uniquely identifiable based on the fields in its key even if a large number of them are empty.

This also has the advantage of reducing the complexity of the join clauses where tables or queries are separated and have to be linked up.

Problems arising with this solution are:

It causes redundancy and all of its associated problems, which is what we are trying to avoid in the first place! With Microsoft Access this also causes a problem because Access limits the length of its keys to 10 fields which is less that what is necessary for the kind of table we need.

‘Autonumbered Keys’

The use of unique autonumbered columns as keys would circumvent both the design problems of redundancy and the technical limit imposed by the MS 10 field limit in Access. They would reduce the length of key necessary and allow data to be stored in smaller separate tables that would remain correctly normalised even when in the worst case scenario all of their fields except the autonumbered key field had missing data. Joins based on short autonumbered keys instead of large natural keys are also greatly simplified.

We have also ascertained that no Microsoft products could support the number of fields required if the architecture was based around ‘natural’ keys. Jet4 (the underlying Access database 'engine') will be its final version and that does not go beyond 10 field compound keys. Future Access versions can also use the 'Microsoft Data Engine' which is basically the same as SQL Server7 without the database tools. This is also limited to 16 columns / 900 bytes for compound keys and again is not sufficient for the length of compound natural keys required.

The pay back for the ‘autonumbered’ solution is artificial as opposed to natural keys and the loss of automatic prevention of duplicate records. I.e. you could enter the same data twice but each record whether typed in or added en masse by a programmatic procedure would receive a unique autonumber value thus disguising its duplicity! Great care would have to be taken to avoid the accidental generation of such duplicate data-sets during ad-hock investigation by researchers.

Microsoft products are, for the present at least, the de-facto standard. But even their fundamental object model is proposed to change hence the stability / longevity of staying with such known products may be more apparent than real!

Large Natural Keys

Alternatively however other products such as ‘MySQL’ do allow sufficient numbers of fields to be included in the large compound keys required by the flatter design. Experience in this project has shown that joins based on large numbers of fields and many with empty strings, though complex, have functioned robustly. Such software is also provided from an ‘Open Source’ which is both technically and ‘philosophically’ allied to Linux an alternative operating system which is also Open Source. Such an approach may be pertinent to software work that is a part of projects with resource / environment implications for developing countries? It possible that there may well be a fundamental shift towards the ‘Open Source’ technologies for software development in any case. Such options may well ease licensing charges and allow for more collaborative software development.

Distinct advantages with this approach that uses only a few ‘flat’ tables that have large natural keys is that though join clauses become large only a few are required and they are usually of the same structure. In a the alternative richly layered table structure a whole series of linked complex joins would be required to bring the necessary data together from a large network of tables.

Furthermore, the simpler ‘flat’ data model imposes much less of a structuring concept on how various entities relate to one an other in a fishery. This makes it more robust for dealing with unanticipated attributes that have to be incorporated and easier to combine and compare data between fisheries where this is required.

Time limitations have prevented the wholesale practical comparison of the alternatives. This is recommended for future work. At present we are at a ‘half way house’ where large flat tables are used as the basis of the system but autonumber fields have had to be used to circumvent the 10 field limit imposed by Access on keys. Programmatic checks have had to be built in to guard against the potential problems arising out of redundancy because of the lack of large natural keys. These compromises have enabled the production of a practical and fully functioning system. This has allowed the clarification of such design and technical issues.

A further example of the 'flatter' design of the PISCES data model is that when a specific instance of a thing is recorded in the three central tables then so also is the 'type' of this thing, right along side it. Normally the type information would be expressed in the separate tables of the thing being instantiated.As an example in the case of FEUs (or boats) we have in the PISCES system this arrangement:

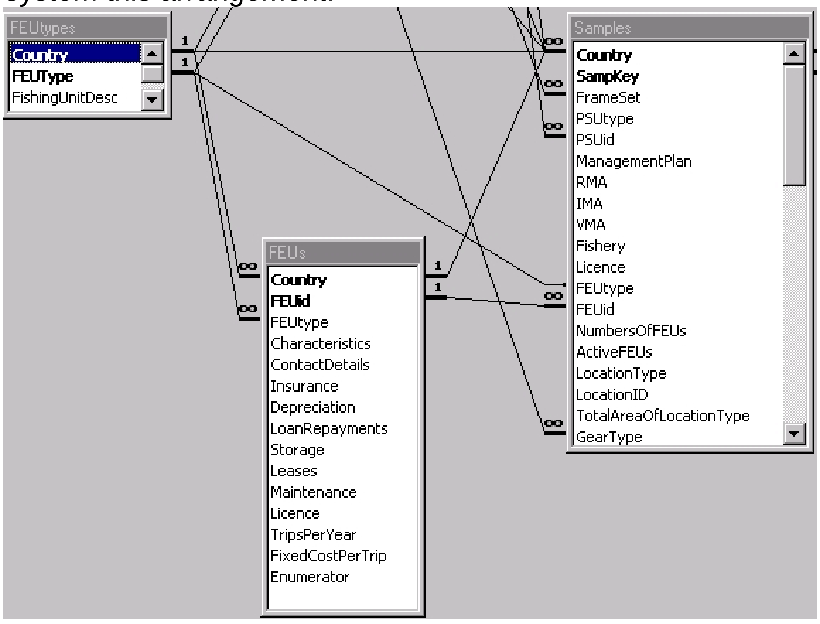


Figure 20 Flat arrangement of relationships between type, entity and instance.

Instead of the usual hierarchy of the classic Entity Relationship Attribute arrangement

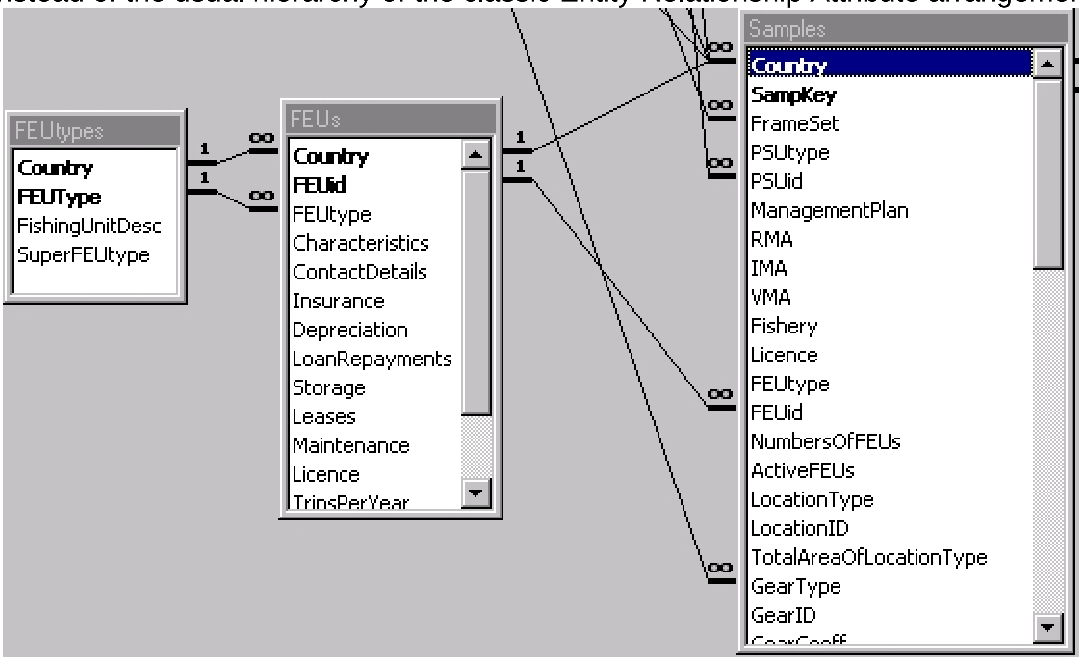


Figure 21FEUs, hierarchy of relations from type, entity and instance

Such flattening of the classic relationship has achieved the simplification required in the joining clauses between tables and the dynamic generation of queries predicated by user choices.

Were a more normalised design used then it would have the following form. Autonumbered keys would also have to be used to allow unique record identification (primary keys) and the links between tables (foreign keys) to function when there were not unique combinations of field values, due to missing data, to form short natural keys.

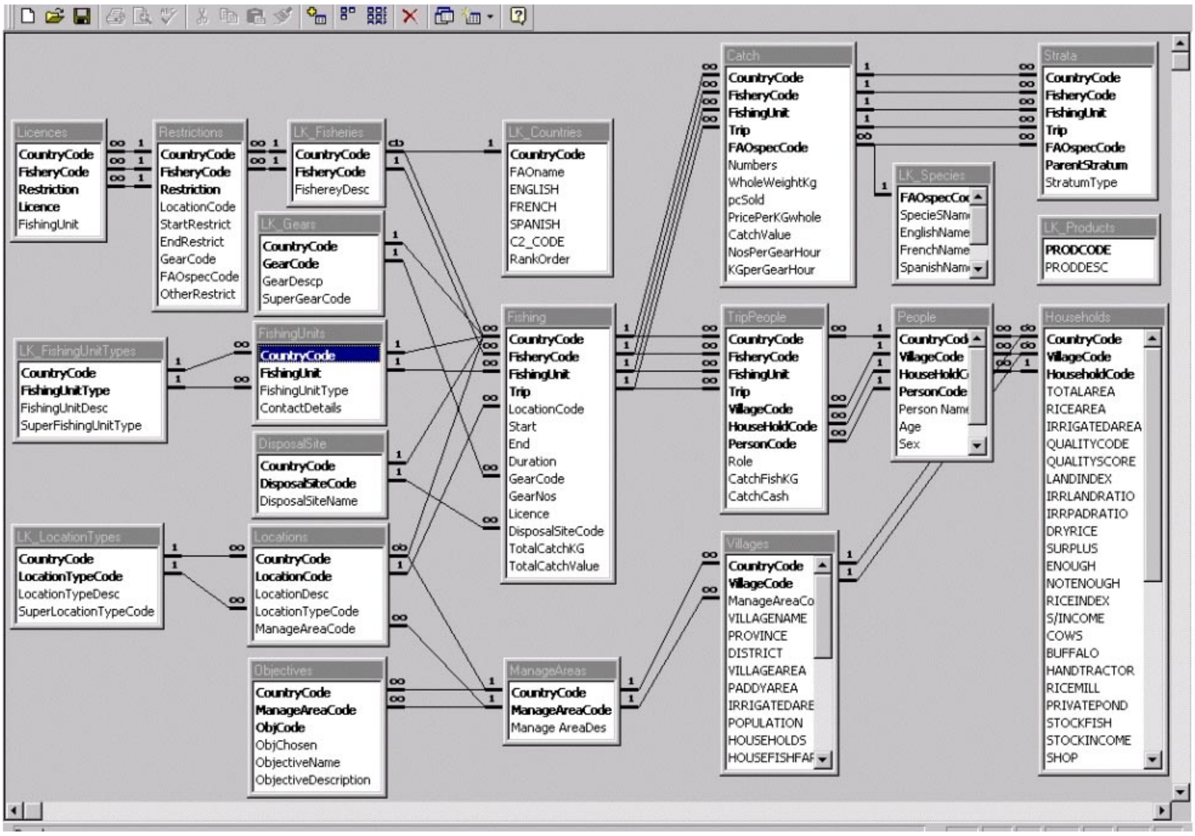
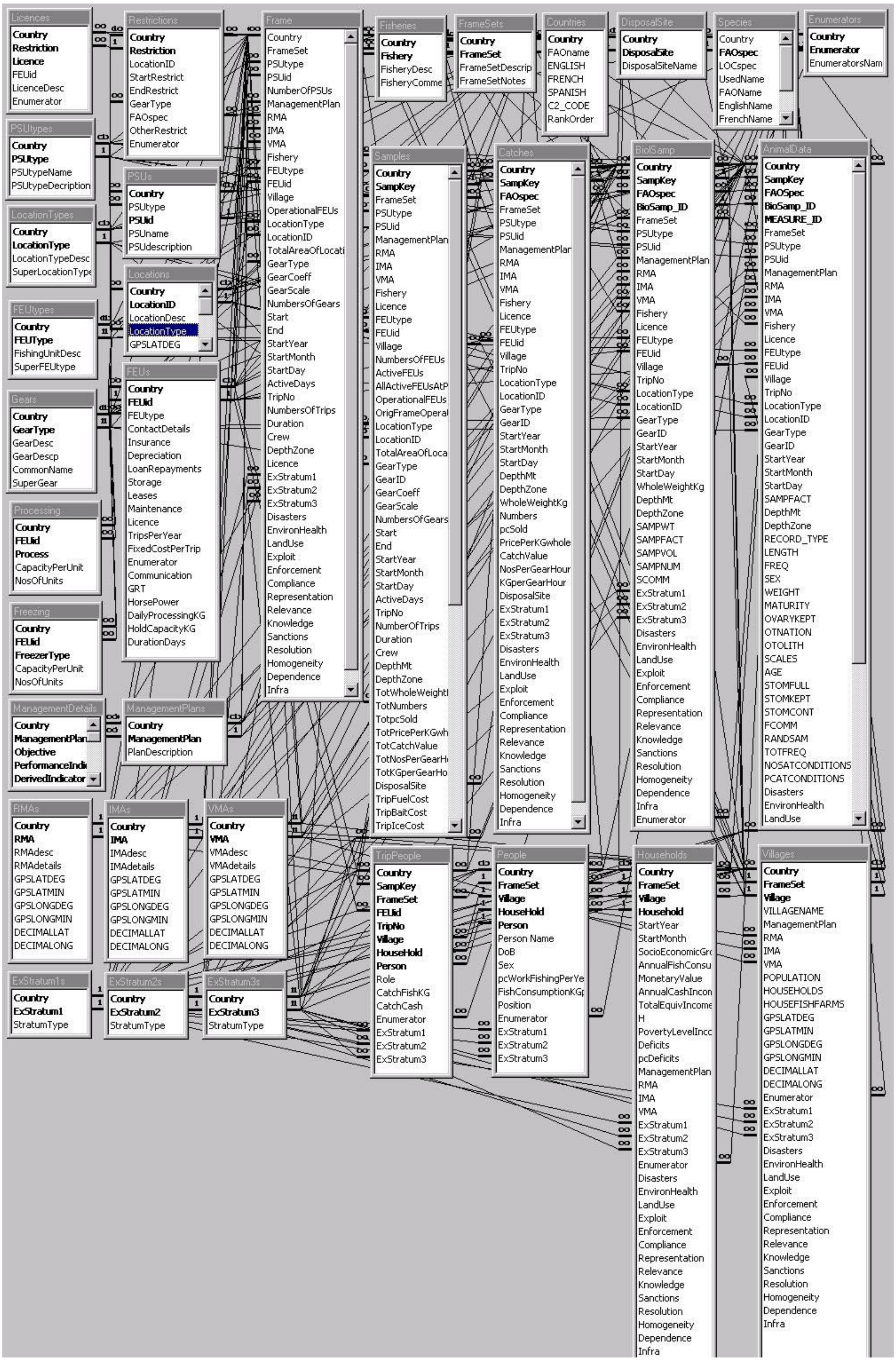


Figure 22 Example of a well-normalised design using natural keys.

In order to satisfy the generic requirements that can allow a natural key to be formed from almost any unanticipated choice of attributes then the design has to be modified as illustrated in fig 22b on the following page for the Pisces system.

Note that because of the 10 field limit Access imposes on keys that an autonumbered field 'SampKey' still has to also be employed, even in this large natural key design.

Fig 22b: The Pisces generic design (following page) allowing natural keys from any choice of attributes.


Licences Country Restriction Licence FEUid LicenceDesc Enumerator
Restrictions Country Restriction LocationID StartRestrict EndRestrict GearType FAOspec OtherRestrict Enumerator
Frame Country FrameSet PSUtype PSUid NumberOfPSUs ManagementPlan RMA IMA VMA Fishery FEUtype FEUid Village OperationalFEUs LocationType LocationID TotalAreaOfLocati GearType GearCoeff GearScale NumbersOfGears Start End StartYear StartMonth StartDay ActiveDays TripNo NumbersOfTrips Duration Crew DepthZone Licence ExStratum1 ExStratum2 ExStratum3 Disasters EnvironHealth LandUse Exploit Enforcement Compliance Representation Relevance Knowledge Sanctions Resolution Homogeneity Dependence Infra
Fisheries Country Fishery FisheryDesc FisheryComme
FrameSets Country FrameSet FrameSetDescrip FrameSetNotes
Countries Country FAOname ENGLISH FRENCH SPANISH C2_CODE RankOrder
DisposalSite Country DisposalSite DisposalSiteName
Species Country FAOspec LOCspec UsedName FAOName EnglishName FrenchName
Enumerators Country Enumerator EnumeratorsNam
PSUtypes Country PSUtype PSUtypeName PSUtypeDecription
PSUs Country PSUtype PSUid PSUname PSUdescription
LocationTypes Country LocationType LocationTypeDesc SuperLocationType
Locations Country LocationID LocationDesc LocationType GPSLATDEG
FEUtypes Country FEUType FishingUnitDesc SuperFEUtype
FEUs Country FEUid FEUtype ContactDetails Insurance Depreciation LoanRepayments Storage Leases Maintenance Licence TripsPerYear FixedCostPerTrip Enumerator Communication GRT HorsePower DailyProcessingKG HoldCapacityKG DurationDays
Gears Country GearType GearDesc GearDescp CommonName SuperGear
Processing Country FEUid Process CapacityPerUnit NosOfUnits
Freezing Country FEUid FreezerType CapacityPerUnit NosOfUnits
ManagementDetails Country ManagementPlan Objective PerformanceIndi DerivedIndicator
ManagementPlans Country ManagementPlan PlanDescription
RMAs Country RMA RMAdesc RMAdetails GPSLATDEG GPSLATMIN GPSLONGDEG GPSLONGMIN DECIMALLAT DECIMALONG
IMAs Country IMA IMAdesc IMAdetails GPSLATDEG GPSLATMIN GPSLONGDEG GPSLONGMIN DECIMALLAT DECIMALONG
VMAs Country VMA VMAdesc VMAdetails GPSLATDEG GPSLATMIN GPSLONGDEG GPSLONGMIN DECIMALLAT DECIMALONG
ExStratum1s Country ExStratum1 StratumType
ExStratum2s Country ExStratum2 StratumType
ExStratum3s Country ExStratum3 StratumType
Samples Country SampKey FrameSet PSUtype PSUid ManagementPlan RMA IMA VMA Fishery Licence FEUtype FEUid Village NumbersOfFEUs ActiveFEUs AllActiveFEUsAtP OperationalFEUs OrigFrameOpera LocationType LocationID TotalAreaOfLoca GearType GearID GearCoeff GearScale NumbersOfGears Start End StartYear StartMonth StartDay ActiveDays TripNo NumberOfTrips Duration Crew DepthMt DepthZone TotWholeWeightI TotNumbers TotpcSold TotPricePerKGwh TotCatchValue TotNosPerGearH TotKGperGearHo DisposalSite TripFuelCost TripBaitCost TripIceCost
Catches Country SampKey FAOspec FrameSet PSUtype PSUid ManagementPlan RMA IMA VMA Fishery Licence FEUtype FEUid Village TripNo LocationType LocationID GearType GearID StartYear StartMonth StartDay DepthMt DepthZone WholeWeightKg Numbers pcSold PricePerKGwhole CatchValue NosPerGearHour KGperGearHour DisposalSite ExStratum1 ExStratum2 ExStratum3 Disasters EnvironHealth LandUse Exploit Enforcement Compliance Representation Relevance Knowledge Sanctions Resolution Homogeneity Dependence Infra
BiolSamp Country SampKey FAOspec BioSamp_ID FrameSet PSUtype PSUid ManagementPlan RMA IMA VMA Fishery Licence FEUtype FEUid Village TripNo LocationType LocationID GearType GearID StartYear StartMonth StartDay WholeWeightKg DepthMt DepthZone SAMPWT SAMPFACT SAMPVOL SAMPNUM SCOMM ExStratum1 ExStratum2 ExStratum3 Disasters EnvironHealth LandUse Exploit Enforcement Compliance Representation Relevance Knowledge Sanctions Resolution Homogeneity Dependence Infra Enumerator
AnimalData Country SampKey FAOSpec BioSamp_ID MEASURE_ID FrameSet PSUtype PSUid ManagementPlan RMA IMA VMA Fishery Licence FEUtype FEUid Village TripNo LocationType LocationID GearType GearID StartYear StartMonth StartDay SAMPFACT DepthMt DepthZone RECORD_TYPE LENGTH FREQ SEX WEIGHT MATURITY OVARYKEPT OTNATION OTOLITH SCALES AGE STOMFULL STOMKEPT STOMCONT FCOMM RANDSAM TOTFREQ NOSATCONDITIONS PCATCONDITIONS Disasters EnvironHealth LandUse
TripPeople Country SampKey FrameSet FEUid TripNo Village HouseHold Person Role CatchFishKG CatchCash Enumerator ExStratum1 ExStratum2 ExStratum3
People Country FrameSet Village HouseHold Person Person Name DoB Sex pcWorkFishingPerYe FishConsumptionKGp Position Enumerator ExStratum1 ExStratum2 ExStratum3
Households Country FrameSet Village Household StartYear StartMonth SocioEconomicGr AnnualFishConsu MonetaryValue AnnualCashIncon TotalEquivIncome H PovertyLevelIncc Deficits pcDeficits ManagementPlan RMA IMA VMA ExStratum1 ExStratum2 ExStratum3 Enumerator Disasters EnvironHealth LandUse Exploit Enforcement Compliance Representation Relevance Knowledge Sanctions Resolution Homogeneity Dependence Infra
Villages Country FrameSet Village VILLAGENAME ManagementPlan RMA IMA VMA POPULATION HOUSEHOLDS HOUSEFISHFARMS GPSLATDEG GPSLATMIN GPSLONGDEG GPSLONGMIN DECIMALLAT DECIMALONG Enumerator ExStratum1 ExStratum2 ExStratum3 Disasters EnvironHealth LandUse Exploit Enforcement Compliance Representation Relevance Knowledge Sanctions Resolution Homogeneity Dependence Infra

7.2.9 Survey design options and the database structure

The critical factor here is how in the structure of the database to enable where required the frame – sampling – raising approach to surveys. The following discussion focuses on how analytical requirements, sampling design and resource limitations dictate the structure of the database.

