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.

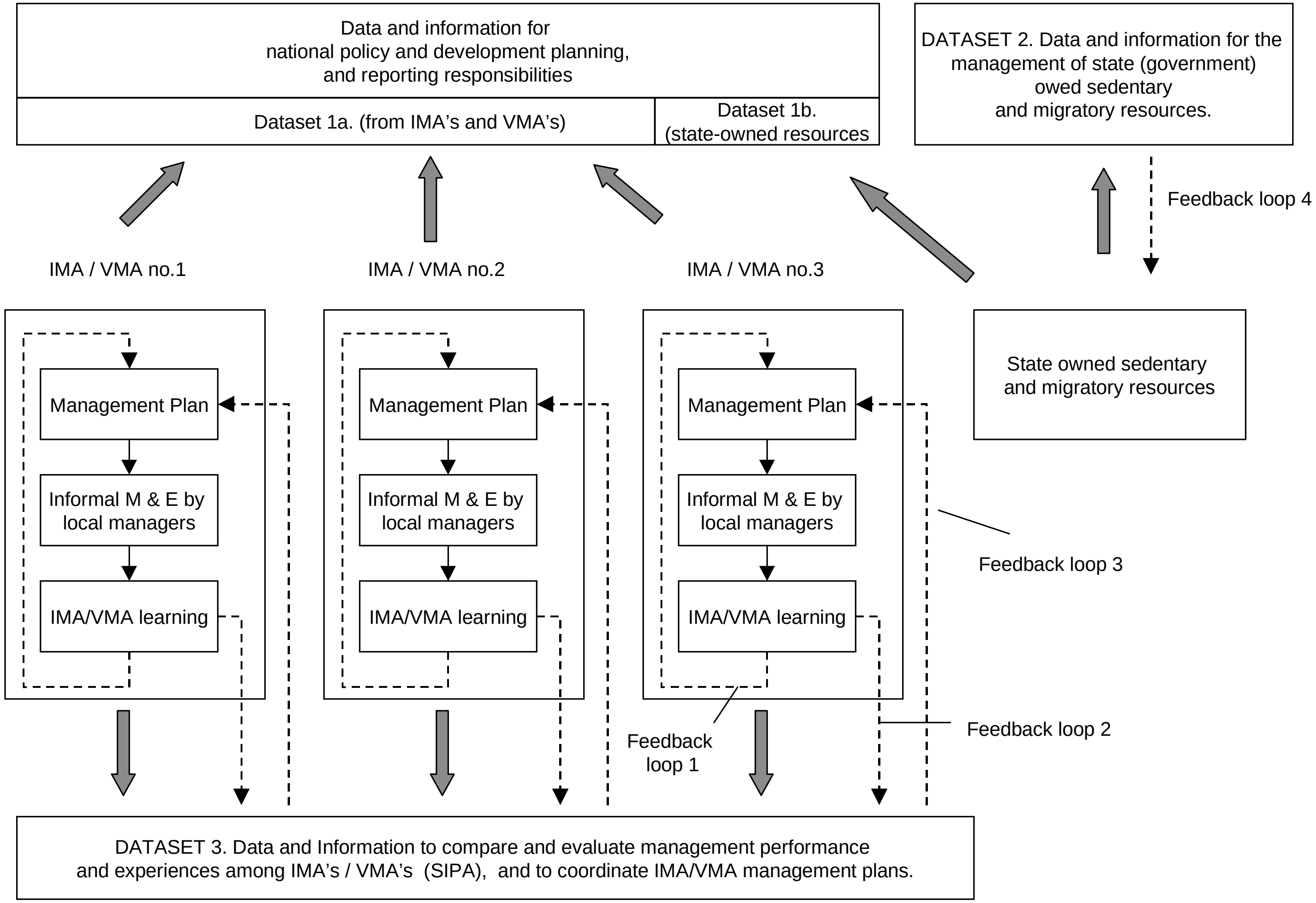

Figure 8 Summary of the proposed data flows and feedback loops for the co-management FIMS (see text for further explanation).

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:

$S = H\,[I + (1 - I)\,Gp]$

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.