We first need to explain how the system is deployed to satisfy the various scenarios identified in the previous chapter (Section 6.2.3).

Table 18: Guidelines for using PISCES to support the main scenarios for the collection of catch and effort data described in Section 6.2.3.

Type	Census in Space	Census in Time	Sampling in Space	Sampling in Time	Frame Survey Required	Method of using the PISCES FIMS
1. Census On Catch And effort	YES	YES	NO	NO	NO	All data entered and analysed via only the Samples and Catches tables. Ignore Frame table.
2. Scenario A						
Catch	NO	NO	YES	YES	NO	Sample effort and catch data into Samples and Catches tables.
Effort	YES	YES	NO	NO	NO	All effort data into Frame table with values for time and location attributes filled to level of detail collected.
3. Scenario B						
Catch	NO	NO	YES	YES	NO	Sample effort and catch data into Samples and Catches tables.
Effort	YES	NO	NO	YES	NO	Location values into Frame.Location attribute Any missing "Time" attributes left empty and appropriate scaling vales inserted into Frame.ActiveDays
4. Scenario C						
Catch	NO	NO	YES	YES	YES	Sample effort and catch data into Samples and Catches tables.
Effort	NO	NO	YES	YES	YES	All frame effort data into Frame table with all location and time attributes filled to level of detail collected. Any missing "Time" attributes left empty and appropriate scaling vales entered into Frame.ActiveDays. Any missing "Location" attributes left empty and appropriate scaling values entered under Frame.TotalAreaOfLocationType* and NumbersOfPSUs.

* Frame.TotalAreaOfLocationType could be replaced by NumbersOfLocations of this type where more appropriate.

The reason for frame /sampling being to reduce the unrealistic effort and resources that would be required with using alternative total enumeration approach and yet to obtain results which are still statistically valid.

The assumptions are that the things in the frame survey (effort measure) change little whereas things in the sampling survey (CPUE) changes constantly. Thus we can measure the CPUE at any time (from a sample) multiply it up by the effort (from the frame) to get an accurate estimate of total catch.

The PISCES system does allow for an updating of the frame at sampling time for the number of operational FEUs. The duration of their operation will most likely vary considerably throughout the year, particularly where there are seasonal effects. Again the system allows for duration figures to also be represented in the 'frame' and for these to be used as the basis of calculation. Indeed for the scenario where the frame table is being used as the storage for a census of effort then you have to use the duration figures stored here in the frame.

We also assume for a generic system of this kind that any one fishing act recorded for a Fishing Unit is only based on one type of gear but perhaps a number of them deployed simultaneously and for the same time. A different type of gear of the same unit could be represented as a separate act. Also if different gears of the same type were being deployed for different times from the same fishing unit then these could accurately be represented as separate acts and hence records in the database system.

Because the PISCES system allows very flexible representation of effort e.g. for summary or detailed data, then care has to be taken that you enter the correct number of active days relevant to any time period you are summarising across.

Where the types and numbers of fishing units was also in a state of flux then the use of the 'FrameSet' field enables two things:

1) to allow the frame survey to be repeated as often as necessary
2) to correctly raise all past, present and future cpue figures against the correctly matching version of the frame survey by comparing dates in their respective primary keys.

The sampling frequency required according to type of data will only be revealed once existing data has been tested for variability. In database design terms the best place for the results to be stored is in the FEUtype table along with the absolute numbers of that type revealed from the frame survey.

This will greatly simplify the sampling design process allowing the rapid allocation of sampling effort according to:

- number of observer days available
- proportions of FishingUnit type
- the absolute numbers of each type
- the inherent variability in the data for each type

Pisces does also allow for the alternative use of water body area as an indication of effort. This can be a requirement in flood plain fisheries for example where catch per unit area is scaled up by water body area as opposed to FEUs .

Degree of Detail

In designing such a database it has to be decided where it is necessary to include detailed breakdown of some factors or to use a more general representation. A few examples will illustrate this.

How to represent the people involved in the fishing activity. The simplest way would be to have an attribute (field) of the fishing table called NosOfPeople to represent the numbers of people involved in the each fishing activity. Coupled to the price field we could thus calculate average income per person. However such a generalisation does not allow us to capture and represent the pattern of income generation among the people involved. Neither does it allow us to follow through individual people to their households and hence villages and calculate how the income distribution accrues to these. Thus in a system such as this where the socio-economic aspects are important a more detailed representation of people is necessary in the form of a people table that can be linked to the fishing table via a participants table. The people table of individuals can then be linked on to the households and villages/settlements tables. It assumes that survey resources for the socio-economic aspects are sufficient to map individual persons and their presence as part of a fishing team and existence in a particular household. See later for a further discussion of this in the context of Socio-economic data per-se as opposed to the example of detail being used here.

Each fishing event is given one corresponding LandingSite field. This may generally be the case and so has been adopted here because it is unlikely that there are the survey resources to define the more detailed distribution of catch information. Thus for a trip catch that may even sell the same species from that trip to a variety of landing sites there is no way of representing that information. It is lost or inaccurately represented as having been landed at the one and only site because the database structure imposes that assumption.

Should it be desired to have the potential to express a more complex sales pattern and there are the resources available to accurately capture that information; then the simple representation could be replaced by the more complex structure.

In most cases, the design and implementation overhead to handle the more complex situations and the representation of them is no greater than to handle the 'simpler' representation. Generally more sophisticated design would be able to handle both the simple and complex representations of what's going on whereas the simpler design can only capture the simpler representation. PISCES has been designed in this way, allowing it a great flexibility of usage which will help reduce the maintenance overheads that would arise with the more constrained design of data model each time they have to be altered to cope with a more complex situation.

Sometimes you would have to have separate approaches to handling the data if survey resources were limited. E.g. if TripPeople could not be traced on fishing trips and back to households then you have to have a FEUincome to village link instead and have to then put up with the assumption that the entire earnings from a particular FEU all go to a particular settlement. There is then no simple way of representing any wider dispersal of the income and wages.

The Frame Survey

The frame survey table will contain data on the numbers of FEUs at each PSU. However, for census approaches to collecting fishing effort (including Scenario A) the frame table would instead contain the actual daily fishing effort (gear hours) recorded.

A major strength of the PISCES system is the flexible way it allows the original effort data to be re-grouped, as the user chooses, to whatever level of detail, whilst simultaneously applying the same grouping criteria to the calculation of CPUE from the sampling data and thus allowing the correct matching of effort and CPUE for the catch estimation.

See the earlier sections on analysis for a description of how this matching and subsequent calculation is carried out.

Choice of Data Recorded Relevant to Type of Analysis

In terms of data entry, it must be remembered that that if the frame data is to be used for the raising of CPUE data then the responsibility is on the user to ensure that the correct representative data from both frame and sampling surveys has been entered. Providing the user has done this then the system itself will take care of the groupings that you select and the subsequent matching between frame and sample data for the raising operation.

Here is a simple example to illustrate the principle of which is applicable to any data sets. If you wish to estimate a raised catch figure by 'village', shall we say, for your fishery, you must ensure that you have the necessary representative data for both frame and sampling surveys for each village. When the data is entered it must always have the relevant village code. Prior to that all the relevant villages must be entered in the Villages reference table.

Analogous requirements must be met if you were intent on analysing by say FEU (boat) type or LocationType (habitat). Of course if you collect and enter a comprehensive range of attributes covering all or many fields then you can then later on analyse according to any one of these or even a combination (2 or more) of attributes according to your choice. For example by boat type by village, or by habitat type by village or by degrees of compliance by IMA. The latter example would result in say a range of catch estimates for each IMA broken down by the three degrees of Compliance (to regulations).

When you later reach the analysis stage, the user can choose whether to also break such results down by time series or not . The time series can be by years, month and year, or even month alone (across years). You can by use of the Extra Stratum fields also analyse by seasons that run across calendar years. The handling of months within such seasons has to improved so that their calendar sequence is preserved across years.

Later during the choice of analysis the user is given the choice as to whether the time series is based on the sampling data or on the frame data (this must be selected for Scenario A types catch and effort strategies.

The reason that the preview of these analytical options are repeated several times at this data entry stage is to highlight to the user that because of the wide range of formats that data can be entered and the flexibility offered during analysis, the user is in return expected to bear responsibility to enter data that are appropriate to the kind of analysis they wish to carry out or only carry out the kind of analysis that is appropriate to the detail they have in their data.

This may seem like stating the obvious but as is often the case with flexible automated systems the responsibility can be overlooked. In future, it is also hoped to include automated traps to warn of attempted inappropriate usage. For the time being, the onus is on the user to have a clear understanding of how the data and its analysis logically relate to one another.

The following lists the frame data and its description. Note that though much of the frame data fields naturally mirror those of the sample table since both are measuring effort, there are however some subtle distinctions for the data that goes into the fields and in how it is used. The user manual draws attention to these distinctions and gives guidance on the correct usage of the relevant fields.

Field Name	Data Type	Description
Country	Text	FAO 3 letter country code
FrameSet	Text	ID Number to indicate which frame survey these sample records should be matched to
PSUtype	Text	Code for type of type of primary sampling unit
PSUid	Text	Identifier of a particular individual Primary Sampling Unit if used
NumberOfPSUs	Text	Numbers of PSUs when they are only identified by type and not by individual IDs
ManagementPlan	Text	Management plan ID
RMA	Text	Regional management area
IMA	Text	Intermediate management area
VMA	Text	Village management area
Fishery	Text	Code for a particular 'fishery'
FEUtype	Text	Code for type of fishing unit. (Person, Vessel, Trap etc)
FEUid	Text	Identifier of the fishing unit (name of person, trap series, vessel etc)
Village	Text	Unique code for village in that country WHERE FEU IS FROM
OperationalFEUs	Number	Total numbers of fishing units capable of fishing
LocationType	Text	Code for the waterbody or ground 'type'
LocationID	Text	Code for the fishing location
TotalAreaOfLocationType	Text	Numbers of locations
GearType	Text	Code for type of gear
GearCoeff	Text	Conversionfactor for any comparative gear efficencies
GearScale	Text	Scaling factor (net area [square meteres], numbers of pots, number of hooks etc)
NumbersOfGears	Text	Numbers of gears
Start	Date/Time	Start date/ time of fishing operation
End	Date/Time	End date/ time of fishing operation
StartYear	Text	Year in four figures (yyyy) when trip started
StartMonth	Text	Month one of {1|..12 +} when trip started
StartDay	Text	Day usualy one of {1|..28|29|30|31} when trip started
ActiveDays	Text	No of active days in the period
TripNo	Text	Identifier for that particular fishing event
NumbersOfTrips	Text	Numbers of fishing trips
Duration	Number	Duration in decimal hours of fishing effort
Crew	Text	Number of crew in the fishing team
DepthZone	Text	Depth zone in 10s of meteres of this fishing event e.g. 1->10 = 10; 11->20 = 20; 21->30 = 30 etc etc
Licence	Text	LicenceID
ExStratum1	Text	First additional stratum if required
ExStratum2	Text	Second additional stratum if required
ExStratum3	Text	Third additional stratum if required
Disasters	Text	Natural Disasters (eg cyclones, extreme floods? Low, Med, High.
EnvironHealth	Text	EnvironmentalHealth of location (i.e. habitat)? Low, Med, High.
LandUse	Text	Adjacent land use? Agriculture, Forestry, Industry.
Exploit	Text	Exploitation intensity at that particular location? Low, Med, High.
Enforcement	Text	Degree of monitoring control and surveillance by the resource users? Low, Med, High
Compliance	Text	Degree of compliance? Low, Med, High.
Representation	Text	Representation of users in rule making? Low, Med, High.
Relevance	Text	Relevance of rules? Low, Med, High.
Knowledge	Text	Level of user information / knowledge? Low, Med or High.
Sanctions	Text	Sanctions for non compliance? Yes or No.
Resolution	Text	Effectiveness of conflict resolution stratergies? Low, Med, High
Homogeneity	Text	Degree of ethnicity amongst users? Single, Mixed
Dependence	Text	Overall dependence of the FEU members on the fishery for their livleyhood? Low, Med, High.
Infra	Text	Transport and Infrastructure (at landing site)? Low, Med, High.
Enumerator	Text	Code for enumerator in that country

Figure 23 Frame table attributes and their description.

7.3 Control and Surveillance - Restrictions and Licences

The structuring of the tables and their relations are based on the following concepts. A given restriction is applied to a particular fishery. This restriction will be composed of some combination of Location, Period, Gear, Species which can be expressed as a record in the restrictions table. Further restricting attributes could be added if required. If a relational 'join' of that restriction record with a fishing table record results in anything other than an empty set then those acts of fishing are in contravention of that restriction. However the concept of a licence is expressed as a permission for a particular FishingUnit to operate within that restriction as granted by its licence number. This licence number is included in all fishing records for that unit. Thus the resultant set from the earlier restrictions <-> fishing tables join can itself be now joined to the licences table in a 'theta' join using a condition of non equality. Any members of the resulting set are illegal fishing operations i.e. they are performing restricted operations without having been granted a licence.

This approach allows a very rational way of expressing restrictions and licensing and an extremely efficient way of monitoring compliance. This compliance is of course in terms of the entered data and not the actual activity on the ground. However it is regularly found that illegal fishing acts are carried out AND RECORDED in databases but such databases do not have the capacity to recognise the contravention in this fashion.

Note that there is a slight complication where the catch table is separate to the fishing table when monitoring species restrictions. In such a case a 'view' must first be constructed to combine the necessary attributes for comparison against the restrictions table.

This method of monitoring contraventions also allows the results to be grouped according to the same strata described for the catch effort data and analysis. Thus we can investigate the degree of conflict per management plan, management area, with time, by gear type, by degree of relevance of the regulations, by degree of involvement of the fishers, by habitat, ad-infinitum.

The present design of the restrictions and licensing does not include all of the additional administrative fields that are normally required with a licensing scheme. For the time being the tables only hold the basic fields needed to define restrictions and those licensed to operate within it in order to test that concept. This has worked very well in the prototype including answering some questions in TCIs on how to monitor a particular boat to see if it has previous contraventions. The administrative elements can be added during future work.

7.4 Management Plans and Areas

The ManagementPlan attribute forms the foreign key to the ManagementPlans table. This table has a plan identifier to label it within the system, a reference to any external documents residing elsewhere and a direct link from 'PlanDescription' to a 'ManagementPlan.doc' document which can describe the plan in free form. The link from the PlanDescription field can be pointed to any type of document residing anywhere on the system.

As a means for demonstrating the handling of management plans in a database there is also a sub table of 'ManagementDetails' which lists the objectives within that management plan. This is the point where in future the system could if desired then link on to the 'GenericFramework' series of tables that would map the Objectives -> Methods -> Models -> DataRequired -> Resources hierarchy that is discussed in detail in the 'Generic Framework' proposals in the 'Technical Reference' section of the user manual.

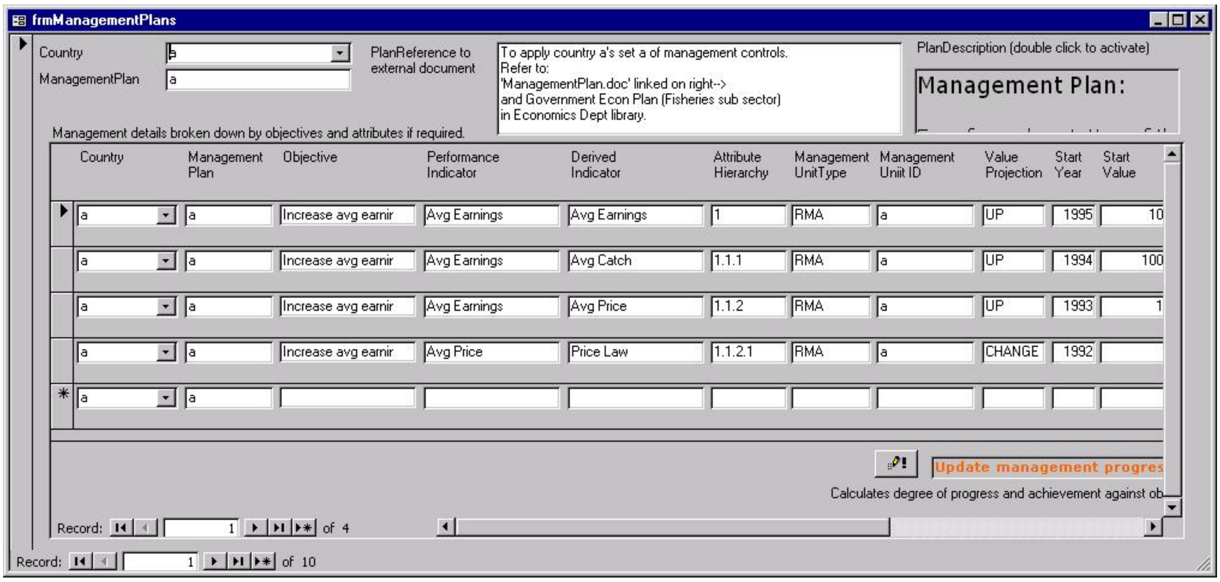


Figure 24 Management plans and details

For now it has been left simply as a table that lists the stated management objectives for that particular management plan and has a simple hierarchical breakdown of these into constituent attributes their start values, present values and target values. Each of these values has an associated date. There is then an associated analytical module to compare the rate of change in these values to calculate the percentage of achievement against the final goal and the rate of progress. Thus if your start value is 10 and your target value is 20 two years hence and your present value is 15 one year on this will calculate your achievement as 50% and progress as 100%. This of course is assuming linear progression.