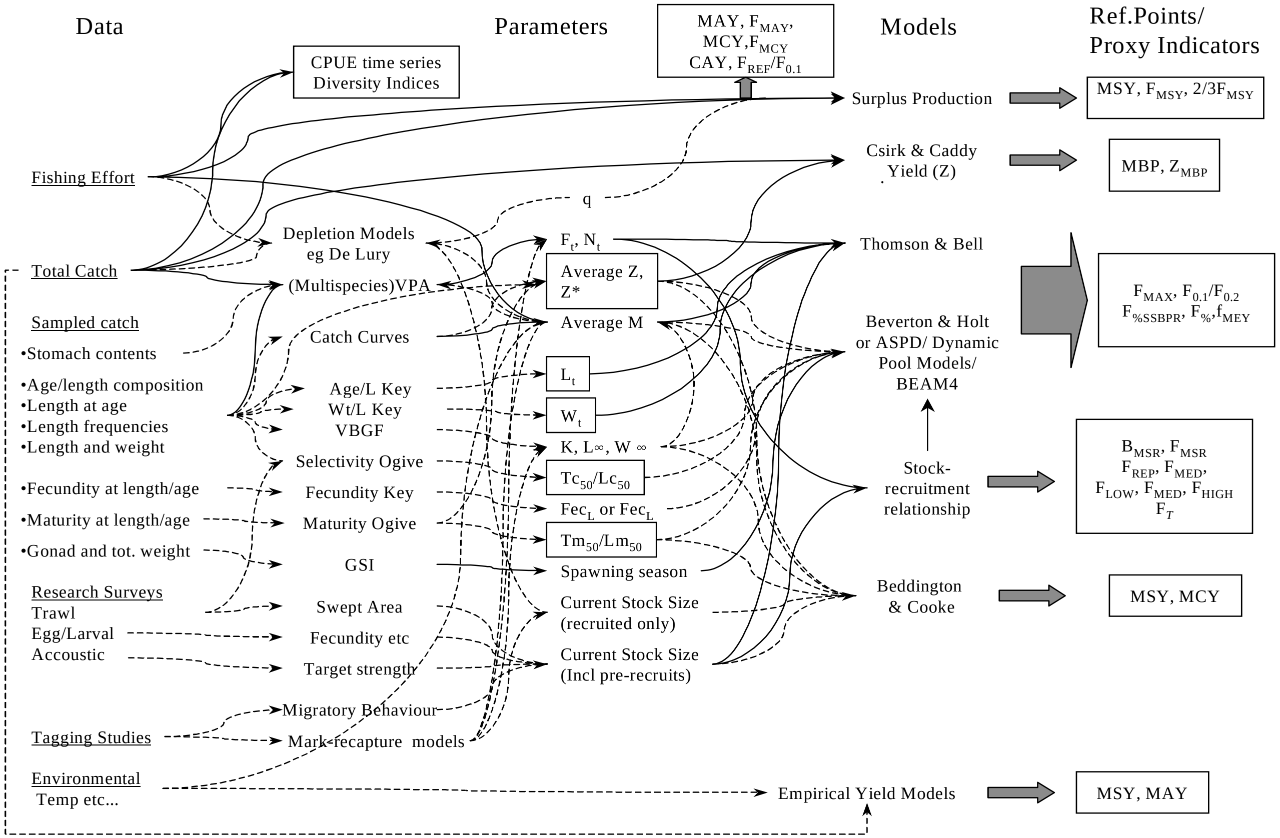

Figure 9. A conceptual flow diagram of key fisheries methodologies, assessment techniques and information requirements. Solid lines indicate a requirement for a time series or multiple sample of the data or parameter estimates (modified from (MRAG 1992)). Reference points in boxes.

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).