This feature is for the time being only intended as a demonstration of the potential for explicit dissolution of objectives into verifiable indicators with a working system to monitor them.

Complex methods of evaluating management performance to meet management objectives could be conducted external to the PISCES system with the later serving as a means to store the results and monitor the progress of these with time.

An important design consideration in the positioning of the ManagementPlans and the four management areas (National Management Areas, Catchment or Regional Management Areas, and Intermediate and Village management Areas) was to have these in both the fishing tables and the village table as well. This allows the expression of effects of management to be expressed for a fishing location e.g. a fishing management measure, or for a village/settlement e.g. for a socio-economic measure. Neither do the two types of management measure have to be mutually exclusive with respect to the type of place they refer to i.e. fishing area / village

7.5 Biological Data

This forms a natural extension to the fishing data. For each species recorded in the catch any number of samples can be taken. The records of samples are stored in the ‘BiolSamp’ table which is not to be confused with the parent ‘Samples’ table which holds the information on fishing events as recorded from a sample or census survey. These BiolSamp records then have the additional fields of BioSamp_ID, SampleWeightKG, SampleNumbers and SampleFactor. The sampling factor is used for weighting length-frequency analyses when these are being combined across samples from a series of catches. A separate AnimalData table then holds all the detailed attributes for measurements on a particular animal, be it a fish, cephalopod, or crustacean.

Field Name	Data Type	Description
Country	Text	SURVEY CODE
SampKey	Number	UNIQUE EVENT NUMBER WITHIN SURVEY
FAOSpec	Text	CCAMLR Species Code
BioSamp_ID	Text	UNIQUE SAMPLE ID WITHIN SURVEY,EVENT,CATCHREC
MEASURE_ID	Number	UNIQUE Measurement ID WITHIN SURVEY,EVENT,CATCHREC,SAMPLE_ID for individ fish or aggregated LF record
SAMPFACT	Number	SAMPWT/CATCHWT FOR THAT SAMPLE_ID
DepthMt	Number	Depth in meteres
DepthZone	Text	Depth zones 1 ->10 =10, etc, 20,40,60,80,100,120.160,200,300,400,600,800,1000,1500,2000
RECORD_TYPE	Text	LFREQ or FISHREC type record
LENGTH	Number	TOTAL LENGTH in cm
FREQ	Number	FREQUENCY (1 for indiviual fish)
SEX	Text	SEX CODE (M - Male,F - Female,U - 3 Unknown)
WEIGHT	Number	TOTAL WET WEIGHT in kg of individual fish only
MATURITY	Number	5 POINT MATURITY INDEX 1-5 of individual fish or group of fish
OVARYKEPT	Text	WAS AN OVARY SAMPLE TAKEN? Y OR N
OTNATION	Text	LOCATION OF THE OTOLITH/SCALE SAMPLE
OTOLITH	Text	WAS AN OTOLITH SAMPLE TAKEN? Y OR N
SCALES	Text	WAS A SCALE SAMPLE TAKEN? Y OR N
AGE	Number	AGE TO NEAREST YEAR BELOW
STOMFULL	Number	5 POINT STOMACH FULLNESS INDEX 0-4
STOMKEPT	Text	WAS A COMPLETE STOMACH KEPT? Y / N
STOMCONT	Text	STOMACH CONTENTS
FCOMM	Memo	FISH RECORD COMMENTS
RANDSAM	Text	IS THIS PART OF A RANDOM SUBSAMPLEAND TO BE INCLUDEDIN LFREC ANALYSIS? Y OR N
TOTFREQ	Number	FREQ * SAMPLING FACTOR * (SEABED AREA FOR THAT DEPTH ZONE / AREA SWEPT BY THIS TRAWL)
NOSATCONDITIONS	Number	The sum of TOTFREQ for a set of specified conditions.
PCATCONDITIONS	Number	The percentage TOTFREQ forms of NOSATCONDITIONS

Figure 25 The AnimalData table

This table also has ‘redundant’ copies of the fields from the samples, catches and BiolSamp tables in order to reduce the need for complex join operations to otherwise access this data. See earlier discussions. Because all attributes relating to the circumstances of the captured animal are available then the length frequency analysis can also be broken down by the values for any one or combination of these. Thus, you can compare length frequency distributions for different co-management arrangements, location types, gears, years, months and all of the other fields that are available for grouping.

The other analysis currently available is for Species Diversity. This again can be grouped by whatever fields. It counts the number of species in the catch records under each grouping

Both the length frequencyand diversity data can beplotted. Length frequency results are only plotted for one grouping at a time though this could be extended into a third dimension as well to allow comparisons between groupings which could or could not include a time series component.

7.6 Socio-Economic Data

The link between fishing activity and the socio-economic effects that has is best represented by the people involved in the activity and recording in which villages and households they live. Hence the:

Fishing -< TripPeople >- People -< Households >- Villages

series of tables and relations.

One critical issue is that for this representation to work we must be able to identify individual people. If instead we simply list the number of people on the trip we have no way of relating the commercial information to the communities they are from. It could be validly argued that an artisanal team would normally come from the same settlement and that a village code in the Fishing record would form a suitable foreign key to a villages table. But this would only allow us to analyse at the village level. It would not allow any analysis at the household or individual person level.

It is unreasonable to usually assume the co-ordination required to assign and maintain individual identifiers for a people across a country. However where such a scheme exists in a country already it could be put to good use. However the worry about tax implications might engender underreporting etc.

However a nation, village, household, individual member series of codes is not unreasonable to assume from a socio-economic survey. I.e. the combination of the 4 codes would uniquely identify an individual.

The critical point is to use the SAME combination of codes to identify members of a fishing team so any given person can be mapped linked between a fishing and a household survey.

It does have organisational / resource implications but its difficult / impossible to avoid this requirement.

For the detailed Household Survey data the Gini Co-efficient and Sen Index are calculated according to a sub-set of the usual choice of groupings that are applicable to the household data.

Field Name	Data Type	Description
Country	Text	FAO 3 letter country code
FrameSet	Text	ID Number to indicate which frame survey these sample records should be matched to
Village	Text	Unique code for village in entire study
Household	Text	Unique code for that house in that village
StartYear	Text	Year in four figures (yyyy) of this household survey
StartMonth	Text	Month one of {1|..12 +} of this household survey
SocioEconomicGroup	Number	Socio-economic group to which the household belongs
AnnualFishConsumptionKG	Number	Annual household fish consumtion in kilograms.
MonetaryValue	Currency	The monetary market equivalent of the fish consumed
AnnualCashIncome	Currency	Annual income of cash only
TotalEquivIncome	Currency	Total annual income of combined cash and equivalent fish value
H	Number	Numbers in household below poverty line (for the Sen Index calculation)
PovertyLevelIncome	Currency	The income at the povrty level.
Deficits	Currency	Value of deficit WHEN TotalEquivalentIncome is below PovertyLevelIncome.
pcDeficits	Number	Percentage of the deficit WHEN TotalEquivalentIncome is below PovertyLevelIncome.
ManagementPlan	Text	Management plan ID in force at that location at that time
RMA	Text	Regional management area
IMA	Text	Intermediate management area
VMA	Text	Village management area
ExStratum1	Text	First additional stratum if required
ExStratum2	Text	Second additional stratum if required
ExStratum3	Text	Third additional stratum if required
Enumerator	Text	Code for enumerator in that country

Figure 26 The Household table.

Such fields would be Country, FrameSet,Village,StartYear, ManagementPlan, National, CMA/RMA, IMA,VMA, and any of the ExStratumFields that were appropriate. Obviously many of the groupings applicable to the fishing tables are not so here. Many of the additional co-management attributes could though also be added to the household table in order to allow appropriate comparisons.

7.7 Coordination and Evaluation of Co-Managed Resources

The principles applied, particularly those concerning the generic nature of the system, are applicable to most kinds of management. Co-management issues are dealt with by providing the means to record the factors identified as being relevant to co-management with every entity and process in the database. Thus any analysis can explicitly take these factors into account as defined by the user. The attributes concerning co-management are part and parcel of the core of the data-model, an inherent part of the system design. For this reason there is no separate co-management ‘module’. All of the analyses provided can be conducted under co-managed terms. For example we could look differences effort, catch, costs, earnings, income, species diversity or length frequency data in relation to any of the following selected example attributes drawn from Table 16 (Section 6.6):

Attribute	Description
Disasters	Natural disasters (eg extreme cyclones, floods)
EnvironHealth	Environmental health of fishery habitat
LandUse	Adjacent land use (Anthropogenic effects)
Exploit	Level of exploitation
Enforcement	Mechanism for enforcement
Compliance	Degree of compliance with regulations
Representation	Representation of users in rule making
Relevance	Relevance of rules
Knowledge	Level of user Information / Knowledge
Sanctions	Sanctions for non compliance
Resolution	Effective conflict resolution mechanisms
Homogeneity	Homogeneity of users
Dependence	Dependence on fishery for livelihood
Infra	Transport and Infrastructure

The reader is also directed to the user manual for example analyses based on co-management attributes.

7.8 Specific attributes and their implications

This section illustrates the significance of overall design issues for the non-IT specialist by referring to examples. Please refer to the user manual for specific field by field guidance for data entry.

Country Codes

For the purposes of any one individual country it would not normally be necessary to have a country code included as one of the key fields. It might be assumed that for the case of artisanal fisheries management that all FEUs operate within that one country.

However for the cases where we want to compare across countries it is vital to also have the country code for the fishing units as well in order to anticipate the use of the same fishing unit identifier in different countries. Such a scenario might arise when the effect of co-management plans are being compared between countries. I.e. the largest management area being based on the country. It is still possible though to represent the situation where an RMA (Regional Management Area) actually extended across country borders in the case of international management co-operation.

Providing that the CountryCode is always the country of origin of the fishing unit then this system also has the added benefit of being able to cope with analyses where fishing units from different countries are operating in foreign waters. This is not an impossible scenario to envisage where the fishing units are small vessels from neighbouring small island states.

This logic could be taken to the extreme with the application of a CountryCode field to nearly all tables e.g. FishingUnitTypes, GearTypes etc because a particular gear type could be subtly different in its efficiency due to differences in its design / operation from one country to another.

This is important when considering the processing during analysis. If the analysis is within country then the country code is irrelevant. However if the analysis is across countries then having the addition of the country code allows us a choice as to whether to group results according to country. We can still ignore it if we wish where it is desired to analyse purely on gear type, for example, where we are confident there are no between country differences in a particular gear. NB this assumes that a particular type code i.e. for gears or fishing unit types or whatever, does represent the same type of thing between countries. This more straight forward approach has been taken for the purposes of this trial system. It assumes the use of comparable codes for particular things, whatever the country.

In order to anticipate where we can not be confident in this then a third field has been added to the suspect tables to group types that are truly compatible (even if they have different type codes) in the particular countries. Such an approach has the added advantage of not having to dictate to countries what their particular codes for types of things. They can use any code they wish. It falls to those doing analyses between countries to assign the matching 'top' level codes for things that are comparable between countries. Analyses can then be framed using these 'top' level codes as opposed to the national codes used at the next level down.

With this combination of approaches data from different countries can be confidently stored and manipulated in the same database safe in the knowledge that the national data sets can be aggregated and dissaggregated as required without fear of confusion or error.

This confers genuine generic capabilities both in storage and analysis that are lacking in comparable systems.

Finally there is another very practical use for country codes where you have data from several different countries resident in one system. In such cases the country code can be used as a filter in all look up tables. Thus once you have stated the country any lookup table that accesses codes will only bring up codes relevant to that country. This is important in terms of the user interface otherwise someone entering the data may have to wade through a great many irrelevant codes before they find the one they need.

LocationCode

Having the LocationCode as part of the primary key of the table allows us to represent a fishing trip that visited several different locations during its course. This may be particularly applicable to a vessel type fishing unit which may move from ground to ground. If it is wished to record multiple locations visited within one trip then it is essential that only the Start and End times of the fishing effort relevant to that location are recorded for each record and NOT the start and end times of the trip. Otherwise there would be an inflated estimation of effort during any analysis.

Analyses can be broken down by trip or trip/location as desired. Where no location data is available for a trip then all values can be simply left as the default value (a 'zero-length string').

It was decided not to use the within country FisheryCode as part of the key for locations because this would allow the use of the same location codes for different fisheries. The convenience of this would be outweighed by the added complication and potential confusion. Thus different location codes must be used throughout a country. This could be altered to the other method of representation if required.

On first appearances the design is simplified by having a LocationCode and LocationType field within the Fishing table. This increases the data redundancy but reduces the need for two additional tables and the increased complexity of analysis queries. It also increases the chance of mistakenly allocating the wrong location type code for a given place and to mistakenly assigning different LocationTypes to the same Location. The later are classic examples of an 'edit anomaly' arising from not having fully normalised tables. Please see the earlier extensive discussion on these issues.

The same argument can be applied to the representation of FishingUnits and FishingUnitTypes. Representing them all simply within the Fishing table or have the more complex addition of two extra tables. The case for extra tables is probably more compelling here rather than with locations.

Gear representation

The comprehensive way to represent the catch pattern is that for each location one or more gears will have been deployed. Each of these individual gears may have fished for a variable time and each will have a catch potentially composed of a variety of species. The FIMS captures this complexity with a hierarchy of tables with one-to-many relationships.

Trip -< Location -< IndividualGearDeployed -< CatchOfThatIndividualGearBySpecies

When sampling resources are scarce, such complexity is sometimes generalised by making the following assumptions:

- at any one location only one type of gear is being deployed
- a number of these gears could be used at that location
- they are all used at the same time and for the same time

Effort calculations will entail multiplying the duration by the number of gears used.

PISCES can cope with either the detailed or the more general representation. Records can be entered in the sample table per gear or for all gears at that location. In the later case the individual 'GearID' column would simply be left once more with the default value of a zero-length string.

Fishing Trip and Crew

This could be a vessels voyage or a walk up the road to set a number of gears at a water body. The 'Crew' refers to the number of people involved in the fishing operation. E.g. a vessels complement or the numbers in a team operating a river trap. At present the number of Crew is not factored into the effort calculation.

As discussed elsewhere the 'TripPeople' table allows the representation of the individual make up of a crew involved on a fishing 'trip' where this is required and survey resources give the capacity to monitor this in the field. This table also contains fields for the weight of fish retained by a crew member and the cash paid in wages. This table is then linked through to the people, households and villages tables to allow an analysis of the income distribution from fishing operations. This set up provides a realistic interface between the fisheries and household surveys.

In future this could be expanded so that the values in the Person and Household tables for fish consumption, equivalent cash value, annual income (from fishing) could be calculated by reference to this source data in the fishing tables as well as being entered explicitly from responses to interviews / questionnaires

Species Codes and their handling

It is hoped that all users will adopt the FAO standard the complete list of which is provided with the system. In order to maintain the utility of the system flexible options are built around the reference table. It does allow users to create their own codes under the FAO code column if there is not a suitable existing code. This is sometimes required for various generic groupings e.g the groupings of river fish used for Bangladesh.

Where there is convergence of code usage, such temporary codes can be replaced by any agreed standard FAO code. This only has to be done once in one place namely the code in the reference table. This change will ‘cascade’ automatically through the entire database modifying that code wherever it appears, be it in the catch table, the BioSamp or AnimalData table.

Species

FAOspec	UsedName	FAOName	EnglishName	FrenchName	SpanishName	LocalName	Rank
T00	Blank					TandC Blank	47
SLC	Panulirus argus	Panulirus argus	Caribbean spiny lobster	Langouste blanche	Langosta común del C	Lobster	46
CON	Strombus spp	Strombus spp	Stromboid conchs	Strombes	Cobos	Conch	45
T03	Scale Fish	Scale Fish	Scale Fish			TandC Scale Fish	44
BOF	Albula vulpes	Albula vulpes	Bonefish	Banane de mer	Macabí	Bonefish	43
BET	Thunnus obesus	Thunnus obesus	Bigeye tuna	Thon obèse(=Patudo)	Patudo	Bigeye tuna	42
BLF	Thunnus atlanticus	Thunnus atlanticus	Blackfin tuna	Thon à nageoires noire	Atún aleta negra	Blackfin tuna	41

Record: 1 of 1492

Figure 27 The species reference table

An improvement that could be made is to add one extra column ‘LocalCode’ to parallel the FAOSpec column. This would allow the FAOSpec column to be the supercode that could embrace any idiosyncratic local use. Again where no FAO code existed then the local could be substituted.

This would mean that users were not forced to adopt FAO codes because they needed to use their own codes in order to maintain consistency with historic data. However they would be able to make full use of FAO coding for their international reporting responsibilities and any intercountry comparisons that had different national codings.

As with all the reference tables once the definitive record is entered in the table then only that can be used in any instance in the database. This is because the foreign key from those tables back to the species table will enforce that data integrity constraint.

7.9 Distributed Databases

One of the fundamental problems with fisheries database systems is how to tackle this problem of them being ‘distributed’ databases. This arises because data may be entered at several sites that may or may not encompass different kinds of fisheries within the country. Also one of the aims of a generic system such as this one is to enable comparisons between countries thus the distributed nature must also encompass this.

Where this requirement is not addressed at the beginning then it can limit the utility of a system and then requires a great deal of additional resources to address the problems that arise in combining data sets analysing across groups etc.

There are modules within proprietary software systems for handling these problems e.g. ‘replication’ within the Microsoft Access development environment.

However it has been felt better to address the issue on a more fundamental level since the aim of the project is to produce a generic design that is generally applicable and not dependent on one type of software and features therein. Thus although the demonstration systems have been in this case produced in Microsoft Access the design of the database structure itself and methods of analysis are generally applicable for any relational database system.

The aim is that data from different data entry sites and different fisheries within a country and even data from different countries can easily be combined in a way that is clear to the user. This means that uniform methods of analysis can be applied whatever the 'scope' of the particular dataset, and that comparisons within and across these different levels can be made with confidence. The structure and processing elements of the database must be designed to meet these requirements in addition to the fundamental aim of being able to represent a wide range of fisheries within a uniform format.

Normally the use of primary and foreign keys based entirely on the natural attributes of the tables allow comprehensive data integrity that ensures all import and reconciliation exercises function as intended. But because we need very long natural keys in a generic system in order to ensure the unique identity a record even where many of the fields have missing data we run into the '10 field' limit imposed by Access. The use of AutoNumbered fields to circumvent this poses a potential problem. For example in the simple case of data accidentally being entered twice or at two different sites. Each instance of the duplicate records would be allocated different values under the AutoNumber field. Because of this the primary key would not carry out its function of preventing duplicates being added to the database.

Therefore future work needs to investigate the feasibility of finding software that can support very large natural keys and to run trials to see if having such large primary and foreign keys slows performance to unacceptable levels with large data sets. The later test is essential because these kinds of tests often work well with small simulated data sets but start to slow dramatically with increasing data because of the 'combinatorial explosion' created by the various relational join operations.

Where it is envisaged that a system is to be used beyond a local setting then the other important aspect of large distributed databases is to first correctly identify the scale of the technology needed to implement and run them. If this is beyond the normal experience of even well qualified fisheries data systems developers then such personnel need to be given appropriate training in the necessary technology and alliances sought with specialist providers who have proven track records for providing appropriate technical solutions.

7.10 Software Specific Features

These have been deliberately kept to a minimum in order to make the transfer of the design to other software as easy as possible.

The entire core of the system is built around a set of relational tables and accompanying SQL based queries. Specific table structures are composed of clearly defined primary and foreign key attributes. Data 'redundancy' has been reduced to a minimum apart from where redundancy has been deliberately employed to aid generification and handling of missing data. Normalisation and decomposition (into smaller representative tables) has been rigorously taken into account. Again as explained earlier there are deliberate compromises where required to satisfy the requirements for the generic aspects of the design and / or coping with potentially missing data.

All data analyses have been based around relational queries wherever possible. These can be implemented in any system that supports the SQL standard for database definition and manipulation. Thus procedural programming has been kept to a minimum since this is language dependent. Where procedural modules have been used the underlying algorithms have been documented in order to ease implementation in any other system.

Cosmetic and other productivity features specific to Microsoft Access have been avoided where at all possible. This again aims to reduce the overheads where the system needs to be implemented in another software system.

7.11 Analysis

All of the main concepts for the analysis have been explained in the context of the design above. All of the details required to carry out an analysis are explained in the user manual which also includes a tutorial section with worked examples and results. The following briefly summarises the facilities and options available.

Choice of Analysis

- Frame Survey Analysis
  - Frame effort
- Frame, Sample and Raise
- Effort, Catch, Costs, Earnings, Wages
- Normal Database Analysis (used for a census system or a simple survey without an associated frame.
    - Effort, Catch, Costs, Earnings, Wages
    - Length Frequency Analysis
    - Species Richness (count)
    - Conflicts
    - Income Distribution
- Household Survey
    - Equity

Choice of Stratification (including time series or not)
Choice of Filters
Source of Time Series Data for Effort or Frame Data
Choice of whether to use an updateable frame survey or not
Execute Analysis

These choices are then converted into a series of linked SQL queries which are run against the underlying database. The results appear as a series of output tables which can be exported to a spreadsheet and also serve as the input to a generic plotting routine.

Depending on the kind of analysis chosen the results are plotted as the value along the y axis and whatever grouping or combination of groupings the user has chosen along the z axis. For example of the user has chosen to analyse catch and group the results by habitat and species and there are 2 of each then there will be four sets of results to be plotted. If the user also chooses to incorporate a time series as part of the result then this is presented along the third (x) axes as years, months or years and months. Days can also be used if so chosen.

Again see the manual for examples of these outputs. At present no statistical breakdown of results is given apart from the variance of the effort calculations. This can easily be expanded to give values for the number in each sample (n) and variance of the result for most of the attributes analysed for. Combining the variance of catch and effort and frame effort to estimate the variability of CPUE and raised catch estimate will be a little trickier but can be achieved.

7.12 Previous Systems

The fisheries investigations carried out in the early stages of this project reviewed many existing stand alone systems with the aim of identifying common and unique features.

Future work needs to concentrate on identifying other studies and projects that are looking at unifying methods of fisheries information handling. This will help identify the strong and weak points of the PISCES design and point to where there is scope for synergy and collaboration.

PISCES is capable of receiving data from most systems that have been looked at even where the internal structures are radically different. For historic data this is achieved via a set of transformation queries that are produced for each system providing the source data. Ongoing data entry can be input directly to PISCES by drawing up appropriate directions of how and where to enter data from a fisheries existing paper records and forms.

7.12.1 ArtFish

Design of Database Structure and Processing Facilities

How the various components link together had to be deduced by a process of trial and error since none of the online documentation explains this. No documentation was distributed with the software and there was no response from telephone numbers or email for this material.

Artfish allows the recording of stratification information, frame survey data and monthly effort and catch sampling data for any one months worth of data. Overall statistics are then produced according to various strata as defined by the user e.g. totals, averages and variability of effort, catch and CPUE by major/minor strata, landing sites, boat-gear type, species. Artmerge can amalgamate the separate monthly databases into a single year using the estimates for each of the strata as its source of data. Artser can then represent the series of months as a table and graph and produce the average and totals for a particular year across any level of stratification.

There were installation problems on some machines. The path was lost and the maintenance facility could not correct for this. The help files in Artfish are very limited especially when it comes to explaining the principles of the system and how the various operations relate to these. There were no help files for Artmerge and Artser. That said once the system can be installed correctly and the operation and directory structures divulged by trial and error, then all works well within its intended design.

This design assumes a very rigid definition of a fishery e.g. sampling at landing sites only, predefined stratification, a rigid frame and sampling procedure supporting one form of sampling design which in turn supports only one form of analysis.

The underlying database is completely orientated to that form of analysis i.e. it is process orientated and not orientated to describing the structure of the fishery and variation therein. In that respect it has very little potential for ‘generic’ use.

For example as in the PISCES system different sites, months and years could all be accommodated within one database structure rather than all being separate and then having very convoluted and limiting processes to amalgamate them for wider analysis. The use of SQL grouping functions working on a unified database could very well provide similar functions to those in Artfish for partitioning results across strata without causing such limitations. This would allow for very flexible post stratification where this was statistically allowable.

The only danger with allowing such flexibility is that it provides the scope for inappropriate usage. More responsibility is devolved on to the user. Conversely the advantage of rigidly constraining the user as they are with ArtFish is that it is easier for the user to understand the system. This reduces the chances of miss-use.

Application Environment

The system remains in ACCESS2. This is not a problem for users with ACCESS97 because it appears that ARTFISH runs with its own runtime version of ACCESS2? This approach is probably preferable to constantly migrating an application with the shifting goal posts of development environments that are constantly produced by vendors. Choosing a development environment and sticking with it will improve consistency, make developers more efficient and reduce maintenance overheads.

Distributed Databases

Facilities for co-ordinating databases between different sites seem to be well implemented. The technology for this has now moved on considerably with the synchronisation facilities with ACCESS97 / 2000 for example. See main body of report for discussion on distributed databases.

CPUE

It copes with the ‘zero catch’ problem by including a catch record defaulted to zero for all species chosen from the look up table. There does not appear to be any use of the alternative left outer join operation to calculate CPUE. There are no real problems with this, since the zero catch records would have to be created anyway via the outer join method. At least the zero catches are explicit with this method.

Frame Survey

This is very simple. Fishing units are classified as Boat/Gear combinations and the total numbers of boats and gears for each combination are recorded per site (PSU).

What is separately termed ‘Table Update’ in fact constitutes a large part of the frame survey. This allows for stratification by major area, minor area, site (landing), and the relationships between these. It also allows for the definition of species to be included, the boat/gear types and the fishing grounds. It is not clearly stated how the stratification is applied in the algorithms.

Temporal Framework

Each month of each year resides in a separate database. Separate facilities provided for merging months (ArtMerge). This makes it very awkward to flexibly check trends over time.

Installation

There are no installation files for the ARTPLAN software mentioned in documentation - ‘software to assist users in better planning of surveys and to provide first order of magnitudes of total catch and fishing effort.’ There were no sign of the files for ARTBIOS:- Biological Sampling of Commercial Groupings for the ArtFish family. It appears from the use of ARTBASIC that these functions now form an integral part of that application. It is very easy for this to go wrong, particularly with the Artbasic and Artdbmntn components. You end up with the system being unable to locate any files despite attempts at re-registering the locations using the maintenance facility.

Set-up and registration

The first time set up is awkward. Though the current help file is well written and the table of contents well laid out with hypertext the main problem is that the help is not context sensitive. It would at least be preferable to guide the user through the first time set up and registering the location of the database files simultaneously to them conducting the operations. This is rather than them knowing how to call up the help files.

User Interface

Even once successfully installed and up and running an icon does not appear in amongst the currently running programs. The only way to get at the active window is by 'minimising' all the other windows. The screen colours for the help files are sometimes opaque.

Operation

No overall guidance given on the principles of the system or either how these tie in with the operation. It is assumed the user is entirely aware of the underlying assumptions on stratification, grounds, gears etc. Much of the framework for this is already there in that the data entry forms are reproduced as sections in the help file but little accompanying explanation is given as to how they should be filled in

e.g. #Gears on the Landing Data Input Form PRESUMABLY refers to the total numbers of gears (though this data is confusingly also recorded elsewhere which would tend to set the alarm bells ringing in terms of database design?) and not the unique id number of one of the gears?

It is not clear whether initial data is entered via the main tables or via 'Tables Update' facilities. Once reference data is entered then it does reappear as intended at the relevant places in the subsequent data recording forms.

Specific Problems

No documentation is distributed with the software. No response from telephone numbers or email for product support. The screen colours for the help files are sometimes opaque meaning for example column headings are obscured for example forms. Can't make an estimate for a major stratum with the estimates button. You have to go via the 'Reports' button. Not entering a sample weight in the landings form caused the entire application to crash!

List of outputs:

- **ARTPLAN** - software to assist users in better planning of surveys and to provide first order of magnitudes of total catch and fishing effort.
  - **ARTFISH** - software to organise and process primary data collected by artisanal fishery sample surveys.
  - **ARTSER** - software to analyse monthly catch and effort estimates resulting from ARTFISH operations.
  - Technical papers on methodological and operational issues.
  - Training material (documents, computer presentations)

Alternative list of outputs from reference table in database

ApplicationName	ApplicationDesc
ArtBasic for Windows	The Data collection and Estimate generator for the ArtFish family
ArtBioS for Windows	Biological Sampling of Commercial Groupings for the ArtFish family
ArtHelp for Windows	Help Text and Tutorial information
ArtMerge for Windows	Component of ArtFish Family Suite for merging monthly estimates into a
ArtDBMnt for	Database Maintenance Utility for the ArtFish Family Suite
ArtSer for Windows	ArtFish Time Series Reporting Tool

The ERA diagram (Entity Attribute Relationship) on the following page (fig 28) was produced by ‘reverse engineering’ ArtFish to try and gain some understanding of how the ‘parts related to the whole’. It reveals that there are in fact some reasonably sound underlying structural concepts but nowhere is this made clear in the documentation or is it explained how it works.

ARTMERGE

This module merges the monthly databases into a single entity. Directory and naming conventions are awkward to use but function correctly once you have worked them out.

The databases used in this process are completely geared to the procedures used in the program for the merging process and are of little use for anything else. E.g. alternative analyses etc. They are employed in an awkward three-stage process.

ARTSER :- ArtFish Time Series Reporting Tool

Plots a time series of the monthly databases in one year blocks. No help file. Awkward / impossible to point it to a new set of databases from which to form the time series until you divulge via trial and error the conventions for the directory structures and naming conventions.

7.12.2 TMAF Fisheries Information Monitoring System for N.E Nigeria

The project as a whole, its methods and outputs are obviously very relevant to this study and have already been taken into account by the earlier fisheries investigation work. However the software and the application are both tightly tailored to this particular project.

It will be interesting to see the how the various statistical outputs were developed. However it is highly unlikely that either the SPSS package or the underlying software model would be generally applicable as a solution. This is because SPSS is not intended to be a database management environment and the disadvantages that this confers outweigh the convenience of having the data immediately available for the statistical powers of the package.

The report makes no reference to formal data modelling considerations. There is a clear assumption that the data is intended only for servicing the statistical analyses and nothing else.

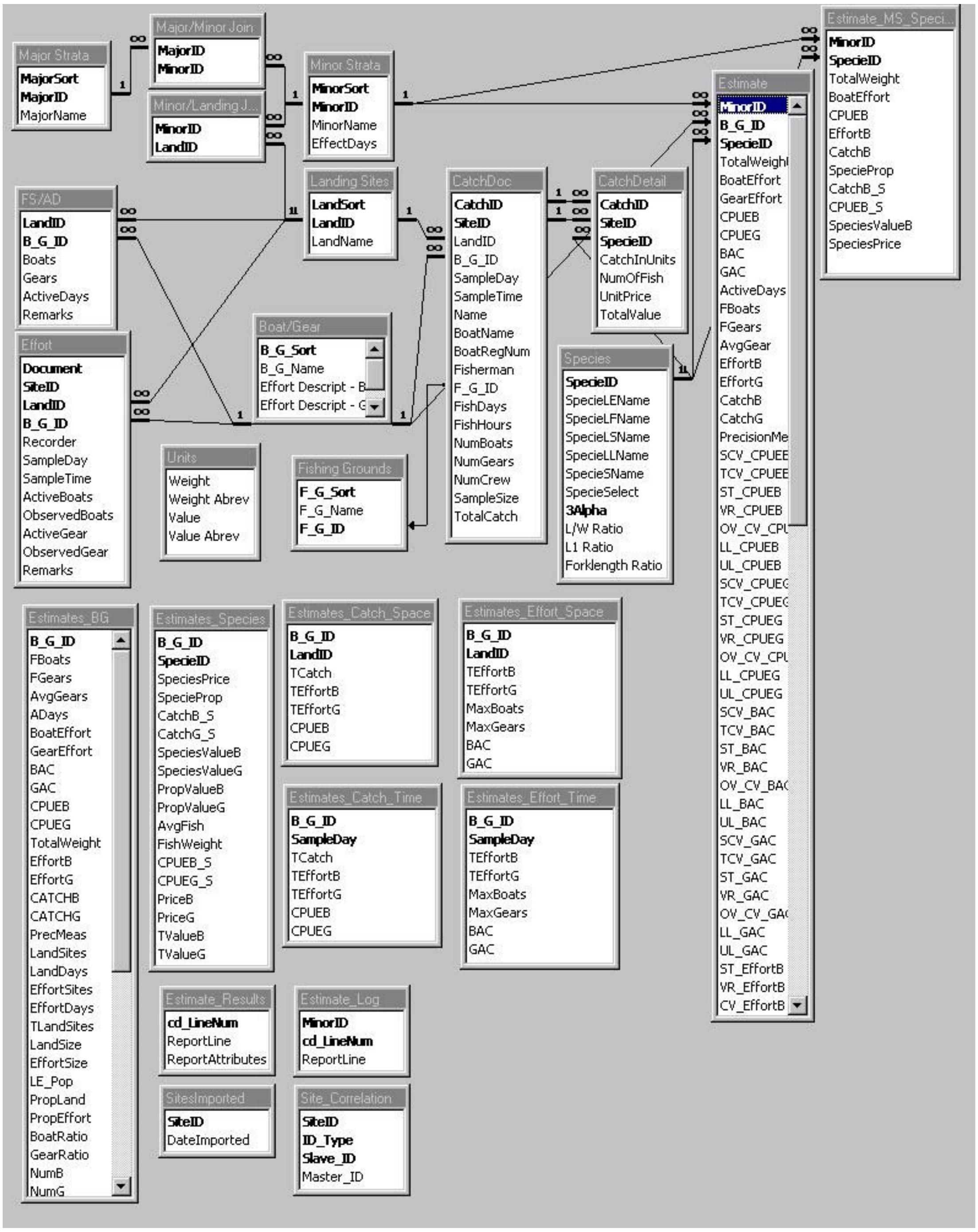


Figure 28 Artfish tables and relationships (ERA diagram)

8. Dissemination

8.1 Introduction

This chapter describes the results of the project dissemination activities undertaken in Dhaka, Bangladesh and in Grand Turk, Turks and Caicos Islands by Dr Ashley Halls and Mr Crag Jones. The main vehicles for dissemination at both sites were workshops, presentations and demonstrations of the FIMS software aimed at target beneficiaries, other stakeholders, and the project's collaborators. For the reasons stated in Section 1.5.2 no training was given in sampling methodologies to provide the array of potential raw data that can be accepted and processed by the FIMS.

8.2 Dhaka, Bangladesh (4th - 8th December 2000)

Dissemination activities in Bangladesh comprised (i) a one-day general workshop attended by NGOs, the academic community and international donor and development agencies, followed by (ii) a half-day software demonstration workshop held at CARE Headquarters, and (iii) a presentation of the projects findings and demonstration of the software to the DoF at their Headquarters.

8.2.1 One Day Workshop: ' A Database and Analytical Framework to Support the Co-Management of Artisanal Fisheries in Bangladesh'

The workshop was held at the Dhaka Ahsania Mission, Dhaka on December 6th. In spite of requested efforts by DFID to encourage participation, attendance by DOF staff was poor and therefore a second presentation and software demonstration was organised at DOF the following day (see below). Twenty-five of the 54 invited participants attended (✓):

Department of Fisheries, Bangladesh

Dr M.A. Matin, Director General, Fisheries Management and Administration
Dr Mokammel Hossain, Director CBFM
Dr Nassirudin Ahmed (FRSS)
Dr Anwar Hossain (FRSS)
Dr Rhakal Chandra Banik (FRSS)
Dr Nassirudin Ahmed, Project Director, Fourth Fisheries, DOF
Mr Monir Hossain, Deputy Assisstant Director, Fourth Fisheries Project, DOF ✓

International Donor Agencies

Mr Donal Brown, Natural Resource Advisor, DFID
Mr Tim Robertson, Fisheries & Aquatic Resource Advisor, DFID
Mr Duncan King, Fisheries Field Manager, DFID
Mr Imtiazuddin Ahmed, The World Bank
Dr Mahfazul Ahmed, UNDP, UN
Dr Aminul Islam, Sustainable Development Advisor, UNDP, UN
Mr Goutam Chandra Dhar, GIS/Database Programmer, FMS, DFID ✓

Research / Development Agencies

Dr Tony Thompson, SUFER Project, DFID ✓
Dr Paul Thompson, Officer in Charge, ICLARM ✓
Mr Md. Nural Islam, Social Scientist, ICLARM ✓
Mr Md Manjur Kadir, Fisheries Biologist, ICLARM
Mr Debashish Mazumder, Fisheries Biologist, ICLARM
Mr William Collis, Winrock International, MACH, USAID
Mr Darrell Deppert, Winrock International, MACH, USAID ✓

Mr Khaja Ahmed, Program Officer, DANIDA
Mr Robert Koudstaal, Team Leader, EGIS
Ms Ingrid Gevers, Fisheries Expert, EGIS ✓
Mr Md. Giaruddin Khan, EGIS ✓
Mr Md Abdullah-Al-Mamun, Fisheries Biologist, EGIS ✓
Mr Md. Gias Uddin Khan, Fisheries Specialist, EGIS ✓
Dr Ainun Nishat, Country Representative, IUCN ✓
Mr Rashiduzzaman Ahmed, SEMP Project, IUCN ✓
Gertjan de Graaf, Fisheries Consultant

Fourth Fisheries Project

Mr David Edwards, Team Leader
Mr Iqbal Hossain, Assisstant Director, M&E ✓
Mr Mohammad Ali, Deputy Assistant Director, M&E
Mr Willie Bourne, M&E Specialist ✓
Mr Zahirul Islam
Mr Mokhlesur Rahman, M&E Specialist

NGOs

Mr Md. Mokarom Hossain, Sector Specialist, BRAC
Mr Shankar Kr. Biswas, Sector Specialist, BRAC ✓
Mr Abdur Rahman, Fisheries Coordinator, PROSHIKA
Mr Shahadat Swapon, Associate Coordinator, PROSHIKA ✓
Ms Anwara Begum Shelly, Director Fisheries, CARITAS
Mr Phanindra Sangra, Prgram Officer, CARITAS ✓
Mr Lizarez Rahman, CARITAS ✓
Mr Sachindra Halder, Director, CNRS ✓
Mr Mokhlesur Rahman, Executive Director, CNRS ✓
Mr Kamal Uddin, Fisheries Biologist, CNRS ✓
Mr M. Anisul Islam, Program Officer, CNRS ✓
Mr Md. Hannah, CNRS ✓
Mr Greg Chapman, Rice-Fish Program Coordinator, CARE
Mr Mike DeVries, ANR Sector Coordinator, CARE
Mr Faheem Khan, MIS Advisor, CARE
Mr Shouroni Zinnat, Assisstant Project Coordinator, CARE ✓
Dr Atiq Rahman, Director, BCAS
Mr Syed Shah Tariquzzaman, SAREAA ✓

The workshop was divided into three sections (i) assembly, and introductions (ii) presentations by Dr Ashley Halls and Mr Crag Jones, and (iii) a discussion session. Finally, Moklesur Rahman (CNRS) summarised the findings of the project and formally closed the workshop.