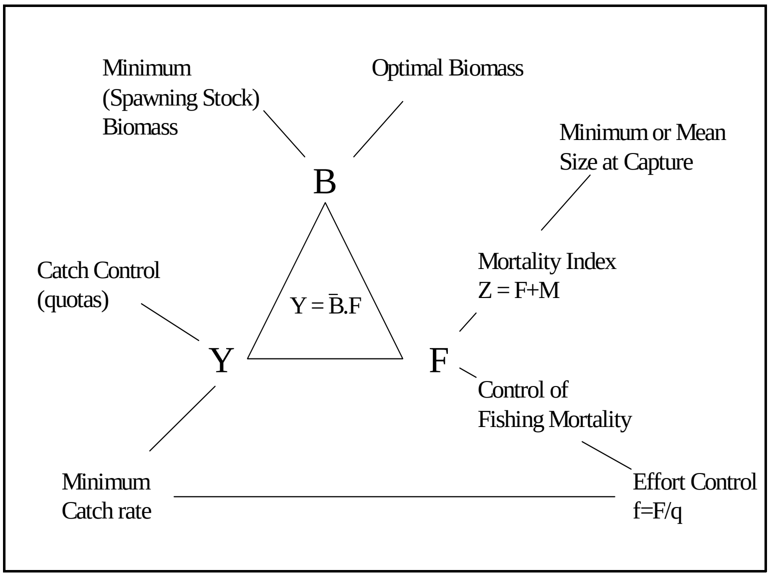

Figure 10. The main population, reference and control variables used in defining biological reference points. In addition to the three primary measures of the state of an exploited population (Y,B and F), other secondary measures shown may also be used as reference variables. Redrawn from (Caddy and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

[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

[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).

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[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.