The presentation given by Dr Ashley Halls described the project purpose, and the theoretical approach and activities employed to identify generic information and data inputs and outputs upon which the datamodel and software were developed. Mr Crag Jones then described the development of the datamodel and the functions of the database highlighting how some of the basic principles of relational database structuring and querying could profitably be applied as a generic system to cover the wide range of fishing situations in Bangladesh.

During the discussion session, participants were encouraged to comment on the results of the work. Suggestions and recommendations to improve the FIMS, particularly with respect to it's utility and applicability to the fisheries of Bangladesh but also to artisanal fisheries more generally, were also sought.

Overall, the project results were well received by all participants who expressed an opinion. Many participants supported the concept of learning lessons about (co-)management on the basis of spatial comparisons of standard, commonly-agreed management performance measures/indicators and those explanatory factors (co-management attributes) that are likely to affect performance (see SIPA - Section 6.6). This approach was regarded as particularly pertinent when funding constraints limit long term monitoring and evaluation and where the effects of influential environmental factors (eg flooding intensity and duration) need to be distinguished ('factored-out') from the effects of management intervention.

Participants agreed amongst themselves that floodplain elevation, flood duration, and flood depth are important attributes that should be included in the FIMS. It was also recommended that Catch Per Unit Area (CPUA) should be included as a co-management performance indicator.

Several participants expressed the opinion that DoF lacked the necessary institutional capacity and resources to replace the existing FRSS system with the PISCES software. Capacity building and training were seen as vital before the system could be implemented effectively by the Department due to the complexity of the system. However, some felt that the additional monitoring activities of co-managed units/projects required to support the SIPA elements of the system may be achievable if District and Thanna Fisheries Officers were supplied with networked computers to allow remote data entry from a local spatial scale. Alternatively, NGOs and donor project staff could undertake this role themselves if mutually agreed standard measures and indicators were employed for every study/project. These may have to include a common sub-set of donor-approved project impact indicators and measures to satisfy their own basic contractual reporting requirements. The latter solution raised questions surrounding ownership rights over the data and who would facilitate and coordinate the monitoring, evaluation and lesson feedback activities.

Many participants representing NGOs recognised that whilst the FIMS is primarily aimed at fisheries departments, the system could be used as a monitoring and evaluation tool to store and process data on local or small scale projects and studies.

Several institutes/projects expressed an interest to collaborate with MRAG, either with respect to helping DoF adopt the PISCES or to help develop the SIPA approach as part of the on-going DFID funded project 'Interdisciplinary Multivariate Analysis (IMA) for Adaptive Co-Management' (R7834).

Representatives of the EGIS project, who have forged a strong working relationship with the DoF during the last two years, believed that the FIMS would be a valuable tool for the Department, and that the system's implementation should be encouraged. EGIS expressed an interest to collaborate with MRAG if an implementation project were funded.

Dr Paul Thompson from ICLARM, Director of the Community-Based Fisheries Management (CBFM) Project in Bangladesh expressed interest in collaborating with MAG. on the IMA project. He suggested that Phase II of the CBFM project could be used to test or validate the IMA statistical methodology if the measures and indicators agreed under the IMA project were employed from the start of the next monitoring and evaluation phase of the CBFM.

Delegates from the Fourth Fisheries Project also expressed interest in collaborating with the IMA project in support of their Fish Sanctuary Programme. They agreed to give further consideration to some form of collaboration after receiving and assessing the Final Technical Report and FIMS software.

Darell Deppert (MACH Project), also believed that the SIPA approach could have an application in the MACH Project and supported the use of a common/standard det of co-management performance and attribute measures and indicators.

Tony Thompson (SUFER Project) suggested that MRAG give the same workshop presentations to Bangladesh Agricultural University and other interested university departments as a means of encouraging the co-management paradigm as well as teaching staff and students about approaches to monitoring and evaluation.

Most of the partcipants present requested to receive copies of the Final Technical Report and FIMS software (see Section 9.4) so that they could explore the utility and applicability of the system for themselves in more detail. All participants were invited to attend a demonstration of the FIMS software at CARE HQ the following day (see below).

8.2.2 Software Demonstration at CARE

A workshop to demonstrate the FIMS software was held at CARE Headquarters on the morning of the 7th December. The following NGO representatives attended:

Mr Sachindra Halder, Director, CNRS
Mr Shaheen Ferdurs, CARE Bangladesh
Mr Selim Reza Hasan, CARE Bangladesh
Mr Uzzal Kumar Roy, CNRS
Mr Mir Atuar Rahman, CARE Bangladesh
Mr Mohammed Sylas, CNRS
Ms Asthma Alam, CARE-CAGES
Mr Alamgir Rahman, CRAE-CAGES

The presentation and demonstration was given by Mr Crag Jones who began with a resume of the project purpose and activities and some technical theory relating to data structures and datamodels for the benefit of those who did not attend the workshop on the previous day. He then gave a comprehensive demonstration of the software.

The theoretical aspects were illustrated with both simulated data and historical data collected for the river fisheries of Bangladesh. The concept of both capturing and representing complexity via the data content as opposed to via data structures was illustrated. The design and utility of a single generic structure to contain such data was demonstrated.

It was shown how this structure (table) has all the relevant attributes (fields) that describe fishing events. Such attributes would be both the inputs and outputs in terms of physical data and measures that profile management areas and measure the performance of management areas.

It was then shown that a range of performance attributes could be analysed against any of the physical or management attributes or any number of combinations of these according to the users choices. This was shown to allow a choice of analyses from the traditional physical kinds all the way through to a comparison between different co-management arrangements.

The choice of whether any one attribute is regarded as an ‘input’ or ‘output’ was explained as an arbitrary one based on the investigators assumption of cause and effect for each of the analytical queries provided. It was shown that the distinction could thus be ignored, thereby meaning that data structures do not have to confine the range of possible analyses allowing more to be added as required.

The example was made where the species attribute could be used as a ‘generic input’ for catch analysis but as a performance indicator where used in the analysis of bio-diversity. The analogous view point was shown to be applicable such things as exploitation methods and exploitation intensity.

Attention was drawn to the fact that additional analyses can be developed confident in the knowledge of a standard source of input data which would ease the comparison between different lines of investigation. That this would also ease the task of preparing datasets in the required format for external analytical tools such as statistical packages was also stressed.

In practical terms it was shown that you could analyse for effort, catch, costs, earnings, income, frame survey effort and the application of this to all the sample data to obtain 'raised' results as nation wide estimates of these. There were also examples given of the mapping of fishing income into communities, the use of household survey data to give estimates of levels of distribution and degree of equity, analysis of species diversity within the fishery, degrees of conflict and detailed biological sampling measurements and analysis of these.

It was demonstrated how all of the outputs from these example analyses could be plotted via a single generic plotting routine that automatically scaled and labeled the axes and data series according to any time series if so chosen. The automatic availability of the results for export to spreadsheets was shown.

It was explained that the user could analyse say a count of species or diversity index plotted against the years for all combinations of Intermediate Management Area in conjunction with the degrees of enforcement of regulations, or compare diversity under specific management plans combined with degrees of fisher representation in the management process. However the lack of either real or simulated example data with these properties precluded a clear demonstration of this which was reserved for the following demonstrations at DoF once example data had been simulated. A more conventional example was given using the real data to give be raised catch estimates by species per gear type per habitat per month etc. Results sets can be grouped according to the values under any number of the fisheries attributes or combinations of these.

It was shown how the FIMS could cope with unanticipated attributes in real Bangladesh data such as the need to express 'District Code' in conjunction with particular Rivers. It was demonstrated that all of the attributes of the original data were preserved after the transformation into the FIMS but that the flexibility by which it could be analysed and illustrated was greatly enhanced. Examples were run of the river data being broken down by species, gear type, village, district, river with or without a time axes of year alone, month alone or combination of year and month.

It was emphasised that the time series attributes are structured and handled in the same fashion as all others except at the plotting stage where they are projected onto their own axis in order to aid visualization. The unique combination of all the values under the attributes that the user chooses to group their results by (the 'strata') are automatically formed were shown to plot as separate series either in the third dimension or as separate lines on a two-dimensional plot where this was clearer.

The unique method of grouping and matching both the frame effort and the sample effort and catch according to matching criteria chosen by the user was clearly demonstrated with real frame data from Bangladesh providing results that closely matched the DoF published results from this data.

It was shown how the system could cope with both detailed data and higher level summary data depending on the survey methods and sources and that such diverse data could also be combined in analyses whilst maintaining an accurate representation of effort at each level.

Attention was drawn to the need for responsibility on the part of the user in return for the flexibility offered by the system. It was pointed out that the data entered should be in a form appropriate to the type of analysis that was envisaged and that the portioning of effort across categories should be appropriate to the level of detail in the data. The existing facilities within the software to handle catch per unit area and raise this according to flood plain area were also discussed.

It was shown how the original FRSS data set had been radically transformed whilst at the same time markedly improving its referential integrity and that similar transformation procedures could be applied to data from the other fisheries. At present for example Bangladesh river data sits happily beside Carribean reef fishery data inside the FIMS with no loss in the range of analyses that can be applied.

Tony Thompson had earlier pointed out the lack of understanding and awareness amongst researches and managers, the world over, of the potential of relational database methodologies for fisheries management; and the need for additional training in this area. This was met with general agreement.

Dr Paul Thompson, highlighted the need for indications of sample sizes and variability of data. It was reported that, time allowing, it was relatively straightforward to place these important aggregate functions within the existing grouping architecture that the analyses suite was based on.

Detailed discussions were held with the software specialists at CARE concerning the structure of the data model and the various modifications that had to be made to allow for missing data where these were irrelevant for a particular implementation. The method of dynamically forming the SQL queries according to user choices was also described.

8.2.3 Presentation and Demonstration at DoF Headquarters.

A second presentation of the project activities and results, and demonstration of the FIMS software were given to the DoF staff at their headquarters on the afternoon of the 7th December. Participants included:

Dr Mokammel Hossain, Deputy Director
Dr Nassirudin Ahmed (FRSS)
Dr S.N. Choudhury, Principal Scientific Officer
Mr Md. Zahirul Islam, Fisheries Management Specialist, Fourth Fisheries Project
Four IT specialists from the FRSS Department

Dr Ashley Halls began with a short presentation describing the background to the project, it's purpose and the research activities undertaken. Mr Crag Jones then gave a demonstration of the FIMS software.

Emphasis was placed upon demonstrating the practical aspects of the software using the DoF river fishery data set to illustrate the enhanced data integrity and flexibility of analysis available with the FIMS. Examples of how information can be displayed graphically or exported to spreadsheet for further analysis, were also presented.

Simulated data sets were used to demonstrate the features of direct relevance to co-management. It was shown how users could examine the correspondence between selected attributes (types of operational rules, fishing gears employed, presence/absence of reserves...etc) and management outcomes such as annual yield or local biodiversity. It was pointed out that the set of attributes and management performance indicators could be further changed or expanded. The same demonstrations of the software functions given at CARE were repeated.

The storage and analyses of biological data were illustrated including the plotting of length frequency distributions. Methods of transforming the original data from its FRSS format into that required by the FIMS was discussed. It was explained that the data structures had been designed to take all of the other fisheries of Bangladesh into account and that similar data transformation exercises could be carried out on that data such that data from all of the fisheries could sit side by side in a single generic system. Attention was drawn to the realistic possibility of combined analysis without preventing the expression of attributes peculiar to one or other of the fisheries. The FIMS was presented as a potentially very useful tool to rationalise DoF data handling requirements and resolve many of the problems they are currently faced with.

Overall, the response from the DoF was very positive and they expressed interest to receive copies of the Final Technical Report and FIMS software. The department also expressed interest in being trained in the use of the software, and thought that the 'best bits' of the software should be included in the database that the Fourth Fisheries Project is currently developing to replace the existing FRSS. The workshop revealed the need to rationalise the approaches being taken by (i) this study, (ii) the Fourth Fisheries Project review of the FRSS and (iii) the work of EGIS into a coherent strategy.

8.3 Turks and Caicos Islands (11th-19th December 2000)

Dissemination activities in the Turks and Caicos comprised a combination of several meetings, two half-day workshops and a one-day software demonstration workshop held at the DECR Headquarters on Grand Turk and attended by staff from the DECR and other Government departments.

8.3.1 Meetings

The following pre-workshop meetings were held with DECR:

Tuesday 12th and Wednesday 13th December

Additional user requirements identified subsequent to the last assessment exercise in June 1999 (see Field Study 2 - Turks and Caicos Islands, Volume II) were discussed with the DECR and David Clements from the Government Statistics Department including: export records, data collected from purchasing slips and recreational diver sitings of species by location.

Friday 15th

An action plan to implement the FIMS in the DECR was discussed including the timetabling of activities, personnel requirements, funding sources and on-going technical support.

8.3.2 Half Day Workshops

Two half day workshops, following the same format as those undertaken in Dhaka, Bangladesh (see above), were held on Thursday 14th December. The following participated:

Morning Presentation

Mr Mark Day, Director
Ms Michelle Fulford, Senior Scientific Officer
Mr Wesley Clerveaux, Scientific Officer
Amber Thomas, Fisheries Officer, Providenciales

Afternoon Presentation

George Kwarteng, Consultant Programmer, Government of the Turks & Caicios Islands
Dexter Henry, TCI Computing Department
Michelle Taylor, National Parks Department
Brian Riggs, TCI Museum

For a number of reasons, the DECR decided not to invite stakeholders representing the School for Field Studies (SFS), the processing industry, the Fisheries Advisory Committee (FAC) or the fishers themselves.

The project results and outputs were well received by the participants, particularly the automatic system functions to alert breaches to technical and licensing regulations. The DECR were also impressed by the flexibility of the FIMS with respect to meeting their reporting requirements and provision of data and information for stock assessment purposes. Some participants were sceptical about the appropriateness of co-management in the TCIs because they believe that communities have no interest in conservation and that resource boundary delineation would be problematic. Conditions to support co-management arrangements were believed only to exist in and around Salt Quay, a small, isolated island with few inhabitants and fishers (see Field Study 2 - Turks and Caicos Islands, Volume II).

Others, on the other hand, were enthusiastic about the prospects for co-management and felt that the Department should consult the community more with a view to establishing co-management arrangements.

Mark Day, Director, DECR expressed considerable interest in installing the FIMS software in the Department to replace the existing, but no longer functioning, DataEase system (see Field Study 2 - Turks and Caicos Islands, Volume II). He intends to seek DFID development funds for a package to install and customise the FIMS, and to institutionally strengthen and train the Department in the use and application of the software. It was agreed that a comprehensive user requirements assessment exercise should be undertaken as a priority activity. Mr Crag Jones estimated that installation, customisation, training in the use of the software, and the reconciliation of all historic data would require approximately 12 man-months.

The possibility of a 'distributed' system to allow data entry from Providenciales, South Caicos and Grand Turk, either via disk mailings or Internet, was discussed. The appropriateness of the FIMS as a regional database to replace the existing OECS/CARICOM system was also discussed.

8.3.3 One-Day FIMS Software Demonstration

It was demonstrated how effort, catch, CPUE costs and earnings results could be grouped by fisherman, boat, fishing method, location, depth, processing plant, island, calendar or season years, months and days as required. The ability of the FIMS to deal with the example 'unanticipated' attributes of Island and Season was demonstrated by placing these in the extra strata fields. The systems ability to deal with data aggregated to varying degrees was successfully demonstrated with historical data provided by the DECR.

The unique method of representing restrictions and licencing to operate within these restrictions was explained showing how all fishing data entered was screened against these criteria. An alternative example was given as to whether the system would be able to reveal any persistent contravention as an aid to assessing the gravity of such problems.

8.3.4 Interim System Training

The prototype version of the FIMS was installed in the DECR to provide an interim system to replace the DataEase system until a fully developed version of FIMS is installed at the Department. An algorithm was included to flexibly define any 'split-year' season and the system was loaded with as much as possible of the Department's historic data. Training was given in data entry and basic reporting. Analyses of catch, effort ,earnings and diversity were demonstrated for various combinations of year, month, day, species, processing plant and fisherman. It was shown how detailed analyses could be successively grouped up across broader and broader categories. The utility of the generic routines for plotting these results were demonstrated as were the transfer of such plots into reports.

A detailed user manual was provided to support the hands-on training. This manual contained detailed instructions on how to set up and run the system on other machines, as well as details of the errors found in the historical data.

Discussions were held with DECR staff on both the scope of the FIMS system and the constraints imposed by the historic data. It was apparent that the staff had a clear understanding of the data problems highlighted and they were able to propose ways of preventing this in future and suggest methods of resolving queries regarding the historic data. DECR Staff were enthusiastic over the proposed FIMS and expressed clear ideas on how it could broaden the use of their data to answer specific questions they had.

In preparation for the anticipated design and installation of the final version of the FIMS software, potential users were encouraged to 'map' and explain their activities. This will help further refine the 'functional decomposition' of activities within DECR and their external interfaces with other government departments, fishermen, the commercial sector, research and management projects and other agencies.

8.4 Distribution of Final Technical Reports and FIMS Software

In addition to those required to satisfy DFID's contractual reporting requirements, it is intended, at least in the first instance, to send copies of the project's Final Technical Report and FIMS software and User Manual to the following:

Bangladesh
DFID, Bangladesh
DoF, Bangladesh
CARE, Bangladesh
CNRS, Bangladesh
ICLARM, Bangladesh
MACH Project, USAID
Fourth Fisheries Project
EGIS Project
SUFER Project, DFID

Turks and Caicos Islands
DECR
School for Field Studies (SFS)

Africa
Lake Uganda Project, DFID
SADC

9. Summary and Conclusions

9.1 *Purpose and Other Expected Outcomes*

The purpose of this project was to examine the feasibility of developing a generic (generally applicable) Fisheries Information Management System (FIMS) or database to support the co-management and development of a diverse range of artisanal fisheries. In addition to the generic database, other planned project outputs included:

- Guidelines and statistical procedures for a generic data collection system to support the FIMS software.
- An evaluation of the cost of implementing the FIMS (both unit costs and national costs at case study sites).
- Training workshops in the use of the generic FIMS and data collection strategy with supporting material/documents.
- A description of the wider utility and applicability of the generic FIMS.

9.2 *Activities and Outputs - Planned and Actual*

These outputs were sought through a number of planned activities (Figure 29). It was intended to identify generic information outputs from the FIMS on the basis of a synthesis of government and community management objectives identified from the literature, company experience and from case studies of two diametrical artisanal fisheries.

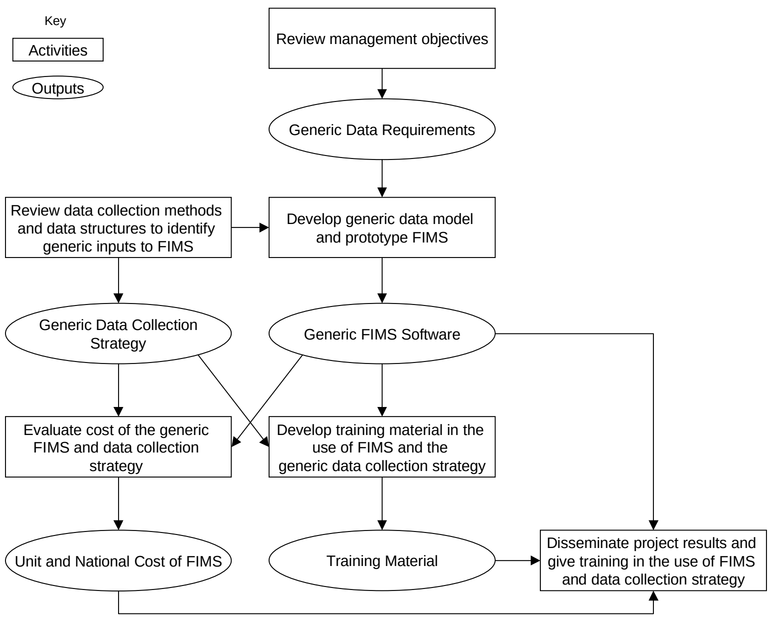


Figure 29 Planned Project Activities and Outputs

The raw data or *inputs* for storing and processing by the database to provide these outputs would be identified from a review of correspondingly appropriate data collection methodologies combined with a review of 'data structures'. This review of data collection methodologies was also intended to provide the basis for developing guidelines and statistical procedures for a generic data collection system to support the database component of the project. The computing hardware requirements for the FIMS software combined with and necessary resources and manpower to support the generic data collection system would then provide the necessary information to evaluate unit costs of the system, as well as the national costs of implementing the FIMS at the case study locations (Figure 29).

Shortly after the project began, it became evident that information requirements (outputs from the FIMS) to support co-management will be governed by more than just management objectives of governments and local fishing communities (Chapter 3). Instead, the information required from a co-management FIMS will be influenced by (i) the nature of the co-management arrangement which will determine which stakeholders are involved in the management decision-making process; (ii) the objectives of these stakeholders; (iii) the basis with which these stakeholders make decisions (eg custom/tradition, empirical or theoretical models, adaptive approaches...etc); (iv) their institutional capacity which will influence the types of decision-making methods and data collection approaches they can employ; (v) the type of management control measures they choose to employ regulate resource exploitation, and of course: (vi) their preferences and local conditions under which they operate (Chapter 3).

The continuous spectrum and evolutionary potential of co-management arrangements coupled with the inter-dependence among several of the factors listed above, presented a dynamic and multi-dimensional problem to identifying management information requirements and therefore designing a general database to support co-management (Chapter 3).

As a means of addressing the problem, idealised co-management arrangements based upon the work of Sen & Nielsen (1996) and Hoggarth *et al* (1999) were identified for the three main environmental regimes in which artisanal fisheries commonly operate. These arrangements effectively matches the main stakeholders with the necessary motivation and institutional capacity to the main management roles that are heavily reliant upon data and information. This is achieved by sharing management responsibilities for *management units* both spatially and hierarchically (Chapter 3). However, whilst these arrangements provide a useful entry point to examine potential information outputs from a FIMS, it should not be seen as a panacea for co-management. Many other arrangements exist along the co-management spectrum which are equally valid or potentially appropriate depending upon the local context (Chapter 3).

It was also necessary to make explicit which of the main stakeholder groups should be the target of the FIMS. It was concluded that government fisheries departments should be the primary targets because they will usually have overall administrative responsibility for the (co-) management of national fisheries resources. They are also the most likely stakeholder group to possess the necessary institutional capacity and resources to formally monitor management performance and therefore require such a system. Designing a system that could also support the needs of intermediaries (eg donor-funded projects, NGO's etc) was rejected. It would be impossible to anticipate their diverse range of remits and interests and potentially esoteric monitoring programmes commonly designed to satisfy donor-specified project impact indicators (Chapter 4). In spite of this, several NGO delegates at the projects' dissemination workshop in Bangladesh believed the FIMS software could effectively be used in support of many of their community project monitoring and evaluation programmes (see later and Chapter 9). It was also concluded that whilst they are the ultimate target beneficiaries of the project, and may in contribute to the data and information contained within it, it would be unrealistic to expect local fishing communities to have any interest, motivation or the necessary institutional capacity to use such a system. Monitoring and evaluation at this level will typically be informal and often based on perception or common knowledge derived from the co-use of the resource under conditions where mutual observations are possible (See Chapter 4 and Project Memorandum Section 15d).

The system was therefore principally designed to support the following heavily-dependent co-management roles of fishery departments at each of the three nested spatial management levels:

- Formulation of management plans.
- National monitoring and evaluation, and control and surveillance for management plans for migratory[1] and state-owned sedentary resources[2].
- National policy and development planning including the coordination of sectoral activities.
- National and international management and reporting responsibilities.
- Coordination of community management plans to ensure complementarity.
- Evaluation of community management plan performance and feedback of lessons of success and experiences to communities.

It was decided that the FIMS must have realistic limits. The system was not, therefore, designed to provide a means to store, collate and process data and information collected from the infinite range of possible special studies designed to address specific questions such as the migratory behavior of key species. This decision was made on the basis that it would simply be impossible to anticipate all the types and formats of data and information that may be collected as part of such studies.

9.2.1 Identification of Generic Information Requirements (Outputs) from the FIMS

Formulation of management plans
Management plans translate and reference how the broad directions and priorities stipulated within fisheries policy are translated into specific fisheries or stocks profiled in the plan. Generic information requirements to formulate management plans were identified from a synthesis of the literature. The main categories of information included the stocks of fishery being considered and area of operation of the fishery; information on environments, habitats or locations critical for the life history of the stocks or species; potential catchment influences on the stock; information relating to the fishery; information relating to the fishers and other important stakeholders; the management objectives; decision-making arrangements including rules and regulations; and any external factors that may affect management (Section 4.2).

National monitoring and evaluation of management plans, and control and surveillance.
Generic information requirements (outputs) from a FIMS to support national monitoring and evaluation activities were identified from a combination of management objectives (and their *status indicators*), technical management models (and their *reference points*) and adaptive management approaches, covering the full range decision-making methods that are employed to evaluate management performance (see above and Chapter 4).

Surprisingly few (16) explicit statements of management objectives for artisanal fisheries were found in the literature despite the screening of more than 2000 published papers, reports and newsletters. Those found all related to broad over-arching national objectives, policies and plans, or the desired course of action for the fisheries sector. No specific management plan objectives were found. This probably reflects the less formal or structured management procedures employed in artisanal fisheries compared to those in the developed world (Section 4.3).

Generic information requirements (outputs) from the FIMS to support biological or resource

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[1]Migratory resources cannot be effectively managed on a local scale.

[2]These refer to non-migratory stocks that are not managed on a local scale.

orientated management objectives, decision-aiding models and adaptive management approaches were identified as catches by species and gear type and corresponding fishing effort by gear type during a specified time period (commonly a year). Other requirements were identified as information to describe the population dynamics of the exploited populations (biological data) derived from the (sampled) including: the length or age composition of the catch and their life history characteristics, typically sex, fecundity, and reproductive condition in relation to length, and gonad weight in relation to somatic weight (Section 4.3).

Spatially referencing these data and information significantly augments its' value allowing: (i) the development of spatial management models (Section 4.3.3); (ii) the identification of important areas for conservation and management (eg spawning locations or nursery areas...etc); (iii) the examination of the spatial and technical interactions among fleets or fishers, and stocks; and (iv) more effective management if the population dynamics of the stock varies significantly on a spatial scale.

Information requirements (outputs) from the FIMS to support common socio-economic management objectives and decision-aiding models were identified to include costs and earnings stratified by various criteria, economic rent, export revenue by species or product type, numbers of individuals employed in the fishery stratified by sub-sector, income stratified by FEU type, industry diversification data, indicators of food supply or security, information describing the extent and frequency of conflicts, information to monitor the existence/maintenance of traditional management practices or culture, and catch and effort information (Section 4.3.4).

Environmental information was also identified as being an important output from a FIMS, particularly to support the management of fisheries operating in environments sensitive to environmental stress or perturbation. The major problem with using environmental data to help interpret management performance is deciding what should be recorded. There is also the risk that apparent correlations with fisheries data are often spurious. General variables that should be available from a FIMS were identified in Section 4.3.5.

Information requirements for control and surveillance were found to typically relate to vessel or gear ownership, identity, communications, fishing power and corresponding licence details (Section 4.4).

National policy and development planning

Information requirements from a FIMS to support national policy and development planning decisions, and reporting responsibilities were examined in Section 4.5. Three main categories of information requirements from the FIMS were identified: (i) resource and fishery related; (ii) socio-economic; and (iii) monitoring control and surveillance (Table 6). Sources for this information were identified as management plans, frame surveys, routine monitoring programmes to evaluate management plan performance, special studies, and information available from other government departments and ministries (eg Departments of Trade, Customs, Bureau of Statistics...etc).

National and international management and reporting responsibilities.

Required outputs from a FIMS to comply with international management responsibilities including the FAO Code of Conduct for Responsible Fisheries and UNCLOS III were identified. Outputs required for international reporting responsibilities were also identified for the main commissions and conventions including the FAO Regional Fishery Commission; Convention for the International Trade in Endangered Species (CITES), and the Convention for Biological Diversity. However, it was recognised that membership to other regional bodies, agencies and organisations such as Organisation for Eastern Caribbean States (OECS) or the South African Development Commission (SADC) may carry with it additional obligations to supply specific information not required for the above (Section 4.7).

Coordination and performance evaluation of community management plans
Adaptive management is likely to be employed by local communities to achieve their objectives for their own *management unit*. However, identifying the best combinations of management tools and decision-making arrangements to achieve specific objectives by individual communities may take several years of (informal) monitoring and evaluation by the local managers. It was concluded that fishery departments or higher level managers have the potential to significantly accelerate this adaptive learning process by monitoring and comparing spatially, performance among individual management plans. The results and management recommendations arising from this approach can then be disseminated to local level managers via appropriate media such as regular radio transmissions, meetings, posters, workshops...etc. This spatial monitoring and evaluation approach also provides and effective means with which to spatially coordinate local management activities thereby promoting harmony and complementarity and helping to minimise conflicts.

Requirements from the FIMS to support this role were therefore identified as being all the information that is typically contained within a management plan and any other attributes that are believed to affect management performance or outcomes, as well as of course, indicators of management performance. It was concluded that the performance indicators must be both relevant and palatable to local level managers if effective feedback and adoption of lessons of success are to be achieved. Whilst these indicators should ideally be selected by the local managers themselves, an extensive literature review discovered no documentation describing management performance criteria as selected and applied by the community itself. Nonetheless, it is recommended that these indicators be negotiated in collaboration with the communities themselves. The DFIDs' five main categories of desirable livelihood outcomes were identified as a useful basis with which to negotiate these indicators (Section 4.9).

9.2.2 Identification of Generic Inputs for the FIMS (database fields)

As explained above, it was intended to identify generic raw data or *inputs* for storing and processing by the FIMS database to provide all the generic requirements (outputs) described above by identifying or formulating a generic data collection system. As a means of attempting to develop such a generic data collection system, factors affecting raw data and their collection and processing were examined in detail in Chapter 5. This included a review of potential sources of data for each required category of requirements, and appropriate data collection tools (eg questionnaires, interviews, direct observation...etc), sampling strata, and the appropriateness of sampling and complete enumeration in relation to the variable or data type in question. It was concluded that it was impossible and wholly inappropriate to design a generic data collection strategy. Effective and appropriate data collection strategies and data processing methods must be designed in accordance to the structure, operations and characteristics of the fishery (the local context), and the available institutional capacity, resources and preferences (see Chapter 5 and Figure 9).

Generic inputs for storage and processing by the FIMS to provide the required outputs were instead identified on the basis of corresponding commonly collected categories of data and information or *generic fields* (Chapter 6). Generic field were identified by reviewing the types of raw data (example fields) that are frequently collected using commonly employed data collection tools and data sources to provide the main categories of information required from the FIMS.

This approach effectively aimed to develop a FIMS that could support a variety of common data collection strategies as opposed to designing a system around a single generic data collection strategy. In addition to increasing the complexity of the database design (and therefore the time and resources required for its development), the inability to develop a generic data collection strategy also had the important implications with respect to delivering several of the expected/planned outputs (see later).

National management plan fields
Raw data to formulate management plans may be assembled and summarised from a an indefinite number of sources using a variety of data collection tools. Furthermore, management plans often contain information that is not efficiently stored in electronic formats such as lengthy text descriptions or figures. Whilst the final FIMS design can provide much of the raw inputs to construct/formulate a management plan (see below), it was concluded that the complete range of generic input requirements could not be identified and therefore supported by the software. However, the FIMS software does allow management plan document identifiers (their more typical format) to be referenced to all the data contained within the database to aid the coordination of management activities both inter- and intra-sectorally (Section 6.1).

Generic fields for monitoring and evaluation of national management plans:

Frame survey Fields
The information recorded during the frame survey helps identify appropriate primary and secondary sampling units and sampling strata, and provides fundamental data for raising sampled catch and effort data to give the total population estimates (see below). They also commonly provide (either by design or otherwise) an important source of information to help formulate management plans and for policy planning and development purposes, and for socio-cultural analyses (see below). However, in common with management plans, frame surveys also typically draw upon data collected and assembled from an indefinite number of sources using an equally diverse range of data collection tools and methodologies. For these reasons, it was only possible to identify, and therefore include in the software generic, data fields that are required to raise sample estimates of catch and effort to give estimated total values, when sampling as opposed to complete enumeration methods are employed (see Sections 6.2.2 and 6.2.3). The frame survey table does however also contain fields to store information describing the attributes of co-management units and to key identifiers to reference other tables containing basic details of FEUs (see later).

Catch and effort fields
Generic fields to support census and sampling approaches to collecting catch and effort data based upon interview techniques, direct observation and log sheet reporting at the harvest and post harvest levels where successfully identified for inclusion in the software. Consequently, the FIMS provides a very general system for supporting catch and effort sampling programmes (see later).

Biological and Environmental Data
Biological and environmental data are most commonly sampled using direct observations at the harvest level. It was therefore relatively straightforward to identify a comprehensive range of generic fields for inclusion in the database (Section 6.2.4).

Control and Surveillance Data Fields
Generic fields for control and surveillance were also readily identified from the literature and case studies (see Section 6.3).

Socio-economic Data Fields:
Cost and Earnings
Generic fields were identified to support cost and earnings surveys directed either at fishing vessels or households (panel surveys). These fields allow cost and earnings data to be sampled alongside catch and effort data (the 'integration principle') so many of the fields identified are common to those required for catch and effort sampling (Section 6.2.6).

Economic Rent
No additional fields to support the estimation of economic rent were identified. Data to estimate economic rent correspond to those fields already identified to support catch and effort, and cost and earnings studies, and control and surveillance data. Data may also be available from *ad hoc* surveys or other government departments which are typically not included in fishery department databases (6.2.6).

Employment
Fields to record the numbers of fishers employed in the catching sector were identified for frame surveys (See Section 6.2.2). Additional fields to record data on employment in the processing sector could be added to a frame survey table if required. Alternatively, employment data may be available from population censuses or *ad hoc* studies that are typically not included in fishery department databases (Section 6.2.6).

Poverty
Information to assess levels of poverty are available from cost and earnings surveys, combined with living cost data which are typically not recorded by fishery departments. Additional fields to support proxy indicators of poverty recorded during frame surveys were also identified. Other proxies for poverty may be available from population census data available from other government departments or ministries (Section 6.2.6).

Industry Diversification
Fields to support the evaluation of the diversity of the fishery were identified for surveys to support catch and effort surveys (species landed), and frame surveys (gear and vessel types). Additional fields to describe the diversity of supporting sectors recorded during frame surveys were also identified (Section 6.2.6).

Food Supply and Security
Fields to support the evaluation of fish supply and trends in average per capita fish consumption correspond to those already identified to support catch and effort surveys. Alternatively, data may be available from other government departments. Additional fields describing fish consumption or food security recorded during frame surveys were also identified. Common fields to support typical household consumption surveys were identified (Section 6.2.6).

Conflicts and Traditional Management
Generic fields to support the evaluation of conflicts and the maintenance of traditional management by means of ad hoc studies were also identified. These can be appropriately modified in accordance with local requirements. Additionally, a frame survey table could also be customised to accommodate similar fields recorded as part of a frame survey (Section 6.2.6).

Generic Fields for Policy and Development Planning
Generic fields to support policy and development planning are restricted to those corresponding to support of the monitoring and evaluation of management plans (see above). However, other sources of data to support this role may be available from frame surveys or other government departments and ministries (Section 6.4).

National and international management and reporting responsibilities.
Generic fields to provide the basic information required for compliance with international management and reporting responsibilities correspond to those already identified to support the monitoring and evaluation of management plans and control and surveillance. Additional information required to support these roles may also be obtained from other government departments and ministries responsible for trade or customs control (Section 6.5)

Fields for coordination and performance evaluation of community management plans
Generic fields to describe the attributes of co-management units and their respective management performance were identified on the basis of the Oakerson Framework (Section 3.1), ICLARM's 'Institutional Analysis Research Framework' developed under their Fisheries Co-Management Research Project, DFID's Sustainable Livelihoods (SL) framework, and from inter-disciplinary comparative studies of African lake and coastal fisheries described by Preikshot *et al*. (1998) and Nielsen *et al*. (1995), respectively. These fields can be easily and objectively scored on a ordinal or presence/absence score, or quantified using interval or ratio scales if available. Basic ranked scores could be replaced later by more precise values (Section 6.6).

The FIMS currently includes only a subset of attribute and performance fields for demonstration purposes. Further fields can be added when a commonly agreed or standard set of attribute and performance indicators/measures have been identified or developed (see below).

A statistical framework for identifying patterns or similarities between combinations of attributes (explanatory variables) and management performance indicators was proposed based upon Multi-dimensional Scaling (MDS). Using this framework, lessons of success, described in terms of combinations of attributes and levels of inputs that appear to give rise to desirable outcomes or objectives, can then be feedback to local level managers via appropriate media to help accelerate their own adaptive management activities (Section 6.6).

A DFID funded project ' Interdisciplinary Multivariate Analsysis for Adaptive Co-Management' (R7834) is currently developing, refining and attempting to validate this approach in collaboration with ICLARM, IFM, Reading University, DFID and independent consultants.

9.2.3 The Generic FIMS Software

Development
The FIMS software entitled 'PISCES - **P**roviding **I**nformation for **S**ocio-Economic **C**atch and **E**ffort Fisheries Surveys was developed using relational data base and systems engineering theory to satisfy the requirements described above (Section 7). The entire principle on which the system is based is that any activity can be described as having taken place under a set of circumstances recorded as fields effectively within a single table. The value for each of these circumstances is recorded for the activity. The set of circumstances or in technical terms the 'attributes' that describe the situation may include the time and place of the activity along with all the other conditions pertaining to it. These 'attributes' (fields) would describe the conditions pertaining in a household or whilst fishing. Such attributes would be both the inputs and outputs in terms of physical data, measures that profile management areas and measure the performance of management areas. A range of performance attributes can be analysed against any of the physical or management attributes or any number of combinations of these according to the user's choices. This allows a choice of analyses from the traditional physical kinds all the way through to a comparison between different co-management arrangements.

The prototype software is designed to run under Microsoft ACCESS97 (Service Release 2b), although it should also be possible to run the system under ACCESS2000 providing the database is only 'opened' and not 'converted'.

Design Features
The entire core of the system is built around a set of relational tables and accompanying SQL based queries. Specific table structures are composed of clearly defined primary and foreign key attributes. Data 'redundancy' has been reduced to a minimum apart from where redundancy has been deliberately employed to aid generification and handling of missing data. Normalisation and decomposition has been rigorously taken into account. Again as explained earlier there are

deliberate compromises where required to satisfy the requirements for the generic aspects of the design and / or coping with potentially missing data.

All data analyses have been based around relational queries wherever possible. These can be implemented in any system that supports the SQL standard for database definition and manipulation. Thus procedural programming has been kept to a minimum since this is language dependent. Where procedural modules have been used the underlying algorithms have been documented in order to ease implementation in any other system. Cosmetic and other productivity features specific to Microsoft Access have been avoided where at all possible. This again aims to reduce the overheads where the system needs to be implemented in another software system.