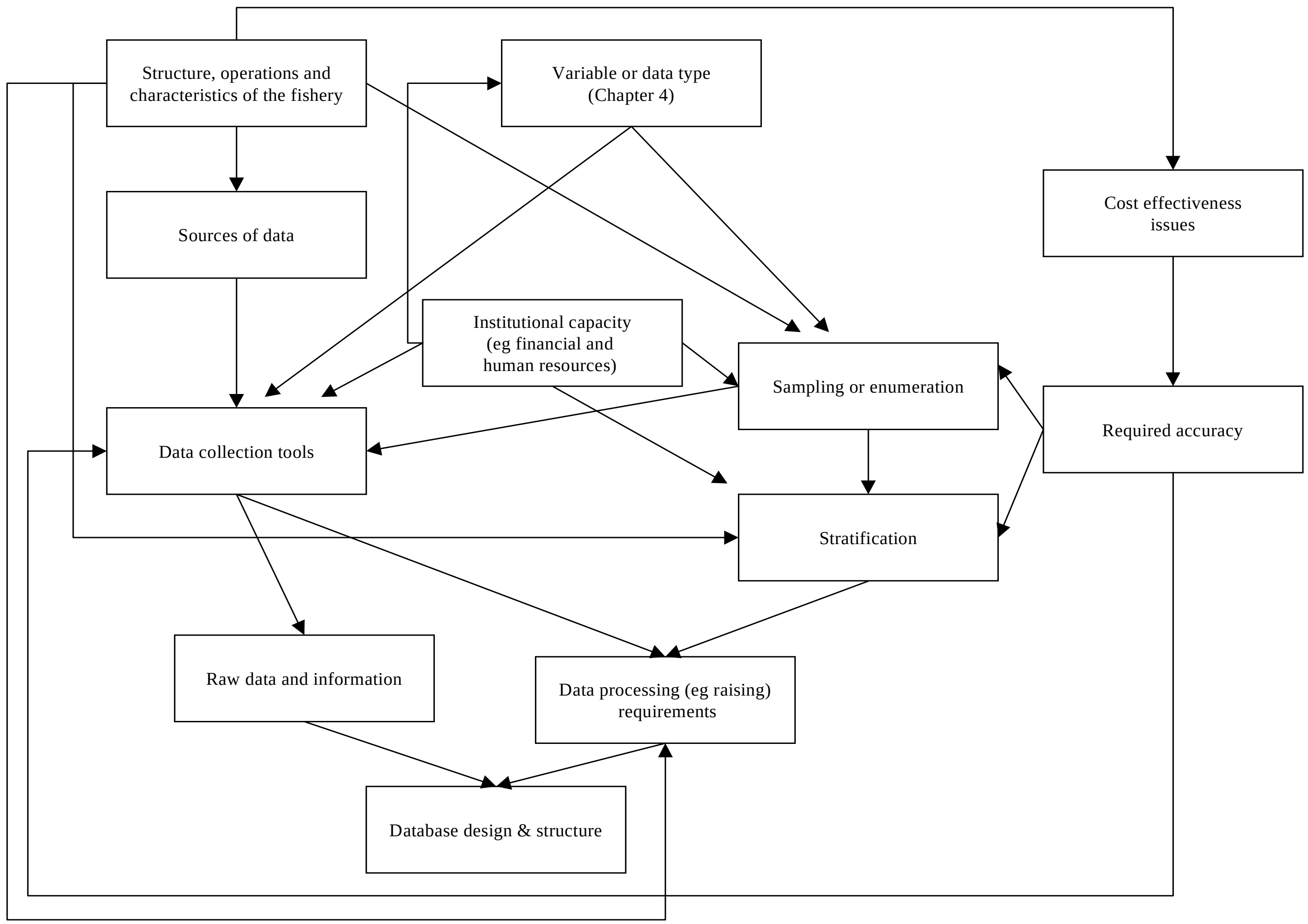

Figure 11 Data collection and processing factors affecting the design of a fisheries database.

(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.

<table>
<tr><th colspan="2">Generic Fields</th><th>Example Data (Fields)</th><th>Units</th></tr>
<tr><td colspan="2">Form Number</td><td>Form number
Serial number</td><td>Alpha-Numeric or Number</td></tr>
<tr><td colspan="2">Enumerator ID</td><td>Name of recorder/observer
Team number
Recorder team ID
Observers ID</td><td>Text
Number
Alpha-Numeric
Alpha-Numeric</td></tr>
<tr><td colspan="2">Major Stratum</td><td>Region
Strata I-XII
Stratum ID</td><td>Text
Roman Numerals
Alpha-Numeric</td></tr>
<tr><td colspan="2">Minor Stratum</td><td>Area
Stratum
Province
Island name
Location/locality
Island ID</td><td>Alpha-Numeric or Text</td></tr>
<tr><td colspan="2">Minor Stratum Descriptors</td><td>Latitude
Length of shoreline
% of shoreline
District</td><td>Degs.Mins.Secs
km
%
Text</td></tr>
<tr><td colspan="2">Survey Date/Period/Time</td><td>Date
Month
Time</td><td>Date
Text
Time</td></tr>
<tr><td colspan="2">PSU ID</td><td>Landing site
Fishing camp
Village name/code
Code of fishing site
Fishing site ID/serial number
Name of fishing Site
Beach name</td><td>Alpha-Numeric or Text</td></tr>
<tr><td colspan="2">PSU Descriptors</td><td>Geographical location
Left bank, right bank
Distance from ’X’
Fishery habitat
Type of fishing site
Environment
Accessibility
Description of boundaries
Permanent landing /fishing site</td><td>Text
Text
km
Text
Text
Text
Text
Text
(Y/N)</td></tr>
<tr><td>FEU’s at PSU’s</td><td>FEU ID</td><td>Vessel ID number
Vessel Name
Name of owner
Home port
Registration number
Fisher name & address</td><td>Alpha-Numeric
Text
Text
Text
Alpha-Numeric
Text</td></tr>
</table>

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

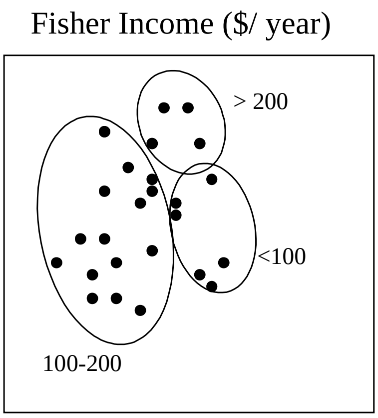

Figure 12. A hypothetical ordination illustrating similarities in fishery attributes and inputs for 25 individual IMA/VMA's. The three ovals superimposed on the ordination indicate three different levels of fisher income (outcomes) for hypothesis testing using ANOSIM (see text for further explanation).

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	$\mu g\ l^{-1}$ 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.