Basic Structure
The PISCES software comprises a set of linked reference and survey tables, data entry forms, predefined SQL queries, and plotting and export facilities. The main software control panel software provides access to all the data entry and analysis facilities.

Management plans
Text field references to management plan documents are held in the ManagementPlan Table. A management plan key identifier field effectively allows all the data contained with the PISCES software to be linked to the management plan document.

Generic fields for monitoring and evaluation of national management plans:

Frame surveys
Generic frame survey fields to support catch and effort surveys are held in Frame Table. Data belonging to other the major generic fields identified in Section 6.2.2 that are commonly collected with frame surveys can be held in several other tables linked to the Frame Table including: Disposal Sites, PSUTypes, PSUs, Location Types, Locations, FEUs and FEU types, Gears, Household table (see User manual and Chapter 7). Other fields included in the Frame Table allow the entry of a selection of the measures and indicators to describe co-management attributes identified in Section 6.6.

Catch and effort
The system design supports the four common catch and effort sampling strategies identified in Section 6.2.3. The 'FrameSet' feature (see Section 7.2.9) also allows for the numbers of operational FEUs at each PSU to be updated during each sampling period (See Section 6.2.3).

The main tables used for storing and processing these data are the Frame Table and the Fishing Samples, and Catches tables (see User manual and Chapter 7). PISCES can hold and process all of the generic catch and effort data fields of identified in Section 6.2.3. Standard FAO species codes can be selected from the PISCES Species Table.

Biological and Environmental Data
All the generic biological data fields identified in Section 6.2.4 have been included in the AnimalData Table. These can be linked to catch records (and thereby management plans) via the BiolSamp Table allowing sub-sampled data and information to be correctly raised in proportion to the total catch and spatially referenced. Time constraints precluded the inclusion of fields to record environmental data. These would have been included in the Samples Table.

Control and Surveillance
The majority of the data inputs for control and surveillance identified in Section 6.3 have been included in PISCES in the following linked tables: Frame Table, Sample Table, FEU, FEUtype, Gears, Restrictions, and Licences. The system automatically alerts the user of any

contraventions to licensing restrictions imposed on fishing activity in terms of fishing location, time periods, gear types and species landed. Further restrictions may be added if required.

Socio-economic Data:
Cost and Earnings
PISCES employs the integration principle (Section 6.2.6) to store and process costs and earning data for FEUs in relation to fishing activity. Variable costs corresponding to fishing trip are held in the Samples Table, whilst fixed costs are held in the FEU Table. Most categories of fixed and variable cost data identified in Section 6.2.6 can be accommodated. Earnings are calculated from the corresponding catch data and price data by species type. The FEU table is linked to The TripPeople Table which provides fields to store information on crew income or catch share for each FEU. PISCES also contains a Household Table providing common fields for recording socio-economic data collected with *ad hoc* household surveys. Important fields describe: socio-economic group, annual household fish consumption and annual household income.

Economic Rent
As described above data to estimate economic rent are available from fields already included in the database to support catch and effort and cost and earnings surveys, control and surveillance data, as well as data from *ad hoc* surveys or other government departments which are typically not included in fishery department databases.

Employment
Employment data in the catching sector are usually collected as part of a frame survey. Due to time constraints, fields to hold employment information have not been included in either the Frame table or perhaps more appropriately, within the FEU table. Therefore no employment information is currently provided by PISCES at present.

Poverty
PISCES has the capacity to help calculate poverty measures based upon annual household income fields. Gini coefficients describing the distribution of income among different household types can also be calculated.

Industry Diversification
Fields to support the evaluation of the diversity of the fishery are contained within the Sample Table (species landed), and the FEU Table (gear and FEU types). Additional fields to provide information on the diversity of supporting sectors could be included in the Frame Table as part of a customisation process.

Food Supply and Security
PISCES can provide landings data with which to calculate fish supply and trends in average per capita consumption in conjunction with data obtained from other sources relating to imports, exports and an estimate of the total population. Annual household fish consumption estimates sampled *ad hoc* are also be available from the Household Table. Routine monitoring of household fish consumption (see Section 6.2.6) is not currently supported by the PISCES software.

Conflict and Traditional Management
Due to time constraints, fields to support the monitoring and evaluation of conflicts and the maintenance of traditional management practices were not included in the PISCES software.

Generic Fields for Policy and Development Planning
Generic fields included in the PISCES system to support policy and development planning are restricted to those corresponding to the monitoring and evaluation of management plans (see above).

National and international management and reporting responsibilities
Generic fields to provide the basic information required for compliance with international management and reporting responsibilities are already included in the PISCES to support the monitoring and evaluation of management plans and for control and surveillance purposes.

Fields for coordination and performance evaluation of community management plans
Fields for the coordination and evaluation of community management plans are contained with the ManagementPlan Table, the FrameTable and the Samples Table. As described above, only a selection of those attributes (but no related performance measures) identified in Section 6.6 have, so far, been included in the PISCES software. The system allows the management plan performance fields (described above) to be linked to these attributes. A link to the ManagementArea Tables, which contains location fields (Latitude and Longitude) detailing the position of each co-management unit, provides a basis for spatially coordinating (co-) management activities.

Analyses and outputs
Several predefined analyses have been included in the PISCES software. The results of these and other custom queries can be grouped according to 40 fields including management plan, management area, sampling strata, FEU type...etc, and presented in a variety of plots and figures or exported in Excel spreadsheet format (see User Manual and Chapter 7).

9.2.4 User manual
A user manual has been produced to accompany the PISCES software. This contains sections describing installation, Operation, Data Entry and Data Analysis.

9.2.5 Dissemination
The results of the project were disseminated at the two case study locations between 4th and 19th December 2000 using a combination of workshops, presentations and demonstrations of the FIMS software aimed at target beneficiaries, other stakeholders, and the project's collaborators (Chapter 8).

The workshop in Dhaka, Bangladesh was attended by more than 25 participants representing NGOs, the academic community and international donor and development agencies. Overall, the project results were well received by all participants who expressed an opinion. Representatives of the EGIS project, who have forged a strong working relationship with the DoF during the last two years, believed that the FIMS would be a valuable tool for the Department, and that the system's implementation should be encouraged. EGIS expressed an interest to collaborate with MAG. if an implementation project were funded.

Many participants supported the concept of learning lessons about (co-)management on the basis of spatial comparisons of standard, commonly-agreed management performance measures/indicators and those explanatory factors (co-management attributes) that are likely to affect performance. Many participants representing NGOs recognised that whilst the FIMS is primarily aimed at fisheries departments, the system could also be used as a monitoring and evaluation tool to store and process data on local or small scale projects and studies.

Most of the participants present requested to receive copies of the Final Technical Report and FIMS software so that they could explore the utility and applicability of the system for themselves in more detail.

A separate presentation and software demonstration was also given to the DoF at their headquarters. This was also well attended and received with many staff also expressing an interest to receive copies of the Final Technical Report and FIMS software. The department also expressed interest in being trained in the use of the software, and thought that the "best bits" of the software should be included in the database which is currently being developed by DoF in association with the Fourth Fisheries Project to replace the existing FRSS database.

Dissemination activities in the Turks and Caicos were attended by staff from the DECR and other Government departments. Unfortunately, stakeholders from the School for Field Studies (SFS), the processing industry, the Fisheries Advisory Committee (FAC) were not represented.

The project results and outputs were well received by the participants, particularly those features relating to the automatic system to alert breaches to technical and licensing regulations. The DECR were also impressed by the flexibility of the FIMS with respect to meeting their reporting requirements and provision of data and information for stock assessment purposes. Some participants were sceptical about the appropriateness of co-management in the TCIs because they believe that communities have no interest in conservation and that resource boundary delineation would be problematic. Conditions to support co-management arrangements were believed only to exist in and around Salt Quay, a small, isolated island with few inhabitants and fishers (see Field Study 2 - Turks and Caicos Islands, Volume II). Others, on the other hand, were enthusiastic about the prospects for co-management and felt that the Department should consult the community more with a view to establishing co-management arrangements. Mark Day, Director, DECR expressed considerable interest in installing the FIMS software in the Department to replace the existing, but no longer functioning, DataEase system (see Field Study 2 - Turks and Caicos Islands, Volume II). He intends to seek DFID development funds for a package to install and customise the FIMS, and to institutionally strengthen and train the Department in the use and application of the software.

The prototype version of the FIMS was installed in the DECR to provide an interim system to replace the DataEase system until a fully developed version of FIMS is installed at the Department and appropriate training was given. A detailed user manual was provided to support the hands-on training, containing detailed instructions on how to set up and run the system on other machines, as well as details of the errors found in the historical data.

Copies of this Final Technical Report, FIMS software and User Manual will be sent to more than 10 donor and development agencies, and NGOs.

9.2.6 Other Planned Activities and Outputs

Because no single generic data collection strategy to support the software could be developed (see Chapter 5) the following two other planned outputs (and corresponding activities) were also not achieved: (i) the estimated cost of the generic data collection strategy in terms of both unit costs and national costs for the two case study fisheries and (ii) training material for the generic data collection strategy.

9.2.7 Summary of Actual Activities and Achieved Outputs

The actual activities and resulting outputs achieved are summarised in Figure 30.

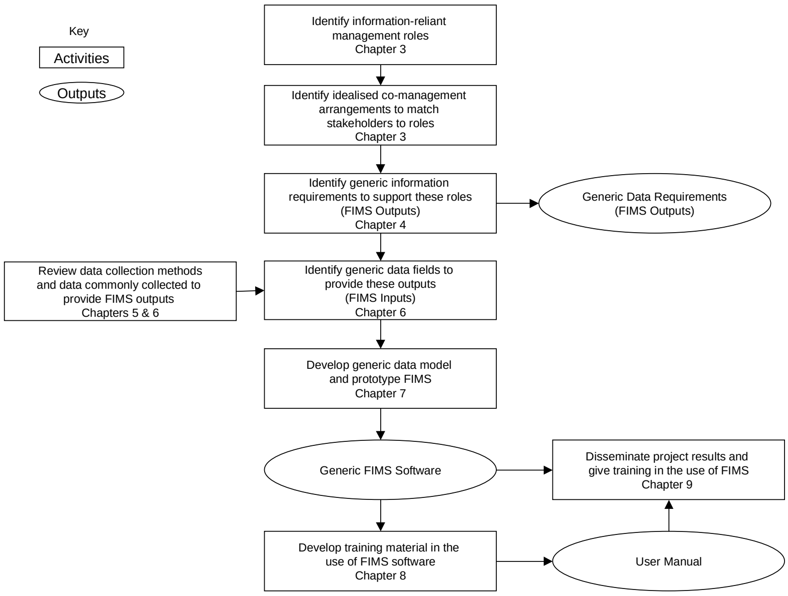

Figure 30 Actual Project Activities and Outputs

9.3 Conclusions

The project has succeeded in fulfilling it's purpose of examining the feasibility of developing a generic database to support the co-management of artisanal fisheries. Prototype software (PISCES) has been developed which can store and process of a wide range of data and information collected using common methodologies to support fundamental co-management roles of fisheries departments. Whilst fisheries departments provide much of the information to support higher level (government) decision-making and policy planning with respect to the fisheries sector, invariably other government departments (eg departments for trade and industry) will be responsible for augmenting these data requirements. The PISCES software is not designed to support these additional requirements. Nonetheless, the PISCES software can:

- Store details of management plan documents with links to key information fields to aid the (spatial) coordination of inter and intra-sectoral management activities;
- Support the monitoring and evaluation of national management plans on the basis of a range of decision-making methods to achieve common management objectives by providing facilities to store and process:

  - Catch and effort data generated by a range of different sampling or enumeration strategies.
  - Biological data sampled by direct observation at the harvest level.
  - Cost and earnings (income) data collected from fishing units (FEUs) or households.
  - Data to help estimate economic rent from the fishery.
  - Sector diversity data (numbers of target species, numbers of different gears and vessel types).
  - Data to help estimate food supply and average per capita fish consumption.

- Support control and surveillance activities by storing information relating to vessel/fisher registration and identification details and licence/quota information. The system also includes facilities to automatically alert breaches to regulations or expired licences.
- Provide information in support of policy and development planning activities.
- Potentially provide all the information required for international management and reporting responsibilities.
- Support the coordination and performance evaluation of community management plans.

All the data and information contained within the database can stratified by more than 5 criteria, spatially referenced, grouped by 40 attributes and either plotted or exported in spreadsheet format.

The key question is how generic or general is the PISCES system? Certain elements of the system will be more generally applicable or generic than others depending upon the specificity of the required outputs and the corresponding range of potential data sources and collection methods.

Outputs that can be explicitly defined including catch and effort, biological, environmental, and control and surveillance data, and information required for international management and reporting responsibilities are all, therefore, likely to be well supported by the software.

Outputs required to support the evaluation of management activities geared towards achieving socio-economic objectives and for policy and development planning purposes are, on the other hand, typically more variable or less explicitly defined reflecting the use of a diverse range of measures, indicators and their proxies, and the wide range of available data collection methodologies and sources. For example, household income and fish consumption data may be monitored either on a routine (monthly) basis by means of a panel survey, or collected during socio-economic baseline/frame surveys. The PISCES software currently does not contain fields or the processing capacity to support the former. Instead fields are provided to record total annual income (from fishing and other activities) and total annual fish consumption generated by annual (ad hoc) surveys.

Fields and data processing facilities provided by the PISCES software for the more explicitly-definable socio-economic data requirements (outputs) such as income (costs and earnings) by FEU type are likely to be more generally applicable.

Data requirements for policy and development planning purposes are often drawn from the results of frame surveys. Frame surveys are also a very general way of collecting data and information about the fishery to help design data collection strategies, formulate management plans, provide baseline socio-economic and employment data, and indicators of poverty, industry diversification, and food security. The types of data and information collected during frame surveys are highly variable. More than 150 example data fields were identified from the literature ranging from answers to specific questions relating to sector support and infrastructure to data on literacy rates of village members (See Section 6.2.2). Whilst many frame survey fields exist in the PISCES software (via linked reference tables with the FrameTable) to record frame survey data, it is likely that significant changes may have to be made to accommodate further fields and to develop appropriate links and processing functions.

Indeed, it is very likely that additional fields may need to be added and existing broad generic fields re-named in several or all of the tables during installation in order to satisfy local requirements and existing data collection systems. In spite of this inevitable customisation, it is estimated that the PISCES software could be installed and working within six weeks compared to six months to develop a bespoke system. Significant costs savings are therefore anticipated.

Whilst the database has been tested using catch and effort datasets provided by the two case study fishery departments, the extent to which the PISCES system it is generally applicable, particularly with respect to accommodating and processing socio-economic data, can only be assessed after further attempts by fisheries departments to adopt the system.

Other factors may influence adoption or uptake, beyond simply its potential applicability and cost. The system as it stands is very complex and demands a high level of understanding of both data collection systems and relational database theory on the part of users (See Chapter 7 and User Manual). Institutional strengthening and training programmes may well be required for successful adoption and uptake. It's robustness and reliability may also be important, particularly with respect to long term uptake. Further testing of the system and error checking is required. Some participants at the dissemination workshop in Bangladesh believed that potential users may resist uptake because they might perceive an off-the shelf system as less desirable that a bespoke system that has been designed for them according to their own specifications and requirements. Notwithstanding these comments, both fishery departments collaborating on the project, and members of SADC have expressed keen interest in the system (Chapter 8).

9.4 Recommendations for Further Work

Further development of the PISCES software is required to provide the necessary fields and processing capacity to support the monitoring and evaluation of data relating to conflicts, the maintenance of traditional management practices, environmental data and employment in the harvesting (and processing) sectors. Further work is also required to improve the user interface and error checking functions. The system would also benefit from:

(i) some means of simplifying or automating the complex decision-making process surrounding the selection of the appropriate tables in the software for the four main catch and effort data collection scenarios,
(ii) an expanded range of pre-defined queries,
(iii) alternative file export definitions, and
(iv) an expanded range of fields and processing functions for socio-economic data.

The User Manual would also benefit from step-by-step tutorials to guide the user through each database table, feature and function.

It is estimated that this further work would require approximately eight man-months of time to complete. No doubt the further scope for improvements will be identified on the basis of feedback from users.

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Annex 1

Management Control, Enhancement and Rehabilitation Measures
(Management Tools and Operational Rules)

In order to achieve the specific management objectives set out in the operational management plan, various management instruments or *tools* may be used to regulate or control the fishery or resource. These may include regulatory measures or tools applied *directly* to the fishery to limit the amount and type of fishing and who can fish (eg gear restrictions; closed seasons/areas (reserves); licensing; catch quotas; size limits etc), or *indirectly* via fiscal or economic measures (eg fuel subsidies or tax on catch) to either stimulate or check the development of the fishery (Table A1).

Table A1 Common management tools and purposes

Category	Management Tool	Purpose(s)
Effort controls	Reserves	Reduce fishing mortality experienced by stocks.
	Closed seasons	Reduce overall fishing mortality and limit the fishing mortality experienced by small/immature fish to improve yield- or value-per-recruit. and to maintain/increase spawning stock biomass.
	Gear Bans	Reduce overall fishing mortality and limit the fishing mortality experienced by small/immature fish to improve yield- or value-per-recruit and to maintain/increase spawning stock biomass. Reallocate fishery benefits among different fisheries/fishers operating different gear types.
	Gear/ vessel licensing	Limit fishing mortality experienced by stocks. Raise revenue.
Size controls	Minimum mesh sizes	Limit the fishing mortality experienced by small/immature fish to improve yield- or value-per-recruit and to maintain/increase spawning stock biomass.
	Minimum landing sizes	Limit the fishing mortality experienced by small/immature fish to improve yield- or value-per-recruit and to maintain/increase spawning stock biomass.
Catch controls	Total allowable catches / Quotas	Limit fishing mortality experienced by stocks.
Stock Intervention	Species introductions / Stocking	Increase overall productivity/value of fishery. Augment natural recruitment.
Enhancement / Rehabilitation / Habitat protection	Reserves	Protect key habitats for different life history stages of stock.
	Water level manipulation (floodplains / reservoirs etc)	Maintain dry season water levels to maximise survival of spawning stock biomass.
	Sluice gate management (Flood control schemes)	Allow access of fish to impounded areas.
	Environmental protection	Maintain/protect overall integrity and natural productivity of fishery environment.
	Habitat restoration	

Inland fisheries are also increasingly being managed by measures to enhance natural recruitment or the productivity of the fishery, including stocking and fertliziation programmes, culling predator species, the construction of artificial reefs and the rehabilitation of important habitats (Table A1).

The choice of realistic and enforceable management instruments and responsibility for control will largely be dictated by the nature and characteristics of the management unit (local conditions). Contemporary ('top-down') centralised management through regulatory controls may not always be appropriate, particularly for the artisanal sector. For the management instruments to be effective, they must be enforced. Legislative measures may be appropriate for commercial fisheries, but for artisanal fisheries, it is important to reduce the need for conventional surveillance given the limited management resources generally available (Mees, 1998).

Annex 2

Standard Fishing Effort Measures by Gear Categories

Source: FAO (1999b).

Priority Level	Fishing Gear Category	Effort Measure	Definition
First	Surrounding nets (eg purse seiners)	Number of sets	Number of times gear has been set or shot, whether or not a catch was made. This measure is appropriate when school size and packing density is related to stock abundance or sets are made in a random manner.
		Searching Time	This represents time on the grounds less time spent shooting net and retrieving catch as well as tome to hove to. This measure is appropriate when school size and packing density are unrelated to stock abundance and a set is only made when a school has been located.
	Surrounding nets with FAD's eg *Katha*	Number of hours since last fishing this FAD	Time in which FAD is left in water since it was last fished.
	Boat seines	Number of hours fished	Number of hours during which the seine was on the bottom and fishing.
	Beach seines	Number of sets	Number of times the gear has been set or shot, whether or not a catch was made.
	Castnet	Number of casts	Number of times gear has been cast, whether or not a catch was made.
	Trawls	Numbers of hours fished	Number of hours during which the trawl was in the water (midwater or bottom), and fishing.
	Boat dredges	Number of hours fished	Number of hours during which the dredge was on the bottom and fishing.
	Gillnets (set or drift)	Number of effort units	(Length of net expressed in 100m units) x (number of set made)
	Gillnets (fixed)	Number of effort units	(Length of net expressed in 100m units) x (number of times the net was cleared)
	Lift net	Number of effort units	Number of hours during which the net was in the water, whether or not a catch was made.
	Traps	Number of effort units	(Number of days fished) x (number of units hauled)
	Longlines	Number of hooks	Number of hooks fished in a given time period
	Pole and Line	Number of days fished	Number of days on which fishing took place, including days spent searching.
	Rod and Reel	Number of line hours	(Number of hours during which the lines were in the water) x (number of lines used).
	Troll	Number of line days	Total number of line days in a given time period.
	Jigs	Number of line days	Total number of line days in a given time period.

	Other small scale net gears eg push net, scoop net etc	Number of operations	Number of fishing operations whether or not a catch was made.
	Other small scale stationary gears eg bag nets, barrier nets etc	Number of hours fished	Number of hours during which the gears were in the water fishing, whether or not a catch was made.
	Harpoons, spears etc	Number of days fished	The number of days (24hr periods) on which fishing took place, including days spent searching.
Second	Boat seines	Number of sets made	Number of times gear has been set or shot, whether or not a catch was made.
	Trawls	Number of sets made	Number of times gear has been set or shot (either in mid-water or to the bottom), whether or not a catch was made.
	Lift net	Number of hours fished	Number of hours gear has been set or shot, whether or not a catch was made.
	All gears	Number of days fished	The number of days (24 hour period, recorded from midnight to midnight) on which any fishing took place. For those fisheries in which searching is a substantial part of the fishing operation, days in which searching but no fishing took place should be included in 'days fished' data.
Third	All gears	Number of days on ground	The number of days (24 hour period, recorded from midnight to midnight), in which the vessel was on the fishing ground, and includes in addition to the days fishing and searching also all the other days while the vessel was on the ground.
Fourth	All gears	Number of days absent from port	The number of days absent from port on any one trip should include the day the fishing craft sailed bu not the day of landing. Where it is known that fishing took place on each day of the trip, the 'number of days absent from port' should include not only the days of departure, but also the day of arrival back in port. Where on any trip a fishing craft visits more than one fishing area an appropriate fraction of the total number of days absent from port should be allocated to each fishing area in proportion to the number of days spent in each, so that the number of days absent on the trip will be the sum of the number of days allocated to all the different fishing areas visited.
Fifth	All gears	Number of trips made	Any voyage during which fishing took place in only one fishing area is to be counted as one trip. When in a single trip a craft visits more than one fishing area, an appropriate fraction of the trips should be apportioned to each fishing area in proportion to the number of days spent fishing in each so that the total number of trips for the statistical area as a whole will be the same as the sum of the trips to each fishing area.

Annex 3

Data Requirements Specified in the United Nations Fish Stock Agreement

Source: FAO (1999b)

AGREEMENT FOR THE IMPLEMENTATION OF THE PROVISIONS OF THE UNITED NATIONS CONVENTION ON THE LAW OF THE SEA OF 10 DECEMBER 1982 RELATING TO THE CONSERVATION AND MANAGEMENT OF STRADDLING FISH STOCKS AND HIGHLY MIGRATORY FISH STOCKS

ANNEX I
STANDARD REQUIREMENTS FOR THE COLLECTION AND SHARING OF DATA

Article 1

General principles

1. The timely collection, compilation and analysis of data are fundamental to the effective conservation and management of straddling fish stocks and highly migratory fish stocks. To this end, data from fisheries for these stocks on the high seas and those in areas under national jurisdiction are required and should be collected and compiled in such a way as to enable statistically meaningful analysis for the purposes of fishery resource conservation and management. These data include catch and fishing effort statistics and other fishery-related information, such as vessel-related and other data for standardizing fishing effort. Data collected should also include information on non-target and associated or dependent species. All data should be verified to ensure accuracy. Confidentiality of non-aggregated data shall be maintained. The dissemination of such data shall be subject to the terms on which they have been provided.

2. Assistance, including training as well as financial and technical assistance, shall be provided to developing States in order to build capacity in the field of conservation and management of living marine resources. Assistance should focus on enhancing capacity to implement data collection and verification, observer programmes, data analysis and research projects supporting stock assessments. The fullest possible involvement of developing State scientists and managers in conservation and management of straddling fish stocks and highly migratory fish stocks should be promoted.

Article 2

Principles of data collection, compilation and exchange

The following general principles should be considered in defining the parameters for collection, compilation and exchange of data from fishing operations for straddling fish stocks and highly migratory fish stocks:

(a) States should ensure that data are collected from vessels flying their flag on fishing activities according to the operational characteristics of each fishing method (e.g., each individual tow for trawl, each set for long-line and purse-seine, each school fished for pole-and-line and each day fished for troll) and in sufficient detail to facilitate effective stock assessment;
(b) States should ensure that fishery data are verified through an appropriate system;
(c) States should compile fishery-related and other supporting scientific data and provide them in an agreed format and in a timely manner to the relevant sub-regional or regional fisheries management organization or arrangement where one exists. Otherwise, States should

cooperate to exchange data either directly or through such other cooperative mechanisms as may be agreed among them;
(d) States should agree, within the framework of subregional or regional fisheries management organizations or arrangements, or otherwise, on the specification of data and the format in which they are to be provided, in accordance with this Annex and taking into account the nature of the stocks and the fisheries for those stocks in the region. Such organizations or arrangements should request non-members or non-participants to provide data concerning relevant fishing activities by vessels flying their flag;
(e) such organizations or arrangements shall compile data and make them available in a timely manner and in an agreed format to all interested States under the terms and conditions established by the organization or arrangement; and
(f) scientists of the flag State and from the relevant subregional or regional fisheries management organization or arrangement should analyse the data separately or jointly, as appropriate.

Article 3

Basic fishery data

1. States shall collect and make available to the relevant subregional or regional fisheries management organization or arrangement the following types of data in sufficient detail to facilitate effective stock assessment in accordance with agreed procedures:

(a) time series of catch and effort statistics by fishery and fleet;
(b) total catch in number, nominal weight or both, by species (both target and non-target) as is appropriate to each fishery. [Nominal weight is defined by the Food and Agriculture Organization of the United Nations as the live-weight equivalent of the landings];
(c) discard statistics, including estimates where necessary, reported as number or nominal weight by species, as is appropriate to each fishery;
(d) effort statistics appropriate to each fishing method; and
(e) fishing location, date and time fished and other statistics on fishing operations as appropriate.

2. States shall also collect where appropriate and provide to the relevant subregional or regional fisheries management organization or arrangement information to support stock assessment including:

(a) composition of the catch according to length, weight and sex;
(b) other biological information supporting stock assessments, such as information on age, growth, recruitment, distribution and stock identity; and
(c) other relevant research, including surveys of abundance, biomass surveys, hydro-acoustic surveys, research on environmental factors affecting stock abundance, and oceanographic and ecological studies.

Article 4

Vessel data and information

1 . States should collect the following types of vessel-related data for standardising fleet composition and vessel
fishing power and for converting between different measures of effort in the analysis of catch and effort data:

(a) vessel identification, flag and port of registry;

(b) vessel type;
(c) vessel specifications (e.g., material of construction, date built registered length, gross registered tonnage, power of main engines, hold capacity and catch storage methods); and
(d) fishing gear description (e.g., types, gear specifications and quantify).

2. The flag State will collect the following information:

(a) navigation and position fixing aids;
(b) communication equipment and international radio call sign; and
(c) crew size.

Article 5

Reporting

A State shall ensure that vessels flying its flag send to its national fisheries administration and, where agreed, to the relevant subregional or regional fisheries management organization or arrangement, logbook data on catch and effort, including data on fishing operations on the high seas, at sufficiently frequent intervals to meet national requirements and regional and international obligations. Such data shall be transmitted, where necessary, by radio, telex, facsimile or satellite transmissions or by other means.

Article 6

Data verification

States or, as appropriate, subregional or regional fisheries management organizations or arrangements should establish mechanisms for verifying fishery data, such as:

(a) position verification through vessel monitoring systems;
(b) scientific observer programmes to monitor catch, effort, catch composition (target and non-target) and other details of fishing operations;
(c) vessel trip, landing and transshipment reports; and
(d) port sampling.

Article 7

Data exchange

1. Data collected by flag States must be shared with other flag States and relevant coastal States through appropriate subregional or regional fisheries management organizations or arrangements. Such organizations or arrangements shall compile data and make them available in a timely manner and in an agreed format to all interested States under the terms and conditions established by the organization or arrangement while maintaining confidentiality of non-aggregated data, and should, to the extent feasible, develop database systems which provide
efficient access to data.

2. At the global level, collection and dissemination of data should be effected through the Food and Agriculture Organization of the United Nations. Where a subregional or regional fisheries management organization or arrangement does not exist, that organization may also do the same at the subregional or regional level by arrangement with the States concerned.

Annex 4

Information that should be included in CITES permits and certificates

a) The full name and the logo of the Convention

b) The complete name and address of the Management Authority issuing the permit

c) A control number

d) The complete names and addresses of the exporter and importer

e) The scientific name of the species to which the specimens belong (or the subspecies when it is relevant in order to determine in which appendix the taxon concerned is included)

f) The description of the specimens, in one of the Convention's three working languages, using the nomenclature of specimens distributed by the Secretariat

g) The numbers of the marks appearing on the specimens if they are marked or if a Resolution of the Conference of the Parties prescribes marking (specimens from ranches, subject to quotas approved by the Conference of the Parties, originating from operations which breed animals included in Appendix I in captivity for commercial purposes, etc.)

h) The appendix in which the species or subspecies or population is listed

i) The source of the specimens

j) The quantity of specimens and, if appropriate, the unit of measure used

k) The date of issue and the date of expiry

l) The name of the signatory and his/her handwritten signature

m) The embossed seal or ink stamp of the Management Authority

n) A statement that the permit, if it covers live animals, is only valid if the transport conditions comply with the CITES Guidelines for Transport of Live Animals or, in case of air transport, with the IATA Live Animals Regulations

o) The registration number of the operation, attributed by the Secretariat, when the permit involves specimens of a species included in Appendix I that originate from an operation practicing breeding in captivity or artificial propagation for commercial purposes (Article VII, paragraph 4, of the Convention), and the name of the operation when it is not the exporter

p) The actual quantity of specimens exported, certified by the stamp or seal and signature of the authority that carried out the inspection at the time of the exportation

Annex 5

Documents Reviewed to Identify Generic Data Requirements for the FIMS

Reference	Country	Environmental Regime	Frame Survey	CAS/ Enviro	Biological	Socio-Economic	MCS
(Alamos 1991)	Malawi	Lake		✔			
(Alamos, Seisay et al. 1990)	Malawi	Coastal	✔				
(Alamos and Davies 1991)	BVI	Coastal	✔				
MRAG (1999)	Fiji/Vanuatu	Coastal			✔		
(Barros and Thiam 1998)	Guinea	Coastal	✔				
(Batista, Inhamuns et al. 1998)	Brazil	River	✔				
Bazigos (1983)	General	General	✔				
Brander (1975)	General	General					✔
Caddy & Bazigos (1985)	General	General	✔		✔	✔	✔
(Carrara and Ardill 1989)	Mauritius	Coastal		✔			✔
(Carrara 1987)	Zanzibar	Coastal		✔			
(Carrara 1990)	Mozambique	Coastal	✔				
(Charlier 1995)	Mozambique	Coastal	✔	✔			
(de Graaf and Ofori-Danson 1996)	Ghana	Lake	✔				
(De Graaf 1995)	Lake Volta	Lake		✔	✔		
(Diallo and Diallo 1997)	Guinea	Coastal	✔				
FAO (1996;1997)	General	General					✔
(Anon 1988)	Bahrain	Coastal	✔				
Flewwelliing (1994)	General	General					✔
(Folack and Njifonjou 1995)	Cameroon	Coastal	✔				
(Friedlander and Parrish 1997)	Hawaii	Coastal		✔			
(Hoekstra 1990)	Kenya	Coastal	✔				
(Hoekstra 1992)	Kenya	Lake				✔	
(Horemans, Ajayi et al. 1996)	Gambia	Coastal		✔			
King (1990)	Mauritius	Coastal			✔		
(Langi 1988)	Tonga	Coastal		✔	✔		
(Lartigue and Kingombo 1996)	Angola	Coastal	✔				
(Lartigue and Kigombo 1997)	Angola	Coastal		✔			
(Leendertse and Horemans 1991)	Tanzania	Lake				✔	
(Mandima 1996)	Zimbabwe	Lake		✔			

(Meredith and Malvestuto 1991)	Nigeria	River		✔			
Mees (1998)	Seychelles	Coastal					✔
(Mino-Kahozi, Lubambala et al. 1997)	Zaire	Coastal	✔				
(Moussalli and Bouhlel 1988)	Oman	Coastal		✔			
Field Study 2 (Volume II)	TCI	Coastal		✔			✔
(MRAG 1998)	BIOT	Marine		✔	✔		
Field Study 1 (Volume II)	Bangladesh	Inland		✔			✔
(MRAG 1997b)	Bangladesh	Inland		✔	✔		
Neiland (1997)	Nigeria	Inland		✔		✔	
(Okpanefe, Abiodun et al. 1991)	Nigeria	Coastal	✔				
(Orach-Meza 1991)	General	Lake		✔			
(Paffen, Coennen et al. 1997)	Tanganyika	Lake	✔				
(Rabuor 1991)	Kenya	Lake		✔			
(Rawlinson, Milton et al. 1995)	Fiji	Coastal		✔			
(Razmjoo 1994)	Iran	Coastal		✔			
(SFA 1990)	Seychelles	Coastal		✔			
(Ticheler, Kolding et al. 1998)	Zambia	Inland			✔		
(van Zalinge, Khalilludin et al. 1987) (van Zalinge, Shuaib et al. 1986)	Pakistan	Coastal	✔	✔	✔		
(Wahyudi, Tampubolon et al. 1994)	Indonesia	Marine				✔	
(Westerlund 1994)	Lesotho	Inland				✔	

Annex 6

Sampling Theory

Estimation of population mean and population total using simple random sampling (SRS)
If there are *N* sampling units in the population, and we measure a desired characteristic *y* of *n* randomly sampled units of the population, then

$$\textit{Sample mean} \quad \bar{y} = \frac{1}{n}\sum_{1}^{n} y_i$$

The estimate of the population total is given by:

$$\textit{Population Total} \quad \hat{Y} = N\,\bar{y}$$

Sample Size
The required minimum sample size *n* may be estimated from:

$$n = \frac{s^2}{\delta^2}.(t_{\alpha,\nu} + t_{\beta(1),\nu})^2$$

where s^2 is the estimate of the population variance, δ minimum detectable difference between the estimated and actual population mean, α is the probability of committing a Type I error, β is the probability of committing a Type II error, and v is the degrees of freedom (n -1) (See (Zar 1984) for further details). Because v depends upon n, n cannot be calculated directly, but must be by iteration.

Estimation of Proportions
This theory is relevant for biological sub-sampling of catch, for example length frequency sampling. Let there be *N* units in the population (eg the number of fish of species *s*, landed at site *x,* on a particular sampling day), of which N_i belong to *i*-class (eg size class *i*), so that the proportion belonging to class *i* is: $P_i = N_i / N$. We want to estimate N_i and P_i from a simple random sample of *n* units, in which n_i is in class *i* so that $p_i = n_i / n$. Then:

$$N_i = N.p_i$$

Stratified Sampling
Suppose there are *N* sampling units in the population, and these are stratified into *k* strata with N_i units in the *i* th stratum. Let a sample of *n* units be drawn, of which n_i are from the *i* th strum. Let y_{ij} be the measurement of the *j* th unit in the *i* th stratum. Then:

$$\textit{Sample mean of the ith stratum} \quad \bar{y}_i = \frac{1}{n_i}\sum_{j}^{n_i} y_{ij}$$

Estimate of the total of the ith stratum $\hat{Y}_i = N_i \, \overline{y}_i$

Estimate of the population total $\hat{Y}_{st} = \sum_{i}^{k} N_i \, \overline{y}_i$

The allocation of *n* among the different strata can be made either by proportionally or optimally. For proportional allocation, n_i is proportional to N_i. If the within-stratum variances are equal this is the most efficient approach, and used when information on strata variances are not available. When within-stratum variances vary significantly, selecting n_i in proportion to the stratum standard deviation is optimal.

Ratio Estimation

This is a method which uses auxiliary information to increase the precision of estimates. Suppose we have selected at random, *n* units out of *N* units in the population, and for each of these selected units we have measured characteristics, *x* and *y*, where *y* is the survey variate, and *x* is another correlated variate. The population total of the x variate is *known* to be:

$$X = \sum_{1}^{N} x_i$$

but *y* may not be known for each unit except for those in the sample. The estimate of the population total *Y* of the survey variate is given by:

$$\hat{Y}_{ratio} = X . \frac{\sum_{1}^{n} y_i}{\sum_{1}^{n} x_i}$$

Unequal Probability Sampling

Stratification and ratio estimation can increase the precision of the estimate. Another technique for this purpose is the selection of sampling units with probabilities proportional to their sizes (PPS). The technique is commonly used for sampling different size clusters of individual units eg boats, households etc, where all clusters cannot be sampled due to logistical or financial reasons.

Method of estimation

Let there be *N* primary sampling units (eg landings sites) and let x_i be the number of secondary sampling units (eg boats) in the *i*th landing site. If *n* landing sites have been selected with PPS, the probability of selecting the *i*th unit is:

$$p_i = \frac{x_i}{\sum x_i}$$

The estimate of the population total Y is given by:

$$\hat{Y} = \frac{1}{n}\sum_{i} \cdot \frac{y_i}{p_i}$$

where y_i is the measurement (eg catch) of the i th unit in the sample.

Two-Stage Sampling
In two-stage sampling, a sample of first-stage units (eg landing sites) are chosen first, and in each of the selected first-stage units, a further sample of survey units (eg boats) is chosen. First-stage sampling units may be randomly selected, or selected using PPS.

Two-stage sampling using SRS

Let

N = Number of first-stage units (eg landing sites)
n = Number of first-stage units selected for sampling
Mi = Number of survey units (eg boats) in the ith first-stage unit
mi = Number of survey units selected in the ith first-stage unit.

The estimate of the population total of the survey characteristic y (eg catch) is given by:

$$\hat{Y} = \frac{N}{n}\sum M_i \bar{y}_i$$

where

$$\bar{y}_i = \frac{1}{m_i} \cdot \sum_{j=1}^{m_i} y_{ij}$$

Two-stage sampling using PPS

Where the first-stage sampling units have been selected with PPS, then the estimate of the population total of the survey characteristic y is given by:

$$\hat{Y} = \frac{1}{n}\sum_{i=1}^{n} \frac{\hat{Y}_i}{p_i}$$

where

$$\hat{Y}_i = \frac{M_i}{m_i}\sum_{j}^{m_i} y_{ij}$$

Stratified Two-Stage Sampling
The theory discussed above is applicable when the PSU's are selected from a stratum. To obtain an estimate of the population total (as well as the variance) we simply add the independent estimates obtained within each stratum.